ADINSTRUMENTS
making science easier

Spirometer

Owner's Guide

This document was, as far as possible, accurate at the time of release. However, changes may have been made to the software and hardware it describes since then. ADInstruments Pty Ltd reserves the right to alter specifications as required. Late-breaking information may be supplied separately.

Trademarks of ADInstruments

PowerLab®, LabTutor® and MacLab® are registered trademarks of ADInstruments Pty Ltd. The names of specific recording units, such as PowerLab 8/30, are trademarks of ADInstruments Pty Ltd. LabChart, Chart and Scope (application programs) are trademarks of ADInstruments Pty Ltd.

Other Trademarks

Apple, Mac and Macintosh are registered trademarks of Apple Computer, Inc.

Windows, Windows XP and Windows Vista are either registered trademarks or trademarks of Microsoft Corporation.

All other trademarks are the property of their respective owners.

Product: ML141 Spirometer

Document Number: U-ML141-OG-003C
Part Number: 4381

Unit 13, 22 Lexington Drive, Bella Vista, NSW 2153, Australia

Web: www.adinstruments.com
Technical Support: support.au@adinstruments.com
Documentation: documentation@adinstruments.com

ADInstruments Pty Ltd. ISO 9001:2000 Certified Quality Management System

Reg. No. 1053

Contents

Safety Notes

Statement of Intended Use

All products manufactured by ADInstruments are intended for use in teaching and research applications and environments only. ADInstruments products are NOT intended to be used as medical devices or in medical environments. That is, no product supplied by ADInstruments is intended to be used to diagnose, treat or monitor a subject. Furthermore no product is intended for the prevention, curing or alleviation of disease, injury or handicap.

Where a product meets IEC 60601-1 it is under the principle that:

- it is a more rigorous standard than other standards that could be chosen, and
- it provides a high safety level for subjects and operators.

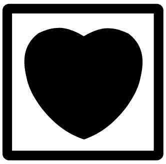
The choice to meet IEC 60601-1 is in no way to be interpreted to mean that a product:

- is a medical device,
- may be interpreted as a medical device, or
- is safe to be used as a medical device.

Safety Symbols

Devices manufactured by ADInstruments that are designed for direct connection to humans are tested to IEC 601-1:1998 (including amendments 1 and 2) and 60601-1-2, and carry one or more of the safety symbols below. These symbols appear next to those inputs and output connectors that can be directly connected to human subjects.

BF symbol: Body-protected equipment



CF symbol: Cardiac-protected equipment

Warning symbol: 'see documentation'

The three symbols are:

- BF (body protected) symbol. This means that the input connectors are suitable for connection to humans provided there is no direct electrical connection to the heart.
- CF (cardiac protected) symbol. This means that the input connectors are suitable for connection to human subjects even when there is direct electrical connection to the heart.
- Warning symbol. The exclamation mark inside a triangle means that the supplied documentation must be consulted for operating, cautionary or safety information before using the device.

Further information is available on request.

Bio Amp Safety Instructions

The Bio Amp inputs displaying any of the safety symbols are electrically isolated from the mains supply in order to prevent current flow that may otherwise result in injury to the subject. Several points must be observed for safe operation of the Bio Amp:

- All Bio Amp front-ends (except for the ML138 Octal Bio Amp) and PowerLab units with a built-in Bio Amp are supplied with a 3-lead or 5-lead Bio Amp subject cable and lead wire system. The ML138 Octal Bio Amp is supplied with unshielded lead wires (1.8 m). Bio Amps are only safe for human connection if used with the supplied subject cable and lead wires.
- All Bio Amp front-ends and PowerLab units with a built-in Bio Amp are not defibrillator-protected. Using the Bio Amp to record signals during defibrillator discharges may damage the input stages of the amplifiers. This may result in a safety hazard.
- Never use damaged Bio Amp cables or leads. Damaged cables and leads must always be replaced before any connection to humans is made.

Isolated Stimulator Safety Instructions

The Isolated Stimulator outputs of a front-end signal conditioner or PowerLab with a built-in isolated stimulator are electrically isolated. However, they can produce pulses of up to 100 V at up to 20 mA. Injury can still occur from careless use of these devices. Several points must be observed for safe operation of the Isolated Stimulator:

- The Isolated Stimulator output must only be used with the supplied bar stimulus electrode.
- The Isolated Stimulator output must not be used with individual (physically separate) stimulating electrodes.
- Stimulation must not be applied across the chest or head.
- Do not hold one electrode in each hand.
- Always use a suitable electrode cream or gel and proper skin preparation to ensure a low-impedance electrode contact. Using electrodes without electrode cream can result in burns to the skin or discomfort for the subject.
- Subjects with implantable or external cardiac pacemakers, a cardiac condition, or a history of epileptic episodes must not be subject to electrical stimulation.
- Always commence stimulation at the lowest current setting and slowly increase the current.
- Stop stimulation if the subject experiences pain or discomfort.

- Do not use faulty cables, or those that have exhibited intermittent faults.
- Do not attempt to measure or record the Isolated Stimulator waveform while connected to a subject using a PowerLab input or any other piece of equipment that does not carry the appropriate safety symbol (see Safety Symbols above).

Always check the status indicator on the front panel. It will always flash green each time the stimulator delivers a current pulse. A yellow flash indicates an 'out-of-compliance' (OOC) condition that may be due to the electrode contact drying up. Always ensure that there is good electrode contact at all times. Electrodes that are left on a subject for some time need to be checked for dry contacts. An electrode impedance meter can be used for this task.

- Always be alert for any adverse physiological effects in the subject. At the first sign of a problem, stimulation must be stopped, either from the software or by flicking down the safety switch on the front panel of any built-in Isolated Stimulator or the ML180 Stimulus Isolator.
- The ML180 Stimulus Isolator is supplied with a special transformer plug pack. The plug pack complies with medical safety requirements. Therefore, under no circumstances should any other transformer be used with the Stimulus Isolator. For a replacement transformer plug pack please contact your nearest ADInstruments representative.

