PowerLab/4ST Owner's Guide

PowerLab/4ST
ADInstruments

Trigger   Audio Out

Output 1

Output 2

CH1

CH2

Isolated Stimulator

Status

Green = pulse
Yellow = OOC

ON

⚠ WARNING
100 Volts @ 20 mA

BIO Amp (CH3 & CH4)
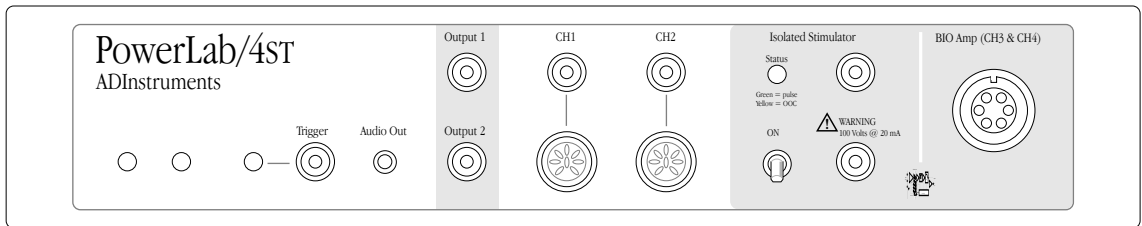
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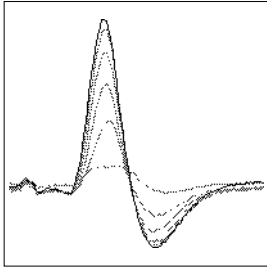All other trademarks are the properties of their respective owners.

Contents

Safety Notes

Product Intention

PowerLab systems have been designed only for use in teaching and research applications. They are not intended for clinical or critical life-care use and should never be used for these purposes, nor for the prevention, diagnosis, curing, treatment, or alleviation of disease, injury, or handicap.

Applicable Safety Standards

The PowerLab/4sᴛ has been designed for safe connection to humans, and conforms to international safety requirements. Specifically, these requirements are IEC601-1 and its addenda (Table S–1), and various harmonised standards worldwide (UL2601.1 in the USA, and AS/NZS3200.1 in Australia and New Zealand). In accordance with European standards it also complies with the electromagnetic compatibility requirements under EN60601-1, which encompasses the EMC directive. Further information is available on request.

Table S–1
Applicable safety standards met by the PowerLab/4sᴛ

EC Standard No.	International Standard — Medical electrical equipment
IEC601-1:1988	General requirements for safety
IEC601-1-1:1992	Safety requirements for medical electrical systems
IEC601-1-2:1993	Electromagnetic compatibility

Isolated Stimulator Safety Instructions

The Isolated Stimulator output, although electrically isolated, can produce pulses of up to 100 volts at up to 20 mA. Injury can still occur from careless use of this device. Several points must be observed for safe operation of the Isolated Stimulator:

• The Isolated Stimulator output should only be used with the supplied bar stimulus electrode or similar electrodes. It must not be used with individual (physically separate) stimulating electrodes. Stimulation must not be applied across the chest or head. Do not hold one electrode in each hand.

• Always use a suitable electrode cream or gel and proper skin preparation to ensure a low-impedance electrode contact. Using electrodes without electrode cream can result in burns to the skin or discomfort for the subject.

• Subjects with implantable or external cardiac pacemakers, a cardiac condition, or a history of epileptic episodes should not be subject to electrical stimulation.

• Always commence stimulation at the lowest current setting and slowly increase the current.

• Stop stimulation if the subject experiences pain or discomfort.

• Do not use faulty cables, or those that have exhibited intermittent faults.

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

• Always be alert for any adverse physiological effects in the subject. At the first sign of a problem, stimulation should be

stopped, either from the software or by flicking down the safety switch on the front panel of the PowerLab.

Bio Amp Safety Instructions

The Bio Amp input amplifiers of the PowerLab/4ST are electrically isolated from the mains supply in order to prevent current flow that could result in injury to the subject. Several points must be observed for safe operation of the Bio Amp:

- The PowerLab/4ST is supplied with a 5-lead Bio Amp cable and lead wire system that meets the safety requirements of the IEC601-1 (UL2601.1 or AS/NZS3200.1) medical standard. This cable is fully insulated and is manufactured with special leads and plugs to prevent accidental connection to power supply sockets. The PowerLab/4ST Bio Amp is only safe for human connection if used with the supplied cable and leads.

- The inputs of the Bio Amplifiers are not defibrillator-protected. Using the Bio Amp inputs of the PowerLab/4ST to record signals during defibrillator discharges may damage the input stages of the amplifiers. This may result in a safety hazard.

- Subjects, Bio Amp cables, and lead wires should be kept well away from power supply cabling. This also helps to reduce power supply interference in recorded signals.

- Never use damaged Bio Amp cables or leads. Damaged cables and leads should always be replaced before any connection to humans is made.

General Safety Instructions

- Since the PowerLab is used in conjunction with a computer (which has much higher leakage currents) the subject must be at least 1.83 metres (6 feet) away from any of the equipment, to avoid contact with the computer. The Bio Amp or BP Amp cable provides enough distance. Alternatively, an isolation transformer can be used to supply power to both the PowerLab and the computer.

- The ordinary outputs (Output 1 and Output 2) and the Channel 1 and Channel 2 inputs of the PowerLab/4sᴛ are not isolated, and must not be used for direct connection to human subjects.

- The PowerLab/4sᴛ should always be fitted with the recommended fuses for safe operation. Specific information on fuse types and replacement is given in a later chapter.

- The PowerLab/4sᴛ is classified as Class I medical equipment, which means that protection against electric shock in the event of a fault relies on a direct connection through the power cable to your building's earth conductor. The power cable supplied with your PowerLab provides the required ground connection to the power outlet. If your building does not have power outlet sockets with a good ground connection, then you may use the ground connection on the rear of the PowerLab to provide the equipotential connection to the building's earth conductor. A ground connection is an essential part of this equipment's safety. Never use the PowerLab without a ground connection.

Safety Symbol Explanation

Every ADInstruments device designed for connection to humans, including the PowerLab/4sᴛ, PowerLab 4/20ᴛ, Bio Amp, BP Amp, GSR Amp and Stimulus Isolator, carries one or more of three safety symbols, as shown in Figure S–1. These symbols appear next to those input and output connectors that can be directly connected to human subjects,

Figure S–1
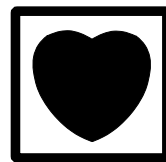Equipment safety symbols on ADInstruments devices designed for safe connection to humans

BF symbol: Body-protected equipment

Warning symbol: see documentation

CF symbol: Cardiac-protected equipment

The three symbols are:

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

• **Warning symbol**. The exclamation mark inside a triangle means that you should consult the supplied documentation (you're reading it) for operating information or cautionary and safety information before using the device.

• **CF (cardiac protected) symbol**. (Appears on some models of Bio Amp, and every BP Amp.) This means that the input connectors are suitable for connection to humans even when there is direct electrical connection to the heart.

Cleaning and Sterilisation

This system is not supplied with materials or components likely to need sterilisation. If you need to clean peripherals likely to be in contact with different subjects, they can be cold-sterilised with an appropriate sterilising agent. No part of the system can be autoclaved.

Storage

It is recommended that the hardware be kept below 40 °C and above 0 °C in a moisture-free or low-humidity environment when not in use (storage only). Electronic components are susceptible to corrosive substances and atmospheres, so it is also advisable to keep the system away from laboratory chemicals.

Preventative Inspection and Maintenance

Both PowerLab systems and ADInstruments front-ends are maintenance free and do not require periodic calibration or adjustment to ensure medical safety. 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.

If you so wish, your PowerLab system can be periodically checked for basic medical safety by using an appropriate medical safety testing device. Tests such as earth leakage, earth bond, insulation resistance, patient leakage and auxiliary currents and power cable integrity can all be performed on the PowerLab system without having to remove

the covers. You should 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 dealer to arrange for the equipment to be checked and serviced. You should not attempt to service the device yourself.

1 Overview
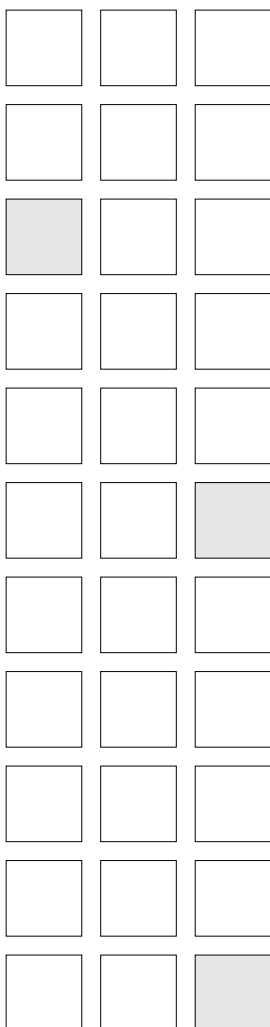
Your PowerLab recording unit, together with a range of specialised application programs, provides a versatile data recording and analysis system when used with a Windows or Macintosh computer. This chapter provides an overview of the PowerLab system and describes the basic features, connectors, and indicators of the PowerLab/4ST. It also discusses the Bio Amp cable and the measurement of signals.

The PowerLab/4ST can record biological signals from humans and other sources, with full electrical isolation, and can also be used for any general-purpose stimulation.

How to Use this Guide

This owner's guide describes how to set up and begin using your PowerLab recording unit. The chapters provide an overview of the PowerLab system (the combined software and hardware package), and a more detailed look at the features of your recording unit and its connection to your computer. Particular features of the software are described. The appendixes provide technical information about the recording unit, and solutions to problems. At the end of this guide is a glossary of hardware terms, an index, and warranty information.

The specifications and diagrams included in the appendixes are there to help the more technically minded to understand what the PowerLab can and cannot do, but this is not a service manual: only an authorised ADInstruments distributor should attempt repairs. If you modify the recording unit yourself, you void any rights you have under warranty.

The user's guides for the Chart and Scope application programs provide detailed information on the software side of the PowerLab system and its uses in acquiring, storing, and analysing data. Read them after you have connected the PowerLab to your computer.

First, Check Your PowerLab!

Please do not attempt to connect the PowerLab to a power outlet or computer or turn it on until you have read the first two chapters of this owner's guide, and have checked it as described below.

1. Check that all items in the accompanying packing list are included in the box.

2. Check that there are no obvious signs of external damage to the PowerLab.

3. Check that there are no obvious signs of internal damage, such as rattling. Pick the PowerLab up, tilt it gently from side to side, and listen for anything that appears to be loose.

4. Check that the correct voltage for your country is shown on the back of the unit. Your PowerLab should be delivered with the

Figure 1–1

The voltage rating on the back panel of the PowerLab
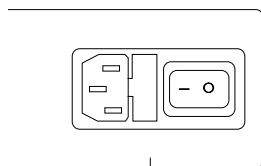
Check the voltage rating beneath the power switch

appropriate mains power voltage set, at either 100–120 volts or 220–240 volts. The setting is indicated at the right of the back panel of the unit, beneath the power switch.

If anything is missing, or the PowerLab seems to be damaged in any way, or if no voltage, or the wrong voltage, is shown on the back panel of the unit, contact your authorised ADInstruments distributor immediately, and describe the problem. Arrangements can be made to replace or repair the PowerLab. (Up-to-date contact addresses are available in the software — see Appendix B in one of the software user's guides for details.)

The PowerLab System

The PowerLab system is an integrated system of hardware and software designed to record, display, and analyse experimental data. The hardware consists of the PowerLab recording unit and possible ancillary devices (front-ends — the PowerLab/4ST has some built in); the software consists of the application programs (such as Chart and Scope) that run on the computer to which the PowerLab is connected.

Your PowerLab has considerable computing power of its own and performs many tasks that are necessary during data recording. Once the PowerLab transfers the data to the computer, the data are available for display, manipulation, printing, storage, and retrieval. The PowerLab/4ST has two non-isolated input channels, and two isolated input channels that are suitable for connection to humans.

Computer Requirements

Computer requirements for both Windows and Macintosh depend on whether you connect your /4ST PowerLab unit to your computer using a SCSI or a USB interface. SCSI allows faster transfer rates, but is less straightforward to use.

Windows

• A computer with a Pentium processor or better

• 32 MB free RAM (48 MB for Windows NT or 2000)

- Windows 95, 98, Me, NT 4.0, 2000 or later Windows operating system

- **Additional requirements for USB**: A USB interface on your computer (this may be added via a card if necessary); Microsoft Windows 98, Me, 2000, or later (Windows 95 and NT will not work with USB).

- **Additional requirements for SCSI**: An appropriate SCSI card and cable (we recommend that you use a card and cable supplied by ADInstruments — others may be suitable, but you should seek technical advice if in doubt); a software component called ASPI (ASPI will already be on your computer unless you are using Windows NT or 2000, in which case you can install it using the installer located on the PowerLab Installer CD).

Macintosh

These requirements assume you are using the latest version of Chart. An older version of Chart is available for use with older Macintosh computers.

- A Power Macintosh computer (or computer with a PowerPC microprocessor)

- 32 MB free RAM (64 MB recommended)

- Mac OS 8.6 or later (Mac OS 9.0 or later recommended)

- **Additional requirement for USB**: A USB interface on your computer (this may be added via a card if necessary)

- **Additional requirement for SCSI**: Either built-in SCSI or an appropriate SCSI card and cable (we recommend that you use a card and cable supplied by ADInstruments — others may be suitable, but you should seek technical advice if in doubt).

The Application Programs

Two main application programs and their documentation are provided with each PowerLab. Scope emulates a two-channel storage

oscilloscope. Chart emulates a multi-channel chart recorder (up to 16 channels, depending on the PowerLab model). Both provide many other powerful features in addition, including computed functions, triggering options, software-controlled stimulus generation, and automated recording and analysis. Their user's guides describe them in full; the Getting Started with PowerLab manual gives summaries. You must install the software to use your PowerLab. Installation instructions are included in the user's guides for the software.

ADInstruments Front-Ends

Front-ends are optional ancillary devices that can be connected to the PowerLab to extend the system's capabilities. The PowerLab/4ST already has three front-ends built in: two Bio Amps and an Isolated Stimulator. The Bio Amps are needed to perform electrically isolated measurements of biological signals, and the Isolated Stimulator can be used for any general-purpose stimulation work.

Up to two more front-ends can be connected to the PowerLab/4ST's analog inputs, to provide additional signal conditioning and other features, and extend the types of experiments that you can conduct and the data you can record. For instance, the Spirometer is available if you need to perform respiratory measurements. Separate front-ends are easily added to or transferred between PowerLabs. They are automatically recognised by the PowerLab system and seamlessly integrated into its programs, operating under full software control. Your ADInstruments distributor will have full information on available front-ends and their uses and specifications, and will be happy to discuss your requirements with you.
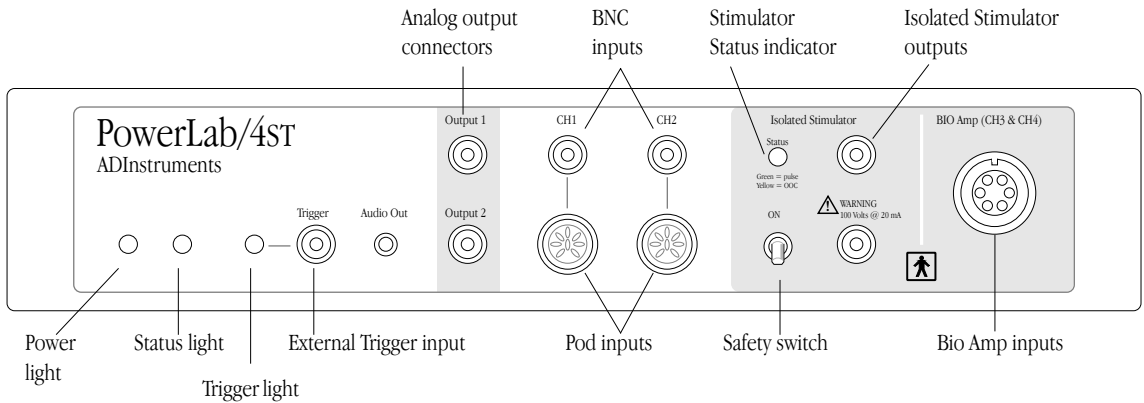
The PowerLab

It is a good idea to get familiar with some of the external features of your PowerLab before connecting it to a power source. The rest of this chapter discusses the different features, connectors, and indicators of the PowerLab/4ST.

The Front Panel

The front panel of your PowerLab provides most of the connectors for interfacing with external signals, and indicators for various functions. This section describes each of the front panel features.

Figure 1–2
The front panel of the
PowerLab/4ST

Power and Status Indicators

The Power indicator on the front panel is a green light, which simply shows that the PowerLab is getting power. The indicator next to it, the Status indicator, provides a visual indication of what the PowerLab is doing, and will flash different patterns and colours depending on the state of the PowerLab.

Status Indicator	Meaning
Off	Idle and not yet initialised by the software.
Yellow flashes	When the PowerLab is powered up, the indicator flashes yellow a number of times equal to the SCSI ID. For example, 4 yellow flashes would indicate a SCSI ID number of 4.
Green constant	Idle, initialised, and waiting for a command from the computer.
Yellow constant	Sampling, or communicating with the computer.
Yellow flash then one or more red flashes	This indicates that the PowerLab has detected an internal fault during the power-up test. The number of red flashes after the yellow flash indicates the type of error that has been detected. This display will keep repeating until the power to the PowerLab is turned off.

