



# LI-7700

Open Path CH<sub>4</sub> Analyzer

Instruction Manual

**LI-COR**<sup>®</sup>

Biosciences



**LI-7700 Open Path CH<sub>4</sub> Gas Analyzer  
Instruction Manual**

**Publication No. 984-10751**

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## Declaration of Conformity

**Manufacturer's Name:** LI-COR, Inc.

**Manufacturer's Address:** 4647 Superior Street  
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**declares that the product**

**Product Name:** Open Path CH<sub>4</sub> Gas Analyzer

**Model Number(s):** LI-7700

**Product Options:** None

**conforms to the following Product Specifications:**

EMC: EN 55011 : 2002 Radiated Emissions, Class A  
IEC 61000-4-2 : 2000 ESD, 4KV/8KV Contact/Air  
IEC 61000-4-3 : 2002 Radiated RF Immunity, 10V/m  
IEC 61000-4-4 : 2004 EFT/Burst  
IEC 61000-4-5 : 2000 Surge Immunity, 1KV  
IEC 61000-4-6 : 2003 Conducted RF Immunity, 3V

**Supplementary Information:**

The product herewith complies with the requirements of the EMC Directive 2004/108/EC.

John Rada  
Director of Engineering

Document #53-11453  
February 9, 2010



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LI-COR has licensed certain aspects of the LI-7700 that were developed with expertise from Southwest Sciences, Inc. (Santa Fe, NM). This project was funded in part by the U.S. Department of Energy through a Small Business Innovation Research grant (DE-FG02-05ER84283).

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## Printing History

New editions of this manual will include all updates. An update addendum may be used between editions to provide up-to-date information. Revisions are indicated by the revision number. Minor updates, which do not alter the meaning of the content, will be incorporated without affecting the revision number.

Publication Number: 984-10751

Version Number	Publication Date	Changes
1	02/2010	First edition
2	10/2010	Second edition
3	12/2013	Third edition; Added version history; Revised for updated Windows software; Added instructions for logging LI-7700 data in GHG files; Reformatted and updated cross references; Added dimensional drawings in specifications.

Build Date: Monday, December 23, 2013

## Laser Safety Information

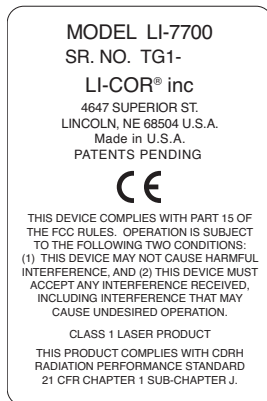
The Center for Devices and Radiological Health (CDRH) was established in October, 1982, by the U.S. Food and Drug Administration (FDA) to protect the public health in the fields of medical devices and radiological health.

Manufacturers of products subject to performance standards under the Radiation Control for Health and Safety Act of 1968 are required to furnish various reports to the CDRH.

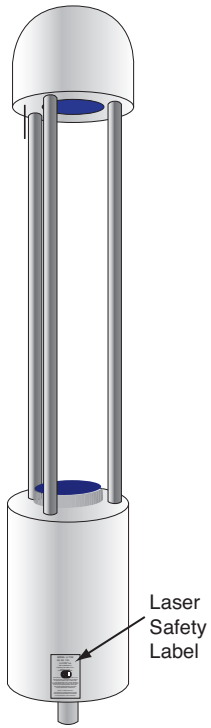
The LI-7700 Open Path CH<sub>4</sub> Analyzer is certified as a Class I Laser product. This means that hazardous laser radiation is not emitted from the instrument. All laser radiation emitted is below the Class 1 Laser limits during any phase of user operation. One laser emits near 1.6 microns and has a peak power rating of 3 milliwatts.

**WARNING: Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.**

The CDRH implemented regulations for laser products on August 1, 1976 (CDRH radiation performance standard 21, Code of Federal Regulations Chapter 1, Subchapter J). Compliance for products marketed in the United States is mandatory. The label that must be attached to laser products marketed in the United States is located on the side of the lower housing of the LI-7700 Open Path CH<sub>4</sub> Analyzer (Figure 2), indicating compliance with CDRH regulations.



*Figure 2-1. CDRH regulation compliance label.*



**Figure 2-2. Location of the CDRH compliance label on the LI-7700 Open Path CH<sub>4</sub> Analyzer.**

Although the LI-7700 is a Class 1 device and no hazardous radiation is emitted, refrain from placing highly reflective objects in the optical path and never attempt to place your head or eyes inside or near the laser path.

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# 1 General Information

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The LI-7700 is a high-speed, high-precision open path methane analyzer designed for use in eddy covariance flux and atmospheric monitoring applications. It uses Wavelength Modulation Spectroscopy (WMS) to make high-speed, precise measurements of methane concentrations at ambient pressure and temperature. It is designed to withstand environmental extremes expected during outdoor deployments. Some features of the LI-7700 include:

- Fast response: data are output at up to 20 Hz bandwidth.
- Low power requirements: 8 W during normal operation.
- Withstands outdoor environmental extremes, including freezing weather and high temperatures (-25 to 50 °C) and rain without damage or calibration shifts.
- Analog input channels to integrate sonic anemometer wind speed (U, V, W) and sonic temperature (T<sub>s</sub>) data with CH<sub>4</sub> data.
- Windows® software for setup and calibration.

Contact LI-COR if you have questions about the suitability of the LI-7700 in your application.

**Suggested Reference:** When referring to this instruction manual in scientific literature or other publications, we recommend the following citation:

LI-COR, Inc. 2013. LI-7700 Open Path CH<sub>4</sub> Analyzer Instruction Manual.; version 3  
LI-COR, Inc. Lincoln, NE.

## What's What

If you have just taken delivery of your LI-7700, check the packaging list to verify that you received everything that was ordered. The standard LI-7700 will include:

### The LI-7700 Open Path CH<sub>4</sub> Analyzer

- LI-7700 Open Path CH<sub>4</sub> Analyzer – This is the sensor. It includes the laser, detector, sampling path, mirrors, heaters, and laser control electronics. The radiation shield is

attached to the upper housing prior to shipment.

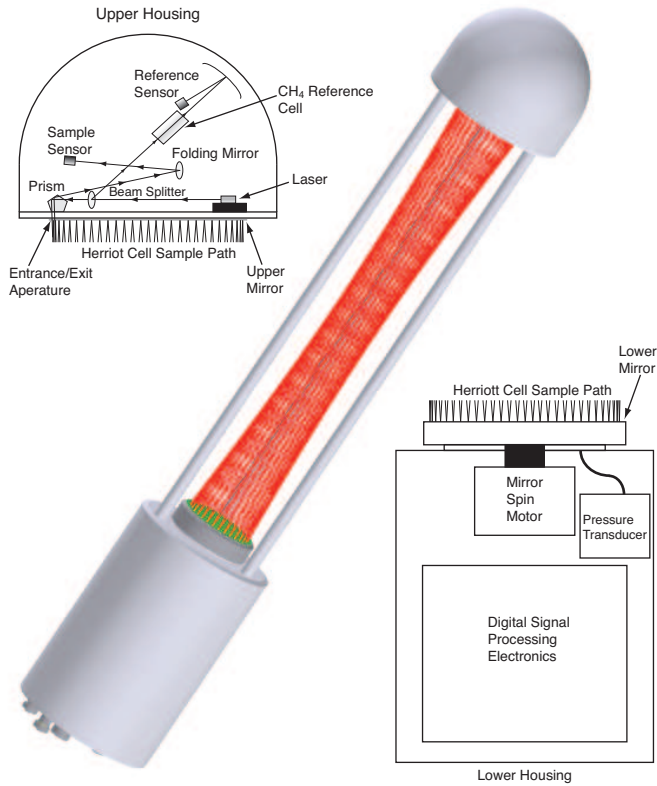


Figure 1-1. Representations of the LI-7700 upper housing (top left), Herriott cell (center), and lower housing (lower right).

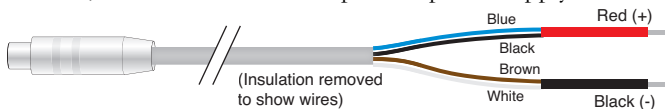
## Spares Kit and Cables

The items in Table 1-1 below are included in the LI-7700 spares kit or shipped separately.

**Table 1-1.** LI-7700 spares and additional components.

Description	Qty.	LI-COR Part No.
Ethernet Cable, Eurofast (0.3 M) 8-pin female to Tj45	1	392-10107
Ethernet Cable, Eurofast (5 M) 8-pin male to 8-pin male	1	392-10108
Power Cable, Eurofast (5 M), 4-pin female	1	9975-030
5 Amp Fuse	1	438-09800
Desiccant Cap Removal Screw (attached to analyzer)	1	125-09760
Calibration Shroud	1	9977-033
Solar Shield Assembly (attached to analyzer)	1	9977-029
Thermocouple Assembly (attached to analyzer)	1	9977-038
Mounting Post (attached to analyzer)	1	9977-018
Mounting Post Screws (1/4"-20, 5/8" long, attached)	1	140-04320
Washer Reservoir Assembly	1	7700-101
Washer Power Cable	1	392-10211
Spray Nozzle Assembly	1	9977-032

- **Standard Spares Kit** – This (part #9977-019) includes the cables, mounting hardware, and other essential components. Several components listed below are attached to the instrument prior to shipping.
- **Ethernet Data Cables** – There are two Ethernet cables provided: part #392-10108 is a 5 m cable terminated on both ends with male Turck connectors; one end attaches to the LI-7700 Ethernet output, while the end attaches to either the 0.3 m Ethernet adapter cable (part #392-10107), or to an LI-7550 Analyzer Interface Unit. When both cables are used, the LI-7700 can be connected to an Ethernet wall socket, Ethernet hub, or the Ethernet port on your computer.
- **Power Cable** – (part #9975-030) Used to connect the LI-7700 to a 10.5 to 30 VDC power supply. The power cable has 4 wires: brown and white are tied to a black lead, which connects to the negative (-) power supply terminal; blue and black are tied to a red lead, which connects to the positive power supply terminal (+).



- **Washer Assembly** – The washer assembly includes a reservoir/pump unit, hose, washer nozzle, and mounting hardware.



Figure 1-2. Washer reservoir for the LI-7700 washer assembly.

- **Mounting Hardware** – This is the hardware required to mount the LI-7700 on typical platforms. It includes the mounting post and two hex screws that secure the post to the base of the LI-7700 analyzer. The post and screws are affixed to the analyzer prior to shipping.
- **Calibration Shroud** – The calibration shroud is used to isolate the LI-7700 optical path during calibration verification.



Figure 1-3. LI-7700 calibration shroud.

- **Computer Software** – The CD includes the LI-7700 configuration/data logging software. The software is compatible with Windows® XP/Vista/7 operating systems.
- **Calibration Certificate** – This documents the performance of your particular instrument when it left the factory. Keep this sheet for future reference.

## Auxiliary Sensor Interface

The 7550-101 is an optional weatherproof junction for analog inputs on the LI-7700, LI-7550, and for the analog outputs from the LI-7550. Detailed instructions for using the

7550-101 are provided later (see "Auxiliary Sensor Interface Terminals (Option 1)" on page 2-30).



Figure 1-4. 7550-101 Auxiliary Sensor Interface.

Table 1-2. 7550-101 Auxiliary Sensor Interface Spare Kit (optional; part #9977-019).

Description	Qty.	LI-COR Part No.
U-Bolt, 1/4 by 20	2	222-08325
Hey Huts	4	798-01788
Quick Connect Plug	10	300-07393
Strain Relief	1	198-01788
Santoprene Tubing	2 ft (60 cm)	222-08325

### Sonic Anemometer Interface Cables

LI-COR can provide cables to carry the analog output from a Gill WindMaster™/Pro or a Campbell® Scientific, Inc. CSAT3 directly to the analog input on the LI-7700 and/or LI-7550. These cables terminate with a Gill or Campbell® bulkhead connector on one end and Turck bulkhead connector(s) on the other (for connecting to the LI-7700 and/or LI-7550).

Description	LI-COR Part No.
Gill WindMaster™/Pro to LI-7700	9977-062
Campbell Scientific® CSAT3 to LI-7700	9977-063
Gill WindMaster™/Pro to GHG System	9975-033
Gill R3™/HS-50™ to GHG system	9975-041
CSAT3 to GHG System	9975-035

## LI-7550 Analyzer Interface Unit

The LI-7550 enhances the functionality of the LI-7700 by providing onboard data logging of eddy covariance data sets ( $\text{CH}_4$ , U, V, W,  $T_s$ , and other variables) to a removable USB data storage device and enabling versatile data output options. Detailed instructions for the LI-7550 are provided later (see "Using an LI-7700 with an LI-7500A or LI-7200  $\text{CO}_2/\text{H}_2\text{O}$  Analyzer" on page 3-9 and "Operation with the LI-7550" on page 3-1).



Figure 1-5. LI-7550 Analyzer Interface Unit.

See "LI-7550 What's What" on page 3-2 for a list of components included in the LI-7550 Spares Kit.

## LI-7700 Components

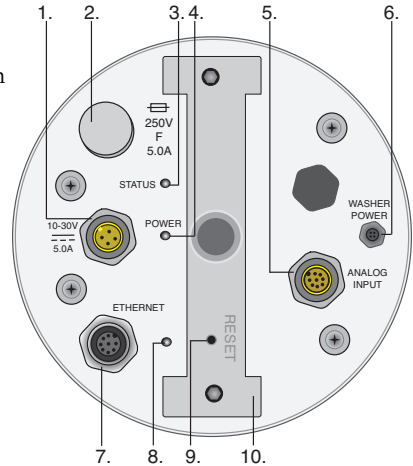


1. **1.** Radiation Shield – reduces condensation on the upper mirror. It is in place when the instrument is shipped and it should be kept in place during normal operation, especially in high-humidity environments.
2. **2.** Upper Housing – encloses the laser source, sensor, and laser control electronics.
3. **3.** Fine-wire Thermocouple – measures the ambient temperature near the optical path. There is a plastic sleeve over the thermocouple. It protects the thermocouple and should be left in place.
4. **4.** Upper Mirror – this is the upper mirror in the optical path. It can be configured to remain slightly above ambient temperatures in condensing conditions.
5. **5.** Desiccant Cap – this seals the desiccant bottle. Only remove the desiccant cap to replace the internal chemical bottle. The desiccant cap removal screw is in place and can be left in place during normal operation.
6. **6.** Sample Volume – the optical path is 0.5 m in length. The laser makes 60 passes in a Herriott cell pattern for a total path length of 30 m. The laser beam is about 1.5 mm in diameter.
7. **7.** Lower Mirror – the lower mirror features automated cleaning and temperature controls to prevent condensation on the mirror surface.
8. **8.** Pressure Transducer – high-speed ambient pressure measurements. The transducer is below the lower mirror.
9. **9.** Lower Housing – houses the digital signal processing electronics and spin motor.

## Cable Connections

The connection panel on the bottom of the analyzer includes the following components:

1. Power In – provide a +10.5 to 30 VDC 3A power supply. The LI-7700 powers on when a suitable power supply is connected. It always starts up with the most recent configuration/settings.
2. Fuse Housing – use only a 250V type F 5.0 Amp fuse. An extra fuse is included in the spares kit (part #438-09800).
3. Status LED – stays solid green when the LI-7700 has finished startup.
4. Power LED – stays solid green when a suitable power supply is connected.
5. Analog Inputs:
6. Washer Power – supplies power to the external washer unit accessory.
7. Ethernet Connection – port for Ethernet communication.
8. Ethernet LED – blinks at about 4 Hz when the Ethernet connection is active.
9. Network Reset – depress this button to reset the network connection.
10. Mounting Post – the mounting post is attached with two 1/4"-20 bolts (5/8").





# 2 Using the LI-7700

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This section covers the basic operation of the LI-7700. You will learn how to use the LI-7700 configuration software, configure the instrument mirror heaters, configure the mirror cleaner, configure data outputs, and other aspects of using the instrument.

## Basic Setup

This section describes basic setup and operation of the LI-7700.

### 1 Install the LI-7700 Computer Software

The LI-7700 software is compatible with Microsoft® Windows XP/Vista/ and 7 operating systems. Place the included software CD in your computer's CD drive. If the software does not start automatically, navigate to the CD directory on your computer and double click on the Setup.exe file on the CD. Follow the on-screen installation instructions.



### 2 Power On

Attach the yellow Turck cable (part #9975-030) to the Power connection on the LI-7700 connection panel ("Cable Connections" on page 1-8). Align the notch in the cable with the notch in the power-in bulkhead connector and push straight in. Tighten the knurled nut.



*Figure 2-1. Attach the power cable leads to a suitable power supply to turn on the LI-7700.*

Attach the red lead to the positive (+) terminal and the black lead to the negative (-) terminal of a power supply. This could be a 10.5 to 30 VDC 3 Amp power adapter plugged into a 110 VAC wall outlet or an automotive

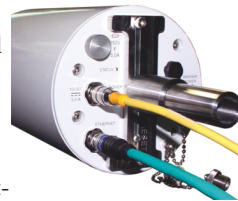
battery, for example. The LI-7700 powers on immediately after power is supplied. It may take 30 seconds or more to boot up, and the power and status LEDs on the bottom of the LI-7700 will illuminate after instrument completes start-up.

Caution: Connecting the power wires with improper polarity will blow the fuse.

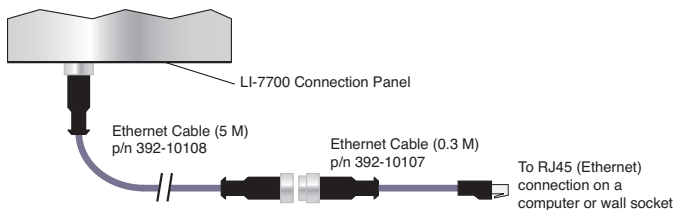
# 3

## Connect the Ethernet Data Cable

Connect one terminal of the 5 m Ethernet data cable (part #392-10108) to the connection labeled Ethernet on the LI-7700.



Attach the other terminal to the 0.3 m Ethernet cable (part #392-10107). Plug the RJ45 (Ethernet) terminal into an Ethernet connection on your network, or plug it directly into your computer's Ethernet port.



**Figure 2-2.** Attach the 5 m Ethernet data cable as shown and then attach the RJ45 connector to an Ethernet port on a computer or your computer network.


If you are using the LI-7700 with an LI-7550 Analyzer Interface Unit, rather than attaching the 0.3 m cable, attach the vacant terminal of the 5 m cable to one of the LI-7550 ports labeled “Ethernet.” Attach the second 5 m data cable to the vacant Ethernet terminal on the LI-7550. Join this cable and the 0.3 m Ethernet cable, and connect it to your computer or network as described above.

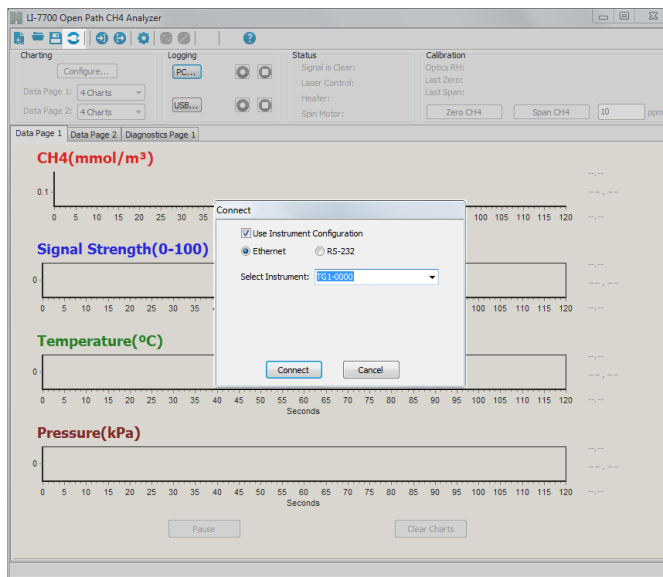
## 4

## Launch the Software and Connect to an LI-7700

Start the LI-7700 application: either double click the LI-7700 software icon on your computer's desktop or launch the software from your computer's Start menu.



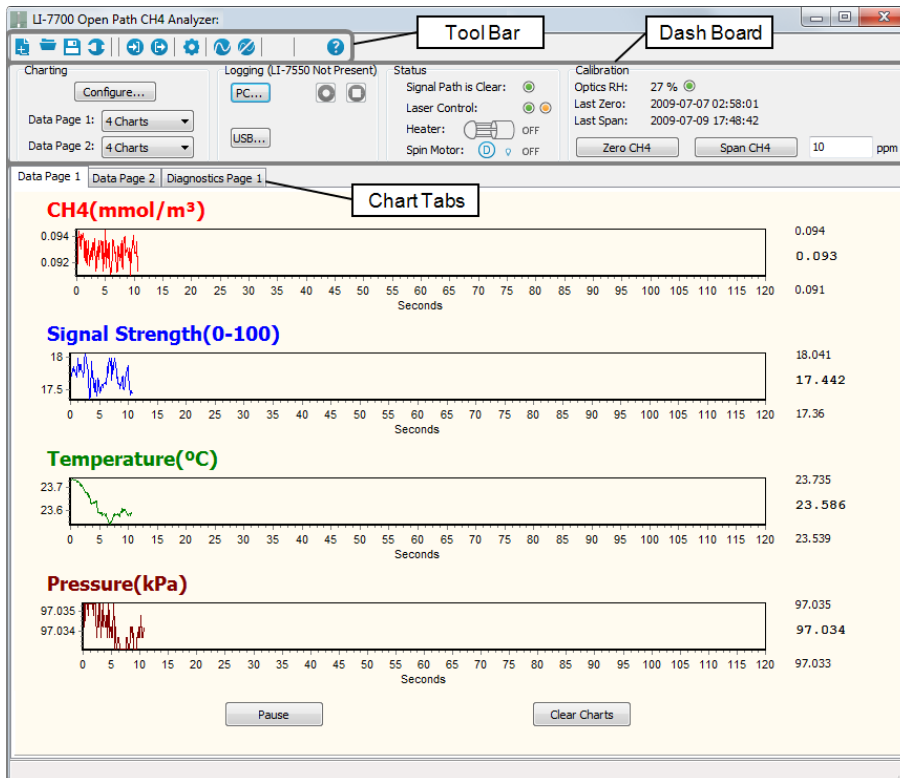
Click on the Connect button (  ), then select the “Ethernet” radio button and then locate your LI-7700 on the “Select Instrument” drop-down menu. Click Connect.



If the instrument is not on the list, wait about 30 seconds for the instrument to finish start-up, then re-launch the software and try to connect again.

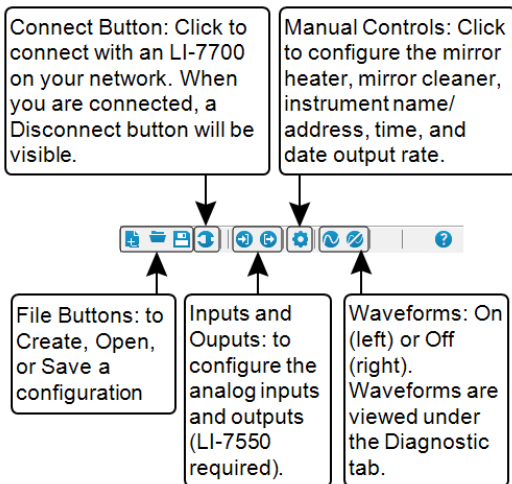
## Main Window

After connecting to an LI-7700, the software window should look similar to the image below. The graphs are set to auto-scale the y-axis by default, so do not be alarmed by the appearance of “noisy” signals.



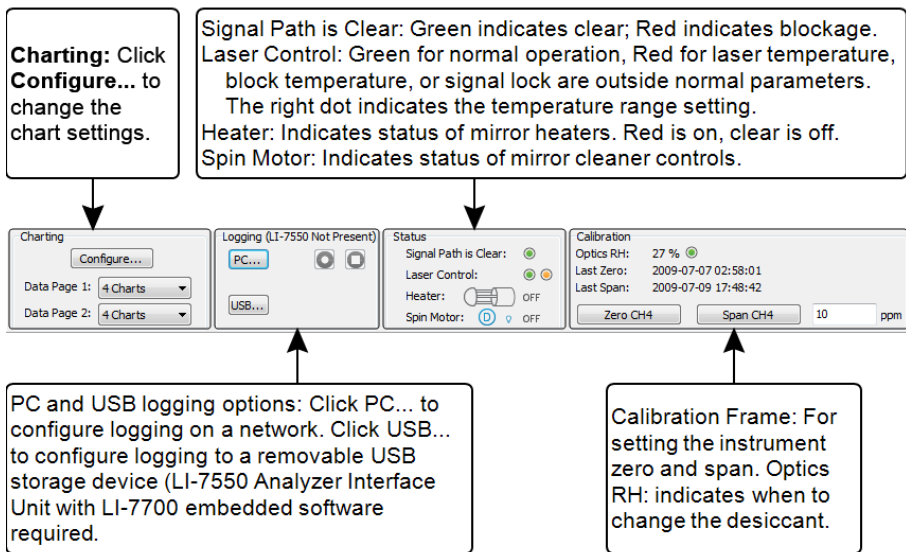
## Tool Bar

The tool bar buttons activate the following options:



## Dashboard

Four groups of settings and operation parameters are displayed in this portion of the main window:



## Chart Tabs

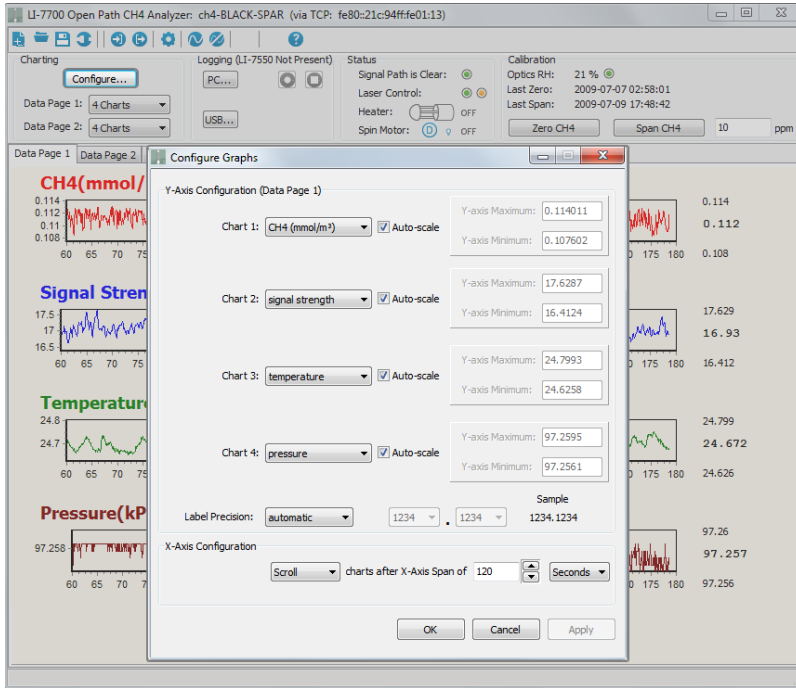
Three pages (tabs) display the live data stream. Configure the data pages with the Configure button in the Charting frame described below. The Diagnostics page displays the instrument waveform, which is turned on or off with the "Waveform" button described above.

## Charting

Two charting pages are visible, and each of these pages can display up to four charts. The charting pages are the two tabs called "Data Page 1" and "Data Page 2" in the main view. To configure the charts, select the tab with the charts you'd like to configure, then click the Configure button in the Charting frame of the main view.

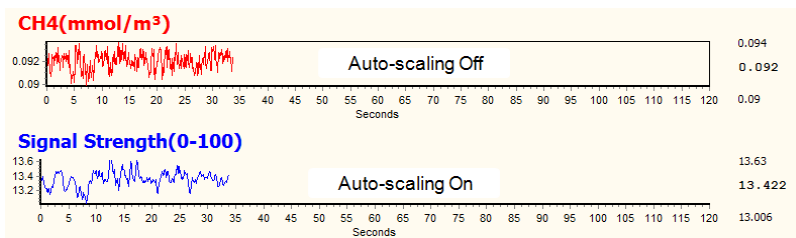
The Configure Graphs dialog box allows you to select which variables are displayed, automatic/manual graph scaling, label precision, scroll settings, and X-axis configuration. Click Apply to implement any changes.

## Configure Charts



In the Configure Graphs dialog you can turn automatic scaling “on” or “off” with the Auto-scale check box. When automatic scaling is on, the software retains a record of the maximum and minimum values encountered and scales the graph accordingly. If you click the Clear Charts button in the main window the chart scaling will reset.

Automatic scaling can be turned on or off simply by double clicking on a graph in the main view. When automatic scaling is on, the graph will have a frame. When automatic scaling is off, the frame will be open, as shown below.



## Logging Methane Data in GHG Files

When you are doing eddy covariance measurements, the simplest way to handle data from the LI-7700 is to record it in GHG files and process it with EddyPro® software or with the SMARTFlux™ system. GHG files are created by LI-COR eddy covariance systems (LI-7500A or LI-7200). When setup properly, they include all the information that is required to compute accurate flux results. This section describes how to configure the LI-7700 with a LI-COR® GHG system.

### About Software Versions

To log GHG files, you must have an LI-7500A or LI-7200 CO<sub>2</sub>/H<sub>2</sub>O analyzer running current software, known as GHG software. The LI-7550 should be configured for the LI-7500A or LI-7200, not the LI-7700 embedded software (see "Getting an LI-7700 to talk to an LI-7550" on page 3-7 for details). The GHG software must be configured properly, and the measurement site must be described accurately, as specified in the LI-7500A, LI-7200, and SMARTFlux™ system instruction manuals.

**Note:** We highly recommend that you always run the most up-to-date software because the new software will correct any known issues and deliver the best performance and features. At the time of this publication, the LI-7500A/LI-7200 run GHG v7.0.1 and the LI-7700 runs version 1.0.5. These are available from the LI-COR® technical support website: [www.licor.com/env/support/](http://www.licor.com/env/support/).

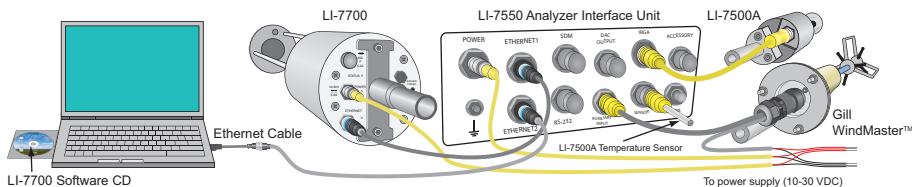
### Connecting your LI-7700

The steps below show how to install the LI-7700 Open Path CH<sub>4</sub> Analyzer in a LI-COR® eddy covariance system. With this configuration, methane data are logged in GHG files (compressed eddy covariance data files) for processing in EddyPro® software or by the SMARTFlux™ system.

# 1

## Connect the LI-7700 to the LI-7550

Install the LI-7700 PC software application from the software CD and use an Ethernet cable to connect the PC to the LI-7700 directly or through the LI-7550 Analyzer Interface Unit (as shown).

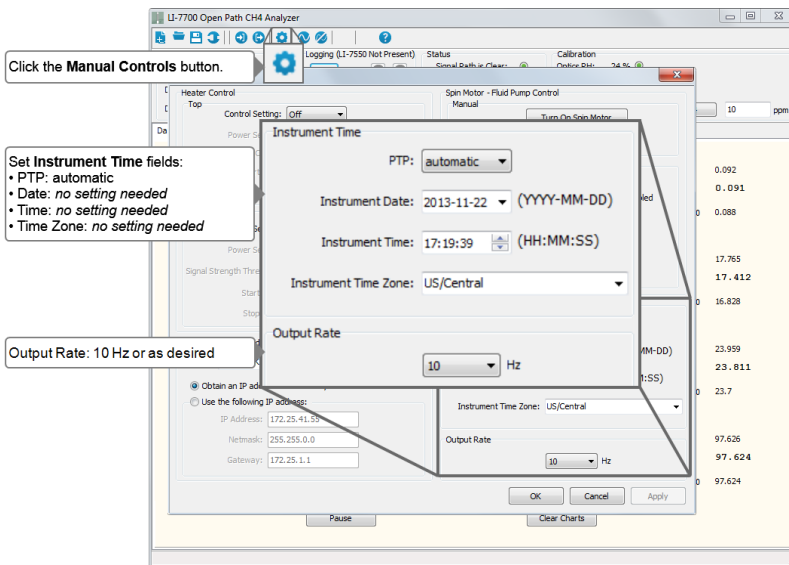
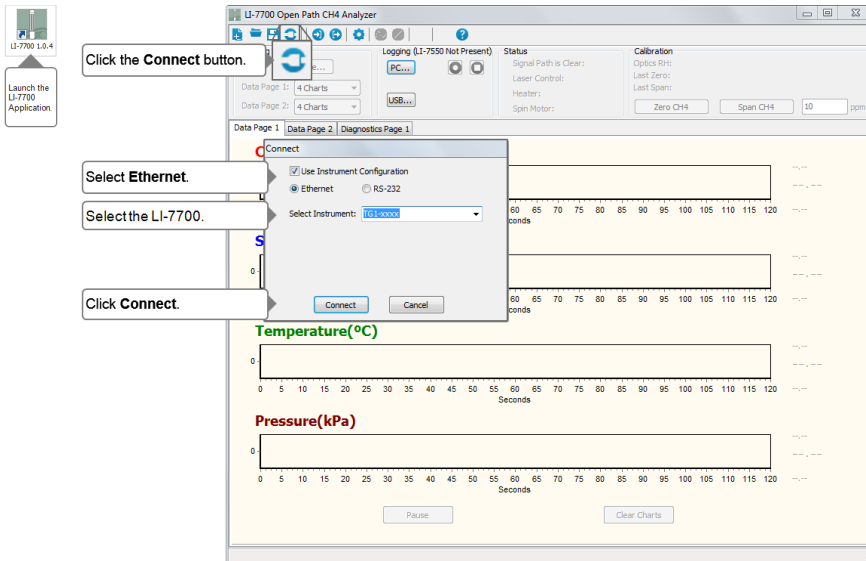




# 2

## Set the LI-7700 PTP Time and Output Rate

Launch the LI-7700 application, connect to the LI-7700, set the **PTP** time to **automatic**, and set the **output rate** to 10Hz (minimum).



Click **OK**, then close the LI-7700 application.

# 3

## Connect to the LI-7700 in GHG v7 Software and Select Variables to Log

In the GHG v7 (LI-7500A/LI-7200) software, Click the **LI-7700** button. Select the LI-7700 and connect to it. Then, click the **Site Setup** button. Enter **CH4 Analyzer** information and select the EddyPro default variables.

**Settings**

LI-7700

Connection Status

Head: None

Connection: Disconnected

Connect to an LI-7700:

LI-7700 Instrument	Version	IP4 Address
None	-	-
LI-7700	1.0-18	172.24.83.33

LI-7700 Hostname: TG1-0xxx

Connect Disconnect

OK Cancel Apply

CO2 (µmol/mol) 392.734

Cell Temperature (°C) 23.92

Time 23:38:38

Date 2013-11-22

CO2 Absorbance 0.04786

H2O Absorbance 0.01008

---

**Site Setup**

CH4 Analyzer

LI-7700

Northward separation (cm): 0.0

Eastward separation (cm): 0.0

Vertical separation (cm): 0.0

CH4 Log Values

- CH4 (µmol/mol)
- CH4 (ppm(v))
- Temperature (°C)
- Pressure (hPa)
- 7700 Auxiliary Input 1
- 7700 Auxiliary Input 2
- 7700 Auxiliary Input 3
- 7700 Auxiliary Input 4
- Thermocouple Input 1
- Thermocouple Input 2
- Thermocouple Input 3
- Signal Strength (RSSI)
- Chip Rate (%)
- Diagnostic Value

Log LI-7700 status records (i, status)

Select All Select None Default

Start Stop Exit

Size: 0.0 Bytes

Free Space: 0.0 Bytes

USB Status: Drive not present

OK Apply Cancel

CO2 (µmol/mol) 392.734

Cell Temperature (°C) 23.92

Time 23:38:38

Date 2013-11-22

CO2 Absorbance 0.04786

H2O Absorbance 0.01008

**Enter the CH4 Analyzer Information:**

- Northward separation (cm)\*:
- Eastward separation (cm)\*:
- Vertical separation (cm)\*:

**Mandatory Information:**

\*One separation value **must** be ≠0 cm.

Northward, Eastward, and Vertical separation are relative to the sonic anemometer. They are measured at the site.

**Select the CH4 Log Values:**


Click **Default** to select the recommended values for EddyPro processing.

You can also verify the connection under the "dashboard" of the GHG v7 (LI-7500A/LI-7200) software main screen. Here the software indicates connection errors with a warning symbol (⚠) and provides guidance to resolve the errors.

# 4

## Turn on Data Logging

Data logging is controlled in the bottom of the **Site Setup** dialog. To start datalogging:

- Click  to activate data logging,
- Insert a suitable USB drive into the USB port.
- Power on the LI-7550 (a USB drive must be in the USB port).

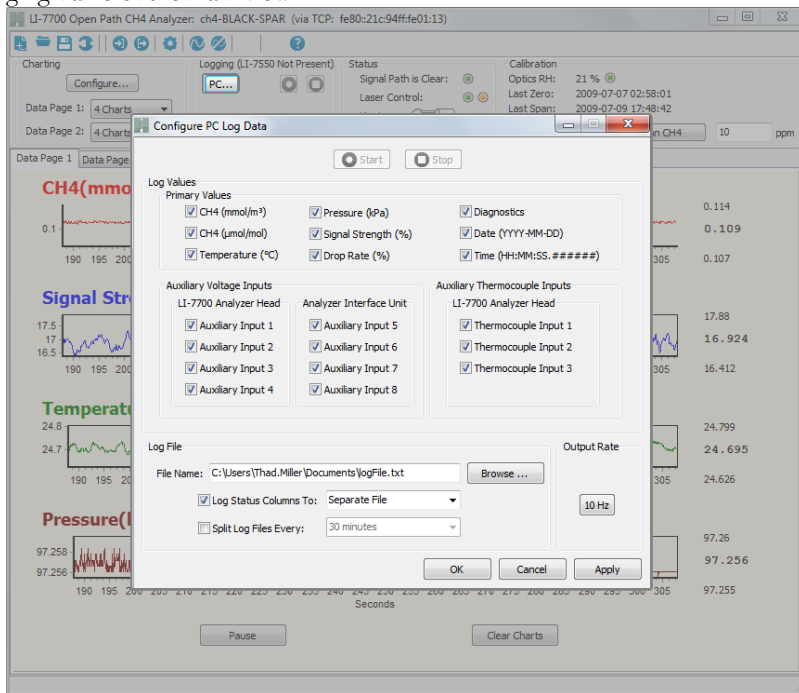
## Configuring the LI-7700

The following sections describe PC/Network data logging, operating temperature range settings, mirror cleaner settings, and mirror heater settings. When the LI-7700 settings are changed, they are implemented to whichever LI-7700 is connected to the interface. After changing the configuration, you could unplug the instrument and deploy it in the field. When it is connected to a power supply it will operate with the previously defined settings. Configurations can be saved and implemented from a file too ("Configuration Files" on page 2-28).

