BRIDGE AMPLIFIERS

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.

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

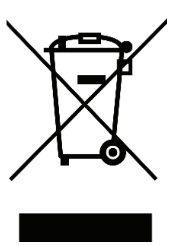
ADInstruments products may be wiped down with a lint free cloth moistened with industrial methylated spirit. Refer to the manufacturer's guidelines or the Data Card supplied with transducers and accessories for specific cleaning and sterilizing instructions.

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.

Environment



WEEE Directive symbol

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.

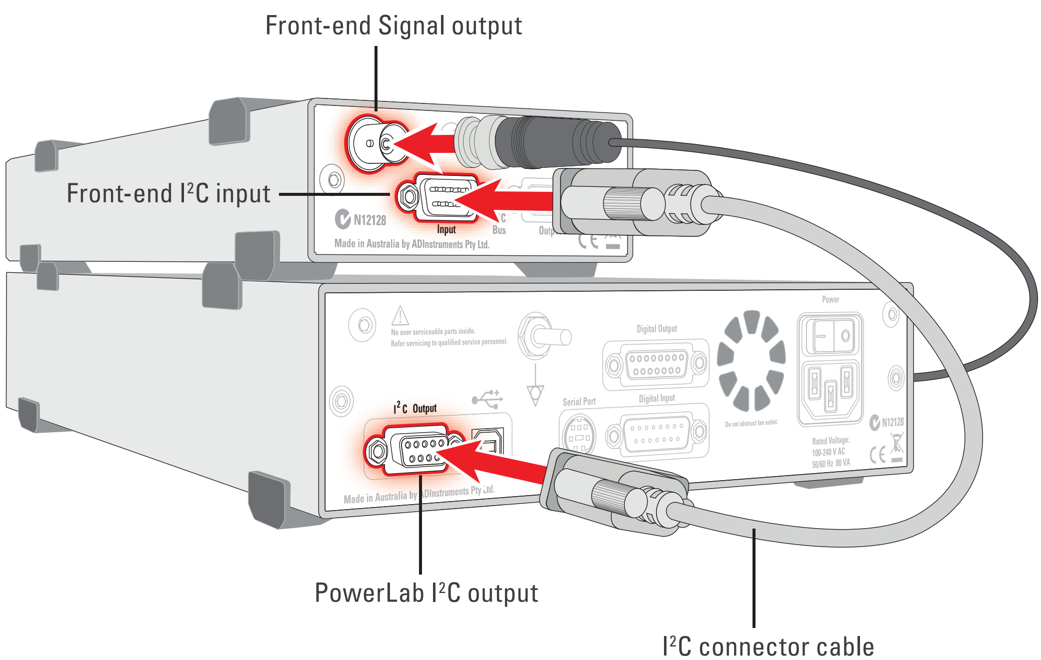


Figure 2–1 Connecting a front-end to the PowerLab: a PowerLab has only one I²C output, and each front-end has one I²C output and one I²C input

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 I^2C cable as in Figure 2–1. The remainder are daisy-chained via I^2C cables, connecting the I^2C output of the last connected front-end to the I^2C input of the front-end to be added (Figure 2–2).

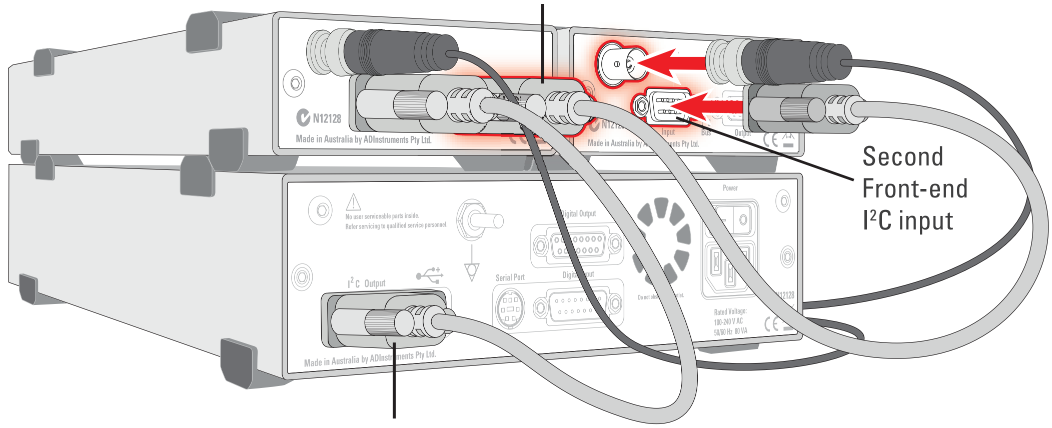


Figure 2–2 Connecting multiple front-ends to the PowerLab (two single front-ends shown for simplicity)

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.

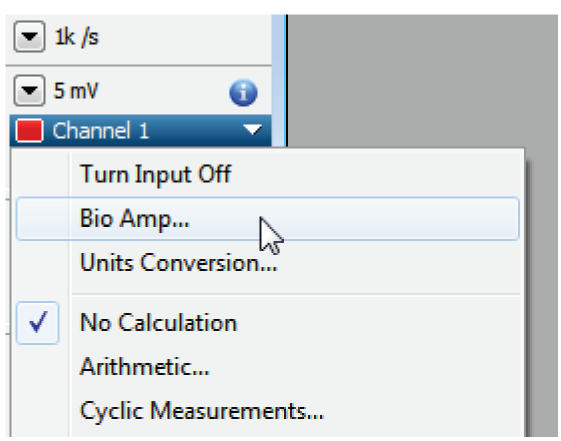
If the indicator lights correctly, the front-end has been found by the PowerLab and is working properly. If the indicator doesn't light, check your cable connections and repeat the start-up procedure.

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 3

Bridge Amp

The Bridge Amp is a modular device, in a family called front-ends, designed to extend the capabilities of the PowerLab system. This chapter provides an overview of the various Bridge Amps, namely the Bridge Amp [FE221], Quad Bridge Amp [FE224] and Octal Bridge Amp [FE228].

The Bridge Amp is designed to allow the PowerLab to connect to most DC bridge transducers, including commonly available force transducers, temperature probes, light meters, displacement transducers, pressure transducers, and similar devices.

Grass transducers can connect to any ADInstruments Bridge Amp using a Grass adapter cable [MLAC11] available from ADInstruments.

The Bridge Amp

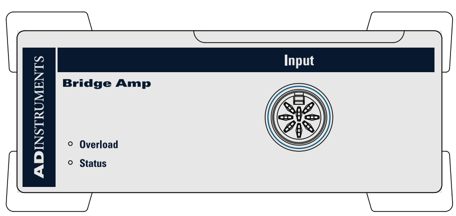
The Bridge Amp is designed to allow the PowerLab to connect to most DC bridge transducers, including force transducers, temperature probes, light meters, displacement transducers, pressure transducers, and similar devices. There are several models of Bridge Amp. The Bridge Amp provides just one connection for a bridge transducer, the Quad Bridge Amp provides four connections for bridge transducers and the Octal Bridge Amp provides eight connections for bridge transducers.

