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# Safety Notes

# Statement of Intended Use

All products manufactured by ADInstruments are intended for use in teaching and research applications and environments only. ADInstruments products are NOT intended to be used as medical devices or in medical environments. That is, no product supplied by ADInstruments is intended to be used to diagnose, treat or monitor a subject. Furthermore no product is intended for the prevention, curing or alleviation of disease, injury or handicap. ADInstruments products are intended to be installed, used and operated under the supervision of an appropriately qualified life-science researcher. The typical usage environment is a research or teaching lab or hospital. ADInstruments equipment is not intended for use in domestic environments.

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

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

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

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

# Safety and Quality Standards

When used with ADInstruments isolated front-ends, PowerLab systems are safe for connection to subjects. The FE231 Bio Amp, FE232 Dual Bio Amp and FE234/FE238 Quad/Octal Bio Amps front-ends conform to international safety requirements. Specifically these are IEC60601-1 and its addenda (Safety Standards, page 3) and various harmonized standards worldwide (CSA601.1 in Canada and AS/NZS 3200.1 in Australia and New Zealand).

In accordance with European standards they also comply with the electromagnetic compatibility requirements under IEC60601-1-2, which ensures compliance with the EMC directive.

#### **Quality Management System ISO 9001:2008**

ADInstruments manufactures products under a quality system certified as complying with ISO 9001:2008 by an accredited certification body.

# Regulatory Symbols

Amplifiers and signal-conditioners manufactured by ADInstruments that are designed for direct connection to humans and animals are tested to IEC60601-1:2012 (including amendments 1 and 2), and carry one or more of the safety symbols below. These symbols appear next to those inputs and output connectors that can be directly connected to human subjects.



**BF (body protected) symbol.** This means that the input connectors are suitable for connection to humans and animals provided there is no direct electrical connection to the heart.



**Warning symbol.** The exclamation mark inside a triangle means that the supplied documentation must be consulted for operating, cautionary or safety information before using the device.



**CE Mark.** All front-end amplifiers and PowerLab systems carry the CE mark and meet the appropriate EU directives.



**UKCA mark.** All front-end amplifiers and PowerLab systems carry the UKCA mark and meet the appropriate UK directives.



**Refer to booklet symbol.** This symbol specifies that the user needs to refer to the Instruction manual or the booklet associated with the device.



**Date of Manufacture/ Manufacturer's name symbol.** This symbol indicates the date of manufacture of the device and the name of the manufacturer



**WEEE directive symbol.** Unwanted equipment bearing the Waste Electrical and Electronic Equipment (WEEE) Directive symbol requires separate waste collection. (See disposal section at the end of this chapter)

Further information is available on request.

# Safety Standards

#### IEC Standard - International Standard - Medical Electrical Equipment

IEC 60601-1-1:2000 Safety requirements for medical electrical systems

IEC 60601-1:2012 + A1 General requirements for safety

# General Safety Instructions

To achieve the optimal degree of subject and operator safety, consideration should be given to the following guidelines when setting up a PowerLab system either as stand-alone equipment or when using PowerLab equipment in conjunction with other equipment. Failure to do so may compromise the inherent safety measures designed into PowerLab equipment. ADInstruments front-ends are only suitable for operation with ADInstruments PowerLabs. Front-ends are suitable for use with any S/, SP/, /20, /25, /30 and /35 series and 15T PowerLabs (FE234 and FE238 only suitable for use with 35 series PowerLabs). Note that compliance with IEC60601-1 can only be achieved when front-ends are used with a /35 series Powerlab.

The following guidelines are based on principles outlined in the international safety standard IEC 60601-1: *General requirements for safety – Collateral standard: Safety requirements for medical systems.* Reference to this standard is required when setting up a system for human connection. The user is responsible for ensuring any particular configuration of equipment complies with IEC60601-1-1. Guidance on compliance with this standard is provided in the following sections.

PowerLab systems (and many other devices) require the connection of a personal computer for operation. This personal computer should be certified as complying with IEC 60950 and should be located outside a 1.8 m radius from the subject (so that the subject cannot touch it while connected to the system). Within this 1.8 m radius, only equipment complying with IEC 60601-1 should be present. Connecting a system in this way obviates the provision of additional safety measures and the measurement of leakage currents.

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

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

- Any electrical equipment which is located within the SUBJECT AREA should be approved to IEC 60601-1.
- Only connect those parts of equipment that are marked as an APPLIED PART to the subject. APPLIED PARTS may be recognized by the BF symbol which appears in the Safety Symbols section of these Safety Notes.
- Never connect parts which are marked as an APPLIED PART to those which are not marked as APPLIED PARTS.

- Do not touch the subject to which the PowerLab (or its peripherals) is connected at the same time as making contact with parts of the PowerLab (or its peripherals) that are not intended for contact to the subject.
- Cleaning and sterilization of equipment should be performed in accordance with manufacturer's instructions. The isolation barrier may be compromised if manufacturer's cleaning instructions are not followed.
- The ambient environment (such as the temperature and relative humidity) of the system should be kept within the manufacturer's specified range or the isolation barrier may be compromised.
- The entry of liquids into equipment may also compromise the isolation barrier. If spillage occurs, the manufacturer of the affected equipment should be contacted before using the equipment.
- Many electrical systems (particularly those in metal enclosures) depend upon the presence of a protective earth for electrical safety. This is generally provided from the power outlet through a power cord, but may also be supplied as a dedicated safety earth conductor. Power cords should never be modified so as to remove the earth connection. The integrity of the protective earth connection between each piece of equipment and the protective earth should be verified regularly by qualified personnel.
- Avoid using multiple portable socket-outlets (such as power boards) where possible as they provide an inherently less safe environment with respect to electrical hazards. Individual connection of each piece of equipment to fixed mains socket-outlets is the preferred means of connection.

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

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

## **Earthing and Ground Loop Noise**

The prime function of earthing is safety, that is, protection against fatal electrocution. Safety concerns should always override concerns about signal quality. Secondary functions of earthing are to provide a reference potential for the electrical equipment and to mitigate against interference.

The earthing (grounding) stud provided on the back panel of the PowerLab is a potential equalization post and is compatible with the DIN 42801 standard. It is directly connected to the earth pin of the power socket and the PowerLab chassis. The earthing stud can be used where other electronic equipment is connected to the PowerLab, and where conductive shields are used to reduce radiative electrical pick-up. Connection to the stud provides a common earth for all linked devices and shields, to reduce ground-loops.