General Safety Instructions

To achieve the optimal degree of subject and operator safety, consideration should be given to the following guidelines when setting up a PowerLab system either as stand-alone equipment or when using PowerLab equipment in conjunction with other equipment. Failure to do so may compromise the inherent safety measures designed into PowerLab equipment. The following guidelines are based on principles outlined in the international safety standard IEC60601-1-1: *General requirements for safety - Collateral standard: Safety requirements for medical systems*. Reference to this standard is required when setting up a system for human connection.

PowerLab systems (and many other devices) require the connection of a personal computer for operation. This personal computer should be certified as complying with IEC60950 and should be located outside a 1.8 m radius from the subject (so that the subject cannot touch it while connected to the system). Within this 1.8 m radius, only equipment complying with IEC60601-1 should be present. Connecting a system in this way obviates the provision of additional safety measures and the measurement of leakage currents.

Accompanying documents for each piece of equipment in the system should be thoroughly examined prior to connection of the system.

While it is not possible to cover all arrangements of equipment in a system, some general guidelines for safe use of the equipment are presented below:

- Any electrical equipment which is located within the SUBJECT AREA should be approved to IEC60601-1.
- Only connect those parts of equipment that are marked as an APPLIED PART to the subject. APPLIED PARTS may be recognized by the BF or CF symbols which appear in the Safety Symbols section of these Safety Notes.
- Only CF-rated APPLIED PARTS must be used for direct cardiac connection.
- Never connect parts which are marked as an APPLIED PART to those which are not marked as APPLIED PARTS.
- Do not touch the subject to which the PowerLab (or its peripherals) is connected at the same time as making contact with parts of the PowerLab (or its peripherals) that are not intended for contact to the subject.
- Cleaning and sterilization of equipment should be performed in accordance with manufacturer's instructions. The isolation barrier may be compromised if manufacturer's cleaning instructions are not followed.
- The ambient environment (such as the temperature and relative humidity) of the system should be kept within the manufacturer's specified range or the isolation barrier may be compromised.
- The entry of liquids into equipment may also compromise the isolation barrier. If spillage occurs, the manufacturer of the affected equipment should be contacted before using the equipment.

- Many electrical systems (particularly those in metal enclosures) depend upon the presence of a protective earth for electrical safety. This is generally provided from the power outlet through a power cord, but may also be supplied as a dedicated safety earth conductor. Power cords should never be modified so as to remove the earth connection. The integrity of the protective earth connection between each piece of equipment and the protective earth should be verified regularly by qualified personnel.
- Avoid using multiple portable socket-outlets (such as power boards) where possible as they provide an inherently less safe environment with respect to electrical hazards. Individual connection of each piece of equipment to fixed mains socket-outlets is the preferred means of connection.

If multiple portable socket outlets are used, they are subject to the following constraints:

- They shall not be placed on the floor.
- Additional multiple portable socket outlets or extension cords shall not be connected to the system.
- They shall only be used for supplying power to equipment which is intended to form part of the system.

Cleaning and Sterilization

ADInstruments products may be wiped down with a lint free cloth moistened with industrial methylated spirit. Refer to the manufacturer's guidelines or the Data Card supplied with transducers and accessories for specific cleaning and sterilizing instructions.

Preventative Inspection and Maintenance

PowerLab systems and ADInstruments front-ends are all maintenance-free and do not require periodic calibration or adjustment to ensure safe operation. Internal diagnostic software performs system checks during power up and will report errors if a significant problem is found. There is no need to open the instrument for inspection or maintenance, and doing so within the warranty period will void the warranty.

Your PowerLab system can be periodically checked for basic safety by using an appropriate safety testing device. Tests such as earth leakage, earth bond, insulation resistance, subject leakage and auxiliary currents and power cable integrity can all be performed on the PowerLab system without having to remove the covers. Follow the instructions for the testing device if performing such tests.

If the PowerLab system is found not to comply with such testing you should contact your PowerLab representative to arrange for the equipment to be checked and serviced. Do not attempt to service the device yourself.

Environment

Electronic components are susceptible to corrosive substances and atmospheres, and must be kept away from laboratory chemicals.

Storage Conditions

- Temperature in the range 0–40 °C
- Non-condensing humidity in the range 0–95%.

Operating Conditions

- Temperature in the range 5–35 °C
- Non-condensing humidity in the range 0–90%.

Disposal

- Forward to recycling center or return to manufacturer.

CHAPTER 1

Overview

The Spirometer is a modular device, in a family called front-ends, designed to extend the capabilities of the PowerLab® system. The Spirometer is a precision differential pressure transducer for measurements of respiration flows.

This chapter provides an overview of the Spirometer Front-end, describing its features, and discusses aspects of its use.

How to Use This Guide

This owner's guide describes how to set up and begin using your Spirometer. The chapters give an overview of front-ends in general and the Spirometer in particular, and discuss how to connect the hardware, perform a simple power-up test, and use the front-end with some ADInstruments programs. The appendices provide technical information about the Spirometer, and take a look at some potential problems and their solutions.

At the end of this guide, you'll find an index. Technical terms that are not defined in the glossary of terms included with the owner's guide for your PowerLab, or in the guide that came with your computer, are defined as they appear.

Checking the Front-end

Before connecting the Spirometer to anything, check it carefully for signs of physical damage.

1. Check there are no signs of damage to the outside of the front-end.
2. Check that there is no obvious sign of internal damage, such as rattling. Pick up the front-end, tilt it gently from side to side, and listen for anything that appears to be loose.

If you have found a problem, contact your authorized ADInstruments representative immediately, and describe the problem. Arrangements can be made to replace or repair the front-end.

Front-end Basics

The PowerLab system consists of a recording unit and application programs that run on the computer to which the unit is connected. It is an integrated system of hardware and software designed to record, display, and analyze experimental data. Your Spirometer is one of a family of front-ends meant for use with your PowerLab system.

