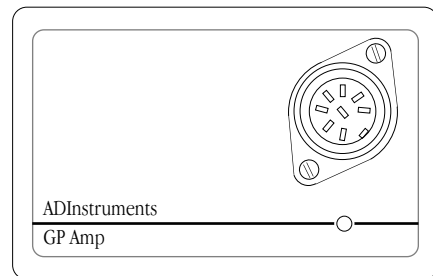
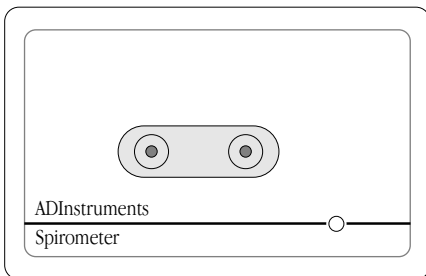


AD Instruments

# Spirometer, GP Amp Owner's Guide



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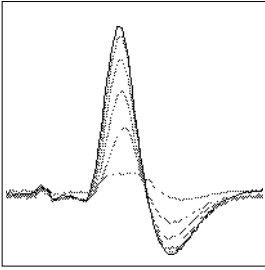
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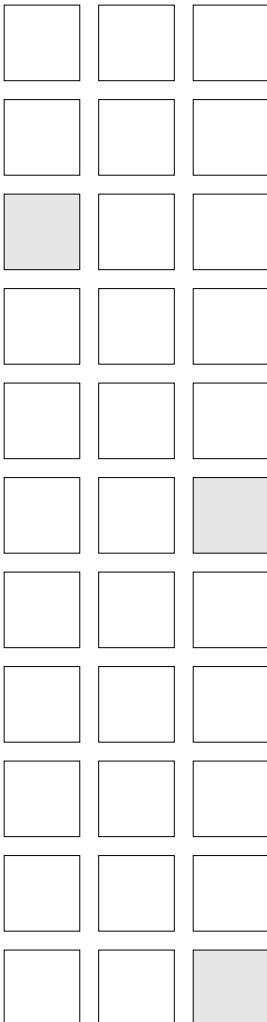
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# 1

## C H A P T E R O N E

# Overview



The Spirometer and GP Amp are two of a family of modular devices called front-ends, designed to extend the capabilities of the PowerLab system. The Spirometer is a precision differential pressure transducer for measurements of respiration flow rates. The GP Amp is a general-purpose, differential amplifier with high input impedance that can be used to measure a variety of signals.

This chapter provides an overview of the front-ends, describing their basic features, and discusses some aspects of their use.

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# How to Use this Guide

This owner's guide describes how to set up and begin using your Spirometer or GP Amp. The chapters give an overview of front-ends in general and the Spirometer and GP Amp 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 appendixes provide technical information about the front-ends, and take a look at some potential problems and their solutions.

Toward the end of this guide, you'll find an index and warranty information. 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 or GP Amp to anything, check it carefully for signs of physical damage.

1. Check that there are no obvious signs of damage to the outside of the front-end casing.
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 authorised ADInstruments distributor immediately, and describe the problem. Arrangements can be made to replace or repair the front-end.

## Front-End Fundamentals

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 analyse experimental data. Your Spirometer or GP Amp is one of a family of front-ends meant for use with your PowerLab system.

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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<sup>2</sup>C (eye-squared-sea) bus. Each new front-end added to the system connects to the back of the previous front-end, in a simple daisy-chain structure. This makes 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 (as do the Spirometer and GP Amp), although the Stimulus Isolator and similar front-ends use the positive analog output of the PowerLab.

Front-ends are automatically recognised 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 flow rates 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.

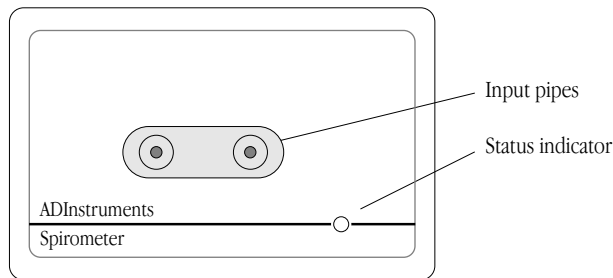
The GP Amp is a general-purpose, differential amplifier with high input impedance, that can be used to measure a variety of signals, or to connect to transducers requiring high input impedances. It is also capable of providing power to a transducer, if necessary.

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

## The Front Panel

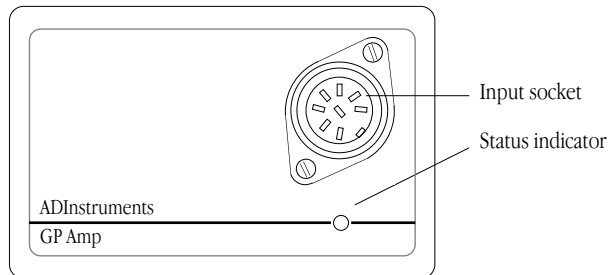
The front panel of the Spirometer is simple, with two input pipes and a small indicator light.

**Figure 1–1**  
The front panel of the Spirometer



The front panel of the GP Amp is simple, with one input socket for a DIN transducer connection and a small indicator light.

**Figure 1–2**  
The front panel of the GP Amp



## The Status Indicator

The Status indicator light of each of these front-ends is located at the bottom right of the front panel. When an ADInstruments program such as Chart starts up, the Status indicator 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 a Status indicator 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

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) attach to the connection pipes on the Spirometer, and at the other end, to the connection pipes on the flow head. The connection is discussed in more detail later.

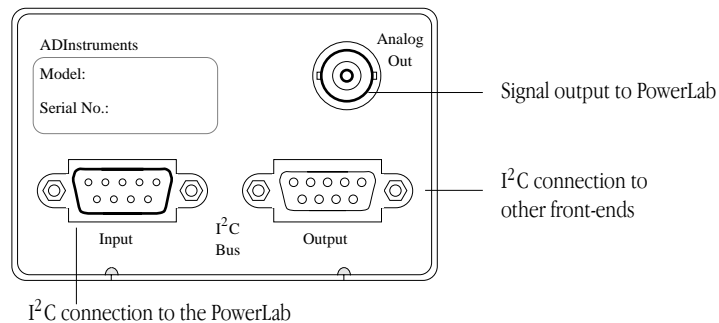
## The GP Amp Input Socket

Transducers are connected to a GP Amp using the eight-pin DIN socket on the front panel. The connector provides terminals for supplying a transducer with power and for measuring the transducer output. The GP Amp is supplied with a DIN plug kit that can be fitted to a transducer that lacks a DIN connection. The connection is discussed in more detail later.

## The Back Panel

The back panels of the Spirometer and GP Amp are much the same, and provide all the sockets required to connect the front-end to the PowerLab and to other front-ends.

**Figure 1–3**  
The back panel of the  
Spirometer and GP Amp



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## **I<sup>2</sup>C Input and Output Sockets**

Two nine-pin sockets are used to communicate with the PowerLab (they are marked 'I<sup>2</sup>C 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 (this is discussed in more detail in the next chapter).

### **The Analog Out Socket**

The BNC socket labelled Analog Out on the back panel provides the signal output to connect 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, remember to connect the cable only to a positive analog input. ADInstruments applications will not find the front-end on starting 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 rate 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 rate), 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.

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

- MLT 1L Respiratory Flow Head, 1 L/min, suitable for mice
- MLT 10L Respiratory Flow Head, 10 L/min, suitable for rats
- MLT 300L Respiratory Flow Head, 300 L/min, suitable for adult humans at rest
- MLT 3813 Heated Flow Head, 800 L/min, suitable for adult humans during exercise
- MLT 1000L Respiratory Flow Head, 1000 L/min, suitable for adult humans during exercise.

### Fitting the Flow Head

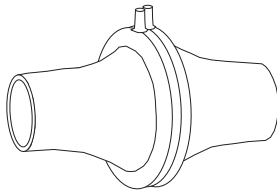
To connect the flow head to the Spirometer, simply push the ends of the two connection tubes firmly over the flow head pipes and over the input pipes on the front panel of the Spirometer. In some cases you may find that the tubes are difficult to fit because they are too tight. If so, dip the ends of 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 rate readings, so ensure that the tubes are pushed on firmly. The flow head is washable and able to be cold-sterilised, 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 1–4**

A flow head, with the pipes in the correct position, upright



More elaborate set-ups are possible. In human respiration, disposable mouthpieces and filters would be usual, to prevent contamination, and minimise drift due to moisture (the filter helps remove droplets). For humans during exercise, the flow head could be fixed in position,

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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:

- MLA 140 Spirometer kit (containing each item below)
- MLA 1026 Pack of 10 vinyl disposable mouthpieces
- MLA 1008 Pack of 50 foam-tipped disposable nose clips
- MLA 304 Pack of 50 disposable droplet filters
- MLA 1011 Clean bore tubing, 250 mm long by 35 mm i.d.

## Calibrating the Flow Head

Before using the flow head, you may want to calibrate the Spirometer to read in terms of flow rate (L/s rather than V). This can be done directly, by using known flow rates, or indirectly, by using a known volume of air, integrating the signal, and inferring the calibration.

At first sight, calibrating directly to a flow rate may seem simpler and more straightforward. In fact, it is difficult in practice, and requires special, often elaborate, equipment, such as a conventional 'bell spirometer', weighted at the top so that it expels air at a constant rate. The air expelled is fed through the flow head and the equipment calibrated accordingly. You could also use a device like a pump that has a known flow rate.

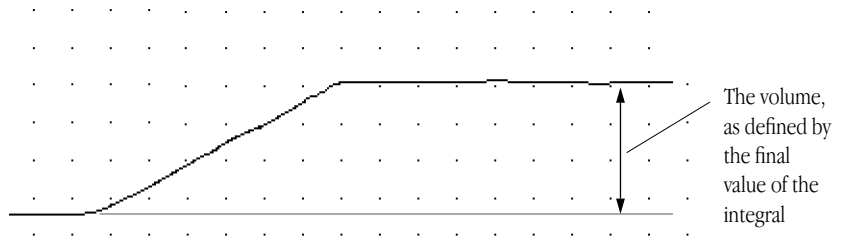
Indirect calibration using volume, however, is reliable, usual, and recommended. A syringe of known volume is one of the easiest ways to calibrate the flow head measurements. To calibrate the Spirometer channel in this way, you should use a syringe of known volume to force air through the flow head at a steady rate, and integrate the results (use the 'Integral' computed function). ADInstruments has calibration syringes available for this purpose, such as the a 3-litre MLA 5530 calibration syringe. The Spirometer will need to be zeroed before measuring the integration. Zeroing and the use of the software are discussed in more detail later.

If the flow rate is constant, you should see a straight line increasing with time as the air is injected (Figure 1–5). In fact, it doesn't matter if

the flow rate varies a little, since the end result depends only on total volume passed through the flow head. If the flow rate exceeds the capacity of the flow head, though, or is so slow as to allow drift to occur, the measurement will be inaccurate. Either is unlikely as long as the syringe plunger is depressed steadily. The point at which the flow stops should represent the volume of air in the syringe. After measuring the integration from a known volume, you can then calibrate the channel by using units conversion.