### PC/Network Datalogging

This section describes how to configure logging to a PC on the same network as the LI-7700. PC/Network datalogging uses the Ethernet output.



1. Establish communication with your LI-7700. Click on the PC... button in the Logging frame of the main view.



**Note:** Auxiliary Inputs 5 through 8 can only be logged when an LI-7550 Analyzer Interface Unit is used.

Select the variables that you'd like to log. Click Apply.

2. Choose a directory that the files will be written to, choose whether to log the "Status" record, and whether it will be part of the data file or a separate log file. Choose how often to split the log files (from 15 minutes to 24 hours). Click Apply.
3. Click the button under "Output Rate" to open the Manual Controls window (see "Manual Controls" on the next page), where you can change the output rate. Click Apply in the Manual Controls window.
4. Click "Apply" or "OK" in the Configure PC Data Logging Window.
5. The Start button will be available (no longer grayed out). You can click Start

() in this window to begin logging immediately or click OK to return to the main view where a second Start button () will be active.

When actively logging, the control settings will be grayed out, a green indicator will appear in the main view, and the Stop button will become active. If you are logging data to a PC, be sure to disable sleep mode so the computer does not enter "stand-by."

## Logging Status Columns

Status data (see "Status Header" on page 4-5) can be logged to the data file, logged to a separate file, or not logged. To log status data, check the "Log Status Columns To:" check box, then select "Separate File" or "Log File." Status data are logged at 2 Hz. If you select "Log File", the status data will be interspersed with the data record.

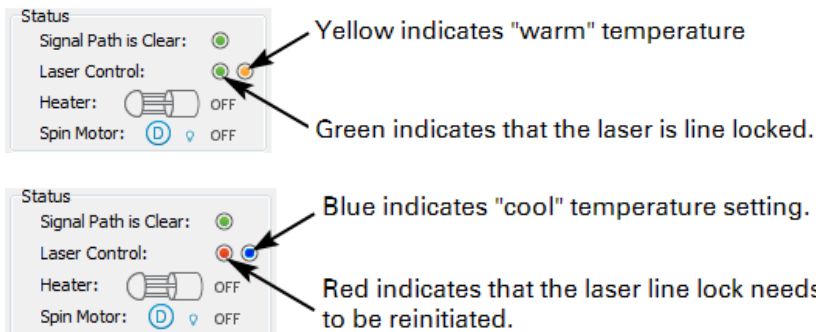
## Splitting Files

To help limit the size of individual files, log files can be split on a periodic basis. The method of splitting is based on the instrument clock, rather than on elapsed time. As such, the file will split when the instrument time crosses a user-specified interval. For example, if the application is set to split the log file every 15 minutes and the logging session starts at 11:25, the first split will occur at 11:30. The second split will occur at 11:45, and so on.

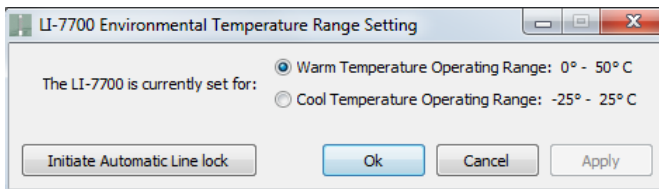
## Operating Temperature Range

Two operating temperature ranges are available: -25 °C to 25 °C (cool) and 0 °C to 50 °C (warm). Select the temperature range setting that reflects the expected temperatures in the environment where you will deploy the LI-7700. If the wrong temperature setting is selected, the instrument may be unable to maintain the required temperature in the internal controls, and thus lose line lock (and it will not record methane data).

The current setting is indicated by either a blue (cool) or yellow (warm) indicator in the main window.



To change the setting, click on the yellow or blue indicator "light." This will open the dialog shown below, in which you can change the setting.



After changing the temperature range setting, it may take up to 5 or 10 minutes for the block temperature to adjust before the instrument returns to normal operation. Look at the Diagnostics Page 1 tab and observe the Block Temperature setting. The "Actual" and "Set" temperatures should be within about 0.5 °C after the temperature adjusts.

**Important:** After changing the operating temperature range, be sure to re-zero and span the analyzer using high-quality (1% or better methane in air) calibration gases.

If the instrument is unable to achieve line lock once the new operating temperature range is established, click the "Initiate Automatic Line lock" button in the temperature range setting window. This will instruct the instrument to re-try the automatic line lock routine.

## Manual Controls

The Manual Controls dialog provides access to controls for the following settings: mirror cleaner settings (see "Configuring Mirror Heater Controls " on page 2-16), mirror temperature controls (see "Determining Mirror Heater Settings " on page 2-18), instrument

time and date (see "Setting the Time " on page 2-24), time zone, IP address, and output rate (Hz).

To change the settings:

1. Click on the Manual Controls button (⚙️) to open the Manual Controls dialog box.
2. Change the settings as desired and then click Apply or OK.
3. Any changes will be implemented immediately to the connected LI-7700. These settings will be saved in the LI-7700 or they can be saved as a configuration file (see "Configuration Files" on page 2-28).

**Note on Embedded Software Versions:** Embedded software (installed on the LI-7700) version 1.0.19 or newer displays the improved spin motor - fluid pump controls (see Figure 2-3 below).

The screenshot shows the 'Manual Controls' dialog box with the following sections and settings:

- Heater Control**
  - Top: Control Setting: automatic, Power Setting: 100 %, Ambient Offset: 5 °C, Start Time: 00:01 (HH:MM), Stop Time: 23:59 (HH:MM)
  - Bottom: Control Setting: automatic, Power Setting: 98 %, Signal Strength Threshold: 50 %, Start Time: 00:01 (HH:MM), Stop Time: 23:04 (HH:MM)
- Instrument Name and Address**
  - Name: TG1-0000, Reboot Instrument button
  - Obtain an IP address automatically (selected)
  - Use the following IP address:
    - IP Address: 172.25.41.55
    - Netmask: 255.255.0.0
    - Gateway: 172.25.1.1
- Spin Motor - Fluid Pump Control**
  - Manual: Turn On Spin Motor, Turn On Fluid Pump buttons
  - Automatic:
    - Default Cleaning Settings (checkbox)
    - Automated mirror spin and mirror wash is disabled
    - Advanced Settings... button
- Instrument Time**
  - PTP: automatic
  - Instrument Date: 2013-11-30 (YYYY-MM-DD)
  - Instrument Time: 14:02:24 (HH:MM:SS)
  - Instrument Time Zone: US/Central
- Output Rate**
  - 10 Hz

Buttons at the bottom: OK, Cancel, Apply

*Figure 2-3. Manual controls window that is displayed when connected to instruments running updated embedded firmware. This window provides improved control over the spin motor - fluid pump. See "Embedded Firmware 1.0.19 and Newer" on page 2-18 for details.*

**Note on Embedded Software Versions:** Embedded software version 1.0.14 and older displays the older spin motor - fluid pump controls shown in Figure 2-4 below. We recommend that you install the newest embedded and desktop software to get the best performance from the instrument. See [www.licor.com/env/support/](http://www.licor.com/env/support/) to get software updates.

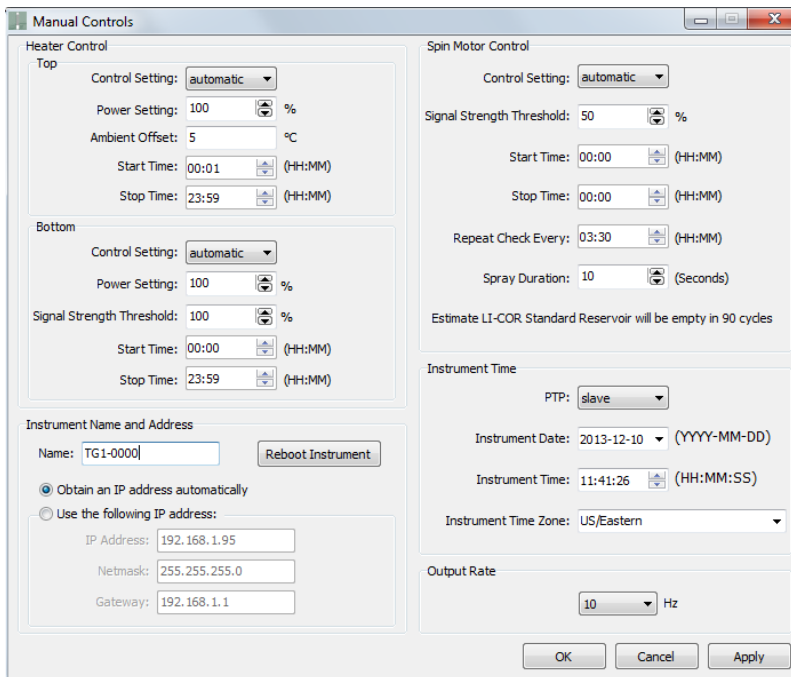


Figure 2-4. Manual Controls window that is displayed when connected to instruments running older embedded firmware. This window provides some control over the spin motor and fluid pump. See "Embedded Firmware 1.0.14 and Older" on page 2-21 for details.

## Configuring Mirror Heater Controls

Mirror heaters serve to keep the mirrors free of condensation and frost. They are configured in the Manual Controls window in the heater control frame. See "Power Requirements Summary" on page A-3 to learn about power requirements for the heaters.



**Heater Control**

**Top**

Control Setting: automatic ▼

Power Setting: 30   %

Ambient Offset: 2 °C

Start Time: 20:00   (HH:MM)

Stop Time: 08:00   (HH:MM)

---

**Bottom**

Control Setting: automatic ▼

Power Setting: 10   %

Signal Strength Threshold: 50   %

Start Time: 20:00   (HH:MM)

Stop Time: 08:00   (HH:MM)

- **Control Setting:** Can be On, Off, or Automatic. Setting to On enables power and ambient offsets for the upper mirror and power settings for the lower mirror. The Automatic setting enables all possible controls.
- **Power Setting:** Specifies how much power is delivered to the mirrors. In environments with light condensation, power settings of 10% or less should be adequate. Settings near 100% should be reserved for circumstances in which severe ice buildup is expected.
- **Ambient Offset:** Specifies how far above the ambient temperature (as measured by the optical path thermocouple) the mirror is heated to. This setting applies only to the upper mirror.
- **Signal Strength Threshold:** (RSSI) for the lower mirror heater. It is enabled when the Control Setting is set to Automatic.
- **Start Time and Stop Time:** Specify when the mirror heaters are on. These are available only when the Control Settings are Automatic.

With the settings shown above, the LI-7700 will deliver 30% of the maximum possible heater power, as needed to keep the mirror 2 °C above ambient temperatures between 8:00 pm (20:00) and 8:00 am (08:00) to the upper mirror. The lower mirror will be heated with 10% of maximum possible power, only if the signal strength is below 50%, between 8:00 pm (20:00) and 8:00 am (08:00).

**Note:** It may take up to 60 minutes for the mirror to reach the set temperature. Account for this when setting the start and stop times.

To save power, set the mirror heaters to operate when condensation is likely. Set them to heat as little as is needed to keep the mirrors free of condensation. Mirror heater power consumption is linear with the setting. Thus, a setting of 100% requires about 8 W, whereas a setting of 10% requires about 0.8 W.

### Determining Mirror Heater Settings

The mirror heaters serve to remove/prevent the buildup of condensation on the mirrors. The best way to determine which settings are best for your application/environment is through experimentation. The following guidelines should serve as a starting point:

1. Make an estimate of when condensing conditions begin and end, and set the mirror heater start and stop times accordingly. Refer to a weather forecast or recent meteorological records. It is easier to prevent condensation than it is to remove condensation, so set the heaters to preempt the formation of dew.
2. Estimate how far below the dew point temperature the actual temperature will fall. Use this to determine power settings and upper mirror ambient offset. If the predicted temperature is only a little below the dew point, a power settings of <10% with an ambient offset (upper mirror) of 1 °C may work fine. Power settings close to 100% should be reserved for extreme conditions where ice buildup is expected.
3. Check your data. If you find data loss or reduced RSSI readings during condensing conditions, it will be worthwhile to boost the power settings or lengthen the time window during those periods.

### Mirror Cleaner

**Note:** The Windows software described here is version 1.0.5. This desktop software is backwards compatible with LI-7700s running all versions of the embedded instrument software. If your embedded instrument software is up-to-date, see "Embedded Firmware 1.0.19 and Newer" below. However, if your embedded instrument software is not updated, refer to "Embedded Firmware 1.0.14 and Older" on page 2-21 for a description of the mirror cleaner settings. We recommend that you download the new instrument firmware from [www.licor.com/env/support/](http://www.licor.com/env/support/) and install it on the LI-7700 to use the improved mirror cleaner algorithm.

### Embedded Firmware 1.0.19 and Newer

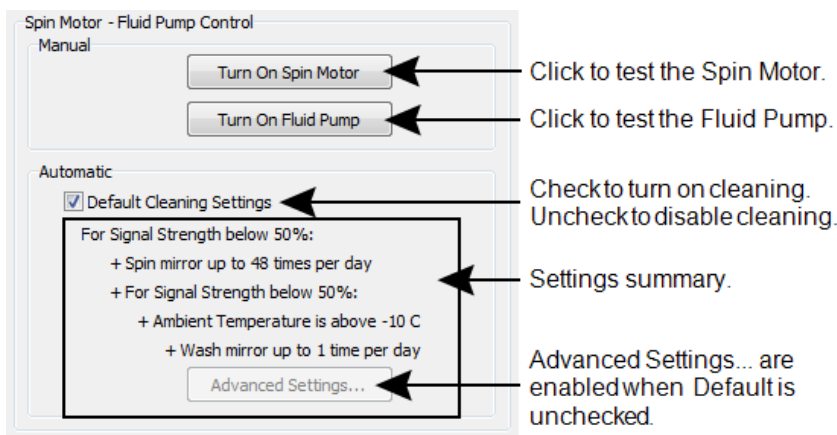
The mirror cleaner provides the capability to automatically apply a cleaning solution (referred to as "washer" hereafter) to the lower mirror and to expel the cleaning solution

and debris using centrifugal force (referred to as "spin" hereafter). You can configure the washer and spin motor timing separately or together to suit a wide range of conditions. The simplest way to configure the mirror cleaner is to use the automatic **Default Cleaning Settings** provided by the software. This combination of settings is suitable for a wide variety of settings.

**Note:** The pump is not designed to operate below freezing temperatures. Therefore, is set to disable when the temperature falls below -10 °C.



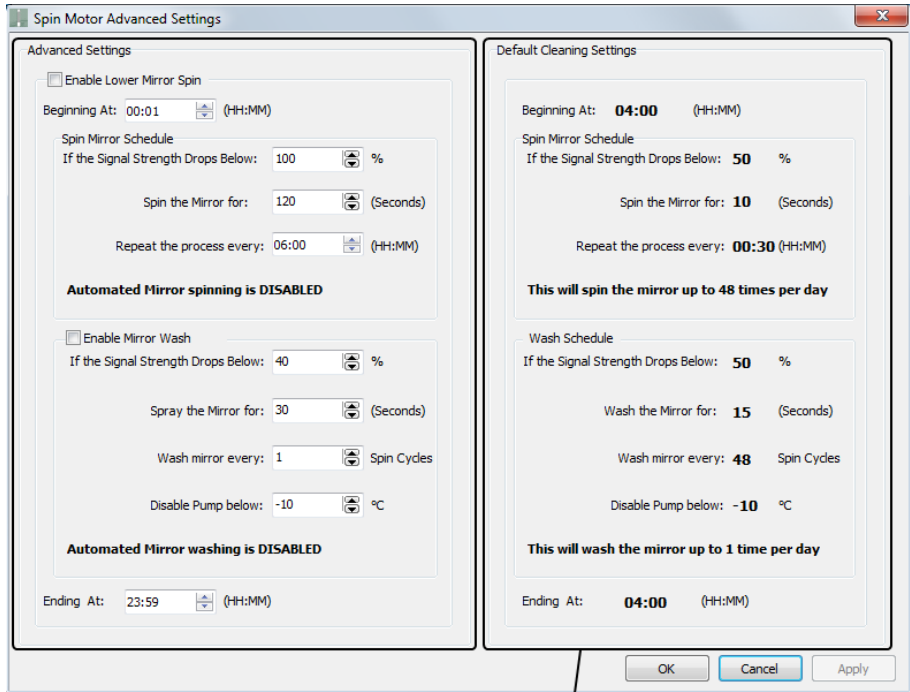
The cleaning settings are set in the Manual Controls window. The washer and spin motor can be controlled independently of each other.



Manual **Spin Motor - Fluid Pump Controls** are simply to test the spin motor and pump. Note that the pump will run if you click **Turn On Fluid Pump**. If you have all the hardware put together and fluid in the reservoir, this could make a mess of your lab, spray cleaning fluid onto your laptop, lab technician, academic adviser, or anything else within range of the spray nozzle. Therefore, we recommend that you use discretion when you click this button.

To extend the life of the pump, refrain from running the pump dry for long periods.

If you find that the Default Cleaning Settings are suitable for your needs, you can activate them with the check box. If you find that they are not satisfactory, or if you wish to try out some other settings, uncheck the box and click **Advanced Settings...**, which provides you with more control over the settings.



**Default Cleaning Settings:** These are presented for reference purposes.

The **Advanced Settings** options are used to develop your own cleaning schedule. The **Default Cleaning Settings** are given to use as a reference.

- **Enable Lower Mirror Settings:** Check this box to configure the Spin settings. Uncheck it to use default settings (or disable it entirely).
- **Beginning at HH:MM:** Set the time to activate the mirror cleaner algorithm.
- **Spin Mirror Schedule:** Here you configure the conditions to activate the spin algorithm.
- **If the Signal Strength Drops Below:** Set the lower bound for the signal strength. If the signal strength drops below this (from a dirty mirror, for example), the spin motor will activate.
- **Spin the Mirror for (seconds):** The duration (number of seconds) of the spin.
- **Repeat the process every:** The amount of time that should pass between each spin. Note that the spin cycle will repeat until the signal strength gets above the lower threshold.

**Summary Note:** The bold note is to inform you of the maximum number of times per day that the mirror will spin, according to the settings.

- **Enable Mirror Wash:** Check this box to configure the fluid pump settings. Uncheck it to use the default settings or disable it entirely.
- **If the Signal Drops Below:** Set the lower bound for the signal strength. If the signal strength drops below this (from a dirty mirror, for example), the mirror cleaner algorithm will activate.
- **Spray the Mirror for (seconds):** The duration (number of seconds) of spray.
- **Wash Mirror every X Spin Cycles:** The number of spin cycles that should include a wash. Typically, one wash per day should be sufficient, but you may need to change this setting for dusty sites.

**Summary Note:** The bold note is to inform you of the maximum number of times per day that the mirror will be washed.

## Embedded Firmware 1.0.14 and Older

In the older instrument embedded software, the mirror - washer unit settings provided less intuitive controls, which lead to undesirable performance under some circumstances. If your instrument is running embedded firmware version 1.0.14 or older, however, the new desktop software will still display the old control interface. This is described below.



There are two components involved with the self-cleaning mirror – the mirror spin motor, which is in the lower housing, and the washer assembly. During the cleaning cycle, the pump and spin motor run simultaneously for the first part of the duration, and the spin motor alone runs for the last 10 seconds of the duration. This provides two benefits: Any drops that fall from the nozzle will be cleared by the spinning mirror, and it allows the mirror to spin without using washer fluid. **Spin Motor Controls** are in the **Manual Controls** window.

Spin Motor Control

Control Setting: automatic

Signal Strength Threshold: 20 %

Start Time: 04:00 (HH:MM)

Stop Time: 20:00 (HH:MM)

Repeat Check Every: 01:00 (HH:MM)

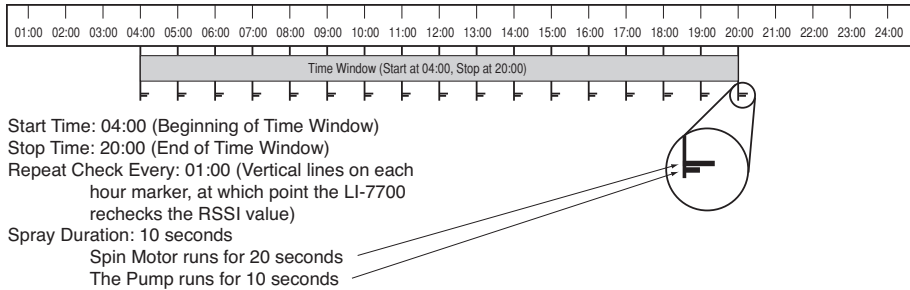
Spray Duration: 10 (Seconds)

Estimate LI-COR Standard Reservoir will be empty in 90 cycles

1. The **Control Setting** can be **On**, **Off**, or **Automatic**. Change the setting to Automatic to enable the remaining controls.
2. **Signal Strength Threshold** refers to a threshold (Received Signal Strength Indicator, or RSSI). If the laser signal strength falls below this threshold, the mirror spin motor and washer pump will activate according to the other settings.
3. **Start Time** and **Stop Time** specify the period of the day in which the mirror cleaner can activate. Set both to 00:00 to allow mirror cleaning for 24 hours a day.
4. **Repeat Check Every** sets the interval at which the instrument re-checks the RSSI value. If the RSSI value is below the Signal Strength Threshold (#2), then it will repeat the cleaning cycle according to the remaining parameters.
5. **Spray Duration**: can be set from 0 to 110 seconds. A setting of 0 will result in no spray, but the mirror will still spin for 10 seconds if the RSSI is below the signal strength threshold.

With the settings shown above, if the signal strength is below 20%, the LI-7700 will initiate a 20 second cleaning cycle starting at 4:00 am (04:00). If the first cleaning cycle fails to raise the signal strength to above 20%, it will repeat every hour until 8:00 pm (20:00) or until the signal strength is above 20%.

Figure 2-5 on the facing page depicts how the LI-7700 uses the Spin Motor Control settings:



**Figure 2-5.** Depiction of mirror heater control settings. The gray bar (“Time Window...”) shows the “Start Time” and “Stop Time”. The “Repeat Check Every:” interval is indicated by the vertical hash marks across the gray bar. Spray duration is indicated in the inset.

If the RSSI value is below the “Signal Strength Threshold”, a cleaning cycle will be initiated according to the “Repeat Check Every” setting. The pump always runs for 10 seconds less than the spin motor. Set the “Spray Duration” to 0 seconds to spin the mirror for 10 seconds without spraying any fluid.

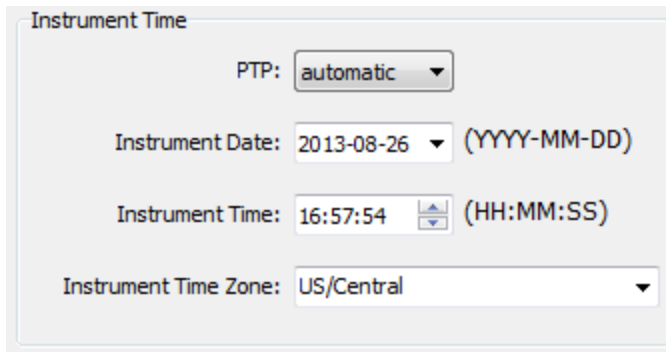
**Important:** The use of a low signal strength threshold (e.g. ~10%) may result in “noisier” data as the signal strength gets lower. Check your data to observe this, and choose a setting that is within the noise tolerance that you prefer. Conversely, a high signal strength threshold (e.g., 80%) will cause the washer fluid to be used more quickly. Also, the spinning mirror will cause perturbations in the pressure measurement. Data collected while the spin motor is active should not be used.

**Note:** The 7700-101 is equipped with an inlet connection that can be used to attach a secondary washer reservoir. In environments where the washer fluid is used quickly, a secondary washer reservoir can be used to refill the 7700-101 reservoir. This will require a pump or siphon to transfer fluid from the secondary reservoir to the 7700-101 reservoir.

## Setting the Time

The LI-7700 is shipped with the time set at the factory. To set your local time:

1. Connect to the LI-7700.



2. Open the Manual Controls dialog box.
3. Set the PTP: field to “automatic.”
4. Select the desired time zone.
5. Click Apply or OK.

You may also adjust the time if desired, but these adjustments apply to the Unix time stamp as well. Therefore, be sure that the instrument time and date match your local time and date and that you have set the correct time zone.

The time stamp in each file header shows the instrument time and time zone. The time stamp associated with each data record will always include Unix time, but you can choose to output the instrument time and date as well. Unix time is in two fields: seconds and nanoseconds. Conventional time includes the date and time resolved to seconds. The nanoseconds field can be used to resolve sub-second time stamps.

## About LI-7700 Time Keeping

Three aspects of time keeping in the LI-7700 are described here – the basis for the actual time (Unix, aka POSIX), the protocol for determining the actual time (Precision Time Protocol), and user-settable time zone and time.

The LI-7700 is a network-based instrument and it is possible for multiple users to log data from a single instrument over multiple TCP/IP connections. Consequently, the instrument uses Coordinated Universal Time (UTC) for its onboard timekeeping tasks. As such, the default time stamp is UTC based, but local time can be set as well.



The LI-7700 internal clock uses Unix time as a standard. Simply put, this is seconds elapsed since the Unix Epoch of 00:00 Coordinated Universal Time (UTC) Jan. 1, 1970 (or 1970-01-01T00:00:00Z ISO 8601). For example, the time stamp 1262884605 translates to 01/07/2010 at 05:16:45 UTC. The date and time are converted into a conventional display format (YYYY-MM-DD; HH:MM:SS), and adjusted based on the time zone settings that you select.

The LI-7700 uses the Precision Time Protocol (PTP) time keeping system. PTP is a high precision time synchronization protocol for networked measurement and control systems. Devices controlled with PTP can maintain accuracy in the sub-microsecond range with a sufficiently accurate master clock. PTP is defined in the IEEE 1588-2002 and 1588-2008 standards, officially entitled “Standards for Precision Clock Synchronization Protocol for Networked Measurement and Control Systems.” A detailed summary of IEEE-1588 is available at [www.ieee1588.com](http://www.ieee1588.com). Full documentation is available for purchase from the Institute of Electrical and Electronics Engineers (IEEE) at [www.ieee.org](http://www.ieee.org).

The basic principle behind the PTP is that the best time keeping can be accomplished with multiple networked devices by synchronizing all the device clocks to the most precise clock on the network. Each clock on the network has a rating that indicates its relative accuracy. The IEEE 1588 protocol specifies the use of a Best Master Clock algorithm to determine which clock on the network is the most accurate. On a network, the most accurate clock becomes the master clock and all other clocks sync to the master clock.

The software implementation of PTP in the LI-7700, which uses the instrument clock, provides accuracy in the 10 microsecond range. Implementation of PTP is most important when the LI-7700 is used in combination with the LI-7550 Analyzer Interface Unit or other network-based sensors.

Three time-keeping settings are available in the Manual Controls dialog. They are:

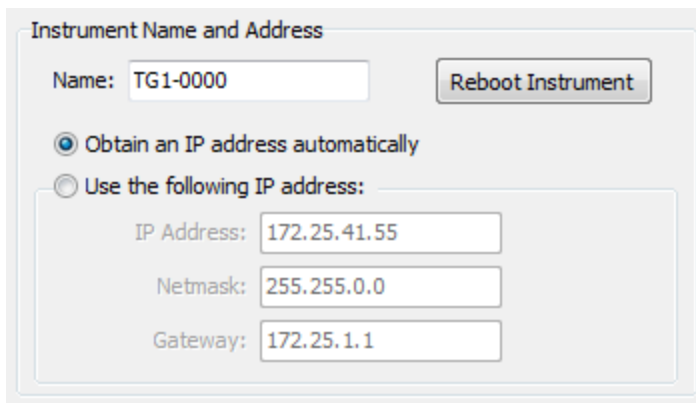
**Automatic:** The LI-7700 searches the network and syncs to the most accurate clock using the Best Master Clock algorithm. The LI-7700 should use this setting in most circumstances.

**Preferred:** The LI-7700 uses its own internal clock unless it finds a better clock on the network. The LI-7550 should use this setting in most circumstances.

**Slave:** The LI-7700 syncs to another clock. It will search the network and synchronize to the best clock.

## Instrument Name and IP Address

The instrument name and IP address are given in the Manual Controls window. To rename your LI-7700, simply type the new name of your LI-7700 into the name field and click “OK” or “Apply.” Then reboot the instrument.



The screenshot shows a dialog box titled "Instrument Name and Address". It contains a "Name:" label followed by a text input field containing "TG1-0000". To the right of this field is a "Reboot Instrument" button. Below the name field are two radio button options: "Obtain an IP address automatically" (which is selected) and "Use the following IP address:". The second option is expanded to show three sub-fields: "IP Address:" with the value "172.25.41.55", "Netmask:" with the value "255.255.0.0", and "Gateway:" with the value "172.25.1.1".

The communication interface to the analyzer head is by Ethernet. More specifically, it is by the IPv6 Ethernet Protocol. As such, it is generally not necessary to configure a static IP address for the instrument if the instrument name is known. The instrument broadcasts its name onto the network, and the LI-7700 Windows Application looks for that broadcast and then populates the “Connect” dialog box accordingly.

## Output Rate

The output rate setting determines the signal averaging done by the digital filter. To avoid aliasing (only a concern for co-spectra, not for fluxes), the LI-7700 output rate should be set at a frequency greater than or equal to 2 times the desired bandwidth, also referred to as the Nyquist frequency (e.g., for a bandwidth of 20 Hz, set the output rate to 40 Hz). This is set in the Manual Controls window.

Instrument Time

PTP: automatic

Instrument Date: 2013-12-04 (YYYY-MM-DD)

Instrument Time: 14:53:53 (HH:MM:SS)

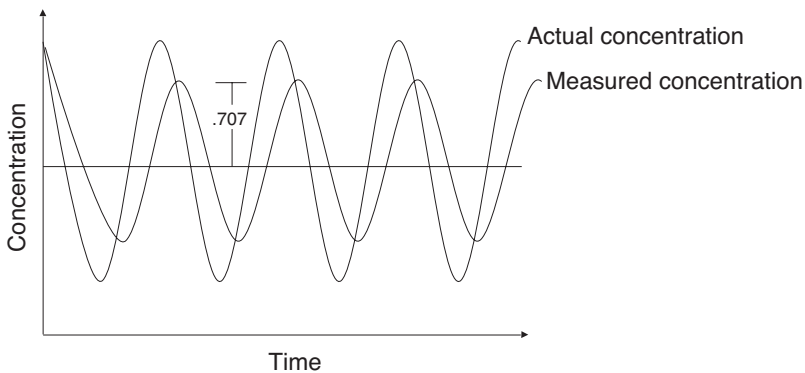
Instrument Time Zone: US/Central

Output Rate

10 Hz

OK Cancel Apply

Bandwidth is the frequency at which the indicated amplitude is 0.707 of the real amplitude.



**Figure 2-6.**  $\text{Bandwidth} = 1 / \text{oscillation period}$ .


Bandwidth is useful for characterizing real-world behavior in which there are fluctuating gas concentrations. Given a sinusoidal oscillation of concentration, the instrument's ability to measure the full oscillation amplitude diminishes as the oscillation frequency increases.

## Configuration Files

The configuration file is an XML text file that includes instructions that specify the operational parameters of the instrument. You can create a configuration file from the instrument, or upload a configuration file to the instrument.


### Creating an Instrument Configuration File

The following procedure describes how to create a new instrument configuration file. See "Configuration File Grammar" on page 7-18 for more information on configuration files.

1. Launch the LI-7700 Windows® software.
2. Be sure the LI-7700 software is not connected to an LI-7700. If needed, click the Disconnect button. Optional: click the New Instrument Configuration button to restore default settings.
3. Click on the Manual Controls button. Set the controls as desired. Click OK or Apply then OK to set the new configuration. Repeat this for the Auxiliary Inputs and LI-7550 Outputs if desired.
4. Click the Save button . A **Save As...** dialog box will open. You can select a directory anywhere on your computer or network. The file will have a ".l77" extension.

### Implementing a Configuration File

The following procedure describes how to implement a configuration file.

1. Be sure the LI-7700 is powered "on" and connected to your computer or network with the Ethernet connection.
2. Launch the LI-7700 software and connect with the LI-7700.
3. Click on the Open button . The **Open** dialog box will appear. Navigate to the directory that has the ".l77" configuration file.
4. Select the file and click Open.

**Note:** When you connect to an LI-7700, at the top of the "Connect" dialog box, there is a "Use Instrument Configuration" check box. Be sure it is checked in order to prevent overwriting the current LI-7700 configuration.

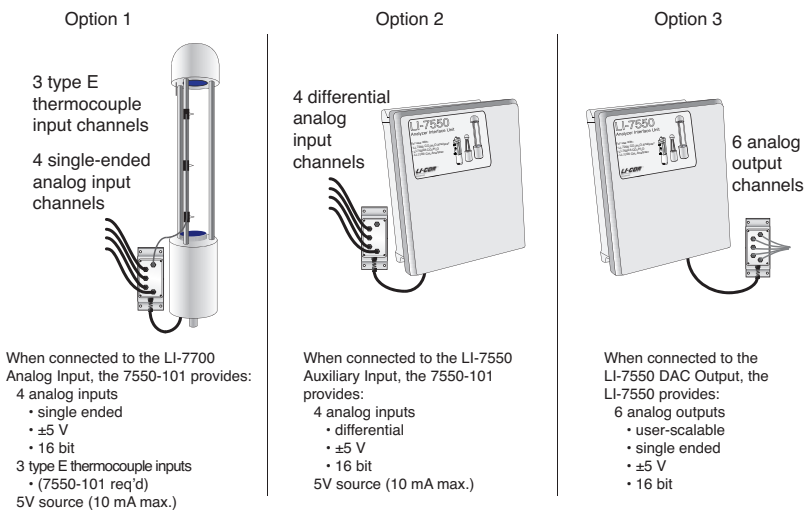
## LI-7700 Analog Inputs

The LI-7700 and the LI-7550 each provide 4 analog input channels. These can be used with either the optional 7550-101 Auxiliary Sensor Interface, the Analog Input/Output

Cable (part #392-10109), or sonic anemometer analog input cables (see "Sonic Anemometer Interface Cables" on page 1-5). The 7550-101 is a weatherproof terminal strip that provides sealed electrical connections. The Analog Input/Output Cable terminates with bare leads on one end and a Turck connection on the other. It is included with the LI-7550 Analyzer Interface Unit and available as an optional accessory.

The 7550-101 Auxiliary Sensor Interface and the Analog Input/Output Cable can be used in any of the three configurations shown in Figure 2-7 below, but the three type E thermocouple connections (Option 1) are only available through the 7550-101 and can only be used with the LI-7700 analog inputs.

The 7550-101 Auxiliary Sensor Interface and the Analog Input/Output Cable can be used to connect analog data sources to the LI-7700 (Option 1) or the LI-7550 Analyzer Interface Unit (Option 2). They can also be configured to distribute the 6 analog outputs of the LI-7550 (Option 3).



**Figure 2-7. The 7550-101 can function as a weather-proof terminal strip for the LI-7700 Analog Input (Option 1), the LI-7550 Auxiliary Input (Option 2), or the LI-7550 DAC Output (Option 3).**

Here we describe how to use the 7550-101 or the Analog Input/Output Cable as shown in Option 1 above. Options 2 and 3 are described later (see "Auxiliary Sensor Interface Terminals (Option 2)" on page 3-17). Note that Options 1, 2, and 3 can be used together in any combination.

## Auxiliary Sensor Interface Terminals (Option 1)

Loosen the four Philips head screws in each corner of the Auxiliary Interface Box module and remove the top cover. The interior of the interface is shown in Figure 2-8 below.

There is a small jumper located at the LK1 label; when using the 7550-101 with the LI-7700 (Option 1), position the jumper over the 2 pins nearest the LI-7700 label (the lower two pins in Figure 2-8 below).

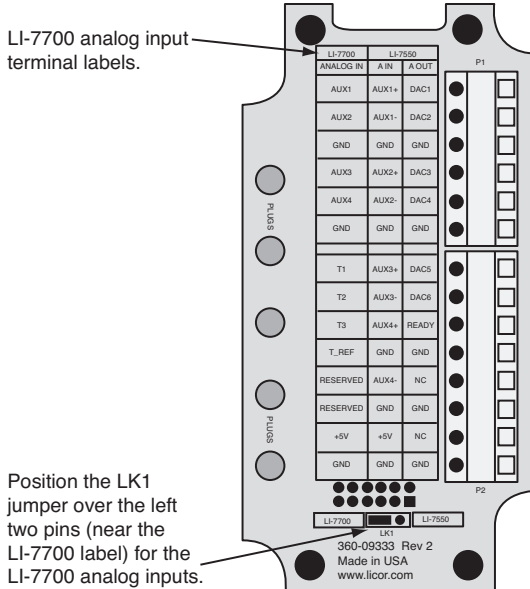


Figure 2-8. Schematic diagram of interior of Auxiliary Sensor Interface.

There are two terminal strips, with connections as follow:

### When Used for Analog Inputs (LI-7700)

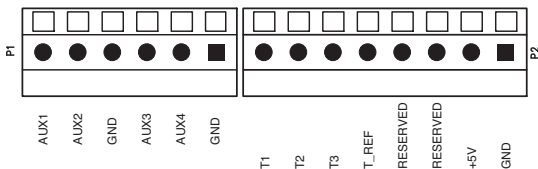


Figure 2-9. Terminal connections for analog inputs (Option 1).