The Front Panel

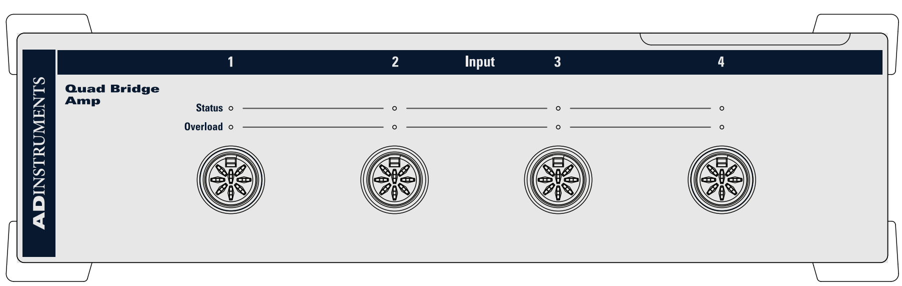
The front panel of a Bridge Amp has a single socket for a transducer connection, a status indicator light and an overload indicator light. The front panel of a Quad or Octal Bridge Amp has four or eight transducer connections, respectively, each of which has a status indicator light and an overload indicator light.

Figure 3–1
The front panels of the Bridge Amps

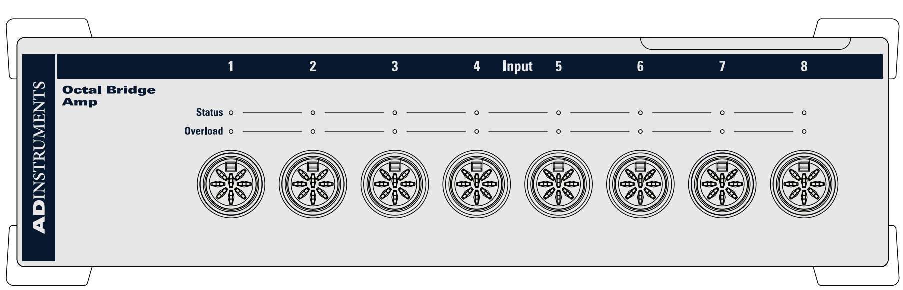
FE221 Bridge Amp



FE224 Quad Bridge Amp



FE228 Octal Bridge Amp



The Status Indicator

The Status indicator of the Bridge Amp is located at the bottom left of the front panel, and the Status indicators of the Quad Bridge Amp and Octal Bridge Amp are located adjacent to each connector on the front panel. When an ADInstruments program such as LabChart starts up, the Status indicator light should glow green, indicating that the program has found the front-end, checked and selected it, and is ready to use it. If the light does not glow when the program is running, this indicates either that the front-end is not connected properly or that there is a software or hardware problem.

The Input Socket

Transducers are connected to a Bridge Amp using the eight-pin DIN sockets on the front panel. The sockets provide terminals for supplying a transducer with power and for receiving the transducer output. Front-ends are supplied with DIN plug kits (one per connection) to be fitted to those transducers that lack them. The connection is discussed in more detail in the Technical section at the end of this chapter.

The Overload Indicator

The Overload indicator is located on the left side of the front panel of the Bridge Amp and below the Status indicator on the Quad and Octal Bridge Amps.

The Overload indicator is normally off. If the indicator lights when a transducer is attached, it indicates an out-of-compliance condition (meaning that the excitation voltage drops because too much current is being drawn by the load). When the Bridge Amp detects a problem with the transducer (for instance a wiring fault with a transducer causing a short-circuit), the overload indicator will glow yellow or amber and will remain on until the fault is rectified.

If the overload indicator remains on with a transducer attached, the transducer should be removed immediately to minimize the risk of damage to the transducer. Check the transducer wiring carefully before re-attaching the transducer. If the fault persists, refer to the Troubleshooting section in this chapter.

For the overload indicator to function, power must be supplied to the Bridge Amp from a PowerLab. LabChart software does not need to be loaded.

When a software application is running and a channel is being zeroed, the Status indicators for the other channels should temporarily be off.

The Back Panel

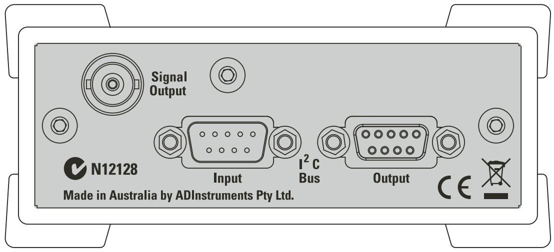
The back panel of the Bridge Amp provides all the sockets required to connect the Bridge Amp to the PowerLab and to other front-ends.

I^2C Input and Output Sockets

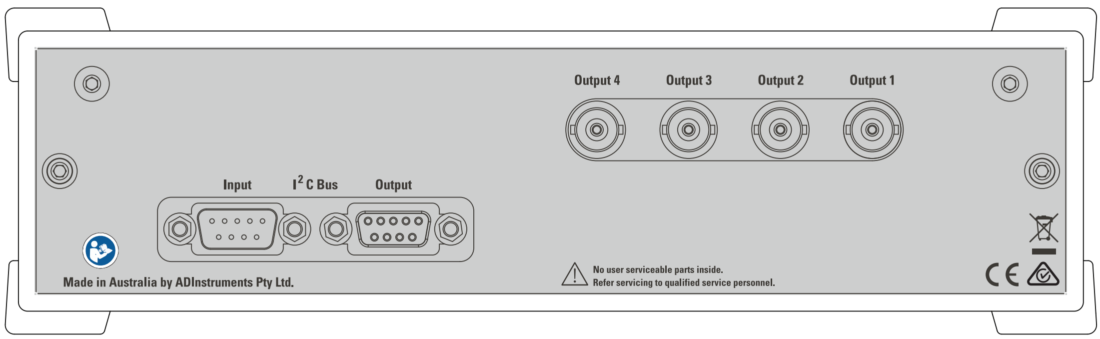
Two nine-pin sockets are used to communicate with the PowerLab (they are marked 'I^2C Bus': a 'bus' is simply information-transmission circuitry such as cables and connectors). These sockets allow multiple front-ends to be used independently with one PowerLab. Power and control signals to the front-ends come from the PowerLab. Many front-ends can be connected to the system, in series, output to input, providing there is the same number of channel inputs available on the PowerLab (this is discussed in more detail in Chapter 2).