**Figure 1–5**

Calibrating to a volume using the Integral computed function



The recommended approach for calibration is, in the first place, to set the Spirometer range to a suitable value, such as 500 mV or 1 V. By trial and error, find a suitable Computed Input range for the integral, such that the integrated signal after injection does not reach the limit (which would reset it to zero). After passing a known volume 'x' litres (L) through the flow head, measure the integral 'y' (in V.s). Then the flow calibration factor can then be calculated as:

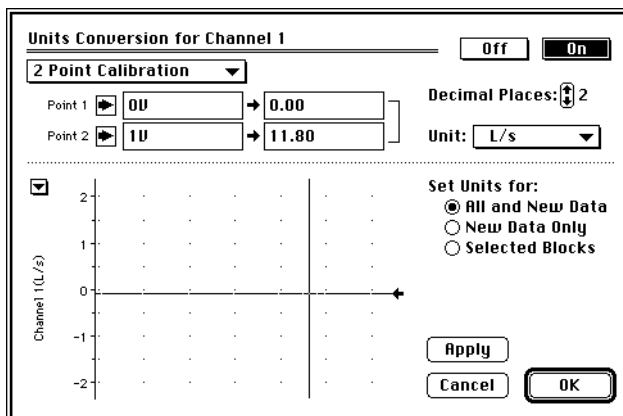
$$1 \text{ volt} \rightarrow x/y \text{ litres per second}$$

The Units Conversion dialog box for the Spirometer channel should be set up to use 2 Point Calibration, and units of L/s (litres per second) defined. The value of zero for zero volts should be entered in the Point 1 row, and the value of x/y for one volt should be entered in the Point 2 row, as shown in Figure 1–6.

Typical x/y values for the MLT300L and MLT1000L flow heads, say, would be about 12 and 40 respectively. Be sure to type the 'V' of '1V' for Point 2 or (depending on the current range setting) it may be misinterpreted as 1 mV, with bizarre results. For the same reason, if the value of y was measured in mV.s, be sure to convert it to V.s (by dividing by 1000). It is always a good idea to check the range settings and units carefully.

**Figure 1–6**

Setting units to calibrate the Spirometer channel



## Correcting for 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 set-up 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 minimised if you leave the PowerLab data acquisition 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 minimised by use of disposable droplet filters.

## Using Transducers with the GP Amp

The GP Amp was designed to allow the PowerLab to connect to transducers that require a high input impedance, including solid-state and piezoelectric transducers. It is capable of supporting various

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powered transducers, if necessary. The GP Amp amplifies the signal from a transducer so it can be used by the PowerLab, and provides power, offsetting, and filtering capabilities. Transducers vary a lot in sensitivity and suitability, so you should read the material on using transducers before connecting a transducer to a GP Amp.

Note that the GP Amp and the Bridge Amp are used with different transducers, and the two should not be substituted for each other. (The Bridge Amp also uses a special amplifier stage to minimise DC drift of the signal with time; the GP Amp does not have this stage.)

## Suitable Transducers

The GP Amp has been designed to connect to transducers that require a high input impedance.

**pH Electrodes.** These electrodes require an amplifier with a high input impedance. The GP Amp is suitable for these transducers, provided that the transducer is carefully shielded, and short, shielded cables are used to connect it to the GP Amp.

**Piezoelectric.** These transducers typically need amplifiers with input impedances of tens of megohms. The GP Amp is suitable for these transducers, provided that the transducer is carefully shielded, and short, shielded cables are used to connect it to the GP Amp.

**Solid State.** These transducers require DC excitation to function correctly. They include semiconductor temperature probes, light meters, and Hall-effect displacement transducers. Transducers with outputs up to  $\pm 10$  V can be used with the GP Amp.

**Transducers with head-stage amplifiers.** These transducers have a built-in amplifier to provide signal conditioning, and invariably use it as a high-impedance interface as close as possible to the electrodes or transducer. They can be used in conjunction with the GP Amp, and the excitation supply from the GP Amp can be used to power them.

## Possibly Suitable Transducers

**DC Strain-gauge.** The GP Amp can be used with bridge-type strain-gauge force transducers, temperature transducers, and pressure transducers, but this is not recommended. The Bridge Amp is

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preferable for these types of transducers because of its low DC drift. If long-term DC drift does not present a problem in your recordings, then these transducers could be used.

## Unsuitable Transducers

Some transducers are not supported and should not be used with the GP Amp. These include LVDT, capacitive bridge, and high-voltage transducers.

**LVDT** (linear variable differential transformer). This type of transducer requires AC excitation voltages. The GP Amp is for use with transducers requiring DC excitation. Connecting an LVDT transducer to the GP Amp may damage the transducer.

**Capacitive Bridge.** These transducers require AC excitation. The GP Amp is for use with transducers requiring DC excitation.

**High-voltage.** Transducers generating more than  $\pm 10$  V full scale will exceed the input range of the GP Amp. A high-voltage powered transducer requires some signal attenuation.

## How Transducers Work

The GP Amp can connect to most bridge-type transducers. The term ‘bridge’ refers to the circuit configuration that is normally called a Wheatstone bridge. These transducers come in two forms: full-bridge and half-bridge. Some explanation is given here of bridge-type transducers, although there are of course other types that work differently, such as the semiconductor transducer.

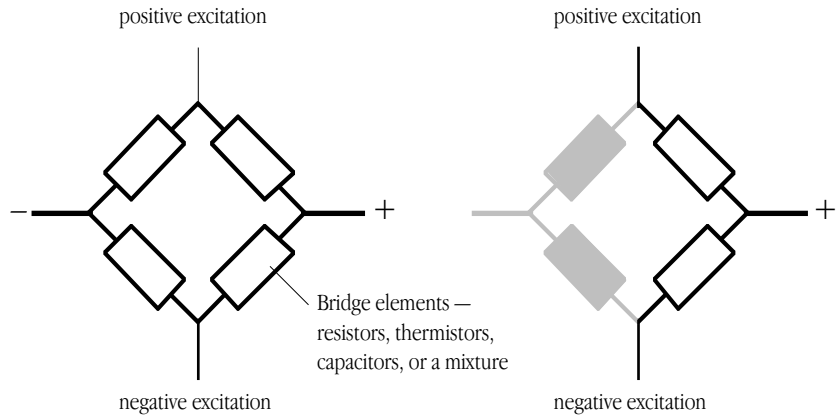
The full-bridge circuit is fairly versatile, in that the circuit elements, shown as the rectangular boxes in Figure 1–7, can be resistive, capacitive, or thermal circuit elements, allowing the bridge to measure force, pressure, temperature, and so forth. This circuit produces an electrical output in proportion to an appropriate stimulus applied to one or more of the four elements. Because of the balancing effect of the four elements, high precision is possible. Full-bridge transducers should work without problems.

A half-bridge transducer only uses half of the full-bridge circuit. It consists of two elements of equal value with an excitation voltage

applied across them. The output of the transducer is taken at the junction of the two elements. The circuit forms a simple voltage divider. If one of the elements changes value owing to an external stimulus, the output voltage will also change. In practice, this configuration is not often used. Half-bridge transducers will require adapting with compensating resistors before use with a GP Amp.

**Figure 1-7**

Left, a full-bridge transducer;  
right, a half-bridge transducer



## Checking the Transducer

Before attempting to connect any transducer to a GP Amp, you will need to determine the three things listed below. (The information should be in the documentation supplied with the transducer; if not, you should consult the manufacturer or supplier of the transducer.)

1. If the transducer requires an excitation voltage, and if so, what the maximum excitation voltage, or recommended range, is for the transducer.
2. The configuration of the transducer wiring connections, so that you know which transducer wire does what.
3. If the transducer is a bridge-type transducer, whether it has a full-bridge or half-bridge configuration.

Those transducers supplied by ADInstruments distributors will almost certainly be supplied pre-adjusted, and require no further work (but check to make sure, or if you have a particular purpose in mind for them). If you don't know which transducer wire does what,

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do not attempt to connect the signal leads from the transducer to the GP Amp, since it may result in incorrect operation, or damage to both transducer and GP Amp.

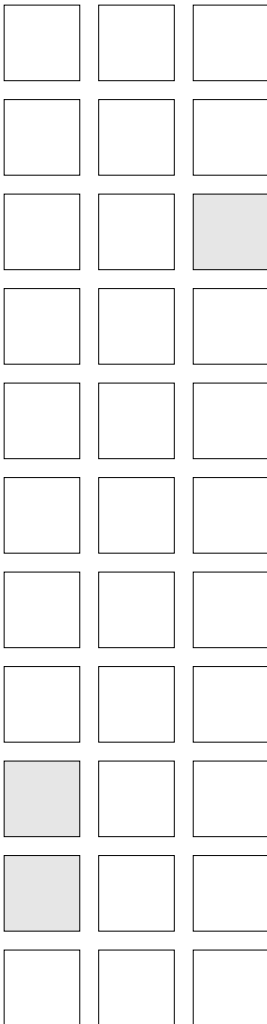
Unpowered transducers, or those with their own power supply, do not have to be supplied with any excitation voltage from the GP Amp: they supply their own signal to it directly. The wiring connections should still be carefully checked before connection, along with transducer impedance and output voltage. Such transducers do not need the excitation range to be adjusted from the default setting.

If you have a transducer which has the wrong plug for the GP Amp (such as Grass rather than DIN), and you use it with other equipment, it may be easier to build an adapter cable or box so that you can quickly connect the transducer to whichever equipment you are using. If you will only be using the transducer with the GP Amp, it is better to change the plug on the transducer than it is to use an adapter cable.

# 2

## C H A P T E R T W O

# Setting Up



This chapter describes connecting the Spirometer or GP Amp 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 application programs.

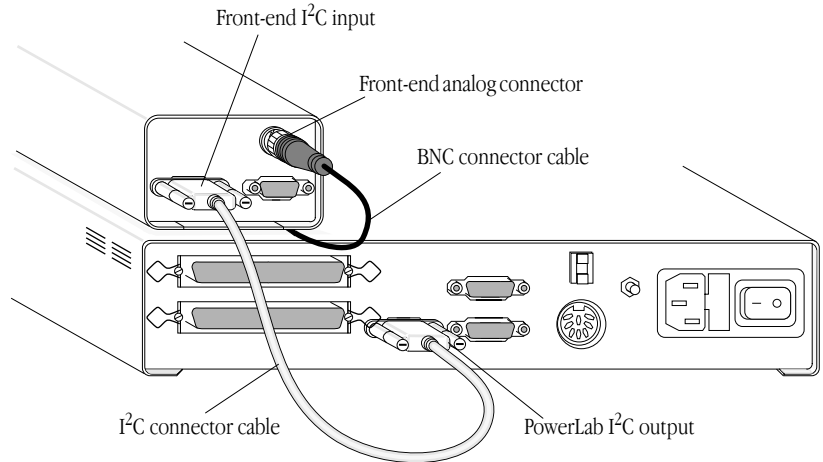
# Connecting to the PowerLab

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

The BNC cable from the Spirometer or GP Amp analog output must connect to a positive analog input of the PowerLab, if the PowerLab has differential (rather than single-ended) inputs. ADInstruments applications will not find the front-end on starting up if a negative input is used. Connect the I<sup>2</sup>C output of the PowerLab to the I<sup>2</sup>C input of the front-end using the I<sup>2</sup>C cable provided. Figure 2–1 shows how to connect up a single front-end to your recording unit.

