BLOOD PRESSURE AMPLIFIER

Owner's Guide

ADINSTRUMENTS
making science easier

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Chapter 1

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.

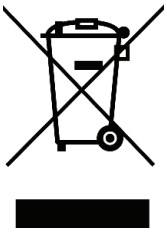
Cleaning and Sterilization

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 symbol

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.

Chapter 2
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^2C (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^2C sockets in a simple daisy-chain structure. The PowerLab provides control and low-voltage power to front-ends through the I^2C 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^2C 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 I²C output of the PowerLab to the I²C input of the front-end using the I²C cable provided. Figure 2–1 shows how to connect up a single front-end to your recording unit.

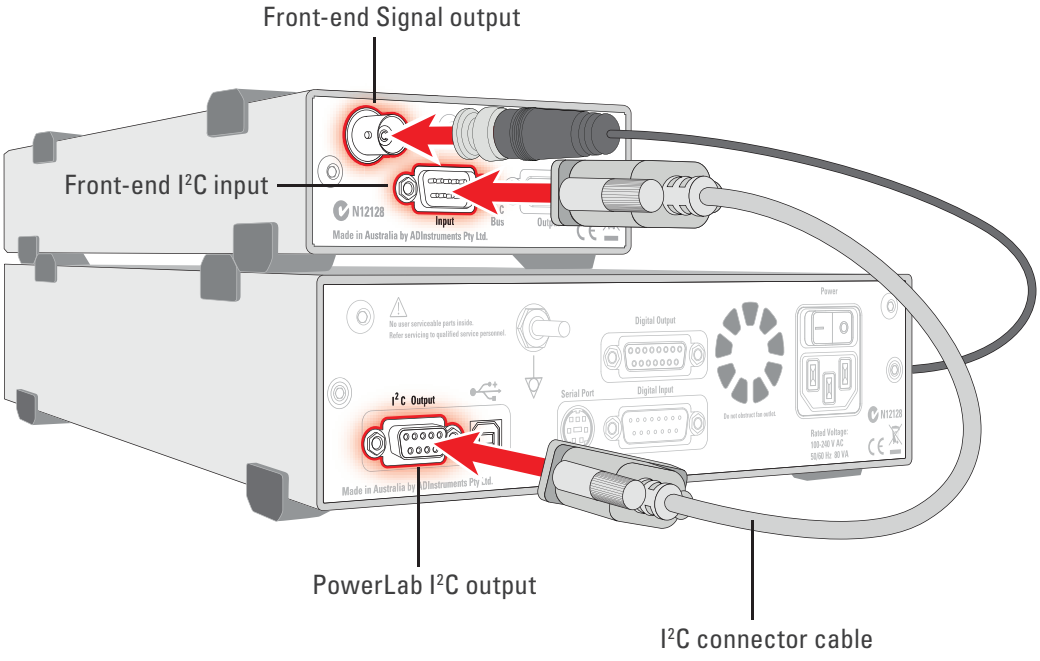


Figure 2–1 Connecting a front-end to the PowerLab: a PowerLab has only one I²C output, and each front-end has one I²C output and one I²C input

Check that the connectors for the I²C 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 I²C cable as in Figure 2–1. The remainder are daisy-chained via I²C cables, connecting the I²C output of the last connected front-end to the I²C input of the front-end to be added (Figure 2–2).

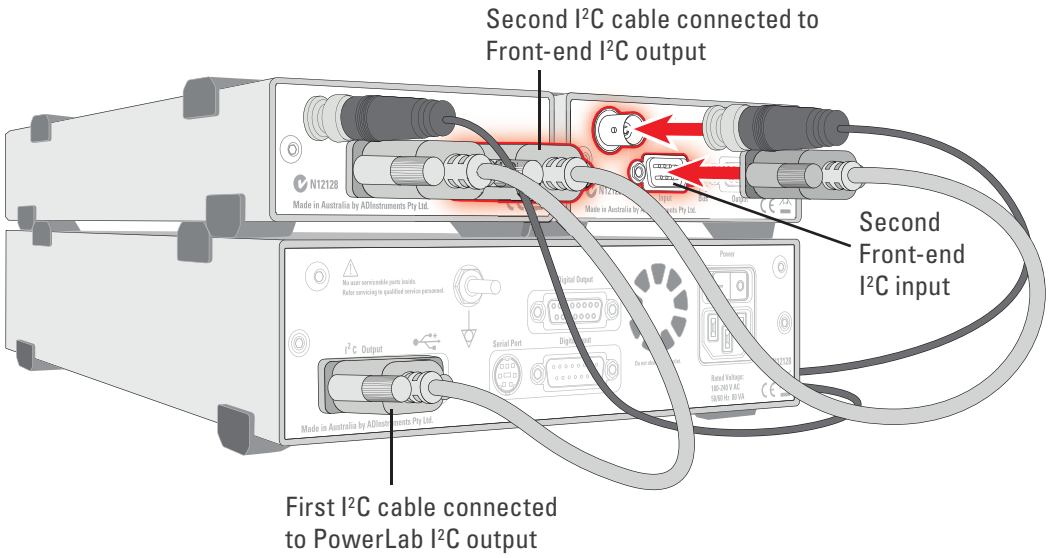


Figure 2–2 Connecting multiple front-ends to the PowerLab (two single front-ends shown for simplicity)

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^2C 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.

