This document was, as far as possible, accurate at the time of release. However, changes may have been made to the software and hardware it describes since then. ADInstruments NZ Limited reserves the right to alter specifications as required. Late-breaking information may be supplied separately.

**Trademarks of ADInstruments**

PowerLab®, LabChart® and ADInstruments® are registered trademarks of ADInstruments NZ Limited.

**Other Trademarks**

Apple, Mac and Macintosh are registered trademarks of Apple Computer, Inc.

Windows, Windows 7, Windows 8, Windows 10 and Windows Vista are either registered trademarks or trademarks of Microsoft Corporation.

All other trademarks are the property of their respective owners.

Document Number: U-STI/OG-01 Rev B, Date of issue: 06/20

Copyright © ADInstruments NZ Limited, 2020. All rights reserved. PowerLab, LabChart and ADInstruments are registered trademarks of ADInstruments NZ Limited. Windows 8, Windows 7, Windows 10, Windows Vista and .NET Framework are trademarks of Microsoft Corporation. Apple, the Apple logo, MacOS, and Macintosh are trademarks of Apple Computer Inc. registered in the U.S. and other countries. Acrobat and Adobe are registered trademarks of Adobe Systems Incorporated. Igor is a trademark of Wavemetrics Inc. MATLAB is a registered trademark of The MathWorks Inc. Grass is a trademark of Astro-Med Inc. All other trademarks are the property of their respective owners.

Web: www.adinstruments.com

Manufactured in Australia by:
ADInstruments (Sydney) Pty. Ltd.,
13/22 Lexington Drive
Bella Vista 2153 New South Wales

Technical Support: support.au@adinstruments.com
Statement of Intended Use

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

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

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

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

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

Safety and Quality Standards

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

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

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

Regulatory Symbols

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

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

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

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

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

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

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

Further information is available on request.
Safety Standards

IEC Standard - International Standard - Medical Electrical Equipment

IEC 60601-1-1:2000  Safety requirements for medical electrical systems
IEC 60601-1:2012 + A1  General requirements for safety

General Safety Instructions

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

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

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

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

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

- Any electrical equipment which is located within the SUBJECT AREA should be approved to IEC 60601-1.
- Only connect those parts of equipment that are marked as an APPLIED PART to the subject. APPLIED PARTS may be recognized by the BF symbol which appears in the Safety Symbols section of these Safety Notes.
- Never connect parts which are marked as an APPLIED PART to those which are not marked as APPLIED PARTS.
• Do not touch the subject to which the PowerLab (or its peripherals) is connected at the same time as making contact with parts of the PowerLab (or its peripherals) that are not intended for contact to the subject.
• Cleaning and sterilization of equipment should be performed in accordance with manufacturer’s instructions. The isolation barrier may be compromised if manufacturer’s cleaning instructions are not followed.
• The ambient environment (such as the temperature and relative humidity) of the system should be kept within the manufacturer’s specified range or the isolation barrier may be compromised.
• The entry of liquids into equipment may also compromise the isolation barrier. If spillage occurs, the manufacturer of the affected equipment should be contacted before using the equipment.
• Many electrical systems (particularly those in metal enclosures) depend upon the presence of a protective earth for electrical safety. This is generally provided from the power outlet through a power cord, but may also be supplied as a dedicated safety earth conductor. Power cords should never be modified so as to remove the earth connection. The integrity of the protective earth connection between each piece of equipment and the protective earth should be verified regularly by qualified personnel.

Avoid using multiple portable socket-outlets (such as power boards) where possible as they provide an inherently less safe environment with respect to electrical hazards. Individual connection of each piece of equipment to fixed mains socket-outlets is the preferred means of connection.

If multiple portable socket outlets are used, they are subject to the following constraints:
• They shall not be placed on the floor.
• Additional multiple portable socket outlets or extension cords shall not be connected to the system.
• They shall only be used for supplying power to equipment which is intended to form part of the system.
Stimulus Isolator Safety Instructions

The Stimulator outputs from the Stimulus Isolator front-end (or any PowerLab with a built-in isolated stimulator) are electrically isolated and safe for human connection. However, they can produce pulses of up to 100 V at up to 20 mA. Injury can still occur from careless use of these devices. Several points must be observed for safe operation of the Stimulus Isolator front-end:

- The FE180 Stimulus Isolator front-end must only be used with the supplied power pack (product code: SP0108), which complies with medical safety standards.
- The Stimulus Isolator must only be used with the supplied bar stimulus electrode.
- The Isolated Stimulator output 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 must 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.

Do not attempt to measure or record the Isolated Stimulator output while connected to a subject using a PowerLab input or any other piece of equipment that does not carry the appropriate safety symbol (see Safety Symbols above).

Always check the status indicator on the front panel. It will 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 poor electrode contact or electrode cream drying up. 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 must be stopped, either from the software or by flicking down the safety switch on the front panel of any built-in Isolated Stimulator or the FE180 Stimulus Isolator.
- The FE180 Stimulus Isolator is supplied with a special transformer power pack, which complies with medical safety requirements. Therefore, under no circumstances should any other transformer be used with the Stimulus Isolator. For a replacement transformer power pack please contact your nearest ADInstruments representative.
- The FE155 Stimulator HC is not safe for human connection and should never be used for human stimulation.
Earthing and Ground Loop Noise

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

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

The earthing stud can also be used where a suitable ground connection is not provided with the mains supply by connecting the stud to an earthed metal infrastructure, such as a metal stake driven into the ground, or metal water piping. This may also be required in laboratories where safety standards require additional grounding protection when equipment is connected to human subjects. Always observe the relevant safety standards and instructions.

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

Cleaning and Sterilization

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

Inspection and Maintenance

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

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

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

Disposal

- Forward to recycling center or return to manufacturer.
- Unwanted equipment bearing the Waste Electrical and Electronic Equipment (WEEE) Directive symbol requires separate waste collection. For a product labeled with this symbol, either forward to a recycling center or contact your nearest ADInstruments representative for methods of disposal at the end of its working life.
The PowerLab system consists of a recording unit and application programs that run on the computer to which the unit is connected. It provides an integrated system of hardware and software designed to record, display, and analyze experimental data.