The terminal positions are numbered and configured as follows, reading from left to right:

**Table 2-1.** Terminal assignments for the 7550-101 and wire colors for the Analog Input/Output cable when using the LI-7700 analog inputs (Option 1).

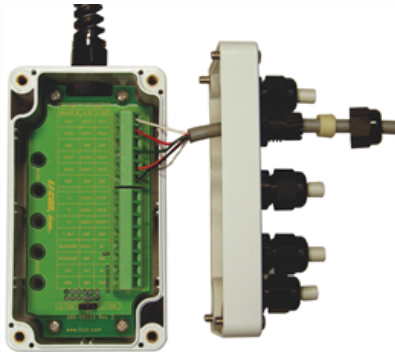
Option 1				
7550-101 Auxiliary Sensor Interface		Description	Analog In/Out Cable(p/n 392-10109)	
Terminal	Input	Wire Color	Pin	
1	AUX1	Auxiliary Input 1 Signal	White	Pin 1
2	AUX2	Auxiliary Input 2 Signal	Brown	Pin 2
3	GND	Ground	Tan	Pin 10
4	AUX3	Auxiliary Input 3 Signal	Green	Pin 3
5	AUX4	Auxiliary Input 4 Signal	Yellow	Pin 4
6	GND	Ground	Tan	Pin 10
7	T1	Thermocouple 1 Signal <sup>1</sup>	Gray	Pin 5
8	T2	Thermocouple 2 Signal <sup>1</sup>	Pink	Pin 6
9	T3	Thermocouple 3 Signal <sup>1</sup>	Blue	Pin 7
10	T_REF	Thermocouple Reference <sup>1</sup>	Black	Pin 11
11	Reserved	Thermistor Input	Red	Pin 8
12	Reserved	Thermistor Reference	Violet	Pin 12
13	+5V	+5V Supply (10 mA max.)	Orange	Pin 9
14	GND	Ground	Tan	Pin 10

<sup>1</sup>Using the thermocouple channels (T1 to T3) requires measurement of the reference junction temperature. This is accomplished with an internal thermistor in the 7550-101.

## Connecting Sensors to the Auxiliary Sensor Interface

There are 5 “gland” type plugs on the Auxiliary Sensor Interface top cover that secure and seal the wires that are connected to terminals inside the box. To attach your sensor (s) to the Auxiliary Sensor Interface, follow these steps:

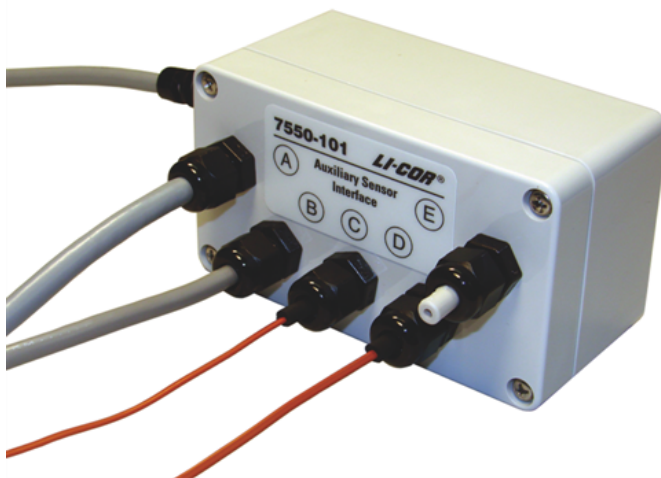
1. Remove the #1 Philips screws from each of the four corners of the Auxiliary Sensor Interface and remove the top cover.
2. Remove the cap from a gland plug by turning the cap counterclockwise.
3. Pass the wires through the top of the plug cap, rubber grommet, and then through the gland plug.
4. Use a small flathead screwdriver to loosen the appropriate screw terminals and insert the wire leads into the terminals. Tighten the screw terminals to secure the wires. Make a note of which plug the wires are passing through and which terminals the wires are connected to. This will be needed later when you configure the sensor coefficients in the software.



Insert the grommet into the gland plug and pull gently on the wires to remove slack from inside the interface. Attach additional sensor wires to the appropriate terminals.

5. When you have finished installing all of your sensors, re-attach the interface top cover and tighten the gland plug caps.





6. Attach the Auxiliary Sensor Interface cable connector to the Analog Input connector on the LI-7700 connection panel.

There are 5 plastic plugs in the interface box gland plugs and 10 extras (part #300-07393) in the spares kit. These should be inserted into unused gland plugs on the Auxiliary Sensor Interface. The plugs prevent foreign materials (e.g., water, insects, dirt) from entering the interface box. Insert the narrow end of the plug through the gland plug and tighten the plug cap (as shown in plug E above). The plugs should always be used in any gland plug that does not have a wire.

There is also a length of Santoprene® tubing in the Auxiliary Sensor Interface spares kit. This tubing can be cut to length and placed around small gauge wires that may not be able to be tightened sufficiently with the gland plugs. It can also be used for oddly shaped wires that can be difficult to seal with the gland plug caps, as in plugs C and D above.

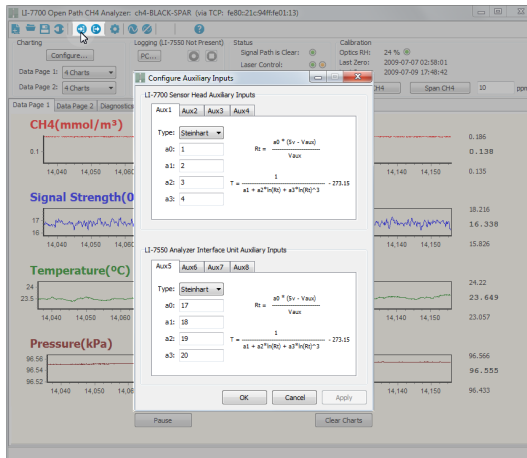
## Thermocouple Inputs

The thermocouple inputs are designed to work with Type E thermocouples (chromel-constantan). The positive (+) thermocouple wire (chromel, purple insulation) should be connected to T1, T2, or T3. The negative (-) thermocouple wire (constantan, red insulation) should be connected to the T\_REF. All three channels share a common connection T\_REF. The range of thermocouple temperature measurements is  $\pm 20$  °C from the reference temperature inside the Auxiliary Sensor Interface.

Thermocouple readings can be influenced by rapid changes to the temperature or by heat loads to the auxiliary sensor interface. To avoid risk of these issues, shield the

auxiliary sensor interface from direct sun and/or thermally insulate the apparatus. A simple solution is to wrap the Auxiliary Sensor Interface with aluminum foil.

## Configuring Auxiliary Inputs (LI-7700)



Analog inputs are configured from the “Configure Auxiliary Inputs” dialog box. Auxiliary inputs 1 through 4 are used with LI-7700 inputs (see "Configuration File Grammar" on page 7-18 "Auxiliary Sensor Interface Terminals (Option 1)" on page 2-30). They are configured with the top four tabs in the Configure Auxiliary Inputs dialog box. One of two mathematical conversions can be applied to the input voltages: 1) a third order polynomial or 2) a Steinhart equation (for computing temperature in °C from a thermistor).

The polynomial can be used to scale inputs from a variety of sensors, such as thermistors or sonic anemometers. Below are several examples demonstrating ways that the polynomial and Steinhart equation can be used.

**Example 1,** Wiring an air temperature sensor into the 7550-101: Set the “Type:” to “Steinhart,” as shown below.

LI-7700 Sensor Head Auxiliary Inputs

Aux1 Aux2 Aux3 Aux4

Type: Steinhart ▾

a0: 1

a1: 2

a2: 3

a3: 4

$$R_t = \frac{a_0 * (5V - V_{aux})}{V_{aux}}$$

$$T = \frac{1}{a_1 + a_2 * \ln(R_t) + a_3 * \ln(R_t)^3} - 273.15$$

For the 1400-101, 1400-102, or 8100-203 temperature sensors, use the following coefficients to log temperature as °C:

LI-7700 Aux Channel	Aux1
Polynomial Values	a0 100,000
(set in LI-7700	a1 1.1259 e-3
software)	a2 2.3459 e-4
	a3 8.6329 e-8

Connect the black lead to a +5V terminal, the red lead to one of the auxiliary input terminals (AUX1, AUX2, etc.), and leave the orange lead disconnected.

**Example 2, Connecting a CSAT3:** These settings convert analog output voltage from a CSAT3 sonic anemometer (Campbell® Scientific, Inc.) to wind speed (m/s). In this example we demonstrate the “high range” (horizontal wind speeds up to ±65.563 m/s, vertical wind speeds up to ±8.192 m/s) scaled to ±5V. The median of the high (+65.563) and low (-65.563) values of the measurement range is the offset (0), and is entered in the a0 field. The slope is found by dividing the wind speed measurement range by the total voltage range:  $131.072 \text{ m s}^{-1} / 10\text{V} = 13.1072 \text{ m s}^{-1} \text{ v}^{-1}$ . If the leads for  $u_x$ , and  $u_y$  are connected to Aux1 and Aux2 inputs, set the Aux1 and Aux2 polynomial values for a1 to 13.1072 and a0, a2, and a3 = 0.

Mutlipliers for  $u_z$  are found similarly. With a measurement range of ±8.192 m s<sup>-1</sup>,  $16.384 \text{ m s}^{-1} / 10\text{V} = 1.6384 \text{ m s}^{-1} \text{ v}^{-1}$ . Using Aux3 to log  $u_z$ , a1=1.6384; a0, a2, and a3 = 0.

Using Aux4 to log the speed of sound, the terms a1=340 (offset), a2=6.5536 (slope) are given in the CSAT3 Instruction Manual. This is shown below. Refer to the CSAT3 Instruction Manual for more information.

LI-7700 Aux Channel	Aux1	Aux2	Aux3	Aux4	
Polynomial Values	a0	0	0	0	340
(set in LI-7700 software)	a1	13.1072	13.1072	1.6384	6.5536
	a2	0	0	0	0
	a3	0	0	0	0
Variable Logged	U <sub>x</sub>	U <sub>y</sub>	U <sub>z</sub>	Speed of Sound	
Units	Windspeed (m/s)			(m/s)	

**Example 3,** Connecting a Gill WindMaster™ or WindMaster Pro™: This example describes how to convert analog signals from a Gill WindMaster™ or WindMaster Pro™ sonic anemometer in the  $\pm 50 \text{ m s}^{-1}$  wind speed range (speed of sound range of  $300\text{-}370 \text{ m s}^{-1}$ ), with analog outputs scaled to  $\pm 5\text{V}$ .

The median of the low (-50) and high (+50) values of the measurement range is the offset (0), and is entered in the a0 field. The voltage output range between -5 to +5V is 10V. To find the slope, divide the measurement range by the voltage range ( $100/10=10$ ). This value is the slope and is entered in the a1 fields for Aux 1, 2, and 3.

For speed of sound, the median of the low (300) and high (370) values of the measurement range is the offset (335), and is entered in the a0 field for Aux4. To find the slope, divide the measurement range by the voltage range ( $70/10=7$ ). This is entered in the a1 field for Aux4.

LI-7700 Aux Channel	Aux1	Aux2	Aux3	Aux4	
Polynomial Values	a0	0	0	0	335
(set in LI-7700 software)	a1	10	10	10	7.0
	a2	0	0	0	0
	a3	0	0	0	0
Variable Logged	U	V	W	Speed of Sound	
Units	Windspeed (m/s)			(m/s)	

Alternatively, you could compute  $^{\circ}\text{C}$  rather than SOS with the following:  $T_s$  range=  $-40^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ . The median (15) is entered in a0 for Aux4. The measurement range ( $|-40 - 70|=110$ ) divided by the voltage range ( $110 \text{ m s}^{-1}/10\text{V}=11 \text{ m s}^{-1} \text{ V}^{-1}$ ) is the slope and is entered in a1 for Aux4. Refer to the WindMaster™/Pro User Manual for more information.

## Deploying the LI-7700 and Accessories

For field deployments, the LI-7700 must be firmly attached to a stable, secure instrument platform. For eddy covariance applications, be sure that the instrument is deployed in accordance to the guidelines set forth by the scientific community for eddy covariance data collection. For example, mounting the LI-7700 too close to the canopy may result in sampling in the roughness sub-layer, which is not representative of the study site. A vertical mounting orientation provides 360° acceptance for wind direction, and this is the recommended orientation. However it is oriented, the LI-7700 should be placed as close to the sonic anemometer as practical without affecting the airflow through the anemometer.

### Installing the LI-7700

The LI-7700 mounting post is designed to fit securely into a 1" crossover fitting, similar to those used in many micrometeorological stations. Crossover fitting suppliers are listed in "Mounting Accessories" on page D-3.

To mount the LI-7700 on a weather station using a 1" (2.54 cm) crossover fitting:

1. Position the crossover fitting on the spar in the approximate position. It should mount so the LI-7700 is correctly positioned in relation to the sonic anemometer and other instruments. Securely tighten the hex-screws on the fitting.
2. Position the LI-7700 in the crossover fitting and tighten the hex-screws. Reposition the fitting as needed. Be sure to securely tighten the cross-over fitting screws. Attach the power and data cables. Route the cables and hoses so that they are not hanging from the LI-7700. Preferably, secure them to the tower with wire ties.
3. Connect the Ethernet cable from the LI-7700 to a data storage device.
4. Connect the power cable to a suitable power supply.



### Vibrations

The LI-7700 may be sensitive to vibration at certain high frequencies, which could affect the measurements. These frequencies are not typically experienced in tower mount

applications. For land-based installations, one of the most likely sources of vibrational problems would be a tower with excessively tight guy wires. For other settings where there may be vibrations in a problematic range, you should try to minimize vibration through alternative mounting attachments.

## Positioning the LI-7700

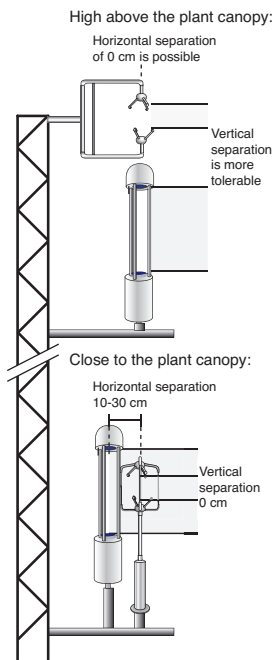


Figure 2-10. Suggested mounting configurations for the LI-7700.

There are numerous factors to take into account when deploying the LI-7700 in eddy covariance flux applications. Addressing these concerns appropriately is critical to minimizing required frequency response corrections. Here we address two of these: instrument height above the canopy and proximity to the sonic anemometer.

For most applications, the LI-7700 and other sensors should never be within the canopy roughness sub-layer, as that may violate the assumptions of the eddy covariance flux method. The minimum recommended height above the canopy is 1.0 to 1.5 m or more, but this will vary depending on surface roughness and other factors.

As with all instrumentation in an eddy covariance flux system, the closer to the canopy, the closer the instruments must be to each other to minimize frequency response corrections for sensor separation. For deployments high above the canopy, the LI-7700

should still be as close as practical to the sonic anemometer, but larger vertical separations are now more acceptable. For example, at heights of 40 meters above the canopy, the anemometer sample path can be above the LI-7700 entirely.

**Important:** Never put scalar measurements (e.g., the LI-7700) above the sonic anemometer, as it may lead to errors and require difficult-to-predict corrections.

For near-surface deployments, the LI-7700 should be 10-30 cm horizontally from the anemometer, and they should have a minimal vertical separation.

## Grounding

The power supply, Ethernet, and analog inputs are all electrically isolated from each other and from the internal circuitry. There also are protection clamps in the form of spark gaps on the isolated circuits to the instrument chassis. For lightning protection, make sure the mounting structure for the instrument is electrically grounded, or run an independent bonding wire from the instrument mount to the earth.

## Mounting the 7550-101 Auxiliary Sensor Interface

The Auxiliary Sensor Interface has an attached mounting plate that can be used to attach the interface to a 1" to 1½" (2.5 to 3.8 cm) diameter post. Two U-bolts and four nuts are included in the 7550-101 spares kit. These can be used to attach the Auxiliary Sensor Interface as shown below in Figure 2-11 on the next page. It can be mounted vertically or horizontally. If you do not want to use the attached mounting plate, remove the top cover of the box and remove the two screws (in opposite corners) that secure the box to the bracket. You can then secure the interface using wire, cable ties, or other methods of your choosing.

7550-101 Auxiliary Sensor Interface

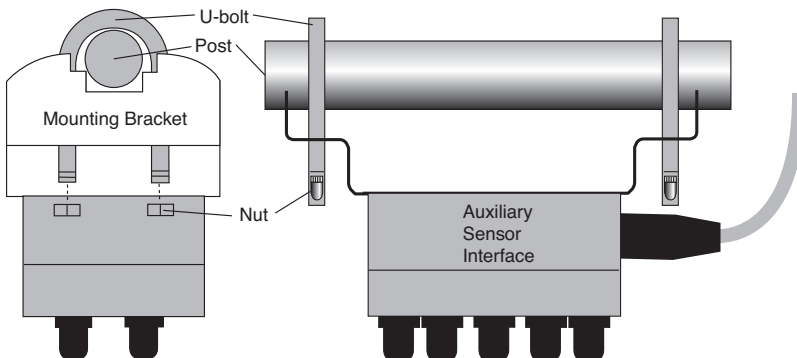


Figure 2-11. Mounting the 7550-101 Auxiliary Sensor Interface.

## Attaching the Mirror Cleaner/Washer Assembly

Follow the steps below to attach the mirror cleaner.

1. Attach the spray nozzle assembly (part #9977-032) to a spar on the LI-7700, as shown below. It snaps into place.
2. Attach the "Quick Connect" hose fitting on the nozzle/hose assembly to the fitting on the washer reservoir (part #7700-101).
3. Connect the washer motor power cable (part #392-10211) to the washer power connection on the LI-7700 connection panel and to the connection on the washer reservoir.
4. Fill the washer with regular automotive windshield washer fluid or an environmentally friendly alternative. If there is risk of freezing temperatures, select a washer fluid that will not freeze.
5. To verify the spin motor operation, set the Control Setting to "On" and click "Apply" in the manual controls window. After observing the spin motor (the pump will not run), set the Control Setting of "Off" and click "Apply."

**Note:** While you may use the "On" setting to spin the mirror, the fluid pump will not power up. It is controlled exclusively by the time scheduling algorithm.

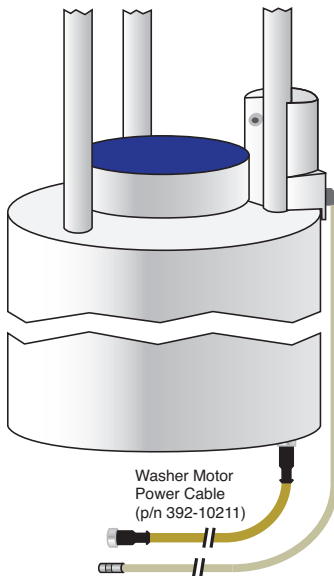


Figure 2-12. Washer nozzle assembly and washer power cable connections.



## Mounting the Washer Reservoir

Two brackets (included) can be used to mount the 7700-101 Washer Reservoir to a tripod or other post using bolts or U-bolts. The hardware required for this is included. Alternatively, the four holes in the corners of the box can be used to attach the box directly to a flat surface. Mounting the 7700-101 is identical to the LI-7550 (see "Mounting the LI-7550 Analyzer Interface Unit " on page 3-30).

The mounting brackets are designed to accommodate a square or circular mounting post up to 1.25" (3.2 cm) in width (diameter). Use a 3/16" hex key to attach the mounting brackets to the Analyzer Interface Unit using the 4 socket head screws (part #140-02654). The U-bolts can then be inserted through the holes in the mounting bracket, and tightened around the post.

Additional Considerations:

1. The cables and hose are 5 meters long. The washer reservoir must be within 5 meters of the LI-7700. The pump is powerful enough to lift the washer fluid 5 meters, but attempts to lengthen the washer hose will result in reduced fluid pressure, which will affect the performance of the pump and mirror cleaner.
2. An additional reservoir can be used with the 7700. This might be necessary in circumstances in which the washer fluid may be used quickly.

The following schematic shows a basic LI-7700 configuration with the washer reservoir, analog input cable, and a sonic anemometer. In this configuration, power is supplied to the sonic anemometer and the LI-7700. Data are output through Ethernet to a suitable data storage device.

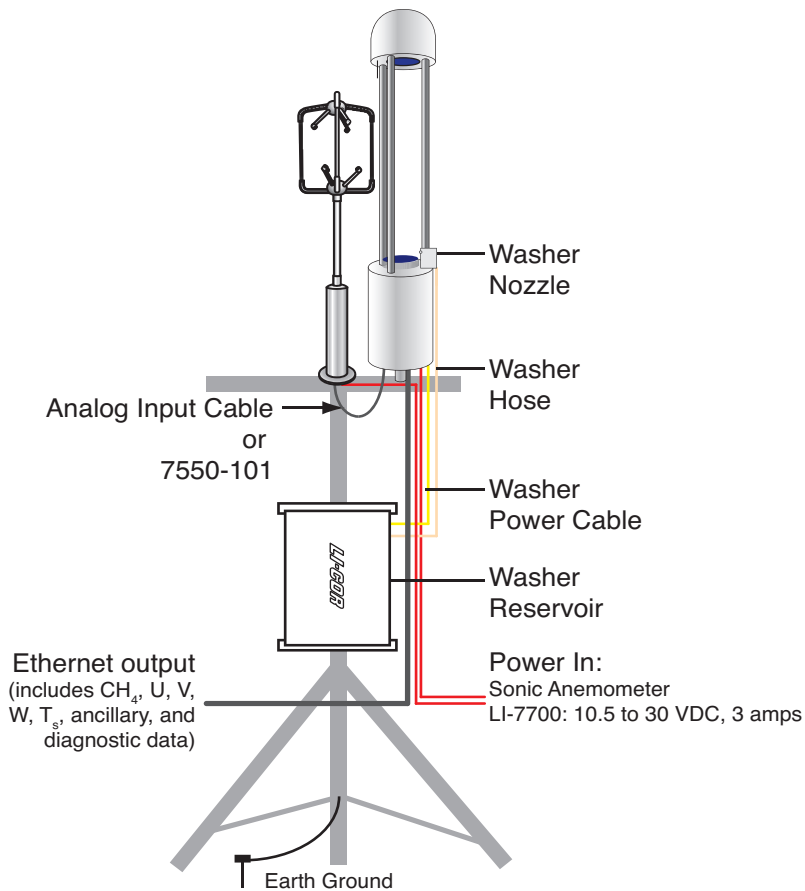


Figure 2-13. A possible field deployment of the LI-7700 and accessories. For eddy covariance flux applications, water vapor flux must also be measured. This can be accomplished with an LI-7500, LI-7500A or LI-7200 CO<sub>2</sub>/H<sub>2</sub>O Analyzer (not shown). Ideally, the LI-7700 should be used in conjunction with an LI-7500A or LI-7200, and data stored in GHG files for processing with EddyPro® software or the SMARTFlux™ system.

# 3 Operation with the LI-7550

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## Introduction to the LI-7550

The LI-7550 is available as an accessory for the LI-7700 Open Path CH<sub>4</sub> Analyzer. When used with the LI-7700 it provides:

- Logging of eddy covariance data sets to a removable USB storage device.
- Ethernet communication/data transfer.
- RS-232 serial communications.
- SDM data output for Campbell Scientific®, Inc. dataloggers.
- 6 high-speed, scalable Digital-to-Analog converters (16 bit,  $\pm 5V$ ).
- 4 additional analog inputs (16 bit, differential,  $\pm 5V$ ).



*Figure 3-1. Inside the LI-7550.*

The LI-7550 is a standard component of the LI-7500A/7200 CO<sub>2</sub>/H<sub>2</sub>O Analyzers and GHG analyzer systems. In these configurations, the LI-7550 requires embedded firmware that is specific to the LI-7500A/7200, and certain features described here are not available. This section describes the functionality that is provided when the LI-7550 is

running LI-7700 embedded firmware, as well as some instructions for LI-COR GHG systems.

## LI-7550 What's What

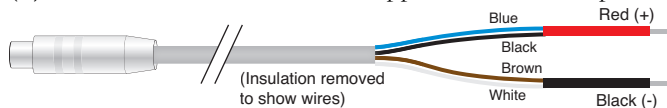
If you just received your LI-7550, check the packaging list and verify that you received everything that was ordered. Most items are part of the standard spares kit.

### Spares Kit and Cables

The standard LI-7550 spares kit (part #9975-023) includes the following items:

Description	Qty.	LI-COR Part No.
Mounting Hardware Kit	1	9972-029
RS-232 Interface Cable	1	392-10268
Power Cable	1	9975-030
Analog Input/Output Cable	1	392-10109
Ethernet Cable, Eurofast (5M) 8-pin male to 8-pin male	1	392-10108
Ethernet Cable, Eurofast (0.3M) 8-pin female to RJ45	1	392-10093
5 Amp Fuse	2	439-04214
4 GB USB Flash Drive	1	636-10723

- Power Cable** - The power cable (part #9975-030) is 5 m long. It has a 4-pin female terminal plug that attaches to the connector labeled POWER on the LI-7550 Analyzer Interface Unit connection panel. The power cable is terminated with black (-) and red (+) leads for connection to a user supplied 10.5-30 VDC power supply.



- Ethernet Cables** - Two Ethernet Cables (part #392-10107 and 392-10108) are included for connecting to a Local Area Network (LAN) or computer via an Ethernet port. Part # 392-10108 is a 5m cable terminated on both ends with male Turck connectors. One end attaches to the LI-7550 Analyzer Interface Unit, and the other end attaches to the short (0.3m) Ethernet adapter cable (part #392-10107). The short cable is terminated with an RJ45 Ethernet connector, which plugs into an Ethernet wall socket or a computer's Ethernet port.
- SDM Interface Cable** - The SDM interface cable (part #392-10093) is for connecting to Campbell® Scientific, Inc (Logan, Utah) dataloggers using the Synchronous Devices for Measurement (SDM) data communication protocol. SDM communications are enabled in the Campbell® Scientific datalogger. The SDM interface

cable plugs into the connector labeled SDM on the LI-7550 Analyzer Interface Unit connection panel. See "SDM" on page 3-21 for modes and configuration information. SDM wire colors and pin assignments are given in Figure 3-3 on page 3-5.

- **USB Flash Drive** – An industrial grade USB flash drive is included in the spares kit. Additional industrial grade 16 GB and 4 GB flash drives are available for purchase directly from LI-COR.
- **Serial RS-232 Cable** - The RS-232 cable (part #392-10268) is a 5m null modem cable with a 6-pin female circular connector that attaches to the connector labeled RS-232 on the LI-7550 Analyzer Interface Unit connection panel. The other end has a standard DB-9 female connector for direct connection to a computer. Alternatively, the RS-232 cable can be connected to an RS-232-to-USB adapter to use the RS-232 connection with a USB port.
- **Analog Input/Output Cable** - The Analog Input/Output Cable (part #392-10109) is for connecting user-supplied sensors (i.e., pressure, temperature, sonic anemometer) to LI-7700 or LI-7550 analog inputs and/or for connecting the LI-7550 analog outputs to a data logger. The pin assignments and wire colors are shown in Figure 3-3 on page 3-5. There are four analog input channels available. When used with external input devices, this cable plugs into the connector labeled Auxiliary Input on the LI-7550 Analyzer Interface Unit connection panel (similar to Option 2 "LI-7700 Analog Inputs " on page 2-28, pin assignments given in Table 3-3 on page 3-18).

This cable can also be used for data output to logging devices using the digital-to-analog converters (DACs). Six DAC channels are available; the pin assignments and wire colors are shown in Figure 3-3 on page 3-5. The cable plugs into the connector labeled DAC OUTPUT on the LI-7550 Analyzer Interface Unit connection panel (similar to Option 3; "LI-7700 Analog Inputs " on page 2-28, pin assignments given in Table 3-6 on page 3-29).

This cable can also be used to connect directly to sensors or output devices; the optional weatherproof Auxiliary Interface Unit (part #7550-101) can be used in place of this cable. Use of the 7550-101 with the LI-7700 is described in the previous chapter, and with the LI-7550 is described later in this chapter. Note that only one Analog Input/Output cable is included with the LI-7550. If you intend to use both the Auxiliary Input and DAC Output ports on the LI-7550 you can acquire an additional 392-10109 cable or the 7550-101 Auxiliary Sensor Interface.

### Cable Connections

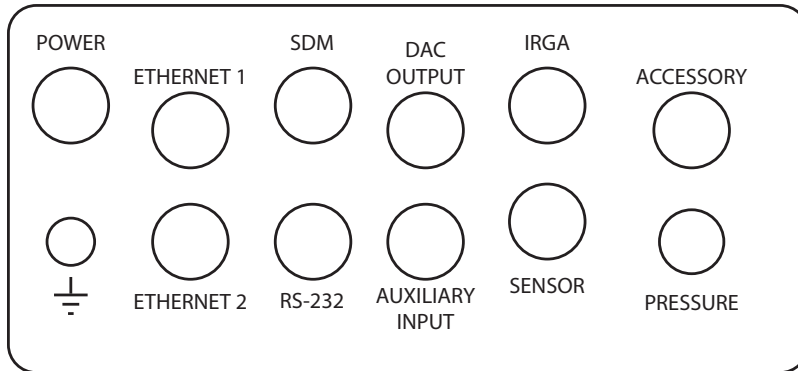


Figure 3-2. LI-7550 connection panel.

Cable connections are found on the bottom panel of the LI-7550. Each connection includes a dust/moisture cover that should be kept in place any time the connection is not in use.

The LI-7550 includes a variety of cables for connecting power, sensors, and external data storage devices. All cables are 5 meters in length and are manufactured by Turck, Inc. (Minneapolis, MN, see "Turck® Cables" on page D-2). If you need longer cables, several custom-length cables can be purchased from Turck, Inc. Table 3-1 below lists both LI-COR part numbers and the corresponding Turck part numbers for each cable. You can also construct your own extension cables. Figure 3-3 on the facing page lists pin assignments and wire colors for the power, SDM, and Analog Input and Output cables. This table is reproduced inside the front cover of the LI-7550 Analyzer Interface Unit.

**Table 3-1.** Turck Eurofast® cables used to connect to the LI-7550. An asterisk (\*) refers to cable length. Note that the maximum length of some cables may be limited (SDM, Serial, and Analog).

LI-COR p/n	Cable	Connection	Turck p/n
9975-030	Power	4-pin female	RK4.41T-*/S529
392-10093	SDM Interface	4-pin male	RSS 4.4T-*
392-10268	Serial	6-pin female to DB-9 female	RKC 6T-*/DB9F/CS12317
392-10109	Analog In/Out	12-pin male	RSS 12T-*
392-10108	Ethernet	8-pin male-male	RSS RSS841-*M
392-10107	Ethernet Adapter	8-pin female to RJ45	RKC RJ45 840-*M

Inside the LI-7550 there are three Ethernet ports and one port for a USB data storage device. Two of the Ethernet ports are connected to the Ethernet ports on the connection panel. It does not matter which ports these internal cables are connected to. The third port is not connected to the panel, but can be used to connect an Ethernet device, such as a laptop computer.





LI-7550 Pin Assignments								
SDM			ANALOG IN			ANALOG OUT		
PIN 1	BROWN	SDM_EN	PIN 1	WHITE	AUX1+	PIN 1	WHITE	DAC1
PIN 2	WHITE	SDM_CLK	PIN 2	BROWN	AUX1-	PIN 2	BROWN	DAC2
PIN 3	BLUE	SDM_DATA	PIN 3	GREEN	AUX2+	PIN 3	GREEN	DAC3
PIN 4	BLACK	GND	PIN 4	YELLOW	AUX2-	PIN 4	YELLOW	DAC4
COUPLING	BARE	EARTH GND	PIN 5	GREY	AUX3+	PIN 5	GREY	DAC5
POWER			PIN 6	PINK	AUX3-	PIN 6	PINK	DAC6
PIN 1	BROWN BLACK	VIN-	PIN 7	BLUE	AUX4+	PIN 7	BLUE	READY
PIN 2	WHITE	VIN-	PIN 8	RED	AUX4-	PIN 8	RED	NC
PIN 3	BLUE RED	VIN+	PIN 9	ORANGE	+5V	PIN 9	ORANGE	NC
PIN 4	BLACK	VIN+	PIN 10	TAN	GND	PIN 10	TAN	GND
INPUT: 10 - 30VDC 			PIN 11	BLACK	GND	PIN 11	BLACK	GND
FUSE: 5A F 125/250V 			PIN 12	VIOLET	GND	PIN 12	VIOLET	GND
 <b>USB LOGGING - USE INDUSTRIAL GRADE ONLY!</b>					 Biosciences LI-COR Biosciences 4647 Superior St. Lincoln, NE 68504 1-800-447-3576 (U.S. & Canada) 402-467-3576 FAX: 402-467-2819 envsales@licor.com • envsupport@licor.com www.licor.com			
<ul style="list-style-type: none"> <li>● SOLID LED - DRIVE MOUNTED, NOT LOGGING</li> <li>●●●● RAPID BLINK - LOGGING</li> <li>●● SLOW BLINK - ERROR. EJECT AND RETRY</li> <li>○ NO LED - DRIVE NOT MOUNTED, OK TO REMOVE</li> </ul> <p><b>WARNING!</b> FAILURE TO PRESS EJECT BUTTON BEFORE REMOVING USB DRIVE WILL RESULT IN LOSS OF DATA!</p>								

Figure 3-3. LI-7550 internal label.

## Basic Setup

This section covers basic operation of the LI-7700 with the LI-7550 Analyzer Interface Unit.

### Power On

The LI-7550 has no power switch – it turns on when power is supplied through the power cable (10.5-30 VDC, 2 amps). When power is supplied the “Power” LED on the indicator panel will illuminate, and it will stay lit as long as power is supplied, The “Ready” LED will turn on when the instrument embedded software has launched and the LI-7550 is ready to communicate with a computer.

### Connecting to the LI-7700 and LI-7550 (Ethernet)

The LI-7700 connects to the LI-7550 using the Ethernet cable (part #392-10108), which terminates with Turck® connections on both ends. Attach one terminal to the Ethernet connection on the LI-7700 and the other to either the Ethernet 1 or 2 terminals on the LI-7550 connection panel. You can now connect the LI-7550 to a computer or network with the vacant Ethernet port on the LI-7550 connection panel (using the Ethernet cables part #392-10108 and part #392-10107 in series), or the vacant Ethernet port inside the box (with a user-supplied Ethernet cable).

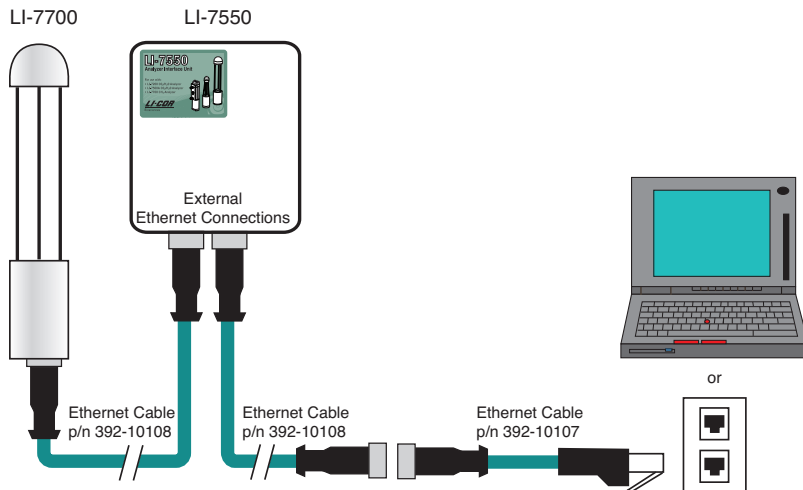



Figure 3-4. Ethernet data cable connections for the LI-7700 and LI-7550.

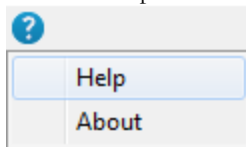


## Getting an LI-7700 to talk to an LI-7550

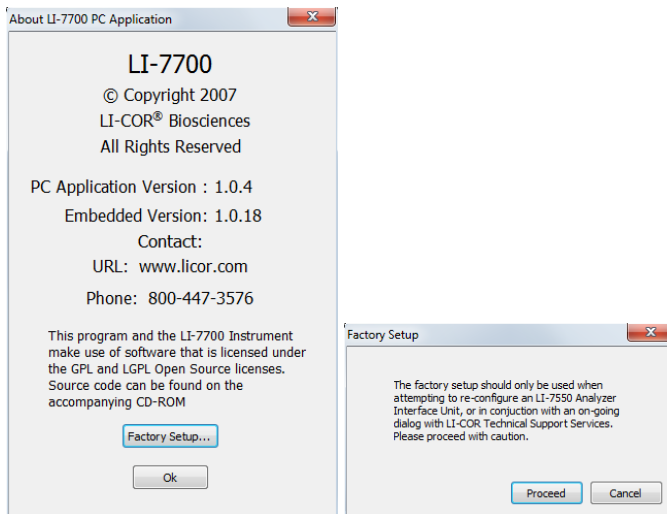
**Note:** The LI-7550 can run two versions of software. One version is required when using the LI-7700 with the LI-7550 exclusively (not with the LI-7500A or LI-7200 CO<sub>2</sub>/H<sub>2</sub>O Analyzer). The other version is required when using the LI-7700 in conjunction with the LI-7500A or LI-7200 CO<sub>2</sub>/H<sub>2</sub>O Analyzer. You can follow the steps below to get the LI-7700 to talk to the LI-7550. Alternatively, you can follow a simplified procedure described in the LI-7500A and LI-7200 instruction manuals. See "Using an LI-7700 with an LI-7500A or LI-7200 CO<sub>2</sub>/H<sub>2</sub>O Analyzer" on page 3-9 for more information.