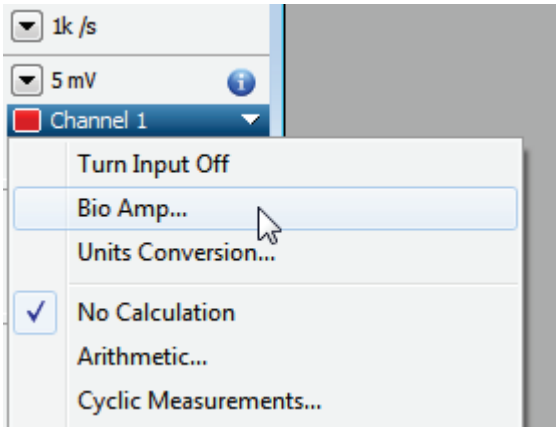


Figure 2–3 Channel Function pop-up menu in LabChart with the Bio Amp front-end connected

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.

Chapter 1

BP Amp

The BP Amp [FE117] is a modular device, in a family called front-ends, designed to extend the capabilities of the PowerLab system. The BP Amp is a blood pressure measurement amplifier and provides full electrical isolation. This chapter describes the basic features of the BP Amp and discusses some aspects of its use as well as its technical specifications.

The BP Amp

The BP Amp is designed to provide a fully subject-isolated blood pressure measurement amplifier for use with economical disposable blood pressure transducers. The BP Amp measures blood pressure directly in mmHg (millimeters of mercury). Units conversion is performed for you. It is precalibrated for use with the MLT0670 disposable blood pressure transducer. The pre-calibration can be overridden if you want to use another kind of transducer.

The rest of this chapter contains general information about the features, connections, and indicators of the BP Amp. It also looks at the disposable blood pressure transducer. More detailed information can be found in the technical section at the end of the chapter.

The Front Panel

The front panel of the BP Amp (Figure 5–1) is simple, with one input connector and an indicator light.

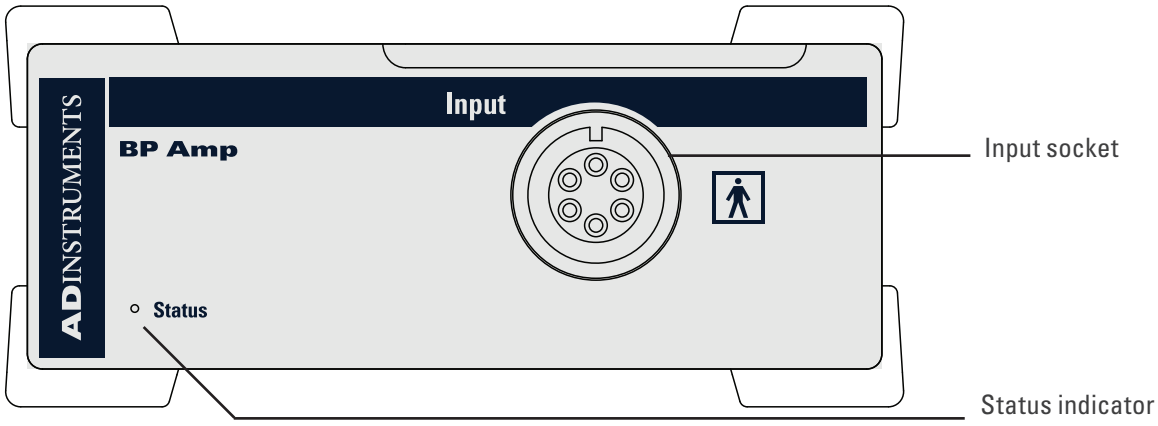


Figure 1–1
The front panel of the BP Amp

The Status Indicator

The status indicator light is located at the bottom left of the front panel. When an ADInstruments program such as LabChart 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 that it is ready for use. 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 Input Socket

Connections are made to the BP Amp using the six-pin socket on the front panel. The Utah Medical transducer cable, supplied with the BP Amp, has a 4-pin transducer connection at the other end, suitable for the MLT0670 blood pressure transducer. The input connection has internal isolation circuitry. The socket and connections to it are discussed in more detail later (“The Disposable BP Transducer” on page 22).

The Back Panel

The back panel of the BP Amp (Figure 5–2) provides all of the sockets that are required to connect the front-end to the PowerLab and to other front-ends.

I²C Input and Output Sockets

Two nine-pin sockets are used to communicate with the PowerLab (they are marked 'I²C Bus': a 'bus' is simply information-transmission circuitry such as cables and connectors). These sockets, in conjunction with the proper cables, allow multiple front-ends to be used independently with one PowerLab. Power and control signals to connected front-ends come from the PowerLab. ADInstruments front-ends are connected to each other in series, output to input (this is discussed in more detail in Chapter 2).