**Figure 2–1**

Connecting a front-end to the PowerLab: a PowerLab has only one I<sup>2</sup>C output, and each front-end has one I<sup>2</sup>C output and one I<sup>2</sup>C input



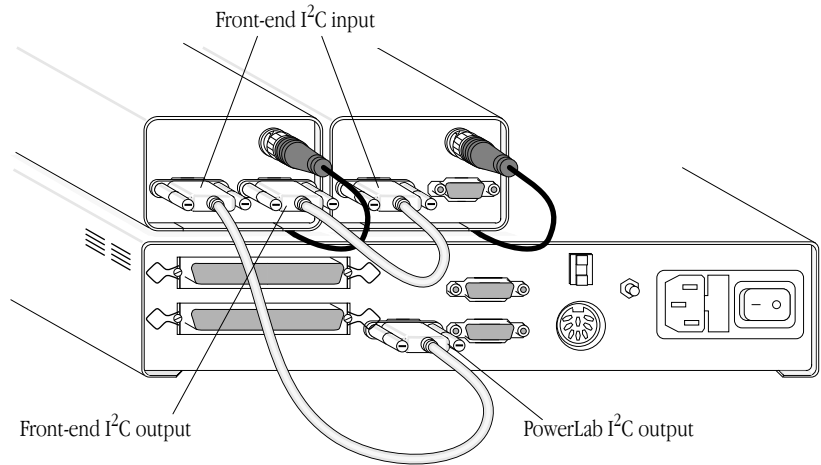
Check that the plugs for the I<sup>2</sup>C bus are screwed in firmly. Check the BNC cable for firm connections as well. Loose connectors can cause erratic front-end behaviour, or may cause the front-end to fail to work at all. The BNC cable can be tucked under the front-end to keep it out of the way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

Multiple separate front-ends can be connected up to a PowerLab. The number of normal front-ends that can be connected depends on the number of (positive) input channels on the PowerLab, since the BNC cable for each front-end is normally connected to one of the positive analog input channels of the PowerLab. The initial front-end should be connected with the I<sup>2</sup>C cable as in Figure 2–1. The remainder are

daisy-chained via I<sup>2</sup>C cables, connecting the I<sup>2</sup>C output of the last connected front-end to the I<sup>2</sup>C input of the front-end to be added.

**Figure 2-2**

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



The I<sup>2</sup>C bus can control a maximum of sixteen front-ends. If you are using a PowerLab/16SP, say, which has sixteen input channels, you cannot use all the analog inputs for normal front-ends while using the positive output of the PowerLab for a front-end such as the Stimulus Isolator (only one such front-end can be in use).

## Using ADInstruments Programs

Front-ends are used with PowerLabs and ADInstruments programs such as Chart and Scope. The amplification and filtering of the Spirometer or GP Amp is combined with that of the PowerLab and the program and presented as a single set of software controls, replacing the Input Amplifier dialog box with the Spirometer or GP Amplifier dialog box. The user's guides supplied with the software detail the Input Amplifier dialog box, and explain relevant terms and concepts.

### The Front-End Driver

A driver is a piece of software the computer uses to drive a peripheral device. In order for a front-end to be recognised by ADInstruments applications, the appropriate front-end driver must be present. The Bridge front-end driver is used with both the Spirometer and GP

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Amp. Front-end drivers are installed when ADInstruments applications are installed on the computer.

The Mac OS software keeps separate drivers in the ADInstruments folder in the System Folder. Scope for Windows has them in the System folder in the ADInstruments folder. Currently, Chart for Windows has them built in, but may be updated at some time in the future to use the common files. To replace the drivers, you generally need to reinstall the ADInstruments software.

## **The Front-End Self-Test**

Once the front-end 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 Chart or Scope.
3. While the program is opening, keep a close eye on the Status indicator for the front-end (at the bottom right of the front panel). During initialisation, 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 quit the application or carry on as appropriate. If the indicator doesn't light, check your cable connections and repeat the procedure.

## **Software Behaviour**

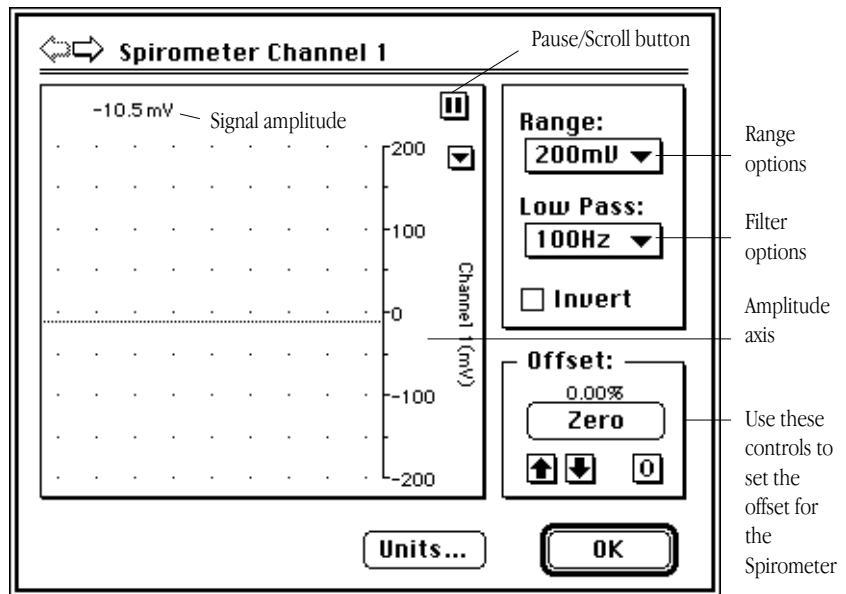
When a Spirometer is properly connected to a channel, the Input Amplifier... menu commands and so on are replaced by Spirometer... where they appear. When a GP Amp is properly connected to a channel, the Input Amplifier... menu commands and so on are replaced by GP Amp... or GP Amplifier... where they appear. If the application fails to find a front-end connected, the normal text remains. If you were expecting a connected front-end and see the normal text, you should quit the program, check the connections, then open it again to see if the front-end commands appear.

The documentation for Chart and Scope does not cover front-end-specific features. These features are described in detail here for Chart. Differences between Chart and Scope should be fairly obvious from perusing the user's guide for Scope. For the most part, dialog boxes for the different application programs should be much the same.

## The Spirometer: Macintosh

The Spirometer dialog box allows software control of the combined filters and other circuitry in the PowerLab and Spirometer. The signal present at a channel's input is displayed so that you can see the effects of changes straight away. Once the settings in the dialog box are changed, click the OK button to apply them.

**Figure 2-3**  
The Spirometer dialog box,  
Macintosh



The Spirometer dialog box appears if you choose the Spirometer... command from a Channel Function pop-up menu (or click a Spirometer... row in the Input Settings column in the Channel Settings dialog box). To set up many channels quickly, click the arrows by the dialog box title to move to the equivalent dialog boxes for adjacent channels. This skips channels that are turned off. The channel number is shown in the title of the dialog box, and the channel title (if any) is shown in the vertical Amplitude axis of the dialog box.

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## Signal Display

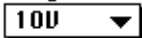
The input signal is displayed so you can see the effect of changing the settings — no data are in fact recorded when setting things up. Slowly changing waveforms will be represented quite accurately, whereas quickly changing signals will be displayed as a solid dark area showing only the envelope (shape) of the signal formed by the minimum and maximum recorded values. The average signal value is shown at the top left of the display area: this is the offset 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 top right of the data display area (it looks like the pause button on a tape or CD player). It then changes to the Scroll button (like the play button on a tape or CD player): click it to start scrolling again. You can shift and stretch the vertical Amplitude axis to make the best use of the available display area. Apart from being at the right rather than the left, it is the same as the Amplitude axis in the main window, and the controls, such as the Scale pop-up menu, function identically. Changes made here are reflected in the main window of the program.

### Setting the Range

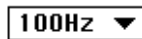
Range:



The Range pop-up menu lets you select the input range or sensitivity of the channel. Changing the range in the Spirometer dialog box is equivalent to changing it in the Chart window. The ranges are the same as normal for Chart.

### Filtering

Low Pass:



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

### Inverting the Signal

Invert

The Invert checkbox allows you to invert the signal on the screen. It provides a simple way to change the polarity of the recorded signal without having to reconnect the tubes to the Spirometer or flow head.

For example, you might be recording an experiment where expiration gives a positive signal, but you want to have expired air shown as a negative signal on the screen. Checking the Invert checkbox would change the display to do this.

## 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 in the equilibrium or rest state. This voltage is shown at the top left of the display area — if it is large, it may indicate a problem. Offsets from a zero reading need to be removed, in a process called *zeroing*. Commonly, one also wants to remove a constant term from a measurement of interest. This enables more accurate measurement of the changes in the signal under some stimulus or other. The offset controls in the Spirometer dialog box can be used to zero the reading manually or automatically.

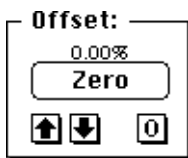
**Manual Zeroing.** The up and down arrow buttons next to the Zero button allow manual adjustment of signal zeroing. Click the up arrow to shift the signal positively, the down arrow to shift it negatively. The offset added by a click of the arrow buttons depends on the range setting. At high ranges, the increments are larger, so that you don't have to click buttons too often.

**Automatic Zeroing.** To perform automatic zeroing, click the Zero button: the program works out a corrective DC voltage that cancels, as closely as possible, the output voltage from the transducer. Auto-zeroing may take 20 seconds or so to work out the best zeroing value at all ranges. A dialog box with a progress bar appears: click the Cancel button or type Command-period to stop the zeroing process. Note that 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 that the Spirometer is kept still and that there is no airflow during the operation.

If there is still some offset after manual or automatic zeroing, then Option-click the up and down arrow buttons to adjust the zeroing slightly, by the smallest increment at any range.

The offset display, a small numeric indicator above the Zero button, shows the corrective voltage used to adjust for transducer offset, as a

**Figure 2-4**  
The Offset controls,  
Macintosh



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percentage value. When the Spirometer is first powered up, the software sets the offset circuit to its default position (no offset adjustment of the transducer is performed) and the offset display has a value of zero. When either the auto-zeroing function is selected or one the manual offset controls is used, this number will change to indicate the corrective adjustment.

**0**

Click the small '0' button to restore the offset circuit to its initial, non-zeroed position (the offset range indicator resets to a value of zero). This can be used to determine the offset generated by the Spirometer's pressure transducer.

