

AD Instruments

Metabolic System Owner's Guide

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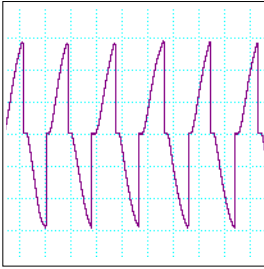
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Product intention

The ADInstruments PowerLab/8M has been designed for use in student teaching and research environments only. This product has not been designed for clinical exercise testing or pulmonary function testing and should never be used for this purpose.

Applicable safety standards

ADInstruments PowerLab/8M has been designed for safe connection to humans using the Bio Amplifier Input and cable. Considerable design effort has been undertaken to make sure that this unit conforms to international patient safety requirements. Specifically the PowerLab/8M has been designed to conform to the requirements of IEC601.1 – “General Requirements for Safety for Medical Electrical Equipment”, and various harmonized standards worldwide (UL2601.1 in the U.S.A., CAN/CSA-22.2 No 601.1 in Canada and AS/NZS3200.1 in Australia and New Zealand). In accordance with Australian, New Zealand and European requirements this system also complies with the EMC requirements of IEC601.1.2 (Class II) - Electromagnetic Compatibility under the European Directive (89/336/EEC) - the EMC Directive.

DO NOT attempt to repair any part of this equipment. Repairs must be undertaken by ADInstruments trained personnel only.

This instrument can be adversely affected by the presence of imaging equipment, such as MRI (Magnetic Resonance Imaging) and CT (Computerized Tomography) devices. Do not use the PowerLab/8M in these environments.

General safety instructions

- The PowerLab/8M is classified as Class I medical equipment. This means that protection against electric shock in the event of a fault relies on a direct connection through the power cable to your building’s earth conductor. The power cable supplied with your PowerLab/8M provides the required ground connection to the power outlet. If your building does not have power outlet sockets with a good ground connection then you may use the

equipotential connection located at the rear or the PowerLab to provide the ground connection to the buildings earth conductor. The ground connection is an essential part of this equipment's safety. Never use the PowerLab/8M without a ground connection.

- The PowerLab should always be fitted with the recommended fuses for safe operation. Refer to the end of Chapter 2 for specific information on fuse types and replacement.

Bio Amplifier safety instructions

The Bio Amplifier input is electrically isolated from the mains supply in order to prevent current flow that could result in injury or death to the subject. Several points must be observed for the safe operation of this system.

- The Bio Amplifier is supplied with a 3 lead subject cable and lead wire system that meets the safety requirements of the IEC601.1 (see page 7) medical standard. This cable is fully insulated and is manufactured with special lead wire plugs to prevent accidental connection to power supply sockets. The Bio Amplifier is only qualified for human connection if used with the supplied cable and lead wires.
- The Bio Amplifier input is not defibrillator protected. Recording signals during defibrillator discharges may damage the inputs of the PowerLab/8M. This may result in a potential safety hazard.
- Subjects, patient cables and lead wires should be kept well away from power supply cabling. This will also help reduce power supply interference in the recorded signals.
- Never use damaged patient cables or lead wires. Damaged cables should always be replaced before any connection to humans is carried out.

Symbol explanation

The PowerLab/8M system carries a set of safety symbols next to the various input and output connectors:



BF Protected (body protected). This connection is suitable for direct non-cardiac connection to humans.



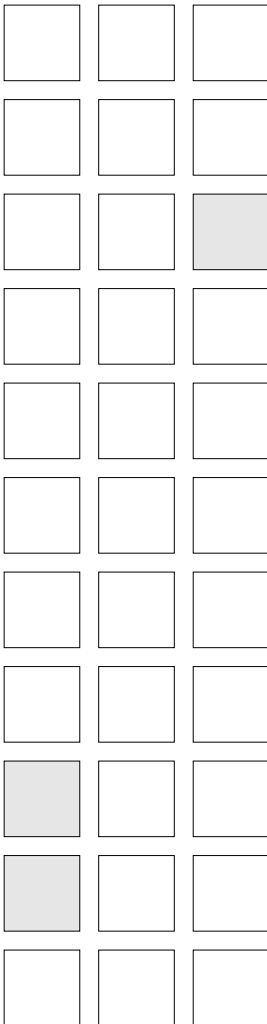
CE Mark



Earth Symbol

1

Introduction



The Metabolic System consists of the PowerLab/8M recording unit and other hardware components, and the Chart and Metabolic Module software, which is used to record parameters from the PowerLab/8M and to calculate and display ventilatory parameters in real time.

Overview of the Metabolic System

The Metabolic System is designed to record and display continuous real-time measurements of metabolic parameters.

The Metabolic System has hardware and software components. The hardware components include a PowerLab/8M recording unit and the MLA245 Gas Mixing Chamber, as shown in Figure 1-1. The software components include the Chart Application and the Metabolic Module provided on the installer CDs. Chart and Metabolic work together to enable the recording and analysis of metabolic parameters in real time.

Overview of setup

Setting up the Metabolic System in preparation for recording involves the following the steps:

1. Unpacking the system and checking the PowerLab/8M and other hardware components.
2. Installing the software on your computer.
3. Connecting together the hardware components (PowerLab/8M, flow head, gas mixing chamber), and connecting to the computer.
4. Setting up the software (Chart and the Metabolic Module).
5. Calibrating the gas analyzers and the flow head.

The first two steps are covered in this chapter. Step 3 is covered in Chapter 2. Steps 4 and 5 are covered in Chapter 3 for the Windows operating system, and in Chapter 4 for the Macintosh operating system.

System components

When you unpack the Metabolic System, you should find all of the components shown below in Figure 1–1.

Figure 1–1

Components of the Metabolic system, labeled as in Table 1–1. Individual items are not all to the same scale or perspective.

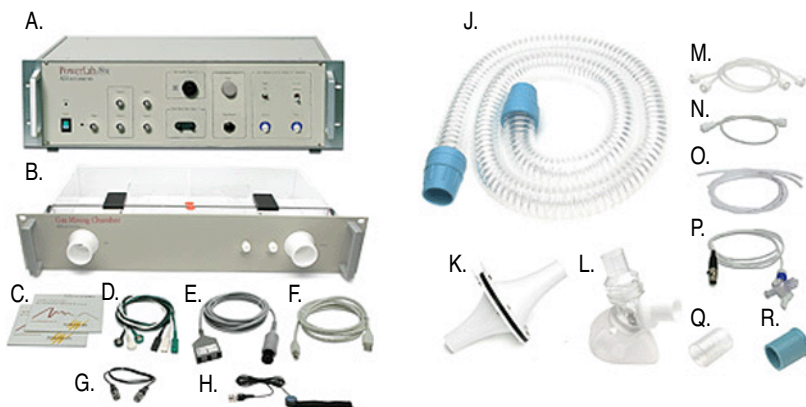


Table 1–1

Components of the Metabolic system. Labels refer to Figure 1–1.

<i>Label</i>	<i>Component</i>
A	PowerLab/8M recording unit
B	MLA245 Gas Mixing Chamber
C	Chart and Metabolic Module software on 2 x CD-ROM
D	MLA2503 3-pack shielded lead wires for MLA2340 Bio Amp cable
E	MLA2340 Bio Amp cable
F	USB cable
G	BNC cable
H	MLT1010 Finger pulse transducer
MLA240 Metabolic Accessory Kit containing:	
J	MLA1015 Breathing Tube
K	MLT1000L Respiratory Flow Head
L	MLA1028 Face Mask
M	Connector tubing with Luer fittings
N	MLA0343 Drying Tube
O	2 x silicone tube (1 mm ID, 30 cm length)
P	Temperature Probe with stopcock
Q	MLA1013 35 mm ID Tubing Adaptor
R	MLA1081 Flow Head Adaptor
not shown	MLA6024 Desiccant Cartridge

Checking the components

Before connecting up the PowerLab/8M or other components, follow the four steps below:

1. Check that all items on the packing list are included in the box. Inspect each item carefully for signs of physical damage.
2. Inspect the outside of the PowerLab/8M for obvious signs of damage to the casing.
3. Check that the correct voltage for your country is shown on the back of the PowerLab/8M. The setting is indicated on the label at the right of the back panel (Figure 2–3), beneath the power switch.
4. Perform the PowerLab/8M self test as described below.
5. Read this Owner's Guide.

If you have found a problem, contact your authorized PowerLab dealer, and describe the problem so arrangements can be made to replace or repair the unit.

PowerLab/8M self test

This section describes the self test performed by the PowerLab unit every time it is switched on. Have the PowerLab connected to a power outlet with the power cord, and switched on at the rear.

When you switch on the PowerLab/8M at the front panel, you should see the green Power indicator illuminate. If this does not light up, check that the system is connected correctly to the power outlet, that the power cable is pushed in firmly to the rear socket, and that the unit is turned on both at the rear and at the front. Lastly, check the fuses.

On start-up, the Status indicator flashes orange four times. This indicates a successful start up and, if using SCSI, that the SCSI ID switch is set to four. When Chart is communicating with the unit (during recording), the Status indicator flickers orange. The idle state is indicated by a green light. Status indicator messages are listed in Table 1–2.

Table 1–2

Status indicator messages for the PowerLab/8M.

<i>Status Indicator</i>	<i>Meaning</i>
Orange flashes	When the PowerLab is turned on, the indicator flashes orange a number of times equal to the SCSI ID number. For example, 4 orange flashes would indicate a SCSI ID number of 4.
Green constant	Idle.
Orange constant or flicker	Active (communicating, processing, or sampling).
Orange flash, separated by red flashes	An error has been detected during self-testing. This display will keep repeating until the power to the PowerLab is turned off.

For the most part, Status indicator messages are useful when moving and reconnecting equipment to ensure that the software is communicating with the hardware. Only rarely is a hardware error indicated. Hardware errors are indicated by red flashes. If this occurs, record the sequence indicated by long and short flashes, and report it to your authorized PowerLab distributor.

Software

Chart software is used to control and display the data recorded by the Powerlab/8M. The Metabolic Module for Chart is used to calculate and display respiratory parameters. The latest versions of the module require Chart 5 (supplied), but versions that work with Chart 4 are also supplied.

Installation

Note that there are two software components that need to be installed in order to use the Metabolic System. These are the Chart Application and the Metabolic Module. Versions of both of these are provided for the Windows and the Macintosh operating systems.

The software supplied with the Metabolic System comes on two CDs:

- **Software Installer CD (installs Chart 5).** Use this first, unless you already have a version of Chart with which to run Metabolic. In that case, skip Part 1 in the instructions below.
- **Metabolic Module CD.** Use this second.

Windows

Part 1

1. Put the CD labeled 'Software Installer' in your CD-ROM drive.
2. The installer should auto-run. (If not, locate the CD-ROM in Windows Explorer and double-click Startup.exe at the top level.)
3. In the Installer window, click the button appropriate to your preferred language version.
4. Click the Install button. A dialog box tells you when everything is installed — exit the installer.

Part 2

1. Put the CD labeled 'Metabolic Module' in your CD-ROM drive.
2. The installer should auto-run. (If not, locate the CD-ROM in Windows Explorer and double-click Startup.exe at the top level.)
3. Click a button to choose Metabolic for Chart 5 or Metabolic for Chart 4, as appropriate.
4. Click the Install button. A dialog box tells you when everything is installed — exit the installer.

Macintosh

Part 1

1. Put the CD labeled 'Software Installer' in your CD-ROM drive.
2. At the top level of the CD, double-click the Chart Installer icon.
3. Read the information in the installer, and click Continue.
4. Click the Install button. A dialog box tells you when everything is installed — quit the installer.