The earthing stud can also be used where a suitable ground connection is not provided with the mains supply by connecting the stud to an earthed metal infrastructure, such as a metal stake driven into the ground, or metal water piping. This may also be

required in laboratories where safety standards require additional grounding protection when equipment is connected to human subjects. Always observe the relevant safety standards and instructions.

Note that electromagnetically-induced interference in the recorded signal can be reduced by minimizing the loop area of signal cables, for example by twisting them together, or by moving power supplies away from sensitive equipment to reduce the inductive pick-up of mains frequency fields. Please consult a good text for further discussion of noise reduction.

# Cleaning and Sterilization

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

# Inspection and Maintenance

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

Your PowerLab system can be periodically checked for basic safety by using an appropriate safety testing device. Tests such as earth leakage, earth bond, insulation resistance, subject leakage and auxiliary currents and power cable integrity can all be performed on the PowerLab system without having to remove the covers. Follow the instructions for the testing device if performing such tests. If the PowerLab system is found not to comply with such testing you should contact your PowerLab representative to arrange for the equipment to be checked and serviced.



WEEE Directive

# Environment

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

#### Disposal

- Forward to recycling center or return to manufacturer.
- Unwanted equipment bearing the Waste Electrical and Electronic Equipment (WEEE) Directive symbol requires separate waste collection. For a product labeled with this symbol, either forward to a recycling center or contact your nearest ADInstruments representative for methods of disposal at the end of its working life.



# Overview

The PowerLab system consists of a recording unit and application programs that run on the computer to which the unit is connected. It provides an integrated system of hardware and software designed to record, display, and analyze experimental data.



Front-ends are ancillary devices that connect 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.

# Introduction

The PowerLab controls front-ends through an expansion connector called the I<sup>2</sup>C (eye-squared-sea) bus. This makes it very easy to add front-ends to the system or to transfer them between PowerLabs. Many front-ends can be added to the system by connecting the I<sup>2</sup>C sockets in a simple daisy-chain structure. The PowerLab provides control and low-voltage power to front-ends through the I<sup>2</sup>C bus so, in general, no separate power supply is required.

In addition, each front-end requires a separate connection to one or more analog input channel(s) of the PowerLab. External signals are acquired through the PowerLab analog inputs and amplified before being digitized by the PowerLab. The digitized signal is transmitted to the computer using a fast USB connection. ADInstruments software applications LabChart, LabTutor, LabStation and Lt receive, display, and record the data and your analysis to the computer's hard disk.

Front-ends are automatically recognized by the PowerLab system. Once connected, the features of the front-end are combined with the appropriate features of the PowerLab (for example, range and filtering options) and are presented as a single set of software controls.

**Note:** The Stimulator front-ends differ from other front-ends in two respects:

- 1. Since they need to produce a reasonably high voltage and current, the Stimulator front-ends require a power supply in addition to the power provided by the I<sup>2</sup>C bus.
- 2. As they produce voltage output for stimulation, they are connected to a positive analog output socket of the PowerLab as a source for timing and producing pulses.

A variety of accessory products are available with ADInstruments Front-ends, such as transducers, signal cables and recording electrodes. Some of these are listed in the Getting Started with Front-end Signal Conditioners booklet, supplied with your Front-end. For more details see: http://www.adinstruments.com/ or contact your local ADInstruments representative.

# Checking the Front-end

Before connecting the front-end 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 authorized ADInstruments representative immediately and describe the problem. Arrangements can be made to replace or repair the front-end.

# Connecting to the PowerLab

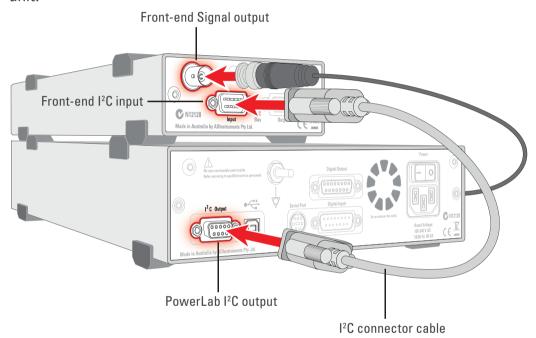
To connect a front-end to the PowerLab, first ensure that the PowerLab is turned off. Failure to do this may damage the PowerLab, the front-end, or both.

The BNC cable from the front-end signal output must connect to an analog input on the PowerLab. If you have an older PowerLab that has differential (rather than single-ended) inputs, the front-end must connect to a *positive* input.

# Single Front-ends

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 connectors 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 behavior, or may cause the front-end to fail to work at all.

# The Signal Output Socket

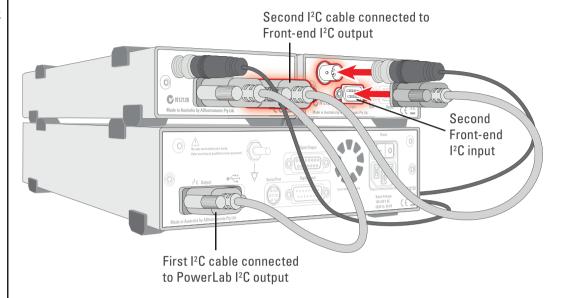
The BNC socket labelled Signal Output on the back panel of the front-end provides the signal output to connect to an analog input socket on the front of the PowerLab. A BNC-to-BNC cable is supplied for this connection. If necessary, use a BNC to DIN smart adapter [MLAC22] to connect the BNC cable to your PowerLab's input.

**Note:** If you have an older PowerLab with differential (rather than single-ended) inputs, the BNC cable must connect to a *positive* analog input on the PowerLab.

## **Multiple Front-ends**

Multiple separate front-ends can be connected up to a 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).

Figure 2–2
Connecting
multiple frontends to the
PowerLab (two
single frontends shown for
simplicity)



The number of normal front-ends that can be connected to a PowerLab depends on the number of analog input channels on the PowerLab. Each BNC cable from a front-end should be connected to one analog input channel on the PowerLab, for example, Input 1 on a /30 or /35 series PowerLab.

**Note:** Only one Stimulator front-end such as a Stimulus Isolator can be connected to the positive output of the PowerLab.