Analog Input Channels (CH1 and CH2)

The PowerLab/4sᴛ has two independent analog inputs (marked CH1 and CH2) used to record external signals, but *not* to connect directly to humans. They are capable of handling signals from ±10 V down to the microvolt (µV) range without the need for additional external amplification. Each of these analog inputs has an independently programmable gain amplifier with its own filtering, and AC/DC coupling. You can set up each channel independently to suit your requirements using the software. Note that applying more than ±15 V to the analog inputs can damage the circuitry.

Each input can be set up as single-ended (with one signal referenced to ground) using the top BNC connector, or either single-ended or differential (with the difference between the positive and negative input signals recorded), using the 8-pin DIN Pod connectors below. Do not attempt to record from both the BNC and Pod connectors for an input at the same time, or the signals will compete.

The Pod connectors on the PowerLab/4sᴛ do not handle transducers directly unless the transducers are so labelled (unsuitable transducers will give a very weak signal). Those transducers designed for Pod use can be provided with power and control, since the Pods provide some functions of the I^{2}C output as well. Pod connectors also let ADInstruments SmartPods be connected — small units that enable precalibrated transducers and so on to be used without having to use a specialised front-end.

The Bio Amp Inputs (CH3 and CH4)

The PowerLab/4sᴛ also has one common connector for two Bio Amp channels (marked 'Bio Amp CH3 & CH4'). These biological amplifiers are needed to perform electrically isolated measurements of biological signals, such as electrocardiograms and electromyograms. The two Bio Amp inputs are internally configured to use Channels 3 and 4 of the PowerLab/4sᴛ.

The Bio Amps have a common six-pin connector with a shared ground signal. The PowerLab/4sᴛ is supplied with a 5-lead Bio Amp cable and lead wires for connection. These inputs should only be used with the supplied Bio Amp cable and approved leads. Other cables may not meet safety requirements.

Audio Out (for Bio Amp Channels)

The PowerLab/4sᴛ has an audio output to monitor the Bio Amp channels. It provides stereo sound (using signals from Channels 3 and 4). The 3.5 mm stereo socket can be used with a wide range of headphones or externally powered speakers. The audio output is of particular use when monitoring nerve firings to control the placement of electrodes, for instance.

Analog Output

The PowerLab can generate a stimulus voltage through its analog output sockets (marked Output 1 and Output 2), giving positive, negative, differential, or independent stimuli, depending on the sockets used and the software settings. One can use either the analog output or the isolated stimulator, but not both at once.

By default, the outputs are used for complementary (differential) stimulation, where Output 1 is positive and Output 2 is negative. When Output 1 is used, a positive stimulus voltage (set up in the software) gives a positive voltage output, and a negative voltage a negative one. When Output 2 is used, the voltage outputs are inverted. When both output sockets are used, the stimulus is the difference between the voltages at the positive and negative outputs: you could generate up to a 20-volt pulse, given a ±10 V stimulus.

The outputs can be used for independent stimulation in Scope and the Macintosh version of Chart, but not in the current version of Chart for Windows (v3.4). The details are discussed in the software user's guides.

Isolated Stimulator

The PowerLab/4sᴛ has a built-in, isolated, constant-current pulse stimulator that can be used for any general-purpose stimulation. The Stimulator section of the front panel has two output sockets, an indicator light, and a safety switch. One can use either the analog output or the isolated stimulator, but not both at once.

The stimulus output is supplied via two 4 mm shrouded banana sockets; the top (red) socket is positive, the bottom (black) socket is

negative. These are similar to the sockets found on many digital multimeters, and designed for use with shrouded male 4 mm plugs (the shrouding is to prevent accidental stimulation while fitting or removing the plugs). The bar stimulus electrode supplied with the PowerLab/4ST uses such plugs. The output is capable of supplying 100 V pulses at currents up to 20 mA, so it should be treated with caution.

The Stimulator Status indicator is a multi-coloured light that is used to indicate the current status or operating condition of the Stimulator. The indicator light will flash green for every stimulus pulse, and may seem to glow green constantly at higher stimulus frequencies. A yellow colour indicates that the output is overloaded or out of compliance (compliance is the ability to supply voltage to meet the required current). This means that the impedance of the tissue being stimulated is too high, or there is a poor electrical connection (possibly due to electrode drying), and that the Stimulator can no longer supply constant current stimulation. If this should happen, try reducing the output current amplitude, and check all connections.

To provide an additional level of safety, a safety switch has been placed on the front panel to allow the output to be switched on and off as needed. The switch should be in the up position when the output is turned on, and should be flicked down to turn it off: that disconnects the output sockets from the internal circuitry, allowing connections to be made in safety while the PowerLab is on.

Trigger

The external trigger connector allows you to use a digital signal level to synchronise recording to an external event. This input can handle voltages of up to ±12 V. The threshold voltage (the voltage above which the trigger circuit activates) is 2.9 volts. When the trigger threshold is crossed, the indicator beside the external trigger connector will glow yellow. The external trigger is described in more detail in Appendix A, and the software documentation covers its practical use in normal recording.

The Back Panel

The PowerLab back panel provides the sockets to connect the PowerLab to the computer, front-ends, the power outlet, and so on. This section describes each of the back panel features.
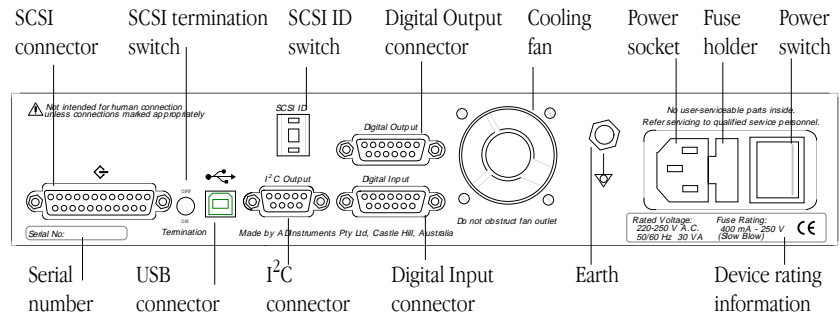
The USB Port

The PowerLab can connect to your computer using a USB (universal serial bus) port, which provides an alternative to the SCSI connection. This works with USB 1.1-compliant computers with USB connectors or a USB card. USB needs a Power Macintosh with Mac OS 8.5 or later, or a PC with Windows 98 or later.

A USB connection is a bit slower than SCSI for data transfer, and so may limit sampling rates (in Chart) or increase delay times between sweeps (in Scope), but it is less fussy. You can safely turn on or off, or disconnect or reconnect, a USB-connected PowerLab while the computer remains on (this is *not* the case with SCSI). The application program (Chart or Scope) should not be on while this occurs, though. Please read the details on USB in Chapter 2 of this guide before connecting your PowerLab to your computer using USB.

The SCSI Port

The PowerLab can connect to your computer using a SCSI port, which provides an alternative to the USB connection. (SCSI is an acronym for small computer system interface, and is pronounced 'scuzzy' — which shows that engineers have no taste in acronyms). SCSI provides fast data transfer, but requires that specific rules be

followed in order for it to work correctly: it is the most complex aspect of setting up a PowerLab system. Please read the details on SCSI in Chapter 2 of this guide before connecting your PowerLab to your computer using SCSI.

The PowerLab/4sT has a single 25-pin connector for connecting SCSI cables, so it has to be used at the end of a SCSI chain. It is terminated internally, but the termination can be switched on and off using the SCSI Termination switch beside the SCSI connector (it should be on).

The SCSI ID Switch

The SCSI ID switch is there if you need to change the SCSI ID number of your PowerLab. The PowerLab is factory-set to an identification number of 4. The SCSI ID can be changed simply by pressing the control buttons while the PowerLab is turned off. The new ID takes effect when the PowerLab starts up again. Only some numbers are valid: they depend on the type of computer, whether it has built-in SCSI or a SCSI card, and the number of built-in and peripheral SCSI devices in the SCSI chain. This is discussed in the next chapter.

I^{2}C Output

The I^{2}C output is a special port designed to connect to front-ends made by ADInstruments. It supplies power and communications. Only two additional front-ends, one for each analog input, can be connected to a PowerLab/4sT. (The analog output cannot be used to add a separate Stimulus Isolator or similar front-end.) *Note*. You should not attempt to run other external devices from the I^{2}C port: it is designed for use only with ADInstruments front-ends. Only 50 mA maximum current can be provided through this bus, so it should not be used for third-party devices drawing more current.

Cooling Fan

The PowerLab/4sT can generate a fair amount of heat, so it is fitted with a small cooling fan in the centre of the rear panel. The fan maintains sufficient airflow in the enclosure to keep the circuitry within operating tolerances. The fan outlet must be kept unobstructed, and far enough from walls or other devices (at least three inches) so as to not impede ventilation. It is also important to make sure that the air inlets underneath the PowerLab are

unobstructed. Blocking the grilles may result in the PowerLab heating up enough internally to affect the performance of the system and reduce reliability.

Digital Input and Output Ports

The digital input and output connectors let you monitor and control external devices respectively with the PowerLab. These recording automation and control features are available in the Macintosh version of Chart, but not in the current version of Chart for Windows (v3.4), or in Scope.

The digital input monitors state changes: you can have a predefined comment automatically inserted during recording when a digital input changes to a particular state. The eight lines of the connector allow monitoring of up to eight devices. The digital output can turn on and off external devices, for example, pumps, relays, and indicator lights, or can signal to some other device. The eight lines of the connector allow control of up to eight devices.

Technical details of the digital input and output connectors are given later in this guide: please refer to the descriptions before attempting to connect equipment to them. More information on the use of digital inputs and outputs is given in the user's guide for the software.

Ground Connection

A special earthing (grounding) stud has been provided on the rear of the PowerLab. This is an equipotential bonding connection post compatible with the DIN 42801 standard. If the ground connector post is used, the power cord ground connection should not be used: a power cord with no ground connection should be used instead.

The ground connector post on the rear panel is used as a primary earth connection (equipotential connection point) in situations that require this type of connection, or if there is no ground provided via the power cord. Safety standards in laboratories and similar environments may require additional grounding protection when connecting equipment to human subjects. In such cases, an equipotential connection may be used for all linked equipment to prevent ground loops, and power cords with no ground connections should be available.

Power Connections

The power switch on the back right of the PowerLab turns the PowerLab on and off; the 3-pin IEC power socket is used to connect your PowerLab to a 3-pin earthed (grounded) power cable.

Power switch

Fuse holder
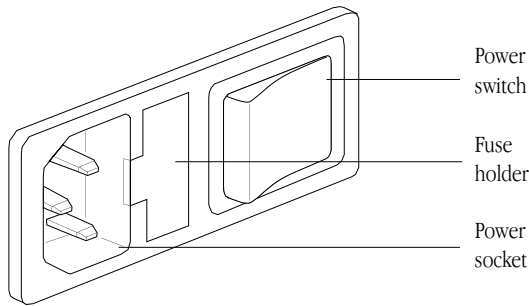
Power socket

Fuse Replacement

The fuse holder is located beside the power socket, and can only be opened when the power cable is removed. To check the fuses, remove the power cable from the PowerLab, and lever the fuse holder out using the tab at its left, which is recessed in the power socket. The fuse holder contains two 'slow-blow' fuses, which protect your PowerLab from power surges.

Fuses

Fuse holder
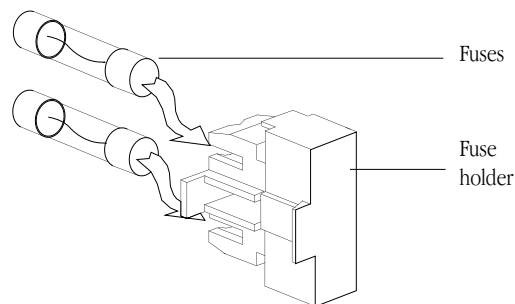
Replacement fuses must be of the correct type, as specified below for 100–120 volts or 220–240 volts operation:

- 100–120 V   1 Amp (5 × 20 mm) slow blow
                   (voltage rating 120 or 250 V)

- 220–240 V   400 mA (5×20 mm) slow blow
  (voltage rating 250 V only)

The correct voltage for your country is shown on the back of the PowerLab, by the power switch (see Figure 1–1, page 3).

The Bio Amp Cable

Connections are made to the Bio Amp inputs using the supplied Bio Amp cable and leads. The cable plugs into the six-pin input socket on the front panel: a notch in the plug ensures that polarity is correct. Only the supplied Bio Amp cable and leads should be used. Other cables may not meet safety requirements. The PowerLab/4ST is supplied with a 5-lead Bio Amp cable and lead wires; it uses a shared ground signal for its Bio Amp channels. The supplied cable is of the sort often used for ECG or EMG work, a Tronomed D-1540 cable, which has a cable yoke with five holes for the leads.

Figure 1–6
The Dual Bio Amp cable yoke, with 5 leads attached
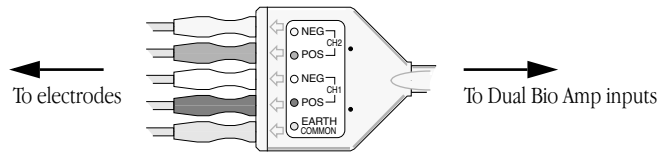
The leads supplied are of the sort often used for ECG work. They click into place in the cable yoke, and have snap connectors at the other end to connect to typical ECG electrodes. The leads are colour-coded for ease of identification. The labels on the Bio Amp cable also have colour spots to help sort out which cables connect where and what they are measuring. (The colours are arbitrary, since the PowerLab system is for general-purpose recording, and 'standard' colour assignments tend to change with the type of recording.)

ADInstruments supplies other types of lead that connect to the Bio Amp cable yoke, such as EEG/EMG leads and dry earth straps. Also available are disposable and reusable electrodes, electrode cream (for reusable electrodes), and abrasive pads, for lightly abrading the skin before the electrodes are attached.

Types of Measurement

The basics of measurement of various standard signals with the PowerLab/4ST, in a series of step-by-step student experiments in electrophysiology, are detailed in the *Physiology Experiments Manual* supplied with the PowerLab/4ST; more are covered in standard electrophysiology texts. ADInstruments also produces materials describing specific uses of the Bio Amp inputs, such as Application Notes that can be downloaded from the ADInstruments web site or obtained from your ADInstruments distributor.

Just as the built-in isolated stimulator can be used for many general stimulation tasks, the Bio Amp inputs can measure a wide variety of biological signal sources. Some of these measurements include:

ECG. Electrocardiogram (also referred to as EKG); a recording of surface potentials due to electrical currents associated with the heartbeat.

EEG. Electroencephalogram; a recording of the electrical activity of the brain. Scalp electrodes record potential waves (10–100 µV) representing the summed activity of cortical neurones.

EMG. Electromyography; a recording of the electrical activity of a muscle, using surface electrodes. The recorded activity may be a voluntary contraction, or evoked by motor nerve stimulation.

EOG. Electro-oculogram; a recording of the potential difference between the front and back of the eyeball, as projected on to the face.

ERG. Electroretinogram; a recording of the electrical signals produced in the retina by a light stimulus.

Cortical Evoked Potentials. Averaged recordings of the electrical activity of the brain when subject to stimulation: visual evoked response, auditory evoked response, and somatosensory response. These should be done with signal averaging, using Scope.

SNAP. Sensory nerve action potential; a recording of evoked responses in stimulated nerves. This is usually done with signal averaging, using Scope.

The built-in PowerLab/4ST Bio Amps are unsuitable for work requiring high-impedance electrodes or using a high bandwidth. Such tasks include intracellular micropipette recordings, which are made from a very fine, electrolyte-filled tube inserted into a nerve or muscle cell, and require an electrometer amplifier; and needle electromyography, the intramuscular recording of the electrical activity of a muscle, which requires low input capacitance and a driven guard.

Recording Technique

Several problems can arise when using the Bio Amp inputs to record signals. These are basically problems of technique, and should be addressed before setting up. It is important to understand the types of problems that can occur, how they manifest, and what can be done to remove them or to minimise their effect. Potential problem areas include aliasing, frequency distortion, saturation, ground loops, electrode contact, motion artefacts, electromagnetic fields, and data display.

There is a good introduction to data acquisition provided in the documentation for Chart and Scope (from v3.6). This information is also available in one of the Application Notes ('Basics of Data Acquisition') that can be downloaded from the ADInstruments web site or obtained from your ADInstruments distributor. It is highly recommended reading for anyone recording biological signals using the Bio Amps. Apart from the general areas covered in that material, two things particularly affect the kind of measurements made with Bio Amp inputs, and can cause 'artefacts' (spurious readings) in the recorded waveform: electrode contact and motion effects.

Electrode Contact. Occasionally during measurement of a biological signal, one of the lead wires connecting the source 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, owing to electric fields caused by the power line or other sources close to the front-end or to the subject. This induced potential results in a constant amplitude disturbance of the recorded waveform at the power line frequency, 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.

Make sure that skin is cleaned and lightly abraded before attaching electrodes to it. Ensure that there is sufficient electrode cream to maintain a good contact: if it dries out, the contact will be poor, and the recorded signal may be degraded or lost.

Motion Effects. A common source of artefacts when recording biological signals is motion of the subject or equipment. For example, 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 Bio Amp cables and leads, particularly bending or rubbing together (triboelectric effects) may generate artefacts 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 leads.