Prior to using the LI-7700 with an LI-7550, the two devices must be configured to communicate with each other. To accomplish this:

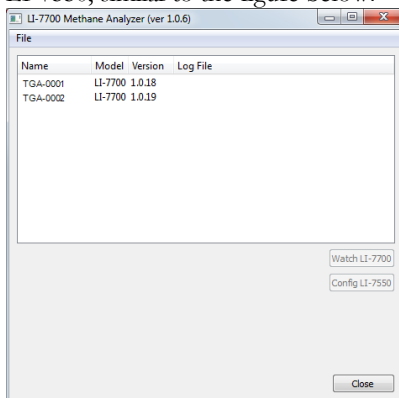
1. Connect power to both devices. Connect the LI-7700 and LI-7550 with the Ethernet cable, as described above. Connect the LI-7550 to your computer or network with the Ethernet cable. Be sure to use a computer that has the LI-7700 Windows Application software (see "Basic Setup" on the previous page).
2. Launch the Windows Application software but do not connect to an instrument.
3. Click the Help icon  and click About.



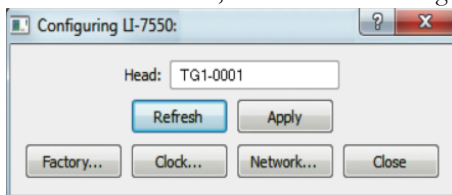
4. In the "About" dialog box (below, left) click Factory Setup... then click Proceed in the warning that appears (below, right).



5. In the “Factory Setup” dialog box you should see both the LI-7700 and the LI-7550, similar to the figure below.



6. Click on the LI-7550, then click the Config LI-7550 button.



7. In the resulting dialog box, confirm that the text in the field called “Head:” matches the text on the Factory Setup display for the name of the LI-7700 Analyzer (it is not

case sensitive), or edit the field so they match. In this case, the name is “TG1-0001”, as shown below.


8. If you changed the name, click the Apply button to confirm the name change. Restart both devices by disconnecting and reconnecting the power supply.
9. Confirm that the two devices are communicating by connecting to the LI-7700 with the Windows Application software. Insert a USB storage device into the LI-7550 USB port. If the USB device appears in the “USB Logging” window (see “USB Data Logging” on page 3-12), both are configured correctly.

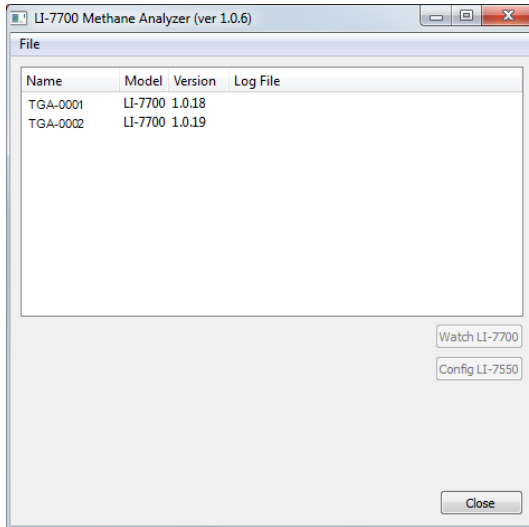
### Using an LI-7700 with an LI-7500A or LI-7200 CO<sub>2</sub>/H<sub>2</sub>O Analyzer

The LI-7700 can be used in conjunction with an LI-7500A or LI-7200 CO<sub>2</sub>/H<sub>2</sub>O Analyzer, but there are a few differences that you should be aware of. There are two versions of software available for the LI-7550 Analyzer Interface Unit. One version is specifically for using the LI-7550 with an LI-7700. If you ordered an LI-7700 with an LI-7550 (but not an LI-7500A or LI-7200), the LI-7550 will have the LI-7700 software installed.

A second software version is specifically for using an LI-7550 with an LI-7500A/7200. If you received an LI-7550 as part of a CO<sub>2</sub>/H<sub>2</sub>O Analyzer or with a GHG-1/GHG-2 system, the LI-7550 will have the LI-7500A/LI-7200 software installed. The latter software configuration is required any time you use the LI-7550 with both an LI-7500A/7200 CO<sub>2</sub>/H<sub>2</sub>O Analyzer and an LI-7700 CH<sub>4</sub> Analyzer.

Which software is the LI-7550 running? There is a sticker inside the LI-7550 that indicates the software version that was loaded at the factory. You can also find the software version by following the steps below:

1. Connect the LI-7550 Analyzer Interface Unit to a suitable power supply, then connect the Ethernet cables to enable communication with your computer.
2. Launch the LI-7700 Windows Application software but do not connect to an instrument.
3. Click the Help button  and click About.
4. In the About dialog, click Factory Setup..., then click Proceed in the warning dialog. You should see window similar to the figure below.



5. The LI-7550 will be listed. If the LI-7550 is configured for the LI-7700, under the “Model” heading, it will read “LI-7550 (LI-7700).” If it is configured for an LI-7500A or LI-7200, it will read “LI-7550 (LI-7500A/7200).”

If the LI-7550 is configured to support an LI-7500A/7200 CO<sub>2</sub>/H<sub>2</sub>O Analyzer, you can log LI-7700 and Auxiliary Input 1-4 data to the LI-7550 USB device in the same data file as CO<sub>2</sub>/H<sub>2</sub>O analyzer data. However, you cannot set up the Auxiliary Inputs 5-8, SDM, RS-232, or DAC outputs from the LI-7700 Application software, nor can you output methane analyzer data using SDM, RS-232, or DACs. Instead, use the LI-7500A/7200 Windows Application software to configure those channels.

In this configuration, the LI-7700 software will prohibit you from configuring LI-7550 Auxiliary Inputs, opening the “Configure LI-7550 Outputs” dialog, or opening the USB... dialog from the LI-7700 application. Conversely, if the LI-7550 is formatted to operate with an LI-7700, you will have access to all functions in the software, but it will be unable to communicate with an LI-7500A/7200.

**Note:** If you are logging data from a sonic anemometer in conjunction with CH<sub>4</sub>, CO<sub>2</sub>, and H<sub>2</sub>O data, sonic anemometer signals must be logged using Auxiliary Inputs 1-4 on the LI-7550. All high-speed gas concentration and wind speed measurements will be logged to the USB device in a single data file.

LI-COR manufactures sonic anemometer interface cables with pre-configured pin-outs for Gill WindMaster<sup>TM</sup>/Pro and Campbell® Scientific CSAT3 anemometers. Contact us to learn more about these accessories.

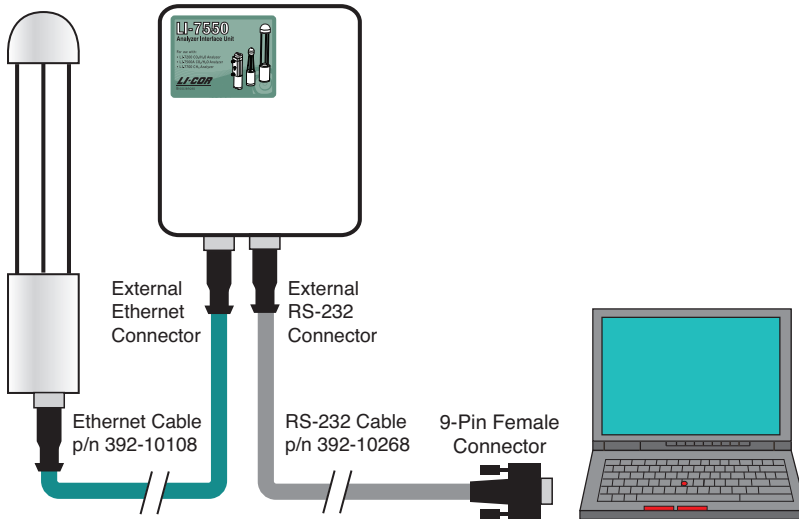
When using the LI-7700 in conjunction with an LI-7500A/7200 CO<sub>2</sub>/H<sub>2</sub>O Analyzer using a shared LI-7550, data output is limited to Ethernet. All data are logged to a single data file to the internal USB storage device.

### Connecting to the LI-7700 and LI-7550 (RS-232 Serial)

**Note:** The procedures described in "Connecting to the LI-7700 and LI-7550 (Ethernet)" on page 3-6 are only available when the LI-7700 and LI-7550 are connected using the Ethernet port. While the RS-232 connection does allow you to configure the LI-7700, and data can be output using the serial connection, the "Factory Setup" application (aka, LI-7700 Finder Application) will not find an LI-7700 or LI-7550 that is connected via the serial connection.

The LI-7550 enables RS-232 communications with the LI-7700. Prior to connecting with RS-232, see "Getting an LI-7700 to talk to an LI-7550" on page 3-7 to enable communication between the LI-7550 and LI-7700. Then, connect the LI-7550 to your computer's RS-232 connection with the RS-232 adapter cable (part #392-10268) and connect the LI-7700 to the LI-7550, as shown below. An RS-232 to USB adapter may be required (392-07713).

To connect, launch the LI-7700 software, click "Connect", check the "RS-232" button, and choose the COM port (between 1 and 32) that the instrument is connected to. Click the "Connect" button.



*Figure 3-5. RS-232 Cable configuration for the LI-7700 and LI-7550. The Ethernet data cable is still used to connect the LI-7700 to the LI-7550, while the RS-232 cable connects the LI-7550 to the computer.*

## Using the LI-7550

**Note:** If the LI-7550 is configured to support an LI-7200 or LI-7500A, it will not be possible to configure Auxiliary Inputs (Aux5 to Aux8), SDM, RS-232, or DAC outputs from the LI-7700 application software. The software will prohibit you from opening the “Configure LI-7550 Outputs” dialog from the LI-7700 application. See "Using an LI-7700 with an LI-7500A or LI-7200 CO<sub>2</sub>/H<sub>2</sub>O Analyzer" on page 3-9 for more details. These features can be configured in the CO<sub>2</sub>/H<sub>2</sub>O analyzer software; however, they will only apply to the CO<sub>2</sub>/H<sub>2</sub>O analyzer data.

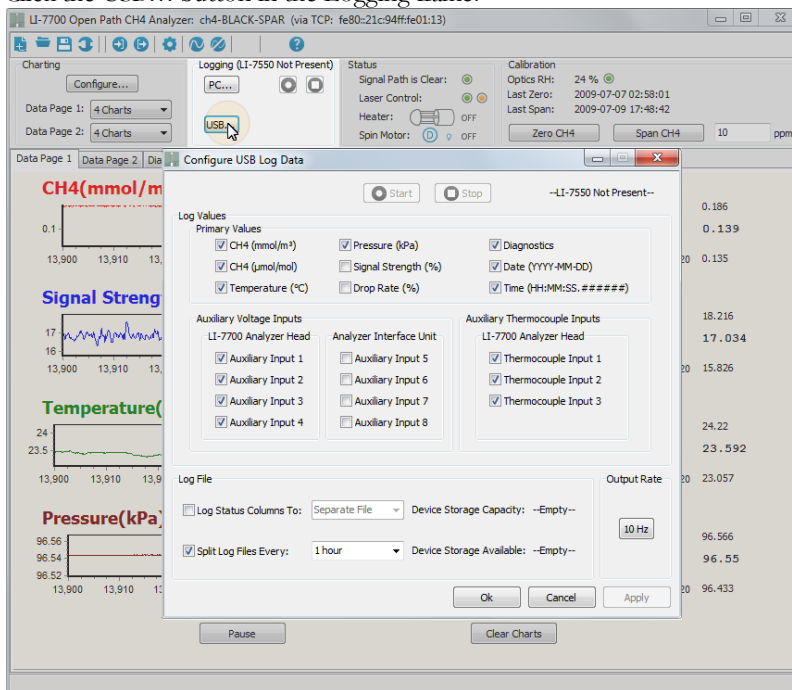
The LI-7550 is configured through the LI-7700 software. When settings are configured in the LI-7700 software, this information is stored in the LI-7700. Then the LI-7550 pulls this information from the LI-7700 when the two components are connected and powered up.



### USB Data Logging

USB data storage (with the LI-7550) is configured in the Logging frame. These settings are configured through the LI-7700 software and implemented automatically when the LI-7700 is connected with an LI-7550 and both instruments are powered up.

To log data to a LI-7550:

1. Click the USB... button in the Logging frame.



2. In the “Configure USB Log Data” dialog box, select the variables that you would like to log and click Apply. Auxiliary Inputs 1-4 and Thermocouple Inputs 1-3 are described in "Auxiliary Sensor Interface Terminals (Option 1)" on page 2-30 (Option 1), and Auxiliary Inputs 5-8 are described in "Auxiliary Sensor Interface Terminals (Option 2)" on page 3-17 (Option 2).
3. In the “Log File” frame, choose to Log Status Columns to a separate file or to the data file. Then choose whether to split the file, and how often (from 15 minutes to 24 hours). Click Apply.
4. To begin logging data immediately click a Start button () or (). Otherwise, logging will begin automatically when a USB storage device is inserted into the USB port, or when the instruments are restarted (if a suitable USB drive is present).
5. To remove the USB storage device press the “Eject” button in the LI-7550. The LI-7550 will stop writing data until another USB device is inserted, after which it will immediately begin logging data.

The LED by the USB port indicates the status of data logging with a blinking pattern, as described in Figure 3-6 on the next page.

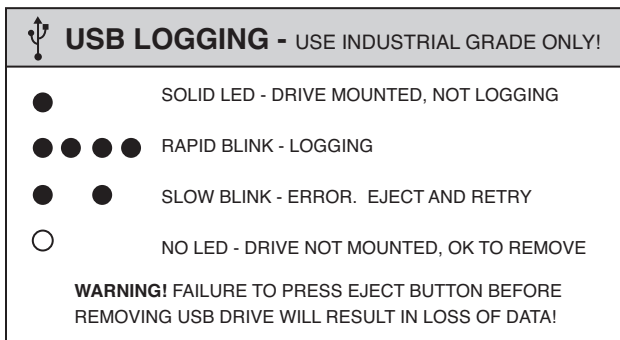


Figure 3-6. USB Logging LED indicators. This cable is printed inside the LI-7550 front cover.

## About USB Devices

**Important:** We recommend that you only use an industrial rated USB flash drive. Non-industrial rated flash drives can fail, causing you to lose data.

Many user-supplied industrial grade flash drives are compatible with the LI-7550, but some devices with custom drivers or encryption may not work. The drive must be formatted to support FAT or Linux ext3 file systems. FAT32 is recommended over FAT16. Contact LI-COR to find out if your USB drive is compatible with the LI-7550.

Note: Data logging will stop when the storage device has reached capacity, but will automatically resume when a USB storage device is reattached, assuming it has storage space available. Data logging also automatically starts when the instrument starts up, following a power interruption for example. Storage devices that are being used for the first time may take about 60-90 seconds to initialize before data will be written to the device.

## USB Storage Capacity

The LI-7550 includes a 4 GB USB flash drive. If you are logging all 20 variables at 10 Hz (samples/second), the 4 GB flash drive can log uncompressed data for about 22 days before becoming full. Table 3-2 on the facing page shows approximately how long the LI-7700 can store data before a 4 GB USB drive becomes full.




**Table 3-2.** Approximate number of days that the LI-7700 can record data before a 4 GB flash drive becomes full.

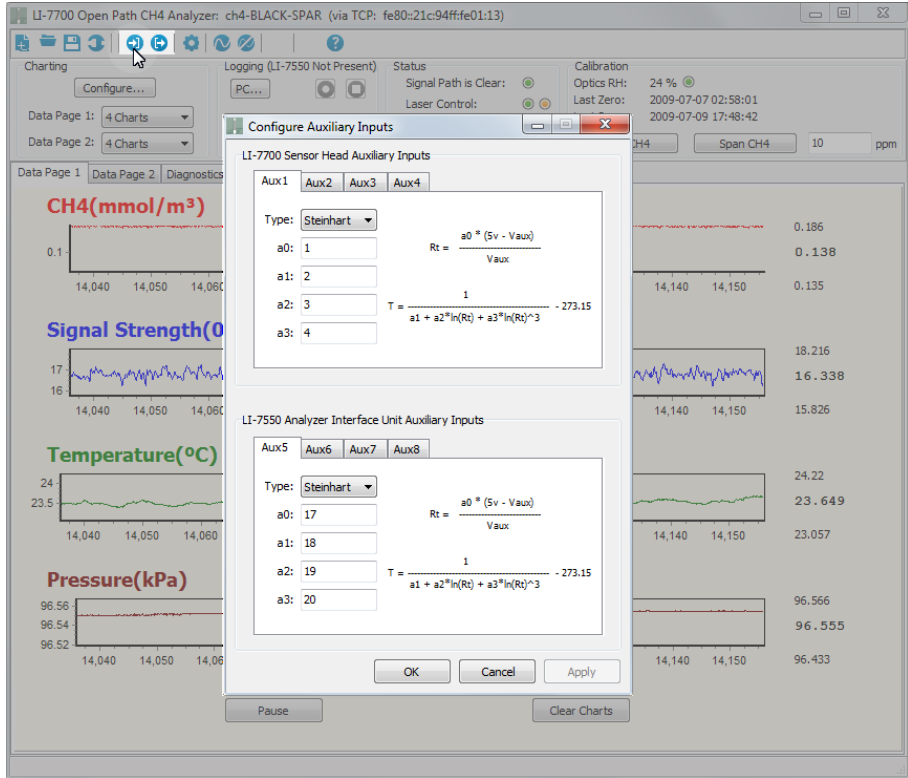
Variables Logged	Time to fill a 4 GB drive (no compression) <sup>1</sup>
All (including status and diagnostics)	~22 days
All (including status but not diagnostics)	~27 days
CH <sub>4</sub> (mmol/m <sup>3</sup> ), Temp., Pressure, Signal Strength, Drop Rate, Status, and Aux. Inputs 1 to 4	~44 days

If you log compressed files in the GHG format, including data provided by the LI-7200 and the LI-7700 (53 columns of data) at 10 Hz, 4GB of data would accumulate over about 46 days.

## Analog Inputs (LI-7550)

Analog inputs (Option 2) are configured from the “Configure Auxiliary Inputs” dialog box (click ). These are labeled Aux5 through Aux8 in the lower block of inputs. Two mathematical conversions of analog input voltages can be configured in the dialog box: 1) a third order polynomial or 2) a Steinhart equation (for measuring temperature with a thermistor).

<sup>1</sup>Actual number of days will depend on the number of variables logged and other factors.



These are described in detail in "Configuring Auxiliary Inputs (LI-7700)" on page 2-34, Configuring Auxiliary Inputs (LI-7700). After configuring the inputs, click Apply or OK to implement the settings.

As mentioned previously, the 7550-101 can serve as a terminal strip for analog inputs or outputs for the LI-7550. Alternatively, the Analog Input/Output Cable (part #392-10109) can be used. To use Options 2 or 3 (Figure 2-7 on page 2-29) with the 7550-101, be sure the LK1 jumper is positioned over the two pins nearest the LI-7550 label. Refer to "Auxiliary Sensor Interface Terminals (Option 1)" on page 2-30 for information on the LI-7700 analog inputs (Option 1). Below we describe how to configure the 7550-101 and the corresponding wires/pins in the Analog Input/Output Cable for LI-7550 analog inputs.

## Auxiliary Sensor Interface Terminals (Option 2)

To gain access to the inside of the 7550-101, loosen the four #1 Philips screws on each corner of the top cover. Remove the cover. The schematic below shows the interior of the interface box.

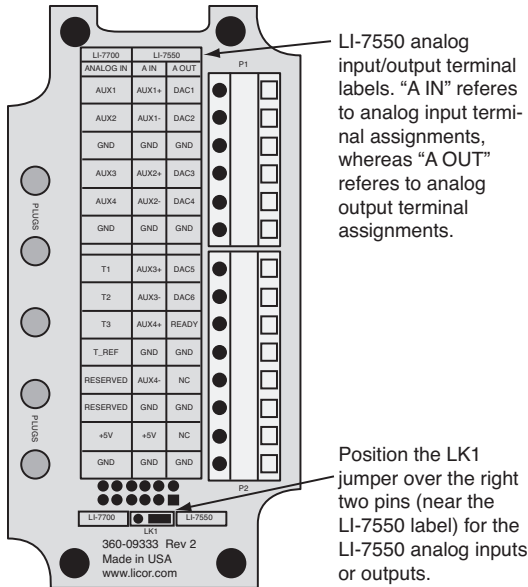


Figure 3-7. Schematic of the Auxiliary Interface Unit interior.

The terminal strips connections are shown below:

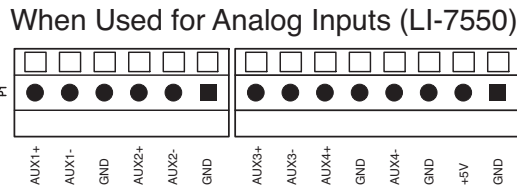


Figure 3-8. Terminal connections for analog inputs (Option 2).

Table 3-3 on the next page shows Auxiliary Sensor Interface input assignments and corresponding wire colors for the input cable.

**Table 3-3.** LI-7550 Analyzer Interface Unit analog inputs for the 7550-101 Auxiliary Sensor Interface and Analog In/Out Cable. 7550-101 terminals and input functions are on the left and corresponding Analog In/Out Cable wire colors and pin assignments are on the right.

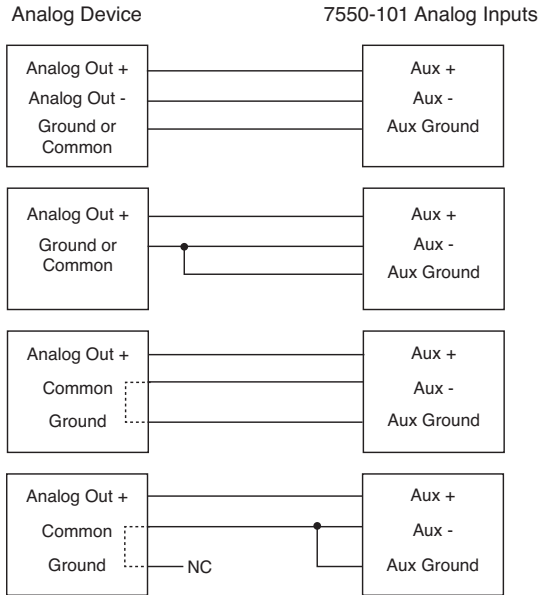
Option 2 <sup>1</sup>				
7550-101 Auxiliary Sensor Interface		Description	Analog In/Out Cable (part #392-10109)	
Terminal	Inputs		Wire Color	Pin
1	Aux1+	Auxiliary Input 1 positive	White	Pin 1
2	AUX1-	Auxiliary Input 1 negative	Brown	Pin 2
3	GND	Ground	Tan	Pin 10
4	AUX2+	Auxiliary Input 2 positive	Green	Pin 3
5	AUX2-	Auxiliary Input 2 negative	Yellow	Pin 4
6	GND	Ground	Tan	Pin 10
7	AUX3+	Auxiliary Input 3 positive	Grey	Pin 5
8	AUX3-	Auxiliary Input 3 negative	Pink	Pin 6
9	AUX4+	Auxiliary Input 4 positive	Blue	Pin 7
10	GND	Ground	Black	Pin 11
11	AUX4-	Auxiliary Input 4 negative	Red	Pin 8
12	GND	Ground	Violet	Pin 12
13	+5V	+5V supply (10 mA max.)	Orange	Pin 9
14	GND	Ground	Tan	Pin 10

### Electrical Connections

All analog devices connected to the 7550-101 Auxiliary Sensor Interface must be referenced to the ground (GND) connection to use Option 2. Some examples are shown below.

---

<sup>1</sup>Analog Inputs  $\pm 5V$



Connection Notes:

1. All LI-7550 auxiliary analog input ground connections are internally connected together.
2. All LI-7550 auxiliary analog output ground connections are internally connected together.
3. Analog devices with both ground and common outputs can share these outputs with their power supply ground.
4. LI-7550 analog inputs are electrically isolated from the LI-7550 power input.
5. LI-7550 analog outputs are electrically isolated from the LI-7550 power input and isolated from the analog inputs.

For additional 7550-101 & Analog Input/Output usage instructions, refer to the following pages:

- LI-7700 Inputs (Option 1) instructions: "LI-7700 Analog Inputs " on page 2-28
- Wiring instructions: "Connecting Sensors to the Auxiliary Sensor Interface " on page 2-32


**Analog Input Time Delays**

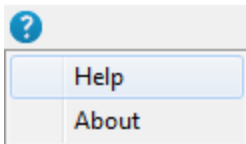
Data from Auxiliary Inputs 5-8 (available only on the LI-7550) have a fixed time delay of 1 second. These values are shifted together in the data files by 1 second from data

acquired with the LI-7700, Auxiliary Inputs 1-4, and the thermocouple inputs.

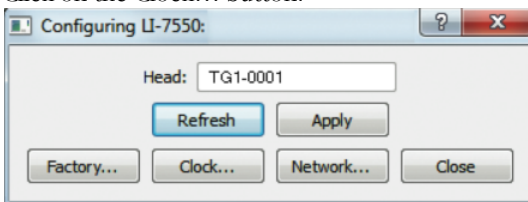
## LI-7550 Clock

The LI-7550 clock is separate from the LI-7700 clock, but it also uses Unix (POSIX) time and the Precision Time Protocol unless the LI-7550 is configured for an LI-7500A or LI-7200. When the two components are used together, set the LI-7700 clock to “automatic” and the LI-7550 clock to “preferred.” This will ensure that the time stamp comes from the LI-7550. The LI-7550 clock has the same setting options as the LI-7700 clock. To view/set the time in the LI-7550:

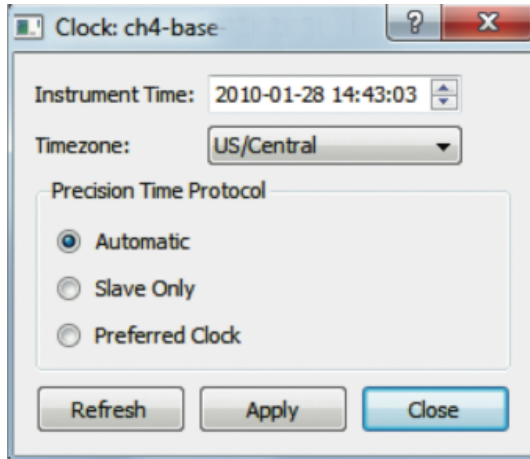
1. Connect the LI-7550 to your computer using the Ethernet, or to your network or computer using the Ethernet cable (RS-232 does not support this).
2. Launch the LI-7700 software, click the Help button , and select About.



3. Click Factory Setup... and click on Proceed after reading the warning.
4. Select the “Base Box” (under the Model heading it will be called LI-7550) and click on Config LI-7550.
5. Click on the Clock... button.



6. Configure the clock settings as desired. In the “Precision Time Protocol” frame, choose “Automatic”, “Slave Only”, or “Preferred Clock.” “Preferred” is the recommended setting when using the LI-7550 with the LI-7700.



7. Apply the settings and close the dialog.

## LI-7550 Outputs

The four output options are described below, including Ethernet, SDM, RS-232, and analog.

### Ethernet

Ethernet output from the LI-7700/7550 combination is configured in the same way as LI-7700 Ethernet output. This is described in "PC/Network Datalogging" on page 2-12.


### SDM

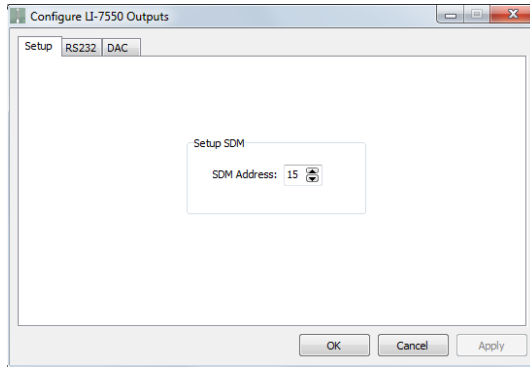
SDM addressing allows for multiple SDM-compatible peripherals to be connected to a single Campbell® Scientific, Inc datalogger. To log the SDM output from the LI-7700, first set up the LI-7700 using the Windows® software, then program the datalogger to poll the LI-7700 for data. The blue wire (SDM\_DATA) should be connected to datalogger terminal C1, white (SDM\_CLK) to terminal C2, and brown (SDM\_EN) to C3. Black and bare leads attach to datalogger ground terminals.

### SDM Time Delay

The SDM output has a fixed time delay of 1 second.

### Configuring LI-7700 SDM Output

1. In the LI-7550 Outputs dialog (  ), under the Setup tab, choose an SDM address between 0 and 14. Address 15 is reserved for the SDMTrigger instruction.



2. Set the LI-7700 output rate in the Manual Controls (⚙️) window. Select an output rate (e.g., 10 Hz) that is twice the desired bandwidth (e.g., 5 Hz) and click Apply or OK.



## Configuring the datalogger:

SDM communications are enabled in Campbell® Scientific dataloggers with the SDM LI7700 instruction. The basic instruction will resemble:

LI7700 (Destination,Repetitions,SDM Address,Mode)

Where:

Destination is the name of the input variable, an array, in which to store the data from the LI-7700,

Repetitions refers to the number of LI-7700s that will be sampled sequentially using sequential addresses,

SDM Address specifies the SDM address of the LI-7700 and needs to match the address set in the LI-7700 software, and

Mode refers to the data that will be retrieved from the LI-7700. Seven data modes are available (Table 3-4 below).

An example of the instruction is given:

LI7700 (CH4(1),1,0,1)

Where: CH4 is the destination name is for the first location in the array, 1 is the number of LI-7700s polled, 0 is the SDM Address, and 1 is “Data-Normal” from Table 3-4 below.

**Table 3-4.** SDM Modes available in the LI-7700.

Mode	LI-7700 Data Sent	Description
0 Data-short	CH4D (mmol/m <sup>3</sup> ) PRESSURE (kPa) TEMP (°C)	Methane number density Pressure measured by the LI-7700 Temperature measured by the LI-7700 thermocouple
1 Data-normal	CH4D (mmol/m <sup>3</sup> ) PRESSURE (kPa) TEMP (°C) DIAG RSSI	Methane number density Pressure measured by the LI-7700 Temperature measured by the LI-7700 thermocouple Diagnostic value, an integer Signal strength (Residual Signal Strength Indicator (0-100%))

**Table 3-4.** SDM Modes available in the LI-7700. (...continued)


Mode	LI-7700 Data Sent	Description
2 Data-normal with fast auxiliaries	CH4D (mmol/m <sup>3</sup> )	Methane number density
	PRESSURE (kPa)	Pressure measured by the LI-7700
	TEMP (°C)	Temperature measured by the LI-7700 thermocouple
	DIAG	Diagnostic value, an integer
	RSSI	Signal strength (Residual Signal Strength Indicator (0-100%))
	AUX1	Auxiliary input 1
	AUX2	Auxiliary input 2
	AUX3	Auxiliary input 3
3 Data-extended	AUX4	Auxiliary input 4
	CH4D (mmol/m <sup>3</sup> )	Methane number density
	CH4 (µmol/mol)	Methane mole fraction
	PRESSURE (kPa)	Pressure measured by the LI-7700
	TEMP (°C)	Temperature measured by the LI-7700 thermocouple
	DIAG	Diagnostic value, an integer
	RSSI	Signal strength (Residual Signal Strength Indicator (0-100%))
	AUX1	Auxiliary input 1
	AUX2	Auxiliary input 2
	AUX3	Auxiliary input 3
	AUX4	Auxiliary input 4
	AUXTC1	Auxiliary thermocouple input 1 (°C)
	AUXTC2	Auxiliary thermocouple input 2 (°C)
AUXTC3	Auxiliary thermocouple input 3 (°C)	

Table 3-4. SDM Modes available in the LI-7700. (...continued)

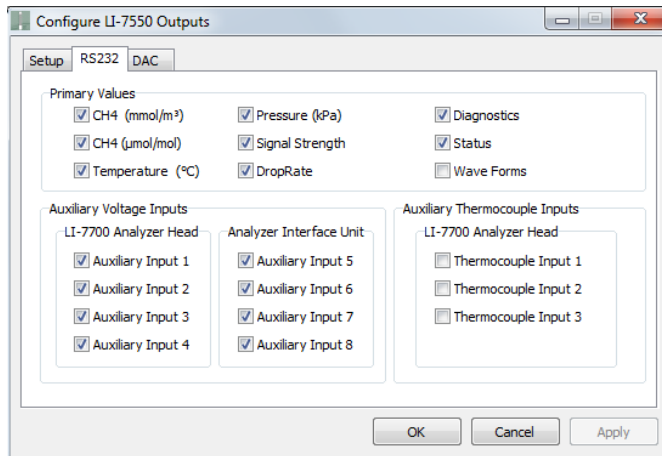
Mode	LI-7700 Data Sent	Description
4 Data-full	CH4D (mmol/m <sup>3</sup> ) CH4 (μmol/mol) PRESSURE (kPa) TEMP (°C) DIAG RSSI AUX1 AUX2 AUX3 AUX4 AUXTC1 AUXTC2 AUXTC3 AUX5 AUX6 AUX7 AUX8	Methane number density Methane mole fraction Pressure measured by the LI-7700 Temperature measured by the LI-7700 thermocouple Diagnostic value, an integer Signal strength (Residual Signal Strength Indicator (0-100%)) Auxiliary input 1 Auxiliary input 2 Auxiliary input 3 Auxiliary input 4 Auxiliary thermocouple input 1 (°C) Auxiliary thermocouple input 2 (°C) Auxiliary thermocouple input 3 (°C) Auxiliary input 5 Auxiliary input 6 Auxiliary input 7 Auxiliary input 8
5 Diagnostic-short	RSSI DIAG DROPRATE	Signal strength (Residual Signal Strength Indicator (0-100%)) Diagnostic value, an integer Percentage of 1000 Hz scans dropped (0-100%)
6 Diagnostic-extended	RSSI DIAG HEATER DROPRATE OPTICSRH LCTACTUAL LCTSETPT	Signal strength (Residual Signal Strength Indicator (0-100%)) Diagnostic value, an integer Upper and lower heater status Percentage of 1000 Hz scans dropped (0-100%) Relative humidity in the upper dome (0-100%) Laser cooler temperature, measured (°C) Laser cooler temperature, set point (°C)
7 Diagnostic-full	RSSI HEATER REFRSSI DROPRATE LCTACTUAL LCTSETPT BCTACTUAL BCTSETPT OPTICSRH	Signal strength (Residual Signal Strength Indicator (0-100%)) Upper and lower heater status Reference signal strength (0-100%) Percentage of 1000 Hz scans dropped (0-100%) Laser cooler temperature, measured (°C) Laser cooler temperature, set point (°C) Block cooler temperature, measured (°C) Block cooler temperature, set point (°C) Relative humidity in the upper dome (0-100%)

## RS-232

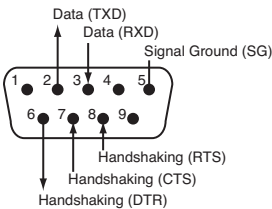
When using RS-232 output, first set the LI-7700 output rate in the Manual Controls window (see "Manual Controls" on page 2-14).

Click the Configure LI-7550 Outputs button (  ) for access to the outputs dialog. The RS-232 tab is used to set the LI-7700 RS-232 port configuration for serial data output. After selecting the desired variables click Apply; the LI-7700 will begin to send data out the RS-232 port according to these parameters.

Since this controls a serial data stream, there is no concept of files or splitting files. The baud rate is set to 57,600. When sending data through the serial connection, note that the baud rate may limit the number of samples that can be output. Therefore, you may have better results if you do not log the Diagnostics or Status data.



## DB-9 Pin Assignments



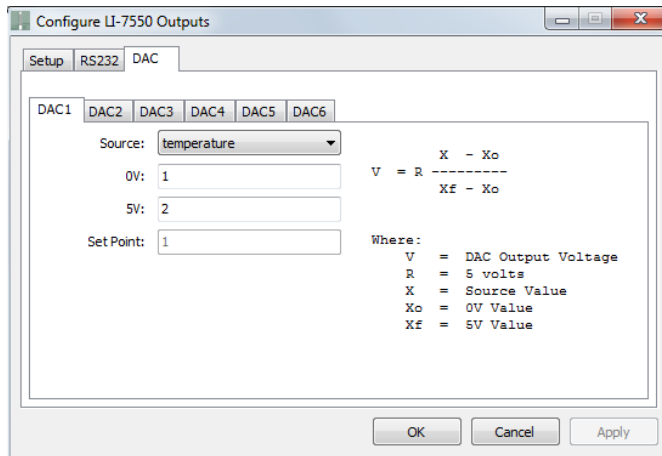
## Analog Outputs

The LI-7550 has the capacity to output up to six variables on Digital to Analog Converter (DAC) channels 1-6. Click the Configure LI-7550 Outputs button (🔧) for access to the outputs dialog. The DAC tab allows you to configure the DAC output channels by specifying the source that drives the analog signal ( $\text{CH}_4$   $\text{mmol m}^{-3}$ ,  $\text{CH}_4$   $\mu\text{mol mol}^{-1}$ , temperature, pressure, signal strength, and set point), the measured value that corresponds to 0V, and the measured value that corresponds to 5V.

For example, DAC1 can be configured to output a voltage signal for  $\text{CH}_4$  with 0  $\text{mmol m}^{-3}$  proportional to 0V, and 5  $\text{mmol m}^{-3}$  equal to 5V by setting the dropdown menu to read  $\text{CH}_4$  ( $\text{mmol m}^{-3}$ ) and entering 0 and 5 in the “0V” and “5V” fields respectively.

**Note:** The LI-7700 analog output signals update at 300 Hz to minimize jitter.

When using the analog outputs, set the LI-7700 output rate to twice the desired bandwidth (in the Manual Controls window). Configure your data storage device to sample at a rate that is equal to or greater than the LI-7700 output rate.