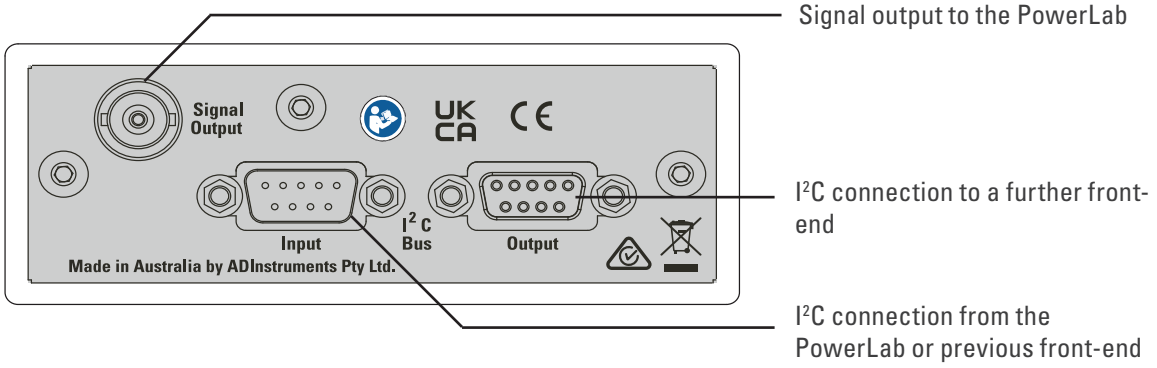


Figure 1–2
The back panel of the BP Amp

The Signal Output Socket

The BNC socket labeled Signal Output on the back panel of the BP Amp 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.

Connecting to the PowerLab

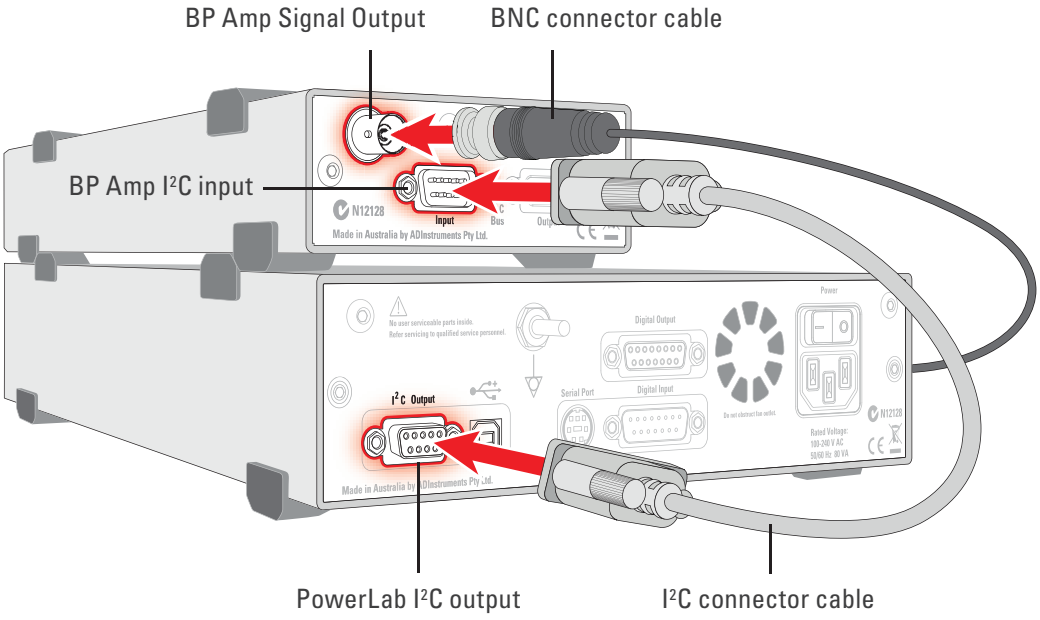
To connect your BP Amp to the PowerLab, first ensure that the PowerLab is turned off. Failure to do this may damage the PowerLab, the front-end, or both.

The BNC cable from the BP Amp signal output must connect to one of the PowerLab's analog inputs (e.g. Input 1). If necessary, use a BNC to DIN smart adapter [MLAC22] to connect the BNC cable to your PowerLab's input.

Connect the I²C output of the PowerLab to the I²C input of the front-end using the I²C cable provided.

Check that the connectors for the I²C 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.