Part 2

1. Put the CD labeled 'Metabolic Module' in your CD-ROM drive.
2. To install the Metabolic Module for Chart 5, double-click the Metabolic(5) Installer icon. To install the Metabolic Module for Chart 4, double-click the Metabolic(4) Installer icon.
3. Read the information in the installer, and click the Install button. A dialog box tells you when everything is installed — quit the installer.

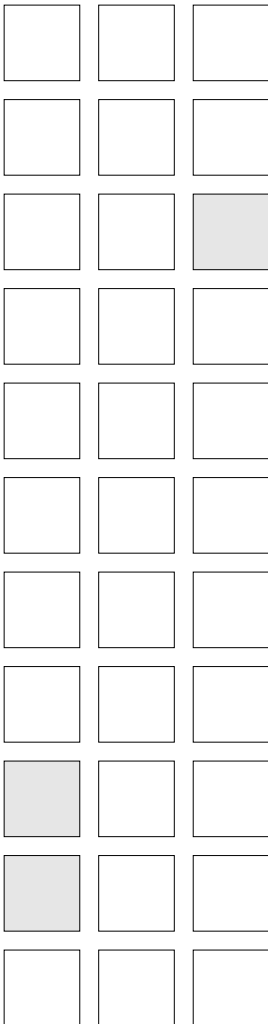
Settings files

A Metabolic settings file is provided on the Metabolic Module Installer CD. For both the Windows and Macintosh platforms, the Metabolic settings file will have been installed inside a folder called Metabolic, inside the Chart folder, when the Metabolic Module was installed. The settings file provides suitable range and units conversion settings for using the Metabolic Module with Chart and the PowerLab/8M.

You use this settings file by simply opening the file. A quick way to do this is by double-clicking on the file from its location. Opening the settings file will automatically open a new Chart document with all the settings applied. This new file should be saved with a new name, to safeguard the original settings file. Before you record data into this new document, you should accurately calibrate the transducers.

2

Hardware



This chapter describes the integrated components of the PowerLab/8M recording unit and the other hardware components supplied with the Metabolic System.

The PowerLab/8M

The PowerLab/8M contains the following integrated components:

- Two general-purpose analog inputs
- Infra-red CO₂ and paramagnetic O₂ gas analyzers
- Temperature sensor
- Bio Amplifier
- Spirometer
- External trigger input
- Two stimulator outputs.

The other major supplied components are:

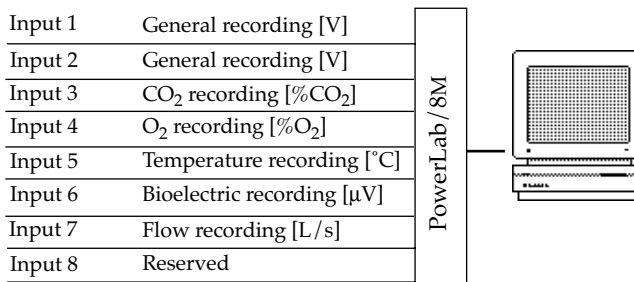
- MLA 245 Gas Mixing Chamber
- MLT 1000L Respiratory Flow Head
- MLA 1028 Face Mask
- MLT415 Temperature Probe.

The PowerLab/8M recording unit has seven recording inputs, a trigger input and two stimulator (analog) outputs:

- Inputs 1 and 2 are independent analog general-purpose recording channels
- Input 3 is a CO₂ respiratory gas analyzer channel
- Input 4 is a O₂ respiratory gas analyzer channel
- Input 5 is a thermistor connection and offset control for a temperature channel
- Input 6 is a biological amplifier input suitable for connection to human subjects for recording biological signals, such as ECG (EKG), EMG and EEG
- Input 7 is a differential pressure input for connection to respiratory flow heads for an air flow channel
- Trigger is a TTL timing trigger input
- Outputs 1 and 2 are stimulator or pulse (analog) outputs.

The PowerLab/8M can record continuously at fast sampling speeds and performs many tasks that are necessary during data acquisition. Data is transferred to the computer via a USB or SCSI communication cable. The data is available on the computer for display, manipulation, printing, storage and retrieval.

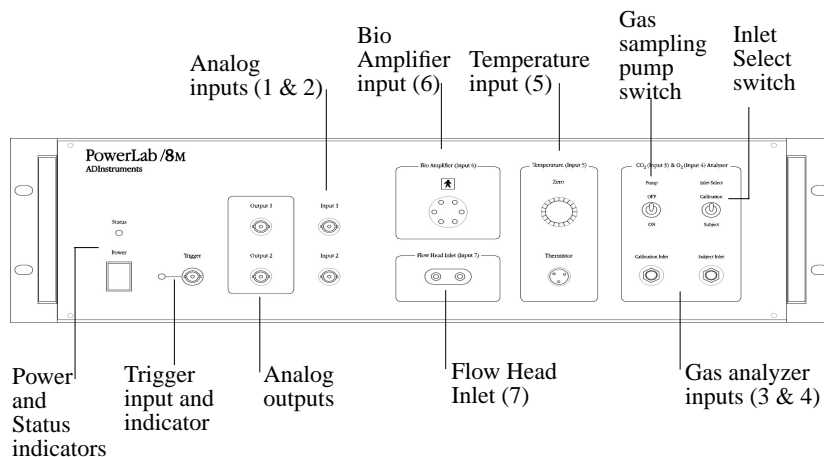
Figure 2–1
A block diagram of the PowerLab/8M inputs.



The front panel

The front panel of the PowerLab/8M provides most of the connectors for interfacing with peripheral equipment, and indicators for various functions. This section briefly describes each of the front panel features. More technical details of each component are provided in Appendix E. The front panel of the PowerLab/8M is shown in Figure 2–2.

Figure 2–2
The front panel of the PowerLab/8M.



Power and Status indicators

The Power switch on the left of the front panel glows green when the PowerLab/8M is switched on. Note that there is also a power switch on the back panel. Both switches must be on for the PowerLab to operate.

Above the Power indicator on the left of the front panel is the Status indicator light. The indicator flashes different patterns of color to provide a visual indication of what the PowerLab/8M is doing during start-up and operation. More details are given on page 14.

Analog inputs (Inputs 1 and 2)

Two general purpose analog inputs, labelled Input 1 and Input 2, are provided on the front panel. These can be used to record signals such as peripheral pulse, blood flow or blood pressure.

These inputs can record signals in the range from ± 2 mV to ± 10 V without the need for additional external amplification. The input signal can optionally be inverted by selecting the Invert checkbox in the Input Amplifier dialog box.

Gas analyzers (Inputs 3 and 4)

The gas analyzer inlets provide access for gases to the gas analyzer transducers that measure respiratory CO₂ (0 %–10 %) and O₂ (0 %–100 %) concentrations.

Two inlet ports labeled Calibration and Subject are provided. This allows permanent attachment of sampling lines from the subject and the calibration gas supply. The sample and calibration gases are drawn through the transducers by the gas sampling pump, which must be on when sampling.

- Do not connect high pressure gases to the Calibration or Subject Inlets. This will lead to incorrect readings and damage the transducers.
- The sample gases should be dried before they reach the transducers so as to prolong transducer life.

The Inlet Select switch determines which inlet is open to the transducers. Switch to Calibration when sampling gas from the Calibration Inlet on the front panel and switch to Subject when sampling from the Subject Inlet.

Gas sampling pump

For gas sampling to operate, a sample must be drawn through the transducers. An On/Off switch activates the pump to draw sample gas through the gas analyzer transducers. Turn the pump on before sampling expired or calibration gases.

Calibration Inlet Subject Inlet



Inlet Select
Calibration



Subject

Pump
Off



On

Temperature (Input 5)

The Temperature input allows for the recording of breath temperature, for example, using input from a thermistor. Thermistors (10 k Ω) that measure biological temperatures in the range of 25–45 °C may be connected. The MLT415 Nasal Temperature Probe is supplied with the PowerLab/8M.

The offset of the temperature input can be adjusted with the zero offset knob.

Bio Amplifier (Input 6)

The Bio Amplifier is used to record biological signals, such as ECG (EKG), EMG and EEG, from humans and other sources, with full electrical isolation. The Bio Amplifier is safe for human connection when used with the supplied Bio Amplifier subject cable and lead wires. Isolated electronic instruments are essential when connecting to human subjects to prevent life threatening potentials and currents. Please refer to the Bio Amplifier safety instructions, page 9.

Flow Head Inlet (Input 7)

The Flow Head Inlet connects to the integrated Spirometer which is a precision differential pressure transducer. The Spirometer can accept input pressures of ± 12.5 cm (5") H₂O (9.3 mmHg, 1240 Pa).

The Metabolic Module software uses the Spirometer signal to calculate respiratory flow rates and volumes.

Stimulator (Analog) outputs

The PowerLab/8M can generate computer controlled outputs through its analog output sockets (labeled Output 1 and Output 2). The outputs can be in the range ± 10 V, and can deliver a stimulus (or series of stimuli) or a continuous voltage. The outputs can be used to control external devices or used to provide stimulus voltage pulses.

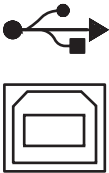
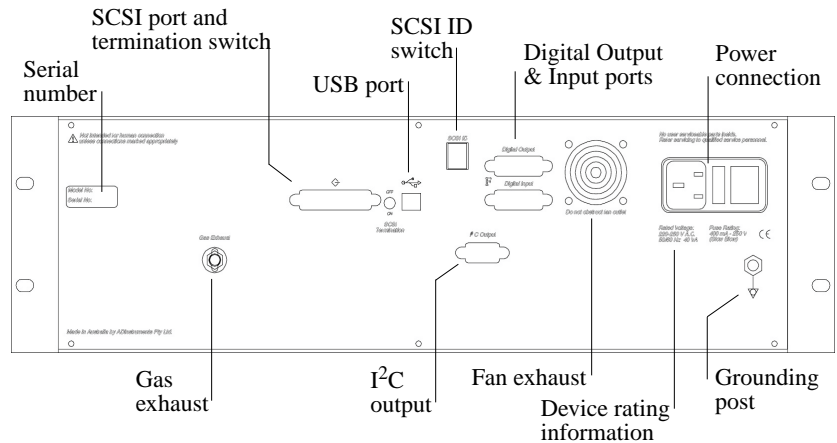
Trigger

An external Trigger input allows a pulse to synchronize recording to an external event. This input can handle voltages up to ± 12 V. A successful trigger event is shown by a lit indicator.

The back panel

The PowerLab/8M back panel provides the sockets to connect the PowerLab/8M to the computer and to the power outlet (see Figure 2–3). Other connector functions are described below. More technical detail is provided in Appendix E.

Figure 2–3
The back panel of the PowerLab/8M.



USB port

The PowerLab/8M is fitted with a USB (Universal Serial Bus) port, which provides an alternative to the SCSI connection. This works with computers with USB connectors or a USB card. USB needs a Power Macintosh with Mac OS 8.6 or later, or a PC with Windows 98 or later. The PowerLab/8M is supplied with a USB cable.

SCSI port

The PowerLab/8M can connect to your computer using the SCSI port, which is an alternative to using the USB connection. SCSI provides fast data transfer. (See Appendix C for further information about SCSI).

SCSI ID switch

A SCSI ID switch is provided to change the SCSI identification number of the PowerLab/8M if required.

I²C output

The I²C output is a special port designed to connect to ADInstruments front-ends.

Digital Input and Output ports

Digital Input and Output connectors allow the PowerLab to be used to monitor and control external devices. Digital input and output control features are available in the Chart Application on the Macintosh platform only.