Front-ends are ancillary devices that connect to the PowerLab recording unit to extend the system’s capabilities. They provide additional signal conditioning, and other features, and extend the types of experiments that you can conduct and the data you can record.

All ADInstruments front-ends are designed to be operated under full software control. No knobs, dials, or switches are needed, although some may be provided for reasons of convenience or safety.
Introduction

The PowerLab controls front-ends through an expansion connector called the I²C (eye-squared-sea) bus. This makes it very easy to add front-ends to the system or to transfer them between PowerLabs. Many front-ends can be added to the system by connecting the I²C sockets in a simple daisy-chain structure. The PowerLab provides control and low-voltage power to front-ends through the I²C bus so, in general, no separate power supply is required.

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

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

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

1. Since they need to produce a reasonably high voltage and current, the Stimulator front-ends require a power supply in addition to the power provided by the I²C bus.
2. As they produce voltage output for stimulation, they are connected to a positive analog output socket of the PowerLab as a source for timing and producing pulses.

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

Checking the Front-end

Before connecting the front-end to anything, check it carefully for signs of physical damage.

1. Check that there are no obvious signs of damage to the outside of the front-end casing.
2. Check that there is no obvious sign of internal damage, such as rattling. Pick up the front-end, tilt it gently from side to side, and listen for anything that appears to be loose.

If you have found a problem, contact your authorized ADInstruments representative immediately and describe the problem. Arrangements can be made to replace or repair the front-end.
Connecting to the PowerLab

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

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

**Single Front-ends**

Connect the I²C output of the PowerLab to the I²C input of the front-end using the I²C cable provided. Figure 2–1 shows how to connect up a single front-end to your recording unit.

Check that the connectors for the I²C bus are screwed in firmly. Check the BNC cable for firm connections as well. Loose connectors can cause erratic front-end behavior, or may cause the front-end to fail to work at all.

**The Signal Output Socket**

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

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

Multiple separate front-ends can be connected up to a PowerLab. The initial front-end should be connected with the I²C cable as in Figure 2–1. The remainder are daisy-chained via I²C cables, connecting the I²C output of the last connected front-end to the I²C input of the front-end to be added (Figure 2–2).

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

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

**Special Cases**

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

**Connecting Stimulator Front-Ends**

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

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

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

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

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

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

Maximum Number of Front-Ends

The I²C bus can control a maximum of sixteen front-ends. Therefore, if you are using a PowerLab 16/30, which has sixteen input channels, you can record from sixteen single channel front-ends.

Using ADInstruments Programs

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

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

Front-end Drivers

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

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

**The Front-end Self-test**

Once the front-end is properly connected to the PowerLab, and the proper software is installed on the computer, a quick check can be performed on the front-end. To perform the self-test:

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

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

**Software Behavior**

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

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

![Figure 2–3 Channel Function pop-up menu in LabChart with the Bio Amp front-end connected](image)

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

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

Aliasing

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

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

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

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

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

Frequency Distortion

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

It can be eliminated by increasing the frequency cut-off of the low-pass filter in the front-end-specific Input Amplifier... dialog to obtain an undistorted waveform.
Similarly, if the high-pass filter was set too high, the amplitude of the T-wave sections may be reduced. The Input Amplifier... dialog allows you to examine ECGs and similar slowly changing waveforms to fine-tune filter settings before recording.

**Saturation**

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

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

**Ground Loops**

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

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

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

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

**Mains filter**

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

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

The filter should not be used when:

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

Electrode Contact

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

Motion Artifacts

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

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

If the subject is liable to move during recording, then special care needs to be taken when attaching the electrodes and securing the patient leads. Make sure the skin is cleaned and lightly abraded before attaching the electrodes.
The FE155 Stimulator HC is a modular device, in a family of front-ends, designed to extend the capabilities of the PowerLab system. It is a general-purpose stimulator, able to provide constant current stimulation with electrical isolation.

The Stimulator HC is essentially an extension of the PowerLab’s analog output. The Stimulator HC provides:

- software adjustable current amplitudes up to 100 mA
- a constant-current, 100-volt compliance, pulsed output
- low leakage capacitance and low noise
- software-adjustable pulse duration
- high-voltage isolation (4000 V\text{rms}).

\textbf{Warning!} The Stimulator HC is NOT for human connection. The output is capable of supplying currents of up to 100 mA, so it should be treated with caution.
The Stimulator HC

The Stimulator HC is designed to provide electrically isolated, constant current stimulation of nerve, muscle or tissue samples. The Stimulator HC uses the positive analog output of the PowerLab. The I2C bus, as well as providing control, also provides the low-voltage power supply required to operate most front-ends. However, as the Stimulator HC needs to produce a reasonably high voltage and current, it has its own power supply. It does not require batteries.

The Front Panel

The front panel of the Stimulator HC has two output sockets, two small indicator lights and a ON/OFF switch.

The Status Indicator

The Status indicator is located at the bottom left of the front panel. When an ADInstruments application starts up, the Status indicator should flash briefly and then remain green, indicating the application has found, checked and selected the front-end, and it is ready for use.

If the Status indicator does not turn on and stay on when the software application is open, this indicates either that the front-end is not connected properly or that there is a software or hardware problem. Try restarting the application; this will sometimes correct the problem. See Troubleshooting for more details.

The Stimulator Pulse Indicator

The current status or operating condition of the Stimulator HC is indicated by the Stimulator Pulse indicator, a multi-colored light that is located on the left-hand side of the front panel. The indicator light will flash green for every stimulus pulse, and may seem to glow green constantly at higher stimulus frequencies.

A yellow color 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 HC can no longer supply constant current stimulation. If this should happen, try reducing the output current amplitude, and check all connections.
The Output Sockets

The stimulus output of the Stimulator HC is supplied through two 2 mm sockets; the left (red) socket is positive, the right (black) socket is negative. The output is capable of supplying 100 V pulses at currents up to 100 mA, so it should be treated with caution. The output connections are isolated internally by isolation circuitry.