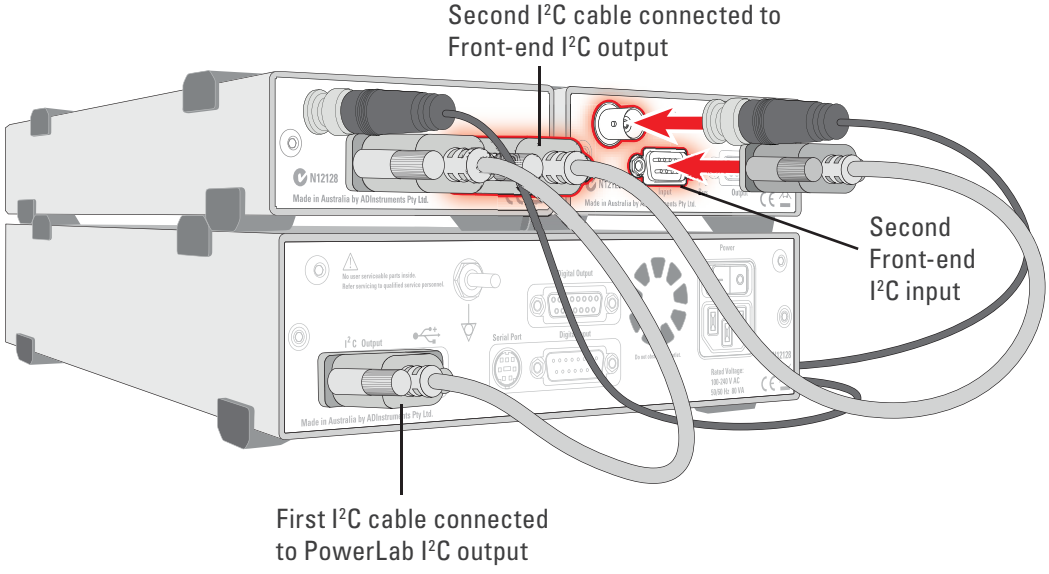
Figure 1–3
Connecting a single BP Amp front-end to the PowerLab



Multiple Front-ends

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 analog inputs on the PowerLab. The initial front-end should be connected with the I²C cable as in Figure 5–3. The remainder are daisy-chained via I²C cables, connecting the I²C output of the last connected front-end to the I²C input of the front-end to be added (Figure 5–4).

Figure 1–4
Connecting two front-ends to the PowerLab: a connection is made from the I²C output on the first front-end to the I²C input on the second front-end



Equipment and Technique

The Disposable BP Transducer

The Disposable BP Transducer [MLT0670] is reliable and economical. Its components and functions are described below.

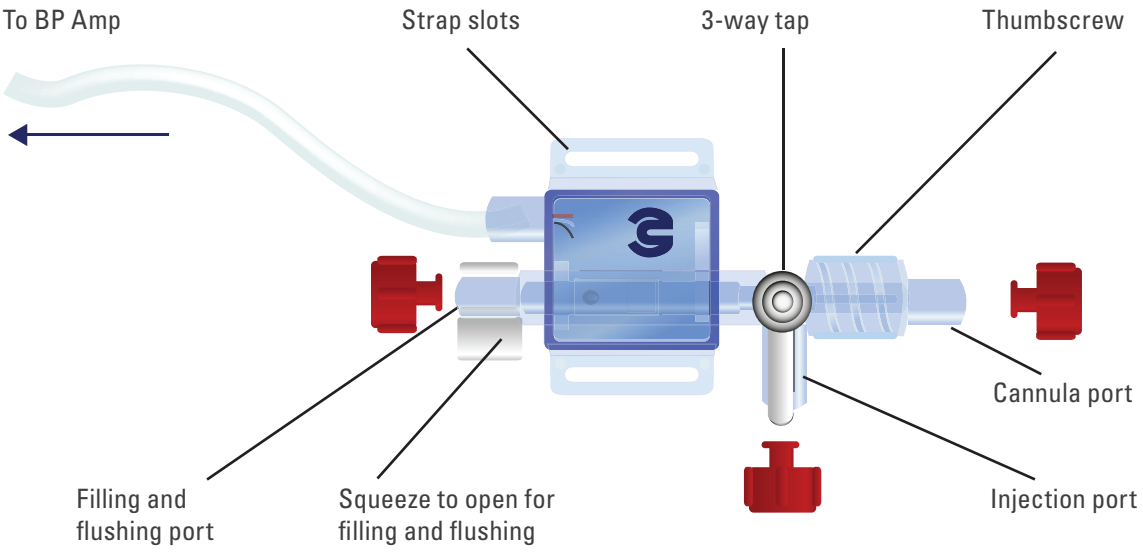


Figure 1–5 The MLT0670 Disposable BP Transducer

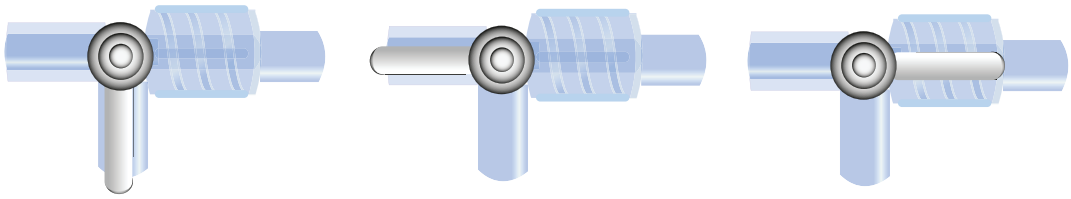
The transducer has three ports, up to two of which can be open at one time. The cannula port is the one that connects a pressure line (cannula or catheter) to the subject. The thumbscrew by the cannula port turns anticlockwise to tighten the connection to the port, and clockwise to loosen it and unscrew the pressure line. Either or both of the other ports can be used.

The flushing port helps to get rid of air bubbles, if the transducer is arranged with this port at the top. The squeeze valve is squeezed to open it for filling and flushing; it is closed in the rest position. The injection port is used to fill the device and pressure line with saline solution and to draw blood from the subject if necessary.