Grounding post



To meet requirements for connecting the Bio Amplifier and other isolated front-ends to humans, a special earthing (grounding) post has been provided on the rear of the PowerLab/8M. This is primarily a back-up grounding connection for use in laboratories, hospitals, and clinical environments, where safety standards require additional grounding protection. Use this connection when using the Bio Amplifier and when further stringent safety requirements are needed to connect laboratory equipment to humans. Use this connection if you are unsure about the ground connection of your power supply outlet (or your power source is not grounded), and want to guarantee a ground connection to the PowerLab/8M.

Cooling fan and gas exhaust

The PowerLab/8M is fitted with a small cooling fan to maintain sufficient air flow in the enclosure to keep the circuitry within operating tolerances. Keep the fan outlet unobstructed, and far enough from walls or other devices (at least three inches) so as to not impede ventilation. It is also important to make sure that the air inlets underneath the PowerLab are unobstructed. Blocking the grilles may result in overheating of the internal components of the PowerLab, which may affect the performance of the system and reduce reliability.

The gas exhaust outlet operates when the inlet pump is on. Keep this outlet unobstructed, and do not connect air lines to it. Connecting air lines increases the load on the gas sampling pump and reduces air flow to the sensors.

Power connection

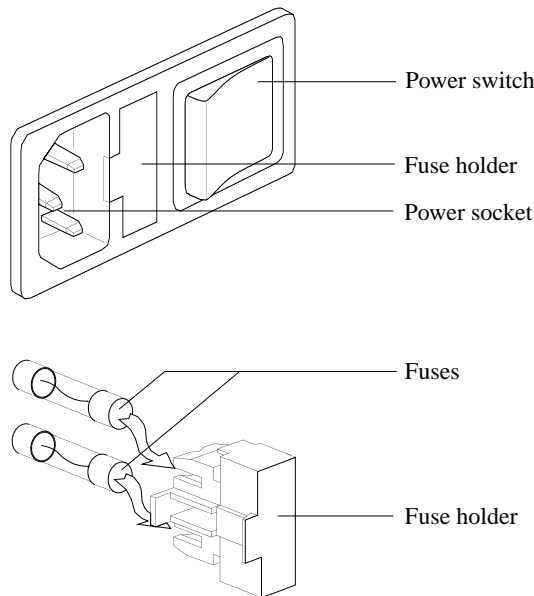
The power switch on the back panel of the PowerLab must be on before the PowerLab can be switched on at the front panel. A three-pin earthed (grounded) power cable connects the three pin IEC power socket to the power outlet. You should ensure that your power supply is also a three pin, earthed socket and that the earth is actually connected.

Fuse replacement

The fuse holder is located beside the power socket. It can only be opened when the power cable is removed. To check the fuses, remove the power cable from the PowerLab/8M, and lever the fuse holder out using the tab at its left, recessed in the power socket. It contains two 'slow-blow' fuses, which protect your PowerLab/8M from power surges.

Figure 2-4

Fuses for the PowerLab/8M are located in the fuse holder on the back panel.



Replacement fuses must be of the correct type, as specified below for 100–120 volts or 220–250 volts operation:

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

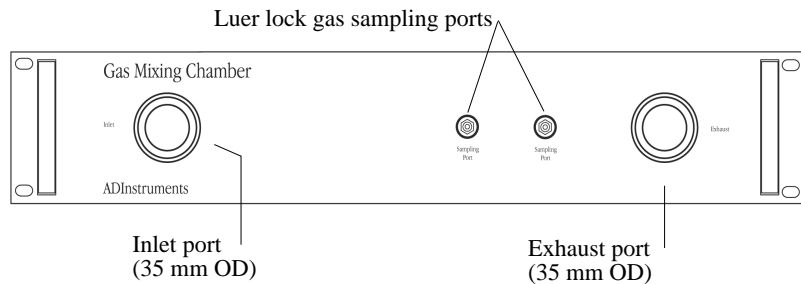
- 220-250 V: 400 mA (5 x 20 mm) slow blow (voltage rating 250 V only)

The correct voltage for your country is shown on the back of the PowerLab/8M, adjacent to the power switch (see Figure 2–3 on page 24).

Gas Mixing Chamber

The MLA245 Gas Mixing Chamber is used to ensure that gases within a single breath are thoroughly mixed before sampling occurs. It also tends to mix a number of breaths, so that the oxygen and carbon dioxide readings show a trend response rather than a breath by breath response.

Figure 2–5
The front panel of the MLA245 Gas Mixing Chamber.



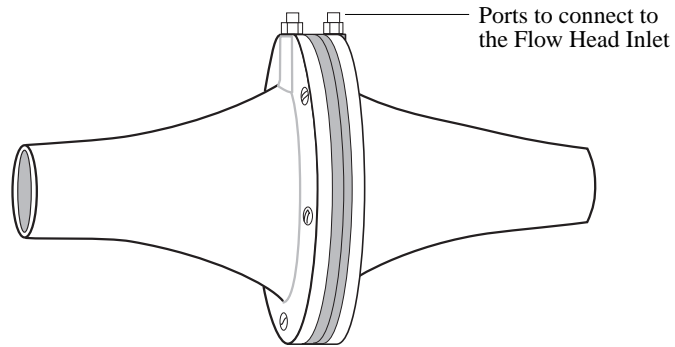
Other components

Flow Head

The MLT1000L Respiratory Flow Head (Figure 2–6) measures air flow by determining the pressure differential created by air passing through a fine mesh inside the flow head.

Ports on either side of the mesh allow the flow head to be connected to the Flow Head Inlet of the PowerLab/8M so that the differential pressure can be measured by the Spirometer.

Figure 2-6
The MLT1000L Respiratory
Flow Head.



Face Mask

The MLA1028 Face Mask features a Y-shaped, two-way, non-rebreathing valve designed to separate inspired and expired gases.

Temperature Probe

The MLT415 Nasal Temperature Probe contains a small biomedical chip thermistor that operates from 0–50 °C. This thermistor is ideal for measuring air temperature. It is well suited to biomedical temperature monitoring where repeatability, high sensitivity and rapid response are required.

The probe is used to provide a temperature measurement of the gas passing through the flow head. Alternatively, it can be used to measure the temperature of inspired air or exhaled breath.

Connecting the PowerLab/8M

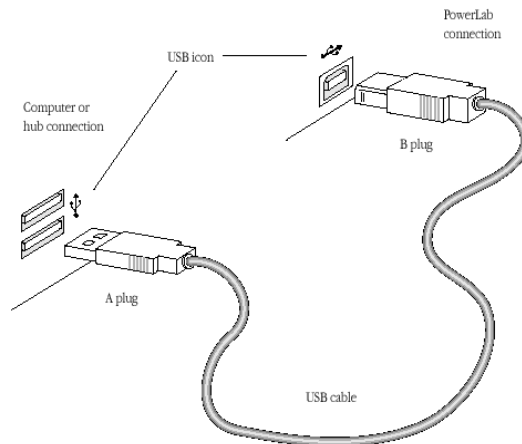
This section describes how to connect the PowerLab/8M to a Windows or Macintosh computer, via USB or SCSI (connection of multiple SCSI devices is covered in Appendix C).

Ensure that the PowerLab/8M is turned off before connecting it to the computer.

Connecting to a computer using USB

The PowerLab is fitted with a USB (Universal Serial Bus) port. USB needs a Power Macintosh running Mac OS 8.6, or later, or a PC with Windows 98, or later. To connect the PowerLab/8M to your computer using USB, simply plug the USB cable into the connectors on the PowerLab and the computer (Figure 3–1). More information on USB is in Appendix C.

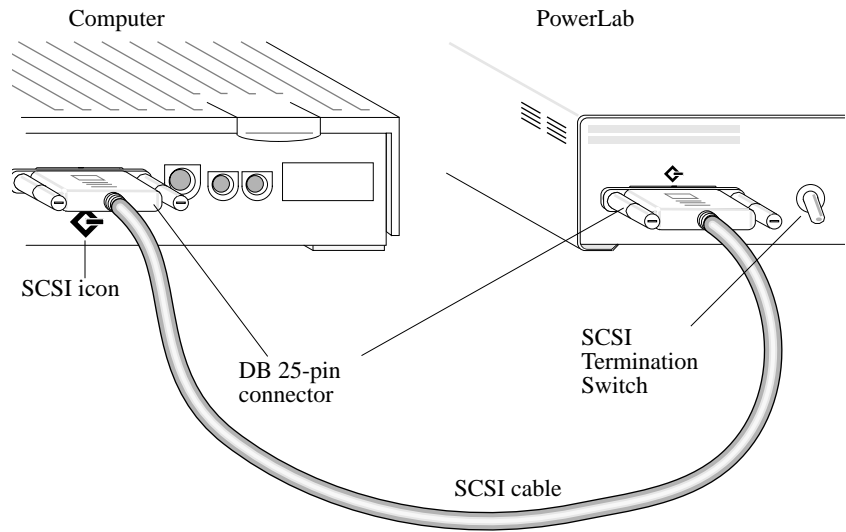
Figure 3–1
Connecting the PowerLab to a computer with a USB cable.



Connecting to a computer using SCSI

If the Powerlab/8M is the only SCSI device to connect to the computer, then simply connect the two together with an approved SCSI cable and terminate the device. For more information on SCSI in general, and on using multiple SCSI devices with the computer and Powerlab/8M, see Appendix C.

Figure 3–2
Connecting the PowerLab to a
computer with a SCSI cable.



Using the general inputs

To use one of the general recording inputs, connect an analog voltage signal of between -10 V and +10 V to the BNC connector on Input 1 or 2. Each input channel has independently adjustable gains with low-pass filtering and AC/DC coupling.

You can set up each input independently to suit your requirements using the Chart software. In the Chart View, open the Input Amplifier dialog box from the Channel Function pop-up menu. The voltage signal can be calibrated in appropriate units through the Units... button. Once settings are made for the filters and range for the signal, click the OK button to apply them. Alternatively, you can select Channel Settings... from Chart's Setup menu. In the Channel Settings dialog box, the title for the channel may also be changed. Clicking on the Input Amplifier item opens the Input Amplifier dialog box.

Using the gas analyzer inlets

The PowerLab/8M has an infrared carbon dioxide transducer dedicated to Channel 3 and a paramagnetic oxygen transducer dedicated to Channel 4. Both of these transducers share the Subject

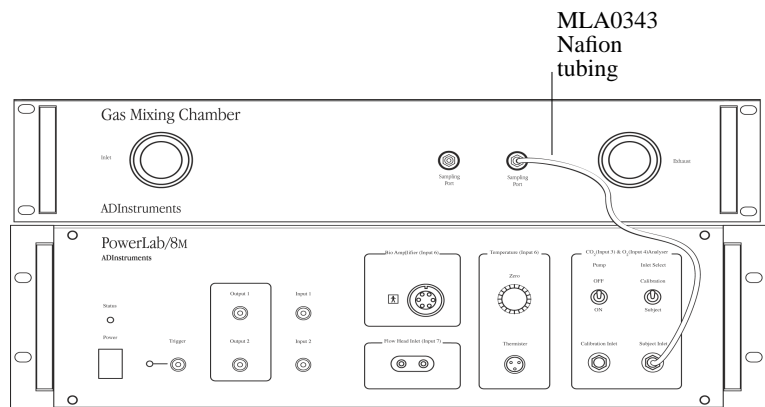
and Calibration Inlets on the front panel of the PowerLab, to measure gas concentrations in dry expired air from the Gas Mixing Chamber.

Connecting the Gas Mixing Chamber to the gas analyzers

Expired gases should be dried so as to minimize condensation in the analyzers and increase the life of the transducers. Under heavy work loads, drying agents should be changed regularly to ensure their integrity over the course of the experiment.