The Safety Switch

For additional safety, a switch on the front panel allows 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 the down position to turn it off: that disconnects the output sockets from the internal circuitry, allowing connections to be made in safety while the front-end is on.

The Back Panel

The back panel of the Stimulator HC provides all the sockets required to connect the front-end to the PowerLab and to other front-ends, and to connect it to its own power supply.

I²C Input and Output Sockets

Two nine-pin sockets are used to communicate with the PowerLab (they are labeled I²C Bus). These sockets, in conjunction with the proper cables, allow multiple front-ends to be used independently with one PowerLab. Power and control signals to connected front-ends come from the PowerLab. ADInstruments front-ends are connected to the system in series; previous device output to current front-end input.

The Stimulator HC has its own power supply, but uses power from the I²C bus for its control circuitry, and uses signals from the bus to set pulse amplitude and duration (the Stimulator HC allows for shorter pulses than the LabChart application usually handles, for instance), and to control a beeper that provides an optional audible pulse signal.
The Signal Input Socket

A BNC socket labeled Signal Input on the back panel of the Stimulator HC is used to connect it to the positive analog output on the front of the PowerLab (see below). A BNC-to-BNC cable is supplied for this connection. The PowerLab output is used to provide the trigger pulses for the Stimulator HC and to establish timing, as well as to check that the front-end is connected.

Power Socket

The Stimulator HC is supplied with a certified power pack, a (nominal) 12-volt AC transformer, since it needs to produce a higher voltage and current than the PowerLab can supply through the I2C bus. The transformer plugs into a normal wall socket, and its cable jack plugs into the power socket at the back of the Stimulator HC. No batteries are used. Only the supplied power pack should be used with the FE155 Stimulator HC.

Connecting to the PowerLab

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

A BNC cable must connect the Signal Input socket on the rear panel of the Stimulator HC to the positive analog output on the front panel of the PowerLab. The positive output socket is labelled + on most PowerLabs and Output 1 on /30 and /35 series PowerLabs. ADInstruments applications will not find the Stimulator HC when starting up if the negative output socket is used.

Single Front-ends

Connect the I2C Output of the PowerLab to the I2C Input of the front-end using the I2C cable provided. Figure 12–3 shows how to connect up a single front-end to your recording unit.

Check that the connectors for the I2C bus are screwed in firmly. Check the BNC cable for firm connections as well. Loose connectors can cause erratic front-end behavior, or may cause the front-end to fail to work at all. The BNC cable can be tucked under the front-end to keep it out of the way if desired.

Multiple Front-ends

The Stimulator HC connects to and uses the analog output of the PowerLab as a source for producing pulses, so only one front-end of this nature can be used per PowerLab. However, multiple front-ends can be connected to PowerLab system. The number of standard front-ends that can be connected depends on the number of analog input channels on the PowerLab, since each front-end is normally requires connection to one of the analog input channels of the PowerLab to operate.
The initial front-end should be connected with an I²C cable as in Figure 12–3. The remainder are daisy-chained via I²C cables, connecting the I²C Output of the previous connected front-end to the I²C Input of the next front-end to be added.

The I²C Bus can control up to a maximum of sixteen front-ends (depending on the PowerLab model). So if you are using a PowerLab 16/30, which has sixteen analog inputs, you can connect up to fifteen single-channel front-ends and the Stimulator HC (representing sixteen front-ends).
Software Requirements

The FE155 Stimulator HC requires the following versions of ADInstruments software applications:

- LabChart version 6, or later, for Windows or Macintosh
- Chart version 5.4.2, or later, for Windows or Macintosh
- Scope for Windows version 3.9.2, or later
- Scope for Macintosh version 4.0.3, or later
- LabTutor version 3, or later.

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

Software Behavior

When the Stimulator HC is properly connected to the output the Stimulator dialog displays the Stimulus Isolator checkbox, which is selected and disabled.

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

The Stimulator HC dialog

The Stimulator HC lets you generate a pulse or series of pulses, for general-purpose stimulation with currents up to 100 mA. The stimulus output is not suitable for human connection. The stimulus is produced from the outputs on the front panel of the Stimulator HC. The stimulus is independent of the PowerLab sampling rate and can be generated whether the PowerLab is sampling or not. The stimulus is set up using the Stimulator dialog. The following information is correct for LabChart 8 for Windows and Mac. The dialogue box and options available will differ with older versions of LabChart.

In LabChart, choose Setup > Stimulator... to display the Stimulator dialog (Figure 12–5).

When setting up the Stimulator HC, you can:

- Choose how stimulation should start.
- Choose a preconfigured stimulus type or mode.
- Optionally, on Windows, create a custom stimulus waveform.
- Set stimulus parameters, such as start delay, pulse width and current amplitude.
Choosing How Stimulation Should Start

Stimulation can be set to start in different ways:

- **When sampling starts:** stimulation begins automatically when the LabChart Start button is clicked, and continues until sampling stops. Use the On and Off buttons to control pulse delivery, if necessary.
- **Manually:** stimulation begins when Stimulate in the dialog is clicked, and continues until sampling stops. Use the On and Off buttons to control pulse delivery, if necessary.
- **Independently of sampling:** stimulation begins when On in the dialog is clicked, whether or not LabChart is sampling. Available in LabChart for Windows only.

In all three modes, you can immediately restart a stimulus waveform by clicking Stimulate.

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

The Stimulator HC only offers the Isolated Pulse stimulation mode (Pulse on Macintosh). This generates a rectangular pulse stimulus that starts at zero current, is raised to the set current amplitude for the set pulse width (duration), and then falls to zero current again. By default, the stimulator is off and the current amplitude is set to zero.

Creating a Custom Stimulus Waveform

In LabChart you can:

- Specify whether parameter controls are displayed in the Stimulator and Stimulator Panel dialogs.
- Define a sequence of segments to create a custom stimulus waveform.

Click Custom... to display the Waveform Customization dialog. For further details on using this dialog consult the LabChart Help Center.

Setting Stimulus Parameters

You use the text boxes and sliders to set values for the stimulus parameters. You can use the Settings dialog for each parameter to configure the range of values available to the parameter text box and slider controls. Using suitable values can improve the precision of control over the stimulus parameter when using the slider and spinner controls.

