GALVANIC SKIN RESPONSE AMPLIFIER

Owner's Guide

ADINSTRUMENTS
making science easier

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Chapter 1

Safety Notes

Statement of Intended Use

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

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

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

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

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

Safety and Quality Standards

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

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

Quality Management System ISO 9001:2008

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

Regulatory Symbols

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

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

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

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

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

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

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

Further information is available on request.

Safety Standards

IEC Standard - International Standard - Medical Electrical Equipment

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

General Safety Instructions

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

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

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

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

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

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

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

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

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

Earthing and Ground Loop Noise

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

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

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

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

Cleaning and Sterilization

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

Inspection and Maintenance

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

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

WEEE Directive symbol

Environment

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

Disposal

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

Chapter 2

Overview

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

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

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

Introduction

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

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

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

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

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

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

Checking the Front-end

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

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

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

Connecting to the PowerLab

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

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

Single Front-ends

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

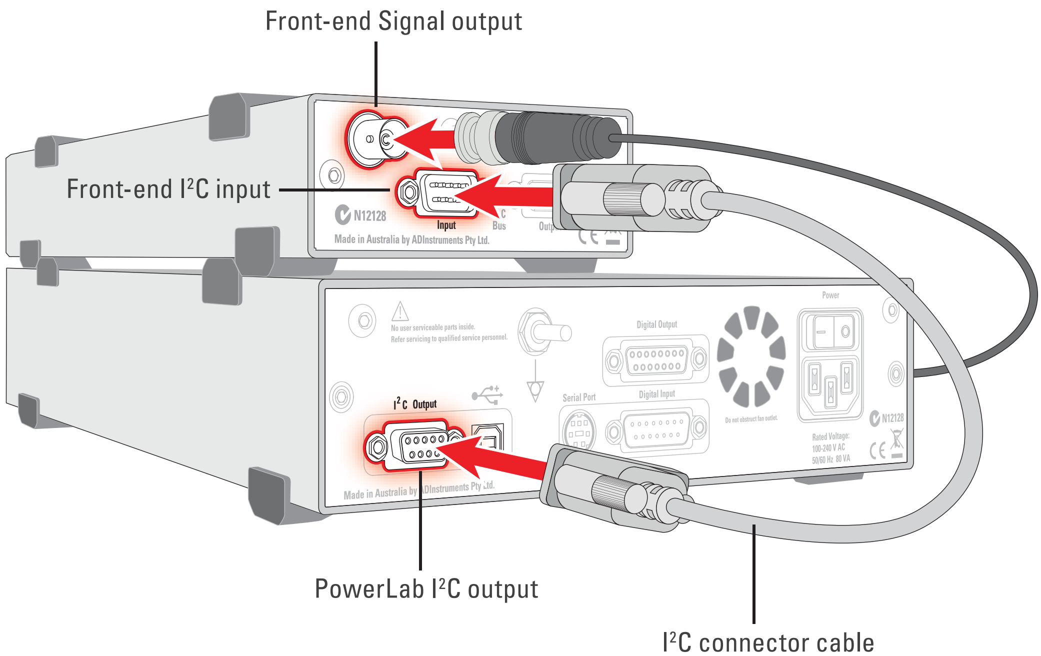


Figure 2–1 Connecting a front-end to the PowerLab: a PowerLab has only one I^2C output, and each front-end has one I^2C output and one I^2C input

Check that the connectors for the I^2C bus are screwed in firmly. Check the BNC cable for firm connections as well. Loose connectors can cause erratic front-end behavior, or may cause the front-end to fail to work at all.