Front-ends are ancillary devices connected to the PowerLab recording unit to extend the system's capabilities. They provide additional signal conditioning and other features, and extend the types of experiments that you can conduct and the data you can record. All ADInstruments front-ends are designed to be operated under full software control. No knobs, dials or switches are needed, although some may be provided for reasons of convenience or safety.

The PowerLab controls front-ends through an expansion connector called the I^2C (eye-squared-sea) bus. Each additional front-end connects to the previous front-end, in a simple daisy-chain structure, making it very easy to add front-ends to the system or to transfer them between PowerLabs. In general, each front-end requires a positive analog input channel of the PowerLab, although the Stimulus Isolator and similar front-ends require the positive analog output.

Front-ends are automatically recognized by the PowerLab system. Any front-end feature such as gain or filtering is combined with the appropriate features of the program and presented as a single set of software controls. This seamless integration of front-ends greatly increases the flexibility and ease of use of the PowerLab system.

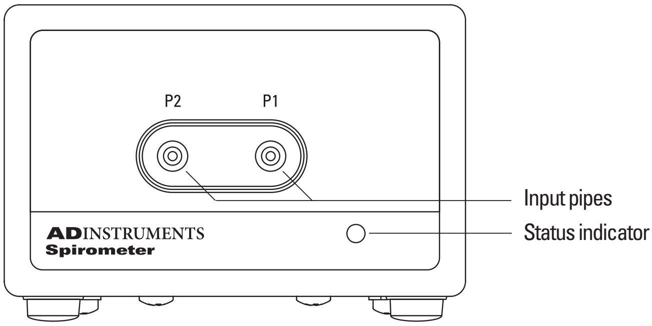
The Front-end

The Spirometer is a precision differential pressure transducer for measuring respiratory variables, such as inspiration and expiration flows and tidal volumes. It measures differential pressure across fine gauze mounted in a flow head. With a flow head of a suitable size, the Spirometer can be used with a variety of creatures, from small animals such as mice and rats, to large animals and humans. Accessories such as flow heads (various sizes), tubing, and calibration syringes are available, and can be purchased separately.

The rest of this chapter contains general information about the features, connections, and indicators of the Spirometer. It also looks at the flow head and its calibration for spirometry. More detailed information can be found in the technical appendices.

The Front Panel

Figure 1–1
The front panel of the Spirometer



The Status Indicator

When an ADInstruments program, such as LabChart, starts up the Status indicator light should flash briefly and then remain green, indicating that the program has found the front-end, checked and selected it, and is ready to use it. If it does not turn on and stay on when the program is run, this indicates either that the front-end is not connected properly or that there is a software or hardware problem.

The Spirometer Input Pipes

WARNING
The Spirometer input is sensitive. Do not blow into or apply high air flows to the Spirometer input, as this may damage the internal transducer

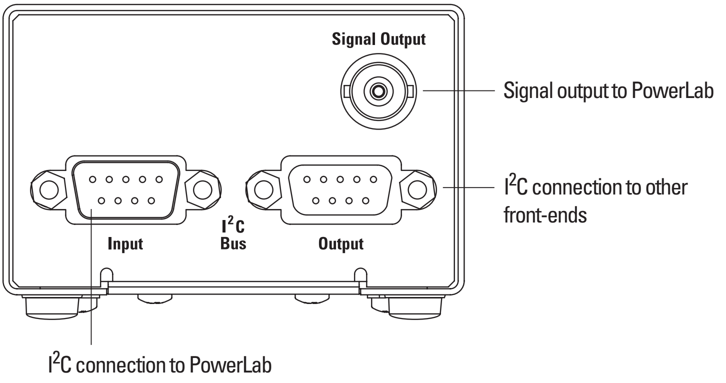
Connections are made to the Spirometer using two pipes on the front panel. These are physical connections for airflow, not electrical ones. Two flexible plastic tubes (3 mm internal diameter, 5 mm external diameter) connect the input pipes on the Spirometer to the connection pipes on the flow head. The input pipes carry a warning symbol (see margin).

The Back Panel

I²C Input and Output Sockets

Two nine-pin sockets are used to communicate with the PowerLab (they are marked 'I²C Bus': a 'bus' is simply information-transmission circuitry such as cables and connectors). These sockets, in conjunction with the proper cables, allow multiple front-ends to be used independently with one PowerLab. Power and control signals to connected front-ends come from the PowerLab. ADInstruments front-ends are connected to each other in series, output to input (discussed in more detail in the next chapter).

Figure 1–2
The back panel of the Spirometer



The Analog Out Socket

The Signal Output provides the signal to an analog input socket on the front of the PowerLab. A BNC-to-BNC cable is supplied for this connection. If you are using a PowerLab with differential inputs, only connect the cable to a positive input. ADInstruments applications will not find the front-end on start up if a negative input is used.

Equipment and Technique

Using the Spirometer

The ADInstruments Spirometer and an attached flow head together function as a pneumotachometer, with an output signal proportional to the airflow during breathing. Airflow is measured by means of a pressure differential across a fine wire mesh inside the flow head. This works on the principle that air flowing through an orifice of fixed cross-section produces a pressure difference across the mesh proportional to the air's velocity — within certain limits. The greater the velocity of the air (that is, the higher the flow), the larger the pressure difference.

The flow head itself contains no electronic parts, and is simply a tube with a wire mesh placed across it. Two pipes, one on either side of the mesh, allow the pressure difference to be measured by a high-precision differential pressure transducer in the Spirometer itself, when connected with plastic tubing.

The Spirometer can support several sizes of flow head, each with differing maximum flows, but all with the same connection to the Spirometer. Standard flow heads, obtainable separately, are:

- MLT1L Respiratory Flow Head, 1 L/min, suitable for mice
- MLT10L Respiratory Flow Head, 10 L/min, suitable for rats
- MLT300L Respiratory Flow Head, 300 L/min, suitable for adult humans at rest
- MLT3813H Heated Pneumotach, 800 L/min, suitable for adult humans during exercise
- MLT1000L Respiratory Flow Head, 1000 L/min, suitable for adult humans during exercise.