The following stimulus parameters can be set:

**Start Delay**: the wait time before stimulation is delivered, once the stimulus waveform has been started (0 to 10 s).

**Repeats**: the number of times the stimulus waveform is repeated, once started.

**Max Repeat Rate**: the maximum frequency with which the stimulus waveform is repeated, within the ranges: 0.1 to 30 Hz, 6 to 1800 /min, and 33.33 ms to 10 s.

**Pulse Width**: the duration of each pulse (10 to 4000 µs).

**Current**: the amplitude of the stimulus current (0 to 100 mA).

**End Delay**: the wait time at the end of a stimulus segment, after which the next segment is delivered. This is not the same as a Delay segment.

**Marker Channel**

If you choose a channel from the Marker Channel pop-up menu, then the start time of a stimulus pulse is marked by a small data spike (this adds to any data in that channel).

**The Beeper**

Check Beep to turn on the Stimulator HC’s internal beeper: when on, it gives an audible beep with every pulse (although it is not very loud, and may not be that clear in noisy environments). On a Macintosh system, click the speaker icon to turn off or on the Stimulator HC’s internal beeper.
The Stimulator Panel

Once you have set up stimulation using the Stimulator dialog, you can easily start or stop stimulation or change settings while sampling, by using the Stimulator Panel. Choose **Stimulator Panel** from the Setup menu to open it, or **Stimulator HC Panel** on Macintosh (Figure 12–7).

You can specify which parameter controls are displayed in the panel using checkboxes in the Panel column of the Stimulator Waveform Customization dialog. See the **LabChart Help Center** for details.

The Stimulator Panel ‘floats’ in front of the active window, can be moved around with its title bar, and can only be dismissed by clicking its close box.

PowerLabs with Independent versus Differential Analog Outputs

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

**For the /20, /25, /26 and 15T series PowerLabs:**

The negative (−) output is the complement of the positive (+) output, so the stimuli from the two outputs are mirror images. If one output gives a positive voltage, the other gives a negative one, and the two together give a differential voltage. Only one Stimulator front-end such as a Stimulus Isolator or Stimulator HC can be connected to the (positive) output of these PowerLabs.
**Note:** If you connect the Stimulator HC to a PowerLab that has an in-built Isolated Stimulator, such as a PowerLab 26T, only the external, connected stimulator is used.

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

The analog outputs labelled Output 1 and Output 2 can function independently. Although only one Stimulator front-end such as a Stimulus Isolator or Stimulator HC can be connected to the positive output (Output 1) of these PowerLabs, the second output (Output 2) remains available for other uses, such as creating analog waveforms or controlling peripheral devices. In LabChart 7 and above for Windows and LabChart 8 and above on Mac, with a Stimulator front-end connected, a second tab appears in the Stimulator dialog and the Stimulator Panel (Figure 12–7). This allows for the independent control of Output 2.
Technical Aspects

The Stimulator HC has been designed to integrate fully into the PowerLab system. It requires connection to the PowerLab via a special communications connector called the I2C bus, and a BNC connector.

**Stimulator HC Operation**

The PowerLab usually provides control and low-voltage power to front-ends through the I2C bus. The Stimulator HC differs from other front-ends in some respects. Since it needs to produce a reasonably high voltage and current, the Stimulator HC has its own power supply in addition to the power for the control circuitry provided by the I2C bus. Front-ends are also usually connected through the analog inputs of the PowerLab but the Stimulator HC is not a signal conditioner; it produces stimulation voltage output and so it is connected to a positive analog output socket of the PowerLab. The overall operation of the Stimulator HC can be better understood by referring to Figure 12–8.

The output stage consists of a constant current source that can produce pulses of variable duration and amplitude under software control. The current source can deliver pulses up to 100 mA at 100-volt compliance levels; its amplitude is set by a digital attenuator network, which is in turn controlled by the I2C logic. The output to the nerve, muscle or tissue sample is through high-isolation optical couplers.

Trigger pulses are delivered to the current source through optical isolation as well. Power for the stimulator current source is derived from the external AC wall transformer (plug pack) coupled through a custom isolation transformer, from which the isolated low voltage and 100-volt supplies are derived. The supplied power pack complies with medical safety requirements: under no circumstances should any other transformer be used in its place.

**Figure 3–7**  
Block Diagram of the Stimulator HC
During operation an indicator light on the front panel lights green with every pulse (it will glow yellow if the Stimulator HC is out of compliance). A small internal beeper can also be enabled to give an audible beep with every pulse delivered.

The digital interface that controls pulse width and current amplitude uses an I²C interface system, and provides a 4-wire serial communication bus to the PowerLab and other front-ends. Signals from the bus also control the beeper. Also present on the connector is a set of power supply rails derived from the PowerLab, used to power the control circuitry of the Stimulator HC.

**Troubleshooting**

This section describes most of the common problems that can occur when using the Stimulator HC with your PowerLab recording unit. It covers how these problems are caused, and what you can do to alleviate them. If the solutions here do not work, earlier chapters, the LabChart Help Center, and the guide to your PowerLab may contain possible solutions. If none of the solutions here or elsewhere are of help, then consult your ADInstruments representative.

Most of the problems that users encounter are connection problems, and can usually be fixed by checking connections and starting up the hardware and software again. Very rarely will there be an actual problem with the front-end or the PowerLab itself.

**Problems and Solutions**

*The status indicators fail to light when the software is started, or the front-end commands and so on do not appear where they should*

The I²C cable or the BNC-to-BNC cable from the front-end to the PowerLab is not connected, has been connected incorrectly (to the wrong input or output, for instance), or is loose.

- Turn everything off. Check to see that all cables are firmly seated and screwed in. The BNC cable from the Stimulator HC must be connected to the positive output on the PowerLab (labelled + on most PowerLabs and Output 1 on /30 and /35 series PowerLabs). Restart the PowerLab and application to see if this has fixed the problem.

You are using an early version of LabChart.

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

The BNC or I²C cable is faulty.

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

The front-end is faulty.