The Signal Output Socket

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

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

Multiple Front-ends

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

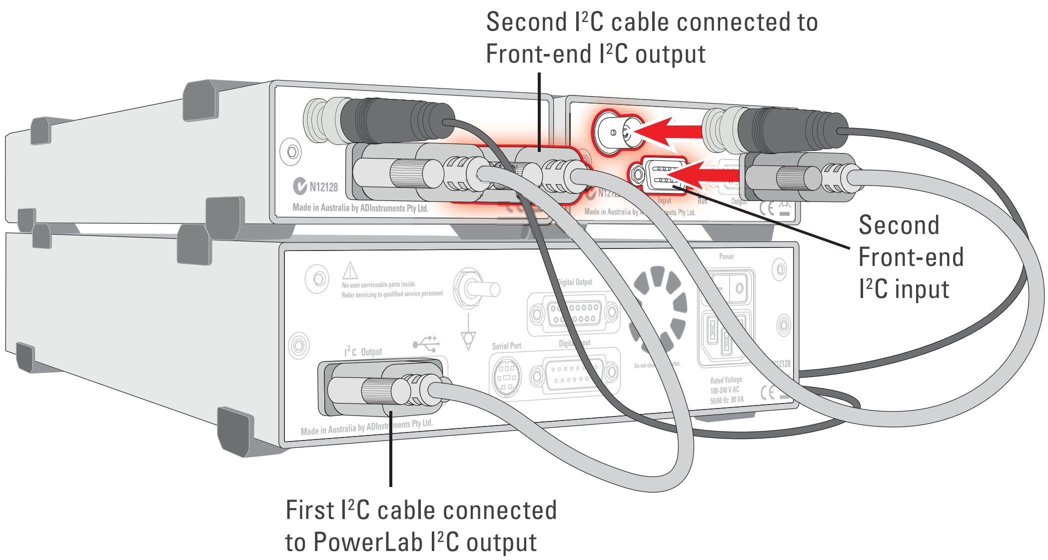


Figure 2–2 Connecting multiple front-ends to the PowerLab (two single front-ends shown for simplicity)

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

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

Special Cases

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

Connecting Stimulator Front-Ends

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

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

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

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

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

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

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

Maximum Number of Front-Ends

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

Using ADInstruments Programs

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

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

Front-end Drivers

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

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

The Front-end Self-test

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

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

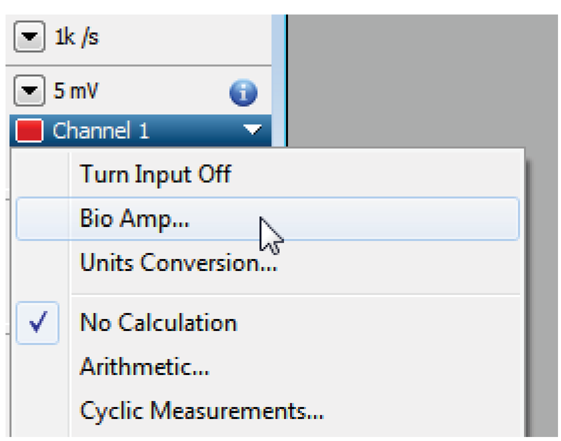
If the indicator lights correctly, the front-end has been found by the PowerLab and is working properly. If the indicator doesn't light, check your cable connections and repeat the start-up procedure.

Software Behavior

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

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

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



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

Preventing Problems

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

Aliasing

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

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

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

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

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

Frequency Distortion

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

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

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

Saturation

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

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

Ground Loops

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

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

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

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

Mains filter

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

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

The filter should not be used when:

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

Electrode Contact

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

Motion Artifacts

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

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

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

Chapter 3

GSR Amp

The FE116 GSR Amp is one of a family of modular devices called front-ends, designed to extend the capabilities of the PowerLab system. Each provides full electrical isolation. This chapter describes the basic features of the GSR Amp and discusses some aspects of its use.

The GSR Amp is designed to provide a fully subject-isolated amplifier for measurement of skin conductivity, in particular the Féré effect, which is the change in skin conductivity when a subject is stimulated. This is also known as the galvanic skin response (GSR), and gives a general measure of autonomic nervous system activity.

Measurement is displayed in SI conductance units (siemens), and absolute conductivity of up to 100 µS (microsiemens) can be measured. Low, constant-voltage AC excitation allows enhanced safety and the use of dry electrodes, with no special electrolytes needed.

The GSR Amp

The GSR Amp provides a fully subject-isolated amplifier for measurement of skin conductivity, in particular the change in skin conductivity in response to stress or anxiety known as the galvanic skin response (GSR). This gives a general measure of autonomic nervous system activity.

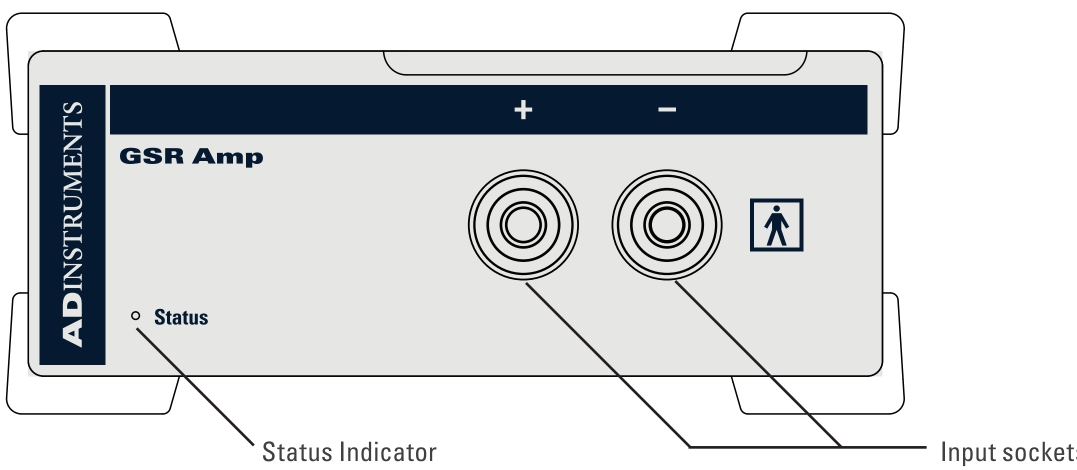
Measurement is displayed in SI conductance units (siemens), and absolute conductivity of up to 100 µS (microsiemens) can be measured. Low, constant-voltage AC excitation allows enhanced safety and the use of dry electrodes, with no special electrolytes needed.