## **Special Cases**

Some front-ends have their own specific connection requirements. Please refer to the individual chapter for each front-end in this guide.

# **Connecting Stimulator Front-Ends**

The PowerLab analog outputs provide a variable, computer-controlled voltage output that can be used with LabChart, LabTutor, LabStation or Lt to connect a Stimulator front-end, or to stimulate directly, or to control a peripheral device. A voltage output is generated by the PowerLab and delivered via the BNC output sockets, giving positive, negative, differential, or independent stimuli, depending on the PowerLab used and the software settings.

The /20, /25, and /26 series PowerLabs have analog outputs labeled + and –. In contrast, the SP, ST, /30 and /35 series PowerLabs have the outputs labeled Output 1 and Output 2.

#### For the /20, /25 and /26 series PowerLabs:

The negative (–) output is the complement of the positive (+) output, so the stimuli from the two outputs are mirror images. If one output gives a positive voltage, the other gives a negative one, and the two together give a differential voltage. One Stimulator front-end such as a Stimulus Isolator or Stimulator HC can be connected to the positive output of these PowerLabs.

**Note:** If you connect the Stimulator HC to a PowerLab that has an in-built Isolated Stimulator, such as a PowerLab 26T, only the external, connected stimulator is used.

#### For /SP, /ST, /30 and /35 series PowerLabs:

Output 1 and Output 2 can function independently. However, only one Stimulator front-end such as a Stimulus Isolator or Stimulator HC can be connected to the positive output (Output 1) of these PowerLabs. With a Stimulator front-end connected, the second output (Output 2) can function independently, and a second tab appears in the Stimulator dialog in LabChart 7 for Windows. Therefore Output 2 remains available for other uses, such as creating analog waveforms and triggering other systems.

#### **Maximum Number of Front-Ends**

The I<sup>2</sup>C bus can control a maximum of sixteen front-ends. Therefore, if you are using a PowerLab 16/30, which has sixteen input channels, you can record from sixteen single channel front-ends.

# Using ADInstruments Programs

Front-ends are designed for use with PowerLabs and ADInstruments programs such as LabChart, LabTutor, LabStation and Lt. The functions of the front-end are combined with those of the PowerLab, and are presented as a single set of software controls in the ADInstruments program. Depending on the front-end(s) connected, front-end-specific dialogs replace the Input Amplifier dialogs or the Stimulator dialog.

The **LabChart Help** detail the Input Amplifier and Stimulator dialogs, and explain relevant terms and concepts, but they do not cover front-end-specific features. These features are described in detail in the following chapters for each front-end.

#### **Front-end Drivers**

A device driver is a piece of software that allows the computer's operating system and other software to interact with a hardware device. ADInstruments applications like LabChart communicate with a front-end via an appropriate front-end driver. These drivers are automatically set up on the computer when ADInstruments applications are installed, and their operation is usually invisible to the user.

However, under certain circumstances you may receive an error message during the startup of LabChart indicating that there is a problem with the front-end driver. Subsequently, the front-end will not function. This is invariably caused by the absence or incompatibility of a driver required for communication with the front-end due to an old version of the software being run. The problem can be remedied simply by reinstalling

and rerunning a current version of the software, which will include the latest front-end drivers.

#### 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:

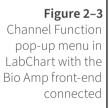
- Turn on the PowerLab and check that it is working properly, as described in the owner's guide that was supplied with it.
- Once the PowerLab is ready, start LabChart, LabTutor, LabStation or Lt.
- While the program is starting, watch the Status indicator on the front-end's front panel. During initialization, you should see the indicator flash briefly and then remain lit.

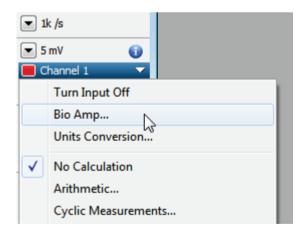
If the indicator lights correctly, the front-end has been found by the PowerLab and is working properly. If the indicator doesn't light, check your cable connections and repeat the start-up procedure.

## **Software Behavior**

When a front-end is connected to a PowerLab and the ADInstruments software is successfully installed, the **Input Amplifier...** menu command from the Channel Function pop-up menu in LabChart should be replaced by the **<Front-end>...** menu command.

For example, with a Bio Amp front-end connected, **Bio Amp...** should appear in the Channel function pop-up menu.





If the application fails to find a front-end attached to a channel, the normal **Input Amplifier...** command or button remains. If you were expecting a connected front-end, you should close the program, turn everything off, check the connections, restart the PowerLab and then relaunch LabChart, LabTutor or the Kuraloud Desktop App.

# Preventing Problems

Several problems can arise when using the PowerLab system for recording biological signals. It is important to understand the types of problems that can occur, how they manifest themselves, and what can be done to remove them or to minimize their effect. These are usually problems of technique, and should be addressed before you set up your equipment.

# **Aliasing**

Recordings of periodic waveforms that have been undersampled may have misleading shapes and may also have artifacts introduced by aliasing. Aliasing occurs when a regular signal is digitized at too low a sampling rate, causing the false appearance of lower frequency signals. An analogy to aliasing can be seen in old films: spoked wagon wheels may appear to stop, rotate too slowly or even go backwards when their rate of rotation matches the film frame speed – this is obviously not an accurate record.

The Nyquist–Shannon sampling theorem states that the minimum sampling rate ( $f_s$ ) to accurately describe an analog signal must be at least twice the highest frequency in the original signal. Therefore, the signal must not contain components greater or equal to  $f_s/2$ . The term  $f_s/2$  is known as the Nyquist frequency ( $f_n$ ) or the 'folding frequency' because frequencies greater than or equal to  $f_n$  fold down to lower frequencies about the axis of  $f_n$ .

When aliasing of noise or signals is seen, or even suspected, the first action you should take is to increase the sampling rate. The highest available sampling rates are 100k/s or 200k/s, depending on your PowerLab. To view the frequencies present in your recorded signal open the Spectrum window in LabChart. For more information about Spectrum, see the LabChart Help Center.

If unwanted high-frequency components are present in the sampled signal, you will achieve better results by using a low-pass filter to remove them. The best kind of filter for this purpose is the Anti-alias filter option available in the front-end-specific **Input Amplifier...** dialog. This is a special low-pass filter that is configured to automatically remove all signals that could alias; i.e., those whose frequency is greater or equal to half the sampling rate.