- This is the least likely event. If the front-end will not work properly after the previous measures, then try using it on another PowerLab. If the same problems recur with a second PowerLab, the front-end may be faulty. Contact your ADInstruments representative to arrange for repairs.
On starting up the software, an alert indicates that there is a problem with the front-end or driver

The correct Stimulator HC driver is not installed on your computer.

• Reinstall the software.

You are using an early version of LabChart.

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

The BNC or I²C cable is faulty.

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

The front-end is faulty.

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

Some software settings don’t resemble those in this guide

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

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

The Stimulator Status indicator shows yellow

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

• Turn the stimulator switch on (move to the up position).
• The impedance of the tissue could be too high for the Stimulator HC to supply constant current at the level requested, or there is an inadequate electrical connection to the tissue.
• Reduce the output current amplitude.
• Check the connections for proper contact and try again. Ensure the tissue is mounted correctly.

The Stimulator Status indicator does not flash green, even when there is an audible beep

The supplied 12-volt AC power supply to the Stimulator HC is not connected or not switched on at the wall or is faulty.

• Close the LabChart application, connect up and turn on the power supply, and start up again.
• If the Status light still does not flash green (and does not light up at all), the 12-volt power supply may be faulty. Have a technician check the fuse and the electrical connections.
• Once you have established that it is not faulty, you should ensure that the output of the 12-volt power supply is indeed 12 volts – use a multimeter to measure this.
Specifications

Output

Safety: Not for Human Connection
EMC: Approved to EN61326-1:2006 Standard
Connection type: Two 2 mm touch-proof safety sockets
Configuration: Constant-current stimulator with hardware-limited repetition rate.
Output waveform: Rectangular, monophasic pulses with software-selectable pulse amplitude and duration.
Isolation rating: 4000 V AC_{rms} for 1 minute
Safety switch: Isolating On-Off switch flicks down to disconnect quickly.
Compliance voltage: 100 V fixed
Current ranges: 1 mA, 10 mA, 100 mA full scale
Current rise time: <1 µs (100 Ω load @ 100 mA)
25 µs (10 kΩ load @ 0.5 mA)
Current fall time: <1 µs (100 Ω load @ 100 mA)
25 µs (10 kΩ load @ 0.5 mA)
Current rise and fall times are proportional to load resistance and capacitance.
Operating duty cycle: up to 20%
Resolution: 1% of full scale (10 µA, 100 µA, or 1 mA)
AC line leakage current: <200 nA p–p
Differential output noise: <1 µA p–p
Power source: Non-isolated circuitry supplied by PowerLab via I^2C connection.
Isolated and high-voltage circuitry derives power from the external 12 V AC, 300 mA_{rms}, wall-plug transformer. High-voltage isolation is provided by an internal isolation transformer. No batteries required.
Pulse control (internal pulse duration control)

Pulse duration range: 0.02 to 5.12 ms in 0.02 ms steps
Duration accuracy: ± 0.01% +5/–0 µs
Repetition rate: Up to 30 Hz
Repetition accuracy: ± 0.1% (determined by PowerLab)
Current rise delay: 22–45 µs (variable)

Control Port

I²C port: Provides control and power. Interface communications rate of ~50 kbits/s.

Physical Configuration

Dimensions (h × w × d): 55 mm × 120 mm × 260 mm (2.2" × 4.7" × 10.2")
Weight: 1.3 kg (2 lb 15 oz)
Operating temperature range: 5–35 °C
Operating humidity range: 0–90% (non-condensing)

ADInstruments reserves the right to alter these specifications at any time.
The FE180 Stimulus Isolator is a modular device, in a family of front-ends, designed to extend the capabilities of the PowerLab system. It is a general-purpose stimulator, able to provide high-voltage, constant-current stimulation, and it provides full electrical isolation.

The Stimulus Isolator is essentially an extension of the PowerLab’s analog output. The Stimulus Isolator provides:

- a constant-current, 100-volt compliance, pulsed output
- high-voltage subject isolation (4000 Vrms)
- low leakage capacitance and low noise
- software-adjustable current amplitudes
- software-adjustable pulse duration.

**Warning!** The output is capable of supplying 100 V pulses and generating currents of up to 10 mA, so it should be treated with caution.
The Stimulus Isolator

The Stimulus Isolator is designed to provide electrically isolated, high-voltage, constant-current stimulation of human or other subjects. It is also able to produce shorter pulses than the LabChart application normally can. The I2C bus, as well as providing control, also provides the low-voltage power supply required to operate most front-ends. However, as the Stimulus Isolator needs to produce a reasonably high voltage and current, it has its own power supply. It does not require batteries.

The rest of this chapter contains general information about the features, connectors and indicators of the Stimulus Isolator. More detailed information can be found in the technical appendices.

The Front Panel

The front panel of the Stimulus Isolator has two output sockets, two small indicator lights and a safety switch.

The Status Indicator

The Status indicator is located at the bottom right of the front panel. When an ADInstruments application such as LabChart starts up, the Status indicator should flash briefly and then remain green, indicating that the program has found the front-end, checked and selected it, and it is ready for use.

If the Status indicator does not turn on and stay on when the software application is open, this indicates either that the front-end is not connected properly or that there is a software or hardware problem. Try restarting the application; this will sometimes correct the problem. If the problem persists, see “Problems and Solutions” on page 43 for more details on possible solutions.

The Output Sockets

The stimulus output of the Stimulus Isolator is supplied via two 4 mm shrouded banana sockets; the left (red) socket is positive, the right (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 stimulating bar electrode supplied with the front-end
uses such plugs. The output is capable of supplying 100 V pulses at currents up to 10 mA, so it should be treated with caution. The output connections are isolated internally by isolation circuitry.

**The Stimulator Status Indicator**

The current status or operating condition of the Stimulus Isolator is indicated by the Stimulator Status indicator, a multi-colored light that is located on the left-hand side of the front panel. The indicator light will flash green for every stimulus pulse, and may seem to glow green constantly at higher stimulus frequencies.

A yellow color 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 Stimulus Isolator can no longer supply constant current stimulation. If this should happen, try reducing the output current amplitude, and check all connections.