Figure 3–3

Connecting the Gas Mixing Chamber to the Subject Inlet of the PowerLab/8M using a length of Nafion tubing.



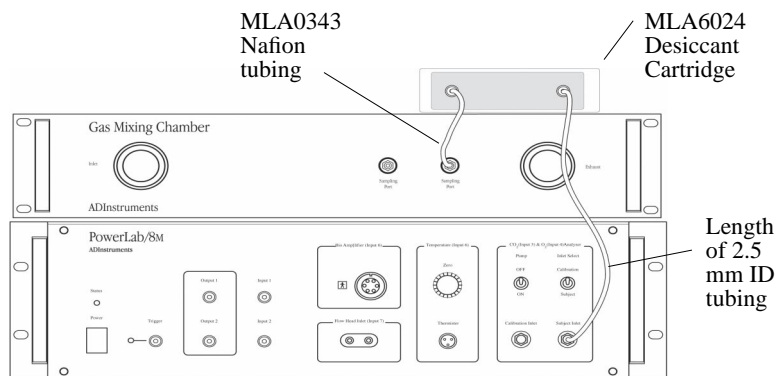
For light applications a length of Nafion tubing (MLA0343), supplied with the Metabolic System, can be used to sample expired gases by connecting the Sampling Port on the Gas Mixing Chamber to the Subject Inlet of the PowerLab/8M (see Figure 3–3).

For heavy and exercise applications the sample should first be passed through a length a Nafion tubing to dry the sample to room humidity, and then through a non-CO₂ absorbing desiccant, such as the MLA6024 Desiccant Cartridge (supplied), as in Figure 3–4. Make air-tight connections to eliminate air leaks that would invalidate CO₂ and O₂ readings.

Chart settings for the gas analyzers

The Metabolic settings file applies settings in Chart for Channels 3 and 4. The particular settings applied are described in Chapter 4 for the Windows platform and Chapter 5 for the Macintosh platform.

Figure 3–4
Connecting the Gas Mixing Chamber to the Subject Inlet of the PowerLab/8M via the Desiccant Cartridge.



The Metabolic settings file applies approximate Units Conversion settings. These settings are updated when the Gas Analyzers are calibrated. You can alter the settings made by the Metabolic settings file through the Input Amplifier and Units Conversion dialog boxes for the relevant channel.

Note that it is important that the signal for Channel 3 is recorded in concentration units of $\%CO_2$, and that the signal for Channel 4 is recorded in units of $\%O_2$, because these are the units that the Metabolic Module software expects to work with.

Excessive vibration of the PowerLab/8M contributes to noise in the O_2 signal. Keep vibration to a minimum when sampling.

Calibrating the gas analyzers

Calibration of the gas analyzers is handled by a procedure in the Metabolic Module. For this reason discussion of gas analyzer calibration is covered in Chapter 4 for the Windows platform and Chapter 5 for the Macintosh platform.

Using the Temperature input

Gas volumes measured by the Spirometer are corrected by the Metabolic Module from BTPS (expired gas) or ATPS (inspired gas) to STPD conditions, and this conversion requires a value for the gas temperature. If you are not recording temperature then you should check that Use Constant is selected for the Temperature Channel

Association in the Hardware Preferences pane of the Metabolic Settings dialog box. The conversion will then use the appropriate default value entered in the Environment pane of the Metabolic Settings dialog box, depending on whether you are measuring inspired or expired air flow. If you are recording temperature using the temperature probe then Channel 5 should be selected for the Temperature Channel Association.

The Zero knob on the front panel PowerLab/8M is used to adjust the offset position of the transducer reading. Under most circumstances there is no need to do this. Moving the knob will upset any previous calibration of the transducer. The transducer should be calibrated before each use, as described below.

Connecting the temperature probe to record gas temperature

The temperature of the gas passing through the Spirometer can be included when calculating oxygen consumption (\dot{V}_{O_2}) and carbon dioxide production (\dot{V}_{CO_2}). Inspired (room) gas temperature can be measured by leaving the MLT415 Temperature Probe in air at a convenient location away from sources of heat. Expired gas temperature can be measured by positioning the temperature probe in the gas stream close to the flow head — one of the sampling ports of the Gas Mixing Chamber is a suitable mounting point. Note that the temperature probe should always be calibrated before each use, as described below.

Calibrating the temperature probe

The Metabolic settings file provides approximate units conversion values for Channel 5. However, you will need to calibrate the MLT415 Temperature Probe before each experiment as follows.

Allow several minutes for the temperature probe and input circuit to warm up.

In the Input Amplifier dialog box for Channel 5 set the range to 1 V. There is no need to adjust the Zero knob on the front panel of the PowerLab/8M.

To convert the voltage readings from the temperature probe to your chosen temperature units (°C, °F or K), use a two-point calibration in the Units Conversion dialog box for Channel 5 (Figure 3–5).

Figure 3–5

The Units Conversion dialog box for Channel 5.

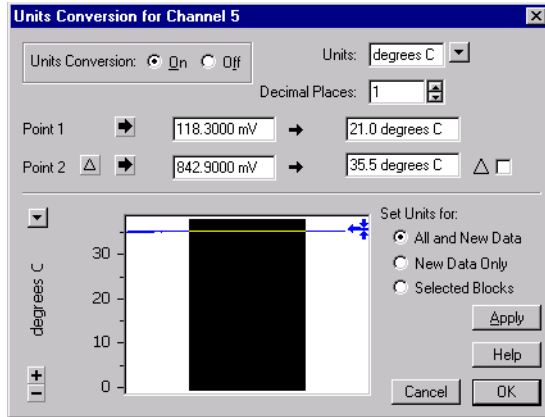


Table 3–1

Temperature vs output voltage for 10kΩ thermistor

Temp (°C)	Output (V)
0	-1.004
5	-0.845
10	-0.664
15	-0.461
20	-0.238
25	0.000
30	0.249
35	0.504
40	0.758
45	1.007
50	1.247

It is preferable to use the two-point calibration procedure with solutions of known temperature, measured with an accurate thermometer, for the reference points. A two point calibration can be performed by using room air temperature as Point 1, and body temperature (measured by placing the probe under the armpit until it becomes stable at a temperature of ~36.4°C) as Point 2.

Approximate thermistor conversion values for either a two-point calibration or multi-point calibration can be found in Table 3–1. These may be used until accurate readings can be obtained. Note that approximate values are not substitutes for values obtained using an accurate thermometer.

Note that any adjustment of the Zero knob will require the recalibration of the temperature probe. The probe should be calibrated before each experiment.

Using the Bio Amplifier

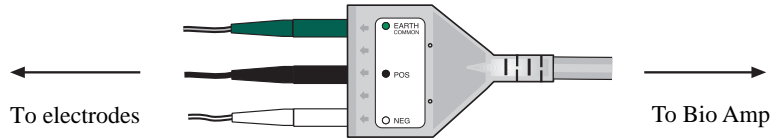
Connecting the Bio Amplifier

Connections are made to the Bio Amplifier input using the supplied Bio Amp Cable and color-coded leads. The cable plugs into the six-pin input on the front panel of the PowerLab. The color-coded lead wires plug into the connector at the other end of the Bio Amp

Cable (Figure 3–6). Only the supplied Bio Amp Cable and leads should be used. Other cables may not meet safety requirements. Please refer to the Bio Amplifier safety instructions, page 9.

Figure 3–6

The lead wires connected to the Bio Amp Cable.

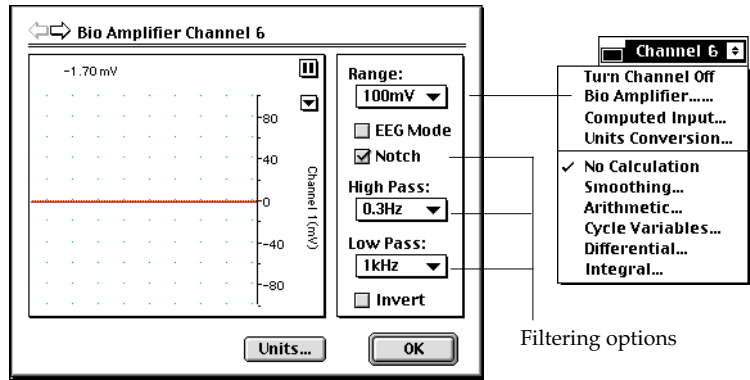


The Bio Amplifier dialog box is shown in Figure 3–7. It shows the type of filters and gain range for the Bio Amplifier. Clicking the OK button applies the changes to the Bio Amplifier channel and closes the dialog box.

The Bio Amplifier has low-pass, high-pass and notch-filter circuitry that can be adjusted to suit the recording. The notch filter reduces mains-frequency interference of sinusoidal waveforms. The high-pass and low-pass filters remove low-frequency and high-frequency signals respectively. Note that the settings for one filter type may restrict the possible settings for the other.

Figure 3–7

The Bio Amplifier dialog box.



EEG Mode. The EEG Mode checkbox supplies a different set of filters more appropriate to EEG recordings.

Range. The Range pop-up menu lets you select the input range or sensitivity of the channel. The settings available are 100, 50, 20, 10, 5, 2 and 1 mV, and 500, 200, 100, 50, 20, 10 and 5 μ V.

Notch Filter. Depending on the power line voltage frequency being used by the PowerLab (the mains frequency) the notch filter is automatically set to filter either 50 or 60 Hz. It provides

approximately 32 dB of attenuation, thus reducing the effect of 50 or 60 Hz signals that are easily picked up by long unshielded leads.

High-Pass Filtering. The High Pass pop-up menu gives the choice of five high-pass filters: 0.1, 0.3, 1, 3 and 10 Hz. The high-pass filter allows high frequencies in the signal to pass, and removes frequency components below the filter frequency (including any DC signal). These filters are useful for removing slowly moving baselines, such as motion or respiration artifacts, particularly in ECG (EKG) recordings.

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

Invert. An invert checkbox allows you to quickly invert the polarity of the signal, without the need to swap attached electrodes.

Filter settings for recording biopotentials

Generally, biopotential recordings from an exercising subject are noisy due to movement artifacts. Noise can be minimized by placing electrodes on the chest rather than the limbs, and using the clip provided with subject cable to attach the cable to the subject's clothing. Normal online filter settings for recording an ECG are: Notch filter on, high-pass 0.3 Hz, and low-pass 100 Hz or lower.

Application Notes describing the recording of ECG, EMG and EEG are available from the ADInstruments web site (www.adinstruments.com).

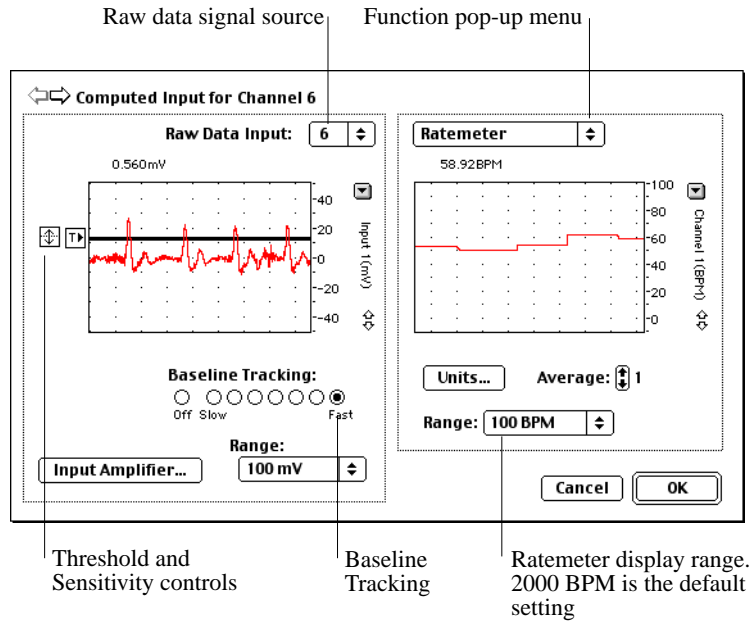
Deriving a rate online

Chart provides both online and offline methods for deriving rates from cyclic data; such as the heart rate from an ECG or pulse signal, or the breathing rate from an air flow signal.