The rest of this chapter contains general information about the features, connections and indications of the GSR Amp. It also looks at signal measurement for GSR. There is more detailed information in the technical section.

The Front Panel

The front panel of the GSR Amp is simple, with a pair of input connectors for bipolar electrodes and a small indicator light.

Figure 3–1
The front panel of the GSR Amp



The Status Indicator

The status indicator light is at the bottom left of the front panel. When an ADInstruments program opens, the status indicator flashes briefly and then remains green, indicating that the program has found the front-end, checked and selected it, and it is ready for use. If it does not light up when the program is open, this indicates a problem with the connection, the software or the hardware.

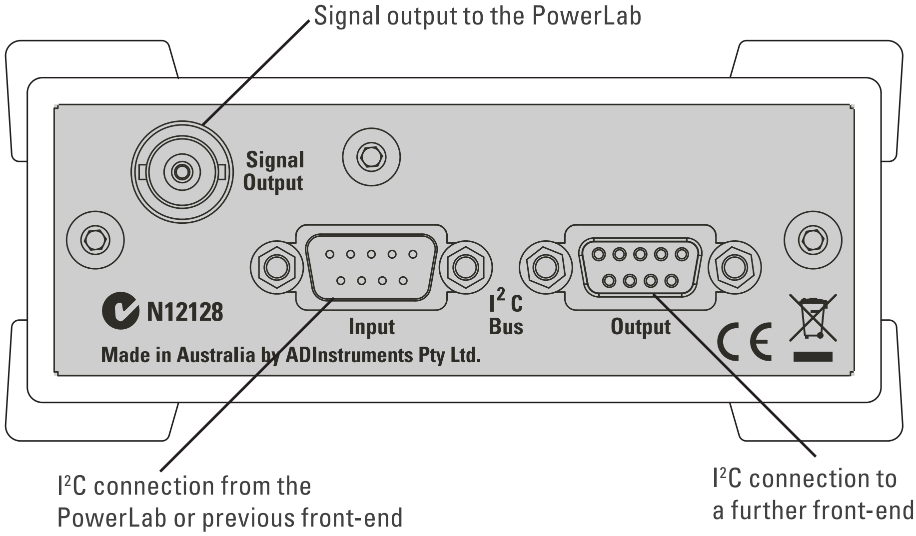
The GSR Amp Input Sockets

Connections are made to the GSR Amp using two 4 mm shrouded banana sockets, similar to sockets found on many digital multimeters, and are designed to be used with shrouded male 4 mm plugs. A cable with these plugs is supplied with the GSR Amp. These provide very low-voltage and low-current AC excitation to measure conductance. As the GSR Amp uses AC excitation, polarity of the connections is not important. The input connections are isolated internally by circuitry.

The Back Panel

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

Figure 3–2
The back panel of the GSR Amp



I^2C Input and Output Sockets

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

The Signal Output Socket

The BNC socket labelled Signal Output on the back panel 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.