**The Safety Switch**

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 front-end is on.

**The Back Panel**

The back panel of the Stimulus Isolator provides all the sockets required to connect the front-end to the PowerLab and to other front-ends, and to connect it to its own power supply.

![Figure 4–2: The back panel of the Stimulus Isolator](image-url)
I²C Input and Output Sockets

Two nine-pin sockets are used to communicate with the PowerLab (they are labeled I²C Bus). These sockets, in conjunction with the proper cables, allow multiple front-ends to be used independently with one PowerLab. Power and control signals to connected front-ends come from the PowerLab. ADInstruments front-ends are connected to each other in series, output to input (this is discussed in more detail in the next chapter).

The Stimulus Isolator has its own power supply, but uses power from the I²C bus for its control circuitry, and uses signals from the bus to set pulse amplitude and duration (the Stimulus Isolator allows for shorter pulses than the LabChart application usually handles, for instance), and to control the beeper that provides an optional audible signal with each pulse.

The Signal Input Socket

A BNC socket labeled Signal Input on the back panel of the Stimulus Isolator is used to connect the front-end to the positive analog output on the front of the PowerLab (see below). A BNC-to-BNC cable is supplied for this connection. The PowerLab output is used to provide the trigger pulses for the Stimulus Isolator and to establish timing, as well as to check that the front-end is connected.

Power Socket

The Stimulus Isolator is supplied with a certified power pack (product code: SP0108), a (nominal) 12-volt AC transformer, since it needs to produce a higher voltage and current than the PowerLab can supply through the I²C bus. The transformer plugs into a normal wall socket, and its cable jack plugs into the power socket at the back of the Stimulus Isolator. No batteries are used. The supplied power pack complies with medical safety requirements; under no circumstances should any other transformer be used with the FE180 Stimulus Isolator.

Connecting to the PowerLab

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

A BNC cable must connect the Signal Input socket on the rear panel of the Stimulus Isolator to the positive analog output on the front panel of the PowerLab. The positive output socket is labelled + on most PowerLabs and Output 1 on /30 and /35 series PowerLabs. ADInstruments applications will not find the Stimulus Isolator when starting up if the negative Output socket is used.

Single Front-ends

Connect the I²C Output of the PowerLab to the I²C Input of the front-end using the I²C cable provided. Figure 13–3 shows how to connect up a single front-end to your recording unit.
Check that the connectors for the I²C bus are screwed in firmly. Check the BNC cable for firm connections as well. Loose connectors can cause erratic front-end behavior, or may cause the front-end to fail to work at all. The BNC cable can be tucked under the front-end to keep it out of the way if desired.

**Multiple Front-ends**

The Stimulus Isolator connects to and uses the positive analog output of the PowerLab as a source for producing pulses, so only one front-end of this nature can be used per PowerLab. However, multiple front-ends can be connected to PowerLab system. The number of standard front-ends that can be connected depends on the number of analog input channels on the PowerLab, since each front-end normally requires connection to one of the positive analog input channels of the PowerLab to operate. The initial front-end should be connected with an I²C cable as in Figure 13–3.

The remainder are daisy-chained via I²C cables, connecting the I²C Output of the previous connected front-end to the I²C Input of the next front-end to be added (Figure 13–4).

The I²C Bus can control up to a maximum of sixteen front-ends (depending on the PowerLab model). If you are using a PowerLab 16/30, which has sixteen analog inputs, you can use up to fifteen single-channel front-ends in addition to the Stimulus Isolator (representing a total of sixteen front-ends).
Software Behavior

When the Stimulus Isolator is properly connected to the output the Stimulator dialog displays the Stimulus Isolator checkbox, which is selected and disabled.

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

The Stimulus Isolator dialog

The Stimulus Isolator provides software-controlled, isolated, constant-current pulse stimuli that can be used with human subjects. The stimulus is produced at the outputs on the front panel of the Stimulus Isolator. The stimulus is independent of the PowerLab sampling rate and can be generated whether the PowerLab is sampling or not. The stimulus is set up using the Stimulator dialog.

Choose **Setup > Stimulator....** to display the Stimulator dialog (Figure 13–5). When setting up the Stimulus Isolator, you can:

- Choose how stimulation should start.
- Choose a preconfigured stimulus type or mode.
- Set stimulus parameters, such as start delay, pulse width and current amplitude.
Choosing How Stimulation Should Start

Stimulation can be set to start in different ways:

- When sampling starts: stimulation begins automatically when the LabChart Start button is clicked, and continues until sampling stops. Use the On and Off buttons to control pulse delivery, if necessary.
- Manually: stimulation begins when Stimulate in the dialog is clicked, and continues until sampling stops. Use the On and Off buttons to control pulse delivery, if necessary.
- Independently of sampling: stimulation begins when On in the dialog is clicked, whether or not LabChart is sampling. Available in LabChart for Windows only.

In all three modes, you can immediately restart a stimulus waveform by clicking Stimulate.

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

The Stimulator only offers the Isolated Pulse stimulation mode. This generates a rectangular pulse stimulus that starts at zero current, is raised to the set current amplitude for the set pulse width (duration), and then falls to zero current again. By default, the stimulator is off and the current amplitude is set to zero.

Creating a Custom Stimulus Waveform

You can:

- Specify whether parameter controls are displayed in the Stimulator and Stimulator Panel dialogs.
- Define a sequence of pulse segments to create a custom stimulus waveform.

Click **Custom...** to display the Waveform Customization dialog. Further details about using this dialog are available in the LabChart Help.

Setting Stimulus Parameters

You use the text boxes and sliders to set values for the stimulus parameters. In LabChart for Windows, you can use the Settings dialog for each parameter to configure the range of values available to the parameter text box and slider controls. Choosing a suitable range of values can improve the precision of control over the stimulus parameter when using the slider and spinner controls.

In LabChart, the following stimulus parameters can be set:

- **Start Delay**: the wait time before stimulation is delivered, once the stimulus waveform has been started.
- **Repeats**: the number of times the stimulus waveform is repeated, once started.
- **Max Repeat Rate**: the maximum frequency with which the stimulus waveform is repeated.
- **Pulse Width**: the duration of each pulse.
- **Current**: the amplitude of the stimulus current.
- **Pulses**: the number of pulses in the stimulus segment.
- **End Delay**: the wait time at the end of a stimulus segment, after which the next segment is delivered.