2
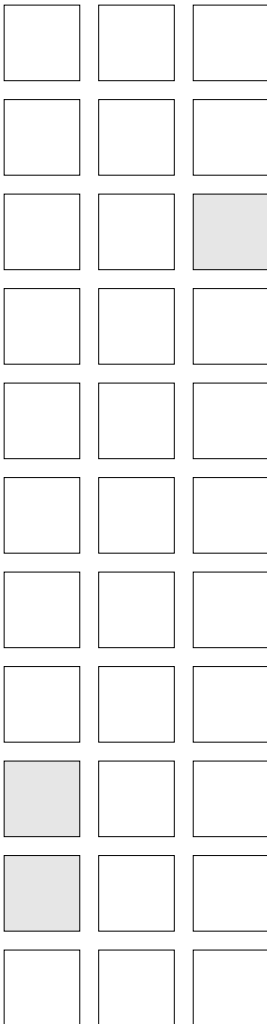
Setting Up

This chapter starts with the PowerLab's internal self-test, then looks at the USB connection. It also looks at the SCSI connection in some detail, including connection and termination rules, and setting the SCSI ID number. It discusses how to connect up your PowerLab to a Windows or Macintosh computer.

Self-Test

Now that you are familiar with some of the features of your PowerLab, you should check that it is working properly before you connect it to your computer.

The PowerLab performs a diagnostic self-test each time it is switched on, whether or not it is connected to a computer. To test that your PowerLab is functioning properly when you turn it on, follow the instructions below, and observe the effects.

1. Connect the PowerLab to a power outlet using the power cable that came with your unit. Turn the power on at the wall.

2. Turn on the power switch located on the rear of the unit.

    The Power indicator on the front panel should glow green while the PowerLab is on (see Figure 1–2).

    The Status indicator should flash yellow a number of times equal to the SCSI ID of the PowerLab (see Table 1–1). If the internal diagnostic check finds no problems, the Status indicator turns off (showing that the PowerLab is idle; it only goes green when the software is running).

If the indicators perform as described above, then your PowerLab has successfully performed its internal self-test, and it can be safely connected to your computer. If your PowerLab would not successfully complete its self-test, something is wrong. If the Power indicator does not glow green when the power switch is turned on, then either the fuse has blown or there is a problem with the power cable or PowerLab itself.

If an error is detected during the self-test, the Status indicator will flash yellow and then a certain number of red flashes depending on the fault. Flashing lights are used when the problem is one that prevents the PowerLab communicating with the computer (such as a hardware fault), and so cannot be shown in the software. The error pattern will continue to be displayed, allowing you to take note of the type of error that occurred. The number of red flashes indicates the probable problem area. If the pattern is simply an alternating red

flash and yellow flash, then the SCSI ID has been set to the numbers 0 or 7, which cannot be used for an S series PowerLab (including the Powerlab/4sT). Switch off your PowerLab, change the SCSI ID for the PowerLab using the control on its back panel, wait about five seconds, and then switch it back on.

If the error pattern is not simple alternating red and yellow flashes, then something may be wrong with the hardware itself. The pattern of red flashes indicates the likely problem area to ADInstruments technicians. Take note of pattern, switch off your PowerLab, wait about five seconds, and then switch it back on. If it still continues to flash the pattern, then the PowerLab needs repair. Contact your authorised ADInstruments distributor as soon as possible. Do not attempt to repair the PowerLab yourself. If your PowerLab has successfully performed its internal self-test, read on to find out how to connect it to your computer.

The USB Connection

This section is essential reading before trying to use your PowerLab with USB. The PowerLab is fitted with a USB (universal serial bus) port, which provides an alternative to the SCSI connection. This works with USB 1.1-compliant computers with USB connectors or a USB card. On a PC, USB requires Windows 98, Me, 2000 or later (95 or NT 4 won't do). On a Macintosh, USB needs a Power Macintosh with Mac OS 8.5 or later (but note that the latest PowerLab software requires Mac OS 8.6).

USB devices are connected in a tree-like structure, with the host, the computer, forming the root of the tree, and hubs allowing multiple devices to connect to them, like the branches of the tree.

Figure 2–1
A USB tree: up to 126 devices can be linked to the computer

Up to 126 linked USB devices

Computer: root hub for the USB tree
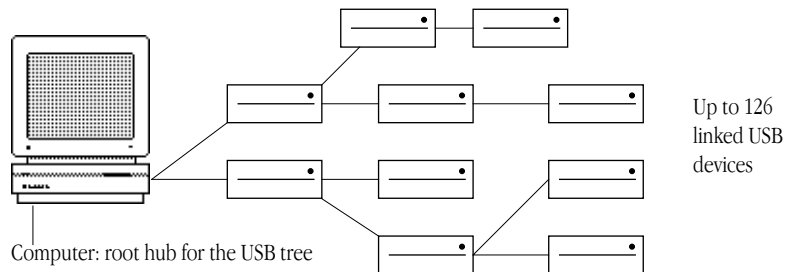
A hub is simply a device that lets you extend the USB tree. It connects to a USB device such as the computer, and multiple USB devices (including other hubs) can connect to it in turn. It provides power for those attached devices that need it. Up to five hubs can be connected between the computer and the furthest USB device. As many as 127 devices can be connected on one tree, counting the computer. The cable between any USB devices (including hubs) must allow a signal to be transmitted in a certain time; in practical terms this means it must be no more than 5 metres (16 feet) in length. Thus, no device can be more than 30 metres (98 feet) from the computer.

USB is more tolerant than SCSI. It lets one plug in and remove devices while the computer is on. It re-enumerates (provides addresses for) devices as they are connected and disconnected, rather than requiring fixed ID numbers. It has only one pair of connector types, unlike SCSI, and does not need termination as SCSI does.

USB still has some restrictions. A USB connection is a bit slower than SCSI for data transfer, and so may limit sampling rates (in Chart) or increase delay times between sweeps (in Scope). Since all the devices on a USB tree have a common communication pathway, if you have many devices with a lot of information to transfer, they compete for time. Using a video camera and a scanner at the same time as a PowerLab may limit the sampling rates considerably.

USB has two sorts of cables, which it should not be possible to interchange. Low-speed cables are cheaper, and suitable for mice and so on. They are either captive (one end is permanently fixed to the device) or use a custom connection, not a standard USB one. All detachable USB cables are high speed, with fully shielded twisted-pair cables, and standard USB connections: a narrow rectangular A plug at one end and a squarer B plug with a bevelled top at the other. All devices that can act as hubs have high-speed connections. The PowerLab needs a high-speed connection, and is provided with a suitable cable.

Connecting the PowerLab Using USB

Use the USB cable supplied with your PowerLab to connect the USB port on its back panel to the USB port on the computer, or to an active USB hub connected to the computer. USB ports and cables should be marked with a trident-like icon (some non-standard ones might have

the letters 'USB' instead). USB cables are directional, and can only be connected one way: the narrow rectangular A plug connects to a hub (including the computer), and the squarer B plug with the bevelled top connects to a USB device, such as the PowerLab. Connecting Macintosh or Windows computers should be much the same in this case: just look for the icons. If the connection is to a USB card installed in the computer, there might not be any icons on the card. The narrow rectangular sockets for the USB A plug are distinctive, though. Any USB icons on the plugs should be on top.

Figure 2–2
Connecting a PowerLab/4sᴛ
to a computer with USB
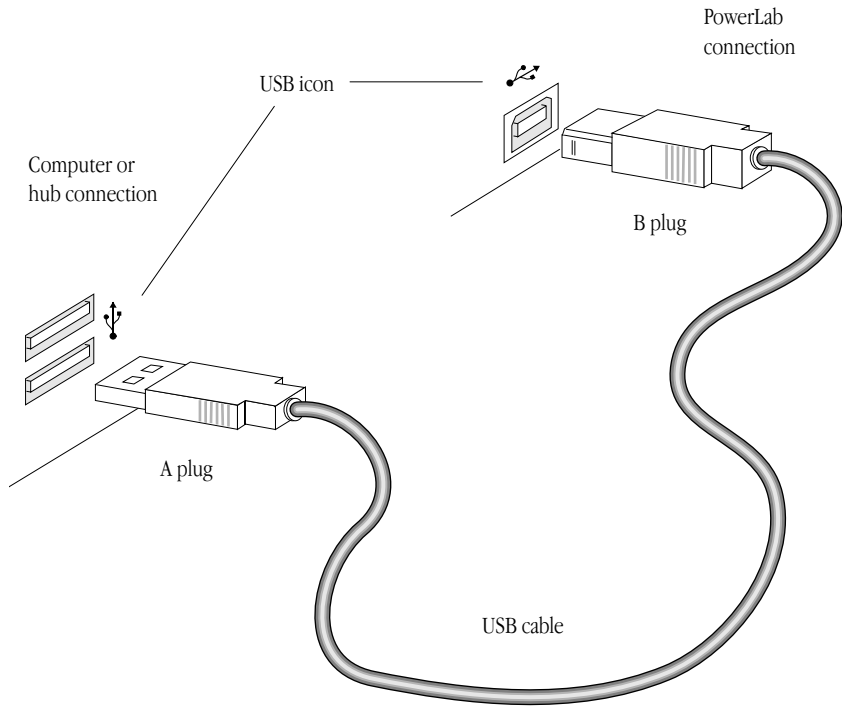
USB Connection Rules

1. *Cable length should be less than 5 metres (16 feet) between devices.*
    Devices include USB hubs. There are a maximum of five hubs on any branch, so the maximum distance between the computer and the Powerlab is 30 metres (98 feet). Do not use extension cables, use hubs between approved high-speed cables.

2. *Never attempt to make your own USB cable, or modify one.*
   USB is sensitive to cable impedances and cable lengths. Only use a certified USB cable from a reliable supplier, never a cheap brand or 'something the workshop whipped up'. Your PowerLab is supplied with the proper USB cable. If you need additional USB cables, you should buy high-speed cables (fully shielded, twisted-pair, and with standard USB connections) for reliable results.

3. *Don't disconnect the PowerLab while a program is using it.*
   Disconnecting a PowerLab while it is sampling is a bad idea and may cause problems in some circumstances. It is better to be safe than sorry, and not even disconnect a PowerLab while Chart or Scope is open. Stop sampling and quit the program first before disconnecting a PowerLab from USB.

You can safely turn on or off, or disconnect or reconnect, a USB-connected PowerLab while the computer remains on as long as the application program (Chart or Scope) is off when you do it.

The SCSI Connection

This section is essential reading before trying to use your PowerLab with SCSI. The user's guide for your computer may have a section on connecting SCSI devices, in which case you should read that as well.
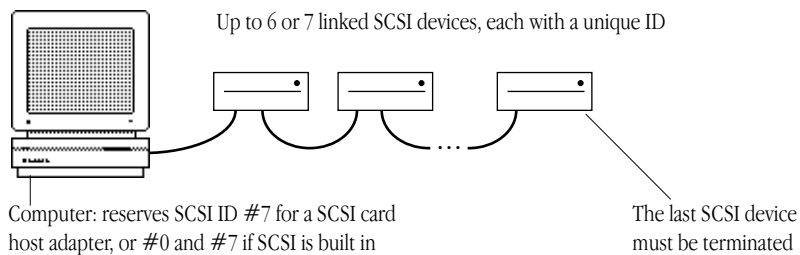
The PowerLab is fitted with a SCSI port, which provides an alternative to the USB connection. SCSI (small computer system interface) is simply a communication standard for connecting a single chain of SCSI devices together on a common high-speed bus (information-carrying pathway). A SCSI connection can easily handle the 4 megabytes per second maximum data transfer rate of the PowerLab, although the speed of your computer may limit this. The PowerLab must be placed at the end of the SCSI chain (if it is the only device, then connected directly to the SCSI port of, or to an installed SCSI card in, the computer).

SCSI Connection Rules

1. *Never alter the SCSI chain while any SCSI devices are on.*
   Disconnecting a SCSI device while there is SCSI hard disk activity

Figure 2–3
A SCSI chain: up to six (or
seven) devices can be linked
to the computer

Up to 6 or 7 linked SCSI devices, each with a unique ID

Computer: reserves SCSI ID #7 for a SCSI card
host adapter, or #0 and #7 if SCSI is built in

The last SCSI device
must be terminated

may cause data loss or electrical damage. Switch all devices off,
including the computer, before adding or removing SCSI devices.

2. *Each SCSI device must have its own unique SCSI ID number.*
   No two SCSI devices can have the same SCSI ID number or
   malfunctions may result. SCSI ID numbers are discussed later.

3. *Total cable length should be less than 6 metres (20 feet).*
   The SCSI circuits can only transmit data reliably over short
   lengths of cable. The total length of the chain is important,
   including short lengths of cable inside the computer and other
   SCSI devices. Internal cabling can be from 10 to 30 cm (4 inches to
   1 foot), depending on the device.

4. *The SCSI chain must be terminated correctly.*
   Failure to terminate the chain properly can result in intermittent
   communication, no communication, or failure of the computer to
   boot up. The correct way of terminating is discussed later.

5. *Turn SCSI devices on and off in the right sequence.*
   Turn on all external SCSI devices before the computer: this
   ensures that the SCSI bus is stable before your computer tries to
   use it. Turn off the computer before turning off other devices. This
   prevents external SCSI devices from 'hanging' the SCSI bus and
   preventing further access. Never operate with some devices in a
   chain turned off, as this degrades performance and signal quality.

6. *Avoid mixing cable types, brands, and styles.*
   A common source of trouble is mixing poor-quality SCSI cables
   with approved high-quality SCSI cables. Different cable types or
   brands may have different types of construction, impedance, and
   wire placement, and this can result in problems when they are

used together. Also, whenever possible, avoid using cable joiners and junctions to extend cable lengths.

7. *Never attempt to make your own SCSI cable, or modify one.*
SCSI is sensitive to cable impedances and cable lengths. Only use an approved SCSI cable from a reliable supplier, never 'something the workshop whipped up'. If you need additional SCSI cables, you should buy cables that are double-shielded (foil and braid), with twisted pairs and shielded connector hoods for the most reliable results. ADInstruments sells approved SCSI cables

Figure 2–4
The SCSI ID switch
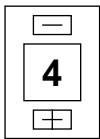
Setting the SCSI ID Number

Your PowerLab was set to a SCSI ID number of 4 at the factory before shipping. To change its SCSI ID, turn off the PowerLab, and all other connected devices in the SCSI chain, before changing the SCSI ID number. The SCSI ID switch is located on the back panel of the PowerLab. A small panel with push buttons above and below it displays the SCSI ID number. Press the [–] button above the indicator to decrease it or the [+] button below the indicator to increase it.

Do not set the SCSI ID to numbers already used by other SCSI devices in the chain. The maximum number of devices within the same SCSI chain is eight. Each device in the chain must have a unique SCSI identification number assigned to it. The numbers range from 0 to 7, with 7 the highest priority device. A computer with built-in SCSI usually reserves the values 0 and 7. On the Macintosh, 7 is used for the computer and 0 may be used for an internal SCSI hard disk (an internal SCSI CD, if there is one, usually takes ID 3, as well). On a PC, SCSI ID number 7 is usually reserved by a SCSI card host adapter or built-in SCSI controller, and SCSI ID number 0 is used by an internal SCSI hard disk, if there is one. To prevent most problems, therefore, the numbers 0 or 7 cannot be used for an S series PowerLab.

Externally connected devices should have readable SCSI ID switches you can check, although some may have ID switches that are difficult to see or read. Internally connected devices should be described in the manual that came with your computer. If you are unsure about the SCSI devices connected to a Macintosh computer, you can use tools such as SCSIProbe (a free utility available from the Internet and user groups), which lists all SCSI devices attached, what they are, and which SCSI ID they use. If you are unsure about the SCSI devices

connected to a Windows computer (particularly internal ones), your PC technical support person or IS manager may be able to help.

To confirm that you have set the right SCSI ID number, turn on the PowerLab and watch to see if the Status indicator flashes yellow a number of times equal to its SCSI ID number.

SCSI Termination Rules

Terminating the SCSI bus is essential to preserve the integrity of the high-speed signals present on the bus. Termination helps keep these signals free from noise and prevents unwanted signal reflections up and down the bus. Without correct termination, the SCSI signals could be swamped by reflections from previous signals, resulting in a jumble of meaningless electronic noise. The way in which you terminate the SCSI chain will depend on the number of SCSI devices you wish to connect to your computer along with the PowerLab. The SCSI connection between your PowerLab and computer is a very good way to provide safe and reliable high-speed data transfer, provided that you follow the rules for proper termination.

A SCSI chain is correctly terminated by placing terminators at each end of the chain. The computer is terminated internally, so forming one end of the chain. (A SCSI host adapter will be terminated: if the SCSI controller and internal SCSI hard disk are both terminated, you may have to alter things — see the documentation that came with the card or computer.) The PowerLab should be at the other end of the chain, with its SCSI termination switch on.
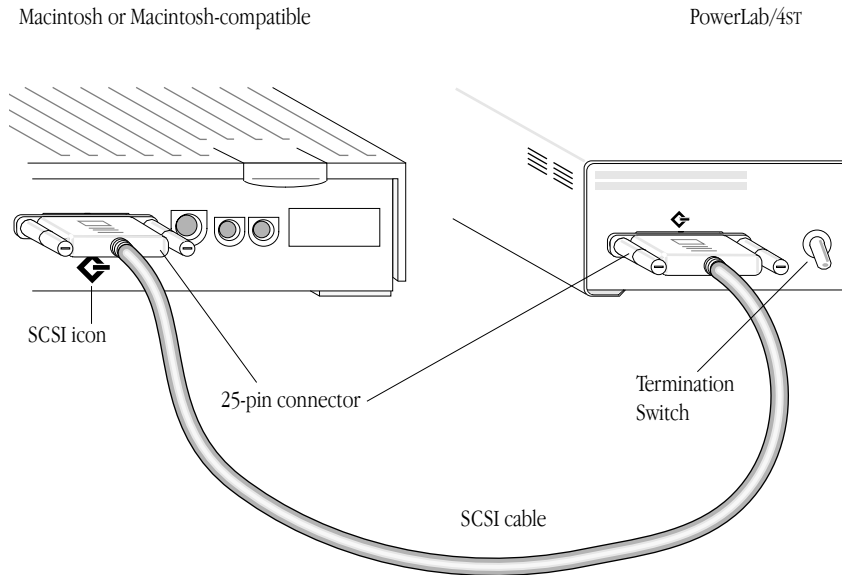
Connecting the PowerLab: Macintosh

Those Macintosh computers without USB (and even some with USB) should have SCSI built in or available through a card. Not all SCSI cards are suitable, especially high-end ones (ultra-wide SCSI and the like). SCSI cards and cables with which the PowerLab should work reliably are sold by ADInstruments. Make sure that you have the correct, 25-pin to 25-pin SCSI cable to connect up your PowerLab. (Most PowerBooks and Duo Docks have a special space-saving square 29-pin SCSI connector, which requires another connector or adapter. This can be purchased separately from your Apple dealer.)