For example, cyclic data can be recorded using a peripheral device, such as a pulse transducer or infrared plethysmograph attached to Inputs 1 or 2, or the Bio Amp channel can be used to record an ECG. A channel calculation can be set up to display the heart rate using the ECG or pulse signal as the source of raw data.

For displays, use the Computed Input available from the Channel Function pop-up menu (Figure 3–8). This takes advantage of the

Figure 3–8
The Computed Input dialog box for the Bio Amplifier channel.



processing power in the PowerLab to calculate the rate. To see the rate displayed choose the Ratemeter function from the pop-up menu. This is used to calculate rates from a periodic signal such as ECG, pulse, or breathing. When using the Ratemeter function be sure to select an appropriate range for the rate display, and apply baseline tracking if the raw data signal source drifts.

Practice is required when attempting to derive a heart rate signal online, especially from an exercising subject. If using an ECG as the raw data source it is worth trying different electrode placements and filter settings. If noise and artifact become too problematic, it may be better to use an offline function and heavily filter the source signal.

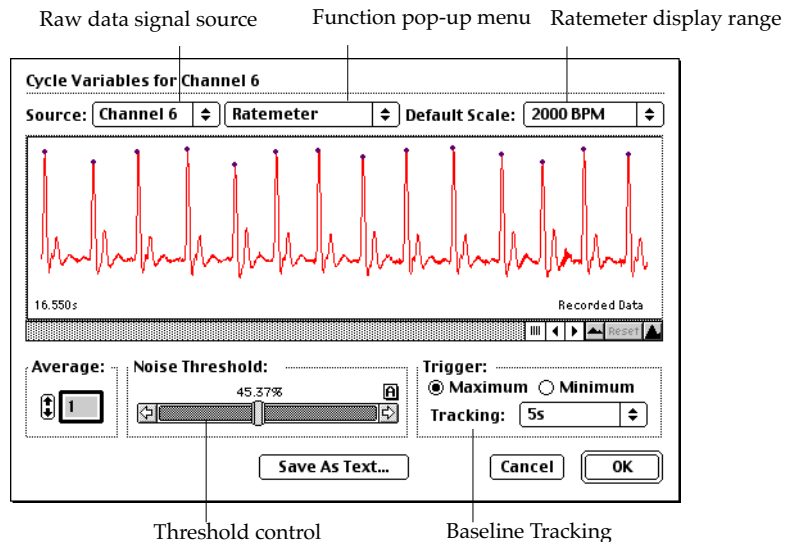
Deriving a rate offline

Cycle Variables is an offline calculation that offers similar functions as Computed Inputs. Offline calculations operate after Chart has finished recording data. An advantage of displaying the heart rate after recording is that you can apply and adjust filter settings applied to the source data.

Open the Cycle Variables dialog box (Figure 3–9) from the Channel Function pop-up menu. To set up Cycle Variables to display heart rate, select a channel for the source data, choose the Ratemeter function and select a suitable range. The heart rate can be displayed in the same channel as the source data if spare channels are not available.

Figure 3–9

The Cycle Variables dialog box for the Bio Amplifier channel.



Using the Flow Head Inlet (Spirometer)

Connecting the flow head into the breathing circuit

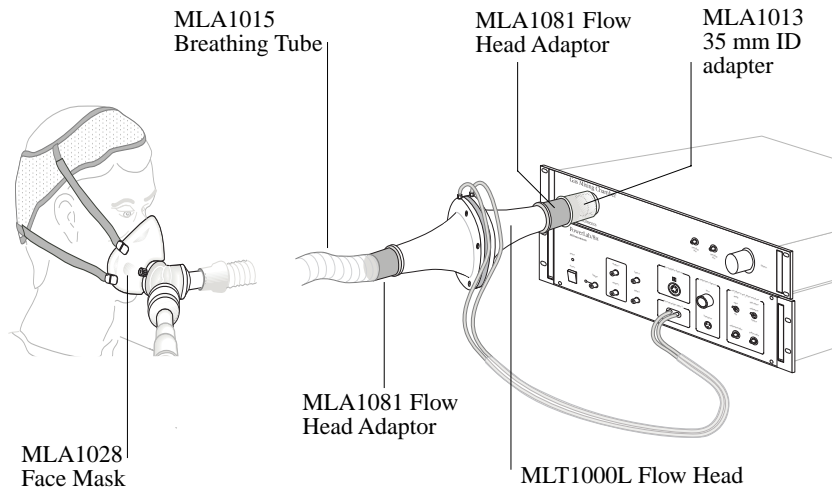
In principle, there are four positions at which the air flow can be recorded. These are on either the inspired or expired side of the face mask, and at either the inlet or exhaust port of the Gas Mixing Chamber. Each of these have their associated advantages and disadvantages. For example, an advantage of measuring inspired air flow is that the gauze in the flow head is less likely to become contaminated with moisture during the course of the exercise. A

disadvantage may be the extra weight of the flow head added to the face mask.

To connect the flow head to record inspired air, use appropriate adapters and a breathing tube to create an airtight link between the flow head and face mask.

To connect the flow head to record expired air flow, use the Flow Head Adapter (MLA1081) and a 35mm ID Tubing Adapter (MLA1013) to attach the flow head to either the inlet or exhaust port of the Gas Mixing Chamber. Use another flow head adapter to attach the Breathing Tube (MLA1015) to the open end of the flow head. The breathing tube attaches directly to the face mask. This arrangement is shown in Figure 3–10.

Figure 3–10
Connecting the MLT1000L Flow Head into the breathing circuit to record expired air flow.



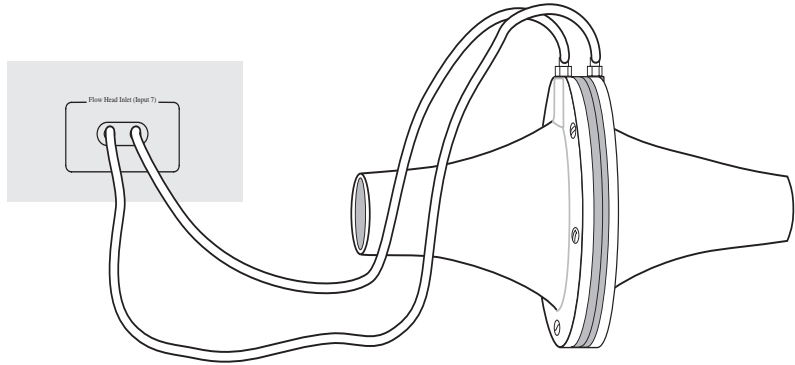
Connecting the flow head to the PowerLab/8M

Connect the flow head to the Flow Head Inlet (Input 7) of the PowerLab/8M using two lengths of 3 mm ID flexible tubing. Gently push one end of each tube over the whole length of a port on the flow head, to make an airtight seal. Then push each of the other ends of the tubes over one of the inlet ports on the PowerLab. Ensure that the tubes are pushed firmly onto the connectors to prevent leakage. Ensure that the tubes are not kinked.

Prevent the tubes becoming blocked by condensation as this will result in erroneous readings. Replace wet tubing with dry tubing if

Figure 3–11

Connecting the MLT1000L Flow Head to the Flow Head Inlet of the PowerLab/8M.



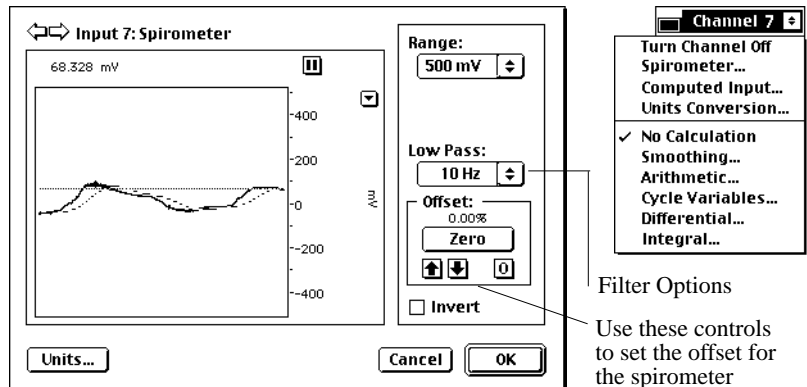
this occurs. To minimize condensation in the tubes, keep the flow head ports pointing upwards when in use. Be careful not to damage the internal mesh or tapered ends of the flow head. Do not insert objects inside the flow head.

Chart settings for the Spirometer

The Flow Head Inlet connects to the Spirometer, which is a differential pressure amplifier. With a flow head attached, the channel functions as a pneumotachometer with the Spirometer dialog box used to control its settings. The Spirometer dialog box appears if you choose the Spirometer... command from Channel Function pop-up menu for Channel 7 (Figure 3–12).

Figure 3–12

The Spirometer dialog box opens when Spirometer... is selected from the Channel 7 Channel Function pop-up menu.



The Spirometer dialog box contains range, filter and offset controls for manual or automatic zeroing. This channel should always be

zeroed before use. The Flow Head Inlet signal is displayed in the Input Amplifier dialog box so that you can see the effects of changes immediately. Once you have chosen the settings from this dialog box, click the OK button to apply them.

Range. The Range pop-up menu lets you select the input range or sensitivity of the channel.

Filtering. The Low Pass pop-up menu gives a choice of low-pass filters to remove high-frequency components from an input signal. The filters, appropriate for the built-in pressure transducer in the Spirometer, are 1, 10, and 100 Hz. The low-pass 10 Hz filter rejects high-frequency components caused by turbulence, while passing the breath-related information. It is suitable for non-forced expiration studies. A 100 Hz cut-off filter is used in forced expiration studies to resolve the peak in the flow signal to determine a PEF value.

Invert. The Invert checkbox allows you to invert the signal on the screen. It provides a simple way to change the polarity of the recorded signal without having to swap the tubing connection arrangement on the Flow Head Inlet or flow head.

Automatic Zeroing. To perform automatic zeroing, click the Zero button: a corrective DC voltage that cancels the output voltage from the transducer is supplied to give the best zero value at all ranges. A dialog box with a progress bar appears: click the Cancel button or type Command-period to stop the zeroing process. Note that variations in the transducer signal during the auto-zeroing operation will cause the software to fail to zero the offset properly.

A small numeric indicator above the Zero button shows the voltage used to adjust for transducer offset, as a percentage value. When the PowerLab/8M is first powered up, the software sets the offset circuit to its default position (no offset adjustment of the transducer is performed) and the offset display has a value of zero. When either the auto-zeroing function is selected or one of the manual offset controls is used, this number will change to indicate the adjustment.

Click the small '0' button to restore the offset circuit to its initial, non-zeroed position (the offset range indicator resets to a value of zero). This displays the offset generated by the pressure transducer.

Calibrating the flow head

There are three options for calibrating the flow head:

Using an approximate conversion factor

You can use an approximate conversion value for converting the voltage signal to L/s. For the MLT1000L Flow Head the linear conversion is given approximately by $0\text{ V} = 0\text{ L/s}$; $1\text{ V} = 40.1\text{ L/s}$. You apply this conversion in the Units Conversion dialog box, opened from the Channel Function pop-up menu.