Fitting the Flow Head

To connect the flow head to the Spirometer, simply push the ends of the two connection tubes firmly over the flow head pipes and over the input pipes on the front panel of the Spirometer. In some cases you may find that the tubes are difficult to fit because they are too tight. If so, dip the ends of the tubes into some boiling water to soften the plastic to make it easier to push the tubes onto the pipes.

Any leakage from the joint will affect the precision of the flow readings, so ensure that the tubes are pushed on firmly. The flow head is washable and able to be cold-sterilized, and should be dried gently before use. Care should be taken to ensure that condensation does not block the tubing connecting the flow head to the Spirometer. To avoid problems, the flow head should be turned so that the tubing connects at the top, not at the bottom.

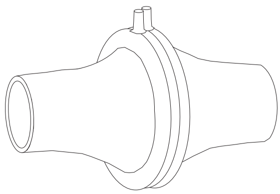


Figure 1–3
A flow head, with the pipes in the correct position: upright

More elaborate setups are possible. In human respiration, disposable mouthpieces and filters would be usual, to prevent contamination, and minimize drift due to moisture (the filter helps remove droplets). For humans during exercise, the flow head could be fixed in position, perhaps attached to a stand, and connected to a mouthpiece and filter by a length of wide-bore flexible tubing, to allow the subject to exercise freely. To obtain useful results with any method of spirometry, all the air breathed by the subject must be measured. A nose clip prevents inadvertent nasal breathing. With a little practice, the subject can prevent air leaks around the mouthpiece.

ADInstruments supplies suitable accessories separately:

- MLA140 Spirometer kit (containing each item below)
- MLA1026 Pack of 10 vinyl disposable mouthpieces
- MLA1008 Pack of 50 foam-tipped disposable nose clips
- MLA304 Pack of 50 disposable droplet filters
- MLA1011A Clean bore tubing, 250 mm long by 35 mm i.d.

Calibrating the Flow Head

Before using the flow head, you will probably want to calibrate the Spirometer to read in terms of flow (L/s rather than V). There are two ways of doing this: using an approximate conversion factor, or injecting a known volume and integrating. The Spirometry Extension for LabChart (available on both Windows and Macintosh platforms) can be used to assist with either of these methods.

Using an approximate conversion factor. You can use an approximate conversion value for converting the voltage signal to L/s. For the MLT1000L Flow Head, the linear conversion is given approximately by 0 V = 0 L/s; 1 V = 40.1 L/s. You apply this conversion in the Units Conversion dialog, opened from the Channel Function pop-up menu.

Injecting a known volume and integrating. You can determine an accurate conversion value for your particular flow head by injecting a known volume of air through the breathing circuit and integrating the flow signal in LabChart. This section describes the procedure in detail.

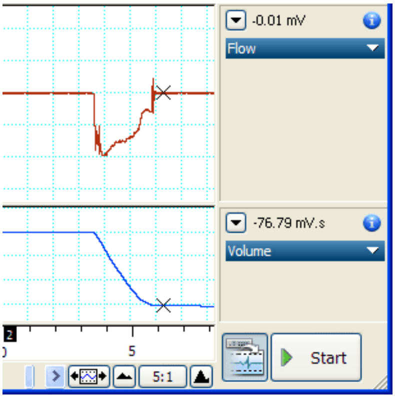
ADInstruments has calibration syringes available for this purpose, such as the a 3-liter MLA5530 calibration syringe. Try to depress the plunger at a steady rate, neither too quickly or too slowly, and try not to bring the plunger to an abrupt stop at the end of the syringe.

Connect the Spirometer to an input on the PowerLab. Set up that input channel using the Channel Settings dialog: change the channel name to 'Flow' and click **Spirometer**… in the Input Settings column to display the Spirometer dialog. You can then set the range to a suitable value, such as 500 mV or 200 mV, and click **Zero** to zero the flow head signal. You should always do this before you start recording.

Set up a new channel for Volume from the Channel Settings dialog. Display the integral of the flow signal in this channel by choosing **Integral**… from the Channel Function pop-up menu and selecting **Flow** as the source channel, using a standard integral with no reset.

Injections can now be recorded and integrated using the spirometer (flow) and volume channels. Making a single injection should produce a trace similar to that shown in Figure 1–4 – a 3 L calibration syringe was used to simulate a single expiration. The absolute value of the integral at the cursor position is 76.79 mV.s. This corresponds to a flow head correction factor of 39.1 L/s/V, obtained by dividing the syringe volume by the integral value (converted to V.s).

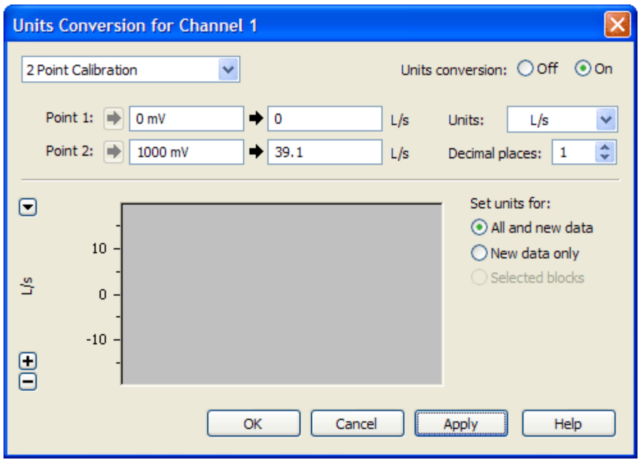
Figure 1–4
The flow signal integrated for a single injection. The value of the integral at the cursor position is –76.79 mV.s



$$\frac{3\ \text{L}}{0.07679\ \text{V.s}} = 39.1\ \text{L/s/V}$$

The correction factor is applied in the Units Conversion dialog (0 V = 0 L/s; 1 V = 39.1 L/s).