The three-way valve controls which ports remain open (although the filling and flushing port requires the squeeze valve to be squeezed in addition). Point the valve handle at the port to be turned off.

The 4-pin connection from the transducer slots into the end of the Utah Medical 650-208 cable that is supplied with the BP Amp. The transducer may be attached to a subject or support frame using a strap through the strap slots.

Figure 1–6
Three-way valve positions on the blood pressure transducer



Measurement position

Injection and blood-sampling position

Flushing and zeroing position

Sterilization of the Disposable BP Transducer

If using the MLT0670 Disposable BP Transducer (stopcock) for measuring blood pressure in human subjects, the transducer must be sterilized prior to use. Although the MLT0670 is supplied in sterile packaging, ADInstruments cannot guarantee its sterility. Therefore it is recommended that the user gas sterilize the transducer prior to use.

Zeroing

When zeroing the BP Amp, close the cannula port (Figure 5–6, right), leaving the central area of the transducer and its pressure sensor open to the atmosphere.

Connecting a Subject

Note. Only appropriately qualified and experienced personnel should attempt to connect the device to a human subject.

Before connecting up a subject, the transducer, pressure line, and so on should be filled with sterile 'heparinized' saline (saline solution containing heparin to prevent blood clots). After this is done, make sure the setup is free of air bubbles, insert the cannula or catheter into the vein or artery, and secure the insertion point.

For animal monitoring, the catheter or pressure line to the cannula is kept as short as possible. When monitoring humans, there are usually extra safety devices, and the transducer will likely be part of an infusion set. A pressure line, if used, should be short and rigid, to avoid losing measurements of fast changes in pressure. The catheter or cannula should lie flat where it enters the blood vessel, to prevent obstruction of the tip.

If the pressure line back-fills with blood, the blood may clot, since it is not circulating. To prevent this, sterile 'heparinized' saline is injected or infused as required to keep the pressure line clear of clottable blood. In a transparent pressure line, diffusing blood can be seen, and the onset of clotting is also indicated by waveform amplitude attenuation in the blood pressure signal. It is important to keep blood out of the transducer itself.

Using LabChart

Once the BP Amp is connected, turn the PowerLab on and launch LabChart. When a BP Amp is properly connected to the PowerLab, the **Input Amplifier...** menu command is replaced by **BP Amp...** for the input channel to which it is connected.

If LabChart fails to find a front-end connected, the normal text remains. If you were expecting a connected front-end and see the normal text instead, you should quit the application, turn the PowerLab off and check the connections. Then restart the PowerLab and re-launch LabChart.

The LabChart Help Center details the Input Amplifier dialog, and explain relevant terms and concepts.

The documentation for LabChart does not cover front-end-specific features. These features are described in detail here for LabChart.

The BP Amp dialog

The **BP Amp...** dialog appears when you choose **BP Amp...** from the Channel Function pop-up menu of the input channel it is attached to, or click **BP Amp...** in the Input Settings column of the Channel Settings dialog. The **BP Amp...** dialog allows software control of the combined filters and other circuitry in the PowerLab and BP Amp. The signal present at an input is displayed so that you can see the effects of changes straight away.

The BP Amp is pre-calibrated and measures blood pressure directly in mmHg (millimeters of mercury). The dialog also allows you to zero the BP Amp. After changing settings in the dialog, click OK to apply them.