For certain PowerLabs, the Anti-alias filter option is not available. Therefore you should select an appropriate low-pass filter to remove any unwanted signals (or noise) occurring at frequencies greater or equal to half the sampling rate.

# **Frequency Distortion**

Frequency distortion will occur if the bandwidth of your recording is made smaller than the bandwidth of the incoming signal. For example, if an ECG was measured with a sampling rate of 100 samples per second (100 Hz) and the Bio Amp had a low-pass filter applied at 50 Hz, the fast-changing sections of the waveform (the QRS complex) may appear smaller and 'blunted', while the slower T-wave sections remain relatively unchanged. This overall effect is called frequency distortion.

It can be eliminated by increasing the frequency cut-off of the low-pass filter in the front-end-specific **Input Amplifier...** dialog to obtain an undistorted waveform.

Similarly, if the high-pass filter was set too high, the amplitude of the T-wave sections may be reduced. The **Input Amplifier...** dialog allows you to examine ECGs and similar slowly changing waveforms to fine-tune filter settings before recording.

#### Saturation

Saturation occurs when the range is set too low for the signal being measured (the amplification, or gain, is too high). As the signal amplitude exceeds the allocated range, the recorded waveform appears as if part of the waveform had been cut off, an effect referred to as clipping.

Clipping can also be caused by excessive baseline offset: the offset effectively moves the whole waveform positively or negatively to an extent that causes all or part of it to be clipped. This problem is overcome by selecting a higher range from the Range menu in the front-end-specific **Input Amplifier...** dialog. In the case of excessive baseline offset, you may wish to apply a high-pass filter with a higher frequency cut-off.

# **Ground Loops**

Ground loops occur when multiple connected pieces of recording equipment are connected to mains power grounds. For safety reasons, *all* electrical equipment should have a proper connection to the mains power grounds, or to a primary earth connection in situations where a mains ground connection is not available. Connecting linked electrical equipment to a common earth connection (equipotential connection point) – such as the earthing (grounding) stud provided on the rear of all PowerLabs – can prevent ground loops.

The electric fields generated by power lines can introduce interference at the line frequency into the recorded signal. Electromagnetic fields from other sources can also cause interference: fluorescent tubes, apparatus with large transformers, computers, laptop batteries, network cables, x-ray machines, microwave ovens, electron microscopes, even cyclic air conditioning.

Reasonable care in the arrangement of equipment to minimize the ground loop area, together with proper shielding, can reduce electrical frequency interference. For example, use shielded cables, keep recording leads as short as possible, and try twisting recording leads together. For sensitive measurements, it may be necessary to place the subject (the biological source) in a Faraday cage.

Interference should first be minimized, and then you can turn on the Mains filter in the front-end-specific **Input Amplifier...** dialog.

#### Mains filter

The Mains filter (/20, /25, /30, /35 and 26T PowerLabs) allows you to filter out interference at the mains frequency (typically 50 or 60 Hz). The mains filter is an adaptive filter which tracks the input signal over approximately 1 second. A template of mains-frequency signal present in the input is computed from the signal. The width of the template is the mains power period (typically 16.6 or 20 ms) as determined from zero-crossings of

the mains power. The filtered signal is obtained by subtracting the template from the incoming signal.

In comparison with a conventional notch filter, this method produces little waveform distortion. It attenuates harmonics of the mains frequency as well as the 50 or 60 Hz fundamental and therefore effectively removes non-sinusoidal interference, such as that commonly caused by fluorescent lights.

The filter should not be used when:

- the interference changes rapidly. The filter takes about 1 second to adapt to the present level. If interference is present and then is suddenly removed, interference in the filtered signal will temporarily worsen.
- your signal contains exact factors or harmonics of frequencies close to the mains frequencies, for example, a 30 Hz signal with 60 Hz mains frequency.
- your signal is already free from interference. If the signal-to-noise ratio is greater than about 64 the mains filter introduces more noise than it removes.
- you are recording at close to maximum sampling rates. The mains filter uses some of the PowerLab's processing power and therefore reduces the maximum rate at which you can sample.

#### **Electrode Contact**

Occasionally one of the lead wires connecting the subject to the front-end may become disconnected, or an electrode contact may become poor. If this should happen, relatively high voltages (potentials) can be induced in the open wire by electric fields generated by power lines or other sources close to the front-end or the subject. Such induced potentials will result in a constant amplitude disturbance in the recorded waveform at the power line frequency (50 or 60 Hz), and loss of the desired signal. If the problem is a recurring one, one of the leads may be faulty. Check connections and replace faulty leads, if necessary.

## **Motion Artifacts**

A common source of artifacts when recording biological signals is due to motion of the subject or equipment. Often applying a high-pass filter can help to remove slowly changing components in a recorded signal.

- Muscular activity generates its own electrical signals, which may be recorded along with an ECG, say, depending on the location of the electrodes.
- If an electrode is not firmly attached, impedance (and hence the recorded signal) may vary as the contact area changes shape owing to movement.
- Movement of patient cables, particularly bending or rubbing together (triboelectric effects) may generate artifacts in a signal.
- Subject respiration can also generate a signal; breathing can result in a slowly changing baseline corresponding to inspiration and expiration.

If the subject is liable to move during recording, then special care needs to be taken when attaching the electrodes and securing the patient leads. Make sure the skin is cleaned and lightly abraded before attaching the electrodes.

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# Chapter 1 pH Amp

The FE165 pH Amp is one of a family of modular devices called front-ends, designed to extend the capabilities of the PowerLab system. The pH Amp is designed to record signals from:

- pH electrodes
- potentiometric ion selective electrodes (ISEs)
- redox (or ORP, oxidation-reduction potentiometric) electrodes
- other high impedance sources up to  $\pm 2 \text{ V}$  requiring electrometer input.



The built-in temperature amplifier can be used to provide automatic temperature compensation (ATC) for pH and ion selective electrodes.