## **Units**

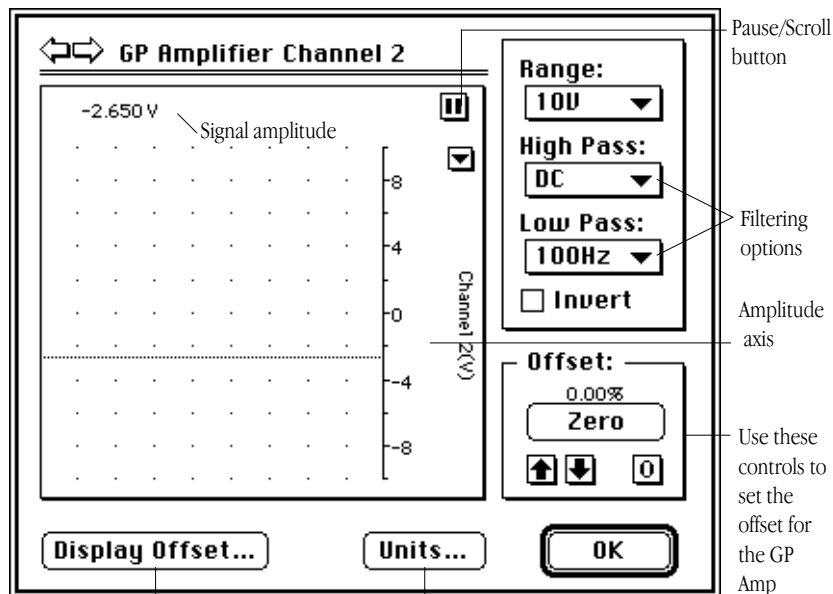
Clicking the Units... button brings up the Units Conversion dialog box, letting you specify the units for a channel, and, using waveform measurements, calibrate the channel. The waveform in the data display area of the dialog box is transferred to the Units Conversion dialog box. (Use the Pause button to capture a specific signal.) The units conversion only applies to subsequently recorded signals, so it is more limited than choosing units conversion directly, as it does not allow the conversion of individual blocks or pages of data.

## **The GP Amplifier: Macintosh**

The GP Amplifier dialog box allows software control of the various amplifiers and filters in the GP Amp and PowerLab for a channel. The signal present at a channel's input is displayed so that you can see the effects of changes straight away. Once the settings in the dialog box are changed, click the OK button to apply them.

The GP Amplifier dialog box appears when you choose the GP Amplifier... command from a Channel Function pop-up menu (or click a GP Amplifier... row in the Input Settings column in the Channel Settings dialog box). To set up many channels quickly, click the arrows by the dialog box title, or press the right or left arrow keys on the keyboard, to move to the equivalent dialog boxes for adjacent channels. This skips channels that are turned off. The channel number is shown in the title of the dialog box, and the channel title (if any) is shown in the vertical Amplitude axis of the dialog box.

**Figure 2-5**  
The GP Amplifier dialog box,  
Macintosh



Click this button to display a voltmeter on screen when setting the offset externally

Click this button to bring up the Units Conversion dialog box

## Signal Display

The input signal is displayed so you can see the effect of changing the settings — no data are in fact recorded when setting things up. Slowly changing waveforms will be represented quite accurately, whereas quickly changing signals will be displayed as a solid dark area showing only the envelope (shape) of the signal formed by the minimum and maximum recorded values. The average signal value is shown at the top left of the display area.



You can stop the signal scrolling by clicking the Pause button at the top right of the data display area (it looks like the pause button on a tape or CD player). It then changes to the Scroll button (like the play button on a tape or CD player): click it to start scrolling again. You can shift and stretch the vertical Amplitude axis to make the best use of the available display area. Apart from being at the right rather than the left, it is the same as the Amplitude axis in the main window, and the controls, such as the Scale pop-up menu, function identically. Changes made here are reflected in the main window of the program.

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## Setting the Range

The Range pop-up menu lets you select the input range or sensitivity of the channel. Changing the range in the GP Amplifier dialog box is equivalent to changing it in the main window. The ranges are the same as normal for Chart.

## Filtering

The High Pass and Low Pass pop-up menus provide signal filtering options appropriate to the type of transducers used with the GP Amp, and the signals usually measured, which tend to be of lower frequency.

**High Pass:**

0.3Hz ▼

**High-Pass Filtering.** There are only two options in the High Pass pop-up menu: DC and 0.3 Hz. If DC is chosen, the GP Amplifier will be DC coupled, and pass both DC and AC signals. When 0.3 Hz is chosen, a high-pass filter before the first amplification stage removes any DC and very low-frequency components from the input. This (AC coupling) option is useful to remove a slowly changing signal component (when recording a fast signal superimposed on a slowly drifting baseline, for instance). It disables automatic zeroing.

**Low Pass:**

100Hz ▼

**Low-Pass Filtering.** The Low Pass pop-up menu gives a choice of low-pass filters to remove high-frequency components from an input signal. The filters for the GP Amp are 1, 10, and 100 Hz. These filters help to eliminate high-frequency components, such as noise. There is also an Off setting, which allows frequencies of up to the GP Amp's bandwidth of 5 kHz. (The highest frequency you can actually record is limited by the transducer you use: such information should be in the documentation supplied with it.)

## Inverting the Signal

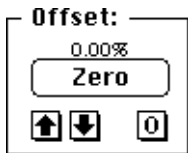
**Invert**

The Invert checkbox allows you to invert the signal on the screen. It provides a simple way to change the polarity of the recorded signal without having to swap the connections to the recording electrodes. For example, you might be recording from a force transducer where an increase in force downwards gives a negative signal, but you want to have a downwards force shown as a positive signal on the screen. Checking the Invert checkbox will change the display to do this.

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## Offset Adjustment

**Figure 2-6**  
The Offset controls,  
Macintosh



Transducers almost always produce some amount of signal, usually small, when in the equilibrium or rest state. Offsets from a zero reading need to be removed, in a process called *zeroing*. Commonly, one also wants to remove a constant term, for instance, baseline blood pressure or the initial tension in a muscle, from a measurement of interest. This enables more accurate measurement of the changes in the signal under some stimulus or other. The offset controls in the GP Amplifier dialog box can be used to zero the reading manually or automatically.

**Manual Zeroing.** The up and down arrow buttons next to the Zero button allow manual adjustment of signal zeroing. Click the up arrow to shift the signal positively, the down arrow to shift it negatively. The offset added by a click of the arrow buttons depends on the range setting. At high ranges, the increments are larger, so that you don't have to click buttons too often.

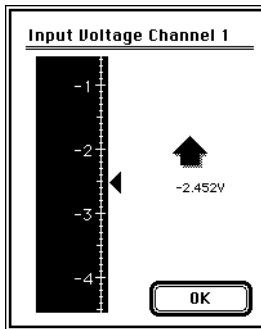
**Automatic Zeroing.** To perform automatic zeroing, click the Zero button: the program works out a corrective DC voltage that cancels, as closely as possible, the output voltage from the transducer. Auto-zeroing may take 20 seconds or so to work out the best zeroing value at all ranges. A dialog box with a progress bar appears: click the Cancel button or type Command-period to stop the zeroing process. Note that 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 that the transducer is kept still and that no varying signal is applied during the operation.

If there is still some offset after manual or automatic zeroing, then Option-click the up and down arrow buttons to adjust the zeroing slightly, by the smallest increment at any range.

The offset display, a small numeric indicator above the Zero button, shows the corrective voltage used to adjust for transducer offset. The offset is given as a percentage value. When the GP Amp is first powered up, the software sets the offset circuit to its default position (no offset adjustment of the transducer is performed) and the offset display has a value of zero. When either the auto-zeroing function is selected or one the manual offset controls is used, this number will change to indicate the corrective adjustment.

**Figure 2–7**

The Input Voltage dialog box, Macintosh



Click the small '0' button to restore the offset circuit to its initial, non-zeroed position (the offset range indicator resets to a value of zero). This can be used to determine the offset generated by a transducer.

## Display Offset

Clicking the Display Offset... button causes the Input Voltage dialog box to appear (Figure 2–7). In it, a voltmeter displays the voltage currently being measured for a channel (the channel is indicated at the top of the dialog box). If a transducer or some other external equipment has offset adjustment capabilities, you can use this to help to zero it.

Because the dialog box allows for such fine adjustment, a vertical arrow appears indicating the zero point if the offset is substantial. This dialog box is not a control, simply an indicator that acts like a voltmeter. It is unavailable when the 0.3 Hz filter is selected for a GP Amp, since AC coupling removes all DC current, and there would be no offset to measure.

## Units

Clicking the Units... button brings up the Units Conversion dialog box, letting you specify the units for a channel, and, using waveform measurements, calibrate the channel. The waveform in the data display area of the dialog box is transferred to the Units Conversion dialog box. (Use the Pause button to capture a specific signal.) The units conversion only applies to subsequently recorded signals, so it is more limited than choosing units conversion directly, as it does not allow the conversion of individual blocks or pages of data.

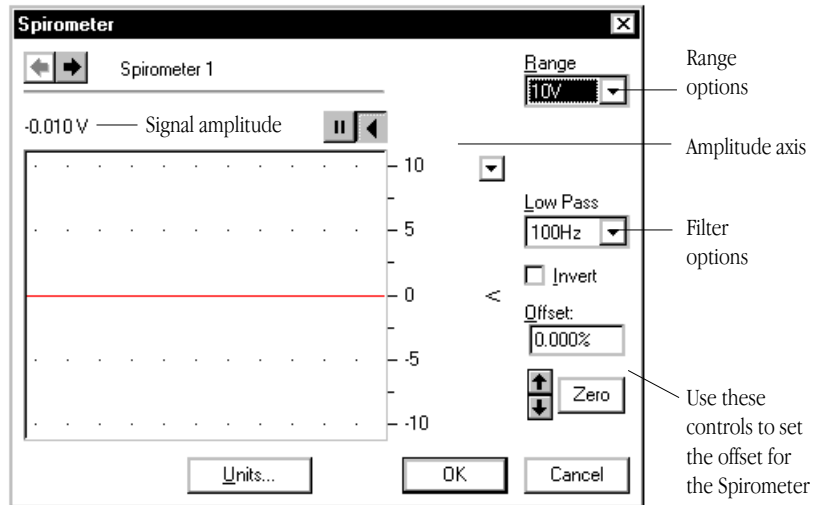
## The Spirometer: Windows

The Spirometer dialog box allows software control of the combined filters and other circuitry in the PowerLab and Spirometer. The signal present at a channel's input is displayed so that you can see the effects of changes straight away. Once the settings in the dialog box are changed, click the OK button to apply them.

The Spirometer dialog box appears if you choose the Spirometer... command from a Channel Function pop-up menu (or click a

Spirometer... row in the Input Settings column in the Channel Settings dialog box). To set up many channels quickly, click the arrows by the dialog box title to move to the equivalent dialog boxes for adjacent channels. This skips channels that are turned off. The channel number is shown in the title of the dialog box, and the channel title (if any) should be shown in the vertical Amplitude axis of the dialog box.