Figure 3–2
The back panels of the Bridge Amps

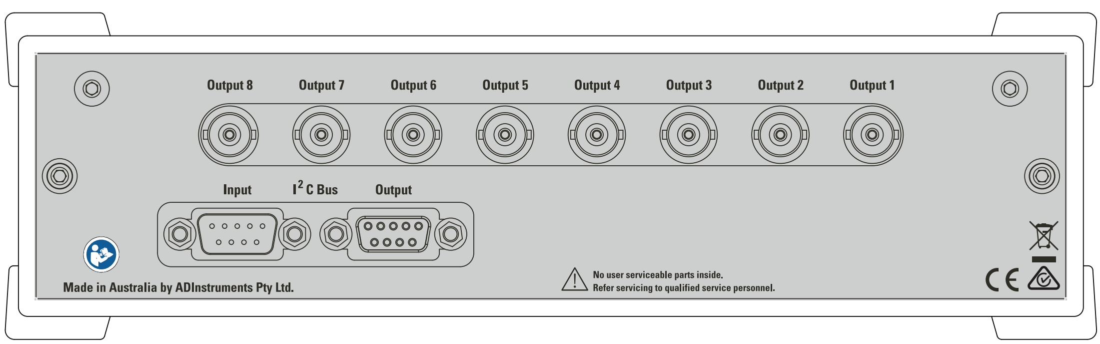
FE221 Bridge Amp



FE224 Quad Bridge Amp



FE228 Octal Bridge Amp



Analog Output Sockets

BNC sockets on the back panel of the Bridge Amp provide the signal outputs to connect to the analog input sockets on the front of the PowerLab. The sockets are labelled Signal Output on a Bridge Amp and Output 1 to 4 or Output 1 to 8 on Quad and Octal Bridge Amps, respectively. You don’t have to match the channel numbers when connecting outputs to inputs, but it helps to prevent confusion if you do. A BNC-to-BNC cable is supplied for each connection.

Setting Up

This section describes connecting a Bridge Amp to your PowerLab.

PowerLab Requirements

The FE221, FE224 and FE228 Bridge Amps will only operate with newer models of PowerLabs, such as the /SP, /20, /25, /26, /30 and /35 series.

Software Requirements

The FE221, FE224 and FE228 Bridge Amps require the following versions of ADInstruments software applications:

- LabChart version 6, or later, for Windows or Macintosh
- Chart version 5.4.2, or later, for Windows or Macintosh
- Scope for Windows version 3.7.8, or later
- Scope for Macintosh version 4.0.3, or later
- LabTutor version 3, or later.

Note: the Bridge Amps will not operate with earlier versions of these applications. If you have queries regarding hardware and software requirements of the Bridge Amps, please contact your local ADInstruments representative.

Connecting to the PowerLab

Connect your Bridge Amp, to the PowerLab, as follows:

- Ensure that the PowerLab is turned off. Failure to do this may damage the PowerLab, the Bridge Amp, or both.
- Connect the I^2C output of the PowerLab to the I^2C input of the front-end using the I^2C cable provided.
- Connect a BNC cable from each signal output, on the rear of the Bridge Amp, to an input on the front panel of the PowerLab.

Note that the Quad Bridge Amp acts just as if it were four individual Bridge Amps; the Octal Bridge Amp, eight. The I^2C connections are internal, though, so there is only one I^2C cable needed to connect the Quad or Octal Bridge Amps to the recording unit.

Check that the plugs for the I^2C bus are screwed in firmly and the BNC cables have firm connections. Loose connectors can cause erratic front-end behavior, or may cause the front-end to fail to work at all. BNC cables can lie under the front-end to keep them out of the way.

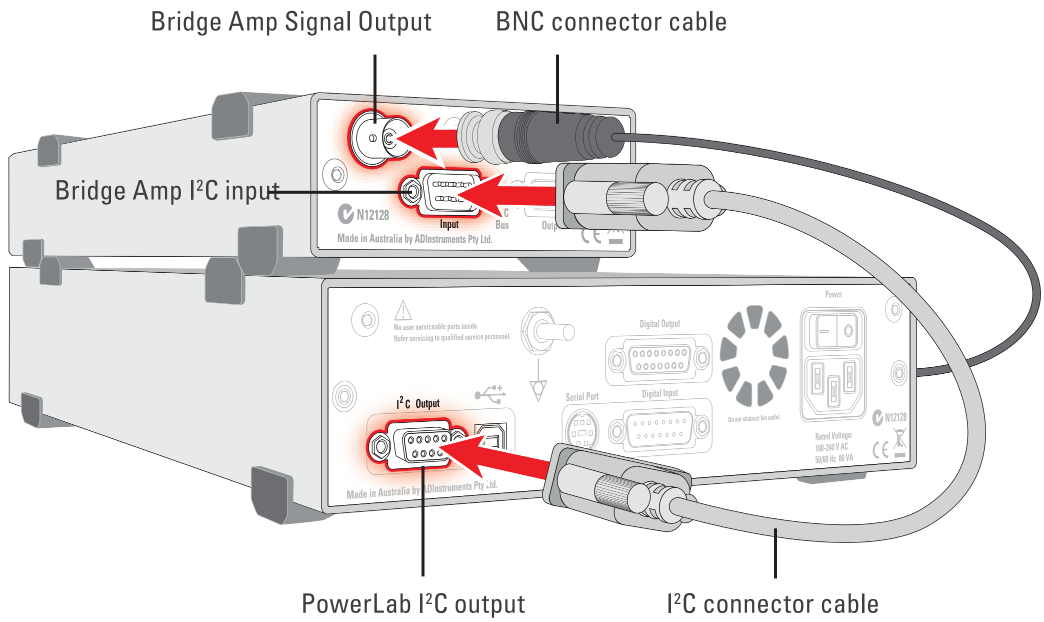


Figure 3–3 Connecting a single Bridge Amp front-end to the PowerLab

Multiple Front-ends

Multiple front-ends can be connected up to a PowerLab. The number that can be connected depends on the number of analog inputs on the PowerLab. The initial front-end should be connected as shown in Figure 6–3. The remainder are daisy-chained via I^2C cables, connecting the I^2C output of the last connected front-end to the I^2C input of the next front-end to be added, as shown in Figure 2–2. The BNC cable for each front-end is connected to one of the inputs of the PowerLab (except where otherwise specified).

Using LabChart

Once the Bridge Amp is connected, turn the PowerLab on and launch LabChart. While the software starts up, keep a close eye on the Status and Overload indicators on the Bridge Amp. During initialization, the Status indicators glow green, flash briefly, and then remain lit.

If the indicator glows green, the Bridge Amp is working properly. If a light does not go on when the program is started, this indicates either that the front-end is not connected properly or that there is a software or hardware problem. If the overload light glows yellow (or amber) on any Bridge Amp, this indicates some fault such as a short circuit, a badly wired bridge transducer, or an excitation overload. In the first instance, check your cable connections and transducers, and repeat the self-test. If this does not solve the problem, contact your ADInstruments representative.

When a Bridge Amp is properly connected to the PowerLab, the **Input Amplifier...** menu commands are replaced by **Bridge Amp...** for the input channel(s) to which it is connected. If the application fails to find a front-end connected, the normal text remains. If this occurs you should quit the application, turn the PowerLab off and check the connections. Then restart the PowerLab and relaunch the application.