Figure 1–5
Setting units to calibrate the Spirometer channel



Using the Spirometry Extension. The Spirometry Extension for LabChart (for either the Windows or Macintosh platforms) is available from the ADInstruments website and can be used to perform the units conversion required for the Spirometer channel, using either an approximate conversion value or a value calculated by integrating the injection of a known volume. The extension adds an item called **Spirometry Flow...** to the Channel Function pop-up menu.

Full details on using the Spirometry Extension can be found in the *Spirometry Extension User's Guide* (Macintosh) which is installed with the software, or in the Help Center (Windows).

Reducing Drift

The Spirometer is subject to drift for various reasons. There are a number of ways to reduce this. Zeroing the Spirometer immediately before use is an essential step in the setup procedure. Zeroing ensures that the recorded flow signal is zero when there is no airflow, and thereby prevents steady drift of the integrated volume trace.

Internal drift in the Spirometer's electronics is minimized if you leave the PowerLab unit and Spirometer turned on for 15 minutes or so, before zeroing and use. We recommend placing the Spirometer beside the PowerLab unit, or on a shelf above, to avoid its being affected by heat from the power supply.

Expired volume is greater than inspired volume in most atmospheric conditions. The increase, due to warming and humidification, is typically 5–10%. For this reason there may be 'breath-dependent drift' of an integrated (volume) trace even when the Spirometer is correctly zeroed. Non-ideal distribution of air flow across the flow head's mesh screen may also contribute to breath-dependent drift. This component of drift is minimized by use of disposable droplet filters.

Finally, if you are using the Spirometry Extension, you can apply drift correction after recording, provided that your recording meets certain conditions. For more details on drift correction, please refer to the *Spirometry Extension User's Guide* (Macintosh) or the Help Center (Windows).

CHAPTER 2

Setting Up

This chapter describes connecting the Spirometer to your PowerLab and performing a quick test to make sure that it is working properly. The best way to configure your system for one or more front-ends is discussed, along with how to use the front-end with ADInstruments software.

Connecting to the PowerLab

To connect a front-end to the PowerLab, first ensure that the PowerLab is turned off. Failure to do this may damage the PowerLab, the front-end, or both.

Connect the Signal Output on the rear panel of the Spirometer to an analog input on the front panel of the PowerLab using a BNC cable. If the PowerLab has differential inputs (+ and – channels), rather than single-ended inputs, then you must connect the BNC cable to one of the positive analog input channels. PowerLab applications will not find the front-end on starting up if a negative input is used.

Single Front-ends

Connect the I^2C output of the PowerLab to the I^2C input of the front-end using the I^2C cable provided.

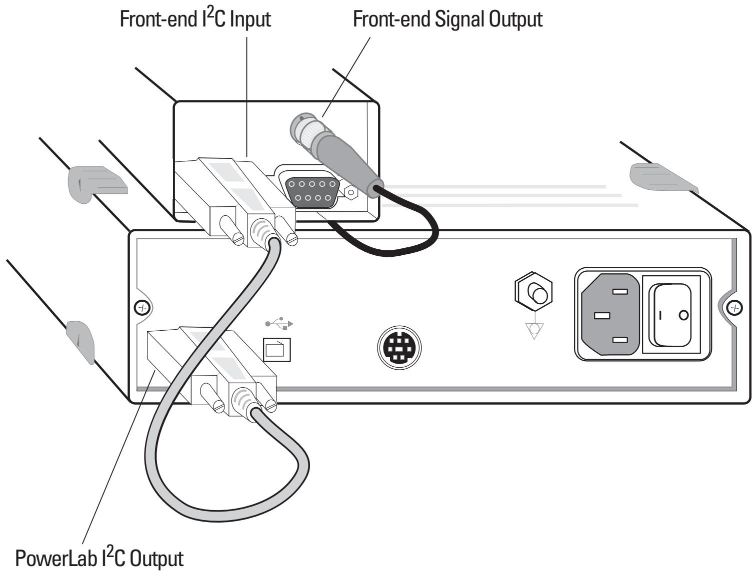


Figure 2–1
Connecting a front-end to the PowerLab: a PowerLab has only one I^2C output, and each front-end has one I^2C output and one I^2C input

Check that the plugs for the I^2C bus are screwed in firmly. Check the BNC cable for firm connections as well. Loose connectors can cause erratic front-end behavior, or may cause the front-end to fail to work at all. The BNC cable can be tucked under the front-end to keep it out of the way if desired.

Multiple Front-ends

Multiple front-ends can be connected up to a PowerLab; up to sixteen, depending on the number of positive inputs sockets on the PowerLab. The first front-end is connected with the I^2C cable as in Figure 2–1. The remainder are daisy-chained via I^2C cables, connecting the I^2C Output of the previous connected front-end to the I^2C Input of the next front-end to be added. The BNC cable for each front-end is connected to one of the positive analog inputs of the PowerLab.

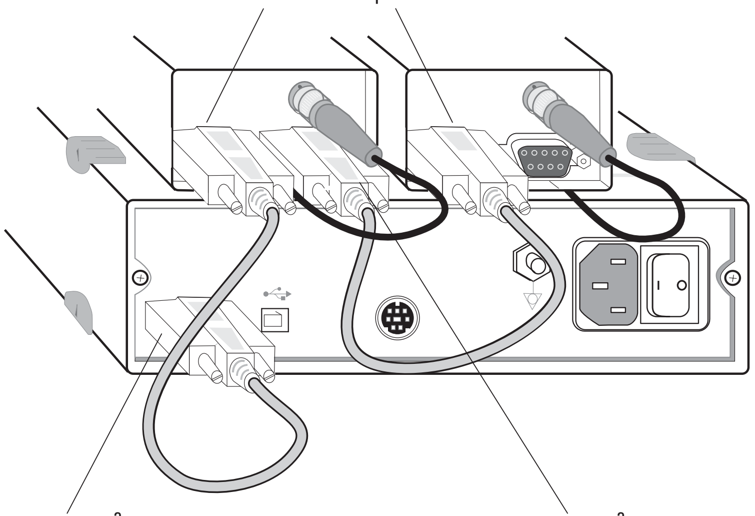


Figure 2–2
Connecting multiple front-ends to the PowerLab (two single front-ends shown for simplicity)

Using LabChart and Scope

Front-ends are used with PowerLabs and ADInstruments programs such as LabChart and Scope. The combined amplification and filtering of the Spirometer, the PowerLab and the program and presented as a single set of software controls.