**Figure 2-8**  
The Spirometer dialog box,  
Windows



## Signal Display

The input signal is displayed so you can see the effect of changing the settings — no data are in fact recorded when setting things up. Slowly changing waveforms will be represented quite accurately, whereas quickly changing signals will be displayed as a solid dark area showing only the envelope (shape) of the signal formed by the minimum and maximum recorded values. The average signal value is shown at the top left of the display area: this is the offset 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 top right of the data display area (it looks like the pause button on a tape or CD player). Click the Scroll button beside it to start scrolling again (like the play button on a tape or CD player). You can shift and stretch the vertical Amplitude axis to make the best use of the available display area. Apart from being at the right rather than the

left, it is the same as the Amplitude axis in the main window, and the controls, such as the Scale pop-up menu, function identically. Changes made here are reflected in the main window of the program.

## 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 box is equivalent to changing it in the Chart window. The ranges are the same as normal for Chart.

## Filtering

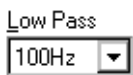
The Low Pass pop-up menu gives a choice of low-pass filters to remove high-frequency components from an input signal. The filters, appropriate for the built-in pressure transducer in the Spirometer, are 1, 10, and 100 Hz. These filters help to eliminate high-frequency components, such as noise.

## Inverting the Signal

The Invert checkbox allows you to invert the signal on the screen. It provides a simple way to change the polarity of the recorded signal without having to reconnect the tubes to the Spirometer or flow head. For example, you might be recording an experiment where expiration gives a positive signal, but you want to have expired air shown as a negative signal on the screen. Checking the Invert checkbox would change the display to do this.

## 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 in the equilibrium or rest state. This voltage is shown at the top left of the display area — if it is large, it may indicate a problem. Offsets from a zero reading need to be removed, in a process called *zeroing*. Commonly, one also wants to remove a constant term from a measurement of interest. This enables more accurate measurement of the changes in the signal under some stimulus or other. The offset controls in the Spirometer dialog box can be used to zero the reading manually or automatically.



**Figure 2–9**  
The Offset controls, Windows



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**Manual Zeroing.** The up and down arrow buttons next to the Zero button allow manual adjustment of signal zeroing. Click the up arrow to shift the signal positively, the down arrow to shift it negatively. The offset added by a click of the arrow buttons depends on the range setting. At high ranges, the increments are larger, so that you don't have to click buttons too often.

**Automatic Zeroing.** To perform automatic zeroing, click the Zero button: the program works out a corrective DC voltage that cancels, as closely as possible, the output voltage from the transducer. Auto-zeroing may take 20 seconds or so to work out the best zeroing value at all ranges. A dialog box with a progress bar appears: click the Cancel button to stop the zeroing process. Note that 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 that the Spirometer is kept still and that there is no airflow during the operation.

If there is still some offset after manual or automatic zeroing, then enter a value directly in the text entry box, or Control+click the up and down arrow buttons to adjust the zeroing slightly, by the smallest increment at any range.

The offset display, the text entry box above the Zero button, shows the corrective voltage used to adjust for transducer offset, as a percentage value. When the Spirometer is first powered up, the software sets the offset circuit to its default position (no offset adjustment of the transducer is performed) and the offset display will have a value of zero. When the auto-zeroing function is selected or a value is entered manually, this number indicates the corrective adjustment.

## Units

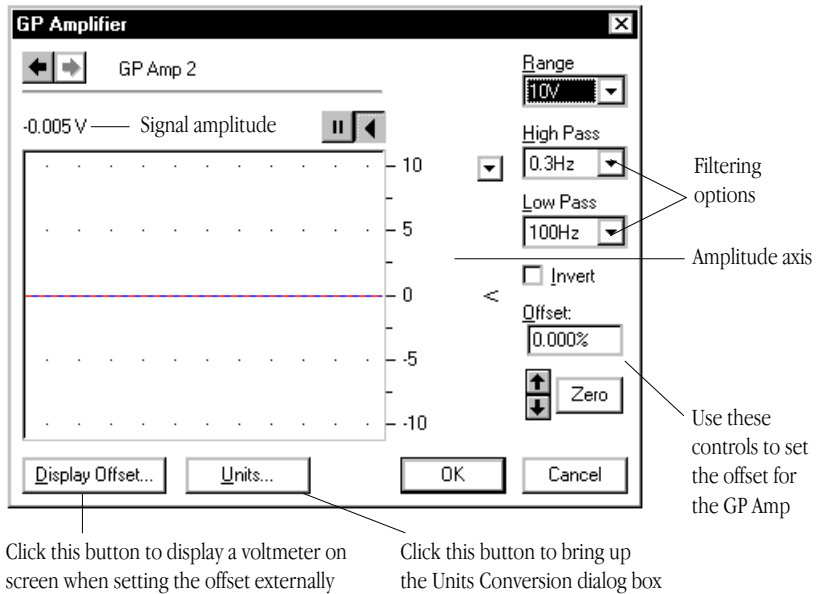
Clicking the Units... button brings up the Units Conversion dialog box, letting you specify the units for a channel, and, using waveform measurements, calibrate the channel. The waveform in the data display area of the dialog box is transferred to the Units Conversion dialog box. (Use the Pause button to capture a specific signal.) The units conversion only applies to subsequently recorded signals, so it is more limited than choosing units conversion directly, as it does not allow the conversion of individual blocks or pages of data.

## The GP Amplifier: Windows

The GP Amplifier dialog box allows software control of the various amplifiers and filters in the GP Amp and PowerLab for a channel. The signal present at a channel's input is displayed so that you can see the effects of changes straight away. Once the settings in the dialog box are changed, click the OK button to apply them.

The GP Amplifier dialog box appears when you choose the GP Amp... command from a Channel Function pop-up menu (or click a GP Amp... row in the Input Settings column in the Channel Settings dialog box). To set up many channels quickly, click the arrows by the dialog box title, or press the right or left arrow keys on the keyboard, to move to the equivalent dialog boxes for adjacent channels. This skips channels that are turned off. The channel number is shown in the title of the dialog box, and the channel title (if any) should be shown in the vertical Amplitude axis of the dialog box.

**Figure 2–10**  
The GP Amplifier dialog box,  
Windows



### Signal Display

The input signal is displayed so you can see the effect of changing the settings — no data are in fact recorded when setting things up.

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Slowly changing waveforms will be represented quite accurately, whereas quickly changing signals will be displayed as a solid dark area showing only the envelope (shape) of the signal formed by the minimum and maximum recorded values. The average signal value is shown at the top left of the display area.



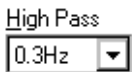
You can stop the signal scrolling by clicking the Pause button at the top right of the data display area (it looks like the pause button on a tape or CD player). Click the Scroll button beside it to start scrolling again (like the play button on a tape or CD player). You can shift and stretch the vertical Amplitude axis to make the best use of the available display area. Apart from being at the right rather than the left, it is the same as the Amplitude axis in the main window, and the controls, such as the Scale pop-up menu, function identically. Changes made here are reflected in the main window of the program.

## Setting the Range

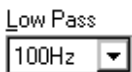
The Range pop-up menu lets you select the input range or sensitivity of the channel. Changing the range in the GP Amplifier dialog box is equivalent to changing it in the main window. The ranges are the same as normal for Chart.

## Filtering

The High Pass and Low Pass pop-up menus provide signal filtering options appropriate to the type of transducers used with the GP Amp, and the signals usually measured, which tend to be of lower frequency.



**High-Pass Filtering.** There are only two options in the High Pass pop-up menu: DC and 0.3 Hz. If DC is chosen, the GP Amplifier will be DC coupled, and pass both DC and AC signals. When 0.3 Hz is chosen, a high-pass filter before the first amplification stage removes any DC and very low-frequency components from the input. This (AC coupling) option is useful to remove a slowly changing signal component (when recording a fast signal superimposed on a slowly drifting baseline, for instance). It disables automatic zeroing.



**Low-Pass Filtering.** The Low Pass pop-up menu gives a choice of low-pass filters to remove high-frequency components from an input signal. The filters for the GP Amp are 1, 10, and 100 Hz. These filters

help to eliminate high-frequency components, such as noise. There is also an Off setting, which allows frequencies of up to the GP Amp's bandwidth of 5 kHz. (The highest frequency you can actually record is limited by the transducer you use: such information should be in the documentation supplied with it.)

## Inverting the Signal

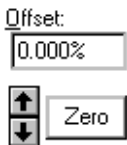
The Invert checkbox allows you to invert the signal on the screen. It provides a simple way to change the polarity of the recorded signal without having to swap the connections to the recording electrodes. For example, you might be recording from a force transducer where an increase in force downwards gives a negative signal, but you want to have a downwards force shown as a positive signal on the screen. Checking the Invert checkbox will change the display to do this.

Invert

## Offset Adjustment

Transducers almost always produce some amount of signal, usually small, when in the equilibrium or rest state. Offsets from a zero reading need to be removed, in a process called *zeroing*. Commonly, one also wants to remove a constant term, for instance, baseline blood pressure or the initial tension in a muscle, from a measurement of interest. This enables more accurate measurement of the changes in the signal under some stimulus or other. The offset controls in the GP Amplifier dialog box can be used to zero the reading manually or automatically.

**Figure 2-11**  
The Offset controls, Windows



**Manual Zeroing.** The up and down arrow buttons next to the Zero button allow manual adjustment of signal zeroing. Click the up arrow to shift the signal positively, the down arrow to shift it negatively. The offset added by a click of the arrow buttons depends on the range setting. At high ranges, the increments are larger, so that you don't have to click buttons too often.

**Automatic Zeroing.** To perform automatic zeroing, click the Zero button: the program works out a corrective DC voltage that cancels, as closely as possible, the output voltage from the transducer. Auto-zeroing may take 20 seconds or so to work out the best zeroing value at all ranges. A dialog box with a progress bar appears: click the Cancel button to stop the zeroing process. Note that 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 that the transducer is kept still and that no varying signal is applied during the operation.

If there is still some offset after manual or automatic zeroing, then enter a value directly in the text entry box, or Control+click the up and down arrow buttons to adjust the zeroing slightly, by the smallest increment at any range.

The offset display, the text entry box above the Zero button, shows the corrective voltage used to adjust for transducer offset, as a percentage value. When the GP Amp is first powered up, the software sets the offset circuit to its default position (no offset adjustment of the transducer is performed) and the offset display will have a value of zero. When the auto-zeroing function is selected or a value is entered manually, this number indicates the corrective adjustment.

## Display Offset

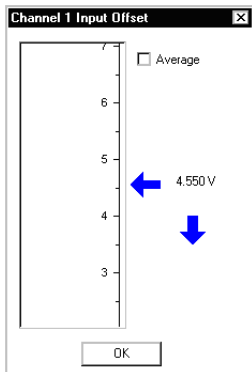
Clicking the Display Offset... button causes the Input Voltage dialog box to appear (Figure 2–12). In it, a voltmeter displays the voltage currently being measured for a channel (the channel is indicated at the top of the dialog box). If a transducer or some other external equipment has offset adjustment capabilities, you can use this to help to zero it.

Because the dialog box allows for such fine adjustment, a vertical arrow appears indicating the zero point if the offset is substantial. This dialog box is not a control, simply an indicator that acts like a voltmeter. It is unavailable when the 0.3 Hz filter is selected for a GP Amp, since AC coupling removes all DC current, and there would be no offset to measure.