Marker Channel

If you choose a channel from the Marker Channel pop-up menu, then the start time of a stimulus pulse is marked by a small data spike (this adds to any data in that channel).

The Stimulator Panel

Once you have set up stimulation using the Stimulator dialog, you can easily start or stop stimulation (or change settings while sampling) by using the Stimulator Panel. Choose **Stimulator Panel** from the **Setup** menu to open it (Stimulus Isolator Panel on Macintosh).
The Stimulator Panel ‘floats’ in front of the active window, so can be moved around to a convenient position, and can only be dismissed by clicking its close box. You can specify which parameter controls are displayed in the panel using checkboxes in the Panel column of the Waveform Customization dialog.

Technical Aspects

The Stimulus Isolator has been designed to integrate fully into the PowerLab system. It requires connection to the PowerLab via a special communications connector called the I²C (eye-squared-sea) bus, and a BNC connector.

Stimulus Isolator Operation

The PowerLab usually provides control and low-voltage power to front-ends through the I²C bus. The Stimulus Isolator differs from other front-ends in some respects. Since it needs to produce a reasonably high voltage and current, the Stimulus Isolator has its own power supply in addition to the power for the control circuitry provided by the I²C bus. Front-ends are also usually connected through the analog inputs of the PowerLab but the Stimulus Isolator is not a signal conditioner; it produces stimulation voltage output and so it is connected to a positive analog output socket of the PowerLab. The overall operation of the Stimulus Isolator can be better understood by referring to Figure 13–8.
The output stage consists of a high-voltage constant-current source that can produce pulses of variable duration and amplitude under software control. The current source can deliver pulses up to 10 mA at 100-volt compliance levels; its amplitude is set by a digital attenuator network, which is in turn controlled by the I²C logic. The output to the subject is through high-isolation optical couplers.

Trigger pulses are delivered to the current source through optical isolation as well. Power for the stimulator current source is derived from the external AC wall transformer (plug pack) coupled through a custom isolation transformer, from which the isolated low voltage and 100-volt supplies are derived. The supplied power pack complies with medical safety requirements: under no circumstances should any other transformer be used in its place.

During operation an indicator light on the front panel lights green with every pulse (it will glow yellow if the Stimulus Isolator is out of compliance). A small internal beeper can also be enabled to give an audible beep with every pulse delivered.

The digital interface that controls pulse width and current amplitude uses an I²C interface system, and provides a 4-wire serial communication bus to the PowerLab and other front-ends. Signals from the bus also control the beeper. Also present on the connector is a set of power supply rails derived from the PowerLab, used to power the control circuitry of the Stimulus Isolator.
Troubleshooting

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

Most of the problems that users encounter are connection problems, and can usually be fixed by checking connections and starting up the hardware and software again. Very rarely will there be an actual problem with the front-end or the PowerLab itself.

Problems and Solutions

The status indicators fail to light when the software is started, or the front-end commands and so on do not appear where they should

The I²C cable or the BNC-to-BNC cable from the front-end to the PowerLab is not connected, has been connected incorrectly (to the wrong input or output, for instance), or is loose.

- Turn everything off. Check to see that all cables are firmly seated and screwed in. The BNC cable from the Stimulus Isolator must be connected to the positive output on the PowerLab (labelled + on most PowerLabs and Output 1 on /30 and /35 series PowerLabs). Restart the PowerLab and application to see if this has fixed the problem.

You are using an early version of LabChart.

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

The BNC or I²C cable is faulty.

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

The front-end is faulty.

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

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

The correct Stimulus Isolator driver is not installed on your computer.

- Reinstall the software.

You are using an early version of LabChart.

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

The BNC or I²C cable is faulty.

- Replace the cable and try again. Immediately label all cables proved faulty so that you don’t use them again by accident.
The front-end is faulty.

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

Some software settings don’t resemble those in this guide

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

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

The Stimulator Status indicator shows yellow

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

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

The impedance of the tissue could be too high for the Stimulus Isolator 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 Stimulator Status indicator does not flash green, or does not light up at all, even when there is an audible beep

The supplied 12-volt AC power supply to the Stimulus Isolator is not connected or is not switched on at the wall or is faulty.

- Close the LabChart application, connect up and turn on the power supply, and start up again.
- If the Status light still does not flash green (and does not light up at all), the 12-volt power supply may be faulty. Have a technician check the fuse and the electrical connections.
- Once you have established that it is not faulty, you should ensure that the output of the 12-volt power supply is indeed 12 volts – use a multimeter to measure this.

Specifications

Output

EMC: Approved to EN61326-1:2006 Standard
Connection type: Two shrouded 4 mm sockets
Configuration: Constant-current stimulator with hardware-limited repetition rate
Waveform: Rectangular, monophasic pulses with software-selectable pulse amplitude and duration

Isolation rating: \( 4000 \text{ V AC}_{\text{rms}} \) for 1 minute

Safety indicators: A single, multi-color indicator displays the isolated stimulator status. A green flash indicates delivery of a valid stimulus. A yellow flash indicates an out-of-compliance condition (OOC)

Safety switch: Isolating On-Off switch flicks down to disconnect quickly

Compliance voltage: 100 V fixed

Current ranges: 100 µA, 1 mA, or 10 mA full scale

Current rise time: <1 µs (1 kΩ load @ 10 mA)

25 µs (100 kΩ load @ 0.5 mA)

Current fall time: <1 µs (1 kΩ load @ 10 mA)

25 µs (100 kΩ load @ 0.5 mA)

*Note: Rise and fall times are proportional to load resistance and capacitance. Unless otherwise specified, all specifications relate to 1 kΩ load resistance in parallel with 220 pF load capacitance at a current of 10 mA.*

Operating duty cycle: up to 20%

Resolution: 1% of full scale (1 µA, 10 µA, or 100 µA)

AC line leakage current: <200 nA p–p

Differential output noise: <1 µA rms

Output capacitance: ~70 pF (without cable)

Power source: Non-isolated circuitry supplied by PowerLab via I^2^C connection.