Injecting a known volume and integrating

You can determine an accurate conversion value for your particular flow head by injecting a known volume of air through the breathing circuit and integrating the flow signal in Chart. This section describes the procedure in more detail.

When using a calibration syringe, try to depress the plunger at a steady rate, neither too quickly or too slowly, and try not to bring the plunger to an abrupt stop at the end of the syringe.

Set up a new channel for Volume in Chart from the Channel Settings dialog box. Display the integral of the flow signal in this channel by choosing Integral... from the Channel Function pop-up menu and selecting Flow as the source channel, using a standard integral with no reset.

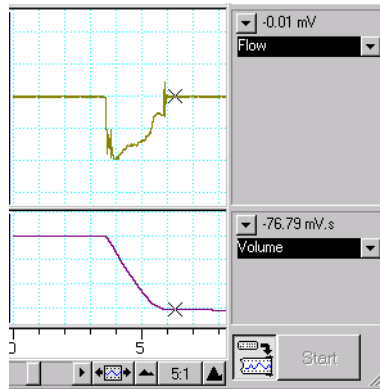
The signal from the flow head should always be zeroed before recording is started. Do this by clicking on the Spirometer... item in the Channel Function pop-up menu for Channel 7. This opens the Spirometer dialog box. You can then zero the flow head signal by clicking the Zero button.

Injections can now be recorded and integrated using the spirometer and volume channels. Making a single injection should produce a trace similar to that shown in Figure 3–13.

In the example shown in Figure 3–13, a 3 L calibration syringe was used to simulate a single expiration. The absolute value of the integral at the cursor position is 76.79 mV.s. This corresponds to a

Figure 3–13

The flow signal integrated for a single injection. The value of the integral at the cursor position is -76.79 mV.s.



flow head correction factor of 39.1 L/s/V, obtained by dividing the syringe volume by the integral value (converted to V.s):

$$\frac{3 \text{ L}}{0.07679 \text{ V.s}} = 39.1 \text{ L/s/V}$$

The correction factor is applied in the Units Conversion dialog box (0 V = 0 L/s; 1 V = 39.1 L/s).

Using the Spirometry extension

The Spirometry extension for Chart (for either the Windows or Macintosh platforms) is freely available from the ADInstruments website and can be used to perform the units conversion required for the Spirometer channel. The extension adds an item called Spiro. Flow... to the Channel Function pop-up menu. When using the Spirometry extension in Windows, ensure that Units Conversion is turned off for the Flow Channel, to ensure that a double conversion is not applied.

You use the Spirometry extension as follows:

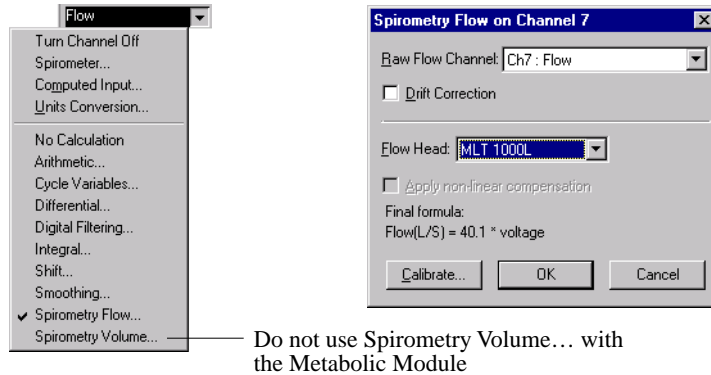
1. Zero the Spirometer using the Zero button in the Spirometer dialog box (open the dialog box by choosing Spirometer... from the Channel pop-up menu). Click OK.
2. Use Chart to record the injection through the flow head of a known volume, as from a calibration syringe like the MLA5530 three litre calibration syringe.
3. Select the whole of the signal deflection due to the injection in the Chart View. Do not use positive and negative deflections in the

same selection.

4. Choose Spirometry Flow... (Spiro. Flow... on the Macintosh) from the Channel Function pop-up menu to open the Spirometry Flow dialog box (Figure 3–14). In the dialog box, select the flow source channel and the type of flow head that you are using. Drift correction should be off.

Figure 3–14

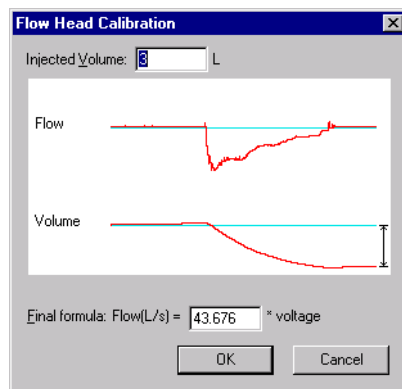
The Channel Function pop-up menu for Channel 7, and the Spirometry Flow dialog box, which opens when you select the Spirometry Flow... item from the menu.



5. Click the Calibrate... button to open the Flow Head Calibration dialog box (Figure 3–15). Enter the volume injected, and click OK. A correction is determined, by comparing the integral of the deflection and the injected volume, and automatically applied to the channel. Click OK twice. The conversion factor displayed in the Spirometry Flow dialog box updates to the new value.

Figure 3–15

The Flow Head Calibration dialog box.



Note that both the Metabolic Module and the Spirometry extension calculate flow volumes. Do not use the Spirometry extension item Spiro. Volume... to calculate V_T as the Spirometry extension expects breath to flow in both directions and does not reset between breaths.

Sampling rate

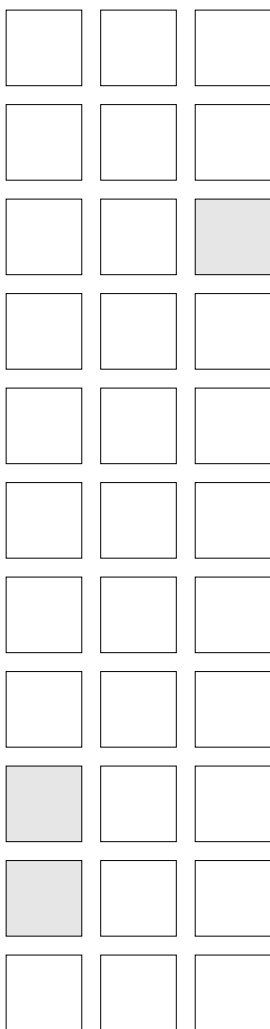
Sampling rates for data acquisition are determined by the type of signals that you are recording. If you are recording simple metabolic parameters such as air flow, temperature and concentration, sampling rates at around 20–100 samples per second are sufficient. Recording data for spirometry studies to determine peak expired airflow (PEF) requires sampling rates of around 100–200 samples per second, as the PEF can be resolved clearly by a faster sampling rate. Sampling rates for metabolic and pulmonary studies are usually too slow for recording ECG patterns which require a sampling rate of at least 400 samples per second to resolve faster components in the cardiac cycle.

Turn unused channels off. They can be turned on later for channel calculations when analyzing data. Other programs that may limit the data transfer rate should be closed. If the computer cannot keep up with the data transfer, Chart will warn you with suggestions to improve the data transfer rate.

4

CHAPTER FOUR

Metabolic for Windows



The Metabolic Module is a software add-on for Chart which adds analysis and control capability to Chart for metabolic experiments.

This chapter describes the general features and use of the Metabolic Module for Windows.

Basics

About the Metabolic Module

The Metabolic Module adds functionality to the Chart Application to calculate and display metabolic data. The module is designed for experiments in human metabolic physiology and the physiology of exercise, not for clinical use.

The PowerLab/8M is used to record ventilatory parameters such as concentrations of CO₂ and O₂, and respiratory air flow. The simultaneous measurement of respiratory gas concentrations and air flow allows metabolic variables to be calculated.

The Metabolic Module uses the ventilatory parameters to calculate and display the following metabolic variables:

- \dot{V}_{O_2} , the rate of oxygen consumption
- \dot{V}_{CO_2} , the rate of carbon dioxide production
- RER, the Respiratory Exchange Ratio, and
- \dot{V}_E , the expired, minute volume.

Minute volume - the respiratory air flow, expressed in L/min.

The Metabolic Module may be used online to perform calculations as data is recorded. It may also be used offline to analyze data from previous experiments.

The Metabolic Module also provides control over some Chart functions, such as calibration.

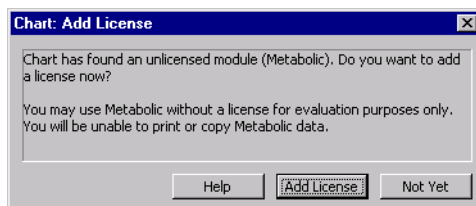
To use the Metabolic Module, start Chart in the normal way (by double-clicking on a Chart file, or by using the desktop or Start menu shortcuts). You can use Metabolic on a trial basis without entering a license code, but you will need to enter one to be able to save or print data analyzed with Metabolic.

Licensing the Metabolic Module

You will have been provided with a license code for the Metabolic Module. When you first start Chart with the Metabolic Module installed, the Add License dialog box (Figure 4-1) will appear, prompting you to enter your license code.

Figure 4–1

The Add License dialog box.

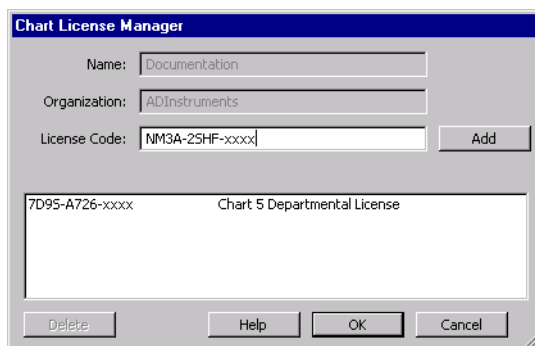


If you click Not Yet, you can use the Metabolic Module for evaluation purposes, but you will not be able to copy or print Metabolic data. Until you enter a license code, the dialog box will reappear every time you start Chart, or create or open a new document.

To add a license code, click Add License. This opens the License Manager dialog box (Figure 4–2).

Figure 4–2

The License Manager dialog box, with a Metabolic license about to be added.



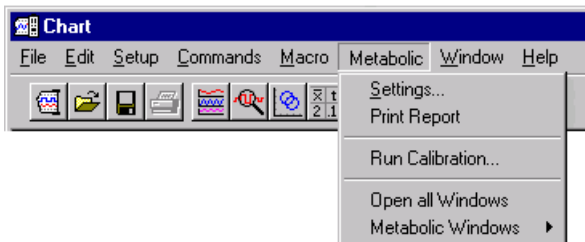
You can also access this dialog box at any time from the Preferences submenu of Chart's Edit menu. Enter your license code in the text box and click the Add button to add it to the list of license codes shown in the dialog box (note that after you have entered your code, the last four characters of the code shown in the list appear as 'xxxx' — this is a security measure).

Further detail on the License Manager dialog box can be found in the *Chart User's Guide*.

Additions to the Chart interface

When you start Chart with the Metabolic Module installed, the module loads automatically, and the Metabolic menu item is added to the Chart menu bar (Figure 4–3). The menu provides access to all

Figure 4–3
The Metabolic menu.



features of the Metabolic Module. The various items of the menu are discussed later in this chapter.

The Metabolic Online Help item is also added to Chart's Help menu. Choose this item to access the online help for the Metabolic Module (Figure 4–4).

Figure 4–4
The Metabolic Online Help menu item, which is added to Chart's Help menu by the Metabolic Module.