## Units

Clicking the Units... button brings up the Units Conversion dialog box, letting you specify the units for a channel, and, using waveform measurements, calibrate the channel. The waveform in the data display area of the dialog box is transferred to the Units Conversion dialog box. (Use the Pause button to capture a specific signal.) The units conversion only applies to subsequently recorded signals, so it

**Figure 2–12**  
The Input Voltage dialog box,  
Windows



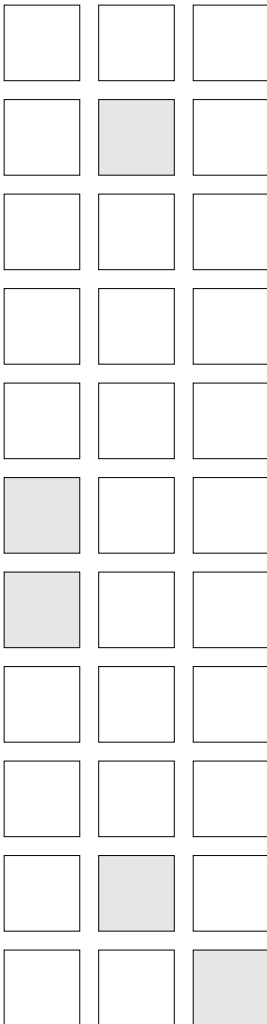
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is more limited than choosing units conversion directly, as it does not allow the conversion of individual blocks or pages of data.

# 3

## CHAPTER THREE

# Adapting Transducers



This chapter looks in detail at the modifications that may be required to connect third-party transducers to the GP Amp. Transducers supplied by ADInstruments should connect directly with no problems, so you probably won't need to read the chapter.

If you are using third-party transducers with your GP Amp, though, or have some half-bridge transducers you want to use with it, you may need to adapt them, so the information is provided here.

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# Introduction

Conventional amplifiers usually have controls on the front to adjust for the connected transducer: this means fiddling around each time you change transducers or amplifiers, with a chance each time of making the wrong settings, and damaging equipment.

Front-ends are designed to be easily transferred between recording units, and quick to disconnect and reconnect, so it makes more sense to adapt the transducer. This work needs only be done once for any third-party transducer, which can then be used with any GP Amp. Once set up, multiple transducers will work with the same GP Amp without needing further adjustment, and one can simply change connected transducers at will.

Some soldering of components is required to adapt third-party transducers for use with your GP Amp. If you have little experience with electronics and no technician to assist you, your ADInstruments distributor should be able to help.

## Unpowered Signal Sources

The GP Amp can be connected to signal sources that do not need to be powered, for example, electrodes or passive transducers such as piezoelectric strain gauges. Connection of unpowered transducers to a GP Amp is relatively straightforward. First read this section carefully. The requirements of the transducer should be determined before attempting to connect it up.

You will need this equipment:

- a soldering iron and resin-cored solder (*only* resin-cored solder!)
- an appropriate connector for your GP Amp (an 8-pin DIN-style male plug with 45-degree pin spacing — one is supplied with the front-end).

### Wiring Up the Transducer

To prepare an unpowered transducer for use with the GP Amp, wire the transducer to the plug so that it can connect up.

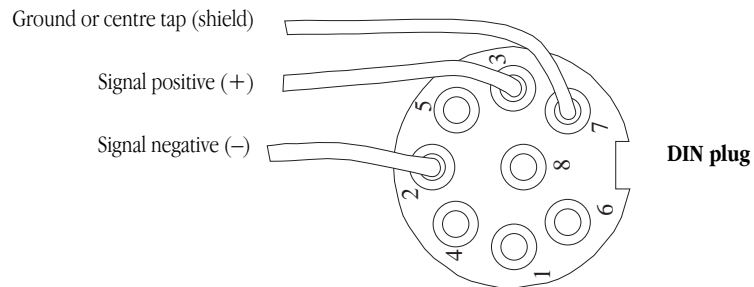
There are several things to note when wiring up transducers:

1. Make sure that the transducer wiring passes through the casing before soldering the wires to the plug.
2. The transducer wires should be cut, stripped, and tinned prior to soldering, to ensure a good connection.
3. The pin numbers shown in the diagrams are the numbers marked on most standard DIN plugs. If the plug has no numbers or different ones, go by the layout shown here.

This procedure is simply a matter of connecting the leads in the right way, and requires no special components. The transducer lead wires should be soldered to the pins of the DIN plug as shown in Figure 3-1 below. Any unused wires from the transducer should be cut and insulated to prevent shorting of signals or damage to the equipment.

**Figure 3-1**

The wiring connections for unpowered signal sources, looking at the rear of the plug

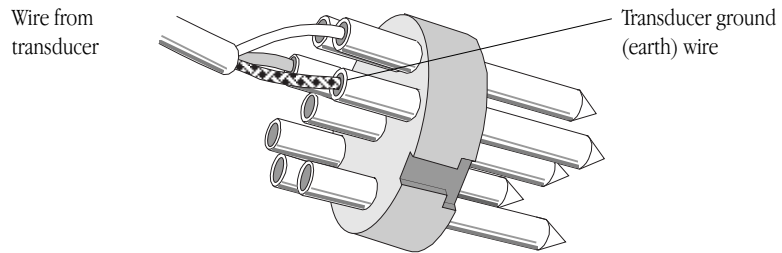


The main insulation sheath of the transducer wiring should be clamped with the strain-relief device within the plug. The transducer will normally have some sort of cable shield, which should be connected to pin 7 of the DIN plug. If the casing of the plug is metal, it is good practice to ensure that the casing will also be connected to the shield. This is not necessary, but is recommended. Figure 3-2 shows how the wires should be physically connected to the connector. You should try to keep the individual wires as short as possible so that they fit inside the connector housing.

Note that you can connect the input as either a single-ended input or differential input as required. To make the input single-ended, simply connect pin 2 of the connector to pin 5, 6, 7, or 8 of the connector. In this case the wire to the negative signal input does not need to be

**Figure 3–2**  
The correct length of wiring to the DIN plug

connected to the connector; you only need two wires to the signal source.



## Testing the Transducer

Once the transducer is connected, it can be tested using Chart or Scope. Looking at the GP Amplifier dialog box, you can see the output from the transducer as you change the force or load on it. You may have to adjust the range of the GP Amp to get a good response. If there appears to be no response from the transducer, recheck the wiring against the diagrams for the appropriate transducer and the manufacturer's instructions. If everything seems to be in order, the joints are soldered properly and so on, and there is still no response, contact your ADInstruments distributor for help.

## Powered Signal Sources

To connect transducers that require some form of power supply to the GP Amp, first read this section carefully. The requirements of the transducer should be determined before attempting to connect it up.

To adapt a transducer for use with the GP Amp, you need to:

- set the excitation voltage for the transducer
- wire the transducer to use the eight-pin DIN plug.

You will also need this equipment:

- a soldering iron and resin-cored solder (*only* resin-cored solder!)
- an eight-pin DIN-style male plug with 45-degree pin spacing (one is supplied with your GP Amp)
- common E12 resistors: 0.25 or 0.125 Watt, 2% or 1% metal film.

## Setting the Excitation Voltage

The first step in preparing a powered transducer for use with the GP Amp is to set the required excitation voltage. Two of the pins in the GP Amp's DIN socket can provide up to 20 volts DC as excitation voltage to power the transducer. The voltage is varied by a resistor fitted between the two corresponding pins of the transducer's DIN plug. When no resistor is present, the GP Amp's internal circuitry cuts off all voltage to prevent mishaps. Once a resistor is fitted, the correct excitation voltage is provided automatically when the transducer is plugged into the GP Amp.

To program the excitation voltage for a particular transducer, choose a value of resistance from Table 3-1 to match the required excitation voltage for your transducer. In most cases, you should be able to get close to the required excitation voltage by selecting one of those values. We recommend that the excitation resistor be 0.25 or 0.125 Watt, 2% or 1% metal film. Larger resistors may not fit in the confined space of the transducer's DIN plug.

**Table 3-1**

Transducer excitation voltage and resistance for use with the GP Amp

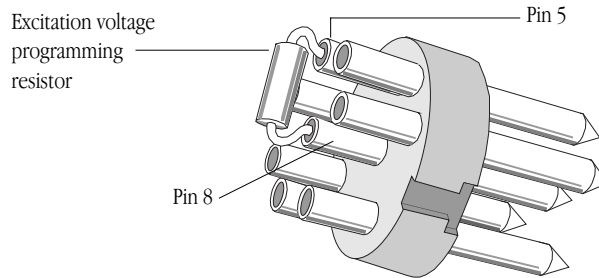
Excitation voltage (DC volts)	Excitation resistance ( $\Omega$ )	Excitation voltage (DC volts)	Excitation resistance ( $\Omega$ )
20	Short circuit	5	470 k
18	12 k	4	560 k
15	47 k	3.5	680 k
12	100 k	3	820 k
10	150 k	2.5	1 M
8	220 k	2	1.2 M
6	330 k		

In general, the output voltage from the transducer is directly proportional to the excitation voltage placed across it. The greater the excitation voltage, the more sensitive the transducer becomes.

However, transducers have a limit to the level of excitation voltage that can be applied before they are damaged. Some resistive elements may start to heat at high excitation voltages, causing their resistance to change. This degrades the accuracy of the transducer. High voltages may also damage capacitive bridge transducer elements. To avoid problems, the excitation voltage should be set according to the transducer manufacturer's recommendation.

To set the excitation voltage for a transducer, you will need to solder the chosen resistor between pins 5 and 8 of the eight-pin DIN plug, as shown in Figure 3–3. Mount the resistor as shown for maximum clearance within the plug.

**Figure 3–3**  
Installing the programming resistor (the pins are labelled on the plug)



## Wiring Up the Transducer

The second step in preparing a powered transducer for use with the GP Amp is to wire the transducer to the DIN plug so that it can connect up. How this is done depends on whether the transducer is full-bridge or half-bridge: use the appropriate subsection below.

There are several things to note when wiring up transducers:

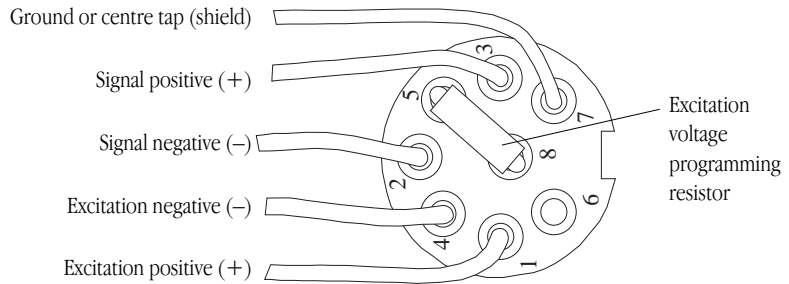
1. Make sure that the transducer wiring passes through the casing before soldering the wires to the plug.
2. The transducer wires should be cut, stripped, and tinned prior to soldering, to ensure a good connection.
3. The pin numbers shown in the diagrams are the numbers marked on most standard DIN plugs. If the plug has no numbers or different ones, go by the layout shown here.