When the Spirometer is connected to a channel and successfully installed, the **Input Amplifier**... menu command from the Channel Function pop-up menu in LabChart is replaced by the **Spirometer**... menu command. In Scope, the **Input Amplifier**... button in the Input A (or Input B) panel is replaced by the **Spirometer**... button. The LabChart Help Center and *Scope User's Guide* have details on the Input Amplifier dialog, and explain some of the software terms used here.

If the application fails to find a front-end attached, the normal text remains. If you were expecting a connected front-end, close the program, turn the PowerLab off and check the connections. Then restart the PowerLab and program. Note: do not leave the PowerLab on while checking the connections, as doing so may damage the PowerLab, the front-end, or both.

Choosing the **Spirometer**… menu command or clicking the button will open the Spirometer dialog. Only the Spirometer dialog for LabChart is described here, but the Spirometer dialog for Scope is similar.

The Front-end Driver

There are several front-end drivers for the various front-ends made by ADInstruments (a driver is a piece of software the computer uses to control a peripheral device). For example the Bridge Amplifier front-end driver is used with the Spirometer and GP Amp; and the Stimulus Isolator front-end driver is used with the Stimulus Isolator.

In order for the Spirometer to be recognized by PowerLab software, the Bridge Amplifier front-end driver must be present. It should have been installed when the LabChart and Scope applications were installed on your computer. If it is not present, then you may need to reinstall the software or obtain a software update.

Front-end Self-test

Once the Spirometer is properly connected to the PowerLab, and the proper software is installed on the computer, a quick check can be performed on the front-end. To perform the self-test:

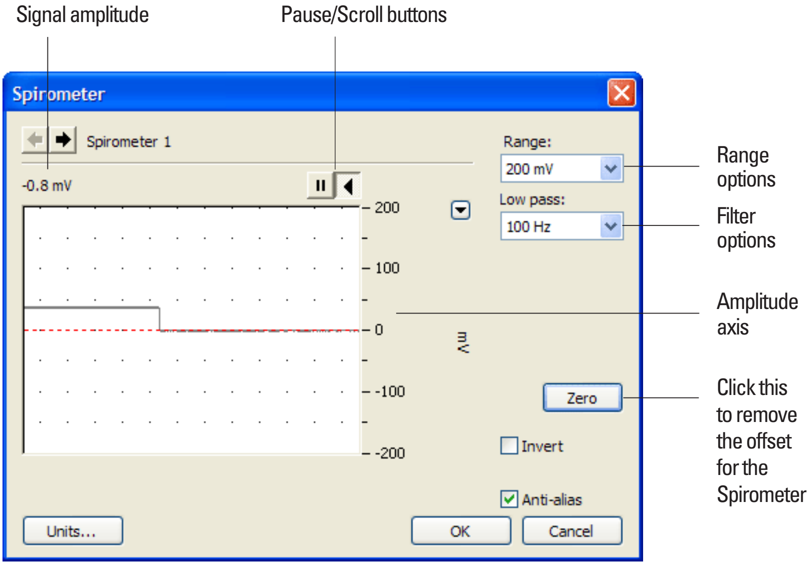
1. Turn on the PowerLab and check that it is working properly, as described in the owner's guide that was supplied with it.
2. Once the PowerLab is ready, open either LabChart or Scope. While the program is opening, keep a close eye on the Status indicator for the Spirometer (at the bottom right of the front panel). During initialization, you should see the indicator flash briefly and then remain lit.

If the indicator lights correctly, the front-end has been found by the PowerLab and is working properly, and you can close the application or carry on as appropriate. If the indicator doesn't light, check your cable connections and repeat the procedure. If this does not solve the problem, contact your ADInstruments representative.

The Spirometer

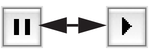
The Spirometer dialog allows software control of the combined filters and other circuitry in the PowerLab and Spirometer. Change settings in the dialog, then click **OK** to apply them. To set up many channels quickly, click the arrows by the dialog title, or press the right or left arrow keys on the keyboard, to move to the equivalent dialogs for adjacent channels. This skips channels that are turned off. The channel number is shown next to the arrows, and the channel title or axis label (if any) is shown along the vertical Amplitude axis.

Figure 2–3
The Spirometer dialog (LabChart for Windows; the Macintosh and Scope versions are similar)



Signal Display

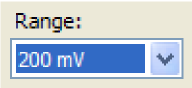
The signal at the channel input is displayed so you can see the effect of changing the settings – data is not recorded while setting things up. Slowly changing signals are represented quite accurately, whereas quickly changing signals are displayed as a solid dark area showing only the envelope (shape) of the signal from minimum and maximum recorded values. The average signal value is displayed at the top of the display area: the offset is displayed when the Spirometer is not zeroed, and may indicate a problem if it is large.



You can stop the signal scrolling by clicking the Pause button at the bottom left (Macintosh) or top right (Windows) of the data display area. This changes to the Scroll button on the Macintosh. Click the Scroll button to start scrolling again.

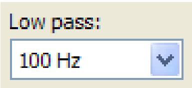
Shift and stretch the vertical Amplitude axis, by clicking and dragging it in various ways, to make the best use of the available display area. It functions the same as the Amplitude axis of the Chart Window, controls are identical and any change is applied to the Chart Window.