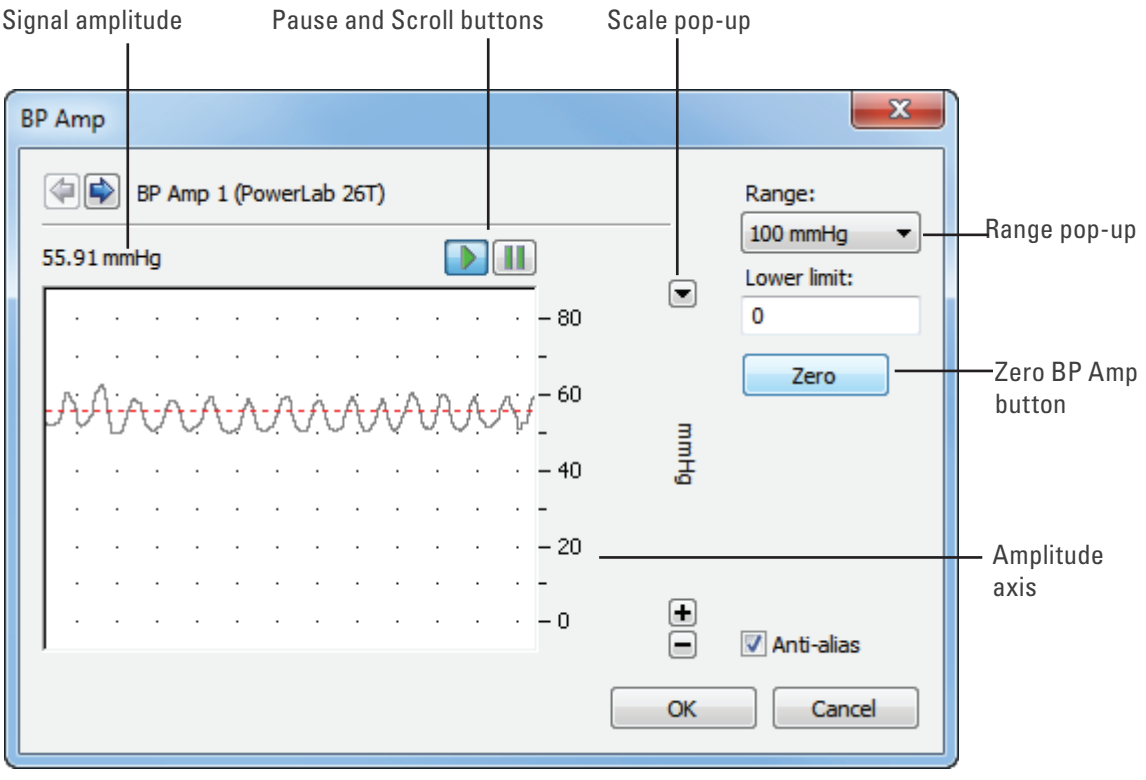


Figure 1–7
The BP Amp dialog for Windows

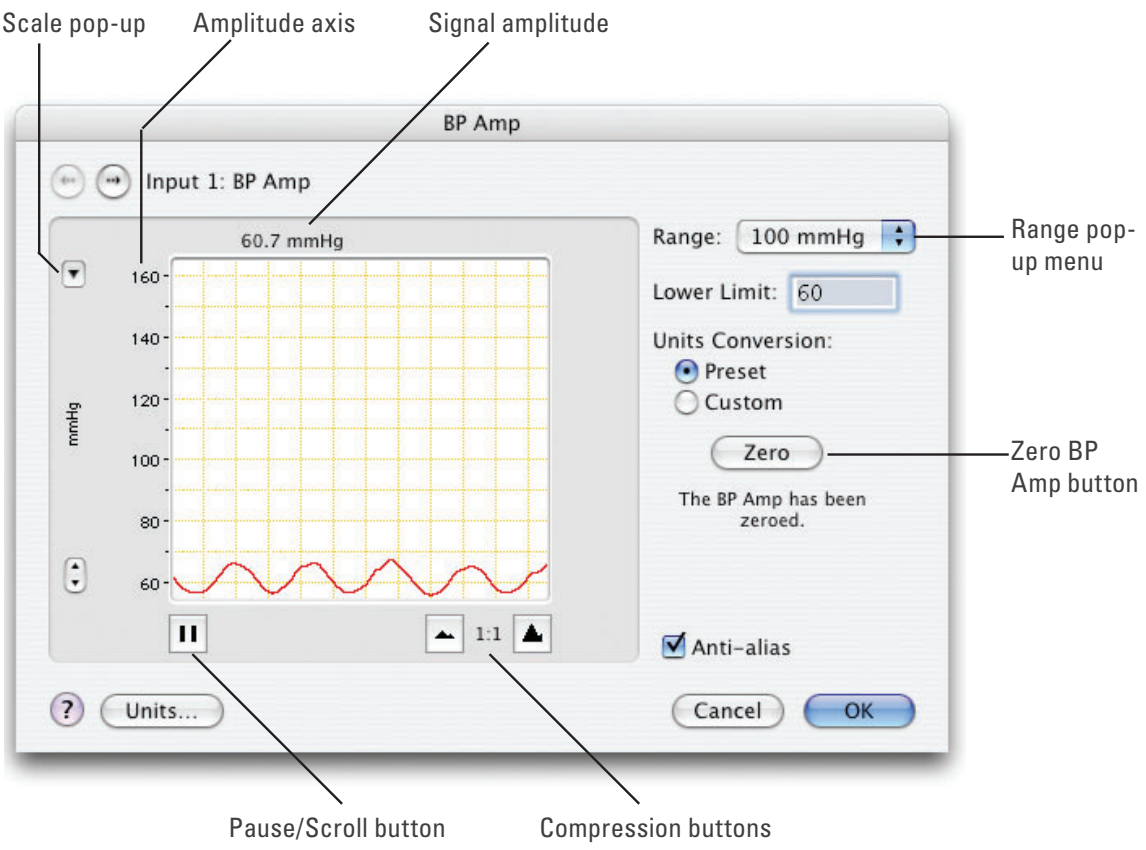


Figure 1–8
The BP Amp dialog for Macintosh

Signal Display

The input signal is displayed to show you the effect of changing the settings — no data are recorded when setting things up. The average signal value is shown above the display area.

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

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

Setting the Range

The Range pop-up menu lets you select the input range or sensitivity of the channel (combined range of the PowerLab and BP Amp). Changing the range in the BP Amp dialog is equivalent to changing it in the Chart Window. There are three ranges: 50, 100 and 250 mmHg.

Lower Limit

The Lower Limit text entry box lets you set the lowest value for the displayed range, in mmHg. You can enter negative values. If you enter 70 with the range set to 50 mmHg, then the display will show values from 70 to 120 mmHg. The display adjusts after a second or so. The display can still be stretched and shifted afterwards.