Connecting to the PowerLab

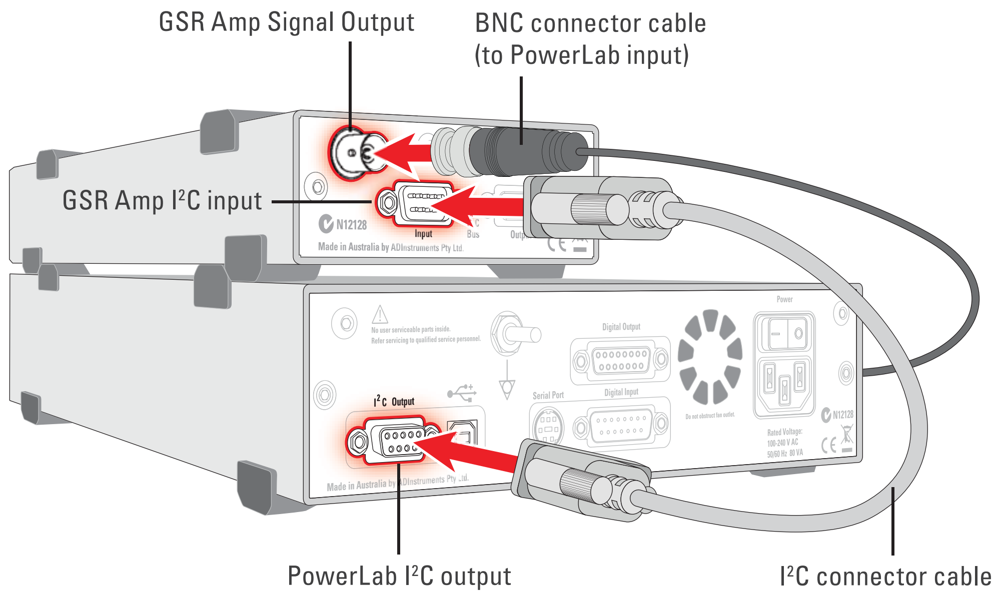
To connect a front-end, such as your GSR Amp, to the PowerLab, first ensure that the PowerLab is turned off. Failure to do this may damage the PowerLab, the front-end, or both.

The BNC cable from the GSR Amp signal output must connect to an analog input on the PowerLab, for example, Input 1 on a /30 series PowerLab. If you have an older model PowerLab with differential (rather than single-ended) inputs, the BNC cable must connect to a *positive* analog input on the PowerLab.

Single Front-ends

Connect the I^2C output of the PowerLab to the I^2C input of the GSR Amp front-end using the I^2C cable provided. Figure 8–3 shows how to connect the GSR Amp to your PowerLab.

Figure 3–3
Connecting a GSR Amp to the PowerLab



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.

Multiple Front-ends

Multiple separate front-ends can be connected up to a PowerLab. The number of normal front-ends that can be connected depends on the number of (positive) input channels on the PowerLab, since each BNC cable from a front-end is connected to one of the analog inputs on the PowerLab. Only one front-end such as a Stimulus Isolator can be connected to the (positive) output of the PowerLab.

The initial front-end should be connected with the I²C cable as in Figure 8–3. The remainder are daisy-chained via I²C cables, connecting the I²C output of the last connected front-end to the I²C input of the front-end to be added (see Figure 2–2 on page 11).

Using LabChart

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

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

The documentation for LabChart does not cover front-end-specific features. The GSR Amp dialogs for LabChart for Macintosh and LabChart for Windows are very similar and are described here together.

Note: You cannot start sampling in LabChart if a connected GSR Amp is not zeroed. Therefore, the first step is to zero the device.

The GSR Amp dialog

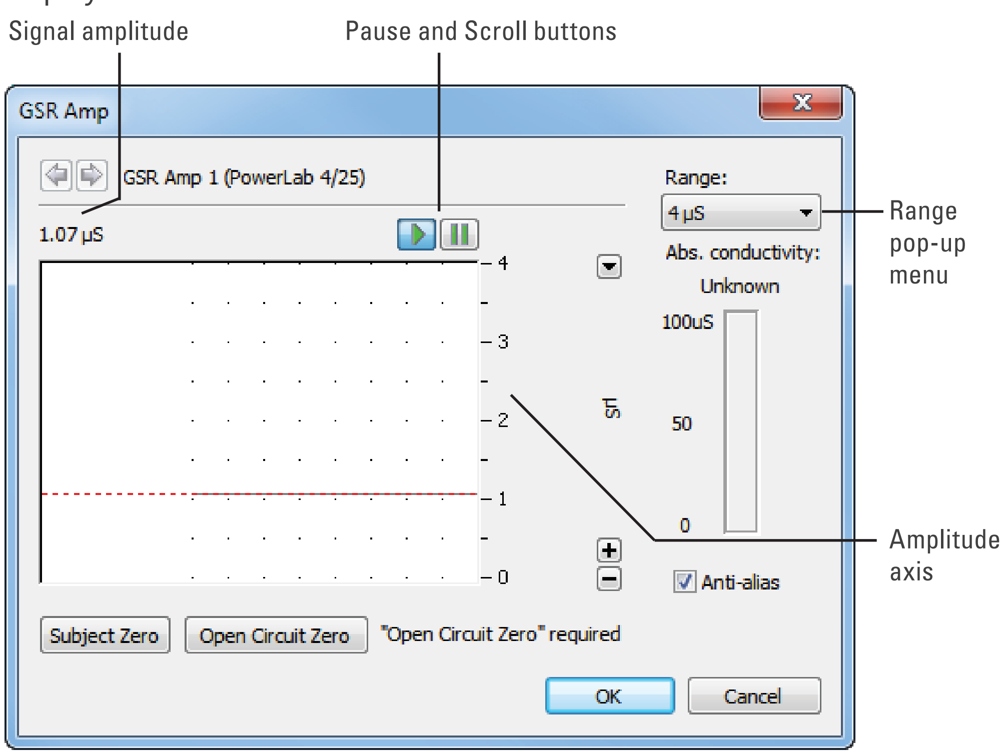
The GSR Amp dialog appears when you choose **GSR Amp…** from a Channel Function pop-up menu (or click **GSR Amp…** in the Input Settings column in the **Setup > Channel Settings…** dialog).