Data channel requirements

The Metabolic Module requires the following three channels of data:

- CO₂ concentration with units of %CO₂
- O₂ concentration with units of %O₂
- air flow with units of L/s.

When the PowerLab/8M is used for data acquisition then, by default, Channels 3, 4 and 7, respectively, are reserved for these inputs. Optionally, Channel 5 of the PowerLab/8M may also be used to sample breath temperature.

Quick setup for the Metabolic Module

Preparing the Metabolic Module to analyze metabolic experiments is convenient and repeatable when a settings file is used.

A Metabolic settings file was installed into a folder called Metabolic, inside the Chart folder, when the Metabolic Module was installed.

The file can be edited to suit your own experimental requirements, if necessary.

When using the Metabolic settings file to prepare the Metabolic Module for online analysis of recordings made with the PowerLab/8M, you can follow this brief outline, which has page references for further details:

1. Open the Metabolic settings file;
2. Open the Metabolic Settings dialog box and enter settings specific to the experiment for:
 - Environment details page 56
 - Subject details, page 57
 - Experiment duration, page 62;
3. Calibrate the transducers:
 - Gas Analyzers, using the automatic routine in the Metabolic Module, page 58
 - Flow Head, page 43
 - Thermistor, page 34, if temperature is being recorded;
4. Save the document as a Chart data file with an appropriate name, according to your laboratory practice.

You are now able to start recording.

Setting up

The Metabolic settings file

Settings in Chart affect the way that data is both recorded and displayed, and include such details as sampling rate, channel ranges, unit conversions, window sizes and positions, and menu layouts.

Any settings to do with modules, including the Metabolic Module, are considered as Chart settings, and are saved along with all other settings for the Chart document.

A Metabolic settings file was added, when the Metabolic Module was installed, to a folder called Metabolic, inside the Chart folder. It provides suitable range, units conversion and channel association settings for using the Metabolic Module with Chart and the PowerLab/8M.

You use this settings file by simply opening the file. A quick way to do this is by double-clicking on the file from its location. Opening the settings file will automatically open a new Chart document with all the settings applied. This new file should be saved with a new name, to safeguard the original settings file. Before you record data into this new document, you should accurately calibrate the transducers.

Alternatively, if you want to do a custom setup, you can develop settings to your own requirements. This can be done by editing an existing settings file. When you have a set of suitable settings, they can be saved as a Chart settings file (with the suffix '.adiset'). You can then reuse the settings by opening this settings file, as described above.

The following sections of this chapter describe in detail how to make settings in Chart and the Metabolic Module.

Chart settings

You usually make the settings described in this section when you are creating a new settings file or are editing an existing settings file.

Chart obtains raw data from the PowerLab/8M through dedicated inputs. By default, these inputs are associated with particular channels in Chart. Unit conversions must be applied to the Chart channel data to give data values that are suitable for the Metabolic Module calculations.

It is also important to choose an appropriate range setting for each channel. A smaller range improves signal resolution, but risks data loss if the channel signal exceeds the range limit.

To make Chart settings for a new document:

1. With the PowerLab/8M connected to the computer and switched on, start Chart and open a new document.
2. Set the sampling rate to 100 /s using the Rate pop-up menu in the Chart View.
3. Choose Channel Settings... from Chart's Setup menu. In the Channel Settings dialog box set the number of channels to a minimum of seven.
4. For each dedicated channel in the Channel Settings dialog box, make settings for Channel Title and Range as in Table 4-1.

Table 4–1

Chart settings for channels dedicated to the PowerLab/8M.

Channel	On	Channel Title	Range
3	✓	%CO ₂	1 V
4	✓	%O ₂	1 V
5	✓	Temperature	1 V
7	✓	Flow	1 V

Note that Channel 5 settings are optional — if you are not measuring gas temperature with the PowerLab/8M then this channel (and all other unused inputs) can be turned off.

Units Conversion needs to be set for each channel. Initially, you can use the approximate values in Table 4–2 on page 54 until accurate values are available from calibrating the transducers. Note that the Metabolic calibration routine and the Spirometry extension will overwrite these approximate values for the gas concentration and flow channels respectively.

From the Channel Settings dialog box, you can open the Units Conversion dialog box for a particular channel by clicking the button in the Units column.

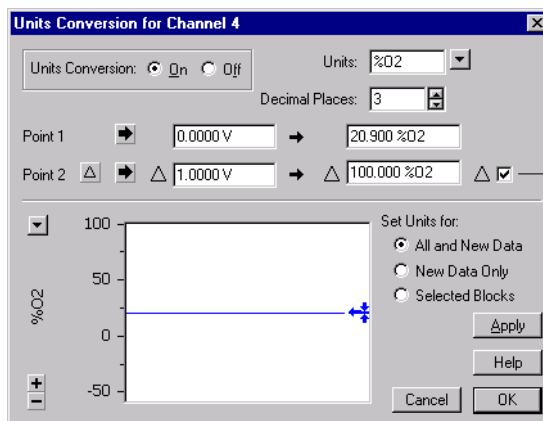
5. In the Units Conversion dialog box (Figure 4–5) for each channel, ensure that Units Conversion is On, and enter approximate calibration values as in Table 4–2. Ensure that the All and New Data option is selected.

▼ **Refer**

Gas calibration, p. 57

Figure 4–5

The Units Conversion dialog box, showing approximate calibration values for Channel 4 (%O₂).



Select the difference checkbox when using point and difference calibration

▼ **Refer**

Units Conversion in the Chart User's Guide.

Note that the data values to convert from are entered into the left-hand text box and the unit values to convert to are entered into the right-hand text box. Units conversion can use either the point-and-difference method or the two-point calibration method.

You should only click the difference (Δ) button, or select the difference checkbox, if you are using the point-and-difference calibration method.

Table 4–2

Units conversion settings in Chart for channels dedicated to the PowerLab/8M.

Channel	Units	Decimal places	Point 1 values		Point 2 values		Δ
			raw	converted	raw	converted	
3	%CO2	2	0 V	0.03	1V	10	✓
4	%O2	2	0 V	20.9	1V	100	✓
5	degrees C	2	200 mV	25	758 mV	40	
7	L/s	2	0 mV	0	1 V	40.1	✓

The approximate calibration values entered here for Channels 3 and 4 will be overwritten when the Metabolic calibration routine is performed. Until then, these values allow you to get the Metabolic Module working for testing purposes.

Again, no settings need to be made for Channel 5 if temperature is not being measured. Note that units for temperature must be specified as 'degrees C', 'degrees F' or 'K'.

6. Save the document as a Chart settings file when you are finished.

Metabolic Module settings

Once Chart has been set up to receive data from the dedicated inputs of the PowerLab recording unit, as described in the previous section, you can set up the Metabolic Module to use the data from the associated channels in Chart. You set up the Metabolic Module using the Metabolic Settings dialog box. The settings made in the dialog box apply only to the current Chart document.

To display the Metabolic Settings dialog box, choose the Settings... command from the Metabolic menu. The dialog box has tabbed pages, with each page containing a group of related settings.

The Metabolic Settings dialog box is described in more detail in the following sections.

Enabling the Metabolic Module

When you open a new Chart document with the Metabolic Module installed, the module is disabled by default. The module must be

enabled before calculations can be performed, either online or offline. When enabled, the module performs respiratory calculations on the data that you are recording or that you have selected in a document. If you are working with a document for which metabolic calculations are not required, then you can disable the module.



To enable, or disable, the Metabolic Module, choose Metabolic > Settings... > General Preferences, and select the On, or Off, option respectively.

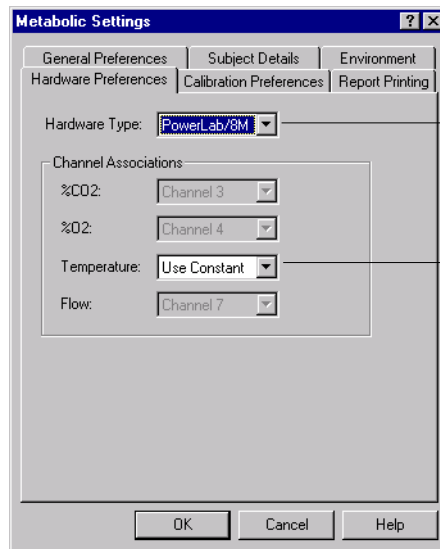
Linking the Metabolic Module to Chart

The Metabolic Module needs to know which channels provide the gas concentrations and flow data that are to be used in calculations. By default, the module expects the data source to be the PowerLab/8M and that the default channel associations are being used.

Only if you have made other channel associations in Chart, do you need to alter the default settings for Hardware Type and Channel Associations.

To set the data source, choose Metabolic > Settings... > Hardware Preferences, and select the data source from the Hardware Type drop-down list, as shown in Figure 4-6.

Figure 4-6
The Hardware Preferences tab of the Metabolic Settings dialog.



Choose your data source from this list

Choose the source of temperature data for calculations from here

If you choose Custom in the Hardware Type drop-down list, then the drop-down lists for Volume, %O₂ and %CO₂ are enabled. You can then select suitable channel associations for these parameters.

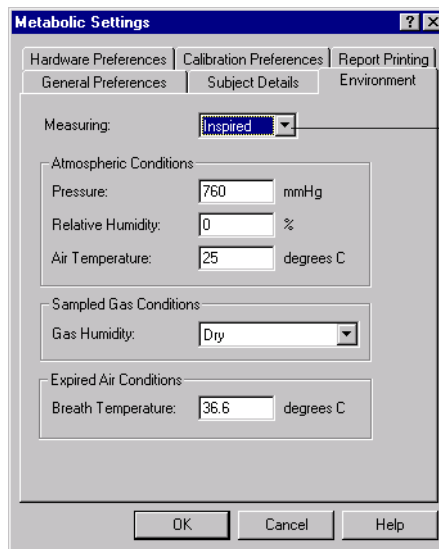
If gas temperature is not being recorded then 'Use Constant' should be selected from the Temperature drop-down list. In this case the default temperature entered in the Environment tab of the Metabolic Settings dialog box is substituted into the calculations.

Environment details

In order for the Metabolic Module to make any required gas volume conversions, you need to supply values for the ambient conditions of atmospheric pressure, relative humidity and air temperature. You also need to specify whether you are measuring inspired or expired air flows.

To set whether your experiment is measuring inspired or expired air flows, choose Metabolic > Settings... > Environment and select Inspired or Expired from the Measuring drop-down list, as shown in Figure 4-7.

Figure 4-7
The Environment tab of the Metabolic Settings dialog box.



Choose the air flow that is being measured

To specify the current atmospheric conditions for pressure, humidity and temperature, you enter appropriate values in the Atmospheric Conditions panel. When your experiment is measuring inspired gas flows, and gas temperature is not being recorded, then the value entered for Air Temperature is used as the default in calculations.

Sampled gas conditions

The Metabolic Module applies a correction to the gas concentration values depending on how dry the gas is when analyzed. This correction is applied to the calibration gas rated concentrations and the measured sampled gas concentrations, as necessary. If the gas sample is dried using only Nafion® tubing then the correction is required, and Atmospheric should be selected from the Gas Humidity drop-down list. If a desiccant is used to completely dry the sampled gas then the correction is not required, and Dry should be selected from the Gas Humidity drop-down list.

Expired air conditions

When your experiment is measuring expired gas flows, and gas temperature is not being recorded, then the value entered for Breath Temperature is used as the default in calculations.

Subject details

The Metabolic Module makes provision for you to record details about the subject. These are optional and not required for the metabolic calculations.

To enter details about the subject choose Metabolic > Settings... > Subject Details.