# The pH Amp

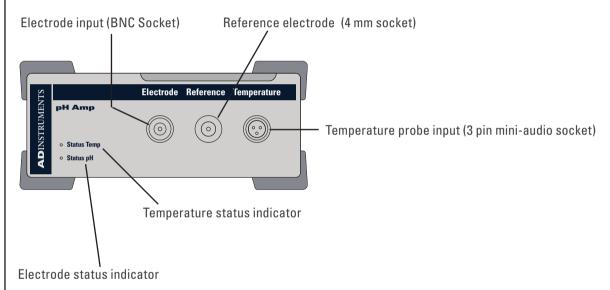
The pH Amp is designed for recording signals from pH and other potentiometric electrodes, and it operate under full software control. It is automatically recognized by ADInstruments software, which controls the gain/ range, signal filtering, and other settings.

#### It provides:

- a very high impedance amplifier suitable for direct connection to pH or other ion selective electrodes;
- software controlled filtering for the pH channel;
- reference electrode input;
- software selectable electrode sensitivity;
- a temperature amplifier, factory configured for use with an RTD temperature probe.

#### The Front Panel

Figure 1–1
The pH Amp
front panel



# The Electrode and Reference Input

The BNC input connector of the pH Amp provides connection for a pH, ISE or redox electrode. Combination electrodes, that is those with an internal reference, will only need to be connected to this input.

Electrodes that do not have an internal reference (most ISEs and some pH electrodes) will need to be used with a separate reference electrode. This electrode is connected via the 4 mm Reference socket and shares the shield (ground) of the BNC electrode input connector.

#### The Online Indicators

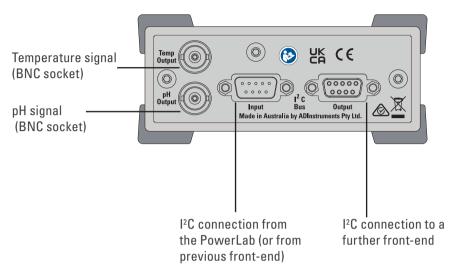
When lit, these indicate that the software has located and initialized the pH Amp. If the software is on and an indicator has not lit up, check that the pH Amp is properly connected. There are two indicators, one to show connection of the electrode signal, and the other to show connection of the temperature signal.

## The Temperature Input

The temperature input can be used with the 100  $\Omega$  platinum resistance (RTD) probe that is supplied with the unit.

## The Back Panel

Figure 1–2 The pH Amp back panel



## **The Signal Outputs**

The pH Output BNC socket provides the signal of the potential at the electrode, while the Temp Output BNC socket provides the signal of the temperature at the temperature probe. The two signals are independent and do not have to be recorded simultaneously.

#### I<sup>2</sup>C Sockets

Two nine-pin sockets are used to communicate with the PowerLab (they are marked '12C Bus': a 'bus' is simply information-transmission circuitry such as cable and connectors). The Input socket connects to the PowerLab (or the output of a previous ADInstruments front-end). This connection provides power and various control signals (such as gain range and filter selection) to the pH Amp from the PowerLab. The Output socket connects further front-ends to the system, in series, output to input (this is discussed in more detail in the next section).

# Connecting to the PowerLab

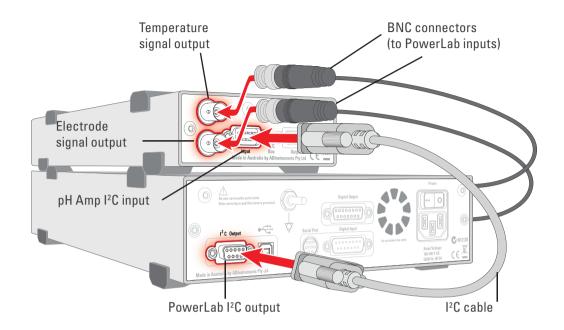
Always make sure that the PowerLab is turned off before you connect or disconnect the pH Amp. Failure to do this may result in damage to the PowerLab, the pH Amp, or both.

Your pH Amp will have been supplied with an I<sup>2</sup>C cable and two BNC cables. Use the BNC cables to connect the signal outputs on the back of the pH Amp to the signal inputs on the front of the PowerLab. You can use the pH Output (electrode signal) and the Temperature Output individually – you do not need to connect both signal outputs to be able to record data.

# **Single Front-end**

Connect the I<sup>2</sup>C Output on the back of the PowerLab to the I<sup>2</sup>C Input on the back of the pH Amp using the I<sup>2</sup>C cable provided. Figure 10–3 shows the connections between the pH Amp and the PowerLab.

Figure 1-3
Connecting the pH Amp front-end to the Powerl ab



Check that all connections are firm. Loose connectors can cause erratic front-end behavior, or may cause the front-end to fail to work at all. The BNC cable can be tucked under the front-end to keep it out of the way, if desired.

Note: If you have an older PowerLab with differential rather than single-ended inputs, the BNC cables must connect to the *positive* analog inputs (+). ADInstruments applications will not find the front-end on start-up if a negative input is used.

## **Multiple Front-ends**

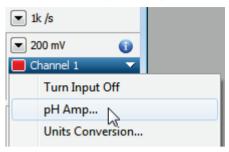
Multiple ADInstruments front-ends can be connected to a PowerLab. The number that can be connected depends on the number of input channels on the PowerLab, since each front-end signal output requires connection to an analog input channel of the PowerLab. The initial ADInstruments front-end should be connected as shown in Figure 10–3.

The remainder are linked via I<sup>2</sup>C cables, connecting the I<sup>2</sup>C Output of the previous frontend to the I<sup>2</sup>C Input of the next. The signal outputs of each ADInstruments front-end are connected to a separate analog input on the PowerLab (see Figure 2–2 on page 11).

# Using LabChart

When the pH Amp is properly connected to a channel, the **Input Amplifier...** menu command is replaced by **pH Amp...** for the channel to which it is connected.

Figure 1–4
Accessing the pH Amp dialog:
LabChart

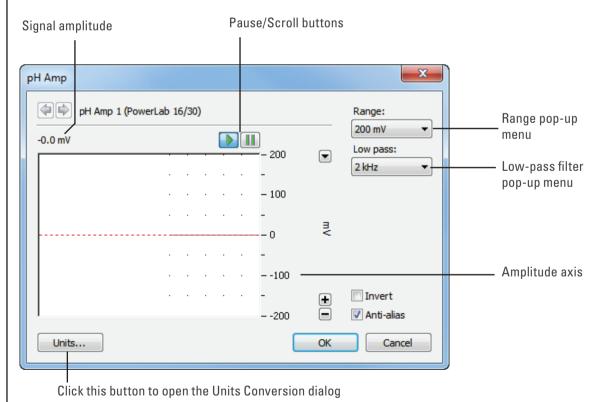


If you were expecting a connected front-end and see the **Input Amplifier...** text instead, you should quit the application, turn the PowerLab off and check the connections. Then restart the PowerLab and relaunch the application.