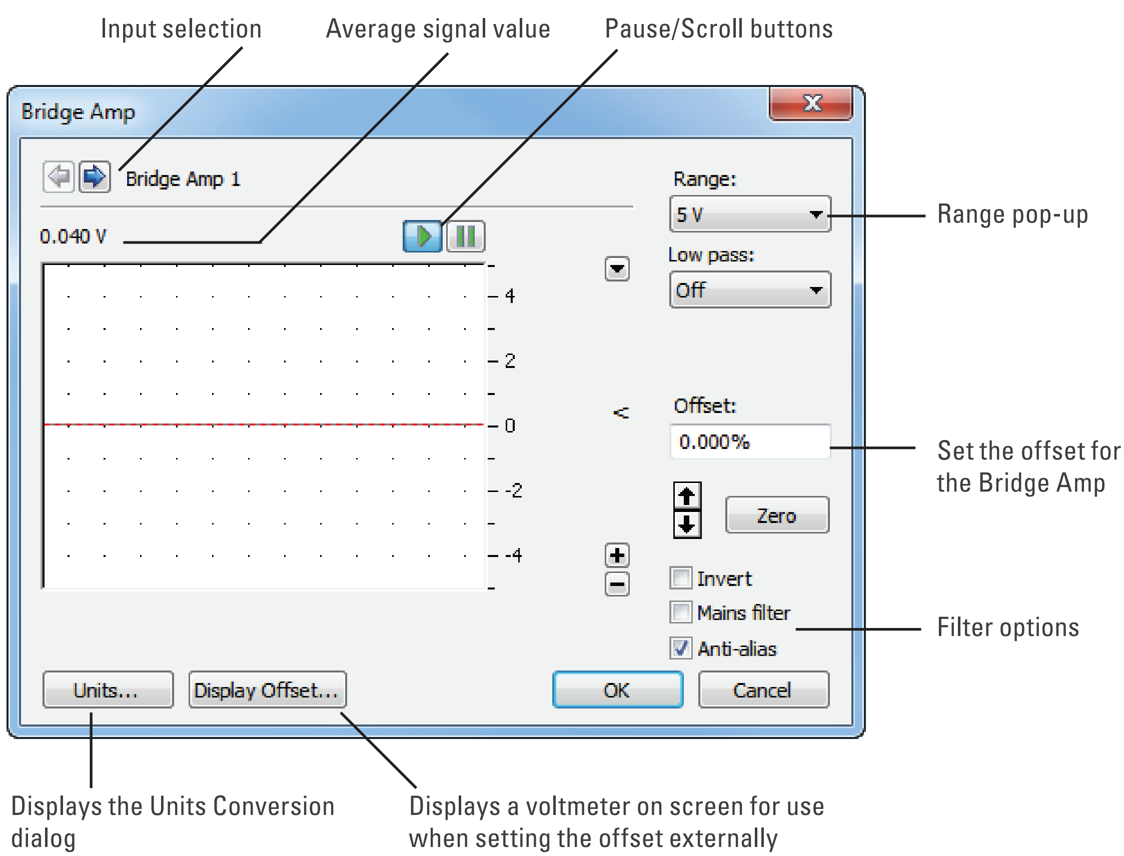
The documentation for LabChart does not cover front-end-specific features. These features are described in detail here for LabChart. For the most part, dialogs for LabChart and Scope should be much the same.

The Bridge Amp dialog

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

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 **Bridge Amp…** in the Input Settings column of the Channel Settings dialog will also open the Bridge Amp dialog.

Figure 3–4 The Bridge Amp dialog for Windows (before zeroing)



Signal Display

The input signal is displayed so you can see the effect of changing the settings — no data are in fact recorded when setting things up. The average signal value is shown at the top left of the display area.

You can stop the signal scrolling by clicking the Pause button at the 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.

You can shift and stretch the vertical Amplitude axis by clicking and dragging it 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 applied to the Chart Window.

On a Macintosh, Show Range Axis in the Scale pop-up menu displays the range axis at the right of the display area, and the Compression buttons adjust the horizontal axis of the data display area.

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 Bridge Amp). Changing the range in the Bridge Amp dialog is equivalent to changing it in the Chart window. The default setting is 5 V and the ranges go down to 200 µV in 14 steps.

Filtering

The filtering options provided are appropriate to the type of transducers used with the Bridge Amp, and the signals usually measured, which tend to be of lower frequency. Low-pass filters allow you to remove high-frequency components, such as noise, from an input signal. The Mains filter allows you to remove interference at the mains frequency (typically 50 or 60 Hz).

Low-Pass Filtering. The Low Pass pop-up menu provides a choice of filters to remove high-frequency components from the signal. They are: 1, 2, 10, 20, 100, and 200 Hz, and 1 kHz. (The highest frequency you can actually record is limited by the transducer you use: such information should be in the documentation supplied with it.)

Mains Filter (/20, /25, /30 and /35 series PowerLabs). The Mains filter checkbox allows you to filter out interference at the mains frequency (typically 50 or 60 Hz). Note that in general it is better to prevent interference at its source than to filter it. The mains filter is an adaptive filter which tracks the input signal over approximately 1 second. It analyzes the signal and creates a template of any interference due to the mains frequency (see “Specifications” on page 37). Subtraction of the template from the incoming signal cancels most of the interference.

In comparison with a notch filter, this method produces little waveform distortion and attenuates harmonics of the mains frequency as well as the fundamental; it 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 be increased.
- your signal contains repetitive components at frequencies close to the mains frequencies.
- 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.

The template is not fully generated until about 1 second after sampling starts and so the mains filter is not fully effective in the first second of each data block.

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 **Bridge 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, if Anti-alias is selected the sampling rate can be scaled down accordingly.

Inverting the Signal

The Invert checkbox allows you to invert the signal on the screen. It provides a simple way to change the polarity of the recorded signal without having to swap the connections to the recording electrodes.

For example, you might be recording from a force transducer where an increase in force downwards gives a negative signal, but you want to have a downwards force shown as a positive signal on the screen. Checking the Invert checkbox will change the display to do this.

Offset Adjustment

Transducers almost always produce some amount of signal, usually small, when in the equilibrium or rest state. Offset from a zero reading need to be removed, in a process called zeroing. Commonly, the user also wants to remove a constant term, for example baseline blood pressure or initial tension in a muscle, from a measurement of interest. This enables more accurate measurement of the changes in the signal under stimuli. The offset controls in the Bridge Amp dialog can be used to zero the reading manually or automatically.

Manual Zeroing. The up and down arrows near the Zero button allow manual adjustment of the signal offset. Click the up arrow to shift the signal positively and the down arrow to shift it negatively. The shift by clicking the arrow buttons depends on the range setting. At high ranges the increments are larger to adjust the offset efficiently.

Automatic Zeroing. To perform automatic zeroing, click Zero: the program works out a corrective DC voltage that cancels, as closely as possible, the output voltage from the transducer. Auto-zeroing may take about 20 seconds to work out the best zeroing value at all ranges. A dialog with a progress bar appears: click the Cancel button or type Command-period to stop the zeroing process. If there is still offset after auto-zeroing, then Option-click the up and down arrow buttons to adjust the zeroing slightly, by the smallest increment at any range.

Note: Variations in the transducer signal during the auto-zeroing operation will cause the software to fail to zero the offset properly, if it zeroes at all. Make sure that the transducer is kept still and that no varying signal is applied during the operation.

The offset display, a small numeric indicator above the Zero button, shows the corrective voltage used to adjust for transducer offset. The offset is given in the units of the channel. When the Bridge Amp is first powered up, the software sets the offset circuit to its default position (no offset adjustment of the transducer) and the offset display value is zero. When either Zero or the manual offset controls are clicked, this value will change to indicate the positive or negative corrective adjustment.