## Wiring Up a Full-Bridge Transducer

This procedure should be used to wire full-bridge transducers only, *not* half-bridge transducers. The transducer lead wires should be soldered to the pins of the DIN plug as shown in Figure 3–4. Any unused wires from the transducer should be cut and insulated to prevent shorting of signals or damage to the equipment.

**Figure 3–4**

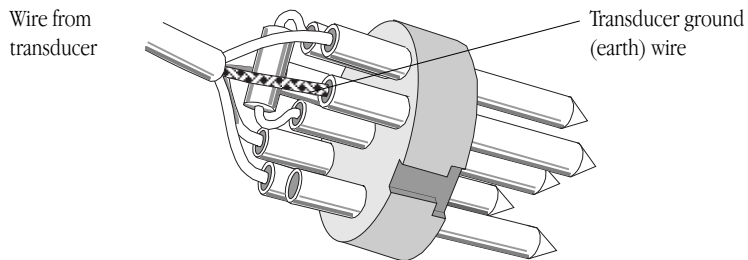
The wiring connections for a full-bridge transducer, looking at the DIN plug from the rear



The main insulation sheath of the transducer wiring should be clamped with the strain-relief device within the plug, so that it just clears the excitation voltage resistor. The transducer will normally have some sort of cable shield, which should be connected to pin 7 of the DIN plug. If the casing of the DIN plug is metal, it is good practice to ensure that the casing will also be connected to the shield. This is not necessary, but is recommended.

**Figure 3–5**

The correct length of wiring to the DIN plug



## Wiring Up a Half-Bridge Transducer

First, consider that if you need to wire up a DIN plug for a half-bridge transducer, it might be better to build an adapter box. All the resistors in the DIN plug will be a tight fit, and will require adept soldering!

This procedure should be used to wire half-bridge transducers only, *not* full-bridge transducers. Half-bridge transducers are missing half the normal full-bridge configuration. To compensate for this, a full-bridge arrangement is made from the half-bridge transducer by adding two resistors. The value of these resistors should be equal to the nominal resistance of the active arms of the bridge, or 1 k $\Omega$ , whichever is the higher value.

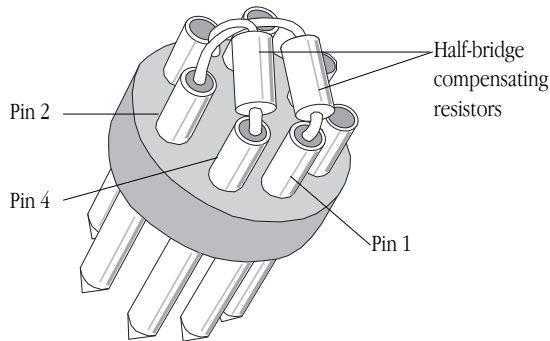
The resistors used should have the specifications listed below. A change of 1 ppm in their relative values will result in a change of 10  $\mu\text{V}$  in the output for a 10-volt excitation voltage. To avoid self-heating effects, keep resistance high and excitation low.

Power rating	0.25 Watt
Temperature coefficient	Better than 10 ppm per $^{\circ}\text{C}$
Matched temperature coefficient	1 ppm per $^{\circ}\text{C}$
Resistor matching	Better than 0.05%
Resistor tolerance	1% or better

Solder the resistors as shown in Figure 3–6. Notice that the top ends of the resistors are joined together and then soldered to pin 2.

**Figure 3–6**

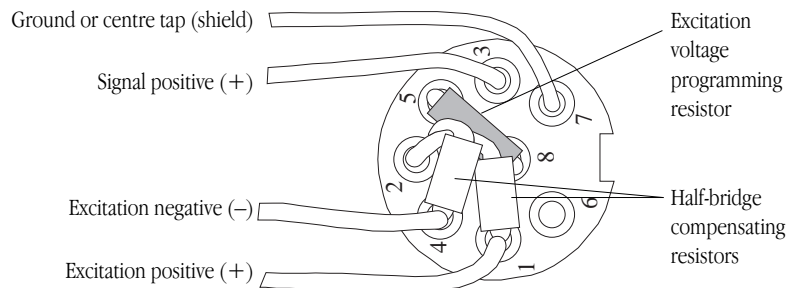
Installing the compensating resistors (the programming resistor has been left out for clarity)



Once the resistors have been soldered into the correct places, connect the transducer wiring to the DIN plug as shown in Figure 3–7. The transducer will normally have some sort of cable shield, which should be connected to pin 7 of the DIN plug. If the casing of the DIN plug is metal, it is good practice to ensure that it will also be connected to the shield. This is not necessary, but is recommended.

**Figure 3–7**

The wiring connections for a half-bridge transducer, looking at the DIN plug from the rear



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## **The Finished Transducer**

After connecting the excitation voltage programming resistor (and installing the compensating resistors for a half-bridge transducer) the transducer should now be fully configured for your purposes. The excitation voltage will be set automatically when the transducer is plugged into the GP Amp.

## **Testing the Transducer**

Once the transducer is connected, it can be tested using Chart or Scope. Looking at the GP Amplifier dialog box, you can see the output from the transducer as you change the force or load on it. You may have to adjust the range of the GP Amp to get a good response. If there appears to be no response from the transducer, recheck the wiring against the diagrams for the appropriate transducer and the manufacturer's instructions. If everything seems to be in order, the joints are soldered properly and so on, and there is still no response, contact your ADInstruments distributor for help.



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# A

## A P P E N D I X A

# Technical Aspects

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This appendix describes some of the important technical aspects of the Spirometer and GP Amp to give some insight into how they work. 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, GP Amp, 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<sup>2</sup>C (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:

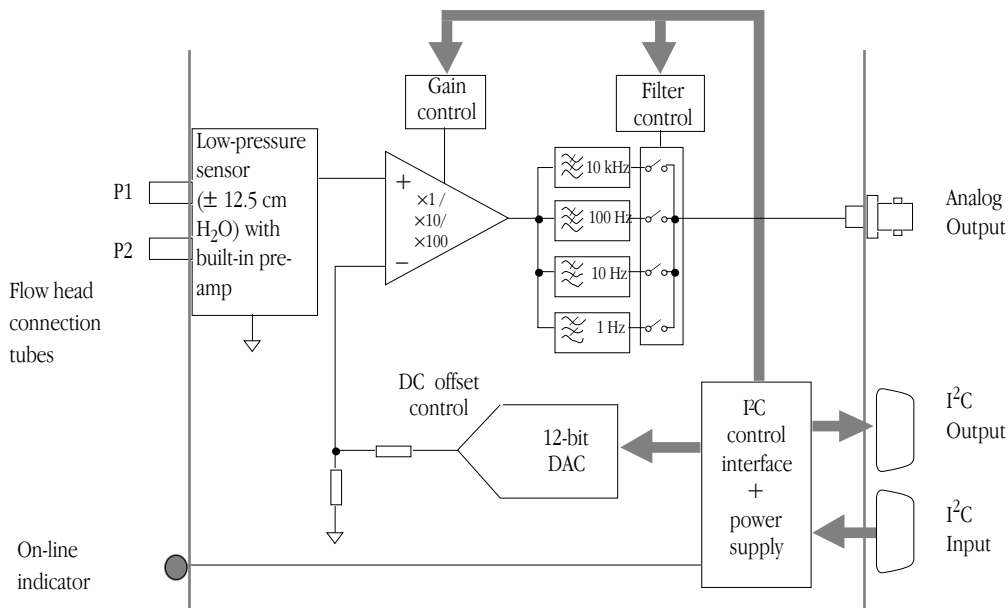
- a precision differential pressure input used to determine flow rates using an attached flow head
- the additional amplification necessary to deal with a variety of flow rates, from fractions of a litre per minute (mice and rats) to a thousand litres per minute (adult humans during exercise)
- additional 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<sup>2</sup>C 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 signal is sent. The overall operation of the Spirometer can be better understood by referring to Figure A-1.

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

**Figure A-1**  
Block diagram of the Spirometer



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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.

## GP Amp Operation

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

- a  $\pm 10$  V DC excitation source that can power transducers requiring such excitation
- the additional amplification necessary to deal with the low signal outputs of most transducers
- high-impedance differential input
- additional programmable filtering to remove unwanted signal frequencies
- digitally controlled zeroing circuitry for offset removal.

The internal functions of the GP Amp are controlled from the PowerLab through the I<sup>2</sup>C bus, which also supplies power to the GP Amp. The front-end is also connected to an analog input channel of the PowerLab via a BNC-to-BNC cable, through which the signal is sent. The overall operation of the GP Amp can be better understood by referring to Figure A-2.

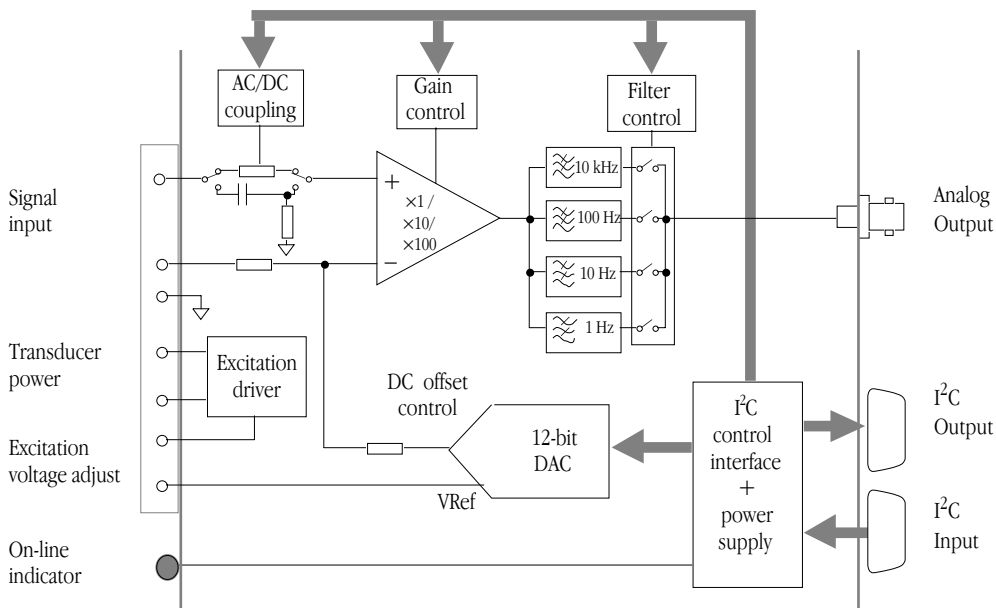
The input stage is a high-impedance differential instrumentation amplifier. The amplifier provides additional signal amplification. The output of the amplifier is passed through a set of software-selectable, fourth-order, low-pass filters. The filters can be turned off, which allows frequencies of up to the GP Amp's bandwidth of 5 kHz. The signal is then sent to the PowerLab.

AC coupling (high-pass filtering) is provided by use of a first-order 0.3 Hz filter. When AC coupling is selected, thus removing the DC content of the signal, the automatic zeroing function is disabled.

To remove any offsets caused by an attached transducer or signal baseline, the GP Amp 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 transducer 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.