# The pH Amp dialog

The pH Amp dialog appears when you choose the **pH Amp...** menu command in LabChart. This dialog allows software control of the various amplifiers and filters of the hardware. Change settings in the dialog, then click **OK** to apply them.

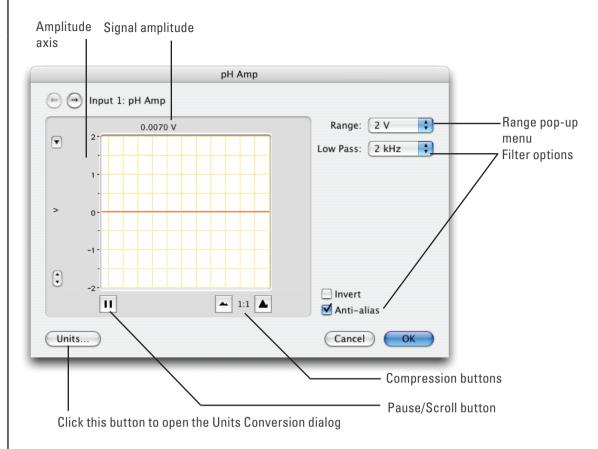
Figure 1-5 The pH Amp dialog (LabChart for Windows)



To set up many channels quickly, open the **Setup > Channel Settings...** dialog. Here you can view all the channels that are turned on, and you can turn off any unnecessary

channels. Clicking on **pH Amp...** in the Input Settings column of the Channel Settings dialog will also open the pH Amp dialog.

Figure 1-6
The pH Amp
dialog (LabChart
for Macintosh)



## Signal Display

The signal at a channel's input is displayed so that you can see the effect of changing the settings – no data are recorded at this time. Slowly drifting signals are shown quite accurately, whereas quickly changing signals are displayed as a solid dark area showing only the envelope (shape) of the signal from minimum and maximum values. The average signal value is displayed at the top of the display area.

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

# **Setting the Range**

The Range pop-up menu lets you select the input range or sensitivity of the channel – the combined range of the pH Amp and PowerLab. Changing the range in the pH Amp dialog is equivalent to changing it in the Chart or Scope window. Changes are applied once you click **OK**.

At 25 °C a pH Amp range of 59 mV corresponds to a range of approximately one pH unit. This relationship is the basis for Table 10–1, which shows the pH ranges corresponding to pH Amp range settings.

For general pH measurements, a range of 500 mV is recommended, while the 200 mV range is suitable for biological pH monitoring.

Table 1–1 pH Amp range settings corresponding to pH ranges

Range setting (mV)	Resolution† (μV)	Range (pH)	Resolution (pH)
± 500	15.6	-1.5 to 15.5*	< 0.001
± 200	6.25	3.6 to 10.4	< 0.001
± 100	3.13	5.3 to 8.7	< 0.001
± 50	1.56	6.2 to 7.8	< 0.001
± 20	0.625	6.7 to 7.3	< 0.001

<sup>†</sup> Resolution is 16 bits, or 0.0015%, of range setting with LabChart software.

# **Filtering**

The Low pass pop-up menu gives the choice of **2 kHz**, **50 Hz** and **10 Hz** low-pass filters. This filter removes high frequency noise. pH and ion selective electrodes have a slow response time, usually in the second time-scale, and the 10 Hz filter setting is suitable for use with these electrodes.

#### Units

Click **Units...** to display the Units Conversion dialog. However, when using LabChart to record data from pH and ion selective electrodes it is recommended that you do NOT use Units Conversion.

For double point calibration or multiple point calibration (more than two points), you should use the **Multipoint Calibration** extension. LabChart extensions are software additions to LabChart that provide extra functionality. All extensions are available as free downloads from LabChart's Feature Manager, or from the ADInstruments website.

To open Feature Manager, on Windows choose **Help > Feature Manager...** and on Macintosh choose **LabChart > Feature Manager...**. For more information, see the **LabChart Help Center**.

<sup>\*</sup> This range will be limited by the pH electrode

# Calibrating the pH Amp Electrode

Calibration of the pH electrode should be performed using the **Multipoint Calibration Extension**.

The **Multipoint Calibration Extension** is a LabChart software plug-in that performs double or multiple point calibration of the pH or ion selective electrode. The resulting calibration information is used to convert the raw voltage signal from the electrode into appropriate units (e.g. pH, pF, pNa), which will then be displayed for that input channel.

Once installed, the extension is loaded automatically when you start LabChart. When loaded, the **Multipoint Calibration Extension** adds the commands: **Multipoint Calibration** (Windows) to each Channel Function pop-up menu.

The calibration is applied to the entire length of the channel. The raw signal can be retrieved by choosing No Calculation from the Channel Function pop-up menu.

Full details on using this extension can be found in the **LabChart Help Center**, which is uploaded when the extension software is installed.

# **Setting Up the Temperature Signal**

The built-in temperature amplifier can be used to provide automatic temperature compensation (ATC) for pH and ion selective electrodes.

Choosing the **Temperature...** menu command in LabChart will open the Temperature dialog, which replaces the Input Amplifier dialog for that channel. The Temperature dialog for LabChart for Macintosh is shown in Figure 10–7 and the temperature Units Conversion dialog is shown in Figure 10–8. The dialogs and controls for LabChart for Windows are similar.

# **Signal Display**

In the Temperature dialog the input signal is displayed so that you can see the effect of changing the settings – no data are actually recorded when setting up the Temperature Amp. The average signal value is displayed at the top of the display area.