The GSR Amp dialog allows software control of the combined options from the circuitry of the PowerLab and GSR Amp. The signal present at a channel's input is displayed so you can see the effects of changing the settings. The GSR Amp is pre-calibrated and measures skin conductivity directly in µS (microsiemens). Once the GSR Amp is zeroed and settings have been changed, click **OK** to apply them.

Signal Display

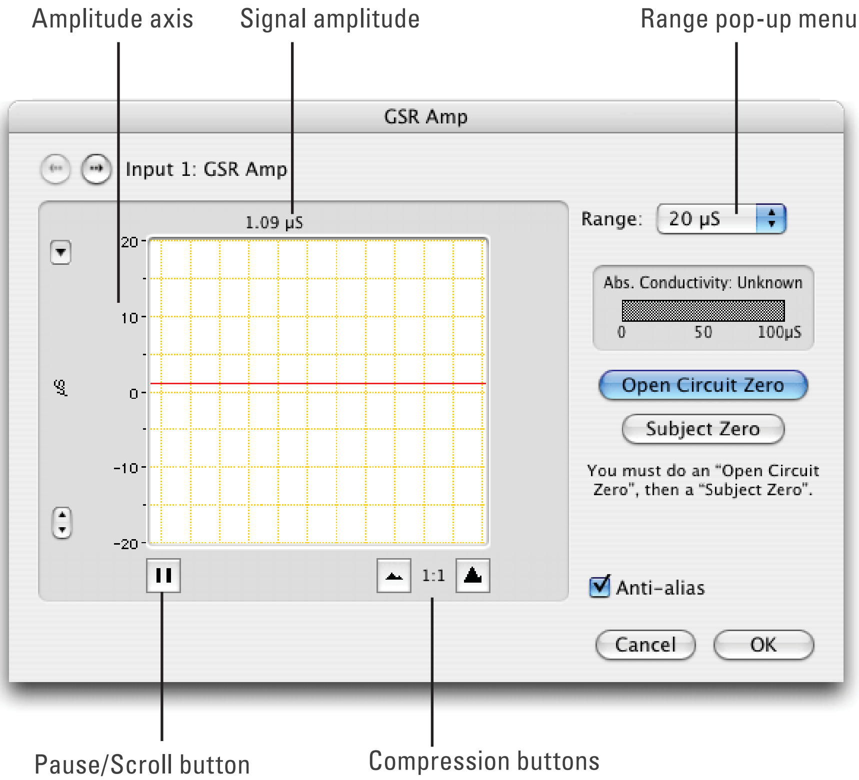
The input signal is displayed so you can see the effect of changing the settings — no data are recorded while you adjust the settings. The average signal value is shown above the display area.

Figure 3–4 The GSR Amp dialog for Windows (before an Open Circuit Zero)



You can stop the signal scrolling by clicking the Pause button at the bottom left (Macintosh) or top right (Windows) of the data display area. This changes to the Scroll button on the Macintosh. Click the Scroll button to start scrolling again. You can shift and stretch the vertical Amplitude axis to make the best use of the available display area. It functions the same as the Amplitude axis of the Chart window, and any change is applied to the Chart window.

Figure 3–5
The GSR Amp dialog for Macintosh (also before zeroing)



Setting the Range

The Range pop-up menu lets you select the input range or sensitivity of the channel. Changing the range in the GSR Amp dialog is equivalent to changing it in the Chart Window. There are six ranges: 1, 2, 4, 10, 20 and 40 µS. The default range is 4 µS.

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

Zeroing

Before measurements can be made with the GSR Amp, it must be zeroed: this is a two-stage process. A note next to the zeroing buttons indicates its status. If you try to start sampling before the GSR Amp has been zeroed, you will receive an alert and the GSR Amp dialog will appear, at which stage the system must be zeroed.

To zero the GSR Amp, first perform an open circuit zero by connecting up the cables and electrodes to the front-end, without connecting them to the subject. Ensure that the metal surfaces of the two electrodes do not touch each other, and then click **Open Circuit Zero**. The status note changes to indicate that subject zeroing needs to be done (the second stage). Connect up the subject (as described below), then click the **Subject Zero** button.