The transducer excitation voltage is generated by a programmable voltage source, which itself is derived from a stable internal voltage reference. The excitation voltage output circuit is a complementary output stage capable of giving up to  $\pm 10$  volts (20 volts DC) excitation at up to 100 mA. The voltage can be adjusted by connecting a resistor between two pins on the DIN plug that plugs into the GP Amp's input socket, so that the correct offset range for the transducer will always be set when it is connected.

**Figure A-2**  
Block diagram of the GP Amp

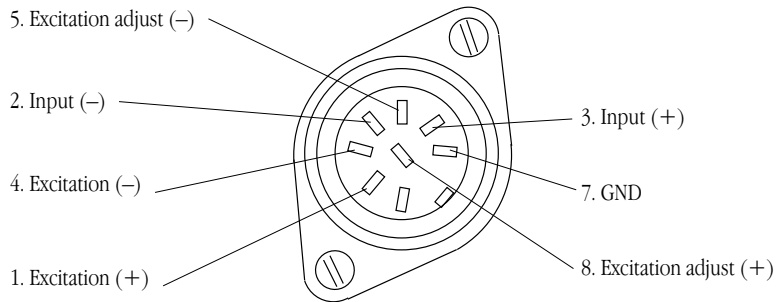


## GP Input Connector

The input connector on the front panel of the GP Amp is an 8-pin DIN connector. Its pin assignments are shown in Figure A-3.

**Figure A-3**

The pin assignments for the GP Amp input



Note that pin 6 is not used. Input (+) is the non-inverting signal input, and Input (-) is the inverting signal input. GND is the Ground (and shield connection point). Excitation (+) is the Positive excitation (10 V) supply output, and Excitation (-) is the Negative excitation (10 V) supply output. The Excitation adjust pins adjust voltage between the Excitation (+) and Excitation (-) terminals.



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# B

## A P P E N D I X B

# Troubleshooting

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This appendix describes most of the common problems that can occur when using the Spirometer or GP Amp 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, your software guide, and the guide to your PowerLab may contain possible remedies. If none of the solutions here or elsewhere appears to help, then consult your ADInstruments distributor.

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: Macintosh

*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<sup>2</sup>C 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. BNC cables from the Spirometer or GP Amp 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.

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You are using an early version of Chart or Scope. You must be using version 3.0 or higher to use Spirometer or GP Amp.

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

The BNC or I<sup>2</sup>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 distributor 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 (it should be in the ADInstruments folder in your System folder).

- Reinstall the software.

You are using an early version of Chart or Scope. You must be using version 3.0 or higher to use the Spirometer or GP Amp.

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

The BNC or I<sup>2</sup>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

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PowerLab. If the same problems recur with a second PowerLab, the front-end may be faulty. Contact your ADInstruments distributor 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 Chart or Scope. Some changes may have been made since then.

- Upgrade to the latest version of the software. Contact your ADInstruments distributor 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 transducer is defective or subject to excessive load, causing the offset range of the GP Amp's zeroing circuitry to be exceeded.

- Check the transducer with another GP Amp if possible and try again. Contact the supplier or manufacturer of the transducer if there still seems to be a problem.

*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.

*The signal from the transducer connected to the GP Amp is weak even at lower ranges*

The connection to the transducer may be connected incorrectly, or may be loose or disconnected. Adaptations within the plug may be faulty or badly wired up.

- Check the connection and try again. If the transducer has been adapted for use with the GP Amp, check the wiring and soldering within the plug.

The transducer itself is faulty.

- Check the transducer with another GP Amp if possible and try again. Contact the supplier or manufacturer of the transducer if there still seems to be a problem.

## **Problems: Windows**

*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<sup>2</sup>C 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. BNC cables from the Spirometer or GP Amp

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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 the software. You must be using version 3.3 or higher of Chart for Windows, and version 3.6 or higher of Scope for Windows, to use the Spirometer or GP Amp.

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

The BNC or I<sup>2</sup>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 distributor 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 drivers are not installed on your computer (Scope for Windows has them in a Common Files folder in the ADInstruments folder; currently, Chart for Windows has them built in).

- Reinstall the software.

You are using an early version of the software. You must be using version 3.3 or higher of Chart for Windows, and version 3.6 or higher of Scope for Windows, to use the Spirometer or GP Amp.

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

The BNC or I<sup>2</sup>C cable is faulty.

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- 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 distributor 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 Chart or Scope. Some changes may have been made since then.

- Upgrade to the latest version of the software. Contact your ADInstruments distributor 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 transducer is defective or subject to excessive load, causing the offset range of the GP Amp's zeroing circuitry to be exceeded.

- Check the transducer with another GP Amp if possible and try again. Contact the supplier or manufacturer of the transducer if there still seems to be a problem.

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***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.

***The signal from the transducer connected to the GP Amp is weak even at lower ranges***

The connection to the transducer may be connected incorrectly, or may be loose or disconnected. Adaptations within the plug may be faulty or badly wired up.

- Check the connection and try again. If the transducer has been adapted for use with the GP Amp, check the wiring and soldering within the plug.

The transducer itself is faulty.

- Check the transducer with another GP Amp if possible and try again. Contact the supplier or manufacturer of the transducer if there still seems to be a problem.



# C

## A P P E N D I X C

# Specifications

## Spirometer Specifications

### Input

Connection type: Two pipes for airflow physically connected by plastic tubes to the flow head

Input configuration: Differential pressure input,  $\pm 12.5$  cm (5")  $H_2O$  (9.3 mmHg, 1240 Pa)

Amplification ranges:  $\pm 2$  mV to  $\pm 10$  V full scale in 12 steps (combined PowerLab and Spirometer)

<i>Volts</i>	<i>cm H<sub>2</sub>O</i>	<i>Pa</i>
$\pm 10$ V	$\pm 12.5$	$\pm 1240$
$\pm 5$ V	$\pm 6.25$	$\pm 620$
$\pm 2$ V	$\pm 2.5$	$\pm 248$
$\pm 1$ V	$\pm 1.25$	$\pm 124$
$\pm 0.5$ V	$\pm 0.625$	$\pm 62$
$\pm 0.2$ V	$\pm 0.25$	$\pm 24.8$
$\pm 0.1$ V	$\pm 0.125$	$\pm 12.4$
$\pm 50$ mV	$\pm 0.0625$	$\pm 6.2$
$\pm 20$ mV	$\pm 0.025$	$\pm 2.48$
$\pm 10$ mV	$\pm 0.0125$	$\pm 1.24$
$\pm 5$ mV	$\pm 0.00625$	$\pm 0.62$
$\pm 2$ mV	$\pm 0.0025$	$\pm 0.248$

Maximum input pressure:  $\pm 5$  psi (34.5 kPa)

Pressure sensitivity: 1.27 V per cm (0.5 V per inch)  $H_2O$

Frequency Response:  $-3$  dB at 1 kHz (1 ms time constant)

Accuracy:  $\pm 0.25\%$  of full scale, after zero correction

Amplifier noise:  $< 3 \mu\text{V}_{\text{rms}}$  at 10 kHz bandwidth  
 $< 1 \mu\text{V}_{\text{rms}}$  for 100 kHz bandwidth and lower

Zeroing and Offset: Manual or automatic software-controlled zeroing, controlled by internal 12-bit DAC; resolution =  $\pm 2048$  steps about 0 V.

## Filters

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

## Control Port

I<sup>2</sup>C port: Provides control and power. Interface communications rate of  $\sim 50$  kbits/s.

## Physical Configuration

Dimensions (h  $\times$  w  $\times$  d): 50 mm  $\times$  76 mm  $\times$  260 mm  
(1.96"  $\times$  3.0"  $\times$  10.2")

Weight: 775 g (1 lb 11 oz)

Power requirements: 2.0 W max

Operating temperature range: 0 to 35 °C, 0 to 90% humidity (non-condensing)

# GP Amp Specifications

## Input

Number of inputs: 1 (standard 8-pin DIN)

Input configuration: Differential

Amplification ranges:  $\pm 2$  mV to  $\pm 10$  V full scale in 12 steps  
(combined PowerLab and GP Amp)

$\pm 10$  V  
 $\pm 5$  V  
 $\pm 2$  V  
 $\pm 1$  V  
 $\pm 0.5$  V  
 $\pm 0.2$  V

	$\pm 0.1\text{ V}$ $\pm 50\text{ mV}$ $\pm 20\text{ mV}$ $\pm 10\text{ mV}$ $\pm 5\text{ mV}$ $\pm 2\text{ mV}$
Amplification accuracy:	$\pm 0.5\%$ (combined PowerLab and GP Amp)
Maximum input voltage:	$\pm 15$ volts
Input impedance:	100 M $\Omega$
Frequency response (-3 dB):	5 kHz maximum at all gains with filters off
CMRR (differential):	100 dB @ 50 Hz (typical)
Input noise:	$<2\ \mu\text{V}_{\text{rms}}$ referred to input at highest gain

## Excitation and Zeroing

Excitation voltage range:	0–20 volts DC ( $\pm 10\text{ V}$ referred to ground), adjusted by external resistor
Transducer drive current:	$\pm 100\text{ mA}$ maximum
Zeroing circuitry:	Software-controlled, either manual or automatic
Internal offset resolution:	12-bit (internal DAC) $\pm 2048$ steps about 0 V. Designed to offset a maximum of $\pm 5\text{ V}$ , giving a resolution of $\sim 2.5\text{ mV}$ .

## Filters

Low-pass filtering:	1, 10, or 100 Hz (software-selectable) using fourth-order Bessel filter, or Off (the non-filtered GP Amp bandwidth is 5 kHz)
High-pass filtering:	DC or 0.3 Hz (software-selectable)

## Control Port

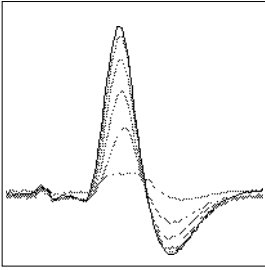
I <sup>2</sup> C port:	Provides control and power. Interface communications rate of $\sim 50\text{ kbits/s}$ .
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## Physical Configuration

Dimensions (h × w × d):	50 mm × 76 mm × 260 mm (1.96" × 3.0" × 10.2")
Weight:	775 g (1 lb 11 oz)
Power requirements:	3.2 W (with no transducer)
Operating temperature range:	0 to 35 °C, 0 to 90% humidity (non-condensing)

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



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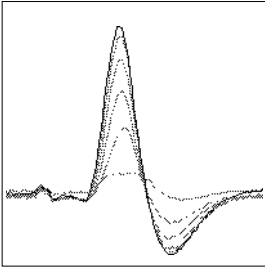
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# Licensing & Warranty Agreement

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## Extent

This Agreement is between ADInstruments Pty Ltd ['ADI'] and the purchaser ['the Purchaser'] of any ADI product — software, hardware, or both — and covers all obligations and liabilities on the part of ADI, the Purchaser, and other users of the product. The Purchaser (or any user) accepts the terms of this Agreement by using the product. Any changes to this Agreement must be recorded in writing and have ADI's and the Purchaser's consent.

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