Setting the Range



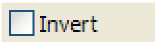
The **Range** pop-up menu lets you select the input range or sensitivity of the channel. Changing the range in the Spirometer dialog is equivalent to changing it in the Chart or Scope window. The available ranges are 500 mV, 200 mV, 100 mV, 50 mV and 20 mV.

Filtering



The **Low Pass** pop-up menu gives a choice of 1, 10 and 100 Hz low-pass filters. These filters are appropriate for the built-in pressure transducer in the Spirometer and help to eliminate high-frequency components, such as noise, from the input signal.

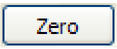
Inverting the Signal



Click the **Invert** checkbox to invert the signal displayed on screen. It provides a simple way to change the polarity of the recorded signal without having to swap the tubes on the Spirometer or flow head. For example, you might be recording an experiment where expiration gives a positive signal, but you want the expired air to give a negative signal on the screen. The Invert checkbox would change the display.

Offset Adjustment

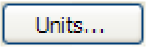
The Spirometer is effectively a pressure transducer and amplifier, transducing flow into voltage. Transducers almost always produce some amount of signal, usually small, when at equilibrium or rest. The signal value above the display area shows this offset – if it is large, it may indicate a problem. Offsets from a zero reading need to be removed, in a process called zeroing. Commonly, you may also wants to remove a constant term from the measurement of interest. This enables more accurate measurement of the changes in the signal under stimulus.



Zeroing. To perform automatic zeroing, click **Zero**: the program works out a corrective DC voltage that cancels, as closely as possible, the transducer output voltage. Auto-zeroing takes a few seconds to work out the best zeroing value at all ranges.

Note: variations in the transducer signal during the auto-zeroing operation will cause the software to fail to zero the offset properly, if it zeroes at all; make sure the Spirometer and flow head are kept still and that there is no airflow during the auto-zeroing.

Units



Click **Units**... to open the Units Conversion dialog, with which you can set the units for a channel and, using waveform measurements, calibrate the channel. The waveform in the data display area of the Spirometer dialog is transferred to the data display area of the Units Conversion dialog. (Use the Pause button to capture a specific signal.) This units conversion only applies to subsequently recorded signals, so it is more limited than choosing **Units Conversion**... from the Channel Function pop-up menu, as it does not allow the conversion of individual blocks or pages of data.

APPENDIX

A Technical Aspects

This appendix describes some of the important technical aspects of the Spirometer to give some insight into how it works. You do not need to know the material here to use a front-end. It is likely to be of especial interest to the technically minded, indicating what a front-end can and cannot do, and its suitability for particular purposes. (You should not use it as a service manual: user modification of the equipment voids your rights under warranty.)

The Spirometer and other ADInstruments front-ends have been designed to integrate fully into the PowerLab system. Each requires connection to the PowerLab via a special communications connector called the I^2C (eye-squared-sea) bus, and a BNC connector.

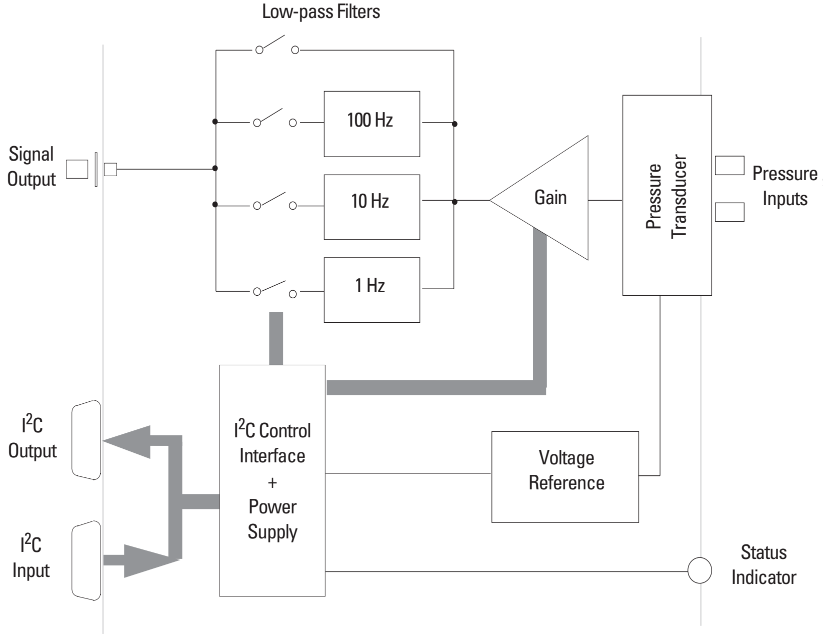
Spirometer Operation

The Spirometer is essentially an extension of the PowerLab's analog input. The Spirometer provides:

- a precision differential pressure input used to determine flow rates using an attached flow head
- the additional amplification necessary to deal with a variety of flow rates, from fractions of a liter per minute (mice and rats) to a thousand liters per minute (adult humans during exercise)
- additional programmable filtering to remove unwanted signal frequencies
- digitally controlled zeroing circuitry, for offset removal of unwanted constant flow rates, for instance, to measure volume accurately when using computed integration.

The internal functions of the Spirometer are controlled from the PowerLab through the I^2C bus, which also supplies power to the Spirometer. The front-end is also connected to an analog input channel of the PowerLab via a BNC-to-BNC cable, through which the pressure signal from the flow head is sent. The overall operation of the Spirometer can be better understood by referring to Figure A–1.

Figure A–1
Block diagram of the Spirometer



The Spirometer and an attached flow head together function as a pneumotachometer, with an output signal proportional to the airflow rate during breathing. Expired or inspired air has to pass through a very fine wire mesh in the attached flow head. This creates a pressure differential between the two sides of the mesh proportional to the flow rate or velocity of the air passing through the flow head. The input of the Spirometer is a differential pressure transducer that converts the differential pressure in the flow head into an analogous voltage. This output voltage is in turn fed into a programmable gain amplifier, which provides additional signal amplification. The output of the amplifier is passed through a set of software-selectable, fourth-order, low-pass filters. The signal is then sent to the PowerLab.