Isolated and high-voltage circuitry derives power from the external 12 V AC, 300 mA_{rms}, wall-plug transformer (product code: SP0108). High-voltage isolation is provided by an internal isolation transformer. No batteries required.

**Pulse control (internal pulse duration control)**

Pulse duration range: 0.01 ms (10 µs) to 2.56 ms in 0.01 ms steps

Duration accuracy: ± 0.01% +5/-0 µs

Repetition rate: Up to 2000 Hz

Repetition accuracy: ± 0.1% (determined by PowerLab)

Current rise delay: 12–22 µs (variable)
Control Port

I²C port: Provides control and power. Interface communications rate of ~50 kbits/s.

Physical Configuration

Dimensions (h × w × d): 55 mm × 120 mm × 260 mm (2.2" × 4.7" × 10.2")
Weight: 1.3 kg (2 lb 15 oz)
Operating temperature range: 5–35 °C
Operating humidity range: 0–90% (non-condensing)

*ADInstruments reserves the right to alter these specifications at any time.*
Chapter 5

Warranty

**Product Purchase and License Agreement**

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

**Responsibilities**

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

**ADI Product Hardware Warranty**

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

To obtain service under this warranty, the Purchaser must notify the nearest ADI office, or Authorized Representative, of the defect before the warranty expires. The ADI or Representative office will advise the Purchaser of the nearest service center address to which the Purchaser must ship the defective product at his or her own expense. The product should be packed safely, preferably in its original packaging. ADI will pay return shipping costs.
Hardware Warranty Limitations
This warranty applies only to the ADI hardware specified in this document and used under normal operating conditions and within specification. Consumables, electrodes and accessories are not covered by this warranty. Third party equipment may be covered by the third party manufacturer’s warranty. To the extent that ADI has the right to pass through any third party manufacturer warranties to Purchaser it will do so to the extent it is able to do so. Copies of applicable third party manufacturer warranties, to the extent they exist, are available upon request. The warranty provided hereunder does not cover hardware modified in any way, subjected to unusual physical, electrical or environmental stress, used with incorrectly wired or substandard connectors or cables, or with the original identification marks altered. Tampering with or breaking of the Warranty Seal will also void the warranty.

Product Types & Warranty Term

ADI manufactured products covered by a five (5) year warranty
1 Data Acquisition Units: PowerLab 35 series with PL prefix
2 Front-ends: ADI Front-end Signal Conditioners with FE prefix.

ADI manufactured products covered by three (3) year warranty
3 Data Acquisition Units: PowerLab 26 series with ML prefix
4 Front-ends: ADI Front-end Signal Conditioners with ML prefix.

ADI manufactured products covered by one (1) year warranty
5 Pods: The entire range of ADI Pod Signal Conditioners.
6 Specialized Data Recorders: Metabolic Systems (e.g., ML240 PowerLab/8M Metabolic System)
7 Instruments: Blood FlowMeter, Gas Analyzers, NIBP System (excluding transducers), STH Pump Controller.

Third Party Products (Including Transducers)
Products not manufactured by ADI are covered by the manufacturer’s warranty.

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

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

EXCEPT FOR THE EXPRESS WARRANTY SET FORTH HEREIN, THE SOLUTION AS WELL AS ALL EQUIMENT AND SOFTWARE PROVIDED HEREUNDER ARE PROVIDED “AS IS” AND ADI MAKES NO WARRANTY. AS TO ITS USE OR PERFORMANCE. EXCEPT FOR ANY WARRANTY, CONDITION, REPRESENTATION OR TERM THE EXTENT TO WHICH CANNOT BE EXCLUDED OR LIMITED BY APPLICABLE LAW, ADI AND ITS SUPPLIERS MAKE NO WARRANTY, CONDITION, REPRESENTATION, OR TERM (EXPRESS OR IMPLIED, WHETHER BY STATUTE, COMMON LAW, CUSTOM, USAGE OR OTHERWISE) AS TO ANY MATTER INCLUDING, WITHOUT LIMITATION, NON INFRINGEMENT OF THIRD PARTY RIGHTS, MERCHANTABILITY, INTEGRATION, OR FITNESS FOR A PARTICULAR PURPOSE. YOU ASSUME RESPONSIBILITY FOR SELECTING THE SOLUTION TO ACHIEVE YOUR INTENDED RESULTS, AND FOR THE INSTALLATION OF, USE OF, AND RESULTS OBTAINED FROM THE EQUIPMENT AND SOFTWARE. WITHOUT LIMITING THE FOREGOING PROVISIONS, ADI MAKES NO WARRANTY THAT THE EQUIPMENT OR SOFTWARE WILL BE ERROR-FREE OR FREE FROM INTERRUPTIONS OR OTHER FAILURES OR THAT THE SOFTWARE OR EQUIPMENT WILL MEET YOUR REQUIREMENTS. UNDER NO CIRCUMSTANCES AND UNDER NO LEGAL THEORY, WHETHER IN TORT, CONTRACT, OR OTHERWISE, SHALL ADI OR ITS SUPPLIERS BE LIABLE TO PURCHASER OR TO ANY OTHER PERSON FOR LOSS OF PROFITS, LOSS OF GOODWILL, OR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, OR DAMAGES FOR GROSS NEGLIGENCE OF ANY CHARACTER INCLUDING, WITHOUT LIMITATION, DAMAGES FOR LOSS OF GOODWILL, WORK STOPPAGE, COMPUTER FAILURE OR MALFUNCTION, OR FOR ANY OTHER DAMAGE OR LOSS. IN NO EVENT SHALL ADI OR ITS SUPPLIERS BE LIABLE FOR ANY DAMAGES IN EXCESS OF THE PRICE PAID FOR THE EQUIPMENT AND SOFTWARE, EVEN IF ADI, OR ITS AUTHORIZED PARTNERS OR SUPPLIERS HAVE BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

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

**Controlling Law and Severability**

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

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

Inquiries

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