If the PowerLab is the only SCSI device to connect to the computer, then simply connect the two together with the correct SCSI cable, and turn the SCSI termination switch on. If you wish to use multiple SCSI devices with the computer, the first and last devices in the chain should be terminated. The PowerLab must be at the end of the chain, since it has only one SCSI connector, and its internal terminator must be switched on.

Figure 2–5
Connecting a PowerLab/4sᴛ to the computer (look for the SCSI icon if the back panel is different)

Macintosh or Macintosh-compatible   PowerLab/4sᴛ

SCSI icon

25-pin connector

Termination Switch

SCSI cable

Connecting the PowerLab: Windows

Most modern PC computers should have SCSI available through a card (some have it built in). Not all SCSI cards are suitable, especially high-end ones (ultra-wide SCSI and the like). ADInstruments sells SCSI cards and cables with which the PowerLab should work reliably. (It may not be possible to find a cable to fit all connections, though.)

Make sure that you have the correct SCSI cable to connect up your PowerLab. It requires a 25-pin D-style connector for the PowerLab. If you have a portable computer with a PC card SCSI adapter, then the card probably needs the specific cable that came with that particular card. You may have to purchase separately a cable adapter to connect the end of your SCSI cable to the 25-pin connector for the PowerLab.

The card should have full instructions on installation with it. The SCSI adapter card will usually be terminated, and at one end of the chain (this is always the case for PC card SCSI adapters), although if the computer has built-in SCSI, you may have an internal SCSI device in your PC that is terminated, with the host adapter in the middle of the chain. If there is a problem with cables, or you are unsure about any devices, such as a hard disk, connected to your computer on SCSI internally, your PC technical support person or IS manager should be able to help you.

If the PowerLab is the only SCSI device to connect to the computer, then simply connect the two together with the correct SCSI cable, and turn the SCSI termination switch on. If you wish to use multiple SCSI devices with the computer, the first and last devices in the chain should be terminated. The PowerLab must be at the end of the chain, since it has only one SCSI connector, and its internal terminator must be switched on.

Figure 2–6
Connecting a PowerLab/4ST
to the computer (25-pin
connector shown)

PC computer

SCSI card

PowerLab/4ST

Termination
Switch

SCSI cable
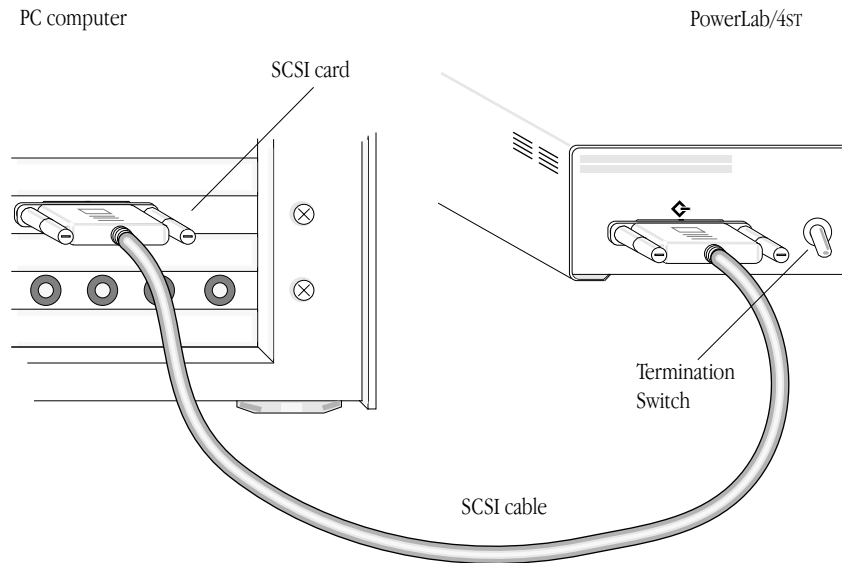
SCSI Cards with Windows NT or Older Computers

Windows 95 and 98 both come with a number of generic SCSI drivers already installed that should work with most cards, including any that ADInstruments supplies. Windows NT may not have the right

SCSI driver available, so the driver might have to be installed manually, perhaps from the original NT system CD. The SCSI card should have instructions on the driver it needs and how to install it.

Older, pre-PCI computers require a special ISA or ISO bus SCSI card. Such a card should come with its own manual, and may take some effort to set up. It will probably require assistance from a PC technical support person.

SCSI Strikes Back

Not following the SCSI device connection and termination protocols can lead to more problems than you might think. The possible dangers include loss of data, intermittent communications, corruption of data on a SCSI hard disk, failure of the computer to boot from a SCSI drive, and failure of the computer to recognise SCSI devices connected to it. Such problems are very unlikely, however, if you follow the rules.

3

Using the Software
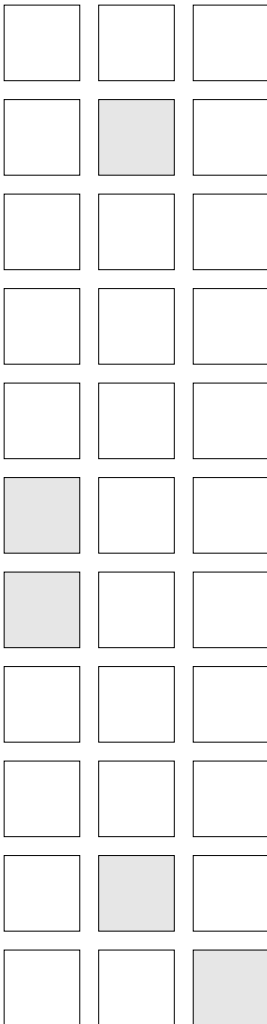
This chapter looks at how to use the built-in Bio Amplifier and Stimulus Isolator front-ends of the PowerLab/4sᴛ with ADInstruments software on a Windows or Macintosh computer. The documentation for Chart and Scope does not cover front-end-specific features. Those features that apply to the PowerLab/4sᴛ (the Bio Amplifier and Isolated Stimulator controls) are described in detail here.

Using ADInstruments Programs

Front-ends are used with PowerLabs and ADInstruments programs such as Chart and Scope, to extend the capabilities of the PowerLab system. The PowerLab/4ST has some front-ends built in: two Bio Amps and a Stimulus Isolator. The Bio Amp's amplification and filtering is combined with that of the PowerLab and the program, replacing the standard Input Amplifier controls with the Bio Amplifier controls for Channels 3 and 4. The PowerLab/4ST has both normal and isolated outputs, and you can switch between them in software. When the isolated output is used, the functions of the Stimulus Isolator are combined with those of the PowerLab and the program, replacing the standard Stimulator controls with the Isolated Stimulator controls.

The Front-End Drivers

A driver is a piece of software the computer uses to drive a peripheral device. In order for a front-end to be recognised by ADInstruments applications, the appropriate front-end driver must be present. The Bio Amplifier front-end driver is used with the Bio Amp. The Stimulus Isolator front-end driver is used with the Isolated Stimulator. Front-end drivers are installed when ADInstruments applications are installed on the computer.

On both Windows and Macintosh, Chart and Scope front-end drivers are kept in an Essential Files folder in the Chart and Scope folders respectively. To replace the drivers, you generally need to reinstall the ADInstruments software.

Software Behaviour

The documentation for Chart and Scope details the standard Input Amplifier and Stimulator dialog boxes, and explains relevant terms and concepts. It does not cover front-end-specific features. These features are described in detail here for Chart. Differences between Chart and Scope should be fairly obvious from perusing the user's guide for Scope. For the most part, dialog boxes and so on for the different application programs should be much the same.

The Bio Amplifier: Windows

The Bio Amplifier dialog box allows software control of the combined input amplifiers and filters in the PowerLab and Bio Amp. The signal present at a channel's input is displayed so that you can see the effects of changes straight away. Once the settings in the dialog box are changed, click the OK button to apply them.
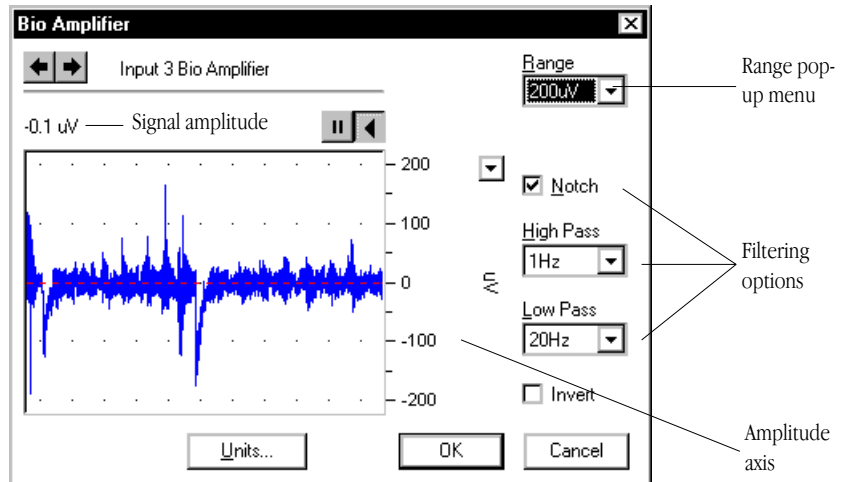
The Bio Amplifier dialog box appears when you choose the Bio Amp… command from a Channel Function pop-up menu (or click a Bio Amp… row in the Input Settings column in the Channel Settings dialog box). To set up many channels quickly, click the arrows below the dialog box title, or press the right or left arrow keys on the keyboard, to move to the equivalent dialog boxes for adjacent channels. This skips channels that are off. The channel number is shown below the title of the dialog box, and the channel title (if any) should be shown in the vertical Amplitude axis of the dialog box.

Signal Display

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

minimum and maximum recorded values. The average signal value is shown at the top left of the display area.

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

Setting the Range

The Range pop-up menu lets you select the input range or sensitivity of the channel — the combined range of the PowerLab and Bio Amp. Changing the range in the Bio Amplifier dialog box is equivalent to changing it in the Chart window. The default setting (if you have not loaded settings files) is 50 mV rather than 10 V, and the ranges go down to 20 µV in 11 steps.

Filtering

Each of the Bio Amps in the PowerLab/4sr has low-pass, high-pass, and notch-filter circuitry that can be adjusted to suit the recording. The notch filter removes excessive mains-frequency interference. The high-pass and low-pass filters provide bandwidth limiting of low-frequency and high-frequency signals respectively; the settings for one filter type may restrict the possible settings for the other.
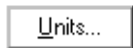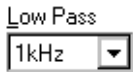
Notch Filter. Click the Notch checkbox to turn the notch filter on and off (it is on when checked). The notch filter is automatically set to either 50 or 60 Hz depending on the power line voltage frequency being used by the PowerLab (the mains frequency). It provides approximately 32 dB of attenuation, thus reducing the effect of the 50 or 60 Hz signals that can easily be picked up by long leads.

High-Pass Filtering. The High Pass pop-up menu gives the choice of four high-pass filters: 0.1, 0.3, 1, and 10 Hz. The high-pass filter allows high frequencies in the signal to pass, and removes frequency components below the filter frequency (including any DC signal).

These filters are useful for removing slowly moving baselines, such as motion or respiration artifacts, particularly in ECG (EKG) recordings.

Low-Pass Filtering. The Low Pass pop-up menu gives the choice of eight low-pass filters: 20, 50, 100, 200, and 500 Hz, and 1, 2, and 5 kHz. The low-pass filter allows low frequencies in the signal to pass, and removes frequency components above the filter frequency. These filters are useful for removing high-frequency signals, such as noise, and to prevent aliasing in the recorded signal.

Low Pass
1kHz

Inverting the Signal

☐ Invert

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

Units

Units...

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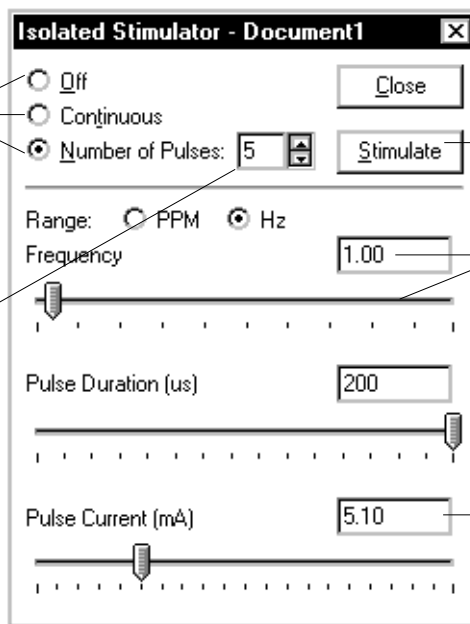
The Isolated Stimulator: Windows

The Isolated Stimulator lets you generate a pulse or series of pulses, using the outputs on the front of the PowerLab/4sT. To set it up, choose Isolated Stimulator from the Setup menu: the Isolated Stimulator dialog box appears (and if the Stimulator dialog box and Stimulator Panel are visible, they are closed). The menu command is ticked when the Isolated Stimulator is in use, and the Stimulator Panel command is dimmed and unavailable. To toggle between the Isolated Stimulator and Stimulator, just choose the appropriate menu command. The two stimulators use different outputs. The settings are independent of the sampling rate, but stimuli can only be generated while sampling. The Isolated Stimulator dialog box is used both to set up stimulation, and control and change it while sampling.

Figure 3–2
The Isolated Stimulator
window, Windows

Click these radio
buttons to turn
stimulation off,
or to choose
continuous
stimulation or a
set number of
pulses

Isolated Stimulator - Document1

○ Off   Close
○ Continuous
◉ Number of Pulses: 5 ⬍   Stimulate

Range: ○ PPM ◉ Hz
Frequency   1.00

Pulse Duration (us)   200

Pulse Current (mA)   5.10

Click the
Stimulate
button to start
a train of
pulses

Use the slider
bar or text
entry button
to set values

Values set by
the various
slider bars are
displayed in
the text entry
boxes

Set the number
of pulses with
the arrows or
text box

The Isolated Stimulator dialog box can be moved around the screen
or left in the background while the Chart window is active. By
default, the stimulator is off: the Off radio button is selected, and the
controls are inactive. The isolated stimulator can only stimulate in
Pulse mode, although this may be continuous or discrete.

(In this case, Scope is different to Chart: it has a dialog box closer to
the normal stimulator, and you can choose Pulse and Multiple in the
Mode pop-up menu for single or multiple pulses.)

Pulse. This setting generates a rectangular pulse stimulus that starts
at zero current, is raised to the set current amplitude for the pulse
duration, and then falls to zero current again.

Setting the Controls

Pulse Current (mA)   10.8

The slider bars for various stimulation parameters can be used to set
the value in the normal way, by dragging the sliding handle. The
value is displayed in the text entry box above the slider bar. You can
enter a value directly by clicking in the text entry box and typing it.
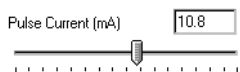
Range: ○ PPM ⊙ Hz

Click the (Range) PPM or Hz radio buttons to set the frequency in pulses per minute or hertz respectively. (It can sometimes be more convenient to have frequency stated in terms of minutes.) The Frequency control is used to set the pulse frequency within these ranges, from 0.1 to 20 Hz in the hertz range, and from 1 to 240 pulses per minute in the PPM range (about 0.017 Hz to 4 Hz).

The Pulse Duration control sets the time for which the pulse lasts. For safety reasons, duration is limited to from 50 μs to 200 μs (0.05 ms to 0.2 ms). The Pulse Current slider control is used to set the exact amplitude of the stimulus current, from 0 to 20 mA.

○ Off
⊙ Continuous
○ Number of Pulses:

If the Continuous radio button is on, the stimulator will give a continuous train of pulses, starting when sampling starts. Stimulation stops when the Off radio button is clicked, so you can use the radio buttons of the dialog box to turn stimulation off or on at will. If the Number of Pulses radio button is selected, then a Number control and a Stimulate button appear to its right. In this case, the stimulator produces a set number of pulses, and stimulation starts when the Stimulate button of the dialog box is clicked.

Number of Pulses: [5] ▢

You can specify the number of pulses to be produced by the stimulator, from 1 to 2000, using the Number control beside it. Click or press the up or down arrows to increment or decrement the number, or type a value in the text box directly.