The “Set Point” field will be available when the “set point” option is selected in the Source drop down menu. Set point is a DC output value for testing DACs and data storage devices. The output voltage is converted via:

$$\text{Output Voltage (V)} = 5 \text{ V} * (\text{Set Point Value} - 0 \text{ V Value}) / (5 \text{ V Value} - 0 \text{ V Value})$$

### Time Delays

The analog outputs on the LI-7550 are delayed by 1 second to account for network latencies. The total delay at a particular output rate is increased by the averaging filter according to the expression:

$$\text{Signal Delay} = 1s + \frac{\left(\frac{40\text{Hz}}{\text{Output Rate}}\right) - 1}{2 \times 40\text{Hz}}$$

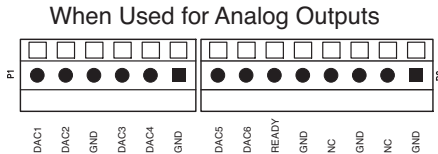
The table below summarizes the delays:

**Table 3-5.** Time delays associated with LI-7550 analog outputs.

Output Rate	Frequency Response (-3db)	Analog Output Signal Delay
40 Hz	20 Hz	1.0 s
20 Hz	10 Hz	1.0125 s
10 Hz	5 Hz	1.0375 s
5 Hz	2.5 Hz	1.0875 s
2 Hz	1 Hz	1.2375 s
1 Hz	0.5 Hz	1.4875 s

### Hardware Configuration (Option 3)

Both the Analog In/Out Cable (part #392-10109, provided) and the 7550-101 Auxiliary Sensor Interface (optional) can be used to distribute the analog output signals. Pin and terminal assignments for both are given in Table 3-6 on the facing page. The schematic below represents the terminal strip inside the 7550-101 when it is configured for analog outputs.



**Figure 3-9.** Terminal connections for analog outputs (Option 3).

**Table 3-6.** LI-7550 Analyzer Interface Unit analog outputs for the 7550-101 Auxiliary Sensor Interface and Analog In/Out Cable. 7550-101 terminals and output functions are on the left and corresponding Analog In/Out Cable wire colors and pin assignments are on the right.

Option 3 <sup>1</sup>				
7550-101 Auxiliary Sensor Interface		Description	Analog In/Out Cable (part #392-10109)	
Terminal	Outputs		Wire Color	Pin
1	DAC1	DAC channel 1 positive	White	Pin 1
2	DAC2	DAC channel 2 positive	Brown	Pin 2
3	GND	Ground	Tan	Pin 10
4	DAC3	DAC channel 3 positive	Green	Pin 3
5	DAC4	DAC channel 4 positive	Yellow	Pin 4
6	GND	Ground	Tan	Pin 10
7	DAC5	DAC channel 5 positive	Grey	Pin 5
8	DAC6	DAC channel 6 positive	Pink	Pin 6
9	READY	Analyzer Ready	Blue	Pin 7
10	GND	Ground	Black	Pin 11
11	NC	No connection	Red	Pin 8
12	GND	Ground	Violet	Pin 12
13	NC	No connection	Orange	Pin 9
14	GND	Ground	Tan	Pin 10

<sup>1</sup>Analog Outputs 0-5V

## Mounting the LI-7550 Analyzer Interface Unit

Two mounting plates (part #9979-022) are included that can be used to mount the LI-7550 using band clamps to secure the box to a tripod or other post. There are holes in the four corners of the box, as well, that can be used to attach the box directly to a flat surface, if desired.

The mounting plates and band clamps are designed to accommodate a square or circular mounting post of up to 2.75" in width (diameter). Hardware is included to attach the mounting plates to the Analyzer Interface Unit using 4 hex head bolts (part #150-12943). The hose clamp mounting brackets are attached to the mounting plates, and then the band clamps can be inserted through the holes in the hose clamp mounting brackets, and tightened around the post, as shown in Figure 3-10 below. The hose clamp mounting brackets can be inserted through any of the holes in the mounting plates to accommodate a variety of mounting options for the LI-7550.

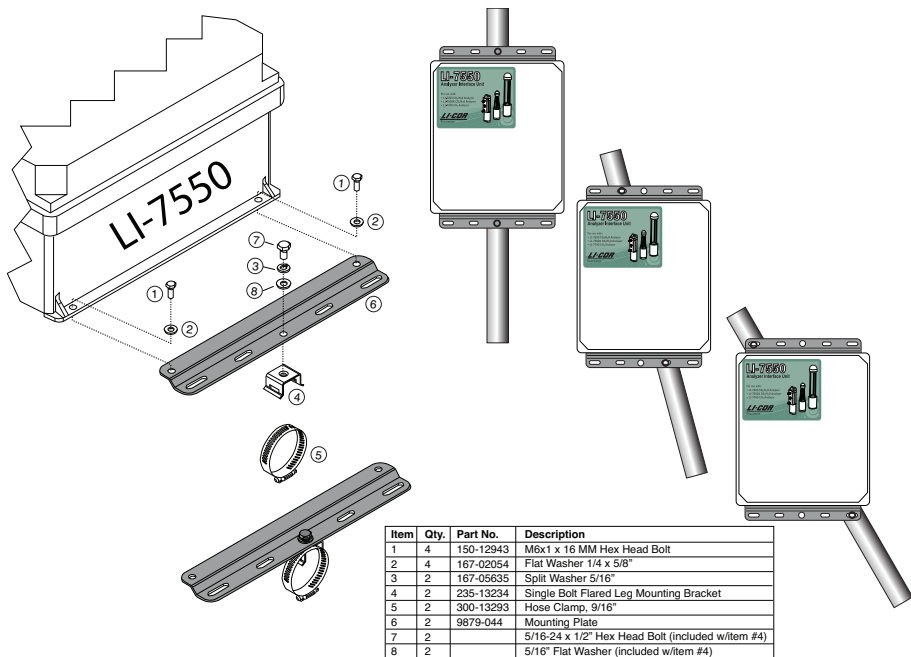


Figure 3-10. Attach mounting plates to Analyzer Interface Unit, attach hose clamp mounting brackets to mounting plates, and secure to mounting post using band clamps.



There are some additional considerations that should be taken into account when locating the Analyzer Interface Unit, including:

- The data cable that connects to the sensor head is 5 meters in length; determine the height at which the sensor head will be mounted, and plan to mount the Analyzer Interface Unit accordingly. This cable could be up to several hundred feet long.
- The thermal properties of the Analyzer Interface Unit are such that it is OK to place the box in direct sun.
- The power cord provided is 5 meters long. Longer cables can be purchased through distributors of Turck, Inc.
- For lightning protection run an independent bonding wire from the instrument ground to the earth.

The following schematic shows one potential configuration.

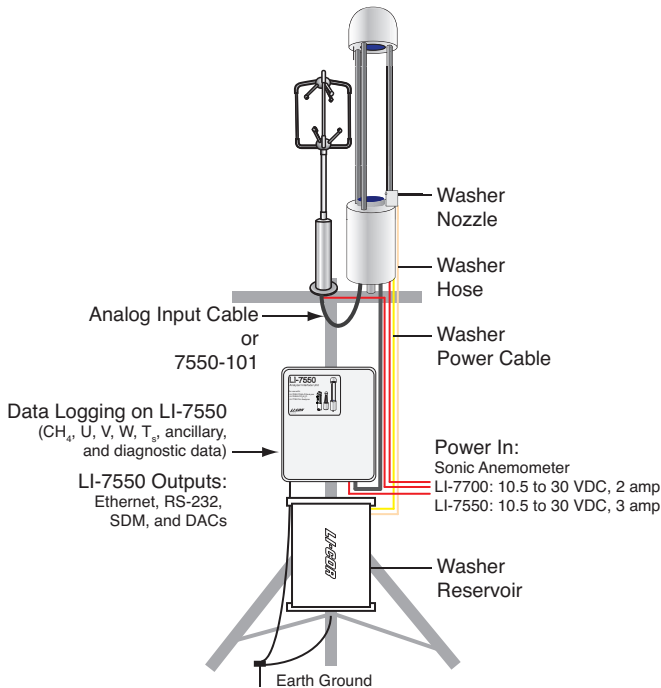


Figure 3-11. A typical field deployment of the LI-7700 and accessories. Eddy covariance flux applications also require measurement of water vapor flux. This can be accomplished with an LI-7500, LI-7500A or LI-7200 CO<sub>2</sub>/H<sub>2</sub>O Analyzer (not shown).



# 4 Data Files

When logging data to a computer or USB storage device (with the LI-7550), the LI-7700 outputs data as tab delimited text files, which can be opened in any common spreadsheet application. Each file consists of a file header, diagnostics header, data header, and data. An example data file and descriptions of the file components are shown below.

Model: LI-7700 Open Path CH4 Analyzer File Type: 2 Instrument: LI-7700-1 Serial Number: 7700-104 Software Version: 1.0.0 Timestamp: 2/18/2010 14:54 Timezone: US/Central		File Header					
		Diagnostics Header					
		Data Header					
		Data					
DATADIAGH	BOXCONNECTED	BADAUXTC3	BADAUXTC2	BADAUXTC1	MOTORFAILURE	CALIBRATING	...
DATAH	SECONDS	NANOSECONDS	DIAG	CH4	CH4D	TEMP	...
DATA	1266526458	500000000	57358	2.53497	0.103356	24.692	...
DATA	1266526459	0	57358	2.5242	0.102793	24.9592	...
DATA	1266526459	500000000	57358	2.52214	0.102688	25.0056	...
DATA	1266526460	0	57358	2.50837	0.102151	24.9534	...
DATA	1266526460	500000000	57358	2.52209	0.102707	24.9605	...
DATA	1266526461	0	57358	2.52735	0.102912	24.9788	...
DATA	1266526461	500000000	57358	2.519	0.102442	25.2609	...
...	...	...	...	...	...	...	...

## File Header

The header is part of every data file produced by the LI-7700. It includes the following fields:

**Table 4-1.** Data file header.

Header Label	Description
Model:	Analyzer
File Type:	Header content descriptor (usually 2)
Instrument:	Instrument name
Serial Number:	Instrument serial number
Software Version:	Instrument firmware version
Timestamp:	Date and time the file was created
Timezone:	Time zone setting in the instrument

## Data

The data is in columns below the DATAH row. The row above the data header includes a list of diagnostic codes that are output with each data file. This information is summarized by the value in the data field called DIAG. These values are described in the section called “Diagnostic Codes” below.

### Data Header

The data header will include all the variables that are selected in the PC or USB logging window. A UTC time stamp (seconds and nanoseconds) is always output with each record in a file. Therefore, it is not necessary to output date and time unless you wish to have the local time stored with the file.

The following list of items may be visible in the data header row, depending on which values are logged:

**Table 4-2.** Data header.

Column Heading	Description
SECONDS	Seconds in UNIX time, or the time the instrument is set to
NANOSECONDS	Nanoseconds
DIAG	Diagnostic value, an integer
CH4	Methane mole fraction ( $\mu\text{mol}/\text{mol}$ )
CH4D	Methane number density ( $\text{mmol}/\text{m}^3$ )
TEMP	Temperature measured with the LI-7700 thermocouple ( $^{\circ}\text{C}$ )
PRESSURE	Pressure measured near the optical path (kPa)
RSSI	Signal strength (Residual Signal Strength Indicator, 0-100%)
DROPRATE	Percentage of 1000Hz scans that were dropped at an output rate of 40 Hz (0-100%).
AUX1	Auxiliary input 1
AUX2	Auxiliary input 2
AUX3	Auxiliary input 3
AUX4	Auxiliary input 4
AUX5	Auxiliary input 5
AUX6	Auxiliary input 6
AUX7	Auxiliary input 7
AUX8	Auxiliary input 8
AUXTC1	Auxiliary thermocouple input 1 ( $^{\circ}\text{C}$ )
AUXTC2	Auxiliary thermocouple input 2 ( $^{\circ}\text{C}$ )

**Table 4-2.** Data header. (...continued)

Column Heading	Description
AUXTC3	Auxiliary thermocouple input 3 (°C)
DATE	Instrument date, reflects time zone setting (MM/DD/YYYY)
TIME	Instrument time, reflects time zone setting (HH:MM:SS.XXXX)
CHK	A check sum feature to check integrity of data

## Diagnostics Header

If the “Diagnostics” check box was checked in the PC, USB, or RS-232 outputs, a diagnostic header and column is included in each data file. The Diagnostics Header is a list of potential diagnostics that are output with each file. The DIAG column contains diagnostic values affiliated with each record in the file, and these values encode one or more pieces of diagnostic information. Each value is an integer between 0 and 65535, which can indicate up to 16 diagnostics. The following guide and example can help interpret this diagnostic information.

**Table 4-3.** Diagnostic codes output with the LI-7700 data record.

Diagnostics Header	Integer	Meaning
NOTREADY	32768	Instrument is not ready
NOSIGNAL	16384	No laser signal detected
REFUNLOCKED	8192	Reference methane signal not locked
BADTEMP	4096	Optical path thermocouple failure
LASERTEMPUNREGULATED	2048	Laser cooler unregulated
BLOCKTEMPUNREGULATED	1024	Block temperature unregulated
MOTORSPINNING	512	Lower mirror spin motor on
PUMPON	256	Washer pump motor running
TOPHEATERON	128	Upper mirror heater on
BOTTOMHEATERON	64	Lower mirror heater on
CALIBRATING	32	Calibration in process
MOTORFAILURE	16	Mirror cleaner motor failure
BADAUXTC1	8	Bad thermocouple values
BADAUXTC2	4	Bad thermocouple values
BADAUXTC3	2	Bad thermocouple values
BOXCONNECTED	1	LI-7550 Attached

If the diagnostic field has a value of 14, this indicates that readings from the thermocouples are bad. This will occur anytime a functioning thermocouple is not attached.

The “14” is the sum of values in the “Integer” column from rows 2, 3, and 4 in the table above (2+4+8). If you are using an LI-7550, this value will be “15” under the same configuration.

### Interpreting a diagnostic code:

1. Identify the integer in the DIAG column of the data file.
2. Find the largest value in the Integer column of Table 4-3 on the previous page which is the value from the DIAG column. The diagnosis associated with that value occurred.
3. Subtract the DIAG value from the Integer. If the difference is 0, there are no other codes. Otherwise, repeat step 2 using the difference rather than the DIAG code.
4. Repeat steps 2 and 3 until the difference equals 0.

### The following example also shows how to interpret the code:

Say, for example, that you encounter the code 17231 associated with a series of logged values in the DIAG column.

1. Refer to Table 4-3 on the previous page and locate the largest value that is 17231. This is 16384, which indicates that no laser signal was detected. Find the difference:  $17231-16384=847$ .
2. In Table 4-3 on the previous page, find the largest value that is the 847. It is 512, which indicates that the lower mirror was spinning. Find the difference:  $847-512=335$ .
3. Find the largest value that is 335. It is 256, which indicates that the pump was running. Find the difference:  $335-256=79$ .
4. Find the largest value that is 79. It is 64, which indicates that the lower mirror heater was on. Find the difference:  $79-64=15$ .
5. Repeating the steps above, it is determined that three thermocouples were not attached or were dysfunctional, and the LI-7700 is connected to an LI-7550.

**Note:** Any time an odd number occurs in the DIAG field, it indicates that an LI-7550 was in use. Even numbers indicate that there was no LI-7550 attached.

In summary, if there is a diagnostic value of 17231, the instrument was in the midst of a cleaning cycle while heating the lower mirror.

## Status Columns

**Note:** If you choose to log status columns to the data file, status records will be interspersed with the data records by time. Only log status records if you are diagnosing the LI-7700.

When logging to a USB storage device or a host PC, you can choose to log status columns to the log file, to a separate file, or not at all. Status data can also be sent through the RS-232 output. Status data are always logged at 2 Hz.

### Status Header

The following header is output with the status file.

**Table 4-4.** Status file header.

Column Heading	Description
SECONDS	Seconds in UNIX time, or the time the instrument is set to
NANOSECONDS	Nanoseconds
DIAG	Diagnostic value, an integer
RSSI	Signal strength (Residual Signal Strength Indicator, 0-100%)
REFRSSI	Reference Signal Strength (0-100%)
LCTSETPT	Laser cooler temperature set point (°C)
LCTACTUAL	Laser cooler temperature measured (°C)
BCTSETPT	Block cooler temperature set point (°C)
BCTACTUAL	Block cooler temperature measured (°C)
CHASSISTEMP	Temperature in lower housing (disabled)
OPTICSTEMP	Reference junction temperature for top thermocouple (°C)
OPTICSRH	Relative humidity in the upper dome (%)
AUXREFTEMP	Temperature of Auxiliary Sensor Interface, 7550-101 (°C)
MOTORSETPT	Spin motor set point (preferred alignment)
MOTORACTUAL	Spin motor position (actual alignment)
USB	Device present
USBCAPACITY	USB device capacity
USBFREESPACE	USB device free space
REF	A diagnostic value used in technical support
GND	
OPTICSDELTA	Temperature difference between air and upper mirror
CHK	A checksum feature to check the integrity of data





# 5 LI-7700 Flux Measurements

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The LI-7700 is an open path methane analyzer. The methane densities it measures are affected by thermal expansion and dilution by water vapor in the same way as densities measured by other open path gas analyzers, such as the LI-7500A CO<sub>2</sub>/H<sub>2</sub>O Analyzer. The impacts of fluctuations in temperature and water vapor density on flux measurements were worked out by Webb, et al. (1980). Small fluctuations in pressure are usually negligible and are ignored. Webb, et al. (1980) derived equations that adjust for the effects of correlated fluctuations in temperature and water vapor, which are applied to the average raw flux over the averaging period. These are often called “WPL corrections,” attributed to the authors E. Webb, G. Pearman, and R. Leuning.

Temperature, pressure, and water vapor also impact the spectroscopic measurements made by the LI-7700 and must be taken into account. It is necessary to adjust spectroscopic light absorption measurements for correlated fluctuations in temperature and water vapor density, just as it is necessary to adjust for thermal expansion and dilution, and we use a strategy similar to the WPL corrections to apply the adjustments (patent pending). As with the WPL corrections, barometric pressure is treated as constant, and we apply the corrections over the averaging period. The spectroscopic effects of pressure, temperature and water vapor can be compensated by deriving multipliers for each of the terms in the WPL formulation. The purpose of this chapter is to show you how to apply these corrections. We derive the equations in "Theory & Equations" on page 6-1.

**Important:** Temperature measurements used in the methane flux calculations should always come from the sonic anemometer.

There is a small thermocouple on the LI-7700 but it should not be used for flux measurements because its frequency response varies between 1 Hz and about 10 Hz, depending upon wind speed. The thermocouple is placed on the instrument for computing slow mole fraction, not number density. Mole fraction is useful for calibration and for estimates of mean concentration, but it should not be used for flux measurements because of limitations in frequency response.

**Important:** Water vapor flux measurements are required to compute methane fluxes with the LI-7700. These data should be acquired with an LI-7500A, LI-7500, LI-7200, or other H<sub>2</sub>O analyzer.

## Computing Fluxes

**Important:** Use the uncorrected methane number density channel (CH4D, mmol/m<sup>3</sup>) for flux measurements.

We shall use Equation 6-36 from Chapter 6, where  $q_{cm}$  is measured methane mass density before correction, so the first step is to compute mass density,  $q_{cm} = m_c \rho_c$ , where  $m_c$  is the molecular weight of methane and  $\rho_c$  is measured raw number density. Equation 6-34 can be written as

$$F_c = A \left\{ \overline{w' q'_{cm}} + B \mu \frac{\overline{q_{cm}}}{\overline{q_d}} \overline{w' q'_v} + C(1 + \mu \sigma) \frac{\overline{q_{cm}}}{\overline{T}} \overline{w' T'} \right\} \quad 5-1$$

where A accounts for spectroscopic effects of temperature, pressure, and water vapor on methane density, B provides spectroscopic corrections to the latent heat flux term for pressure and water vapor, C provides spectroscopic corrections to the sensible heat flux term for temperature, pressure and water vapor (Table 5-1 on the facing page), and other terms and factors have their usual meanings, which are defined in Table 5-2 on page 5-4.

Spectroscopic effects of water vapor are taken into account using the concept of equivalent pressure,  $P_e$ . Equivalent pressure accounts for the fact that partial pressures of different gas species are not equal in their effects on pressure broadening. This concept is explained in detail in Chapter 6. For now, we note that water vapor is the only constituent of air that is both variable and present in sufficient quantities to affect pressure broadening, so  $P_e$  is computed with water vapor as the only variable gas. Thus,  $\overline{P_e} = \overline{P}(1 + 0.46\overline{x_v})$ , where  $\overline{x_v}$  is the mole fraction of water vapor. With this introduction to  $P_e$ , the definitions of coefficients of A, B, and C are given in Table 5-1 on the facing page.

**Table 5-1.** Definition of variables A, B, and C.

Variable	Definition	Source
A	$A = \bar{\kappa}$ . Dimensionless. Corrects methane density for spectroscopic effects of T, P and water vapor.	Given in Table 5-3 on page 5-13.
B	$B = 1 + (1 - 1.46\bar{x}_v)\alpha_v\bar{P}_e\frac{\kappa_{Pe}}{\bar{\kappa}}$ . Dimensionless. Corrects the latent heat flux term for spectroscopic effects.	
C	$C = 1 + (1 - \bar{x}_v)\bar{T}\frac{\kappa_T}{\bar{\kappa}} + \bar{x}_v(B-1)$ . Dimensionless. Corrects the sensible heat term for spectroscopic effects.	
$\bar{x}_v$	Mole fraction of water vapor, dimensionless. $\bar{x}_v = \bar{\rho}_v / \bar{\rho} = \bar{\rho}_v R\bar{T} / \bar{P}$	From the LI-7500A or similar instrument, $\bar{T}$ , and $\bar{P}$ .
$\alpha_v$	Water vapor broadening factor, dimensionless. $\alpha_v = a_v - 1 = 0.46$ . $a_v$ is the foreign gas broadening coefficient for water vapor on methane, $a_v = 1.46$ .	Specific to the LI-7700. See "Compensating for Water Vapor: Equivalent Pressure, $P_e$ " on page 6-6.
$\kappa_{Pe}$	$\kappa_{Pe} = \left. \frac{\partial \kappa}{\partial P_e} \right _T$ . Rate of change in $\kappa$ with $P_e$ at constant $T = \bar{T}$ , kPa <sup>-1</sup> .	Given in Table 5-4 on page 5-13.
$\kappa_T$	$\kappa_T = \left. \frac{\partial \kappa}{\partial T} \right _{P_e}$ . Rate of change in $\kappa$ with T at constant $P_e = 1$ .	Given in Table 5-5 on page 5-14.

Section 5. LI-7700 Flux Measurements

**Table 5-2.** Variables used in Equation 5-3 and to compute values for A, B, and C. Numerical values given below are used in the example calculation.

Variable	Description	Source
$F_c = \text{mg CH}_4 \text{ m}^{-2} \text{ h}^{-1}$	correct methane flux	Computed
$\overline{w'q'_{cm}} = -0.468 \text{ mg CH}_4 \text{ m}^{-2} \text{ h}^{-1}$	uncorrected methane flux	Measured with the LI-7700 and sonic anemometer
$\overline{w'q'_v} = 91.04 \text{ g H}_2\text{O m}^{-2} \text{ h}^{-1}$	water vapor flux	Measured with a CO <sub>2</sub> /H <sub>2</sub> O analyzer and sonic anemometer
$\overline{w'T'} = 47.63 \text{ K m h}^{-1}$	heat flux	Measured in the field with a sonic anemometer
$\overline{x}_v = 0.02$	water vapor mole fraction	Measured with a CO <sub>2</sub> /H <sub>2</sub> O analyzer (e.g., LI-7500A)
$\mu = 1.6077$	ratio of dry air formula weight to water vapor molecular weight	Given
$\sigma = 0.0127$	ratio of water vapor mass density to dry air mass density $= (1/\mu) \times (\overline{x}_v / (1 - \overline{x}_v))$	Calculated based on $\overline{x}_v = 0.02$
$\overline{q}_{cm} = 1.227 \text{ mg CH}_4 \text{ m}^{-3}$	average mass density of methane	Measured with the LI-7700
$\overline{q}_d = 1154 \text{ g m}^{-3}$	average mass density of dry air	From measured T and P
$\overline{P} = 97.7 \text{ kPa}$	average pressure	Measured in the field
$\overline{P}_e = 97.7(1 + 0.46 \cdot 0.02) \approx 98.6 \text{ kPa}$	equivalent pressure	
$\overline{T} = 22.25 \text{ }^\circ\text{C} = 295.38 \text{ K}$	average temperature (K)	Measured in the field
$\alpha_v = 0.46$	water vapor broadening factor, dimensionless	Given
$\overline{\kappa} = 0.97329$	corrects for spectroscopic effects of T, P, and $x_v$	Interpolated from Table 5-3 on page 5-13
$\kappa_{Pe} = 0.0092655$	rate of change in $\kappa$ with $P_e$ at constant $T = \overline{T}$	Interpolated from Table 5-4 on page 5-13
$\kappa_T = 0.0010965$	rate of change in $\kappa$ with T at constant $P_e = \overline{P}_e$	Interpolated from Table 5-5 on page 5-14

## Example Calculation

We present the example in two steps. First, we compute A, B, and C using the individual factors shown in Table 5-2 on the previous page to illustrate the magnitudes of all the factors entering into the calculation. In a second step we show a somewhat simpler approach.

## Full Computation

In this example we calculate average CH<sub>4</sub> flux for a one-hour period over a maize field at Mead, Nebraska. This experimental site has a multi-year history of chamber measurements with very small CH<sub>4</sub> fluxes (-0.1 to 0.1 mg m<sup>-2</sup> h<sup>-1</sup> year round; Timothy J. Arkebauer, pers. comm.). Measurements were made near 11:30 am on the morning of June 06, 2009.

Using the definitions and values shown in Table 5-1 on page 5-3 and Table 5-2 on the previous page, with  $\overline{K}$  and the derivatives from Table 5-3 on page 5-13, Table 5-4 on page 5-13, and Table 5-5 on page 5-14, we find

$$A = \mathbf{0.97},$$

$$B = \left[ 1 + (1 - 1.46\overline{x}_v)\alpha_v \overline{F}_e \frac{\kappa_{Pe}}{\overline{\kappa}} \right]$$

$$B = \left[ 1 + (1 - 1.46 \cdot 0.02)0.46(98.6) \frac{0.00927}{0.973} \right] = \mathbf{1.42}, \text{ and}$$

$$C = \left[ 1 + (1 - \overline{x}_v)\overline{T} \frac{\kappa_T}{\overline{\kappa}} + \overline{x}_v(B-1) \right]$$

$$C = \left[ 1 + (1 - 0.02)295.38 \frac{0.001097}{0.973} \right] + 0.02(1.4195 - 1) = 1.326 + 0.00839 = \mathbf{1.33} \quad 5-2$$

so

$$F_c = \mathbf{0.97} \left\{ \overline{w'q'_{cm}} + \mathbf{1.42} \mu \frac{\overline{q_{cm}}}{\overline{q_d}} \overline{w'q'_v} + \mathbf{1.33} (1 + \mu\sigma) \frac{\overline{q_{cm}}}{\overline{T}} \overline{w'T'} \right\} \quad 5-3$$

Equation 5-3 is the standard WPL equation (Equation 24 in Webb, et al., 1980) with three multipliers in bold to account for spectroscopic effects.

$$F_c = 0.97 \left\{ -0.468 + 1.42 \cdot 1.6077 \frac{1.227}{1154} 91.04 + 1.33(1 + 1.6077 \cdot 0.0127) \frac{1.227}{295.38} 47.63 \right\} = 0.021 \quad 5-4$$

The final flux, corrected for thermal expansion, water vapor dilution, and spectroscopic effects, is 0.021 mg CH<sub>4</sub> m<sup>-2</sup> h<sup>-1</sup>.

For comparison, note that the raw uncorrected flux was -0.468 (-0.47) mg CH<sub>4</sub> m<sup>-2</sup> h<sup>-1</sup> and the flux computed according to the traditional WPL equation, but not corrected for spectroscopic effects, was -0.11 mg CH<sub>4</sub> m<sup>-2</sup> h<sup>-1</sup>.

### Simplified Computation

Now, as the second step, we note that the calculations can be simplified by tabulating two collections of coefficients:  $\alpha_v \bar{P}_e \frac{\kappa_{Pe}}{\bar{\kappa}}$  and  $\bar{T} \frac{\kappa_T}{\bar{\kappa}}$ . Table 5-6 on page 5-14 gives a subset of values for  $\alpha_v \bar{P}_e \frac{\kappa_{Pe}}{\bar{\kappa}}$  and Table 5-7 on page 5-15 gives a subset of values for  $\bar{T} \frac{\kappa_T}{\bar{\kappa}}$ . Thus,

$$A=0.97$$

$$B= 1 + (1 - 1.46 \cdot \bar{x}_v) \alpha_v \bar{P}_e \frac{\kappa_{Pe}}{\bar{\kappa}}, \text{ so}$$

$$B= 1 + (1 - 1.46 \cdot 0.02) 0.432 = 1.42$$

$$C= 1 + (1 - \bar{x}_v) \bar{T} \frac{\kappa_T}{\bar{\kappa}} + \bar{x}_v (B-1), \text{ so}$$

$$C= 1 + (1 - 0.02) 0.332 + 0.02(1.42 - 1) = 1.33$$

Using the tables with collected constants considerably simplifies the calculations and makes it easier to implement the calculations into flux computation software.

### Finding Multipliers

We present three options for acquiring values for  $\bar{\kappa}$ ,  $\alpha_v \bar{P}_e \frac{\kappa_{Pe}}{\bar{\kappa}}$ , and  $\bar{T} \frac{\kappa_T}{\bar{\kappa}}$ :

1. **Low Resolution Look-up Tables** (Table 5-8 on page 5-15, Table 5-9 on page 5-16, and Table 5-10 on page 5-17);
2. **Parametric Equations** (Equation 5-5 on page 5-9, Equation 5-6 on page 5-10, and Equation 5-7 on page 5-11); or
3. **High Resolution Digital Tables** (provided with the LI-7700 software CD).

## Low Resolution Look-up Tables

Tables 5-8, 5-9, and 5-10 provide values  $\bar{\kappa}$ ,  $\alpha \sqrt{\bar{P}_e} \frac{\kappa P_e}{\bar{\kappa}}$ , and  $\bar{T} \frac{\kappa T}{\bar{\kappa}}$  for temperatures from -30 to 50 °C in 10 °C increments, and pressures from 50 to 110 kPa in 5 kPa increments. Always compute equivalent pressure ( $\bar{P}_e = \bar{P}(1 + 0.46\bar{\alpha}_v)$ ) before entering the table, and use linear interpolation between temperature and equivalent pressure values to approximate the correct values, as shown below.

### Interpolate to find $\bar{\kappa}$

As an example, with  $\bar{P}_e = 98.6$  kPa and  $\bar{T} = 22.25$  °C, first find the value of  $\bar{\kappa}$  at 22.25 °C and 95 kPa, which is

$$0.9381 + \left[ \frac{(0.9496 - 0.9381)}{(30 - 20)} \right] (22.25 - 20) = 0.9407$$

Then find the value at 22.25 °C and 100 kPa, which is

$$0.9839 + \left[ \frac{(0.9949 - 0.9839)}{(30 - 20)} \right] (22.25 - 20) = 0.9864$$

And finally, find the value at 98.6 kPa and 22.25 °C, which is

$$0.9839 + \left[ \frac{(0.9949 - 0.9839)}{(30 - 20)} \right] (22.25 - 20) = 0.9864$$

Excerpt from Table 5-8 on page 5-15.

	20 °C	22.25 °C	30 °C
95 kPa	0.9381	0.9407	0.9496
98.6 kPa		0.97	
100 kPa	0.9839	0.9864	0.9949

**Interpolate to find**  $\alpha_{\nu} \bar{P}_e \frac{\kappa_{Pe}}{\bar{\kappa}}$

With  $\bar{P}_e = 98.6$  kPa and  $\bar{T} = 22.25$  °C, first find the value for  $\alpha_{\nu} \bar{P}_e \frac{\kappa_{Pe}}{\bar{\kappa}}$  at 22.25 °C and pressure of 95 kPa, which is

$$0.4196 + \left[ \frac{(0.4102 - 0.4196)}{(30 - 20)} \right] (22.25 - 20) = 0.4175$$

Then find the value at 22.25 °C and 100 kPa, which is

$$0.4396 + \left[ \frac{(0.4299 - 0.4396)}{(30 - 20)} \right] (22.25 - 20) = 0.4374$$

And finally, find the value at 98.6 kPa and 22.25 °C, which is

$$\alpha_{\nu} \bar{P}_e \frac{\kappa_{Pe}}{\bar{\kappa}} = 0.4175 + \left[ \frac{(0.4175 - 0.4374)}{(95 - 100)} \right] (98.6 - 95) = 0.432$$

Excerpt from Table 5-9 on page 5-16.

	20 °C	22.25 °C	30 °C
95 kPa	0.4196	0.4175	0.4102
98.6 kPa		0.43	
100 kPa	0.4396	0.4374	0.4299

**Interpolate to find**  $\bar{T} \frac{\kappa_T}{\bar{\kappa}}$

With  $\bar{P}_e = 98.6$  kPa and  $\bar{T} = 22.25$  °C, first find the value at 22.25 °C and 95 kPa, which is

$$0.3459 + \left[ \frac{(0.3870 - 0.3459)}{(30 - 20)} \right] (22.25 - 20) = 0.3551$$



Then find the value at 22.25 °C and 100 kPa, which is

$$0.3141 + \left[ \frac{(0.3558 - 0.3141)}{(30 - 20)} \right] (22.25 - 20) = 0.3235$$

And finally, find the value at 98.6 kPa and 22.25 °C, which is

$$\bar{T} \frac{\kappa_T}{\bar{\kappa}} = 0.3551 + \left[ \frac{(0.3551 - 0.3235)}{(95 - 100)} \right] (98.6 - 95) = 0.332$$

Excerpt from Table 5-10 on page 5-17.

	20 °C	22.25 °C	30 °C
95 kPa	0.3459	0.3551	0.3870
98.6 kPa		0.33	
100 kPa	0.3141	0.3235	0.3558

### Parametric Equations

Below are formulas that can be used to approximate values for  $\bar{\kappa}$ ,  $\alpha_v \bar{P}_e \frac{\kappa_{Pe}}{\bar{\kappa}}$ , and  $\bar{T} \frac{\kappa_T}{\bar{\kappa}}$ . Using the formulas, these values can be approximated with reasonably good precision. The formulas were derived empirically from high-resolution tables. They are presented in a Microsoft® Excel file on the LI-7700 Software CD. The file is called LI\_7700\_Flux\_Multipliers and the formulas are under the “Parametric Equations” tab.

### Computing $\bar{\kappa}$

To compute  $\bar{\kappa}$  as a function of temperature and pressure, first compute equivalent pressure,  $\bar{P}_e = \bar{P}(1 + 0.46\bar{x}_v)$ . Then,

$$\bar{\kappa} = Q \times P_e + R \times P_e + S \tag{5-5}$$

where

$$Q = a_0 \times T^2 + a_1 \times T + a_2$$

$$R = b_0 \times T^2 + b_1 \times T + b_2$$

$$S = c_0 \times T^2 + c_1 \times T + c_2$$

and coefficients =

	0	1	2
<i>a</i>	0	$-1.3 \times 10^{-7}$	$3.7 \times 10^{-5}$
<i>b</i>	$4.0 \times 10^{-8}$	$1.1 \times 10^{-5}$	$2.18 \times 10^{-3}$
<i>c</i>	$2.0 \times 10^{-6}$	$9.8 \times 10^{-4}$	0.378

As an example, we compute  $\bar{\kappa}$  with  $\bar{P}_e = 98.6$  kPa and  $\bar{T} = 22.25$  °C.

$$Q = \left(0 \times 22.25^2\right) + \left(-1.3 \times 10^{-7} \times 22.25\right) + 3.7 \times 10^{-5} = 3.41 \times 10^{-5}$$

$$R = \left(4.0 \times 10^{-8} \times 22.25^2\right) + \left(1.1 \times 10^{-5} \times 22.25\right) + 2.18 \times 10^{-3} = 2.45 \times 10^{-3}$$

$$S = \left(2.0 \times 10^{-6} \times 22.25^2\right) + \left(9.8 \times 10^{-4} \times 22.25\right) + 0.378 = 0.40$$

and

$$\bar{\kappa} = \left(3.41 \times 10^{-5} \times 98.6^2\right) + \left(2.45 \times 10^{-3} \times 98.6\right) + 0.40 = 0.97$$

With this formula,  $\bar{\kappa}$  can be computed with an accuracy of better than 0.1% for pressures between 80 to 100 kPa, and temperatures between -30 to 50 °C, and with an overall accuracy of better than 0.3% for the entire range. T is temperature (°C) and  $P_e$  is equivalent pressure (kPa).

### Computing $\alpha_v \bar{P}_e^{\frac{\kappa P_e}{\bar{\kappa}}}$

To compute  $\alpha_v \bar{P}_e^{\frac{\kappa P_e}{\bar{\kappa}}}$  as a function of temperature and pressure, first compute equivalent pressure,  $\bar{P}_e = \bar{P}(1 + 0.46\bar{x}_v)$ , then

$$\alpha_v \bar{P}_e^{\frac{\kappa P_e}{\bar{\kappa}}} = (a \times T + b) \times P_e + (c \times T + d) \tag{5-6}$$

with coefficients:

$$\begin{aligned} a &= -8.2 \times 10^{-6}; \\ b &= 4.3 \times 10^{-3}; \\ c &= -1.7 \times 10^{-4}; \\ d &= 0.03. \end{aligned}$$

For example, we compute the value with  $\bar{P}_e = 98.6$  kPa and  $\bar{T} = 22.25$  °C.

$$\alpha_v \bar{P}_e \frac{K P_e}{\bar{\kappa}} = \left( -8.2 \times 10^{-6} \times 22.25 + 0.0043 \right) \times 98.6 + \left( -1.7 \times 10^{-4} \times 22.25 + 0.030 \right) = 0.43$$

With this formula,  $\alpha_v \bar{P}_e \frac{K P_e}{\bar{\kappa}}$  can be computed with an accuracy of better than 0.1% for temperatures between 0 and 50 °C and at all pressures. Overall accuracy is better than 0.3% for the entire range. T is temperature (°C) and P<sub>e</sub> is equivalent pressure (kPa).