On a Macintosh, click the small 0 button to restore the offset circuit to its initial, non-zeroed position (and the offset display value to zero). This can be used to determine the offset generated by a transducer.

Display Offset

Click **Display Offset…** to display the Input Value dialog, which is a voltmeter displaying the voltage currently being measured for an input (the input channel is indicated at the top of the dialog). If a transducer or some other external equipment has offset adjustment capabilities, you can use this to zero it.

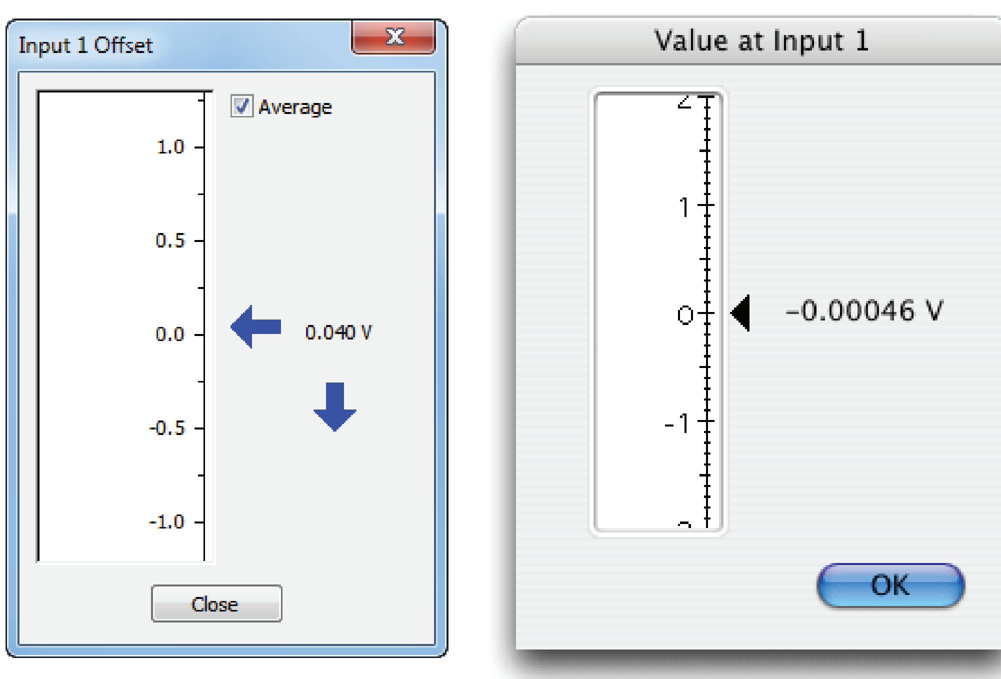


Figure 3–5
The Input Value dialog, Windows (left) and Macintosh (right)

Because the dialog allows for such fine adjustment, a vertical arrow appears indicating the zero point if the offset is substantial. This dialog is not a control, simply an indicator that acts like a voltmeter.

Units

Click **Units…** to display the Units Conversion dialog, in which you specify the units for the channel and calibrate the channel. The waveform in the display area of the Bridge Amp dialog is transferred to the data display area of the Units Conversion dialog. (Use the Pause button to capture a specific signal.) The units conversion only applies to subsequently recorded signals, so it is more limited than choosing **Units Conversion…** from a Channel Function pop-up menu, which allows units conversion of previously recorded data.

Using Transducers

Bridge Amps are designed to allow the PowerLab to connect to most DC bridge transducers, including commonly-available force, pressure, and displacement transducers, temperature probes, light meters, and similar devices. They are capable of supporting various powered transducers, and certain low-impedance unpowered (or self-powered) transducers. However, because transducers vary in sensitivity and suitability, you should read the following sections before connecting a transducer to a Bridge Amp.

The 'Adapting Transducers' section describes the modifications that may be required to connect third-party transducers to the Bridge Amp. Transducers supplied by ADInstruments should connect directly without modification, so if using these you need not read this section. If you are using powered third-party transducers with your Bridge Amp you may need to adapt them using the information provided in this later section.

NOTE: Please ensure that any modifications made to transducers are carried out by experienced technical staff. Some soldering of components is required to adapt third-party transducers for use with your Bridge Amp. Incorrect wiring may damage the transducer or Bridge Amp. If you have little experience with electronics and no technician to assist you, please contact your nearest ADInstruments representative for further assistance.

Compatibility

Transducers supplied by ADInstruments will operate with the FE22x Bridge Amps. All transducers which operated with the older model ML110, ML112, ML118, ML119 Bridge Amps will operate with the FE22x Bridge Amps. The ML110 and ML112 amplifiers had provision for increasing offsetting resolution via an optional resistor installed in the transducer connector. Transducers which have this offsetting resistor fitted will operate with the FE22x Bridge Amps without modification.

Suitable Transducers

The Bridge Amps are designed to connect to transducers that require DC excitation voltages, such as DC strain-gauge or semiconductor transducers.

If you are uncertain about the suitability of your transducer, please provide ADInstruments with an accurate circuit of the transducer and a sample, and we will see about testing the device for compatibility. Half-bridge transducers will need to be wired up with compensating resistors before they can be used with any of the Bridge Amps (see Technical Aspects section).

DC Strain-gauge. These are full-bridge or half-bridge transducers requiring a DC excitation voltage, and output voltages of less than 200 mV full scale. They include strain-gauge force transducers, temperature transducers and pressure transducers.

Semiconductor. These are powered transducers typically used for light, displacement, and temperature measurements, giving output voltages less than 200 mV full scale.

Generally, a Bridge Amp can be used with transducers that:

- require DC excitation voltages, not AC
- have transducer output voltages less than 5 V full scale
- have transducer impedances less than 10 kΩ.

Unsuitable Transducers

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

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

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

Piezoelectric. These transducers are not recommended owing to the relatively low input impedance of the single Bridge Amp (piezoelectric transducers typically need amplifiers with input impedances of tens of megaohms), and their half-bridge configuration.

High-voltage. Transducers generating more than ± 5 V full scale will exceed the input range of the Bridge Amp. A high-voltage powered transducer may require some signal attenuation.