The Bio Amplifier: Macintosh

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

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

Figure 3–3
The Bio Amplifier dialog box,
Macintosh
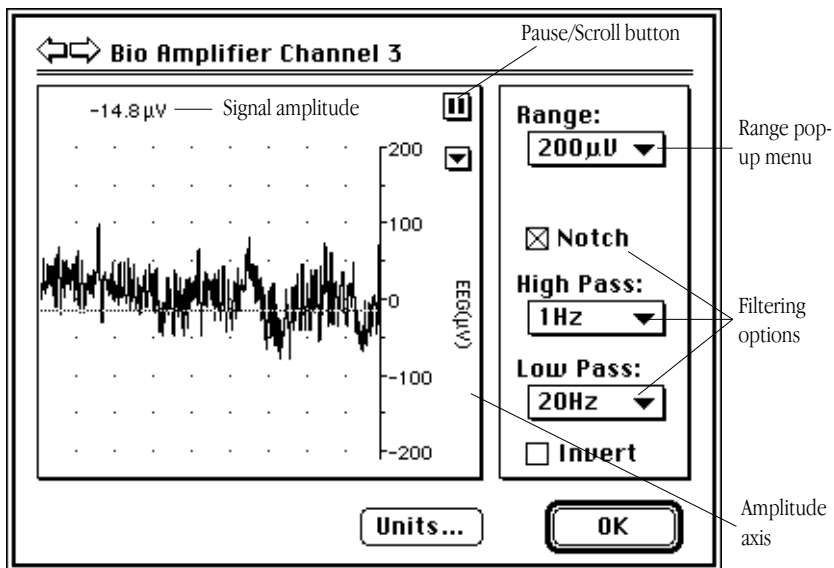
is shown in the title of the dialog box, and the channel title (if any) is shown in the vertical Amplitude axis of the dialog box.

Signal Display

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

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

Setting the Range

The Range pop-up menu lets you select the input range or sensitivity of the channel — the combined range of the PowerLab and Bio Amp. Changing the range in the Bio Amplifier dialog box is equivalent to changing it in the Chart window. The default setting (if you have not loaded settings files) is 50 mV rather than 10 V, and the ranges go down to 20 µV in 11 steps.

Filtering

Each of the Bio Amps in the PowerLab/4ST has low-pass, high-pass, and notch-filter circuitry that can be adjusted to suit the recording. The notch filter removes excessive mains-frequency interference. The high-pass and low-pass filters provide bandwidth limiting of low-frequency and high-frequency signals respectively. Note that the settings for one filter type may restrict the possible settings for the other.

☐ Notch

Notch Filter. Click the Notch checkbox to turn the notch filter on and off (it is on when checked). The notch filter is automatically set to either 50 or 60 Hz depending on the power line voltage frequency being used by the PowerLab (the mains frequency). It provides approximately 32 dB of attenuation, thus reducing the effect of the 50 or 60 Hz signals that can easily be picked up by long leads.

High Pass:
0.1Hz ▼

High-Pass Filtering. The High Pass pop-up menu gives the choice of four high-pass filters: 0.1, 0.3, 1, and 10 Hz. The high-pass filter allows high frequencies in the signal to pass, and removes frequency components below the filter frequency (including any DC signal). These filters are useful for removing slowly moving baselines, such as motion or respiration artifacts, particularly in ECG (EKG) recordings.

Low Pass:
200Hz ▼

Low-Pass Filtering. The Low Pass pop-up menu gives the choice of eight low-pass filters: 20, 50, 100, 200, and 500 Hz, and 1, 2, and 5 kHz. The low-pass filter allows low frequencies in the signal to pass, and removes frequency components above the filter frequency. These filters are useful for removing high-frequency signals, such as noise, and to prevent aliasing in the recorded signal.

Inverting the Signal

□ Invert

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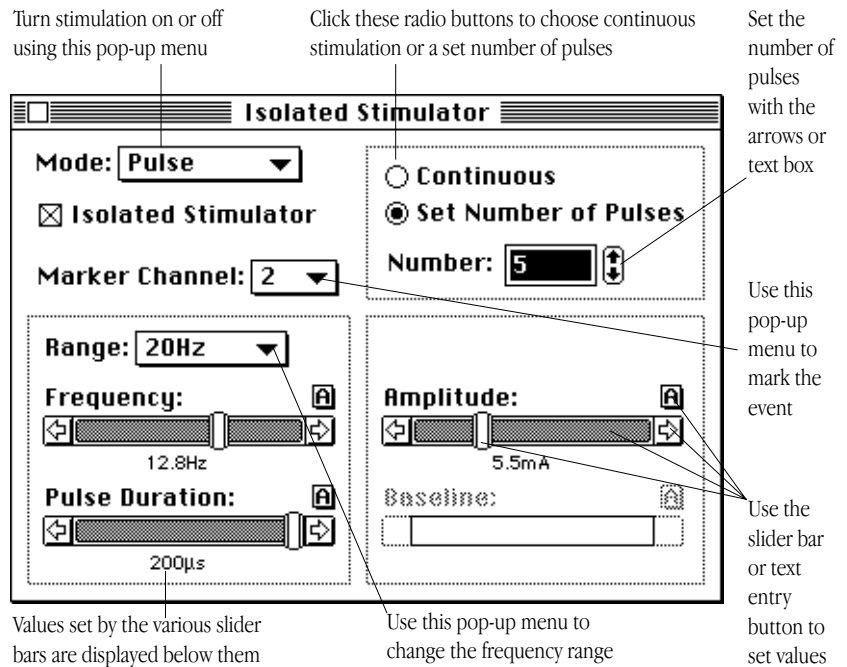
Units

Units…

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

The Isolated Stimulator: Macintosh

The Isolated Stimulator lets you generate a pulse or series of pulses, using the outputs on the front of the PowerLab/4sT. To set it up, choose Isolated Stimulator or Stimulator from the Setup menu (depending on the software version): the Isolated Stimulator or Stimulator window appears. Turn the Isolated Stimulator checkbox in the window on or off to toggle the window between Isolated Stimulator and Stimulator, respectively. The two stimulators use different outputs.

The Isolated Stimulator window is a normal window with a close box and title bar, and can be moved around the screen or left in the background while the Chart window is active. By default, the stimulator is off: Off is selected in the Mode pop-up menu, and the controls are inactive. The isolated stimulator offers only one active stimulation mode, Pulse, in the Mode pop-up menu. Since the isolated stimulator can only produce pulses, the Baseline control, which appears in the normal Chart Stimulator window, is dimmed. The settings are independent of the sampling rate, but stimuli can only be generated while sampling.

Figure 3–4
The Isolated Stimulator
Window, Macintosh

Turn stimulation on or off
using this pop-up menu

Click these radio buttons to choose continuous
stimulation or a set number of pulses

Set the
number of
pulses
with the
arrows or
text box

Isolated Stimulator

Mode: Pulse

☒ Isolated Stimulator

Marker Channel: 2

○ Continuous
◉ Set Number of Pulses

Number: 5

Range: 20Hz

Frequency: [A]
12.8Hz

Pulse Duration: [A]
200µs

Amplitude: [A]
5.5mA

Baseline: [A]

Use this
pop-up
menu to
mark the
event

Use the
slider bar
or text
entry
button to
set values

Values set by the various slider
bars are displayed below them

Use this pop-up menu to
change the frequency range

(In this case, Scope is different to Chart: it has a dialog box for the
simulator rather than a window, and you can choose Pulse and
Multiple in the Mode pop-up menu for single or multiple pulses.)

Pulse. This setting generates a rectangular pulse stimulus that starts
at zero current, is raised to the set current amplitude for the pulse
duration, and then falls to zero current again.

Marker Channel

If you choose a channel from the Marker Channel pop-up menu, then
the point when a pulse stimulus starts is marked by a small data
spike (this adds to any data in the channel). If you choose Off, no
mark is added. The stimulus marker works at any sampling rate, up
to a stimulus frequency of about 10 Hz.

Amplitude: [A]
5.5mA

[A]
□ 2.15 mA
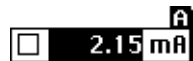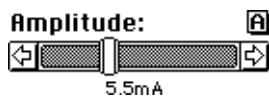
Setting the Controls

The slider bars for various stimulation parameters can be used to set
the value in the normal way, by dragging the sliding handle, or

clicking or pressing the arrows or the slider bar area (click for a single increment, press to scroll). The value is displayed below the slider bar. Alternatively, you can enter a value directly by clicking the Text button above the slider bar at its right end: a small text entry box appears. Type in the value you want, and to enter it, either click the close box at its left, or press Return or Enter.

⦿ Continuous
○ Set Number of Pulses

By default, the stimulator gives a continuous train of pulses, and the Continuous radio button (at the top right of the window) will be on. In this case, stimulation starts when sampling starts. The Stimulator Panel miniwindow will have Off and On buttons, though, so you can use it to turn the continuous stimulation off or on at will. If the Set Number of Pulses radio button is selected, then the stimulator produces a set number of pulses. In this case, stimulation starts when the Stimulate button of the Stimulator Panel is clicked.

Number: 5

You can specify the number of pulses that the stimulator is to produce, from 1 to 2000, using the Number control below it. Click or press the up or down arrows to increment or decrement the number, or type a value in the text box directly.

The (frequency) Range pop-up menu lets you select the range for the Frequency control, from 2 Hz or 20 Hz. You can also choose PPM (pulses per minute), since it can sometimes be more convenient to have frequency stated in terms of minutes. The Frequency control is used to set the pulse frequency within these ranges, from 0.1 Hz to the maximum in each hertz range, and from 2 to 200 pulses per minute in the PPM range (about 0.033 Hz to 3.3 Hz). The Pulse Duration control sets the time for which the pulse lasts. For safety reasons, duration is limited to from 50 µs to 200 µs (0.05 ms to 0.2 ms). The Amplitude slider control is used to set the exact amplitude of the stimulus current, from 0 to 20 mA.

The Isolated Stimulator Panel

Once you have set up stimulation using the Isolated Stimulator window, you can easily start or stop stimulation or change settings while sampling, by using the Isolated Stimulator Panel miniwindow. Choose Isolated Stimulator Panel from the Setup menu to bring it up.
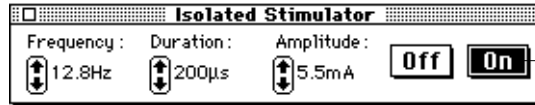
The Isolated Stimulator Panel miniwindow 'floats' in front of the active window, can be moved around with its title bar, and can only

Figure 3–5
The Isolated Stimulator Panel
miniwindow
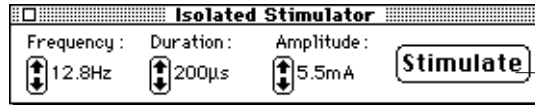
This button appears when
discrete stimulation is
chosen — click to stimulate

These buttons appear when
continuous stimulation is
chosen — click to start or stop

be dismissed by clicking its close box. If continuous stimulation was chosen, then the Panel will have Off and On buttons, so you can turn stimulation off or on at will. If you have chosen discrete stimulation, then the Panel will have a Stimulate button: click it to deliver a set number of pulses.

Click or press the up or down arrows to increment or decrement the stimulus parameters during sampling — the currently measured value is shown beside the control. To alter the magnitude of this change, hold down the Command key while clicking the control. A dialog box will appear for that control, in which you can set the magnitude of the change by clicking the up or down arrows.

Figure 3–6
The Isolated Stimulator Panel
increment dialog boxes
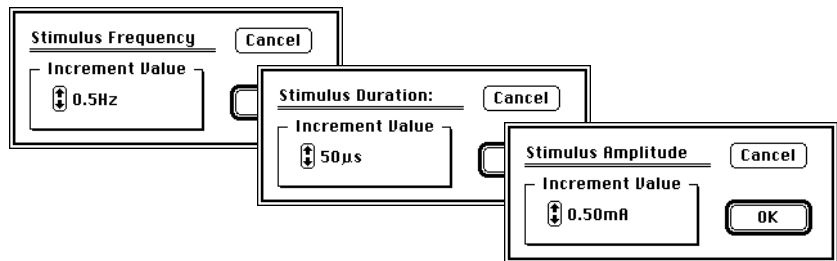
A

Technical Aspects

This appendix describes some of the important technical aspects of the PowerLab/4ST, to give some insight into how it works. You do not need to know the material here to use your PowerLab. It is likely to be of especial interest to the technically minded, indicating what the PowerLab can and cannot do, and its suitability for particular purposes. You should not use it as a service manual: remember that user modification of the PowerLab voids your rights under warranty.

How Does it Work?

The PowerLab/4ST is essentially a smart peripheral device designed specifically to perform the various functions needed for data acquisition, signal conditioning, and pre-processing. It contains its own microprocessor, memory, and specialised analog amplifiers for signal conditioning. The block diagram in Figure A–1 shows the essential elements of the PowerLab/4ST.

All sampling, output, and communication functions are controlled by an internal 32-bit, 68340 microprocessor running at 16 MHz (16 million cycles per second). This CPU (central processing unit) has access to 512 kilobytes of RAM (random access memory) for data storage and buffering prior to transmission to the computer. The PowerLab makes use of FIFO (first in, first out) memory devices, which provide a temporary storage area for both analog input and analog output signals. These storage areas help increase the processing capacity of the hardware by relieving the load on the PowerLab microprocessor.

The PowerLab can use SCSI or USB, whether built-in or via a card, to communicate with the computer. SCSI (small computer system interface) provides data transfer rates of up to 4 MB per second on fast computers. The lower-speed USB (universal serial bus) provides data transfer rates of up to 500 kB per second.

Figure A–1
Block diagram of the
PowerLab/4ST
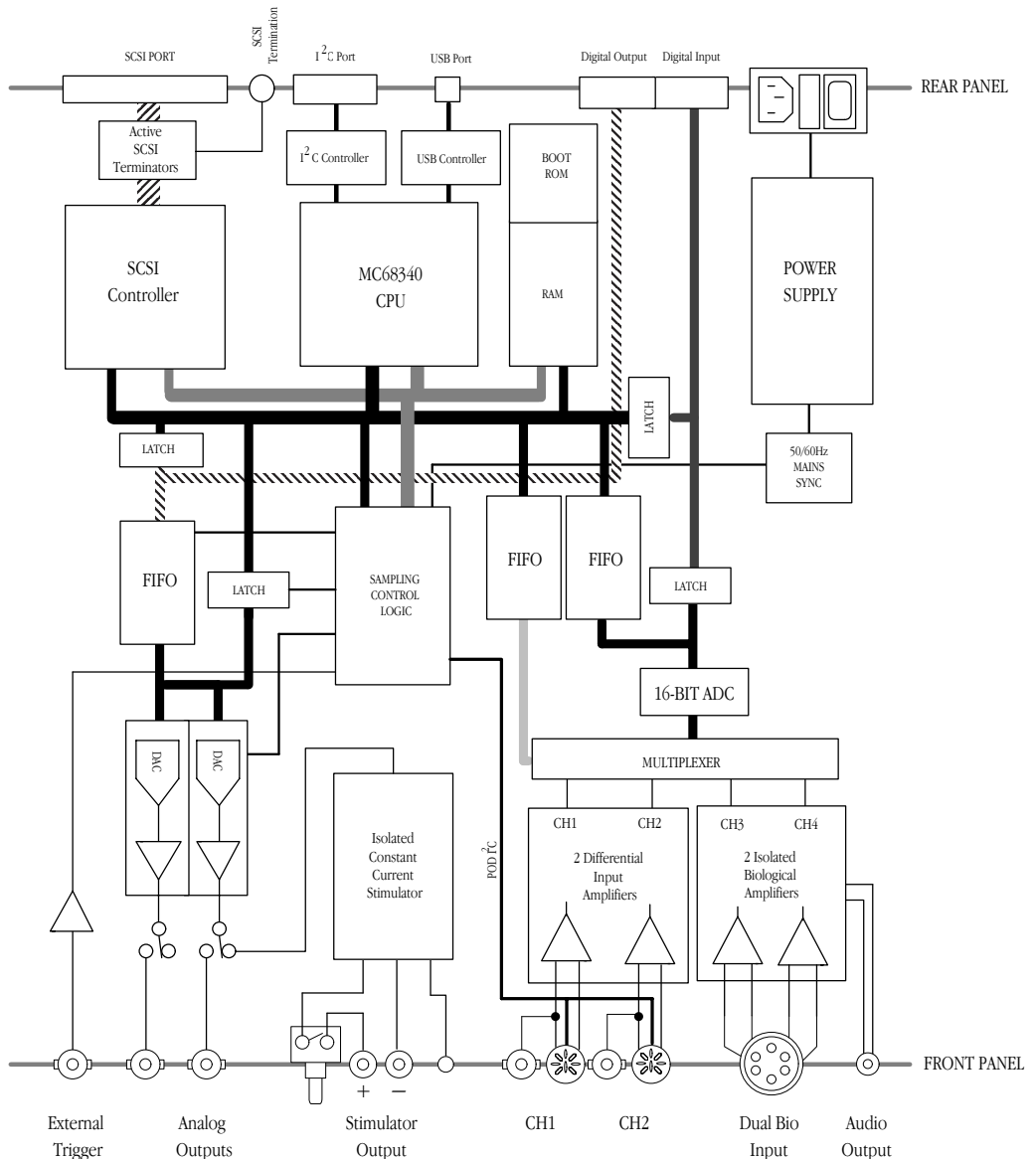
The PowerLab has two non-isolated input channels with software-controlled gain options, used for general-purpose inputs for analog signals (Channels 1 and 2). It also has two isolated biological input amplifiers (Channels 3 and 4). Each bio amplifier provides a high-impedance, electrically isolated differential amplifier with extensive software-controlled gain and filtering options. Each bio amplifier has adjustable low-pass and high-pass filters and a 50/60 Hz notch filter that can be used to remove unwanted power signal frequencies.