### Computing $\bar{T} \frac{K T}{\bar{\kappa}}$

To compute  $\bar{T} \frac{K T}{\bar{\kappa}}$  as a function of temperature and pressure, first compute equivalent pressure,  $\bar{P}_e = \bar{P} (1 + 0.46 \bar{x}_v)$ , then

$$\bar{T} \frac{K T}{\bar{\kappa}} = \left( a \times T^2 + b \times T + c \right) \times P_e + \left( d \times T^2 + e \times T + f \right) \quad 5-7$$

with coefficients:

$$\begin{aligned} a &= -4.0 \times 10^{-8}, \\ b &= 1.55 \times 10^{-5}, \\ c &= -7.0 \times 10^{-3}, \\ d &= -4.7 \times 10^{-6}, \\ e &= 3.0 \times 10^{-3}, \\ f &= 0.927. \end{aligned}$$

For example, we compute the value with  $\bar{P}_e = 98.6$  kPa and  $\bar{T} = 22.25$  °C.

$$\bar{T} \frac{K T}{\bar{\kappa}} = \left[ \left( -4.0 \times 10^{-8} \times 22.25^2 \right) + \left( 1.55 \times 10^{-5} \times 22.25 \right) + -7.0 \times 10^{-3} \right] \times 98.6 + \left( -4.7 \times 10^{-6} \times 22.25^2 \right) + \left( 3.0 \times 10^{-3} \times 22.25 \right) + 0.927 = 0.33$$

With this formula,  $\bar{T} \frac{K T}{\bar{\kappa}}$  can be computed with an accuracy of better than 0.2% at pressure of 100 kPa, between -30 and 40 °C. Overall accuracy is better than 0.8% for the entire range. T is temperature (°C) and P<sub>e</sub> is equivalent pressure (kPa).

## High Resolution Digital Tables

The LI-7700 software CD includes tab delimited text files and a Microsoft® Excel file called “LI\_7700\_Flux\_Multipliers.” These files contain high-resolution tables of  $\bar{\kappa}$ ,  $\alpha_v \bar{P}_e \frac{\kappa_{Pe}}{\bar{\kappa}}$ , and  $\bar{T} \frac{\kappa_T}{\bar{\kappa}}$ , covering temperatures of -50 to 55 °C and pressures of 50 to 115 kPa in 1 degree and 1 kPa increments. As in the example given in Table 5-3 on the facing page, Table 5-4 on the facing page, and Table 5-5 on page 5-14, use linear interpolation between temperature and equivalent pressure values to acquire more accurate estimates. Compute equivalent pressure  $\bar{P}_e = \bar{P}(1 + 0.46\bar{\alpha}_v)$  before entering the table.

In the Excel file, values for  $\bar{\kappa}$  are in the tab called “PT”, for  $\alpha_v \bar{P}_e \frac{\kappa_{Pe}}{\bar{\kappa}}$  are in a tab called “Pderivative”, and for  $\bar{T} \frac{\kappa_T}{\bar{\kappa}}$  are in a tab called “Tderivative.”

Values for  $\bar{\kappa}$  are also in a tab-delimited text file called “LI\_7700\_Flux\_Mult\_PT.”

Values for  $\alpha_v \bar{P}_e \frac{\kappa_{Pe}}{\bar{\kappa}}$  are in a tab-delimited text file called “LI\_7700\_Flux\_Mult\_Pderiv.”

Values for  $\bar{T} \frac{\kappa_T}{\bar{\kappa}}$  are in a tab-delimited text file called “LI\_7700\_Flux\_Mult\_Tderiv.”

These files can also be acquired by contacting LI-COR technical support at [envsupport@licor.com](mailto:envsupport@licor.com).

**Table 5-3.** Sample calculation of the spectroscopic correction factor,  $\bar{\kappa}$ . Values for  $\bar{\kappa}$  were computed by propagating the effects of temperature and pressure on absorption as described by Rothman, et al. (2009) through the WMS protocol and tabulating the results in 1 °C and 1 kPa increments over the range -50 to 55°C and 50 to 115 kPa. This is a subset of the high-resolution table stored in the instrument and provided as a digital resource from LI-COR. The value at 22.25 °C and 98.6 kPa (equivalent pressure) was determined by linear interpolation. Compute equivalent pressure,  $\bar{P}_e = \bar{P}(1 + 0.46\bar{\alpha}_v)$ , before entering the table.

Equivalent Pressure (kPa)	Temperature (°C)						
	20	21	22	22.25	23	24	25
96	0.94707	0.94817	0.94928		0.95040	0.95153	0.95267
97	0.95616	0.95725	0.95834		0.95945	0.96057	0.96170
98	0.96532	0.96640	0.96749	0.96776	0.96858	0.96969	0.97081
98.6				0.97329			
99	0.97456	0.97563	0.97671	0.97698	0.97779	0.97889	0.98001
100	0.98389	0.98494	0.98601		0.98709	0.98817	0.98927
101	0.99329	0.99433	0.99539		0.99645	0.99753	0.99862

**Table 5-4.** Rate of change of  $\kappa$  with  $P_c$  at constant temperature,  $\bar{P}_e = \bar{P}(1 + 0.46\bar{\alpha}_v)$ . The value at 22.25 °C and 98.6 kPa was determined by linear interpolation. Compute equivalent pressure,  $\bar{P}_e = \bar{P}(1 + 0.46\bar{\alpha}_v)$ , before entering the table.

Equivalent Pressure (kPa)	Temperature (°C)						
	20	21	22	22.25	23	24	25
96	0.00909	0.00907	0.00906		0.00905	0.00904	0.00904
97	0.00916	0.00915	0.00914		0.00913	0.00912	0.00911
98	0.00924	0.00923	0.00922	0.0092175	0.00921	0.00920	0.00919
98.6				0.0092655			
99	0.00932	0.00931	0.00930	0.0092975	0.00929	0.00928	0.00927
100	0.00940	0.00939	0.00938		0.00937	0.00936	0.00935
101	0.00949	0.00947	0.00946		0.00945	0.00944	0.00943

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**Table 5-5.** Rate of change of  $\kappa$  with temperature at constant  $P_e$ ,  $\kappa_T = \left. \frac{\partial \kappa}{\partial T} \right|_{P_e}$ . The value at 22.25 °C and 98.6 kPa was determined by linear interpolation. Compute equivalent pressure,  $\overline{P}_e = \overline{P}(1 + 0.46\overline{x}_v)$ , before entering the table.

Equivalent Pressure (kPa)	Temperature (°C)						
	20	21	22	22.25	23	24	25
96	0.00110	0.00111	0.00112		0.00113	0.00114	0.00115
97	0.00109	0.00110	0.00111		0.00112	0.00113	0.00114
98	0.00108	0.00109	0.00110		0.00111	0.00112	0.00113
98.6			0.001094	0.0010965	0.001104		
99	0.00107	0.00108	0.00109		0.00110	0.00111	0.00112
100	0.00105	0.00107	0.00108		0.00109	0.00110	0.00111
101	0.00104	0.00106	0.00107		0.00108	0.00109	0.00110

**Table 5-6.** Computed values for  $\alpha_v \overline{P}_e \frac{\kappa_{P_e}}{\overline{\kappa}}$ . Compute equivalent pressure,  $\overline{P}_e = \overline{P}(1 + 0.46\overline{x}_v)$  before entering the table.

Equivalent Pressure (kPa)	Temperature (°C)						
	20	21	22	22.25	23	24	25
96	0.4236	0.4226	0.4217		0.4207	0.4197	0.4188
97	0.4276	0.4266	0.4257		0.4247	0.4237	0.4228
98	0.4316	0.4306	0.4297		0.4287	0.4277	0.4268
98.6			0.4321	0.4318	0.4311		
99	0.4356	0.4346	0.4337		0.4327	0.4317	0.4307
100	0.4396	0.4386	0.4376		0.4367	0.4357	0.4347
101	0.4436	0.4426	0.4416		0.4406	0.4396	0.4387

**Table 5-7.** Computed values for  $\frac{\bar{T}^{KT}}{\bar{K}}$ . Compute equivalent pressure,  $\bar{P}_e = \bar{P}(1 + 0.46\bar{x}_v)$ , before entering the table.

Equivalent Pressure (kPa)	Temperature (°C)						
	20	21	22	22.25	23	24	25
96	0.3395	0.3437	0.3479		0.3520	0.3561	0.3603
97	0.3332	0.3374	0.3415		0.3457	0.3498	0.3540
98	0.3268	0.3310	0.3352	0.3362	0.3394	0.3435	0.3477
98.6				0.3324			
99	0.3205	0.3247	0.3289	0.3299	0.3330	0.3372	0.3414
100	0.3141	0.3183	0.3226		0.3267	0.3309	0.3351
101	0.3078	0.3120	0.3163		0.3205	0.3247	0.3288

**Table 5-8.** Values for  $\bar{K}$  from -30 °C to 50 °C and 50 kPa to 110 kPa. Compute equivalent pressure,  $\bar{P}_e = \bar{P}(1 + 0.46\bar{x}_v)$ , before entering the table and interpolate between temperature and pressure values to find the value with reasonably good precision.

Equivalent Pressure (kPa)	Temperature (°C)								
	-30	-20	-10	0	10	20	30	40	50
50	0.5450	0.5557	0.5670	0.5789	0.5914	0.6045	0.6182	0.6324	0.6472
55	0.5769	0.5872	0.5983	0.6100	0.6224	0.6354	0.6490	0.6632	0.6779
60	0.6105	0.6204	0.6311	0.6426	0.6548	0.6676	0.6811	0.6952	0.7100
65	0.6457	0.6552	0.6656	0.6768	0.6887	0.7014	0.7147	0.7287	0.7434
70	0.6828	0.6918	0.7017	0.7125	0.7242	0.7366	0.7498	0.7637	0.7782
75	0.7218	0.7302	0.7396	0.7500	0.7613	0.7734	0.7864	0.8001	0.8146
80	0.7627	0.7705	0.7793	0.7892	0.8001	0.8119	0.8246	0.8381	0.8524
85	0.8058	0.8127	0.8210	0.8303	0.8408	0.8522	0.8645	0.8778	0.8918
90	0.8510	0.8571	0.8646	0.8733	0.8832	0.8942	0.9062	0.9191	0.9329
95	0.8984	0.9036	0.9103	0.9183	0.9276	0.9381	0.9496	0.9622	0.9757
100	0.9483	0.9524	0.9581	0.9654	0.9740	0.9839	0.9949	1.0071	1.0203
105	1.0006	1.0035	1.0082	1.0146	1.0225	1.0317	1.0422	1.0539	1.0667
110	1.0554	1.0571	1.0607	1.0661	1.0731	1.0817	1.0915	1.1027	1.1151

**Section 5. LI-7700 Flux Measurements**

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**Table 5-9.** Values for  $\alpha_v \bar{P}_e \frac{K_{Pe}}{\bar{\kappa}}$  from -30 °C to 50 °C and 50 kPa to 110 kPa. Values in this table can be approximated with equation 5-6 on page 5-10. Compute equivalent pressure,  $\bar{P}_e = \bar{P}(1 + 0.46\bar{\alpha}_v)$ , before entering the table and interpolate between temperature and pressure values to find the value with reasonably good precision.

Equivalent Pressure (kPa)	Temperature (°C)								
	-30	-20	-10	0	10	20	30	40	50
50	0.2636	0.2561	0.2491	0.2426	0.2364	0.2305	0.2250	0.2198	0.2148
55	0.2882	0.2801	0.2725	0.2654	0.2587	0.2523	0.2463	0.2407	0.2353
60	0.3125	0.3038	0.2956	0.2880	0.2807	0.2739	0.2674	0.2613	0.2555
65	0.3366	0.3273	0.3185	0.3103	0.3026	0.2953	0.2884	0.2818	0.2756
70	0.3603	0.3504	0.3412	0.3324	0.3242	0.3165	0.3091	0.3022	0.2956
75	0.3838	0.3734	0.3636	0.3544	0.3457	0.3375	0.3297	0.3223	0.3153
80	0.4071	0.3961	0.3858	0.3761	0.3669	0.3583	0.3501	0.3423	0.3349
85	0.4301	0.4186	0.4078	0.3976	0.3880	0.3789	0.3703	0.3621	0.3544
90	0.4529	0.4408	0.4295	0.4189	0.4088	0.3993	0.3903	0.3818	0.3737
95	0.4754	0.4628	0.4510	0.4399	0.4295	0.4196	0.4102	0.4013	0.3928
100	0.4977	0.4846	0.4724	0.4608	0.4499	0.4396	0.4299	0.4206	0.4118
105	0.5197	0.5062	0.4935	0.4815	0.4702	0.4595	0.4494	0.4398	0.4307
110	0.5415	0.5275	0.5144	0.5020	0.4903	0.4793	0.4688	0.4588	0.4494



**Table 5-10.** Values for  $\frac{\bar{T}^{kT}}{\bar{k}}$  from -30 °C to 50 °C and 50 kPa to 110 kPa. Values in this table can be approximated with equation 5-7 on page 5-11. Compute equivalent pressure,  $\bar{P}_e = \bar{P}(1 + 0.46\bar{x}_v)$ , before entering the table and interpolate between temperature and pressure values to find the value with reasonably good precision.

Equivalent Pressure (kPa)	Temperature (°C)								
	-30	-20	-10	0	10	20	30	40	50
50	0.4602	0.5016	0.5404	0.5784	0.6151	0.6505	0.6854	0.7189	0.7527
55	0.4202	0.4625	0.5023	0.5412	0.5787	0.6150	0.6505	0.6848	0.7193
60	0.3807	0.4240	0.4647	0.5044	0.5428	0.5798	0.6162	0.6511	0.6862
65	0.3417	0.3860	0.4276	0.4682	0.5074	0.5452	0.5822	0.6178	0.6536
70	0.3033	0.3485	0.3910	0.4324	0.4724	0.5109	0.5487	0.5850	0.6214
75	0.2655	0.3116	0.3549	0.3971	0.4379	0.4771	0.5155	0.5525	0.5896
80	0.2282	0.2751	0.3193	0.3623	0.4038	0.4437	0.4828	0.5204	0.5581
85	0.1913	0.2391	0.2841	0.3279	0.3701	0.4107	0.4505	0.4887	0.5270
90	0.1550	0.2036	0.2494	0.2939	0.3368	0.3781	0.4185	0.4574	0.4962
95	0.1192	0.1686	0.2152	0.2604	0.3040	0.3459	0.3870	0.4264	0.4658
100	0.0838	0.1340	0.1813	0.2273	0.2715	0.3141	0.3558	0.3958	0.4358
105	0.0489	0.0999	0.1479	0.1945	0.2395	0.2827	0.3249	0.3655	0.4060
110	0.0145	0.0662	0.1150	0.1622	0.2078	0.2516	0.2945	0.3356	0.3766

## Zero Flux Validation

As a test of performance of the LI-7700 and the procedures described above, LI-COR deployed the LI-7700 in an agricultural field near Lincoln, NE. This research site has a year-round history of chamber-based methane measurements, which show methane flux ranging from -0.12 to 0.13 mg m<sup>-2</sup> h<sup>-1</sup> (Timothy J. Arkebauer, pers. comm.). Ensemble average flux measurements corrected with the standard WPL correction and for spectroscopic effects with the procedure described above, were not significantly different from zero in either winter (-0.11 +/- 0.19 mg m<sup>-2</sup> h<sup>-1</sup>, Figure 5-1 on the next page) or summer (0.13 +/- 0.29 mg m<sup>-2</sup> h<sup>-1</sup>, Figure 5-2 on the next page).

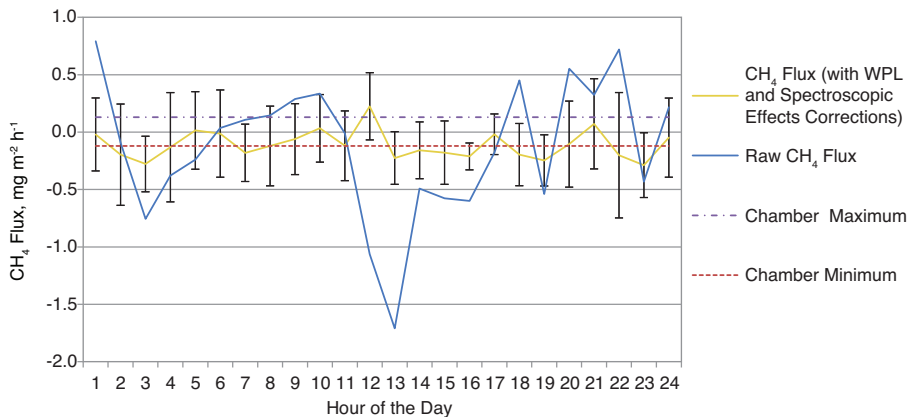


Figure 5-1. Ensemble averaged hourly methane fluxes at a research facility near Mead, Nebraska. Error bars show 1 standard deviation from the mean flux. These data were gathered over a partially frozen bare field in November, when temperatures ranged from -2 to 7 °C.

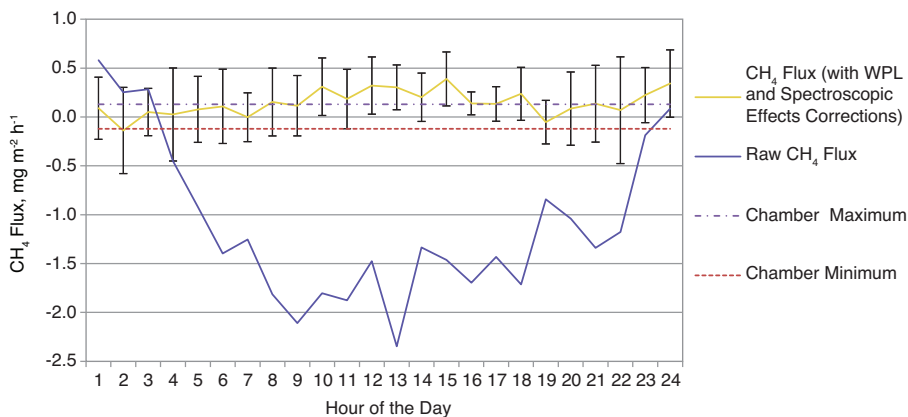


Figure 5-2. Ensemble averaged hourly methane fluxes at a research facility near Mead, Nebraska. Error bars show 1 standard deviation from the mean flux. These data were gathered over a maize field from June through August, when temperatures ranged from 15 to 38 °C.

## References

Rothman L.S., I. E. Gordon, A. Barbe, D. C. Benner, P. F. Bernath, et al. 2009. The HITRAN 2008 molecular spectroscopic database. *Journal of Quantitative Spectroscopy & Radiative Transfer*, 110: 533-572.

Webb E.K., G. Pearman, and R. Leuning. 1980. Correction of flux measurements for density effects due to heat and water vapor transfer, Quarterly Journal of the Royal Meteorological Society, 106: 85-100.



# 6 Theory & Equations

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## Absorption of Infrared Radiation by a Gas

The Beer-Lambert Law describes the absorption of radiation by a gas sample:

$$I = I_0 e^{-\alpha} = e^{(-S(T)g(\nu-\nu_0)Nl)} \quad 6-1$$

where  $I$  and  $I_0$  are received and incident optical power,  $\alpha$  is an absorbance,  $S(T)$  is absorption line strength as a function of temperature,  $g(\nu-\nu_0)$  is a normalized lineshape function for the line at  $\nu_0$ ,  $N$  is gas number density and  $l$  is the path length.

When fractional absorbance  $\Delta I/I_0$ , is small ( $<0.01$ ), linear approximation can be used:

$$\frac{I_0 - I}{I_0} = \frac{\Delta I}{I_0} \cong \alpha \quad 6-2$$

Using Wavelength Modulation Spectroscopy (WMS), the LI-7700 laser scans across a single feature in the  $2\nu_3$  absorption band of methane near 1.6 microns with high resolution and at a high repetition rate. The wavelength is modulated at sub-MHz frequency, virtually eliminating  $1/f$  flicker noise of the laser source and allowing detection of fractional absorption less than  $10^{-5}$ , which is not attainable with conventional direct absorption. The LI-7700 demodulates the resulting signal at twice the modulation frequency, and then compares the result to a reference signal shape, which is stored in the LI-7700, to determine the  $\text{CH}_4$  concentration (the measured lineshapes are visible on Diagnostic Page1). Pressure and temperature induced changes in lineshape and population distribution, as well as changes in laser power and mirror reflectivity are compensated using computational fitting algorithms so that measurements are accurate over a wide range of pressures, temperatures, and environmental conditions.

## Temperature Dependence of Absorption Line Strength

Line strength of a particular transition is a fundamental spectroscopic property and it is proportional to the population (number of molecules) in the lower state of the transition and the absorption cross-section for that transition. The population in an individual rotational state can be calculated from Boltzmann's distribution:

$$S(T) \propto \frac{e^{-hc \frac{E_{rot}}{kT}}}{Q(T)} = \frac{N''}{N} \quad 6-3$$

where  $h$  is Planck's constant,  $c$  is the speed of light,  $k$  is Boltzmann's constant,  $N$  is total number density,  $N''$  is the number density of the probed state,  $E_{rot}$  is rotational energy of the probed state, and  $Q(T)$  is the partition function. The absorption cross-section and rotational energy for a particular transition can be obtained from the HITRAN database (Rothman, et al., 2009). The partition function  $Q$  is also available as a function of temperature from HITRAN.

## Line Broadening Mechanisms

In the near infrared region, under ambient atmospheric conditions, the main sources of line broadening for CH<sub>4</sub> are Doppler broadening and pressure (collisional) broadening. For a single rotational line, the intensity profile of Doppler broadening as a function of wavelength is described by the Gaussian:

$$g_D(\nu; \Delta\nu_D) = \frac{\sqrt{\ln 2}}{\sqrt{\pi} \Delta\nu_D} e^{-\ln 2 \left( \frac{\nu - \nu_0}{\Delta\nu_D} \right)^2} \quad 6-4$$

where  $\Delta\nu_D$  is the Doppler half width at half maximum (HWHM) of a Gaussian profile and is:

$$\Delta\nu_D(T) = \sqrt{\ln 2} \frac{\nu_0}{c} \sqrt{\frac{2kT}{m}} \quad 6-5$$

where  $k$  is the Boltzmann constant,  $m$  is molecular mass, and  $T$  is temperature (K).

Pressure broadening is described by the Lorentzian lineshape:

$$g_L(\nu; \Delta\nu_L) = \frac{1}{\pi} \frac{\Delta\nu_L}{(\nu - \nu_0)^2 + (\Delta\nu_L)^2} \quad 6-6$$

where  $\Delta\nu_L$  is Lorentzian half width and can be calculated using empirically determined parameters from HITRAN database:

$$\Delta\nu_L(P, T) = \gamma(T_0, P_0) \left[ \frac{P}{P_0} \right] \left[ \frac{T_0}{T} \right]^r \quad 6-7$$

where  $T$  is temperature (K),  $P$  is pressure in Pa;  $\gamma(T_0, P_0)$  (pressure broadening at  $T_0$  and  $P_0$ ) and  $r$  (temperature dependence of pressure broadening) are parameters from the HITRAN database for the individual line,  $T_0=296$  K,  $P_0=101325$  Pa.

The Voigt lineshape is a convolution of the Lorentzian and Gaussian:

$$g_v(\nu; \Delta\nu_D; \Delta\nu_L) = \int_{-\infty}^{+\infty} g_D(\nu'; \Delta\nu_D) g_L(\nu - \nu'; \Delta\nu_L) d\nu' \quad 6-8$$

It can be rewritten in the form:

$$g_v(\nu) = \frac{1}{\pi \Delta\nu_D} \sqrt{\left(\frac{\ln 2}{\pi}\right)} \left(\frac{\Delta\nu_L}{\Delta\nu_D}\right) \sqrt{\ln 2} \int_{-\infty}^{+\infty} dt \frac{e^{-t^2}}{y^2 + (x-t)^2} \quad 6-9$$

$$\text{where } x \equiv \sqrt{\ln 2} \frac{\nu - \nu_0}{\Delta\nu_D} \text{ and } y \equiv \sqrt{\ln 2} \frac{\Delta\nu_L}{\Delta\nu_D}. \quad 6-10$$

The Voigt integral has no analytic solution but can be approximated by numerical methods to a high degree of accuracy.

In summary, the population of the lower state is a function of temperature and two different mechanisms responsible for lineshape changes: Doppler broadening (a function of temperature), and pressure broadening (a function of both temperature and pressure). To calculate number density from measured absorption, knowledge of both temperature and pressure to a high degree of accuracy is absolutely essential.

## Wavelength Modulation Spectroscopy

With WMS, the wavelength of light emitted by the laser is modulated by injection current at sub-MHz frequency  $f$  while scanning across the absorption feature.

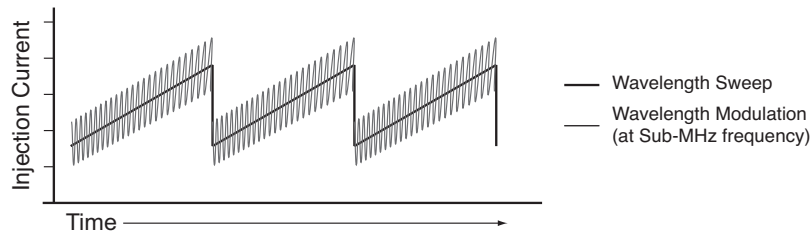
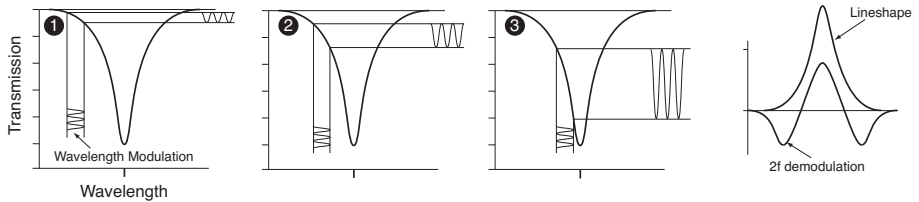


Figure 6-1. WMS uses wavelength sweep and modulation over a methane absorption feature to measure absorption by methane.

Wavelength modulation over the lineshape results in modulation at  $f$  and its higher harmonics ( $2f$ ,  $3f$ , etc), which are proportional to the absorption and resemble a derivative of the corresponding order. Because very strong amplitude modulation is also present at carrier frequency  $f$ , higher order harmonics are preferable for detecting a small absorption feature. The LI-7700 uses phase-sensitive demodulation by a digital lock-in amplifier at  $2f$  to obtain a background-free signal with excellent noise rejection.



**Figure 6-2.** The wavelength is modulated and simultaneously swept across the absorption feature. Demodulation at  $2f$  results in a background free signal with low noise.

The magnitude of the waveform is linear with number density  $\rho_{cm}$  ( $=N$  from the previous discussion) and proportional to incident power  $I_0$ . The recorded waveform is compared by least squares fitting with the reference waveform (with  $P_0$ ,  $T_0$ ,  $\rho_{0cm}$  calculated using the HITRAN database and numerical computation methods for a WMS transfer function).

The sample waveform is computed from:

$$\hat{\alpha}[i] = \frac{r[i]}{I_0} \quad 6-11$$

where  $\hat{\alpha}[i]$  is the measured lineshape,  $I_0$  is the received laser power, and  $r[i]$  is the detector output, which is also an array of  $M$  spectral samples. Number density (not corrected for temperature and pressure) is computed from:

$$\rho_{cm} = K_s \left( \sum_{i=1}^M \hat{\alpha}[i] \alpha_{ref}[i] - K_z \right) \quad 6-12$$

where  $\rho_{cm}$  is measured methane number density before correction for pressure and temperature,  $i$  is waveband 1 through  $M$ ,  $K_s$  is the span value,  $K_z$  is the zero value,  $\hat{\alpha}[i]$  is the measured lineshape, and  $\alpha_{ref}[i]$  is the reference lineshape. Number density,  $\rho_{cm}$ , as shown in Equation 6-12, is not corrected for fast temperature and pressure fluctuations. It is a standard value, which requires subsequent processing when computing fluxes with the eddy covariance method.



## Compensating for Temperature and Pressure Changes

Effects of temperature and pressure-induced changes in lineshape and population distribution, and resulting changes in WMS waveforms are pre-calculated and tabulated as a broadening compensation function,  $\kappa(T, P)$ .  $\kappa(T, P)$  is stored in the instrument as a look-up table and is shown in Figure 6-3 below. When precise temperature and pressure measurements are available, they can be implemented as:

$$\rho_c = \rho_{cm} \times \kappa(T, P) \quad 6-13$$

where  $\rho_{cm}$  is the measured methane number density before correction,  $T$  is temperature ( $^{\circ}\text{C}$ ), and  $P$  is atmospheric pressure (kPa). Atmospheric pressure and air temperature are measured by the LI-7700 using an on-board pressure sensor and thermocouple, and are output with the data stream; however, because the LI-7700 temperature measurements are relatively slow,  $\kappa(T, P)$  is not applied to the  $\text{CH}_4$  number density channel ( $\text{mmol m}^{-3}$ ).

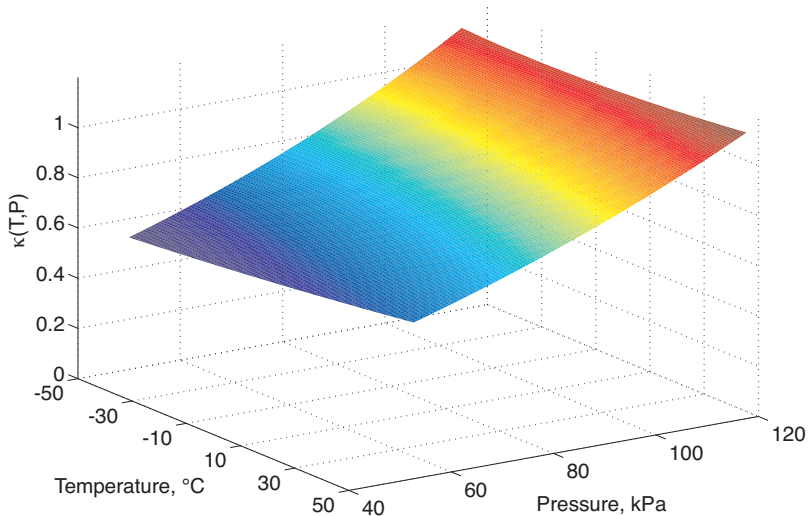


Figure 6-3. 3-D plot of  $\kappa(T, P)$ .

The impact of broadening on flux calculations is accounted for in a manner similar to that used by Webb, et al., (1980) for thermal expansion and water vapor dilution, using temperature and windspeed measured by the sonic anemometer and water vapor measured with an LI-7500A Open Path  $\text{CO}_2/\text{H}_2\text{O}$  Analyzer, or similar instrument. This will be described in the next section.

On-board measurements of temperature and pressure are used to compute methane mole fraction ( $\mu\text{mol mol}^{-1}$ ,  $x_c$ ):

$$x_c = \frac{\rho_{cm}RT}{P} \times \kappa(T, P) \quad 6-14$$

where  $R$  is the gas constant ( $8.314 \text{ J K}^{-1} \text{ mol}^{-1}$ ).  $x_c$  is suitable for calibration, diagnostics, and atmospheric monitoring, when slow changes in temperature are expected. The mole fraction output is fully corrected for temperatures and pressures measured with on-board sensors, but it is not suitable for flux measurements because the response time of the thermocouple is relatively slow (roughly 1Hz cutoff frequency). The thermocouple is designed to provide accurate and robust temperature measurements, not fast temperature measurements.

As described in the previous section, only the  $\rho_{cm}$  channel (methane density,  $\text{mmol m}^{-3}$ ), which is uncorrected for  $T$  and  $P$ , should be used for flux measurements. Temperature and pressure corrections are then applied over each averaging interval (e.g., half hour) using the modified WPL procedure presented in "LI-7700 Flux Measurements" on page 5-1.

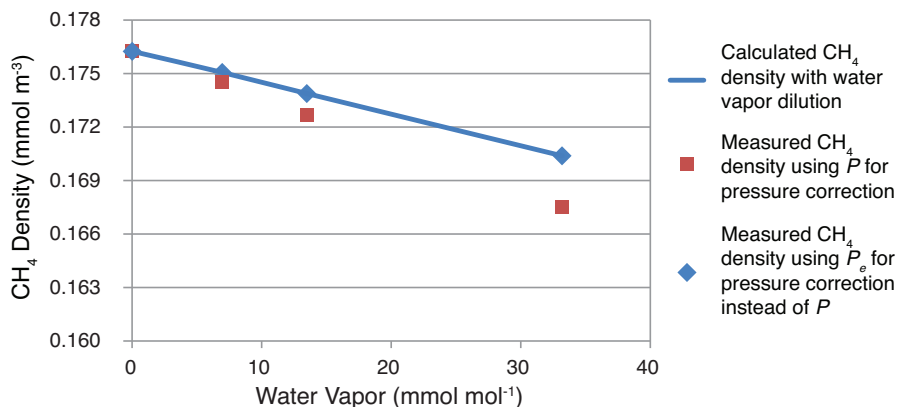
### Compensating for Water Vapor: Equivalent Pressure, $P_e$

Different gases are not equally effective in causing pressure broadening of absorption lines. The effects of pressure broadening by different diluent gases, including water vapor, can be represented with a single quantity called equivalent pressure,  $P_e$  (kPa) (Burch, et al., 1962). Equivalent pressure can be defined as  $P_e = p_{N_2} + \sum a_i p_i$ , where  $p_{N_2}$  is the partial pressure of nitrogen, and  $p_i$  gives the partial pressures of other diluent non-absorbing gases, each multiplied by its foreign gas coefficient  $a_i$ . The coefficients  $a_i$  reflect the ability of each diluent gas to cause pressure broadening relative to broadening caused by  $N_2$ . Self-broadening by methane on methane is neglected because its concentration is so low.

Methane measurements are made in air where water vapor is the only variable component in sufficient concentration to affect broadening. Therefore, we define  $P_e$  relative to dry air instead of nitrogen, so we have  $P_e = p_d + a_v p_v$ , where  $p_d$  is partial pressure of dry air (kPa),  $a_v$  is the foreign gas broadening coefficient for water vapor relative to dry air, and  $p_v$  is water vapor partial pressure (kPa). Total air pressure  $P$  can be written as  $P = p_d + p_v$ . Subtracting  $P$  from  $P_e$  and rearranging gives

$$P_e = P(1 + \alpha_v x_v) \quad 6-15$$

where  $\alpha_v = a_v - 1$ , and  $x_v = p_v/P$  is water vapor mole fraction. For the LI-7700,  $a_v$  is found experimentally to have a value of 1.46 (Figure 6-4 below), but this value may vary for other instruments depending upon the gas species, the absorption line or lines being measured, and the instrument design.



**Figure 6-4.** Calculated water vapor dilution effects and actual response of the LI-7700 at  $0.176 \text{ mmol/m}^3 \text{ CH}_4$ ,  $P$  of  $97.7 \text{ kPa}$ , and  $T$  of  $42.8 \text{ }^\circ\text{C}$ . Blue line: Expected theoretical methane density based upon dilution. Red squares: Measured  $r_{cm}$  based upon barometric pressure and temperature. Methane density is increasingly underestimated as water vapor mole fraction increases. Blue diamonds: Measured  $r_{cm}$  using  $P_e$  computed from the water vapor mole fraction at each point instead of  $P$  in  $\kappa(T, P_e)$ . The water broadening coefficient used here is specific to the LI-7700 but is consistent with water vapor broadening parameters extrapolated from Gharavi and Buckley (2005) over much higher temperatures and water vapor mole densities.

Using the Ideal Gas Law,  $P_e$  also can be re-written as

$$P_e = P + \alpha_v RT \rho_v \quad 6-16$$

where  $\rho_v = p_v (RT)^{-1}$  is water vapor number density ( $\text{mol m}^{-3}$ ). Now we can view the effects of water vapor as a perturbation on the total pressure, so  $\kappa(T, P)$  shown in Figure 6-4 above can be generalized as  $\kappa(T, P_e)$ , which includes pressure broadening by water vapor using Equation 6-15 and Equation 6-16.

For slow measurements, it follows that to correct methane density for pressure broadening due to water vapor, simply use  $P_e$  as defined in Equation 6-15 and Equation 6-16, instead of  $P$  when entering the table for  $\kappa(T, P)$  in Equation 6-13. For methane mole fraction,  $x_e$ , a pressure correction has already been applied by the instrument based upon

the measured  $P$  according to Equation 6-14, so to correct for water vapor, simply multiply  $x_c$  by  $\kappa(T, P_e) / \kappa(T, P)$ .

We now have the tools to examine how the spectroscopic effects of  $T$ ,  $P$ , and water vapor will propagate into methane flux measurements.

## Derivation of Multipliers for Flux Measurements

The instantaneous concentration of methane in the turbulent atmosphere above a surface is affected by the exchange of methane, heat, and water vapor with the surface. When the instantaneous methane concentration is measured with an open path instrument it is necessary to know the instantaneous temperature and water vapor concentration in order to correct for thermal expansion and dilution. Webb, et al., (1980) showed how corrections for such affects could be made using statistical parameters measured over an appropriate averaging period (e.g., 30 minutes). Similarly, it is also necessary to correct for the spectroscopic effects of fluctuations in temperature and water vapor, because even though these effects are small, they are highly correlated with the methane transport we wish to measure. In the derivation that follows we show that spectroscopic effects can be treated in a manner similar to thermal expansion and dilution (patent pending), and can be combined with the formulation proposed by Webb, et al., (1980).

Pressure-related fluctuations are usually neglected, but it may be necessary to pay attention to this if the research site is at a high elevation. This can be done as part of the WPL correction using a third pressure term (Massman & Tuovinen, 2006). The derivation that follows can be extended to include spectroscopic effects of pressure fluctuations if such are needed. We are neglecting them here.

Before beginning we note once again that only the uncorrected methane density ( $\text{mmol m}^{-3}$ ) should be used for flux calculations. Mean  $\text{CH}_4$  mole fraction ( $\mu\text{mol mol}^{-1}$ ) reported by the LI-7700 is compensated for pressure in real time and for temperature using a relatively slow thermocouple, but not water vapor, so it is not suitable for flux calculations. The methane mole fraction output can be used for calibration and diagnostic purposes but we do not recommend its use for flux calculations.