How Transducers Work

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

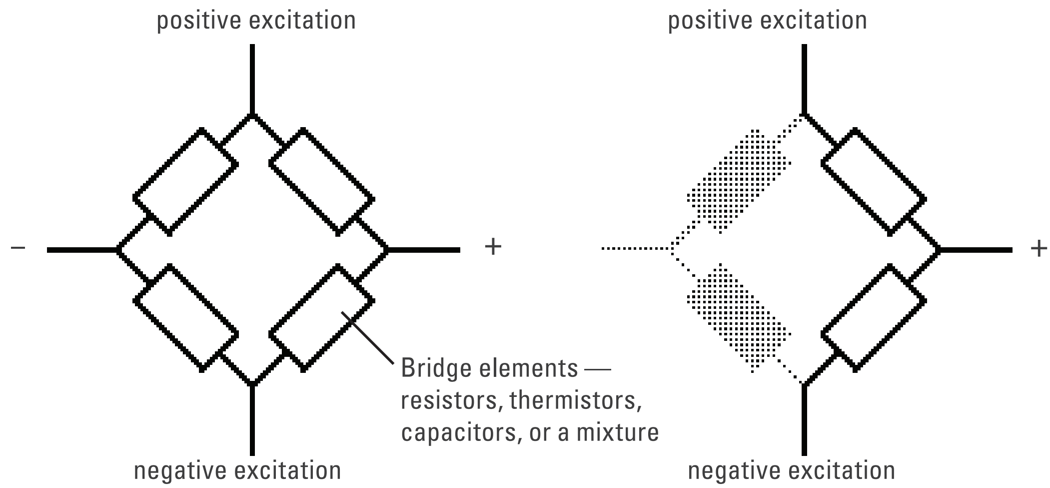


Figure 3–6
Left, a full-bridge transducer; right, a half-bridge transducer

The full-bridge circuit is fairly versatile, in that the circuit elements, shown as the rectangular boxes in Figure 6–6, can be resistive, capacitive, or thermal circuit elements, allowing the bridge to measure force, pressure, temperature, and so forth. This circuit produces an electrical output in proportion to an appropriate stimulus applied to one or more of the four elements. Because of the balancing effect of the four elements, high precision is possible. Full-bridge transducers should work without problems.

A half-bridge transducer only uses half of the full-bridge circuit. It consists of two elements of equal value with an excitation voltage applied across them. The output of the transducer is taken at the junction of the two elements.

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

Checking the Transducer

Before attempting to connect any transducer to a Bridge Amp, you will need to determine the three things listed below. (This information is normally supplied with the transducer; if not, you should consult the manufacturer or supplier of the transducer.)

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

Transducers supplied by ADInstruments are supplied pre-adjusted, and need no adjustment.

Do not attempt to connect the signal leads from the transducer to the Bridge Amp if the wiring configuration is not known. Connecting an incorrectly wired transducer to an excitation source is likely to damage both the transducer and Bridge Amp.

Unpowered transducers, or those with their own power supply, do not have to be supplied with any excitation voltage from the Bridge Amp: they supply their own signal to it directly. The wiring connections should still be carefully checked before connection, along with transducer impedance and output voltage. Such transducers do not need the excitation range to be adjusted from the default setting. If they have low output voltages, though, then it is possible that their offset ranges require adjusting.

Using Grass Transducers with Bridge Amps

Most Grass transducers should have an impedance of about 350 Ω or so. A few Grass and Grass-compatible transducers have a much lower impedance of about 250 Ω. Grass transducers can connect to any ADInstruments Bridge Amp using a Grass adapter cable available from ADInstruments. Use the MLAC11 Grass Adapter Cable to connect a Grass transducer to the FE221, FE224 or FE228 Bridge Amp.

Adapting Transducers

This section describes the modifications that may be required to connect third-party transducers to the Bridge Amp. Transducers supplied by ADInstruments should connect directly without modification, so if using these you need not read this section.

If you are using powered third-party transducers with your Bridge Amp you may need to adapt them using the information provided here.

NOTE: Please ensure that any modifications made to transducers are carried out by experienced technical staff, as incorrect wiring may damage the transducer or Bridge Amp. If you are unsure, please contact your nearest ADInstruments representative for further assistance.

Introduction

Conventional amplifiers usually have controls on the front to adjust for the connected transducer: this means making adjustments each time you change transducers or amplifiers.

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

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

Transducer Adaptations

This section covers adapting transducers for use with the ADInstruments Bridge Amps.

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

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

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

You will need the following equipment:

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

Setting the Excitation Voltage

The first step in preparing a powered transducer for use with the Bridge Amps is to set the required excitation voltage. Two of the pins in the Bridge Amp's DIN socket can provide up to 20 volts DC as excitation voltage to power the transducer.

The voltage is varied by a resistor fitted between the two corresponding pins of the transducer's DIN plug. When no resistor is present, the Bridge Amp's internal circuitry cuts off all voltage to prevent mishaps. Once a resistor is fitted, the correct excitation voltage is provided automatically when the transducer is plugged into the Bridge Amp.

Table 3–1 Transducer excitation voltage and resistance

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

To program the excitation voltage for a particular transducer, choose a value of resistance from Table 6–1 to match the required excitation voltage for your transducer. In most cases, you should be able to get close to the required excitation voltage by selecting one of those values. We recommend that the excitation resistor be 0.25 or 0.125 Watt, 2% or 1% metal film. Larger resistors may not fit in the confined space of the transducer's DIN plug.

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

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

To set the excitation voltage for a transducer, you will need to solder the chosen resistor between pins 5 and 8 of the eight-pin DIN plug, as shown in Figure 6–7. Mount the resistor as shown for maximum clearance within the plug.

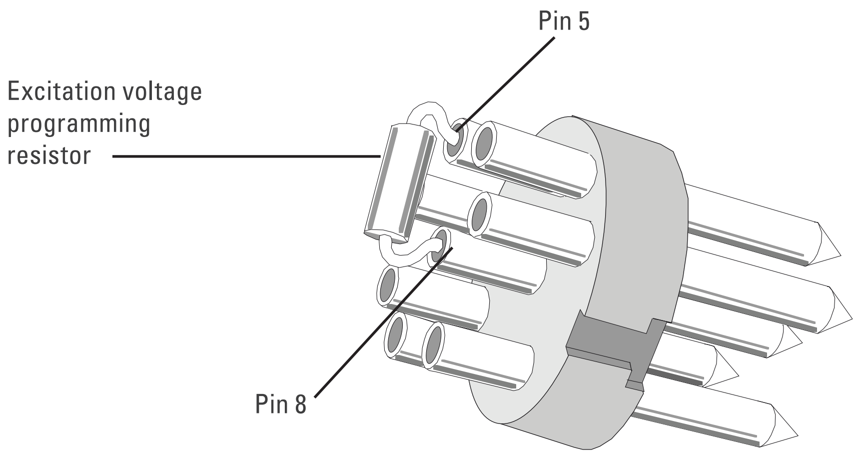


Figure 3–7 Installing the programming resistor (the pins are labeled on the plug)

Wiring Up the Transducer

The second step in preparing a powered transducer for use with the Bridge Amp is to wire the transducer to the DIN plug.