Figure 1-7
The Temperature
dialog (LabChart
for Macintosh)

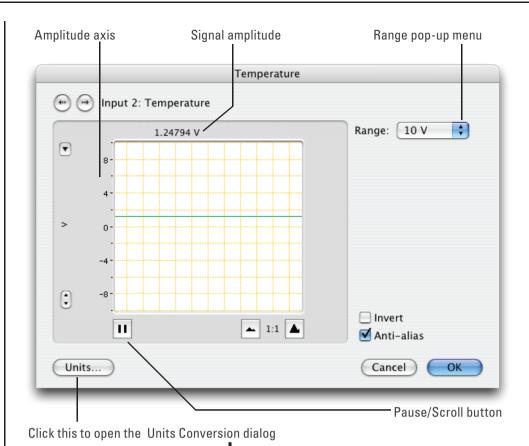
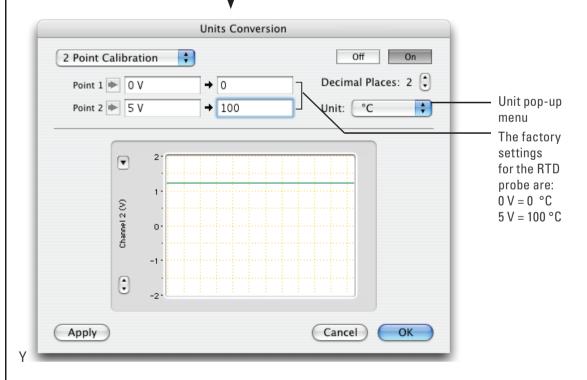


Figure 1–8
The Units
Conversion dialog
(LabChart for
Macintosh)



# **Setting the Range**

The Range pop-up menu is used to select the input range, or sensitivity, of the temperature measurement. The 2 V setting is suitable for temperatures up to 40  $^{\circ}$ C and the 5 V setting is suitable for up to 100  $^{\circ}$ C.

## **Inverting the Signal**

The Invert checkbox changes the polarity, to invert displayed signals.

#### **Anti-alias**

Click the Anti-alias checkbox to turn anti-aliasing on and off. Aliasing occurs when a regular signal is digitized at too low a sampling rate, causing the false appearance of lower frequency signals. To prevent aliasing, the Anti-alias filter applies a low-pass filter that attenuates all frequencies in the incoming signal that are greater than half the sampling rate. For certain PowerLabs, the Anti-alias filter option is not available and an appropriate low-pass filter can be applied to remove any unwanted signals (or noise) occurring at frequencies greater than half the sampling rate.

#### Units

Click **Units...** to display the Units Conversion dialog, with which you can set the units and calibrate the channel. The signal in the data display area of the Temperature dialog is transferred to the data display area of the Units Conversion dialog – use the Pause button if you want to capture a specific signal.

The raw temperature signal is in volts and must be converted to degrees Celsius, Fahrenheit or Kelvin for relevant analysis. The temperature amplifier has been factory set, for the RTD temperature probe provided with the unit, to produce 0 mV at 0 °C with an output of 50 mV/°C. If temperature accuracy is of critical importance, you should use two precision temperature sources to calibrate the temperature probe more accurately.

This units conversion only applies to subsequently recorded signals, so it is more limited than choosing **Units Conversion...** from the Channel Function pop-up menu, as it does not allow conversion of pre-recorded blocks of data. For more information about units conversion, see the **LabChart Help Center**.

## The Temperature Probe

The pH Amp is supplied with a RTD-type temperature probe with  $100~\Omega$  nominal resistance. The factory settings of the temperature amplifier with the temperature probe are to produce an output of 0 mV at 0 °C and 50 mV/°C (i.e. 5 V at 100~°C).

**Note:** Only use these values to calibrate the probe supplied with the pH Amp. You can substitute other RTD probes for the one provided, but the factory calibration will no longer apply, and you should use two precision temperature sources to calibrate the probe.

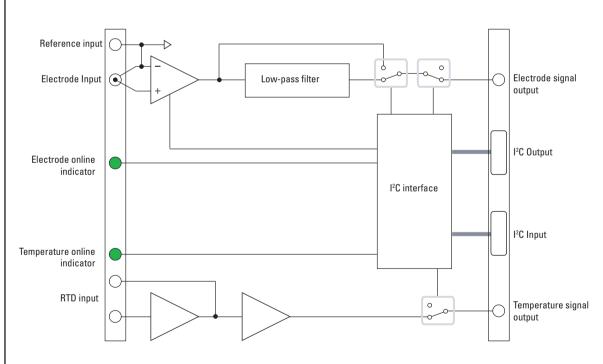
# Technical Aspects

As with other PowerLab front-ends, all internal functions of the pH Amp are controlled from the PowerLab by sending information on a special communications connection called the I<sup>2</sup>C (eye-squared-sea) bus. This connection supplies power to the ADInstruments front-end as well. ADInstruments front-ends are connected to the analog inputs of the PowerLab via BNC-to-BNC cables, through which the amplified and filtered signal is sent to the PowerLab. The overall operation of the pH Amp can be better understood by referring to Figure 10–9.

The pH input amplifier of the pH Amp is an electrometer type amplifier with extremely high input impedance. The input also has provision for connecting a reference electrode to the analog ground of the amplifier. The input amplifier gain can be set by the software to 1 or 10, depending on the required sensitivity. The output of the electrometer amplifier is fed to a 2 pole, 10 Hz low-pass filter which is software selectable. The output is then fed to the PowerLab for further amplification and filtering.

The temperature amplifier is effectively a separate ADInstruments front-end. It consists of a bridge circuit that is factory configured for use with RTD temperature probes. The pH Amp comes supplied with an RTD temperature probe. The output from the temperature amplifier has been factory set with the supplied RTD probe to produce 0-5 V over 0-100 °C.

Figure 1-9 Block diagram of the pH Amp



# Troubleshooting

If you experience any difficulty with the pH Amp use this section to try to resolve the problem. In the majority of cases, the problem can usually be fixed by ensuring that the connecting cables are correctly connected and firmly attached and then re-starting the LabChart software.

If the solutions here do not work, earlier chapters, the LabChart Help Center, and the guide to your PowerLab may contain possible solutions. If none of the solutions here or elsewhere are of help, then consult your ADInstruments representative.

The online indicator fails to light when LabChart is opened

- If the PowerLab is off check switches and power connections.
- The BNC to BNC cable from the pH Amp or the temperature output to the analog input channel of the PowerLab may not be properly connected. Check that the cable is firmly connected to the BNC connector on the back panel of the pH Amp and to a BNC input on the front panel of the PowerLab.