We begin by defining  $\kappa(T, P_e)$  as before, and

$$\rho_c = \rho_{cm} \kappa \tag{6-17}$$

where  $\rho_{cm}$  is measured gas density ( $\text{mol m}^{-3}$ ) not corrected for  $T$  and  $P$  effects,  $\rho_c$  is the actual density of the sample ( $\text{mol m}^{-3}$ ), and  $\kappa$  is the broadening compensation function using  $P_e$  rather than  $P$ . Using Reynolds decomposition, each term can be written:

$$\rho_c = \bar{\rho}_c + \rho'_c \quad 6-18$$

$$\rho_{cm} = \bar{\rho}_{cm} + \rho'_{cm} \quad 6-19$$

$$\kappa = \bar{\kappa} + \kappa' \quad 6-20$$

Mean quantities are indicated by the over-bars. The deviation of an instantaneous quantity from the mean is indicated by a prime. The instantaneous quantity is indicated by the absence of over-bar or prime. Instantaneous deviations in  $\kappa$  due to fluctuations in temperature and water vapor density from their means can be described by a Taylor series expansion:

$$\kappa = \bar{\kappa}(\bar{T}, \bar{P}_e) + \left. \frac{\partial \kappa(\bar{T}, \bar{P}_e)}{\partial T} \right|_{\bar{P}_e} \delta T + \left. \frac{\partial \kappa(\bar{T}, \bar{P}_e)}{\partial P_e} \right|_{\bar{T}} \delta P_e + \dots \quad 6-21$$

The terms  $\delta T$  and  $\delta P_e$  represent small deviations and can be denoted as  $T'$  and  $P_e'$ , respectively.

Also, we denote  $\kappa_T = \left. \frac{\partial \kappa(\bar{T}, \bar{P}_e)}{\partial T} \right|_{\bar{P}_e}$  and  $\kappa_{P_e} = \left. \frac{\partial \kappa(\bar{T}, \bar{P}_e)}{\partial P_e} \right|_{\bar{T}}$ , giving

$$\kappa \approx \bar{\kappa} + \kappa_T T' + \kappa_{P_e} P_e' \quad 6-22$$

where higher order terms are neglected. Expanding Equation 6-17 with Equation 6-18, Equation 6-19 and Equation 6-22 leads to:

$$\bar{\rho}_c + \rho'_c = (\bar{\rho}_{cm} + \rho'_{cm})(\bar{\kappa} + \kappa_T T' + \kappa_{P_e} P_e') \quad 6-23$$

$$\bar{\rho}_c + \rho'_c = \bar{\kappa} \bar{\rho}_{cm} + \kappa_T \bar{\rho}_{cm} T' + \kappa_{P_e} \bar{\rho}_{cm} P_e' + \bar{\kappa} \rho'_{cm} + \kappa_T T' \rho'_{cm} + \kappa_{P_e} P_e' \rho'_{cm} \quad 6-24$$

From Equation 6-17 and with  $\bar{\rho}_c = \bar{\kappa} \bar{\rho}_{cm}$ , the first terms on the left side and right side of Equation 6-24 cancel. Multiplying by  $w'$ , time averaging, and noting that triple prime terms are small compared to double prime terms, yields

$$\overline{w' \rho'_c} = \overline{\bar{\kappa} w' \rho'_{cm}} + \kappa_T \overline{\bar{\rho}_{cm} w' T'} + \kappa_{P_e} \overline{\bar{\rho}_{cm} w' P_e'} \quad 6-25$$

where  $\overline{(w' \rho'_c)}$  is the raw flux in  $\text{mol m}^{-2} \text{s}^{-1}$ .

$P_e'$  can be re-written in terms of water vapor density  $\rho_v'$  using Equation 6-16; thus,  $\delta P_e = \delta P + \alpha_v R \bar{T} \delta \rho_v + \alpha_v R \bar{\rho}_v \delta T$ . If barometric pressure  $P$  were considered to vary its effect would enter the derivation here; but at constant  $P$ , and substituting primes for deltas,

$$P_e' = \alpha_v R \bar{T} \rho_v' + \alpha_v R \bar{\rho}_v T' \quad 6-26$$

and

$$\overline{w' \rho_c'} = \bar{\kappa} \overline{w' \rho_{cm}'} + \kappa_T \overline{\rho_{cm}} \overline{w' T'} + \kappa_{Pe} \overline{\rho_{cm}} \left( \alpha_v R \bar{T} \overline{w' \rho_v'} + \alpha_v R \overline{\rho_v} \overline{w' T'} \right) \quad 6-27$$

Substituting  $R \bar{T} = \frac{\bar{P}}{\bar{\rho}} = \frac{\bar{P}_d}{\bar{\rho}_d} = \frac{\bar{P}}{\bar{\rho}_d} (1 - \bar{x}_v)$  gives

$$\overline{w' \rho_c'} = \bar{\kappa} \overline{w' \rho_{cm}'} + \overline{\rho_{cm}} \left( \kappa_T + \kappa_{Pe} \alpha_v R \bar{\rho}_v \right) \overline{w' T'} + \kappa_{Pe} (1 - \bar{x}_v) \frac{\bar{\rho}_{cm}}{\bar{\rho}_d} \alpha_v \overline{P w' \rho_v'} \quad 6-28$$

where  $\bar{\rho}_d$  is the number density of dry air ( $\text{mol m}^{-3}$ ).

With a small change in notation, Equation 24 of Webb et al. (1980) can be rewritten as:

$$F_c = \overline{w' q_c'} + \mu \frac{\bar{q}_c}{\bar{q}_d} \overline{w' q_v'} + (1 + \mu \sigma) \frac{\bar{q}_c}{\bar{T}} \overline{w' T'} \quad 6-29$$

where  $F_c$  is mass flux of non-reactive gas ( $\text{g m}^{-2} \text{s}^{-1}$ ),  $q_i = m_i \rho_i$  is mass density ( $\text{g m}^{-3}$ ) of a non-reactive gas (methane, dry air, or water vapor denoted by subscripts  $c$ ,  $d$ , or  $v$  respectively),  $\mu = m_d / m_v$  is a ratio of the formula weight of dry air to the molecular weight of water vapor, and  $\sigma = \bar{q}_v / \bar{q}_d$ .

Equation 6-28 can be rewritten in terms of mass flux by multiplying each term on both sides by the molecular weight of nonreactive gas ( $m_c$ ) and by changing variables in the last term on the right by noting that  $\frac{w' \rho_v'}{\bar{\rho}_d} = \frac{w' q_v'}{\bar{q}_d} \mu$  to give

$$\overline{w' q_c'} = \bar{\kappa} \overline{w' q_{cm}'} + \left( \kappa_T + \kappa_{Pe} \alpha_v R \bar{\rho}_v \right) \overline{q_{cm}} \overline{w' T'} + \kappa_{Pe} \mu (1 - \bar{x}_v) \frac{\bar{q}_{cm}}{\bar{q}_d} \alpha_v \overline{P w' q_v'} \quad 6-30$$

Substituting Equation 6-30 into Equation 6-29 and noting that  $\bar{q}_c = \bar{q}_{cm} \bar{\kappa}$ ,

$$F_c = \overline{\kappa w' q'_{cm}} + (\kappa_T + \kappa_{Pe} \alpha_v R \overline{p_v}) \overline{q_{cm} w' T'} + \kappa_{Pd} \mu (1 - \overline{x_v}) \frac{\overline{q_{cm}}}{q_d} \alpha_v \overline{P w' q'_v} + \overline{\kappa} \mu \frac{\overline{q_{cm}}}{q_d} \overline{w' q'_v} + \overline{\kappa} (1 + \mu \sigma) \frac{\overline{q_{cm}}}{\overline{T}} \overline{w' T'} \quad 6-31$$

We now wish to rearrange Equation 6-31 to put it into a form similar to Equation 6-29. To do that, we note  $1 + \mu \sigma = 1 / (1 - \overline{x_v})$ ; and multiplying the second term on the right by  $(1 + \sigma \mu)(1 - \overline{x_v}) = 1$  gives

$$F_c = \overline{\kappa w' q'_{cm}} + (1 - x_v)(1 + \sigma \mu) (\kappa_T + \kappa_{Pe} \alpha_v R \overline{p_v}) \overline{q_{cm} w' T'} + \kappa_{Pd} \mu (1 - \overline{x_v}) \frac{\overline{q_{cm}}}{q_d} \alpha_v \overline{P w' q'_v} + \overline{\kappa} \mu \frac{\overline{q_{cm}}}{q_d} \overline{w' q'_v} + \overline{\kappa} (1 + \mu \sigma) \frac{\overline{q_{cm}}}{\overline{T}} \overline{w' T'} \quad 6-32$$

Collecting like terms in  $\overline{w' q'_v}$  and  $\overline{w' T'}$  and factoring yields

$$F_c = \overline{\kappa w' q'_{cm}} + \overline{\kappa} \mu \frac{\overline{q_{cm}}}{q_d} \overline{w' q'_v} + (1 - \overline{x_v}) \alpha_v \overline{P} \kappa_{Pd} \mu \frac{\overline{q_{cm}}}{q_d} \overline{w' q'_v} + \overline{\kappa} (1 + \mu \sigma) \frac{\overline{q_{cm}}}{q_d} \overline{w' T'} + (1 - \overline{x_v}) \overline{T} (\kappa_T + \kappa_{Pe} \alpha_v R \overline{p_v}) (1 + \mu \sigma) \frac{\overline{q_{cm}}}{\overline{T}} \overline{w' T'} \quad 6-33$$

or,

$$F_c = \overline{\kappa} \left\{ \overline{w' q'_{cm}} + \left[ 1 + (1 - \overline{x_v}) \alpha_v \overline{P} \frac{\kappa_{Pe}}{\overline{\kappa}} \right] \mu \frac{\overline{q_{cm}}}{q_d} \overline{w' q'_v} + \left[ 1 + (1 - \overline{x_v}) \overline{T} \frac{(\kappa_T + \kappa_{Pe} \alpha_v R \overline{p_v})}{\overline{\kappa}} \right] (1 + \mu \sigma) \frac{\overline{q_{cm}}}{\overline{T}} \overline{w' T'} \right\} \quad 6-34$$

Now we note that  $R \overline{p_v} = \overline{P} \overline{x_v} / \overline{T}$ , so

$$F_c = \overline{\kappa} \left\{ \overline{w' q'_{cm}} + \left[ 1 + (1 - \overline{x_v}) \alpha_v \overline{P} \frac{\kappa_{Pe}}{\overline{\kappa}} \right] \mu \frac{\overline{q_{cm}}}{q_d} \overline{w' q'_v} + \left[ 1 + (1 - \overline{x_v}) \overline{T} \frac{\kappa_T}{\overline{\kappa}} + \overline{x_v} (1 - \overline{x_v}) \alpha_v \overline{P} \frac{\kappa_{Pe}}{\overline{\kappa}} \right] (1 + \mu \sigma) \frac{\overline{q_{cm}}}{\overline{T}} \overline{w' T'} \right\} \quad 6-35$$

where  $\left[ 1 + (1 - \overline{x_v}) \alpha_v \overline{P} \frac{\kappa_{Pe}}{\overline{\kappa}} \right]$  is the latent heat multiplier and

$\left[ 1 + (1 - \overline{x_v}) \overline{T} \frac{\kappa_T}{\overline{\kappa}} + \overline{x_v} (1 - \overline{x_v}) \alpha_v \overline{P} \frac{\kappa_{Pe}}{\overline{\kappa}} \right]$  is the sensible heat multiplier. Both multipliers involve the term  $(1 - \overline{x_v}) \alpha_v \overline{P} \frac{\kappa_{Pe}}{\overline{\kappa}}$ .

We need to write Equation 6-35 in terms of  $P_e$  so we can build a table that involves only  $P_e$  instead of both  $\overline{P}$  and  $P_e$ . From Equation 6-16,  $\overline{P} = \overline{P}_e / (1 + \alpha_v \overline{x_v})$ ;  $\alpha_v = 0.46$ , and for dew points below 32 °C at one atmosphere,  $\overline{x_v}$  is always less than 0.05, so to a good approximation,  $(1 - \overline{x_v}) / (1 + 0.46 \overline{x_v}) \approx 1 - 1.46 \alpha_v$ . The error in this expression is less than 0.2% for dew points below 32 °C and one atmosphere, and much less for more moderate dew points. Thus, Equation 6-35 becomes

$$F_c = A \left\{ \overline{w' q'_{cm}} + B \mu \frac{\overline{q_{cm}}}{q_d} \overline{w' q'_v} + C (1 + \mu \sigma) \frac{\overline{q_{cm}}}{\overline{T}} \overline{w' T'} \right\} \quad 6-36$$

$$\mathbf{A} = \bar{\kappa}$$

$$\mathbf{B} = \left[ 1 + (1 - 1.46\bar{x}_v)\alpha_v \bar{P}_e \frac{\kappa_{Pe}}{\bar{\kappa}} \right]$$

$$\mathbf{C} = \left[ 1 + (1 - \bar{x}_v)\bar{T} \frac{\kappa_T}{\bar{\kappa}} + \bar{x}_v(\mathbf{B}-1) \right]$$

Equation 6-36 is now in a form similar to Equation 24 of Webb et al. (1980), except that the latent heat flux term is multiplied by a spectroscopic correction factor dominated by water vapor and the sensible heat flux term is multiplied by a spectroscopic correction factor dominated by temperature. It should be noted, however, that temperature, pressure, and water vapor mole fraction all enter into both terms because they all are used to determine the entry point in the correction tables summarized by the response surface of  $\kappa$  shown in Figure 6-3 on page 6-5. Tables are provided in Chapter 5 giving  $\kappa$ , its derivatives, and the factors  $\bar{T} \frac{\kappa_T}{\bar{\kappa}}$  and  $\alpha_v \bar{P}_e \frac{\kappa_{Pe}}{\bar{\kappa}}$ .

For typical conditions at or near sea level, and for a wide range of air temperatures and humidities, the first multiplier, **A**, ranges between 0.93 and 1.02; the second multiplier, **B**, ranges between 1.40 and 1.45; and the third multiplier, **C**, ranges from 1.10 to 1.45. Step-by-step instructions are given in Chapter 5 for applying these corrections. Software utilities and digital copies of the tables are also available from LI-COR.

The last term in multiplier **C** is multiplied by the mole fraction of water vapor, which is often near 0.02. This causes the third term in C to be small when compared to the first two terms. Thus, one may choose to neglect the third term in C, which introduces about a 1% error in C but simplifies the calculation somewhat. C itself should not be neglected. The sample calculation given in Chapter 5 shows the magnitude of the term to be about 0.008 for that example. The third term in C derives from the change of variables when we expressed  $P_e$  in terms of water vapor number density instead of mole fraction. The total derivative of Equation 6-27 then involved a temperature derivative as well as a vapor density derivative, which leads to the third term in C.

## References

- Burch, D.E., and D. Williams. 1964. Test of theoretical band model approximations. *Applied Optics*, 3: 55-61.
- Gharavi, M., and S. G. Buckley. 2005. Diode laser absorption spectroscopy measurement of line strengths and pressure broadening coefficients of the methane  $2\nu_3$  band at elevated temperatures. *Journal of Molecular Spectroscopy*, 229: 78-88.



Massman, W. J. and J. P. Touvinen. 2006. An analysis and implications of alternative methods of deriving the density (WPL) terms for eddy covariance measurements. *Boundary Layer Meteorology*, 121: 221-227.

Webb E.K., G. Pearman, and R. Leuning. 1980. Correction of flux measurements for density effects due to heat and water vapor transfer, *Quarterly Journal of the Royal Meteorological Society*, 106: 85-100.



# 7 Advanced Operation

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This section describes a variety of maintenance and diagnostic procedures, including zero and span calibrations, laser temperature controls, line locking, and communications grammar.

## Calibration

The implementation of the zero and span into calculations is given in Equation 6-12. The overall accuracy of the LI-7700 depends upon its calibration. Always use quality zero and span gases in a balance of air with CH<sub>4</sub> accuracy greater than 1%. Use gases that are free of Volatile Organic Compounds (VOCs) other than methane. The list of suppliers (see "Calibration Gases" on page D-2) provides more information. Check the readings every 6 months.

### Performing a Zero Calibration

To zero the LI-7700:

1. Connect the LI-7700 to a power supply and a computer. Launch the LI-7700 software and connect with the instrument.
2. Remove the radiation shield and install the calibration shroud. Ensure that it seals around the top and bottom openings.
3. Connect the "zero gas" (0 ppm CH<sub>4</sub> in air) to the shroud fittings.
4. Flow the gas through the shroud. Allow from 10 to 30 minutes for equilibration, depending on flow rate.
5. Click the Zero CH<sub>4</sub> button in the calibration frame. When the instrument begins the zero operation, the panel will update to reflect the activity. The Zero CH<sub>4</sub> will change to "Abort." Clicking Abort terminates the zero procedure. It usually takes about 10 seconds to zero. If it takes significantly longer, check for leaks and verify the calibration tank pressure.
6. After the software completes the zero operation choose either to apply the new calibration value or revert to the previous calibration value.

If the application is closed or if the LI-7700 is powered off before a confirmation command is received the new calibration will not be applied.


## Performing a Span Calibration

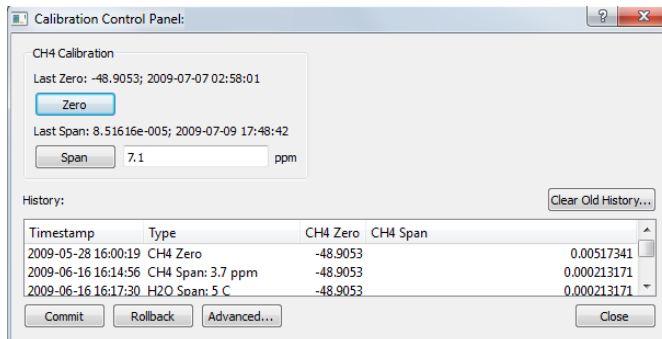
Performing a span is essentially the same as a zero, except that you must flow the span gas through the optical path and enter the span gas concentration in parts per million (ppm). Select a span gas with a methane concentration at or slightly above the methane concentrations you expect to measure. For measurement of methane in ambient air, 2 ppm methane in a balance of air is ideal.

Following the completion of the “Zero Calibration” above,

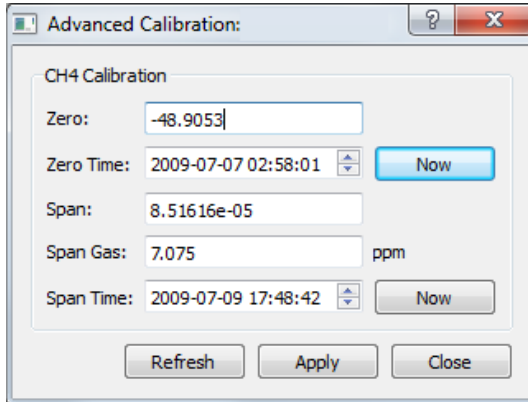
1. Connect the “span gas” (~2 ppm CH<sub>4</sub> in air) to the shroud fittings.
2. Type the concentration (ppm) of the span gas into the field on the calibration pane.
3. Flow the gas through the shroud. Allow from 10 to 30 minutes for equilibration, depending on flow rate.
4. Click the Span CH<sub>4</sub> button in the calibration frame. When the instrument begins the zero operation, the panel will update to reflect the activity. The Span CH<sub>4</sub> will change to “Abort.” Clicking Abort terminates the zero procedure. It usually takes about 10 seconds to zero. If it takes significantly longer, check for leaks and verify the calibration tank pressure.
5. After the software completes the zero operation choose either to apply the new calibration value or revert to the previous calibration value.

## Restoring a Previous Calibration

Should the calibration need to be restored to the factory original calibration or any other prior calibration; this is accomplished through the LI-7700 Finder Application. Launch the LI-7700 software, click the help question mark  > About > Factory Setup... > Proceed. Select your LI-7700 from the list and select Watch LI-7700. In the next window, click Cal.... This will display the calibration history for the instrument.



Make a note of the time stamp and write down the “CH4 Zero” and “CH4 Span” values associated with it with the previous calibration. Click the Advanced... button...



Advanced Calibration:

CH4 Calibration

Zero: -48.9053

Zero Time: 2009-07-07 02:58:01 Now

Span: 8.51616e-05

Span Gas: 7.075 ppm

Span Time: 2009-07-09 17:48:42 Now

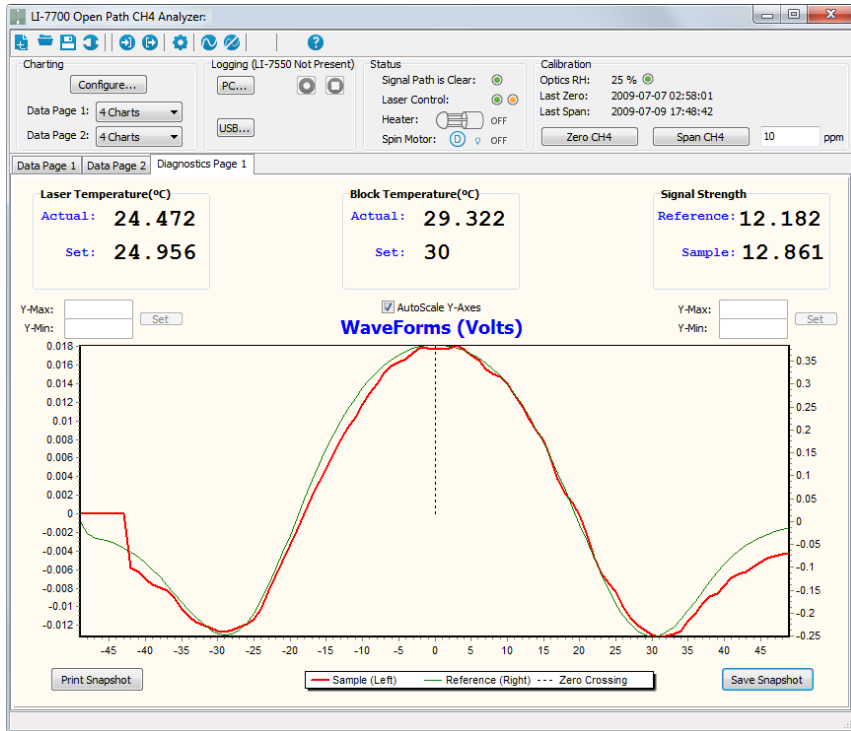
Refresh Apply Close

Enter the “CH4 Zero” into the “Zero” field, then enter the “CH4 Span” into the “Span” field. Click both “Now” buttons to record the time that you entered these values. Close each of the open windows and verify the readings provided by the LI-7700.

## Diagnostics

### Laser Temperature Control

During normal operation, the instrument uses an automatic control loop to maintain the laser temperature, which in turn keeps the laser wavelength tuned to the absorbance feature of interest. In the LI-7700, the laser scans a sealed vessel of methane along with the open path cavity. The results of the cavity scan (reference) and optical path scan (sample) are displayed as a waveform on the Diagnostics Page of the Main View:



The above display indicates normal operation by the following features:

- A standard bell shaped curve for both the sample and reference paths
- Both overlay nicely, with the peak at or very near the zero point on the horizontal axis
- The waveform has sufficient depth (e.g., not too shallow vertically)

The two status indicators located in the status panel above the chart display should further support this state. Both the Laser Temperature and Reference Lock indicators should show green. If either or both are red, then the instrument is not functioning normally and it may be necessary to manually adjust the laser temperature parameters. When the laser is scanning across the desired methane absorption feature, line lock is established. Otherwise, line lock is not established and the instrument will not measure methane density.

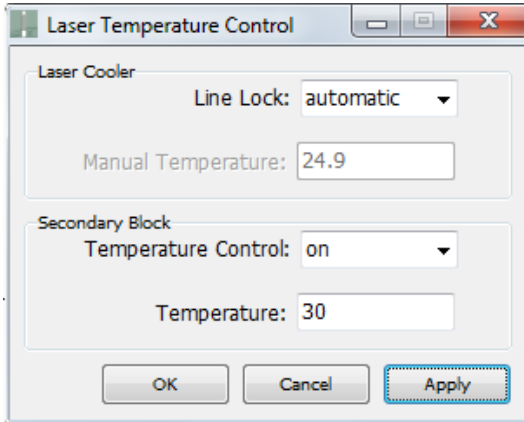
### Opening the Laser Temperature Control Dialog

1. Place the mouse pointer over the red light indicator on the status panel and click the left mouse button (the indicator must be red to complete this action).

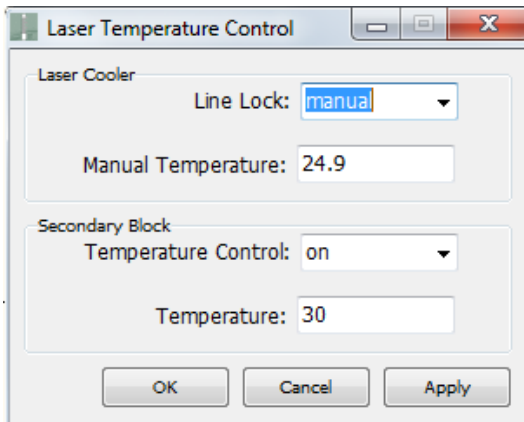
-or-

- Press the Ctrl, Alt and L keys simultaneously. This can be done at any time when you are connected to an instrument.

The Laser Temperature Control dialog will open:



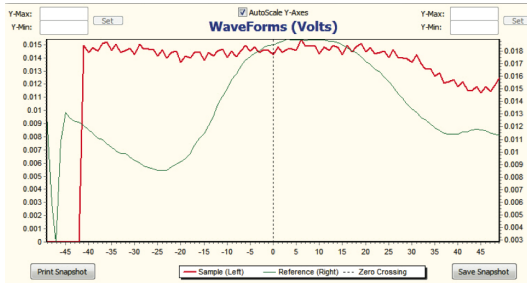
It is only possible to open this dialog when the application is connected to an instrument. As the dialog indicates, there are two temperature parameters that may be manipulated. Laser Cooler temperature is the primary one and should be altered first. In order to change the value, the Line Lock setting must be changed from “Automatic” to “Manual”, as shown below.



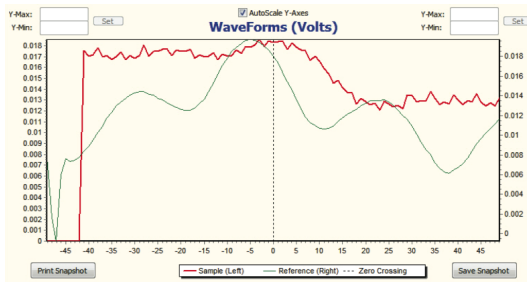
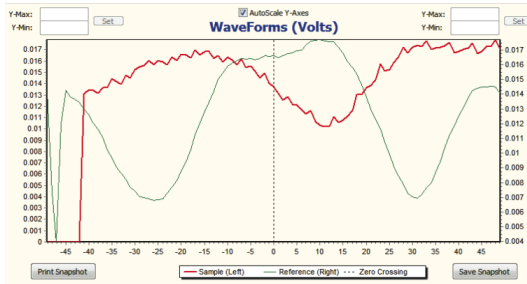
This will allow you to set the temperature manually. When you are changing the laser cooler temperature, watch the diagnostics page and see how the waveform changes as the temperature setting is increased or decreased.

## Manual Line Lock Example

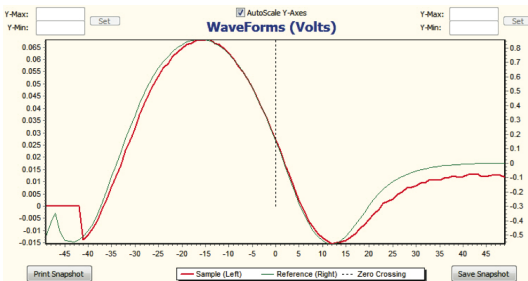
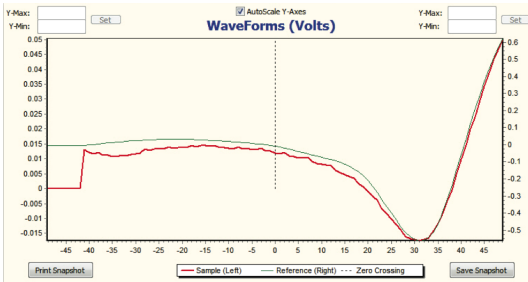
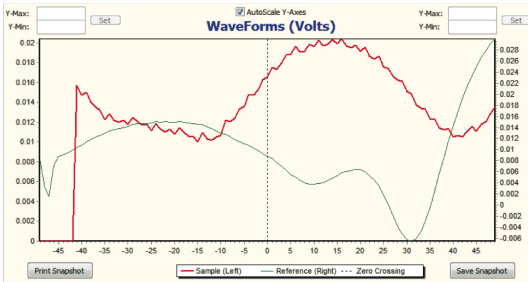
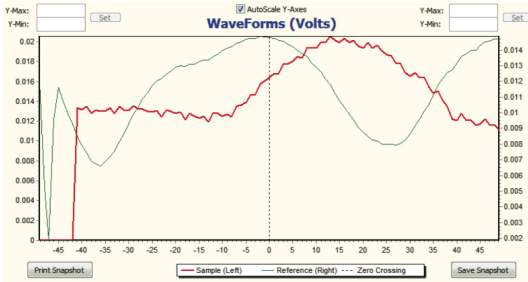
In this example, the automatic line lock was disabled and the laser temperature was manually driven from a value of 10.0 to 16.0. This resulted in the following waveform display:



At this point, the desired positions could be either to the right or to the left. Since the line lock temperature value was known to be higher, the values were incremented in single digits (e.g., 11, 12, ..., 16), and the following series of images were taken:







## Re-enabling Automatic Line Lock

As the previous images show, the waveform is gradually shifting from right to left as the temperature parameter is increased from 10.0 to 16.0 °C. At this point, since the top of the bell shape is relatively close to the zero point on the horizontal axis, you can attempt to have the instrument re-lock automatically by setting the line lock parameter back to “automatic.” This should cause the wave to slide further to the right or left until the peak is at or very near the zero point. If this does in fact occur, the relocking was successful and the dialog may be closed. If not, repeat the process, or simply restart the instrument.

## Networking

The LI-7700 supports IPv4 and IPv6. IPv4 is the first Internet Protocol to be widely used. It is nearly 20 years old and will be superseded by IPv6. IPv6 provides many advantages, one of which is that it allows for substantially more IP address. This will help accommodate the growing number of devices that are connected to the Internet.

### Enabling IPv6 on Windows XP


Microsoft® Windows XP includes IPv6 but it is not enabled by default. Windows Vista and 7 have IPv6 enabled by default. The following steps will install IPv6 on Windows XP (administrative privileges may be required):

1. Click the Start menu, and then click All Programs. Click Accessories, and then click Command Prompt.
2. At the command prompt, type: `ipv6 install` and press the Enter key.

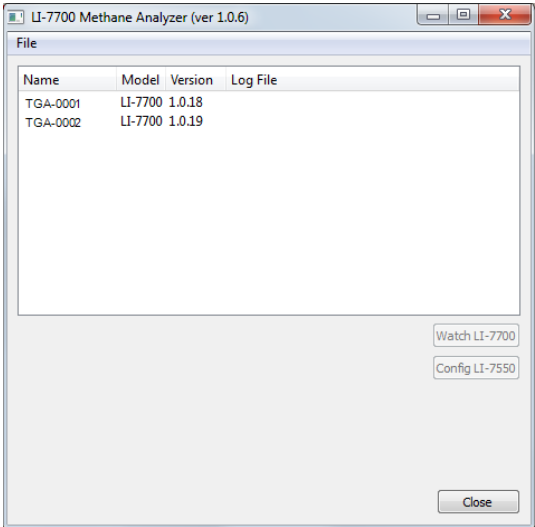
## The LI-7700 Finder Application

To use the LI-7700 finder Application, connect to the LI-7700 (and LI-7550 if applicable) using the Ethernet connection. The finder application will not see devices that are connected using the RS-232 serial connection.

Caution: The LI-7700 Finder Application provides access to advanced settings. Changing some of these settings may undesirably alter the performance of your LI-7700. Use caution when altering these settings, and consult with LI-COR Biosciences technical support personnel if you have questions.

The LI-7700 Finder provides access to internal LI-7700 settings, many of duplicated in the normal software interface. It also is used to set the LI-7550 clock. To launch the application click the help question mark  > About > Factory Setup... > Proceed.

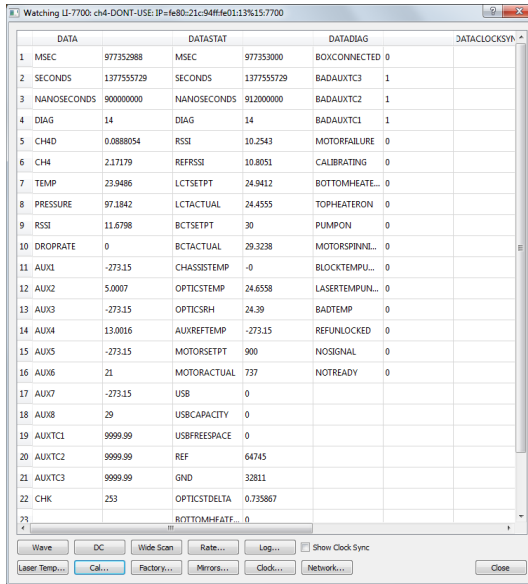
Upon launching the application, you will see a list of all LI-7700s and LI-7550s on your local network.



When you select an LI-7700, you can select Watch LI-7700, or when you select an LI-7550 you can choose Config LI-7550.

Selecting Watch LI-7700 opens a variables window:

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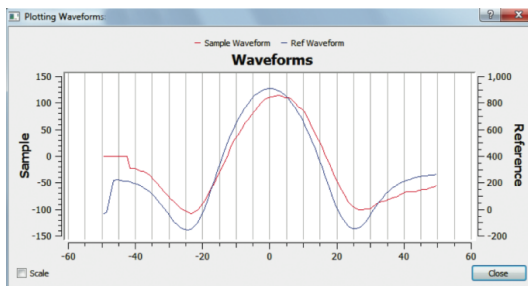
Watching LI-7700: ch4-DONT-USE: IP-fe80:21c94ff60113%15:7700

	DATA		DATASAT		DATADIAG		DATACLOCKS
1	MSEC	977352988	MSEC	977353000	BOXCONNECTED	0	
2	SECONDS	137755729	SECONDS	137755729	BADAUXTC3	1	
3	NANOSECONDS	900000000	NANOSECONDS	912000000	BADAUXTC2	1	
4	DIAG	14	DIAG	14	BADAUXTC1	1	
5	CH4D	0.0888054	RSSI	10.2543	MOTORFAILURE	0	
6	CH4	2.17179	REFRSSI	10.8051	CALBRATING	0	
7	TEMP	23.9486	LCTSETPT	24.9412	BOTTOMHEATE...	0	
8	PRESSURE	97.1842	LCTACTUAL	24.4555	TOPHEATERON	0	
9	RSSI	11.6798	BCTSETPT	30	PUMPNON	0	
10	DROPRATE	0	BCTACTUAL	29.3238	MOTORSPINN...	0	
11	AUX1	-273.15	CHASSISTEMP	-0	BLOCKTEMP...	0	
12	AUX2	5.0007	OPTICSTEMP	24.6558	LASERTEMPUN...	0	
13	AUX3	-273.15	OPTICSRH	24.39	BADTEMP	0	
14	AUX4	13.0016	AUXREFTEMP	-273.15	REFUNLOCKED	0	
15	AUX5	-273.15	MOTORSETPT	900	NOSIGNAL	0	
16	AUX6	21	MOTORACTUAL	737	NOTREADY	0	
17	AUX7	-273.15	USB	0			
18	AUX8	29	USBCAPACITY	0			
19	AUXTC1	9999.99	USBFREESPACE	0			
20	AUXTC2	9999.99	REF	64745			
21	AUXTC3	9999.99	GND	32811			
22	CHK	253	OPTICSDelta	0.735867			
23			BOTTOMHEATE...	0			

Buttons: Wave, DC, Wide Scan, Rate..., Log..., Show Clock Sync, Laser Temp..., Cal..., Factory..., Mirror..., Clock..., Network..., Close

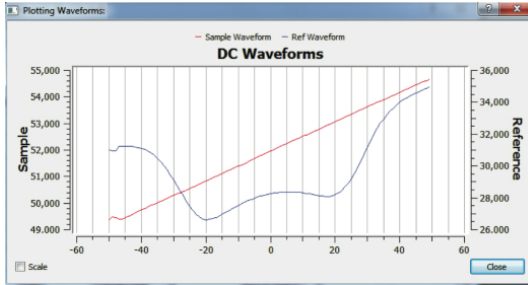
This displays numerous parameters used by the LI-7700. Along the bottom of the window are nine buttons, which are described below:

Click the Wave button:



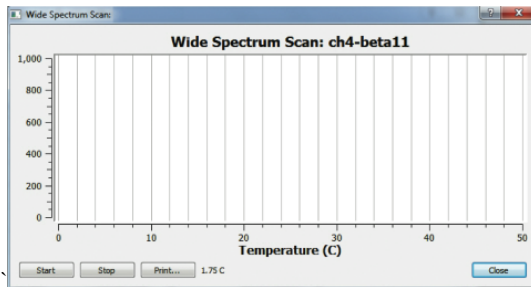
The window above shows the waveform. It is identical to the waveform displayed in the Diagnostic Page 1 tab on the Main View.

Click the DC button:



This window shows the un-inverted measurement of the sample and reference.

Click the Wide Scan button:



This window can be used to gather diagnostic information. After performing a wide scan you either must select “Rollback” in the Factory Settings dialog or restart the instrument to restore normal operation.

Click the Laser Temp... button:

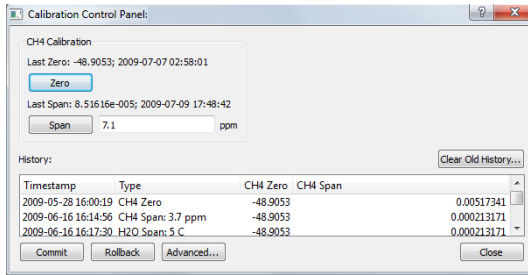
The 'Laser Temperature Control' dialog box has two sections. The first section, 'Cooler Temperature Control', has a radio button for 'Automatic' (selected) and a radio button for 'Manual' with a value of '16.30 C'. The second section, 'Block Temperature Control', has a radio button for 'On' (selected) with a value of '30.00 C' and a radio button for 'Off'. A 'Close' button is at the bottom.