To remove any offsets caused by its pressure transducer or a signal baseline, the Spirometer uses a DC offset circuit consisting of a 12-bit DAC (digital-to-analog converter) that is internally connected to the input stage when in the DC coupling mode.

Zeroing of offsets is achieved by applying a corrective DC voltage to the input stage via the DAC, under software control. Since the DAC is only capable of producing corrective voltages in ‘steps’, a facility to set the offset range is provided to decrease the size of these steps and make the zeroing circuit more sensitive, especially at the higher range settings.

APPENDIX

B Troubleshooting

This appendix describes most of the common problems that can occur when using the Spirometer with your PowerLab recording unit. It covers how these problems are caused, and what you can do to alleviate them. If the solutions here do not work, earlier chapters, the LabChart Help Center, and the guide to your PowerLab may contain possible solutions. If none of the solutions here or elsewhere are of help, then consult your ADInstruments representative.

Most of the problems that users encounter are connection problems, and can usually be fixed by checking connections and starting up the hardware and software again. Very rarely will there be an actual problem with the front-end or the PowerLab itself.

Problems and Solutions

The status indicators fail to light when the software is started, or the front-end commands and so on do not appear where they should

The I^2C cable or the BNC-to-BNC cable from the front-end to the PowerLab is not connected, has been connected incorrectly (to the wrong input or output, for instance), or is loose.

- Turn everything off. Check to see that all cables are firmly seated and screwed in. The BNC cable from the Signal Output of the Spirometer must be connected to a positive input on the PowerLab. Make sure the input is the same channel from which you expect to use the front-end in the software. Start up again to see if this has fixed the problem.

You are using an early version of LabChart or Scope.

- Upgrade to the latest version of the software. Contact your ADInstruments representative for information.

The BNC or I^2C cable is faulty.

- Replace the cable and try again. Immediately label all cables proved faulty so that you don't use them again by accident.

The front-end is faulty.

- This is the least likely event. If the front-end will not work properly after the previous measures, then try using it on another PowerLab. If the same problems recur with a second PowerLab, the front-end may be faulty. Contact your ADInstruments representative to arrange for repairs.

On starting up the software, an alert indicates that there is a problem with the front-end or driver

The correct Bridge driver is not installed on your computer.

- Reinstall the software.

You are using an early version of LabChart or Scope.

- Upgrade to the latest version of the software. Contact your ADInstruments representative for information.

The BNC or I^{2}C cable is faulty.

- Replace the cable and try again. Immediately label all cables proved faulty so that you don't use them again by accident.

The front-end is faulty.

- This is the least likely event. If the front-end will not work properly after the previous measures, then try using it on another PowerLab. If the same problems recur with a second PowerLab, the front-end may be faulty. Contact your ADInstruments representative to arrange for repairs.

Some software settings don't resemble those in this guide

You are using an early version of the front-end driver, or of LabChart or Scope. Some changes may have been made since then.

- Upgrade to the latest version of the software. Contact your ADInstruments representative for information.

The trace will not zero properly when using the automatic or manual zeroing controls

Variations in the signal during auto-zeroing may cause the software to fail to zero the offset properly, if it zeroes at all.

- Make sure that the apparatus is kept still and that no varying signal is applied during auto-zeroing.

The signal from the flow head is beyond the range of the Spirometer's zeroing circuitry.

- You may need to use another, more suitable, flow head.

The signal is noisy at lower ranges

This is usually the amplified noise from the transducer and its associated circuitry, not a fault as such.

- Set the low-pass filter to remove the noise.

The signal recorded by the Spirometer is weak even at lower ranges

The tubing connection to the flow head may be leaking, or there is condensation in the tubing or on the gauze of the flow head.

- Check the connection and try again.

- Ensure that both the tubing and gauze is clean and is free from condensation, otherwise dry it. Make sure that the flow head is used with the tubes upwards.

APPENDIX

C Specifications

Input

Connection type:	Two pipes for airflow physically connected by plastic tubes to the flow head
Input configuration:	Differential pressure input, ±1″ (2.5 cm) H_2O (1.9 mmHg, 249 Pa)
Amplification ranges:	±20 mV to ±500 mV full scale in 5 steps (combined PowerLab and Spirometer)

Volts	inches H_2O	Resolution
± 500 mV	±1	±15.6 μV
± 200 mV	±0.4	±6.25 μV
± 100 mV	±0.2	±3.125 μV
± 50 mV	±0.1	±1.56 μV
± 20 mV	±0.04	±0.625 μV

Maximum input pressure:	± 28.1″ H_2O (7 kPa)
Pressure sensitivity:	0.5 V per inch (1.27 V per cm) H_2O
Temperature drift:	0.05% of full scale per °C
Warm-up time:	~ 2 minutes
Max zero pressure offset:	< 1% full scale, software removable
Zero offset correction:	Software removed (up to ±10% full scale)
Response time:	1 ms (10–90% full scale)
Linearity:	± 0.5% full scale

Repeatability:	± 0.25% full scale
Long term stability:	± 0.5% full scale
Amplifier noise:	< 150 µV rms @ 100 Hz < 50 µV rms @ 10 Hz < 35 µV rms @ 1 Hz

Filters

Low-pass filtering:	1, 10 or 100 Hz (software-selectable) using fourth-order Bessel filter

Control Port

I^2C port:	Provides control and power. Interface communications rate of ~50 kbits/s.

Physical Configuration

Dimensions (h × w × d):	50 mm × 76 mm × 260 mm (1.96" × 3.0" × 10.2")
Weight:	800 g (1 lb 12 oz)
Power requirements:	1.5 W
Operating conditions:	5–35 °C, 0–90% humidity (non-condensing)

ADInstruments reserves the right to alter these specifications at any time.

Index

T

U

Z