Zeroing

Before measurements can be made with the BP Amp, it must be zeroed. A note below the Zero button indicates its status. To zero the BP Amp, connect up the blood pressure transducer and leave it open to the atmosphere (arranging the transducer valve is described in Figure 5–6 on page 23), then click **Zero** in the BP Amp dialog. If you start sampling before the BP Amp has been zeroed, you will receive an alert and the BP Amp dialog will appear, at which stage the amp must zeroed.

On a Macintosh, **Zero** will be highlighted if the BP Amp is not zeroed. After clicking Zero, the note below the Zero button changes to indicate that the BP Amp has been zeroed, and the **OK** button is highlighted.

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 sampling rate must be at least twice the highest frequency in the incoming waveform.

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. If this reveals unwanted high-frequency components 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 in the **BP Amp...** 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. A high sampling rate, however, will use more computer memory and may limit recording time, so once you have established the frequencies of interest to you in an incoming signal, the sampling rate can be scaled down accordingly with the Anti-alias filter applied.

Units

The BP Amp measures pressure directly in mmHg (millimeters of mercury), once the BP Amp is zeroed. The BP Amp is pre-calibrated for use with the MLT0670 Disposable BP Transducer, but most blood pressure transducers connecting to the 4-pin connection of the supplied cable should also work. To open the Units Conversion dialog, choose **Units Conversion...** from the Channel Function pop-up menu (Windows).

In the Units Conversion dialog you can check the preset unit conversion or – if you prefer or are using another transducer – do your own calibration, using a pressure standard. On a Macintosh, you can click **Units...** in the BP Amp dialog to open the Units Conversion

dialog, and select **Preset** or **Custom** to change between the preset calibration and the one you set yourself in the Units Conversion dialog.

Technical Aspects

This section describes some of the important technical aspects of the BP Amp, to give some insight into how it works. You should not use this section as a service manual: user modification of the equipment voids your rights under warranty.

The BP 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^2C bus, and a BNC connector.

BP Amp Operation

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

- full electrical isolation from power-line (mains) circuitry to guarantee subject safety
- measurement of blood pressure directly in mmHg: units conversion is done for you
- precalibration with the MLT0670 blood pressure transducer, for convenient set-up
- the ability to override calibration when using other transducers.

The internal functions of the BP Amp are controlled from the PowerLab through the I^2C bus, which also supplies power to the BP 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 BP Amp can be better understood by referring to Figure 5–9.

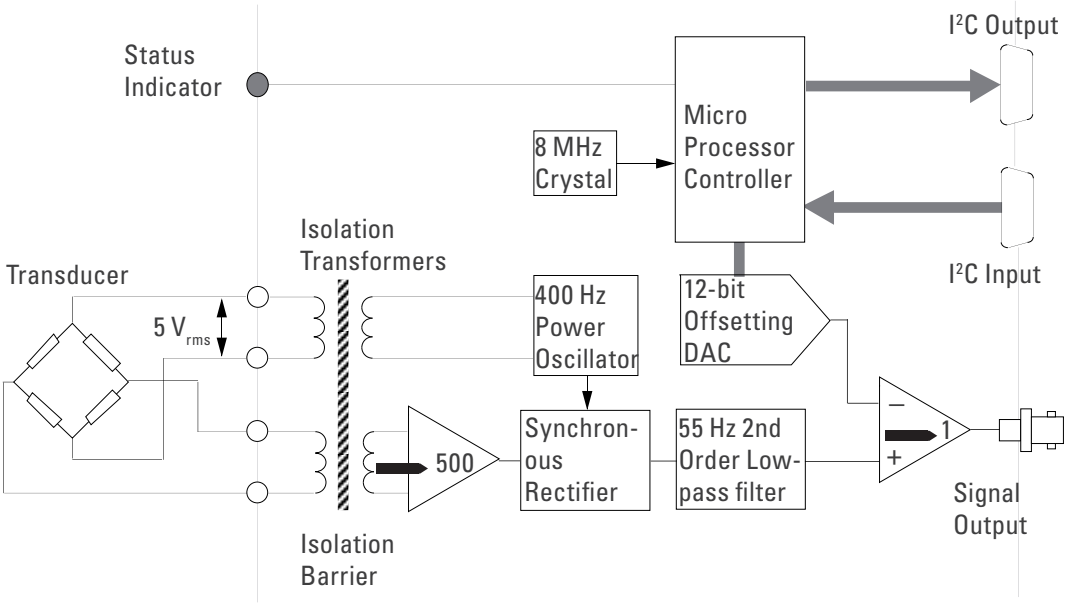


Figure 1–9
Block diagram of the BP Amp

A power oscillator circuit running at 400 Hz is used to excite the transducer bridge. The BP Amp uses AC excitation for isolation, and for freedom from thermoelectric DC errors. The input signal from the connected transducer is fed across an isolation transformer into a stable, accurate, fixed-gain amplifier. The output of this amplifier is fed into a synchronous (phase-sensitive) rectifier to recover the DC content of the signal. For the bridge used, each mmHg of the signal gives about 25 µV of signal for 5 V_{rms} excitation. The synchronous demodulation scheme is very effective at cancelling systematic and thermal (amplifier) noise.