The outputs of the various amplifiers are multiplexed to a 16-bit ADC (analog-to-digital converter). The ADC can sample at up to 200,000 samples per second. The CPU assembles groups of samples into blocks and then transmits them to the computer, where the application program receives, records, and displays the data. Sampled data from the ADC are stored in FIFOs until the CPU is ready to read them. The FIFOs let the CPU know when they are getting full, at which point it will read all of their data very quickly. This frees the CPU from the need to read every sample from the ADC as it is ready, so that it can perform other tasks.

The external trigger input (marked 'Trigger' on the front panel) is connected to a comparator circuit that triggers when the input voltage exceeds 2.9 volts. This signal is fed to circuitry that notifies the CPU that an external trigger event has been detected. The CPU then carries out the task for which the trigger is being used (such as pre-triggering or post-triggering). When the trigger threshold is crossed, the indicator beside the trigger connector glows yellow.

Two 14-bit DACs (digital-to-analog converters) are used to control the analog outputs of the PowerLab (marked 'Output 1' and 'Output 2' on the front panel). The DACs produce waveforms under software control that are fed through an attenuation network to produce different full-scale ranges. The signals are then buffered by a power amplifier to give them the capability to drive heavier loads. The PowerLab can store stimulation data in FIFOs, so that it can stimulate at a frequency independent of the analog input sampling rate. The FIFOs also allow the generation of much faster stimuli and continuous waveforms, with little or no load on the CPU. One can use either the analog output or the isolated stimulator, but not both at once. The choice of output is made through software.

The Isolated Stimulator output provides a software-controlled, isolated, constant-current pulse stimulator that can be used for any general-purpose stimulation. The output stage consists of a high-voltage, constant-current source that can produce pulses of variable duration and amplitude under full software control. One can use either the analog output or the isolated stimulator, but not both at once. The choice of output is made through software.

The PowerLab is also fitted with an I^{2}C front-end expansion port. This 9-pin port supplies both power and control to ADInstruments front-ends using a 4-wire serial bus (two wires for standard I^{2}C and two control lines).

The digital input and output connectors provide a means of using the PowerLab to monitor and to control external devices respectively. The digital input monitors state changes: the eight lines of the connector allow monitoring of up to eight devices. The digital output can turn on and off external devices or can signal to some other device. The eight lines of the connector allow control of up to eight devices. These recording automation and control features are available in the Macintosh version of Chart, but not in the current version of Chart for Windows (v3.4), or in Scope.

The PowerLab uses an IEC601-1 compliant linear power supply, not a switching power supply, which makes it a little heavier, but a lot quieter electrically. It is important to note that the PowerLab has a limited amount of power available for external devices. Because of these power restrictions, you should not use the PowerLab as a power source for external devices other than front-ends produced by ADInstruments.

Analog Inputs (CH1 and CH2)

▲ *Caution*
Applying more than ±15 V to the input can damage the channel input circuits.

PowerLab input amplifiers have been designed with a considerable amount of computer-controlled gain (up to × 5000). Thus it is possible to record a variety of signals without any external pre-amplification. Each analog input is a separate DC amplifier, with programmable gain able to be set independently (the gain is set through the software range control: the less the range, the more the gain). The input amplifiers of the PowerLab/4sт can be set by the software to be either single-ended — positive or negative — or differential. In the differential setting, the amplifier measures the difference between the

positive and negative inputs of a Pod connector, irrespective of ground. Differential signals can only be recorded using the Pod connectors; the BNC analog inputs are all single-ended.

It is important to note that the PowerLab grounds the inputs to amplifiers not in use. It also grounds each amplifier and measures the DC offset voltage when the gain is changed. In this way, the software corrects for any DC drift or offset in the circuits that may develop over time or between readings. The operation of the input amplifiers is illustrated by the block diagram below.

Figure A–2
Block/schematic diagram of
the input amplifier circuitry for
PowerLab/4sт CH1 and CH2
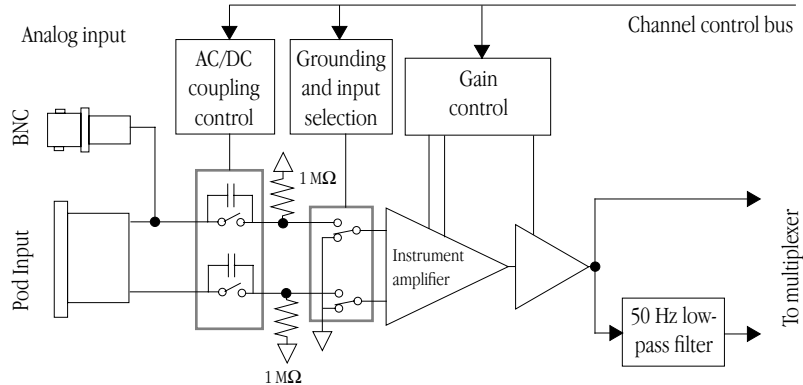
The input amplifiers can be set to pass both DC and AC signals, or to pass only AC signals without passing DC signals. Input impedance is one megohm (1 MΩ). Each channel produces two outputs filtered at different frequencies, only one of which is selected at any one time when running an ADInstruments application: a signal with bandwidth of DC to 20 kHz, and one with a bandwidth of DC to 50 Hz (DC is zero Hz).

Bio Amp Inputs (CH3 and CH4)

The PowerLab/4sт also has one common connector for two Bio Amp channels (marked 'Bio Amp CH3 & CH4'). These two independently controllable, electrically isolated, biological amplifiers are suitable for a range of basic physiological measurements. The two Bio Amp inputs are internally configured to use Channels 3 and 4 of the PowerLab/4sт. The Bio Amps have a common six-pin connector with a shared ground signal. The PowerLab/4sт is supplied with a 5-lead Bio Amp cable and lead wires for connection. (These inputs should

only be used with the supplied Bio Amp cable and approved leads. Other cables may not meet safety requirements.)

Each amplifier consists of an electrically isolated, AC coupled, differential amplifier with programmable gain able to be set independently (the gain is set through the software range control: the less the range, the more the gain). The gain is controlled by optically isolated digital control signals from the non-isolated section. The signal is then applied to an isolation amplifier which provides electrical isolation of the input stage from the supply.

The non-isolated stage consists of a series of filters and amplifiers. The first part of the stage is a high-pass filter designed to remove any DC components from the signal and the isolated stage. This is followed by amplification and an active notch filter. The notch can be turned on or off under software control as needed. The frequency of the notch filter is automatically set to either 50 or 60 Hz to match the frequency of the connected power supply.

The low-pass filter is an eighth-order, switched-capacitance, Bessel-type filter, with a software-selectable range of frequencies. The output of the biological amplifier is then passed to the standard PowerLab input amplifier circuit. An amplifier connected to the output of the biological amplifier is used to provide an audio output facility that can be used with headphones or powered speakers.

Figure A–3
Block/schematic diagram of one of the two PowerLab/4ST bio amplifiers (CH3 and CH4)
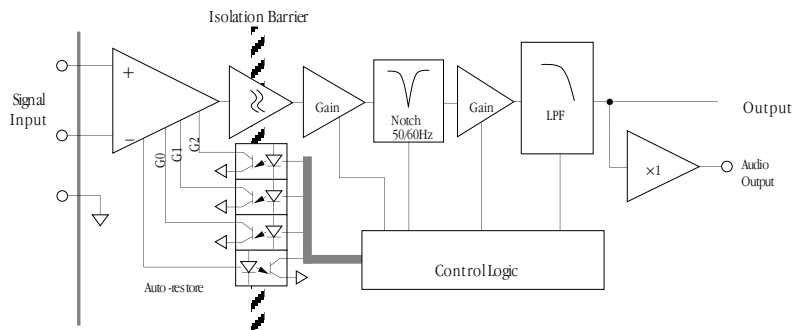
PowerLab Accuracy

Your PowerLab was calibrated at the factory to an accuracy of better than 0.1%. Some 'zero drift' or 'gain drift' can occur with time. This

can affect the accuracy of measurements, especially at the highest input gains. The unit can be recalibrated, but in most circumstances this is not necessary in its lifetime. There are several reasons for this.

DC drift compensation. Each time that recording is started manually or by triggering or the gain is changed (that is, very often in most cases), the input to the amplifier is grounded and any DC due to the amplifier's drift with temperature and age is measured. The measured voltage is removed from the readings for that input through software correction, in a process transparent to the user.

Calibration facilities. It is recommended and sound practice to calibrate a measuring system from the transducer to the output. After applying two known values to a transducer (say at 20% and 80% of full scale) and recording the signal, you can use the units conversion feature of ADInstruments applications to convert and display transducer readings in the appropriate units. This will compensate for any minor inaccuracies in amplifier gain and transducer calibration.

The External Trigger

The external trigger provides a digital input for synchronising sampling to external devices. The external trigger input represents 1 TTL (transistor–transistor logic) load. The input is off for input voltages between –12 V and the external trigger level, and on between that and +12 V. The input will be overloaded if the voltage is outside the range –12 V to +12 V. The external trigger level is 2.9 V ± 0.25V; once on, the trigger turns off at 1.8 V ± 0.25V, giving a hysteresis voltage of 1.1 V. When the external trigger input is on, the indicator beside it is on.

The PowerLab/4sT has an optically isolated external trigger input, thus there is no direct connection between the external trigger ground and the ground of the device connected to it. This removes ground noise and current problems, and improves static discharge immunity. In order for the external trigger to work, though, a voltage must be applied between the outer ring and the inner pin on the connector. Applying a voltage to the centre pin won't result in triggering (as it could on earlier PowerLabs). The equivalent circuit of the external trigger is basically an LED (light-emitting diode) in series with a resistor, thus the device driving the external trigger must be capable

of supplying at least 1 mA of current to cause the optocoupler to work. (The second diode shown below protects the optocoupler.)
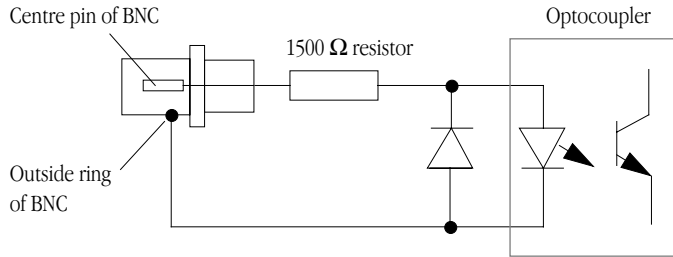
The Analog Output

The analog outputs provide computer-controlled variable outputs (±10 V) that can be used with the Chart and Scope applications either directly as a stimulator, or to control peripheral devices. All stimulation voltage is generated by the PowerLab via the output sockets on the front of the PowerLab (marked Output 1 and Output 2), giving positive, negative, differential, or independent stimuli, depending on the sockets used and the software settings.
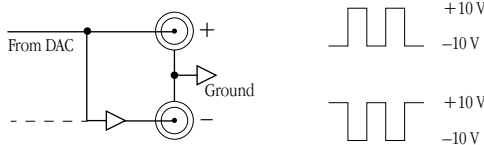
By default, the outputs are used for complementary (differential) stimulation, where Output 1 is positive and Output 2 is negative. When Output 1 is used, a positive stimulus voltage (set up in an application) gives a positive voltage output, and a negative voltage a negative one. When Output 2 is used, the voltage outputs are inverted. When both output sockets are used, the stimulus is the difference between the voltages at the positive and negative outputs: you could generate up to a 20-volt pulse, given a ±10 V stimulus.

The outputs can be used for independent stimulation in Scope and the Macintosh version of Chart, but not in the current version of Chart for Windows (v3.4). The details are discussed in the software user's guides.

The Isolated Stimulator Output

The Isolated Stimulator output provides a software-controlled, isolated, constant-current pulse stimulator that can be used for any general-purpose stimulation.

Figure A–6
Block/schematic diagram of the isolated stimulator
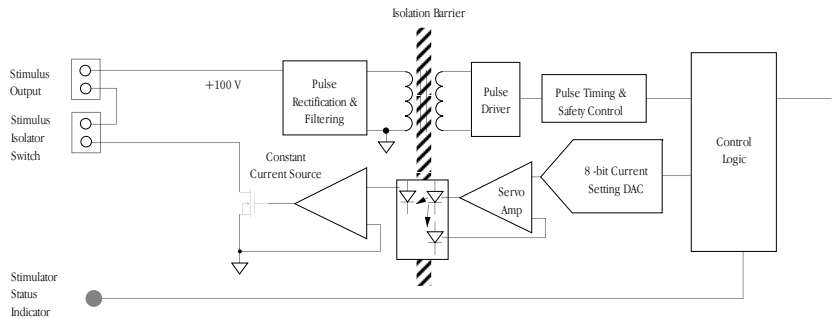
The output stage consists of a high-voltage, constant-current source that can produce pulses of variable duration and amplitude under full software control. The current source can deliver pulses up to 20 mA at 100 V maximum compliance levels; its amplitude is controlled by optically isolated digital control signals from the non-isolated section. The output to the subject is through high-isolation optical couplers.

Software and hardware safety features limit the energy delivered by the pulses to within international safety standards. The pulse duration of the stimulator can be set from 50 μs to 200 μs, and the pulse frequency can be adjusted between 1 pulse per minute and 20 pulses per second.

The Stimulator Status indicator is a multi-coloured light on the front panel that indicates the status or operation of the Stimulator. The indicator light flashes green for each stimulus pulse, and may seem to glow green at high stimulus frequencies. A yellow colour indicates that the output is overloaded or out of compliance (compliance is the ability to supply voltage to meet the required current).

Connections

This section of the appendix contains 'pinout' and electrical details of some of the connectors fitted to the PowerLab. You should read it carefully before attempting to connect cables other than those supplied with the unit to the PowerLab. Using cables that are wired incorrectly can cause internal damage to the PowerLab and will void your rights under warranty.

USB Port

The PowerLab is fitted with a USB (universal serial bus) port, which provides an alternative to the SCSI connection. This works with computers with USB connectors or a USB card. USB needs a Power Macintosh with Mac OS 8.5 or later, or a PC with Windows 98 or later.

Figure A–7
The USB connector

Your PowerLab is supplied with a proper high-speed USB cable. If you need additional USB cables, you should buy high-speed cables (fully shielded, twisted-pair, and with standard USB connections) for reliable results.

SCSI Port

The PowerLab uses a single 25-pin D-type female connector for the SCSI port. If you are using a Macintosh, you probably need a 25-pin to 25-pin cable. If you are using a Windows PC, the connection at the other end of the cable depends on your set-up.
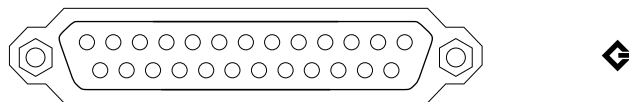
Figure A–8
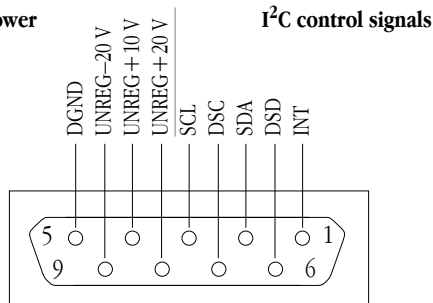The 25-pin SCSI connector

SCSI is sensitive to cable impedances and connection lengths. The incorrect wiring of a SCSI cable can result in damage to the SCSI

circuitry, or random SCSI activities being performed. You should, therefore, use only approved SCSI cables such as the ones available from ADInstruments, and never attempt to make your own.

I^{2}C Expansion Port

The I^{2}C port on the back panel of the PowerLab provides expansion support for ADInstruments front-ends. This port provides both power and control signals for these front-ends. The I^{2}C bus has a daisy-chain structure that allows simple connection of additional front-ends to the system. The PowerLab/4sT can add two single-channel front-ends. You should not attempt to run other external devices from the I^{2}C port: it is designed for use only with ADInstruments front-ends. Only 50 mA maximum current can be provided through this bus, so it should not be used for third-party devices drawing more current.