There are several things to note when wiring up transducers:

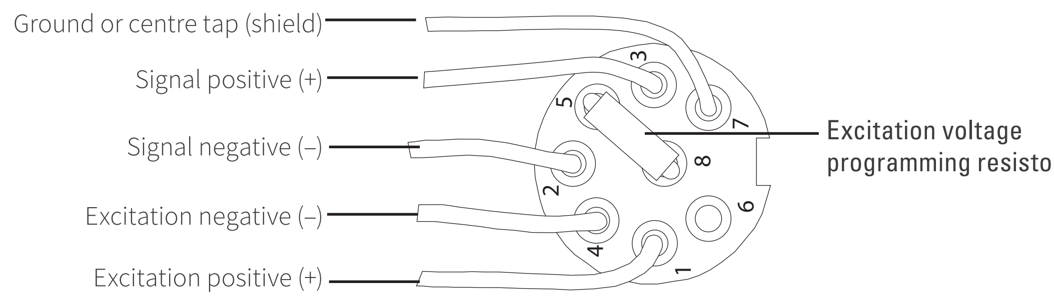
1. Make sure that the transducer wiring passes through the casing before soldering the wires to the plug.
2. The transducer wires should be cut, stripped and tinned prior to soldering, to ensure a good connection.
3. The pin numbers shown in the diagrams are the numbers marked on most standard DIN plugs.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

Wiring Up a Full-Bridge Transducer

This procedure should be used to wire full-bridge transducers only, not half-bridge transducers. The transducer lead wires should be soldered to the pins of the DIN plug as shown in Figure 6–8.

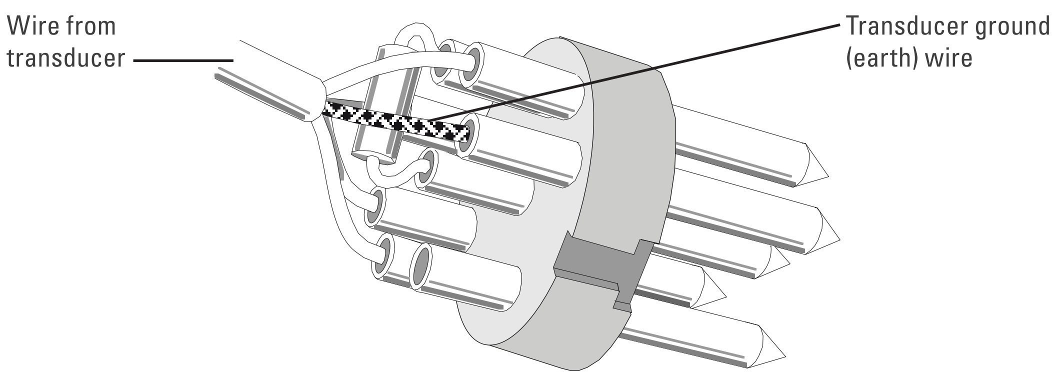
Any unused wires from the transducer should be cut and insulated to prevent shorting of signals or damage to the equipment.

Figure 3–8
The wiring connections for a full-bridge transducer, looking at the DIN plug from the cable side



The main insulation sheath of the transducer wiring should be clamped with the strain-relief device within the plug, so that it just clears the excitation voltage resistor. The transducer will normally have some sort of cable shield, which should be connected to pin 7 of the DIN plug. If the casing of the DIN plug is metal, it is recommended and good practice to ensure that the casing will also be connected to the shield.

Figure 3–9
The correct length of wiring to the DIN plug



The Finished Transducer

After connecting the excitation voltage programming resistor and wiring up the transducer to the DIN plug, the transducer should now be fully configured for your application. The excitation voltage will be set automatically when you plug the transducer into the Bridge Amp.

Technical Aspects

This section describes some of the important technical aspects of the Bridge Amp to give some insight into how it works. You do not need to know the material here to use the Bridge Amp. It is likely to be of special interest to the technically minded, indicating what the Bridge Amp can and cannot do, and its suitability for particular applications.

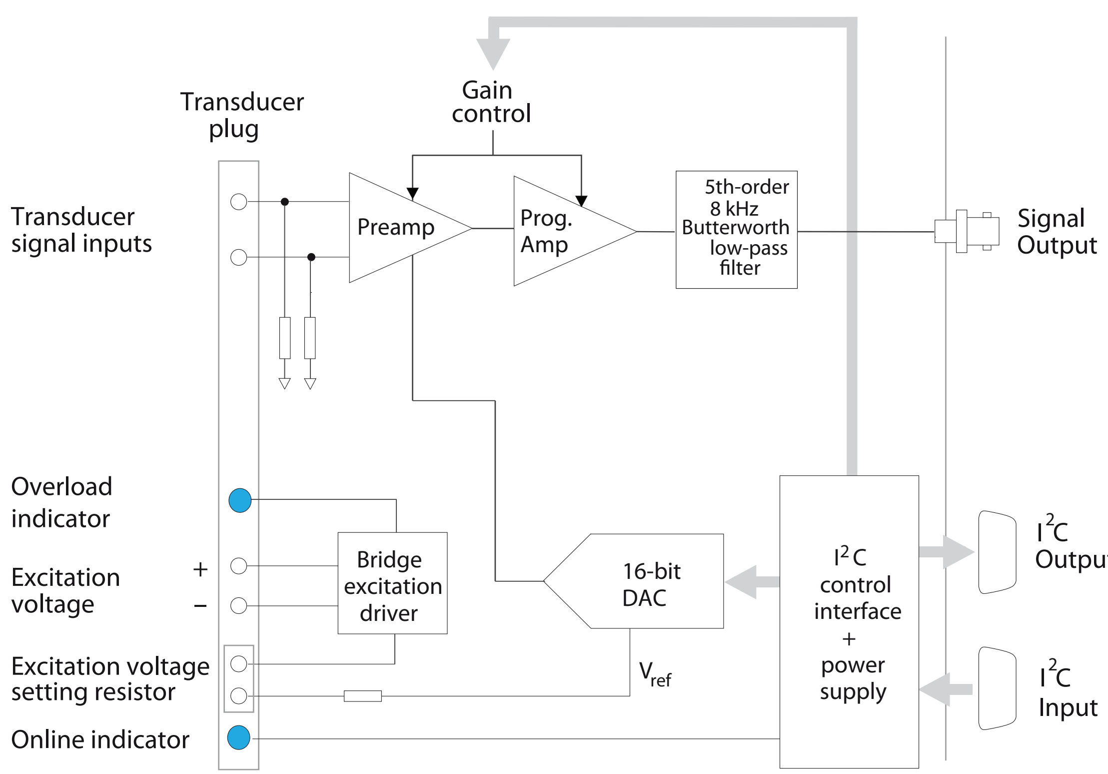
Note: You should not use this section as a service manual: user modification of the equipment voids your rights under warranty.

Bridge Amp Operation

The Bridge Amp and other ADInstruments front-ends have been designed to integrate fully with the PowerLab system. The Bridge Amp is essentially an extension of the PowerLab's input amplifiers, so the amplification (and hence the ranges) offered in LabChart are the combination of both pieces of hardware. The Bridge Amp provides:

- the additional amplification necessary to deal with the low signal outputs of most transducers
- additional programmable filtering, to remove unwanted signal frequencies
  a stable DC excitation voltage supply for powering the transducer
- digitally-controlled transducer zeroing circuitry.

Figure 3–10 Block diagram of the FE221 Bridge Amp. The FE224 and FE228 Bridge Amps are similar but with four or eight inputs, respectively



Technical Description

The PowerLab provides control and low-voltage power to front-ends through a special expansion connector called the I^2C (eye-squared-sea) bus. Front-ends are also connected to the analog inputs of the recording unit via a BNC-to-BNC cable. The overall operation of the Bridge Amps can be better understood by referring to Figure 6–10.