## Section 7. Advanced Operation

---

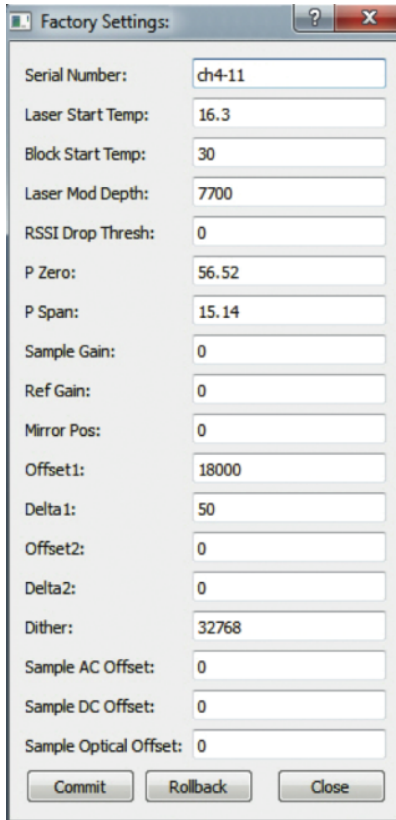
The laser temperature control dialog is similar to the Laser Temperature control described above in the Manual Line Lock example (see "Manual Line Lock Example" on page 7-6).

Click the Cal... button:



This advanced calibration tab provides access to many of the same calibration functions available in the Main View.

Click the Factory... button:

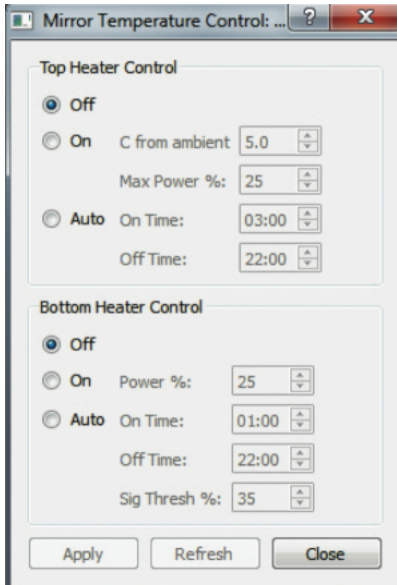


The image shows a 'Factory Settings' dialog box with a title bar containing a question mark icon and a close button. The dialog contains a list of settings, each with a label and a text input field. At the bottom, there are three buttons: 'Commit', 'Rollback', and 'Close'.

Setting	Value
Serial Number:	ch4-11
Laser Start Temp:	16.3
Block Start Temp:	30
Laser Mod Depth:	7700
RSSI Drop Thresh:	0
P Zero:	56.52
P Span:	15.14
Sample Gain:	0
Ref Gain:	0
Mirror Pos:	0
Offset1:	18000
Delta 1:	50
Offset2:	0
Delta 2:	0
Dither:	32768
Sample AC Offset:	0
Sample DC Offset:	0
Sample Optical Offset:	0

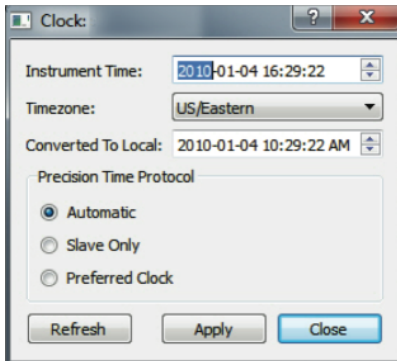
The window above is used to perform diagnostic checks. Do not change any settings in this window unless in consultation with LI-COR Biosciences technical support.

Click the Heaters... button:



Provides access to mirror heater controls.

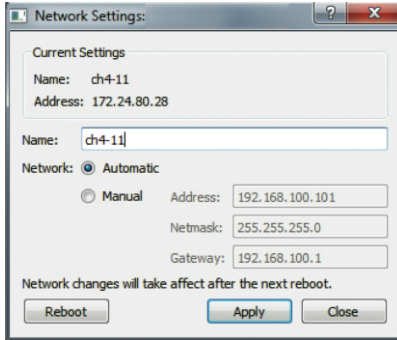
Click the Clock... button:



Here you can set the LI-7700 clock.

Click the Network... button:





This window allows you to change the instrument name and network settings.

## Communications Grammar

### LI-7700 XML Communications

The configuration grammar used to communicate with the LI-7700 is based upon the eXtensible Markup Language (XML). XML relies on the use of tags to “markup”, or give structural rules to a set of data.

A tag is a descriptive identifier, enclosed between a less than (<) and greater than (>) symbol, used in part to describe a piece of data. For example, <NAME> is a tag that describes someone’s name. Each tag must have a corresponding end tag, denoted by ‘/’. Extending the example above, the end tag of <NAME> is </NAME>.

Elements are the basic unit of XML content. An element consists of a start tag and an end tag, and everything in between. For example, consider the following element:

```
<NAME>Jane</NAME>.
```

In this example, <NAME> (start tag) and </NAME> (end tag) comprise the markup, and “Jane” comprises the data.

Elements can also contain other elements other than data.

```
<NAME>
  <FIRST>Jane</FIRST>
  <LAST>Smith</LAST>
</NAME>
```

In this example, the outermost element <NAME> encompasses two other elements that contain data. All elements combined make up the XML document.

## Connecting with a Terminal Program

This section describes the protocol used by the LI-7700 to communicate via Ethernet for both configuration and data output purposes. Commands sent to the LI-7700 have a certain structure that must be followed, and data sent by the LI-7700 comes packaged in a particular way.

Communication is accomplished with a terminal program (e.g., Tera Term). When you communicate with the LI-7700 with a Transmission Control Protocol (TCP) connection, the LI-7700 address should be in the form:

XXX.XXX.XXX.XXX:YYYY

where XXX represents an integer number from 0-255 and YYYY represents the port number. All LI-7700s use the port number 7700 by default. If you connect with the serial RS-232 port, simply select the COM port that you used to connect your LI-7700.

## Element Descriptions

The following types of data are used in XML grammar:

{val   val   val   ...}	The value will be a member of the specified set. The “ ” means “or”.
{bool}	Boolean values, TRUE   FALSE.
{float}	Floating point values in decimal or exponential notation.
{int}	Integer
{string}	String

## Sending Commands

When you make the initial connection to the instrument it will send data as tab-delimited text. It includes a header followed by data, similar to that shown below

```

DATAEVENTMODELLI-7700
DATAEVENTVERSION1.0.14
DATAEVENTNAME1TG1-0XXX
DATAEVENTSNTG1-0XXX
DATAEVENTBOXDISCONNECTED
DATAHMSECSECONDSNANOSECONDSDIAG...
DATADIAGHBOXCONNECTEDBADAUXTC3BADAUXTC2...
DATA4954420631317223547014...
DATA4954430631317223548014...
...
    
```

Headers and labels for these data are similar to the data files created by the LI-7700, which are described beginning in Section 4. on page 4-1. Subsequent data packets will not include the header information.

### To set the output rate to 0:

Send the following command:

```
<licor><li7700>
<output><rate>0</rate></output></li7700></licor>
```

If the command is received the instrument will reply with this message:

```
<licor><li7700><ack>>true</ack></li7700></licor>
DATAEVENTCONFIGCHANGED
```

### Example of an incorrect command and response from instrument:

The command below is incorrect because the rate is a floating point (10.0), when it should be a value (e.g., 10).

```
<licor><li7700>
<output><rate>10.0</rate></output></li7700></licor>
```

Instrument response to the erroneous command:

```
<licor><li7700><error>XML error in item &quot;rate&quot;;
invalid option: 10.0</error></li7700></licor>
DATAEVENTCONFIGCHANGED
```

### To request a data record:

```
<licor><li7700><cmd><poll>>true</poll></cmd></li7700></licor>
```

If the command is received the instrument will reply with this message and a full data record:

```
<licor><li7700><ack>>true</ack></li7700></licor>
DATA 4129091253 1317290569 900000000 143 0.0835644 2.00288 ...
```

### To change the top mirror heater settings:

```
<licor>
<li7700>
<cfg>
<heater>
<top>
<control> on | off | auto </control>
<deltat> {float (-5.0 - 5.0)} </deltat>
<heaterpower>{Int}</heaterpower>
```

```
<ontime>{HH:MM}</ontime>
<offtime>{HH:MM}</offtime>
</top>
</heater>
</cfg>
</li7700>
</licor>
```

This would change the mirror heater settings to whichever values you specify.

### To set the temperature range to the 0C...50C range:

```
<licor><li7700>
<cfg><temprange>high</temprange></cfg></li7700></licor>
```

### To set the temperature range to the -25C...25C range:

```
<licor><li7700>
<cfg><temprange>low</temprange></cfg></li7700></licor>
```

### To force the instrument to re-linlock:

```
<licor><li7700>
<cmd><linelock>>true</linelock></cmd></li7700></licor>
```

## Configuration File Grammar

Configuration files are constructed when you save an instrument configuration (see "Configuration Files" on page 2-28). You can view or edit the configuration grammar by opening the configuration file in a text editor. Below is an example of a typical configuration file with hypothetical values for elements:

```
<licor>
  <li7700>
    <serialnumber>77H-Beta9</serialnumber>
  <output>
    <rate>10</rate>
    <waveforms>true</waveforms>
    <status>true</status>
    <dataclock>true</dataclock>
  </output>
  <box>
    <output>
      <data>
        <ch4>true</ch4>
        <ch4d>true</ch4d>
        <temp>true</temp>
        <pressure>true</pressure>
```

```

    <rss1>true</rss1>
    <aux1>true</aux1>
    <aux2>true</aux2>
    <aux3>true</aux3>
    <aux4>true</aux4>
    <aux5>true</aux5>
    <aux6>true</aux6>
    <aux7>true</aux7>
    <aux8>true</aux8>
    <auxtc1>false</auxtc1>
    <auxtc2>false</auxtc2>
    <auxtc3>false</auxtc3>
    <diag>true</diag>
    <seconds>true</seconds>
    <nanoseconds>true</nanoseconds>
    <droprate>true</droprate>
    <chk>true</chk>
  </data>
  <waveforms>false</waveforms>
  <status>true</status>
  <dataclock>false</dataclock>
</output>
  <usb>
    <data>
      <ch4>true</ch4>
      <ch4d>true</ch4d>
      <temp>true</temp>
      <pressure>true</pressure>
      <rss1>false</rss1>
      <aux1>true</aux1>
      <aux2>true</aux2>
      <aux3>true</aux3>
      <aux4>true</aux4>
      <aux5>false</aux5>
      <aux6>false</aux6>
      <aux7>false</aux7>
      <aux8>false</aux8>
      <auxtc1>true</auxtc1>
      <auxtc2>true</auxtc2>
      <auxtc3>true</auxtc3>
      <diag>true</diag>
      <seconds>true</seconds>
      <nanoseconds>true</nanoseconds>
      <date>true</date>
      <time>true</time>
      <droprate>false</droprate>
      <chk>true</chk>
    </data>
  </usb>

```

```
        <status>off</status>
        <split>60</split>
    </usb>
</box>
<cfg>
<sdmaddress>15</sdmaddress>
<aux1>
    <type>steinhart</type>
    <a0>1</a0>
    <a1>2</a1>
    <a2>3</a2>
    <a3>4</a3>
</aux1>
<aux2>
    <type>poly</type>
    <a0>5</a0>
    <a1>6</a1>
    <a2>7</a2>
    <a3>8</a3>
</aux2>
<aux3>
    <type>steinhart</type>
    <a0>9</a0>
    <a1>10</a1>
    <a2>11</a2>
    <a3>12</a3>
</aux3>
<aux4>
    <type>poly</type>
    <a0>13</a0>
    <a1>14</a1>
    <a2>15</a2>
    <a3>16</a3>
</aux4>
<aux5>
    <type>steinhart</type>
    <a0>17</a0>
    <a1>18</a1>
    <a2>19</a2>
    <a3>20</a3>
</aux5>
<aux6>
<type>poly</type>
    <a0>21</a0>
    <a1>22</a1>
    <a2>23</a2>
    <a3>24</a3>
</aux6>
```

```
<aux7>
  <type>steinhart</type>
  <a0>25</a0>
  <a1>26</a1>
  <a2>27</a2>
  <a3>28</a3>
</aux7>
<aux8>
  <type>poly</type>
  <a0>29</a0>
  <a1>30</a1>
  <a2>31</a2>
  <a3>32</a3>
</aux8>
<heater>
  <top>
    <heaterpower>100</heaterpower>
    <control>off</control>
    <deltat>5</deltat>
    <ontime>00:01</ontime>
    <offtime>23:59</offtime>
  </top>
  <bottom>
    <heaterpower>98</heaterpower>
    <control>off</control>
    <signalstrengthlevel>50</signalstrengthlevel>
    <ontime>00:01</ontime>
    <offtime>23:04</offtime>
  </bottom>
</heater>
<linelock>
  <lasercooler>
    <control>auto</control>
    <temp>24.9</temp>
  </lasercooler>
  <laserblock>
    <control>on</control>
    <temp>30</temp>
  </laserblock>
</linelock>
<cleancycle>manual</cleancycle>
<spinmirror>
  <control>off</control>
  <ontime>00:01</ontime>
  <offtime>23:59</offtime>
  <duration>120</duration>
  <repeatinterval>06:00</repeatinterval>
  <signalstrengthlevel>100</signalstrengthlevel>
```

```
<wash>
  <control>off</control>
  <interval>1</interval>
  <duration>30</duration>
  <signalstrengthlevel>40</signalstrengthlevel>
  <coldtempthreshold>-10</coldtempthreshold>
</wash>
</spinmirror>
<dac1>
  <set>1</set>
  <src>temp</src>
  <low>1</low>
  <high>2</high>
</dac1>
<dac2>
  <set>1</set>
  <src>pressure</src>
  <low>3</low>
  <high>4</high>
</dac2>
<dac3>
  <set>1</set>
  <src>rssi</src>
  <low>5</low>
  <high>6</high>
</dac3>
<dac4>
  <set>1</set>
  <src>set</src>
  <low>7</low>
  <high>8</high>
</dac4>
<dac5>
  <set>1</set>
  <src>ch4d</src>
  <low>7</low>
  <high>8</high>
</dac5>
<dac6>
  <set>1</set>
  <src>ch4</src>
  <low>7</low>
  <high>8</high>
</dac6>
<network>
  <name>ch4-BLACK-SPAR</name>
  <configuration>auto</configuration>
  <ipaddress>172.25.41.55</ipaddress>
```



```
<netmask>255.255.0.0</netmask>  
<gateway>172.25.1.1</gateway>  
</network>  
<temprange>high</temprange>  
</cfg>  
</li7700>  
</licor>
```

## Maintenance

Below you will find some basic maintenance procedures that may be required from time to time.

### Changing the Internal Desiccant Bottle

There is one internal desiccant bottle in the LI-7700. It is filled with Blue-Indicating Drierite<sup>®</sup>. The desiccant cap is above the circular plug located on the bottom of the top dome of the analyzer (see below). The desiccant bottle should be changed annually when the LI-7700 is used in humid environments. Desiccant bottles and recharge kits are available from LI-COR.

In the Calibration frame (see "Main Window" on page 2-4), there is a field that reads "Optics RH:". Normally this should be near zero. If the indicator turns from green to red (indicating the optics RH: >30%), then it is time to change the desiccant. To change the desiccant:

1. Remove the setscrew that secures the desiccant plug. If it is not in place, insert the knurled screw from the spares kit (part #125-09760) into the desiccant plug. Grip the screw with your fingers or a pair of pliers and pull straight out to remove the desiccant plug.



2. Remove the seal from the top of the replacement desiccant bottle. Insert the bottle cap first and replace the foam disk and cover. Press firmly to secure the desiccant

cover and replace the setscrew.



**Note:** a droplet of saliva or dish soap applied to the o-rings can ease insertion of the desiccant cover.

Over time, the “Optics RH:” should approach zero. This may take several minutes to several hours, depending on the humidity level. There should be no need to perform any other maintenance procedures (e.g., zero or span) after this.

### **Mirrors - Cleaning and Care**

The upper and lower mirrors are extremely scratch resistant, however, the mirror surfaces should be treated the same way you would treat the surface of an expensive lens. In general, refrain from applying a lot of pressure when cleaning a dry mirror. If the mirror is dusty, just wipe it with a soft, clean, moistened cloth. If a sticky substance, such as pollen, has built up on the mirror, a mild soap or a commercial glass cleaner such as Windex® can be used.

**Note:** Products such as Rain-X® can be applied to the lower mirror to help the glass shed water.

There may be the appearance of “spots” on the mirrors. These are normal and are the result of the manufacturing process. The spots are in the visible spectrum and will not affect reflectance near 1.6 microns, which is where the LI-7700 operates.

The washer reservoir uses standard over-the-counter windshield washer fluid. If fouling of the mirror is minor, tap water will work fine. Cleaners that contain methyl alcohol (methanol) and isopropyl alcohol are suitable. Refrain from using cleaners that contain

powerful solvents such as acetone. As a general rule, if the cleaner is safe for automotive finishes, it is probably safe to use in the LI-7700 washer reservoir.

The washer should be filled with windshield washer fluid with a temperature rating suitable for the environment in which it will be deployed. For highly sensitive environments, select an environmentally friendly solution.

## Changing the Thermocouple

The fine wire thermocouple should be replaced if the wire is broken or if it reads incorrectly. One spare thermocouple is included in the spares kit, and others can be purchased from LI-COR Biosciences (part #9977-038). To replace the thermocouple:

1. Disconnect the power supply to turn the LI-7700 off.
2. Fully loosen the two screws (#1 Philips) that secure the thermocouple assembly to the bottom of the upper housing. The screws will be retained in the thermocouple base.

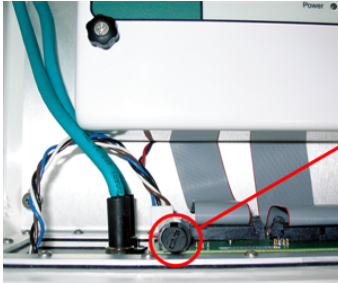


3. Grasp the thermocouple housing and pull it straight out. It should slide out fairly easily.



4. Insert the new thermocouple. Do not force it in, and be sure the bend is directed toward the optical path. Handle the thermocouple carefully to protect the fine wires.
5. Replace the two screws. Connect with the LI-7700 and verify that the temperature readings are correct.

## Changing the LI-7550 Fuse



Fuse holder cover - turn counterclockwise to release

The LI-7550 power supply is protected by a 5A 125/250V, 5x 20 mm fast blow fuse located near the connection panel inside the Analyzer Interface Unit case. If the LI-7550 fails to power up when connected to a suitable power supply, check to see if the fuse has blown.

To check the fuse, disconnect the power cable to turn off the unit and open the case of the LI-7550 Analyzer Interface Unit. The fuse is located on the inside wall, opposite the connection panel, in the lower left hand corner, as shown above. Replacement fuses (part #439-04214 in the spares kit) plug into the fuse holder. Use a standard screwdriver to push down on the fuse holder cap and turn counterclockwise to release the cap. Check the fuse and replace if necessary. Note that sometimes it may not be evident that the fuse has blown and an ohmmeter may be used to check the status of the fuse.

## Changing the LI-7700 Fuse

If the LI-7700 fails to power up when connected to a suitable power supply, check to see if the fuse has blown. The LI-7700 fuse is enclosed within the knurled fuse cover on the connection panel. One extra 250V type F 5.0 Amp fuse (part #438-09800) is included in the spares kit. To replace the fuse, disconnect the power supply to power off the LI-7700, remove the fuse cover and pull out the old fuse. Insert the replacement fuse and reattach the fuse cover.



# A Specifications

---

## LI-7700 Open Path CH<sub>4</sub> Analyzer

**Calibration Range:** 0-40 ppm @ 25 °C

0-25 ppm @ -25 °C

0-50 ppm total

**Bandwidth:** 0, 1, 2, 5, 10, or 20 Hz

**Linearity:** Within 1% of reading across full calibration range

**Resolution:** 5 ppb (RMS @ 10 Hz, typical ambient levels)

**Operating Temperature Range:** -25 °C to 50 °C

**Operating Pressure Range:** 50 to 110 kPa

**Relative Humidity Range:** 0 to 100%

**Detection Method:** Wavelength Modulation Spectroscopy, 2f Detection

**Data Communication:** Ethernet

**Data Inputs:** 4 Analog Inputs (single ended, ±5 V, 16 bit), 3 type E thermocouple

**Power Requirements:** 10.5 to 30 VDC

**Power Consumption:** 8 watts nominally, up to 41 watts with accessories, see "Power Requirements Summary" on page A-3 for details.

**Size:** 14.33 cm (5.64 in) dia., 83 cm (32.7 in) height, 94.6 cm (37.25 in) height with mounting post

**Weight:** 5.2 kg (11.5 lbs.)

**Optical Path:** 0.5 m physical path length (1.65 ft), 30 m measurement path (98.4 ft)

**Cable Length (Power and Data):** 5 m (16.4 ft)

## 7700-101 Washer Assembly

**Power Requirements:** 8 watts, see "Power Requirements Summary" on page A-3 for details.

**Operating Temperature Range:** -10 °C to 50 °C

**Size:** 44.5 x 32.8 x 15 cm (17.5 x 12.9 x 6 in) external dimensions

**Weight:** 3.2 kg (7 lbs)

**Fluid Capacity:** 4 L (1.1 U.S. gallons)

**Maximum pumping height:** 5 m above pump with provided tubing and nozzle

**Cable Length:** 5 m (16.4 ft)

**Tube Length:** 5 m (16.4 ft)

## LI-7550 Analyzer Interface Unit (optional)

**Data Storage:** Removable USB Storage. 4 GB provided, (>1 TB max; expandable with user-supplied industrial grade USB Flash Drive)

**Data Communication:** Ethernet

Synchronous Devices for Measurement: (33.3 Hz)

RS-232: (57,600 baud, 20 records per second)

6 Digital-to-Analog Converters: (0-5 V, 300 Hz)

**Inputs:** Ethernet, 4 Analog Inputs (differential,  $\pm 5$  V, 16 bit)

**Operating Temperature Range:** -25 °C to 50 °C

**Power Requirements:** 10.5 to 30 VDC

**Power Consumption:** 10W nominally

**Dimensions:** 35 ´ 30 ´ 15 cm (13.8 ´ 12 ´ 6 in) external dimensions

**Weight:** 4.4 kg (10 lbs)

**Cable Length (Power, Data, Analog Input/Output, Ethernet, and SDM):** 5 m (16.4 ft)

## 7550-101 Auxiliary Sensor Interface (optional)

**Size:** 11.5 cm x 6.5 cm x 4.2 cm (4.5 in x 2.6 in x 1.7 in.)

**Weight:** 0.39 kg (0.85 lbs) including mounting bracket

**Cable Length:** 0.75 m (2.5 ft)

## Power Requirements Summary

The LI-7700 uses about 8 watts during normal operation, but when accessories and mirror heaters are used, power requirements could be up to or greater than 41 watts. Table A-1 below can be used to determine how much power is required in a variety of configurations:

**Table A-1.** Typical LI-7700 power requirements for a variety of configurations.

	CH <sub>4</sub> Analyzer	Washer Assembly	Mirror Heaters	LI-7550	LI-7550	Power Consumption
			Upper	Lower		
Normal Operation (watts)	8					8
	8				10	18
During Cleaning Cycle (watts) <sup>1</sup>	8	8				16
	8	8			10	26
Mirror Heaters On (watts) <sup>2</sup>	8		0 to 7.5			8 to 15.5
	8		0 to 7.5	0 to 7.5		8 to 23
	8		0 to 7.5	0 to 7.5	10	18 to 33
	8	8	0 to 7.5	0 to 7.5	10	26 to 41

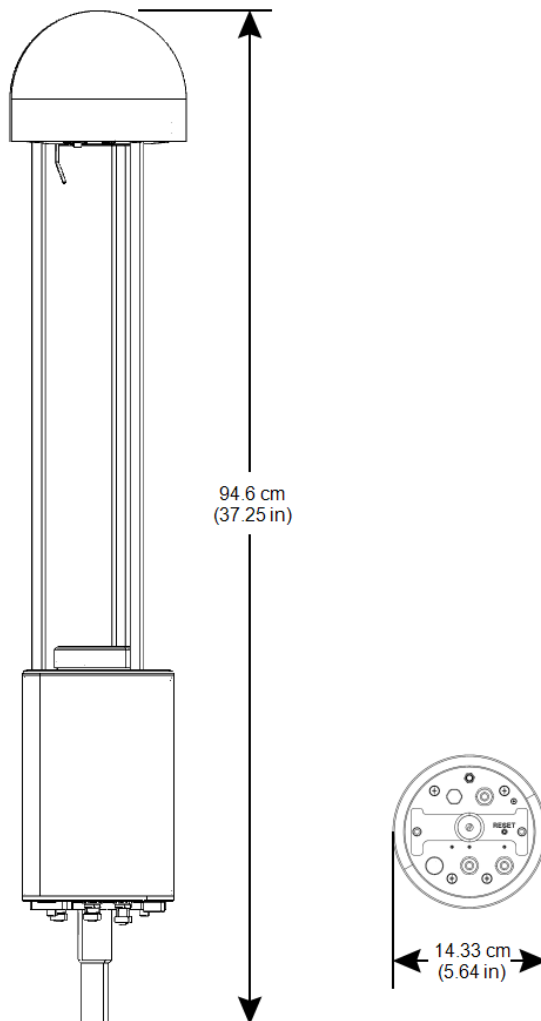
<sup>1</sup>Cleaning cycle duration is from 10 to 120 seconds. Cleaning cycle frequency and duration are user settable.

<sup>2</sup>Power used for mirror heaters is from 0 to 7.5 watts each, linear with power setting.

## Dimensions

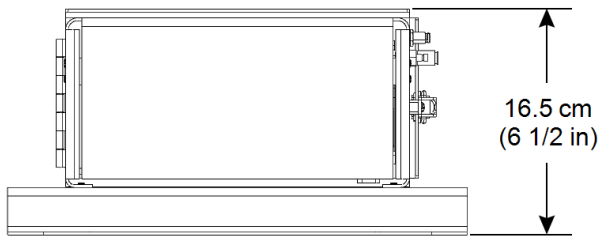
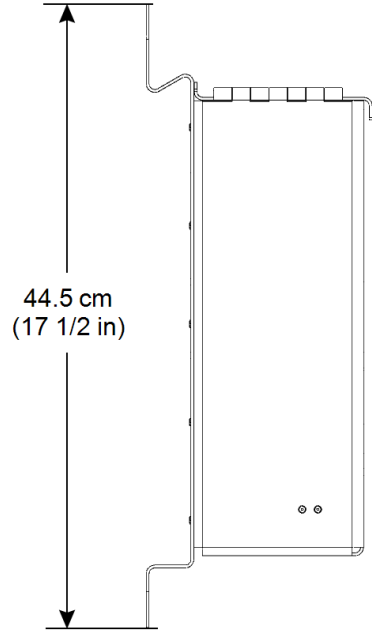
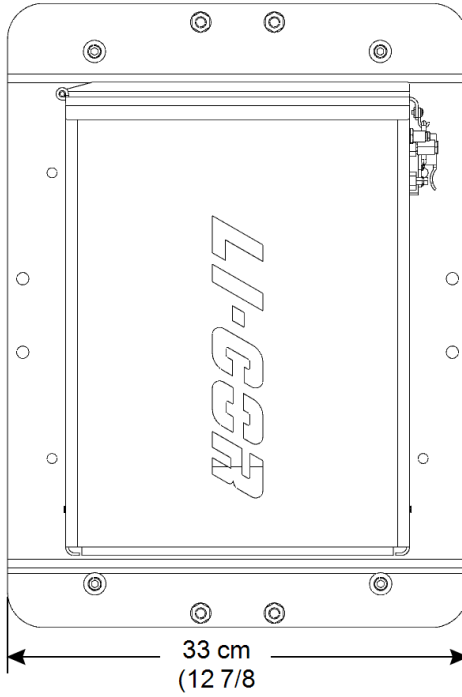
Dimensional drawings show the approximate dimensions of the LI-7700 and its accessories. Contact LI-COR® if you have additional questions.

### LI-7700

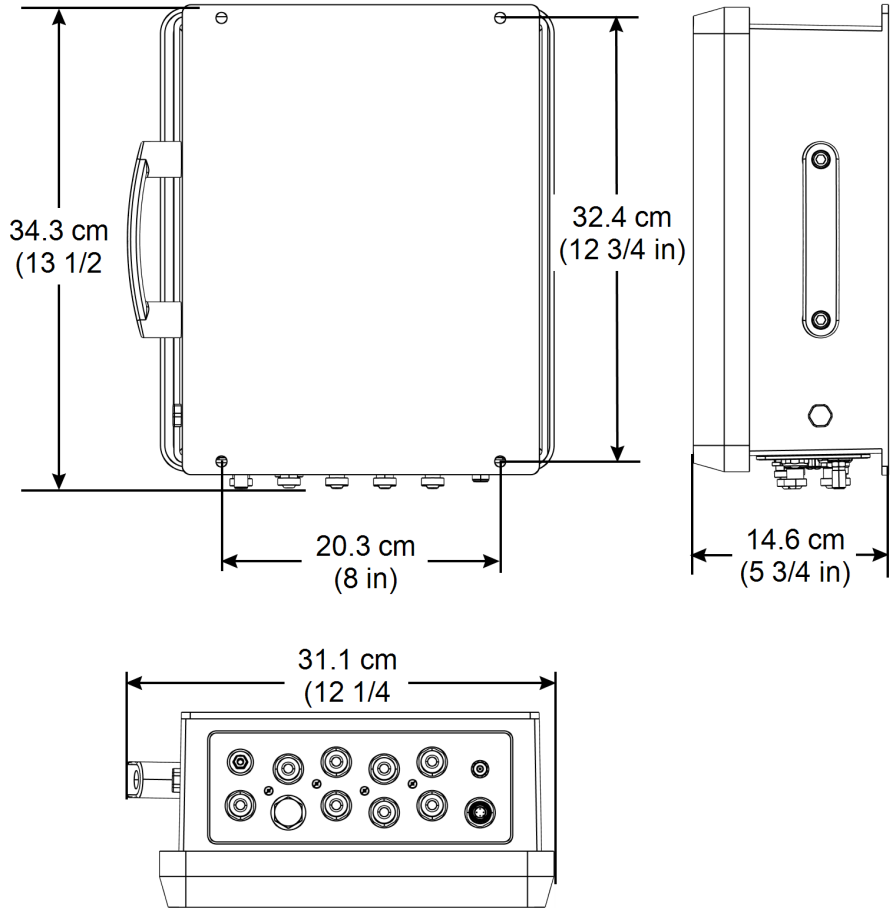




**7700-101 Washer Assembly**



### LI-7550 Analyzer Interface Unit



# B Software Change Log

---

Release Date	Embedded Software Version	Compatible Windows Software	New Features Added	Bugs Fixed
December, 2013	1.0.19	1.0.5	Updated mirror cleaner/spin motor algorithm to improve winter performance and give users more intuitive setup options.	n/a
December, 2010	1.0.14 or lower	1.0.5/1.0.4	First public release	



# C Troubleshooting

---

## **LI-7700 will not power up:**

Power supply inadequate – be sure the power supply is 10.5 to 30 VDC, 3 Amps.

Power supply connected improperly – this will blow the fuse. Connect the power supply correctly and replace the fuse.

Blown fuse – replace the fuse.

## **Signal strength (RSSI) excessively low:**

Clean the upper and lower mirrors with water and a mild soap solution or commercial glass cleaner. If this does not work:

Check the reference signal strength (click the “Diagnostics Page 1” tab on the software main screen, Signal Strength, Reference is on the right). Typically, the reference signal strength is between 50 and 60%. If it is lower than this, check the Laser Control Status on the main page. If the indicator is a blue dot, click it and change the temperature range setting to Warm (see "Operating Temperature Range" on page 2-13).

If this does not bring the signal strength up, contact technical support at [envsupport@licor.com](mailto:envsupport@licor.com) or 800-447-3576 (U.S. and Canada) or 402-467-3576 (International).

## **Lower mirror spin motor runs loudly at start-up:**

Power supply inadequate – be sure the power supply is 10.5 to 30 VDC, 3 Amps.

### **Temperature readings are unreasonable:**

Thermocouple damaged – replace the optical path thermocouple.

### **LI-7700 not visible on the network:**

Check the Ethernet data cable connections.

Enable TCP/IP v6 on Windows® XP computers (see ).

Ensure that the correct version of mDNS responder is installed on your computer.

### **Pressure measurements noisy:**

The mirror washer causes perturbations in the pressure measurement due to the proximity of the pressure sensor to the lower mirror. One way to reduce this effect is to set the cleaner to operate less frequently.

### **Optics RH warning in the software or diagnostic data:**

Desiccant needs to be replaced. The RH warning turns on if the relative humidity in the head is over 30%.

### **Data loss during night/morning hours:**

Mirrors may be covered in condensation. Check the signal strength (RSSI) data during those periods. If the signal strength drops in condensing conditions, turn on the mirror heaters or boost the power delivered to the mirror heaters during those time periods.

### **Washer fluid used up too quickly:**

Check the washer mirror settings. Try lowering the signal strength threshold, setting the stop time close to the start time, or reducing the duration of the cleaning cycle.

Attach an auxiliary reservoir to the washer assembly.

### **No methane data stream:**

If your computer goes to “sleep”, the methane graph will not update upon “waking up.” Click the “Clear Charts” button.

Be sure the “Pause/Resume” button has not been pressed.

### **Methane density data near zero, negative, or otherwise unbelievable:**

Check the Diagnostics Page1 tab. If the graph does not make a nice bell curve shape, check the “Laser control:” in the Status frame. If the indicator is red, the reference signal is “unlocked.” Click the red indicator or press Ctrl +Alt +L to open the Laser Temperature Control window. Follow the steps described on page "Laser Temperature Control" on page 7-3 to re-enable the line locking.

Check the zero and span using the procedure described in "Calibration" on page 7-1. Restore the factory settings using the procedure described there.

If these do not work, contact technical support at [envsupport@licor.com](mailto:envsupport@licor.com) or 800-447-3576 (U.S. and Canada) or 402-467-3576 (International).

**Instrument does not keep time when disconnected from power supply:**

The internal battery needs to be replaced. Contact technical support at [envsupport@licor.com](mailto:envsupport@licor.com) or 800-447-3576 (U.S. and Canada) or 402-467-3576 (International).





# D Suppliers

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The company names and contact information given below are the most current we have at the time of this printing. In some cases, the information may change without notice.

## Desiccant

Desiccant	LI-COR Part Number
Bulk Drierite <sup>®</sup> 10-20 mesh, 1 lb. (0.45 kg) bottle	622-04299
Scrub Bottle Kit (1 pre-charged scrub bottle)	7700-950

Additional Drierite<sup>®</sup> Suppliers:

W. A. Hammond Drierite <sup>®</sup> Company www.drierite.com 937-376-2927	VWR Scientific Products www.vwrsp.com 800-932-5000 908-757-4045
Thomas Scientific www.thomassci.com 800-345-2100 856-467-2000	GFS Chemicals, Inc. www.gfschemicals.com 800-394-5501 740-881-5501
	LI-COR Biosciences 4421 Superior Street Lincoln, NE 68504 USA 800-447-3576 402-467-3576 envsales@licor.com www.licor.com

## Calibration Gases

### U.S. & International

Scott Specialty Gases  
6141 Easton Road  
Plumsteadville, PA 18949  
Phone: 215-766-8860  
FAX: 215-766-0320  
www.scottgas.com  
Check for local distributors

### U.S.

Air Liquide America Specialty Gases LLC  
6141 Easton Road, Box 310  
Plumsteadville, PA 18949  
Phone: 800-217-2688  
FAX: 215-766-2476  
solutions.center@airliquide.com  
www.alspecialtygases.com or www.scottgas.com  
Check for local distributors

### Canada

Air Liquide Canada Inc.  
1250 Rene-Levesque Boulevard West  
Suite 1700  
Montreal, PQ H38 5E6  
Phone: 800-217-2688  
FAX: 514-846-7700  
Email: info.alc@airliquide.com  
www.specialtygas.ca

## Turck® Cables

Turck, Inc.  
3000 Campus Drive  
Minneapolis, MN 55441  
Phone: 612-553-7300

FAX: 612-553-0708

www.turck.com

**Table D-1.** Turck cables used with the LI-7700.

LI-COR p/n	Cable	Connector	Turck p/n
392-10108	Ethernet	8-pin male-male	RSS RSS841-*M
392-10107	Ethernet Adapter	8-pin female to RJ45	RKC RJ45 840-*M
392-10109	Analog In/Out	12-pin male	RSS 12T-*
392-10268	Serial	6-pin female to DB-9 female	RKC 6T-* DB9F/CS12317
392-10093	SDM Interface	4-pin male	RSS 4.4T-*
392-10094†	Power	4-pin female	RK4.41T-*/S529
392-10211	Washer Assembly Power Cable	4-pin male-male	PKG V-4M-* PKGV4M/S90

\* refers to cable length

† when ordering a power cable from LI-COR, request part #9975-030. Power cables provided by Turck may have bare leads; the brown and white leads connect to the negative terminal, and the blue and black connect to the positive terminal.

## Industrial Rated USB Flash Drives

Flash Drive Capacity	LI-COR Part Number
4 GB	616-10722
16 GB	616-10723

LI-COR Biosciences  
 4421 Superior Street  
 Lincoln, NE 68504 USA  
 800-447-3576  
 402-467-3576  
 envsales@licor.com  
 www.licor.com

## Mounting Accessories

Mounting hardware, including a tripod and extension, is available directly from LI-COR®. Contact LI-COR for details (envsales@licor.com).

*Appendix D. Suppliers*

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<b>Part</b>	<b>Part #</b>
Heavy Duty Adjustable Tripod (includes cross arm)	7900-300
Cross Arm Kit	7900-330
Crossover Fitting (to mount the LI-7700 to the tripod cross arm)	7900-342

# Warranty

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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.

**IMPORTANT:** Please return the User Registration Card enclosed with your shipment so that we have an accurate record of your address. Thank you.

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*Measuring Change in a Changing World*<sup>®</sup>

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