The rectified signal then passes through a 55 Hz, second-order, low-pass filter, which provides output filtering of the data, and anti-alias filtering for the PowerLab input. A precision X1 instrumentation amplifier finally compares the signal with the output of the 12-bit DAC. The DAC provides an exact offset voltage for zeroing and offsetting of the synchronously demodulated and filtered signal. This ensures maximum signal-to-noise ratio, good zeroing resolution, and maximum resolution in the displayed signal.

The control for offsetting and zeroing functions in the BP Amp is provided by an on-board microcontroller, which also communicates with the PowerLab over the I^2C bus.

The good reproducibility of the blood-pressure transducers ensures good overall accuracy without the need for the user to apply units conversion. The only operations required are selection of pressure-range and an optional baseline pressure (zero is the default), then clicking on the Zero button with the pressure transducer open to the atmosphere (before connection to the subject).

Troubleshooting

This section describes most of the common problems that can occur when using the BP Amp with your PowerLab recording unit. Most of the problems that users encounter are connection problems, and can usually be fixed by checking connections and starting up the hardware and software again. Very rarely will there be an actual problem with the front-end or the PowerLab itself.

Problems and Solutions

The status indicator fails to light when the software is started, or the front-end commands do not appear where they should

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

- Turn everything off. Check to see that all cables are firmly seated and screwed in. BNC cables from the BP 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.

You are using an early version of LabChart.

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

The BNC or I^2C cable is faulty.

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

The front-end is faulty.

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

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

The correct drivers are not installed on your computer.

- Reinstall the software.

You are using an early version of LabChart.

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

The BNC or I^2C cable is faulty.

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

The front-end is faulty.

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

Some software settings don't resemble those in this guide

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

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

Specifications

Input

Connection type:	6-pin socket to fit Utah Medical 650-208 transducer cable with a 4-pin transducer connection cable
Safety:	Approved to IEC 60601-1 Standard (BF rating)
EMC:	Approved to EN61326-1:2006 Standard
Input impedance:	> 10 kΩ at 400 Hz AC
Configuration:	Isolated AC bridge
Isolation rating:	4000 V AC_{rms} for 1 minute
Input ranges:	50–250 mmHg full scale in 3 steps
	(combined PowerLab and BP Amp)
	0–250 mmHg
	0–100 mmHg
	0–50 mmHg
User offset:	Arbitrary scale offset
	(for example, –50 with 100 mmHg range gives –50 to 50 mmHg range)
Frequency response:	–3 dB at 50 Hz
Sensitivity:	Correct for 5 µV/V/mmHg transducer standard (~350 Ω bridge)
Accuracy:	± 2% (± 0.2 mmHg) all points, after zero correction
Input leakage current:	< 3 μA_{rms} at 240 V, 50 Hz
	< 2 μA_{rms} at 120 V, 60 Hz
Zeroing and offset:	Automatic software-controlled fast zeroing, controlled by internal 12-bit DAC; resolution = ± 0.2 mmHg (with supplied transducer)

Transducers

Transducer type:	Precalibrated for use with MLT0670 Disposable BP Transducer: no further calibration needed for normal applications
Excitation:	~5 V_{rms} AC at 400 Hz ± 5%
Alternative types:	Transducers up to 1 kΩ with ~ 5 µV/V/mmHg sensitivity, with a 4-pin transducer connection cable: they will need calibration.

Filters

Low-pass filtering:	Fixed 50 Hz (–3 dB) two-pole Bessel filter (limited by PowerLab setting)

Output

Signal:	± 2.0 V full scale: suitable for PowerLab

Control Port

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

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)
Power requirements:	2.5 W max
Operating temperature range:	5–35 °C
Operating humidity range:	0–90% (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

[1] Data Acquisition Units: PowerLab 35 series with PL prefix
[2] Front-ends: ADI Front-end Signal Conditioners with FE prefix.

ADI manufactured products covered by three (3) year warranty

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

ADI manufactured products covered by one (1) year warranty

[6] Specialized Data Recorders: Metabolic Systems (e.g., ML240 PowerLab/8M Metabolic System)
[7] 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

ADI products are produced to high standards, and should perform as described in the supplied documentation. There is a limited hardware warranty, and technical support is provided for all ADI products. Nevertheless, since ADI products could be affected by external factors (for instance, the computer system on which they run and other hardware and/or software provided by third parties), absolute performance and reliability of products and the overall solution cannot be guaranteed. No warranty, either expressed or implied or statutory, other than that expressly contained in this Agreement, is made in respect to ADI products or software, third party products or software, the overall solution or otherwise. The Purchaser therefore assumes all risks as to the performance and reliability of the products, the software, the solution and the results gained using them. ADI neither assumes or authorizes any person to assume on its behalf any liability in connection with the sale, installation, service or use of its products. ADI shall not be held responsible for special, consequential or punitive damages of any kind arising out of

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ADI is acting on behalf of its suppliers for the purpose of disclaiming, excluding and/or limiting obligations, warranties and liability as provided in this agreement, but in no other respects and for no other purpose. The foregoing provisions shall be enforceable to the maximum extent permitted by applicable law.

Controlling Law and Severability

This license shall be governed by the laws of the territory into which the software is sold, or if sold into the United States of America, by the laws of the State of California.

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.

Inquiries

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