The subject zero gives an absolute measure of the skin conductivity of the subject, i.e. the baseline conductivity from which relative changes are measured. The absolute conductivity value is shown when everything is zeroed. Normal baseline conductivity values should be in the range of 10 to 50 µS, depending on the individual and the air humidity level (which affects skin conductivity). A scale measuring the change in conductivity (also in µS) is used for the final record. This scale corresponds to the GSR readout in a traditional polygraph.

Units

The GSR Amp measures conductivity directly in microsiemens (µS): units conversion is done once the GSR Amp is zeroed.

Equipment and Technique

Measurement of GSR

Electrical resistance decreases (and conductance increases) between two points on the skin when a subject experiences a stressful stimulus. This is known as the Féré effect, after its discoverer. Terms such as psychogalvanic reflex and skin conductance response have also been used to describe this effect. The modern term is galvanic skin response, or GSR.

The change in conductivity on stimulation is due to an increase in the activity of sweat glands, which provides a good general indicator of autonomic nervous system activity. The increased conductivity arises through increased skin moisture, pre-secretory activity of the sweat gland cell membranes, or both. The soles of the feet and palms of the hands, including the palmar surfaces of the fingers and the plantar surfaces of the toes, have the highest concentrations of these sweat glands (at least 2000 per cm^2, about ten times higher than elsewhere), and so provide the best places to measure GSR.

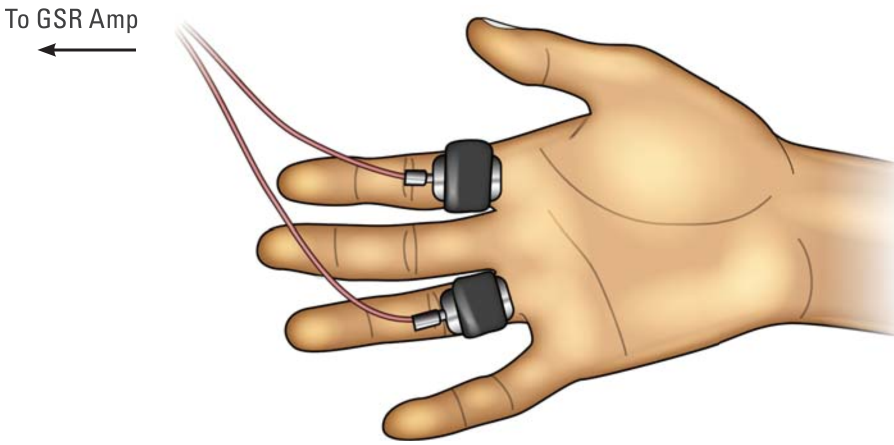
The latest recommendations for the preparation of skin are described in Boucsein et al., 2012. Skin preparation should consist of washing the hands *without* soap (it can cause swelling of the epidermis), followed by rinsing and thorough drying. Alcohol should *not* be used to clean the fingers as it penetrates and dries out the skin too much to allow reliable measurement. Skin abrasion is neither necessary nor desirable (it reduces sensitivity).

The electrodes supplied for use with the GSR Amp should be used with an electrode gel or paste that contains a chloride salt such as NaCl or KCl. NaCl-containing electrode gel is most commonly used, with concentrations in the range of 0.05–0.075 molar (0.3–0.4% by weight) — this approximates the concentration of NaCl in the sweat that reaches the epidermal surface.

The bipolar electrodes should be attached to the palmar surfaces of the fingers of one hand with the attachment straps, firmly but not tightly (see Figure 8–6). Normally, the middle segments (phalanges) of the first and second fingers are used, although you may want to use the first and third fingers to remove any chance of contact between the electrodes; consistent sites should be used in any event.

The subject should keep the hand still to avoid movement artifacts, and have a few minutes to relax, to establish good baseline conduction — you will need to perform a second subject zero before commencing measurement. The galvanic skin response to a stimulus or series of stimuli can then be measured, relative to the baseline conductivity.