Either or both online indicators fail to light when the application is opened, and the pH Amp is not accessible from LabChart

- The I<sup>2</sup>C cable from the pH Amp to the PowerLab may not be properly connected. Check to see that the I<sup>2</sup>C cables are firmly seated and screwed in.
- Try new cables to check that the BNC and/or I<sup>2</sup>C cables are working correctly
- If you have tried the above suggestions and still cannot get the pH Amp to work properly, then try using it on another PowerLab if you have access to one. If the online indicators still fail to light on the second PowerLab, the unit may be faulty and should be returned for repair.

# Specifications

## pH Amplifier

pH amplifier: High impedance, electrometer type.

 $\pm$  200  $\mu$ V to  $\pm$  2 V full scale in 13 steps (combined Input ranges:

PowerLab and pH Amp)

Input resolution: 16 bits, 0.0015% of range

Input impedance:  $10^{13} \Omega$  typical

Amplifier noise:  $< 1~\mu V_{rms}~(< 4~\mu V~p-p)$  with a bandwidth of DC–10 Hz

Maximum Input: ± 10 V

Input connection type: Insulated BNC

10 Hz (-3 dB frequency) Low pass filter:

Low pass filter accuracy:  $\pm 3.0\%$ 

Low pass filter type: Bessel (2 pole)

## Temperature Amplifier

Temperature probe type: RTD –  $100 \Omega$  type (supplied with unit)

Temperature range: ± 100 °C Temperature accuracy: ± 0.2 °C

Amplifier output: 0 V @ 0 °C, 50 mV/°C (factory set)

Resolution °C Output ranges: Temperature °C Range

> ± 10 V  $\pm 200$ ± 5 V± 100 0.05 ± 2 V± 40 0.02

0.01 ± 500 mV ± 10 0.01

0.1

Input connection: 3 pin mini-audio jack

#### **Control Port**

I<sup>2</sup>C input and output: Male and female DB-9 pin connectors. Provides control

and power.

+ 1 V+ 20

Power requirements: ± 17 V DC

+8 V DC

~3 W

# **Physical Configuration**

Dimensions (h × w × d): 55 mm × 120 mm × 260 mm (2.2" × 4.7" × 10.2")

Weight: 1.2 kg (2 lb 11 oz)

Operating conditions: 5–35 °C

0-90% humidity (non-condensing)

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

# Chapter 1 Warranty

## **Product Purchase and License Agreement**

This Agreement is between ADInstruments NZ Ltd ['ADI'] and the purchaser ['the Purchaser'] of any ADI product or solution — 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 or solution. Any changes to this Agreement must be recorded in writing and have ADI's and the Purchaser's consent.

## Responsibilities

The Purchaser and any others using any ADI product or solution agree to use it in a sensible manner for purposes for which it is suited, and agree to take responsibility for their actions and the results of their actions. If problems arise with an ADI product, ADI will make all reasonable efforts to rectify them. This service may incur a charge, depending on the nature of the problems, and is subject to the other conditions in this Agreement. ADI does not separately warrant the performance of products, equipment or software manufactured by third parties which may be provided to Purchaser as part of an overall solution. However, as further noted below, ADI will pass through to Purchaser all applicable third party warranties to the extent it has the right to do so.

## **ADI Product Hardware Warranty**

ADI warrants that PowerLab Data Acquisition Units (PL prefix)1 and Front-ends (FEprefix)2 shall be free from defects in materials and workmanship for five (5) years from the date of purchase. Other PowerLab Data Acquisition Units3, Front-ends4 and Pods5 shall be free of defects in material and workmanship for three (3) years from their date of purchase. ADI also warrants that ADI Specialized Data Recorders6 and Instruments7 shall be free of defects in material and workmanship for one (1) year from their date of purchase. If there is such a defect, as Purchaser's sole remedy hereunder, ADI will repair or replace the equipment as appropriate, and the duration of the warranty shall be extended by the length of time needed for repair or replacement.

To obtain service under this warranty, the Purchaser must notify the nearest ADI office, or Authorized Representative, of the defect before the warranty expires. The ADI or Representative office will advise the Purchaser of the nearest service center address to which the Purchaser must ship the defective product at his or her own expense. The product should be packed safely, preferably in its original packaging. ADI will pay return shipping costs.

#### **Hardware Warranty Limitations**

This warranty applies only to the ADI hardware specified in this document and used under normal operating conditions and within specification. Consumables, electrodes and accessories are not covered by this warranty. Third party equipment may be covered by the third party manufacturer's warranty. To the extent that ADI has the right to pass through any third party manufacturer warranties to Purchaser it will do so to the extent it is able to do so. Copies of applicable third party manufacturer warranties, to the extent they exist, are available upon request. The warranty provided hereunder does not cover hardware modified in any way, subjected to unusual physical, electrical or environmental stress, used with incorrectly wired or substandard connectors or cables, or with the original identification marks altered. Tampering with or breaking of the Warranty Seal will also void the warranty.

## **Product Types & Warranty Term**

#### ADI manufactured products covered by a five (5) year warranty

- <sup>1</sup>Data Acquisition Units: PowerLab 35 series with PL prefix
- <sup>2</sup> Front-ends: ADI Front-end Signal Conditioners with FE prefix.

#### ADI manufactured products covered by three (3) year warranty

- <sup>3</sup> Data Acquisition Units: PowerLab 26 series with ML prefix
- <sup>4</sup> Front-ends: ADI Front-end Signal Conditioners with ML prefix.
- <sup>5</sup> Pods: The entire range of ADI Pod Signal Conditioners.

#### ADI manufactured products covered by one (1) year warranty

- <sup>6</sup> Specialized Data Recorders: Metabolic Systems (e.g., ML240 PowerLab/8M Metabolic System)
- <sup>7</sup> Instruments: Blood FlowMeter, Gas Analyzers, NIBP System (excluding transducers), STH Pump Controller.

#### Third Party Products (Including Transducers)

Products not manufactured by ADI are covered by the manufacturer's warranty.

#### **Accessories and Consumables**

Accessories and Consumables are not covered by any type of warranty.

#### **General Limitations**

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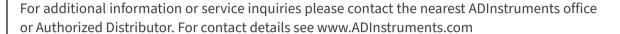
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## **Technical Support**

The Purchaser is entitled to free technical support for any ADI product for one year from its date of purchase. Our technical support staff can provide advice concerning installation and operation of ADI products. Services outside of this may incur a charge. Technical support staff will not provide experimental protocols or procedural instructions for conducting experiments. However, information of this type may be provided in the supplied product documentation, or on ADI web sites.

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