Figure A–9
The pin assignments for the I^{2}C port

Front-end power   DGND   UNREG–20 V   UNREG + 10 V   UNREG + 20 V   SCL   DSC   SDA   DSD   INT   **I^{2}C control signals**
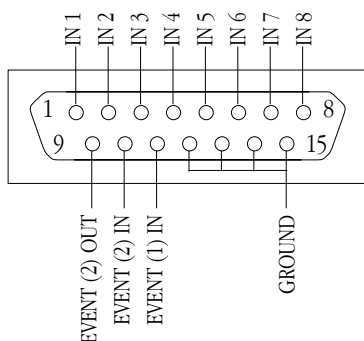
Digital Input and Output Ports

The digital input port and digital output port are 15-pin connectors situated on the back panel of the PowerLab. The eight digital input lines respond to standard TTL signals with a threshold of 2.2 V. The eight digital output lines can turn on and off, or signal to, up to eight external TTL devices. The digital output lines are capable of driving five TTL loads overall (50 mA maximum load per line; 250 mA maximum total load). These recording automation and control features are available in the Macintosh version of Chart, but not in the current version of Chart for Windows (v3.4), or in Scope.
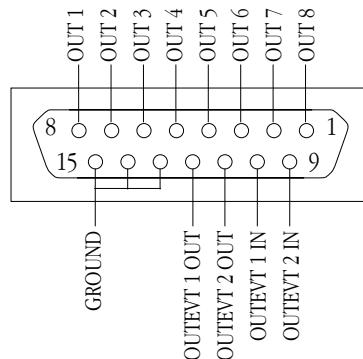
Figure A–10
The pin assignments for the
digital input and output
connectors

Digital input

Digital output

IN 1 IN 2 IN 3 IN 4 IN 5 IN 6 IN 7 IN 8

OUT 1 OUT 2 OUT 3 OUT 4 OUT 5 OUT 6 OUT 7 OUT 8

1 ○ ○ ○ ○ ○ ○ ○ 8
9 ○ ○ ○ ○ ○ ○ 15

8 ○ ○ ○ ○ ○ ○ ○ 1
15 ○ ○ ○ ○ ○ ○ 9

EVENT (2) OUT EVENT (2) IN EVENT (1) IN GROUND

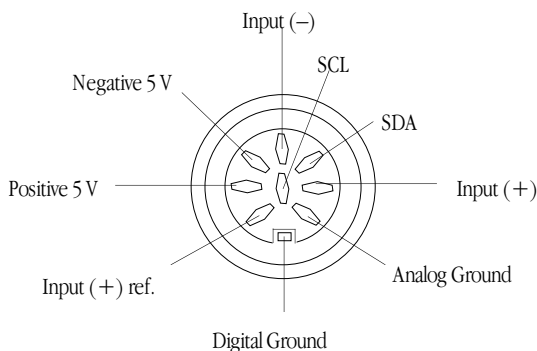GROUND OUTEVT 1 OUT OUTEVT 2 OUT OUTEVT 1 IN OUTEVT 2 IN

Pod Connectors

The Pod connectors on the PowerLab/4sᴛ are 8-pin DIN connectors.
Do not attempt to record from both the BNC and Pod connectors for
an input at the same time, or the signals will compete.

Pod connectors allow the connection of ADInstruments Pods —
small, low-cost units that provide alternatives to front-ends for
specific tasks, for use with precalibrated transducers and so on. (Pods
are supported by Scope v3.6.3 and later, Chart for Macintosh v3.6.3
and later, and Chart for Windows v3.4.7 and later.)

Input (−)

SCL

Negative 5 V

SDA

Positive 5 V

Input (+)

Input (+) ref.

Analog Ground

Digital Ground

The Pod connectors on the PowerLab/4sᴛ do not handle transducers
directly unless the transducers are so labelled (unsuitable transducers
will give a very weak signal). Transducers designed for direct

connection can be provided with power and control, since the Pod connectors provide some functions of the I^2C output as well as alternative analog inputs to the BNC connectors.

Bio Amp Input Connector

The PowerLab/4ST also has one common connector for two Bio Amp channels, Channels 3 and 4. The biological amplifiers both have differential inputs, and have a common six-pin connector with a shared ground signal. The entire connector is physically and electrically isolated to ensure subject safety. The PowerLab/4ST is supplied with a 5-lead Bio Amp cable and lead wires for connection. These inputs should only be used with the supplied Bio Amp cable and approved leads. Other cables may not meet safety requirements.

Figure A–12
The pin assignments for the Bio Amp input connector

Polarising Notch

Isolated Ground

CH4 Negative

CH3 Positive

CH4 Positive

CH3 Negative
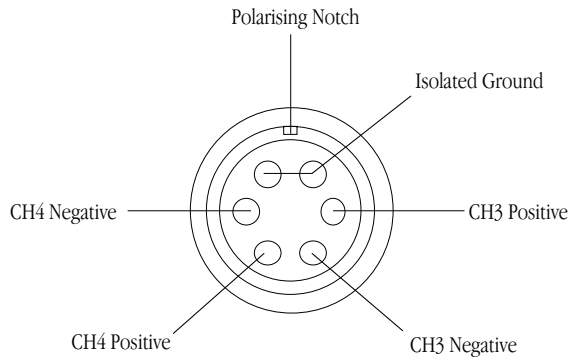
APPENDIX B

B

Troubleshooting

This appendix describes most of the common problems that can occur with your PowerLab recording unit. It covers how these problems are caused, and what you can do to alleviate them. If the solutions here do not work, your software guide may contain remedies for possible software problems. If none of the solutions here or in the software guide appears to help, then consult your ADInstruments distributor.

Problems: Macintosh

Nearly all the problems that users encounter are connection problems and SCSI problems. Improper connections can result in a loss of all or some of a signal. SCSI difficulties can cause data loss, failure of the computer to recognise that SCSI devices are attached to it, and difficulties using other SCSI devices. Incompatible SCSI adapter cards and cables may also cause problems. Obviously, the SCSI problems will not apply if you use USB.

The PowerLab Status indicator light flashes yellow then red when the PowerLab is turned on

▼ **Refer**
Self-Test, p. 20

If the pattern is simply an alternating red flash and yellow flash, then the SCSI ID has been set to the numbers 0 or 7, which cannot be used by an S series PowerLab. Only 1 to 6 are valid SCSI ID numbers.

• Switch off your PowerLab and any other connected devices, change the SCSI ID for the PowerLab using the control on the back panel, wait about five seconds, and then switch it back on. Check any other connected SCSI devices as well at the same time.

An internal problem has been discovered by the diagnostic self-test (this is performed by the PowerLab each time it powers up).

- Turn everything off, and then after at least five seconds turn the PowerLab back on again. This should clear a temporary problem. If not, then the PowerLab may need repair. Take note of the flashing pattern, and consult your ADInstruments distributor.

The computer refuses to boot with the PowerLab connected, or the computer can't find the PowerLab

The PowerLab is off or the power is switched off at the wall, the power cable is not connected firmly, or a fuse has blown.

- Check switches, power connections, and fuses.

A poor connection between PowerLab and computer, or bad cable.

- Ensure that the cable is firmly attached at both ends and try again. If there is still a problem, try a new cable.

SCSI problems: two SCSI devices on the bus have the same SCSI ID, or termination is incorrect or unsuitable.

- Check that each device has a unique ID number and that the SCSI chain is terminated correctly. (As a last resort, if the PowerLab is the only connected SCSI device, try leaving it unterminated.)

The SCSI adapter card is incompatible with the computer or the PowerLab or both. We cannot guarantee that the PowerLab will work reliably with a card we did not supply.

- Try another card, preferably one we supplied.

The PowerLab has an internal problem or has 'hung'.

- Turn everything off, and then after at least five seconds turn the PowerLab back on again. Turn on the computer and try using the software again.

The PowerLab is connected via USB and the computer does not properly support USB.

- USB needs a Power Macintosh with Mac OS 8.5 or later; it simply will not work with earlier hardware, such as a 68K Macintosh, or earlier operating systems, such as System 7: use SCSI with these.

The computer hangs up while recording, or there is data loss

A poor connection between PowerLab and computer, or bad cable.

- Ensure that the cable is firmly attached at both ends and try again. If there is still a problem, try a new cable.

SCSI problems: two SCSI devices on the bus have the same SCSI ID, or termination is incorrect or unsuitable.

- Check that each device has a unique ID number and that the SCSI chain is terminated correctly. (As a last resort, if the PowerLab is the only connected SCSI device, try leaving it unterminated.)

The PowerLab doesn't work or the program crashes after a short time

A poor connection between PowerLab and computer, or bad cable.

- Ensure that the cable is firmly attached at both ends and try again. If there is still a problem, try a new cable.

SCSI problems: two SCSI devices on the bus have the same SCSI ID, or termination is incorrect or unsuitable.

- Check that each device has a unique ID number and that the SCSI chain is terminated correctly. (As a last resort, if the PowerLab is the only connected SCSI device, try leaving it unterminated.)

Partitioning problems on the hard disk (while rare, this can happen even with new disks).

- Use disk-checking utility applications to check the SCSI driver and root directory on the hard disk. Partitioning programs may also have effective low-level disk checking. The programs will probably fix the problems, or otherwise indicate what needs to be done (such as reinstalling the SCSI driver), and their manuals should explain the technical details involved.

The PowerBook computer stops working normally, and instead shows a diamond with its SCSI ID number on screen

The PowerBook is acting as a SCSI hard disk. This means that the wrong (30-pin) connector and cable were used to connect it to the PowerLab. You need a different (29-pin) cable and connector to make a normal SCSI connection to peripherals.

• Use the correct cable to connect your PowerBook to the PowerLab (the cable should be available from your Apple dealer).

Signals seem weak or interacting on Channels 1 or 2

You may be using both the BNC connector and the Pod connector for an input at the same time, with resultant signal competition.

• Make certain that you use only *one* of the alternative connectors (BNC or Pod) for an input when recording.

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

The correct Bio Amplifier or Stimulus Isolator driver is not installed on your computer (they should be in the Essential Files folder in the Chart or Scope folder).

• Reinstall the software.

The Isolated Stimulator Status indicator shows yellow

This means that the Isolated Stimulator is out of compliance. You could be attempting stimulation while the output safety switch is turned off (in the down position).

• Turn the output safety switch on (move it to the up position).

The impedance of the tissue could be too high for the Isolated Stimulator to supply constant current at the level requested, or there is an inadequate electrical connection to the subject.

• Reduce the output current amplitude.

- Check the connections for proper contact and try again. Ensure the connection is not dry (apply electrode cream) and that the leads are properly connected.

The trace will not zero properly when adjusting high-pass filtering in the Bio Amplifier dialog box

The input is receiving signals at a level that has saturated the input amplifier, resulting in a large offset. This is normally due to poor contact between the electrodes and the subject.

- Check the connections for proper contact and try again. Ensure the connection is not dry (apply electrode cream) and that the leads are properly connected.

The signal appears to display a constant amplitude oscillation

Frequency interference from power lines can become superimposed on the smaller signals being measured on Channels 3 and 4.

- Turn on the internal notch filter (use the checkbox in the Bio Amplifier dialog box) to remove excessive line voltage frequency interference.

If you are using cables and leads that were not supplied with your Bio Amp, they may be unshielded or of low quality.

- Check to make sure that you are using high-quality shielded cables and high-quality leads. Only the supplied Bio Amp cable and leads should really be used.

The Bio Amp signal is noisy at lower ranges

This is probably the amplified noise from the electrodes, not a fault as such. There is, in addition, noise that cannot be avoided by any amplifier (called 'thermal' or 'Johnson' noise).

- Set the low-pass filter to remove the noise. (But be careful, since important components of the signal could also be attenuated.)

This could be due an electrically noisy environment, particularly if there is some equipment that produces a radio frequency that interacts with the Bio Amp modulator, giving a heterodyne effect.

- Turn off pieces of unnecessary equipment to try and isolate the cause, then either leave the equipment off, or, if possible, move the subject or equipment outside the area of any interfering field.

- At the lowest ranges you may have to shield, shorten, or even replace the leads connected to the Bio Amp cable, since they will tend to act as radio receptors.

The Bio Amp signal appears to be unusual, very weak, clipped, or distorted in some way

This may be a problem of technique: the sampling rate, range, or filter settings may be inappropriate for the signal you are recording.

- Make sure the settings are appropriate for the expected signal.

You may be using the wrong Bio Amp cable. The 3-lead Bio Amp cable used with the single Bio Amp has a different pin arrangement, and cannot be used with the PowerLab/4ST.

- Use the correct, supplied, 5-lead Bio Amp cable.

Problems: Windows

Most problems that users encounter are connection problems and SCSI problems. Improper connections can result in a loss of all or some of a signal. SCSI difficulties can cause data loss, failure of the computer to recognise that SCSI devices are attached to it, and difficulties using other SCSI devices. Incompatible SCSI adapter cards and cables may also cause problems. Obviously, the SCSI problems will not apply if you use USB.

The PowerLab Status indicator light flashes yellow then red when the PowerLab is turned on

If the pattern is simply an alternating red flash and yellow flash, then the SCSI ID has been set to the numbers 0 or 7, which cannot be used by an S series PowerLab. Only 1 to 6 are valid SCSI ID numbers.

• Switch off your PowerLab and any other connected devices, change the SCSI ID for the PowerLab using the control on the back panel, wait about five seconds, and then switch it back on. Check any other connected SCSI devices as well at the same time.

An internal problem has been discovered by the diagnostic self-test (this is performed by the PowerLab each time it powers up).

• Turn everything off, and then after at least five seconds turn the PowerLab back on again. This should clear a temporary problem. If not, then the PowerLab may need repair. Take note of the flashing pattern, and consult your ADInstruments distributor.

When Windows starts up, it doesn't recognise the PowerLab

This should happen only the first time PowerLab hardware is connected to the computer. Windows may bring up the New Hardware wizard, and ask if you want to install a driver.

• Leave the wizard on its default settings and click the OK button. Insert the CD, or Disk 1 of the provided installation disks. The PowerLab setup information file should be selected in the dialog box that appears. Click the OK button, and continue.

There is an alert about ASPI when the software starts up

ADInstruments software needs ASPI (advanced SCSI programming interface) to communicate with the PowerLab. An alert appears if it can't be found. ASPI is present by default in Windows 95 or later (although it could have been removed), but not in Windows NT 4. A version suitable for most SCSI cards supplied by ADInstruments is provided on the software CD. Other SCSI cards should come with instructions on what to do.

- Install the appropriate version of ASPI on the computer, or ask your PC technical support person or IS manager to do it.

The computer refuses to boot with the PowerLab connected

The SCSI adapter card is incompatible with the computer or the PowerLab or both. We cannot guarantee that the PowerLab will work reliably with a card we did not supply, and some computers and SCSI adapter cards just won't work together.

- Try another card, preferably one we supplied. Ask your PC technical support person or IS manager to check compatibility.

A poor connection between PowerLab and computer, or bad cable.

- Ensure that the cable is firmly attached at both ends and try again. If there is still a problem, try a new cable.

SCSI problems: two SCSI devices on the bus have the same SCSI ID, or termination is incorrect or unsuitable.

- Check that each device has a unique ID number and that the SCSI chain is terminated correctly. (As a last resort, if the PowerLab is the only connected SCSI device, try leaving it unterminated.)

The computer is running off a SCSI hard drive, and the PowerLab has an internal problem or has 'hung'.

- Turn everything off, and then after at least five seconds turn the PowerLab back on again. Turn on the computer and try using the software again.

The computer can't find the PowerLab

The PowerLab is off or the power is switched off at the wall, the power cable is not connected firmly, or a fuse has blown.

- Check switches, power connections, and fuses.

A poor connection between PowerLab and computer, or bad cable.

- Ensure that the cable is firmly attached at both ends and try again. If there is still a problem, try a new cable.

SCSI problems: two SCSI devices on the bus have the same SCSI ID, or termination is incorrect or unsuitable.

- Check that each device has a unique ID number and that the SCSI chain is terminated correctly. (As a last resort, if the PowerLab is the only connected SCSI device, try leaving it unterminated.)

The PowerLab has an internal problem or has 'hung'.

- Turn everything off, and then turn the PowerLab back on again after at least five seconds. Turn on the computer and try using the software again.

Windows NT may not have the right SCSI driver available (it does not have many already installed, as do Windows 95 and 98).

- The driver might have to be installed manually, perhaps from the original NT system CD. The SCSI card should have instructions on the driver it needs and how to perform the installation.

The PowerLab is connected via USB and the computer does not properly support USB.

- USB needs a USB 1.1-compliant PC with Windows 98, Me, 2000 or later; it simply will not work with earlier operating systems, such as Windows 95 or Windows NT 4: use SCSI with these.

The computer hangs up while recording, or there is data loss

A poor connection between PowerLab and computer, or bad cable.

- Ensure that the cable is firmly attached at both ends and try again. If there is still a problem, try a new cable.

SCSI problems: two SCSI devices on the bus have the same SCSI ID, or termination is incorrect or unsuitable.

- Check that each device has a unique ID number and that the SCSI chain is terminated correctly. (As a last resort, if the PowerLab is the only connected SCSI device, try leaving it unterminated.)

The PowerLab doesn't work or the program crashes after a short time

The SCSI adapter card is incompatible with the computer or the PowerLab or both. We cannot guarantee that the PowerLab will work reliably with a card we did not supply, and some computers and SCSI adapter cards just won't work together.

- Try another card, preferably one we supplied. Ask your PC technical support person or IS manager to check compatibility.

A poor connection between PowerLab and computer, or bad cable.

- Ensure that the cable is firmly attached at both ends and try again. If there is still a problem, try a new cable.

SCSI problems: two SCSI devices on the bus have the same SCSI ID, or termination is incorrect or unsuitable.

- Check that each device has a unique ID number and that the SCSI chain is terminated correctly. (As a last resort, if the PowerLab is the only connected SCSI device, try leaving it unterminated.)

Signals seem weak or interacting on Channels 1 or 2

You may be using both the BNC connector and the Pod connector for an input at the same time, with resultant signal competition.

- Make certain that you use only *one* of the alternative connectors (BNC or Pod) for an input when recording.

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

The correct Bio Amplifier driver is not installed on your computer (they should be in the Essential Files folder in the Chart or Scope folder).

- Reinstall the software.

The Isolated Stimulator Status indicator shows yellow

This means that the Isolated Stimulator is out of compliance. You could be attempting stimulation while the output safety switch is turned off (in the down position).

- Turn the output safety switch on (move it to the up position).

The impedance of the tissue could be too high for the Isolated Stimulator to supply constant current at the level requested, or there is an inadequate electrical connection to the subject.

- Reduce the output current amplitude.

- Check the connections for proper contact and try again. Ensure the connection is not dry (apply electrode cream) and that the leads are properly connected.

The trace will not zero properly when adjusting high-pass filtering in the Bio Amplifier dialog box

The input is receiving signals at a level that has saturated the input amplifier, resulting in a large offset. This is normally due to poor contact between the electrodes and the subject.

- Check the connections for proper contact and try again. Ensure the connection is not dry (apply electrode cream) and that the leads are properly connected.