The digital control interface used to control filter settings, gain, coupling, and zeroing circuits uses an I^2C interface system, which provides a 4-wire serial communication bus to the recording unit and other front-ends. All control of the Bridge Amp is through this bus. Also present on the I^2C connector is a set of power supply rails derived from the recording unit. The Bridge Amp has its own on-board regulators to ensure a stable power supply.

The input stage consists of a low-drift instrumentation amplifier with programmable gain (fully software-controlled). The gain of this stage is combined with the gain of the recording unit to give a total gain of up to 50 000 (at this amplification, 200 µV is full scale). From the input amplifier, the signal is passed to a fixed fifth-order, low-pass, filter. The filter allows a range of cutoff frequencies to be selected under software control.

The excitation voltage output circuit is a complementary output stage, derived from a stable internal voltage reference, capable of giving up to ± 10 volts (20 volts DC) excitation. The excitation voltage for each channel is completely independent from other channels. The transducer excitation voltage can be adjusted by connecting a resistor between two pins on the plug that plugs into the Bridge Amp's input socket. This resistor is usually placed inside the transducer's DIN plug so that the transducer will always get the correct excitation voltage when it is connected.

To remove any offsets caused by an attached transducer or signal baseline, a DC offset circuit with a 16-bit DAC (digital-to-analog converter). This is internally connected to the input stage. Transducer offsets are zeroed by applying a corrective DC voltage to the input stage via the DAC, under software control.

The DAC is only capable of producing corrective voltages in discrete steps.

Troubleshooting

This section describes most of the common problems that can occur when using the Bridge 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 Bridge Amp or the PowerLab itself.

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.

Problems and Solutions

The Status indicator fails to light when the software is started, or the Bridge Amp… command does not appear where it should

The I^2C cable or one or more BNC-to-BNC cables from the Bridge Amp to the PowerLab are not connected, have been connected incorrectly (to the wrong input, for instance), or are loose.

- Turn everything off. Check to see that all cables are firmly inserted and screwed in. Make sure the input is the same channel from which you expect to use the Bridge Amp in the software. Ensure no other equipment is attached to the particular channel of the PowerLab from which you expect to see the Bridge Amp. 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 Bridge Amp is faulty.

- This is the least likely event. If the Bridge Amp will not work properly after the previous measures, then try using it on another PowerLab. If the Bridge Amp's Status indicator fails to light with a second PowerLab, the Bridge Amp may be faulty. Contact your ADInstruments representative to arrange for repairs.

One or more overload indicators glow amber

If a light glows amber (yellow), it indicates some fault such as a short circuit, a badly wired bridge transducer, or an excitation overload.

- Check to see that all transducer connections are firm.
- Check for short circuits and badly wired bridge transducers, by changing them around, connecting new ones, and so on.
- Check transducer impedances. In particular, a low-impedance Grass transducer (250 Ω or so) may suffer overload if the excitation is too high.

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

The correct Bridge driver is not installed on your computer.

- Reinstall the software.

You are using an early version of LabChart.

- 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 Bridge Amp is faulty.

- This is the least likely event. If the Bridge Amp will not work properly after the previous measures, then try using it on another PowerLab. If the Bridge Amp's

Status indicator fails to light with a second PowerLab, the Bridge Amp may be faulty. Contact your ADInstruments representative to arrange for repairs.

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

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

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

The transducer is defective or subject to excessive load, causing the offset range of the Bridge Amp's zeroing circuitry to be exceeded.

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

You are using an unmodified half-bridge transducer.

- Half-bridge transducers may require rewiring with compensating resistors before they can be used with Bridge Amps.

The signal from the transducer is noisy at lower ranges

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

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

The signal from the transducer is weak even at lower ranges

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

- Check the connection and try again. If the transducer has been adapted for use with the Bridge Amp, check the wiring and soldering within the plug.
- Ensure that the particular channel in LabChart has been correctly recognized as a Bridge Amp (and not as Input Amplifier).

The transducer itself is faulty.

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

The signal from the transducer drifts excessively.

- Both the Bridge Amp and transducer require time to reach thermal equilibrium. Allow 5 minutes of warm-up time with the transducer connected and then try to re-zero the transducer.
- The transducer itself may be of low quality.
- The excitation voltage may be too high and causing the transducer to self-heat and drift. Try reducing the excitation voltage.

Specifications

Single, Quad and Octal Bridge Amps (FE221, FE224 & FE228)

Input

Number of inputs:	1 (single), 4 (Quad) or 8 (Octal); 8-pin DIN
Connection type:	8-pin DIN socket
EMC:	Approved to EN61326-1:2006 Standard
Configuration:	Differential
Input range:	± 200 µV to ± 5 V full scale in 14 steps
	(combined PowerLab and Bridge Amp)
	± 5 V
	± 2 V
	± 1 V
	± 500 mV
	± 200 mV
	± 100 mV
	± 50 mV
	± 20 mV
	± 10 mV
	± 5 mV
	± 2 mV
	± 1 mV
	± 500 µV
	± 200 µV
Accuracy:	± 0.5% (combined PowerLab and Bridge Amp)
Maximum input voltage:	± 10 volts
Input impedance:	2 × 1 MΩ (single-ended) 2 MΩ (differential)
Low-pass filtering:	1 Hz to 1 kHz in seven steps (software-selectable)
Frequency response (–3 dB):	2 kHz maximum at all gains with the low-pass filter off
CMRR (differential):	100 dB @ 50 Hz (typical)
Noise:	<1 μV_{rms} referred to input at highest gain

Excitation and Zeroing

Excitation voltage range:	0–20 V DC (± 10 V referred to ground), adjusted by external resistor
Transducer drive current:	± 45 mA maximum
Zeroing circuitry:	Software-controlled, either manual or automatic
Internal offsetting range:	± 10 V (1–5 V range)
	± 1 V (100–500 mV range)
	± 100 mV (0.2–50 mV)
Internal offset resolution:	16-bit (internal DAC) ± 32 000 steps about 0 V.
	1, 2, 5 V - 310 µV/step
	100 mV, 200 mV, 500 mV - 31 µV/step
	200 µV to 50 mV - 3 µV/step

Control Port

I^2C port:	Power and control bus for front-end units. Supports a number of front-ends dependent on the PowerLab. Interface communications rate of ~50 kbits/s.

Physical Configuration

Dimensions (h × w × d) and Weight:

Single (FE221):	55 mm × 120 mm × 260 mm
	(2.2" × 4.7" × 10.2"); 1.2 kg
Quad (FE224):	70 mm × 240 mm × 260 mm
	(2.8" × 9.4" × 10.2"); 2.4 kg
Octal (FE228):	70 mm × 240 mm × 260 mm
	(2.8" × 9.4" × 10.2"); 2.6 kg
Power requirements:	0.8 W (FE221); 2.5 W (FE224); 5.0 W (FE228)
	(without transducer attached)
Operating conditions:	5–35 °C, 0–90% humidity (non-condensing)

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

Chapter 5

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 sale, installation service or use of its products.

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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

For additional information or service inquiries please contact the nearest ADInstruments office or Authorized Distributor. For contact details see www.ADInstruments.com

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