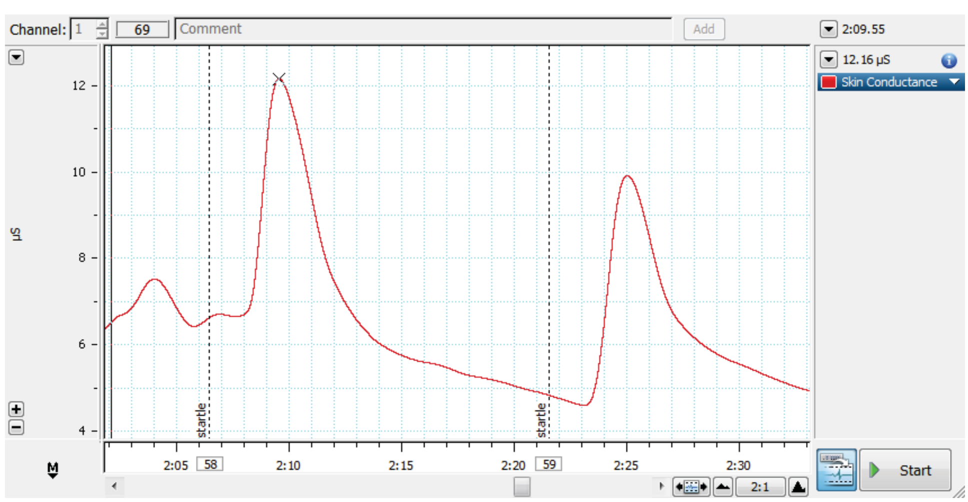
Figure 3–6
Connecting the electrodes to the subject: the GSR Amp uses AC excitation, so the polarity of the connections is unimportant



Increased arousal due to physical or emotional stimuli increases conductivity. Typically, there is a short time lag, followed by a sharp increase and an exponential decay to baseline level. The whole response may take up to 40 seconds, although the decay phase is highly dependent on the subject.

The response is not fast, so a recording speed of 4 samples per second is adequate for most purposes. Good stimuli for evoking the response include a sudden loud noise (as shown in Figure 8–7), or a full inhalation, two second breath hold, then full exhalation.

Figure 3–7
A typical GSR response to a startle stimulus, recorded from the palmar surface of the fingers



Technical Aspects

The following section describes some of the important technical aspects of the GSR Amp to give some insight into how it works. You do not need to know the material here to use a front-end. It is likely to be of special interest to the technically minded, indicating what a front-end can and cannot do, and its suitability for particular purposes.

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

GSR Amp Operation

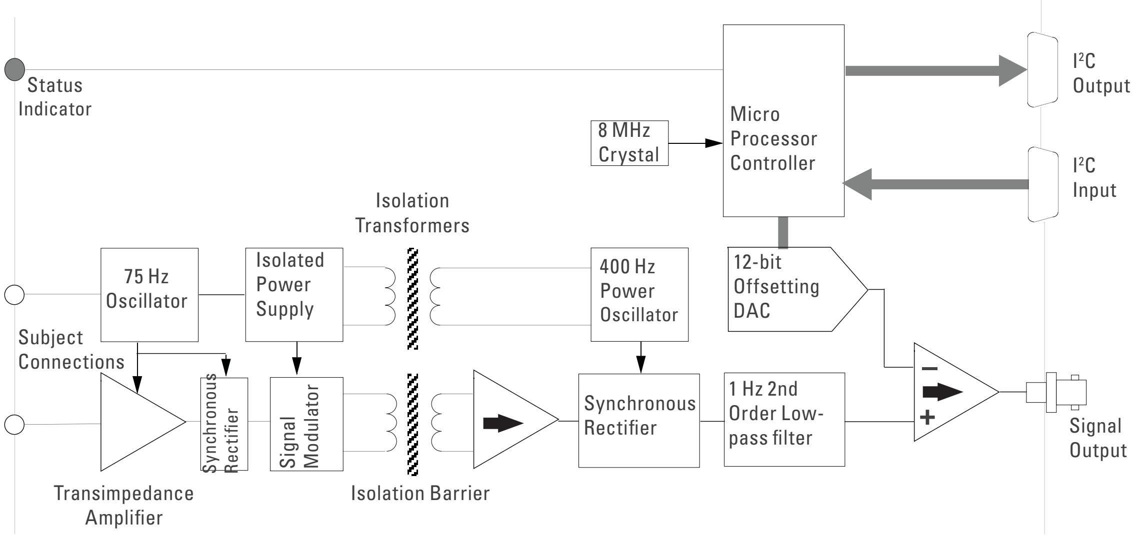
The GSR Amp and other ADInstruments front-ends have been designed to integrate fully into the PowerLab system. Each requires connection to the PowerLab via a special communications connector called the I^2C (eye-squared-sea) bus, and a BNC connector.

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

- full electrical isolation from power-line (mains) circuitry to guarantee subject safety
- measurement of the Féré effect, a general measure of autonomic nervous system activity, directly in SI conductance units (siemens)
- low, constant-voltage AC excitation (22 mV_{rms} @ 75 Hz) allows enhanced safety and the use of dry electrodes, with no special electrolytes needed
- measurement of absolute conductivity up to 100 µS (microsiemens).