The signal appears to display a constant amplitude oscillation

Frequency interference from power lines can become superimposed on the smaller signals being measured on Channels 3 and 4.

- Turn on the internal notch filter (use the checkbox in the Bio Amplifier dialog box) to remove excessive line voltage frequency interference.

If you are using cables and leads that were not supplied with your Bio Amp, they may be unshielded or of low quality.

- Check to make sure that you are using high-quality shielded cables and high-quality leads. Only the supplied Bio Amp cable and leads should really be used.

The Bio Amp signal is noisy at lower ranges

This is probably the amplified noise from the electrodes, not a fault as such. There is, in addition, noise that cannot be avoided by any amplifier (called 'thermal' or 'Johnson' noise).

- Set the low-pass filter to remove the noise. (But be careful, since important components of the signal could also be attenuated.)

This could be due an electrically noisy environment, particularly if there is some equipment that produces a radio frequency that interacts with the Bio Amp modulator, giving a heterodyne effect.

- Turn off pieces of unnecessary equipment to try and isolate the cause, then either leave the equipment off, or, if possible, move the subject or equipment outside the area of any interfering field.

- At the lowest ranges you may have to shield, shorten, or even replace the leads connected to the Bio Amp cable, since they will tend to act as radio receptors.

The Bio Amp signal appears to be unusual, very weak, clipped, or distorted in some way

This may be a problem of technique: the sampling rate, range, or filter settings may be inappropriate for the signal you are recording.

- Make sure the settings are appropriate for the expected signal.

You may be using the wrong Bio Amp cable. The 3-lead Bio Amp cable used with the single Bio Amp has a different pin arrangement, and cannot be used with the PowerLab/4sT.

- Use the correct, supplied, 5-lead Bio Amp cable.

C

Specifications

Analog Input, Channels 1 and 2

Input configuration:	2 single-ended or differential channels (the latter only through the Pod connectors)
Amplification ranges:	±2 mV to ±10 V full scale in 12 steps
	± 10 V ± 5 V ± 2 V ± 1 V ± 0.5 V ± 0.2 V ± 0.1 V ± 50 mV ± 20 mV ± 10 mV ± 5 mV ± 2 mV
Maximum input voltage:	±15 volts
Input impedance:	≈ 1 MΩ ‖ 47 pF @ DC
Low-pass filtering:	20 kHz or 50 Hz (software-selectable)
AC coupling:	DC or 0.1 Hz (software-selectable)
Frequency response (–3 dB):	20 kHz @ ±10 V full scale, all ranges (no 50 Hz low-pass filter)
DC drift:	Software corrected
CMRR (differential):	96 dB @ 50 Hz (typical)
Channel crosstalk:	–110 dB typical

Input noise:	$< 1\ \mu V_{rms}$ referred to input
Pod connectors:	Combine power, I^2C and single-ended or differential analog input signals on one connector, support SmartPod transducers etc.

Supply voltage:	±5V regulated
Maximum current:	50 mA per pod port
Communications:	2-wire I^2C
Signal input:	Positive and negative analog inputs
Connector type:	8-pin DIN.

Bio Amp Input, Channels 3 and 4

Input configuration:	2 differential channels with common isolated ground reference
Input impedance:	100 MΩ to ground (~200 pF per lead) using supplied Bio Amp cable and leads
Safety:	Approved to IEC601-1 BF (body protection) standard
Isolation rating:	4000 V AC_{rms} for 1 minute
Amplification ranges:	±20 µV to ±50 mV full scale in 11 steps
	± 50 mV ± 20 mV ± 10 mV ± 5 mV ± 2 mV ± 1 mV ± 500 µV ± 200 µV ± 100 µV ± 50 µV ± 20 µV
Gain accuracy:	± 1% all ranges
Non-linearity:	< 1% of full scale (better for ranges under 1 mV)
Notch-filtering:	50 or 60 Hz notch filter, automatically selected to match supply frequency
High-pass filtering:	Single-pole 0.1, 0.3, 1, and 10 Hz (–3 dB) with accuracy of ±10%. High-pass filters are phase-matched to within 1° phase shift at the –3 dB frequency to allow for accurate waveform arithmetic.

Low-pass filtering:	8th-order Bessel-type filters (linear time delay). Frequencies software-selectable at 20, 50, 100, 200, and 500 Hz, and 1, 2, and 5 kHz. Frequency accuracy is ±2%.
DC blocking:	± 0.5 V
Baseline restoration:	Automatic
Noise levels:	0.1 Hz to 5 kHz 1.95 µV 0.1 Hz to 1 kHz 1.25 µV 0.1 Hz to 50 Hz 0.5 µV 0.1 Hz to 20 Hz 0.2 µV
IMRR (isolation mode):	> 130 dB (@ 50 to 100 Hz)
CMRR (common mode):	> 75 dB (DC to 100 Hz) > 60 dB (@ 1 kHz)
Input leakage current:	< 6 µA rms @ 240 V, 50 Hz < 4 µA rms @ 120 V, 60 Hz
Audio output:	Stereo output supplying signals from both Bio Amp channels. Suitable for earphones, headphones, or most externally powered speakers. Output is a 100 mV signal for any full-scale signal. Current limited to ± 5 mA.

Sampling

ADC resolution:	16 bits (150 µV resolution at 10 V range)
Linearity error:	±1 LSB (from 0 °C to 70 °C)
Maximum sampling rates:	200 kHz on one channel; 100 kHz on two channels; 40 kHz on three or four channels.
Available sampling rates:	200 kHz down to 0.003 Hz using Chart 200 kHz down to 2 Hz using Scope 200 kHz to 1 Hz using Chart for Windows Sampling on USB rather than SCSI may limit the maximum sampling rates.

Analog Output

Number output channels:	2
Output configuration:	Single-ended or differential
Output resolution:	14 bits (0.6 mV resolution at 10 V range)

Maximum output current:	±25 mA
Output impedance:	0.1 Ω typical
Slew rate:	10 V/μs
Settling time:	2 μs (to 0.01% of FSR for LSB change)
Linearity error:	±1 LSB (from 0 °C to 70 °C)
Output ranges:	±200 mV to ±10 V full scale in six steps

± 10 V
± 5 V
± 2 V
± 1 V
± 500 mV
± 200 mV

Isolated Stimulator Output

Output configuration:	Constant-current stimulator with hardware-limited repetition rate
Isolation rating:	4000 V_{rms} to ground as per IEC601-1 2000 V_{rms} (60 seconds) to Bio Amp inputs
Pulse duration:	50–200 μs (software-selectable)
Compliance voltage:	100–110 V typical
Output current:	0–20 mA in 0.1 mA steps (software-selectable)
Pulse rate:	Software-selectable, but hardware-limited to a maximum of 20 Hz for safety
Safety indicators:	A single multi-colour indicator displays the isolated stimulator status. A green flash indicates delivery of a valid stimulus. A yellow flash indicates an out-of-compliance condition.
Safety switch:	Isolating On-off switch flicks down to disconnect quickly

External Trigger

Trigger threshold:	+2.9 V (TTL compatible)
Hysteresis:	1.1 V (turns off at +1.8 V)

Input load:	1 TTL load
Maximum input voltage:	±12 V
Minimum pulse width:	5 µs

Microprocessor and Data Communication

Processor:	16 MHz 68340
Memory:	512 K RAM
Data communication:	SCSI (up to 4 megabytes/s, maximum, dependent on computer)
	USB (up to 500 kilobytes/s, maximum dependent on setup)

Expansion Ports

I^{2}C expansion port:	Power and control bus for front-end units. Supports up to two more front-ends connected to the PowerLab's analog inputs. Interface communications rate of up to 10,000 bits/s.
Digital output:	8 independent lines, TTL output level (50 mA maximum load per line; 250 mA maximum total load)
Digital input:	8 independent lines, TTL input level, threshold 2.2 V

Physical Configuration

Dimensions (w × h × d):	300 mm × 60 mm × 300 mm (11.8″ × 2.4″ × 11.8″)
Weight:	4.7 kg (10 lb 6oz)
Operating voltage:	220–240 V or 110–120 V (internally set)
Nominal power needs:	15 VA (no extra front-ends attached)
Maximum power needs:	18 VA (full complement of front-ends)
Replacement fuses:	100–120 V: 1 Amp (5 × 20 mm) slow blow (voltage rating 120 or 250 V)

	220–240 V: 400 mA (5 × 20 mm) slow blow (voltage rating 250 V only)
Operating temperature range:	0 to 35 °C, 0 to 90% humidity (non-condensing).

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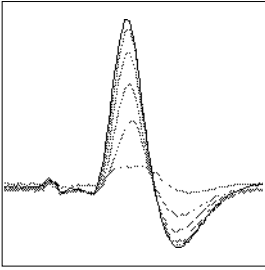
Glossary

This covers terms used in this owner's guide, those for ADInstruments front-ends, and the user's guides for ADInstruments software. General and specific computer terminology should be covered in the material that came with your computer, or in a recent dictionary.

AC coupling. A filter option. When AC coupling is chosen, a 0.1 Hz high-pass filter before the first amplification stage removes DC and frequency components below 0.1 Hz. This removes slowly changing baselines.

ADC (analog-to-digital converter). A device that converts analog information into some corresponding digital voltage or current.

amplitude. The maximum vertical distance of a periodic wave from the zero or mean position about which the wave oscillates.

analog. Varying smoothly and continuously over a range. An analog signal varies continuously over time, rather than changing in discrete steps.

analog input. This refers to the connectors on the front of the PowerLab marked 'CH1' and so on. These inputs are designed to accept up to ±10 volts. Inputs can be either single-sided or differential (the latter only in the case of the Pod connectors).

analog output. The connectors on the front of the PowerLab marked 'Output' that provide a software-controlled variable output (±10 V). The PowerLab/4ST also has a software-controlled, isolated, constant-current pulse stimulator ('Isolated Stimulator') that can be used for any general-purpose stimulation.

analysis. When the PowerLab is not physically connected to the computer, then ADInstruments software can be used to analyse and manipulate existing files if the analysis option is chosen.

BNC. A sort of cable or connector; a BNC-to-BNC cable connects two BNC connectors.

bridge transducer. A type of transducer using a Wheatstone bridge circuit. In its basic form, the bridge consists of four two-terminal elements (usually strain gauges) connected to form a quadrilateral. An excitation source is connected across one diagonal, and the transducer output is taken across the other.

bus. A data-carrying electrical pathway.

Chart. An application supplied with a PowerLab that emulates a multi-channel chart recorder, with other powerful options. (Macintosh and Windows versions differ.)

connector. A plug, socket, jack, or port used to connect one electronic device to another (via a cable): a PowerLab to a computer, say.

CPU (central processing unit). A hardware device that performs logical and arithmetical operations on data as specified in the instructions: the heart of most computers.

DAC (digital-to-analog converter). A device that converts digital information into some corresponding analog voltage or current.

DC offset. The amount of DC (direct current) voltage present at the output of an amplifier when zero voltage is applied to the input; or the amount of DC voltage present in a transducer in its equilibrium state.

differential input. Input using both positive and negative inputs on a PowerLab. The recorded signal is the difference between the positive and negative input voltages: if both were fed exactly the same signal, zero would result. Can reduce the noise from long leads.

digital. Varying discretely. A digital signal changes to discrete values rather than varying continuously. A digital time display might read 2:57 instead of using the positions of a pair of hands on a clock face.

DIN (Deutsche Industrie Norm). A sort of cable or connector; there are various sorts with different numbers of pins.

envelope form. The overall shape of a signal, outlined by the minimum and maximum recorded values. Often used to display quickly changing signals.

excitation voltage. The voltage supplied to a bridge circuit from which the transducer output signal is derived. Manipulating the transducer changes the measurement elements of the bridge circuit, producing a change in its output voltage.

external trigger. Refers to the connector on the front of the PowerLab marked 'Trigger'. This input lets recording be started from an external source. The trigger level (the voltage necessary to have an effect) depends on the hardware and cannot be changed.

filter. An electronic device or a program that alters data in accordance with specific criteria. Filters in the PowerLab can be used to reduce or to eliminate electronic noise or drift from data readings.

frequency. The number of complete cycles per second of a waveform. Frequency is usually expressed in hertz, Hz (cycles per second), kilohertz, kHz (thousands of cycles per second), or megahertz, MHz (millions of cycles per second).

frequency response. The bandwidth in which a circuit passes a signal without too much attenuation. A low-pass filter's frequency response is the frequency where the output voltage becomes 0.707 ($1/\sqrt{2}$) of the input voltage or has been attenuated by 3 decibels. If a low-pass filter has a frequency response of 200 Hz, say, then the signal is effectively unattenuated up to 150 Hz, and is 0.707 of the original value at 200 Hz.

front-end. An ancillary device that extends PowerLab capabilities, providing additional signal conditioning and features for specialised work. Front-ends are recognised automatically by the PowerLab system and seamlessly integrated into its applications, operating under full software control.

gain. The amount of amplification of a signal.

half-bridge transducer. A bridge transducer only using 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.

hertz (Hz). The unit of frequency of vibration or oscillation, defined as the number of cycles per second. The PowerLab's maximum sampling rate can be up to 100 kHz for E series and 200 kHz for SP and ST PowerLabs.

high-pass filter (HPF). A filter that passes high-frequency signals, but filters low ones, by blocking DC voltages and attenuating frequencies below a certain frequency, called the cutoff, or –3 dB, frequency.

I²C. The I²C (eye-squared-sea) connection is used by the PowerLab to control front-ends. It provides power and communications using a 4-wire serial bus (two wires for standard I²C and two control lines).

IEC. International Electrotechnical Commission.

low-pass filter (LPF). A filter that passes low-frequency signals and DC voltages, but filters high ones, by attenuating frequencies above a certain frequency, called the cutoff, or –3 dB, frequency.

Macintosh. A family of Apple computers with built-in graphics and an elegant user interface. Of the Mac OS (operating system) versions, System 7 is needed and System 7.6 recommended normally; a Power Macintosh and Mac OS 8.5 or later are needed for USB.

MacLab. An earlier name for the PowerLab, before it became cross-platform.

Peaks. A simple chromatography analysis package. It reads acquired data from Macintosh Chart, Scope, or text files. (Available for Macintosh only.)

Pod connector. A special 8-pin DIN connector on some PowerLabs giving differential or single-sided connections for some analog inputs (Channels 1 to 2 on the PowerLab/4ST). Pods can connect to them, and they can also provide power and control for some types of transducers.

Pods. Small, low-cost units that connect to the Pod connectors on the PowerLab. They give alternatives to front-ends for specific tasks, for use with precalibrated transducers and so on.

port. A socket in a computer where you plug in a cable for connection to a network or a peripheral device. Also, any connection for transferring data, for instance between the CPU and main memory.

PowerChrom. A versatile, flexible, and powerful chromatography program for use with a PowerChrom recording unit. (Available for Macintosh only.)

PowerChrom System. The system consists of a PowerChrom recording unit and the

PowerChrom program. It provides general-purpose manual or automatic recording and analysis of chromatographic peaks.

PowerLab. The PowerLab hardware unit is a self-contained data acquisition hardware unit that connects to a Windows or Macintosh computer. When used in conjunction with programs such as Chart and Scope, it functions as a versatile laboratory instrument.

PowerLab system. The system consists of a hardware unit and applications software (and possibly ancillary devices). It provides a multi-purpose data recording, display, and analysis environment for experimental data.

range. In Chart and Scope, the range is the greatest positive and negative voltage that can be displayed, usually from ±2 mV to ±10 V, in 12 steps. (Range is inversely proportional to gain, the extent of amplification.)

Scope. An application supplied with a PowerLab that emulates a two-channel storage oscilloscope, with added powerful options. (Macintosh and Windows versions are very similar.)

SCSI (small computer system interface). A connection protocol that provides a computer with fast access to peripheral devices, but has to be set up carefully. SCSI devices can be linked together in a chain, and require termination to prevent signal loss.

serial. A connection interface in which information is sent sequentially, one bit at a time, over a single wire or channel. Much slower than SCSI, but less fussy. (Macintosh and PowerLab/800 only.)

TChart. A simplified version of the Chart program once used for teaching. Its manual of experiments is now available for Chart.

terminator. A device used in a SCSI chain to maintain signal integrity. Some models of PowerLab have them built in.

transducer. A physical device that converts a mechanical, thermal, or electrical stimulus into a proportional electrical output. For example, there are common transducers to measure force, displacement, temperature, pressure, and similar parameters.

trigger. A signal such as a voltage pulse, used to determine when sampling will begin. Sampling can be made to begin when the trigger level is reached, after it, or even prior to it. See also external trigger.

TTL (transistor-transistor logic). A family of integrated circuits with bipolar circuit logic, used in computers and related devices. TTL is also a standard for interconnecting such ICs, defining the voltages used to represent logical zeroes and ones (binary 0 and 1).

USB (universal serial bus). A relatively new low-to-medium speed connection protocol, for linking multiple peripherals from mice to printers. (Available on newer PowerLabs, such as the PowerLab/4ST.)

waveform. The shape of a wave; a graph of a wave's amplitude over time.

Windows. An operating system for PCs with a graphical user interface. Chart for Windows and Scope for Windows require Windows 95 or NT 4 or later. Windows 98, Me, 2000 or later is needed for USB.
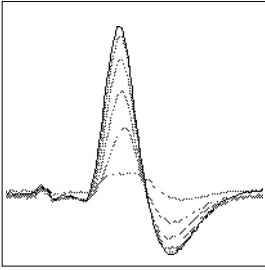
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voltage rating 2–3

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