The internal functions of the GSR Amp are controlled from the PowerLab through the I^2C bus, which also supplies power to the GSR Amp. The front-end is also connected to an analog input channel of the PowerLab via a BNC-to-BNC cable, through which the signal is sent. The overall operation of the GSR Amp can be better understood by referring to Figure 8–8.

Figure 3–8
Block diagram of the GSR Amp



The 75 Hz oscillator supplies a near-square wave, low-impedance, low-voltage signal (22 mV_{rms}) to an electrode on a finger of the subject. If the skin has measurable conductance (rather than behaving as an insulator), then current flows, from an electrode on another finger of the subject, into the very low impedance input of the transimpedance amplifier.

The transimpedance amplifier converts current to voltage. The current will change as the autonomic reflexes change the skin's conductivity. The resulting signal is passed through a synchronous rectifier to obtain a DC voltage proportional to skin conductance, then via a modulator to produce a 400 Hz AC signal suitable for passing across the isolation barrier (providing electrical protection for the subject).

On the other side of the isolation barrier, the AC signal is multiplied then synchronously rectified, restoring a DC voltage proportional to skin conductance. To reduce noise in the rectified signal, it is passed through a 1 Hz, second-order, low-pass filter, which leaves the general signal trends unchanged, but removes higher-frequency fluctuations. The signal at this point consists of the overall (baseline) skin conductivity plus a component representing the Féré effect changes, or galvanic skin response (GSR).

A precision ×1 instrumentation amplifier compares the signal with the output of the 12-bit digital-to-analog converter (DAC). The DAC provides an exact offset voltage for zeroing and offsetting of the synchronously demodulated and filtered signal. This ensures maximum signal-to-noise ratio, good zeroing resolution, and maximum resolution in the displayed signal. The DAC removes the constant baseline, allowing just the fluctuations to be observed.

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

Troubleshooting

This section describes most of the common problems that can occur when using the GSR Amp with your PowerLab recording unit. If the solutions here do not work, earlier chapters, the LabChart Help Center, and the guide to your PowerLab may contain possible remedies. 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 I^2C cable or the BNC-to-BNC cable from the front-end to the PowerLab is not connected, has been connected incorrectly (to the wrong input or output, for instance), or is loose.

- Turn everything off. Check to see that all cables are firmly seated and screwed in. BNC cables from the GSR Amp must be connected to a positive input on the PowerLab. Make sure the input is the same channel from which you expect to use the front-end in the software. After checking connections, 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 I^2C cable is faulty.

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

The front-end is faulty.

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

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

The correct BP/GSR drivers are not installed on your computer.

- Reinstall the software.

You are using an early version of LabChart.

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

The BNC or I^2C cable is faulty.

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

The front-end is faulty.

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

Some software settings don't resemble those in this guide

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

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

Specifications

Input

Connection type:	2 × 4 mm shrouded sockets. Custom cable with two shrouded banana plugs and terminated with two dry, bright-plated, bipolar electrodes with Velcro™ attachment strap suitable for adult fingers.
Excitation:	Constant-voltage AC excitation
	(22 mV_{rms} @ 75 Hz)
Current density:	0.5 µA .cm^{-2}
Safety:	Approved to IEC 60601-1 Standard (BF rating)
EMC:	Approved to EN61326-1:2006 Standard
Configuration:	Transformer isolation (AC bridge operation)
Isolation rating:	4000 V AC_{rms} for 1 minute
Input ranges:	1–40 µS full scale in 6 steps
	(combined PowerLab and GSR Amp)
	0–40 µS
	0–20 µS
	0–10 µS
	0–4 µS
	0–2 µS
	0–1 µS
Frequency response:	–3 dB at 1 Hz
Accuracy:	± 5%
Input leakage current:	< 3 μA_{rms} at 240 V, 50 Hz
	< 2 μA_{rms} at 120 V, 60 Hz
Zeroing and offset:	Automatic software-controlled fast zeroing, controlled by internal 12-bit DAC; resolution = ± 0.2 µS

Output

Signal:	± 2.0 V full scale: suitable for PowerLab

Control Port

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

Physical Configuration

Dimensions (h × w × d):	55 mm × 120 mm × 260 mm (2.2" × 4.7" × 10.2")
Weight:	1.2 kg (2 lb 10 oz)
Power requirements:	2.5 W max
Operating conditions:	5–35 °C
	0–90% humidity (non-condensing)

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

Chapter 4

Warranty

Product Purchase and License Agreement

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

Responsibilities

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

ADI Product Hardware Warranty

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

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

Hardware Warranty Limitations

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

Product Types & Warranty Term

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

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

ADI manufactured products covered by three (3) year warranty

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

ADI manufactured products covered by one (1) year warranty

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

Third Party Products (Including Transducers)

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

Accessories and Consumables

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

General Limitations

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

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

Inquiries

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