Gas calibration

It is important to accurately calibrate each of the transducers used. The Chart Settings section describes how to enter initial approximate units conversion values. This section describes how to calibrate the gas analyzer, flow and temperature transducers.

A less rigorous, but more convenient, alternative to a full calibration for the gas analyzers is to perform a correction for offset. This does not require the use of a calibration gas, and is described after the Calibrating the gas analyzers section.

All connections between the flow head, gas mixing chamber, PowerLab/8M and computer should be set up as described in Chapter 3.

▼ Refer

Chart settings, p. 52

Calibrating the gas analyzers

The Metabolic Module has a routine that calibrates the gas analyzers using calibration gases. The calibration routine should only be run after Chart and Metabolic Module settings have been made, and before running an experiment. Note that, in particular, the calibration routine depends on settings made in the Environment tab of the Metabolic Settings dialog box.

The calibration is a simple flushing and reading procedure during which you switch the gas sampling line between two different gas mixtures of known composition. Typically, the first gas will be atmospheric air, and the second (calibration) gas will be similar in composition to expired air. The procedure allows time for you to switch from the first gas to the calibration gas.

A one litre bottle filled from the calibration gas cylinder provides a suitable container from which to draw a sample. This bottle should have a narrow neck so that draft effects are minimal. Note that high pressure gases, for example from the calibration gas cylinder, should never be connected (even using a regulator) to the PowerLab/8M gas analyzer inlets.

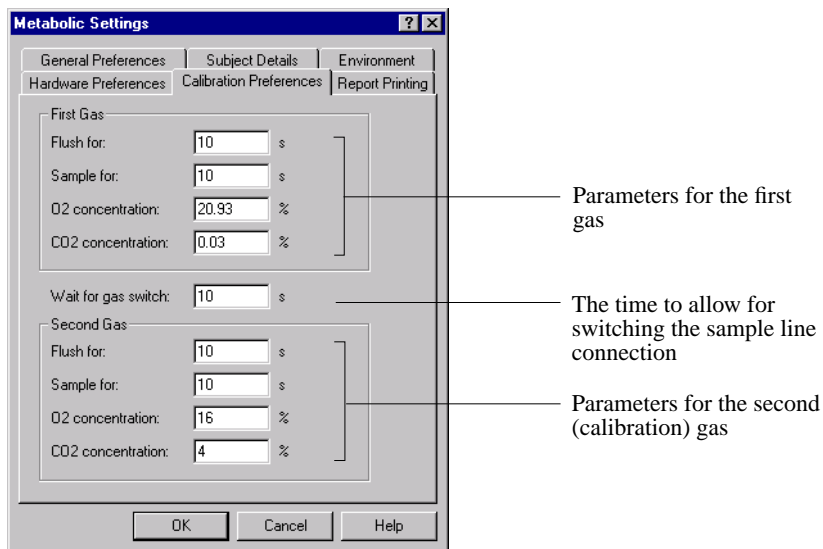
Settings for the calibration process are entered in the Calibration Preferences tab of the Metabolic Settings dialog box (Figure 4–8). The default values assume that the first gas is room air and that the second gas is the calibration gas.

Flushing times are required to be in the range 0–60 seconds. Sampling times are required to be in the range 10–120 seconds. The Wait for gas switch time must be less than 180 seconds. If no value is entered then zero seconds is used as the switching time.

Concentration values for the room air and your calibration gas must also be entered in the Calibration Preferences tab of the Metabolic Settings dialog box. Room air has concentrations of 20.93 %O₂ and 0.03 %CO₂ at 0 % humidity. These are the default values that appear for First Gas concentrations in the Calibration Preferences tab.

Generally, a calibration gas has concentrations of around 16 %O₂ and 4 %CO₂ in a dry balance of N₂. These are the default values that appear for Second Gas concentrations, but should be replaced by the actual O₂ and CO₂ concentration values supplied with your calibration gas. The two gases that are sampled during calibration must be sufficiently different that the CO₂ and O₂ transducer signals

Figure 4–8
The Calibration Preferences
tab of the Metabolic Settings
dialog box.



differ by at least 1% of the full scale range, otherwise the calibration routine will fail. .

To run the Metabolic calibration routine:

1. Fill the 1 L bottle with the calibration gas and leave the gas flowing into the bottle for a few minutes. The gas flow should be just audible when the outlet is held to the ear.
2. Enter settings in the Calibration Preferences tab of the Metabolic Settings dialog box to suit your calibration gas, as discussed above.

Then, on the front panel of the PowerLab/8M:

3. Connect the supplied Nafion® sampling line to the Subject Inlet (or the Calibration Inlet) of the PowerLab/8M, but leave the other end open to room air initially.
4. Switch the Inlet Select switch to Subject (or Calibration, if you are using the Calibration Inlet).

The O₂ sensor is very sensitive to changes in gas flow. It is important, therefore, to use the same sampling line and gas inlet port for both the calibration gas and the sample gas, so that the sampling line resistance is kept as constant as possible.

5. Switch the gas sampling Pump On.

Now, open the Metabolic Gas Calibration dialog box by choosing the Run Calibration... command from the Metabolic menu. The

Metabolic Gas Calibration dialog box also has a Calibration Settings... button which opens the Calibration Preferences tab of the Metabolic Settings dialog box.

6. Begin the calibration routine by clicking the Start button in the Metabolic Gas Calibration dialog box.
7. Sampling occurs from room air, to obtain the first calibration point.

During calibration, the Metabolic Gas Calibration window indicates progress with messages: Ready to calibrate; Flushing first gas...; Sampling first gas...

8. When the message 'Waiting for gas switch...' is displayed, change from room air to the calibration gas by putting the open end of the sampling line into the 1 L bottle previously filled with the calibration gas.

This arrangement allows quick switching between gases during calibration, and maintains constant sampling line resistance. This latter point is essential because the O₂ sensor is affected by flow, so the sampling line resistance must remain constant between calibration points.

9. Sampling now occurs from the calibration gas in the 1 L bottle, to obtain the second calibration point. Do not use the Inlet Select switch.

The Metabolic Gas Calibration window continues to display progress messages: Flushing second gas...; Sampling second gas...

When the calibration process is complete, the Metabolic Gas Calibration window displays the 'Finished calibration' message. If the calibration process fails to complete, then the message 'Failed calibration.' is displayed.

After calibration, the Metabolic Module automatically annotates the CO₂ and O₂ traces (Channels 3 and 4 in the Chart View). These comments contain the times and values, with standard deviations, of the readings (see Figure 4–9). If a correction for gas humidity has been applied then this is also noted in the comments. Gas concentration values and the voltage readings from the calibration are used to automatically convert the raw voltage readings from the CO₂ and O₂ channels to %CO₂ and %O₂ using Units Conversion (see Chapter 3 of the *Chart User's Guide* for details). If Units Conversion is already applied (such as in the Metabolic Module settings file) then the existing values are modified.

Figure 4–9

Calibration annotations viewed in the Comments window.

Channel	Number	Time	Comment
4	1	0.01 s	Metabolic gas calibration: Start sampling first %CO2 concentration.
3	3	0.01 s	Metabolic gas calibration: Start sampling first %CO2 concentration.
4	2	10 s	Metabolic gas calibration: Finished sampling first %CO2 concentration. 21.75V +/- 28.45mV converted to 20.93%CO2
3	4	10 s	Metabolic gas calibration: Finished sampling first %CO2 concentration. 103.01mV +/- 573.44uV converted to 0.03%CO2
4	5	0.01 s	Metabolic gas calibration: Start sampling second %CO2 concentration.
3	7	0.01 s	Metabolic gas calibration: Start sampling second %CO2 concentration.
4	6	10 s	Metabolic gas calibration: Finished sampling second %CO2 concentration. 16.56V +/- 28.83mV converted to 15.70%CO2
3	8	10 s	Metabolic gas calibration: Finished sampling second %CO2 concentration. 539.38mV +/- 1.20mV converted to 4.20%CO2

Offset correction for the gas analyzers

A less rigorous, but more convenient, alternative to performing a full calibration of the Gas Analyzers is to only correct for transducer offset. This does not require the use of a calibration gas, but can not reveal whether a transducer is performing within manufactured tolerances.

You can perform the offset correction for each gas analyzer as follows:

1. Make settings for Chart and the Metabolic Module as described above.
2. Connect the Nafion® sampling line to the Subject inlet and leave the other end open to the room air. Set the Inlet Select switch to Subject as described in the previous section.
3. Switch the gas sampling Pump On to sample from the room air.
4. In the Chart View click on the Start button to begin sampling in Chart.
5. After a stable signal has been recorded for about 30 seconds on the channel being corrected, stop sampling and switch Off the sampling Pump.
6. Make about a 30 second selection from a stable portion of the obtained signal trace and open the Units Conversion dialog from the Channel Function pop-up menu.
7. In the Units Conversion dialog make a selection from the displayed data and click the Arrow button for Point 1. This enters the mean value of the selection into the left-hand text box for Point 1.
8. Click Apply to see how the units conversion will be applied. Click OK to apply the changes to the channel and return to the Chart View.

Using Metabolic

Online and offline use

When enabled and appropriately set up, the Metabolic Module will perform metabolic calculations online (in real time) whenever Chart is recording.

You start both recording and calculations together by clicking the Chart Start button. You can view the results of the metabolic calculations in the various Metabolic windows (see below) as recording proceeds.

The Metabolic Module may also be used offline to perform metabolic calculations on previously recorded data.

Whenever you make a selection in the Chart View, the Metabolic Module uses the selected data to make calculations. This requires that the selection period is greater than the current value for the Averaging Time period — see Reducing noise in the calculations, below. The Metabolic Module uses the calibration settings associated with the recorded data, and displays the results in the Metabolic windows. Note that an entire data block can be selected by double-clicking in the Time axis.

Experiment duration

In online use, you can use the Metabolic Module to control the duration of recording for an experiment.

To set the recording time, choose Metabolic > Settings... > General Preferences, and enter the number of seconds for the Recording Time.

Changing the Recording Time causes a recalculation by the Metabolic Module if there is data currently selected. Note that the Metabolic Module does not analyze data over more than a single block of the Chart file. Therefore, if you are not certain of exactly how long the experiment will take, you should set the recording time to be sufficiently large that all the data from the experiment will be contained in a single block.

Reducing noise in the calculations

When recording, Chart uses a sampling rate which, for respiratory physiology experiments, may typically be set at 100 /s. However, in order to reduce noise in the results, respiratory calculations are performed on smoothed data. Smoothing is done by averaging data points from a period of time. You can set the duration of the time period to be used by the Metabolic Module in the averaging process.

To set the averaging time period for Metabolic Module calculations, choose Metabolic > Settings... > General Preferences, and enter the number of seconds for the Averaging Time.

Allowable values for the Averaging Time are 1–120 seconds. The message 'Insufficient Selected Data' will be displayed in the Metabolic plot windows if a data selection in the Chart View is of shorter duration than the specified Averaging Time.

Viewing the calculation results

The Metabolic Module provides eight windows for viewing the results of metabolic calculations:

- Metabolic Log window
- VE (BTPS) vs. VO₂ (i.e. \dot{V}_E vs. \dot{V}_{O_2})
- VE (BTPS) vs. VCO₂ (i.e. \dot{V}_E vs. \dot{V}_{CO_2})
- VCO₂ vs. VO₂ (i.e. \dot{V}_{CO_2} vs. \dot{V}_{O_2})
- RER vs. Time
- VO₂ vs. Time (i.e. \dot{V}_{O_2} vs. time)
- VCO₂ vs. Time (i.e. \dot{V}_{CO_2} vs. time)
- VE (BTPS) vs. Time (i.e. \dot{V}_E vs. time).

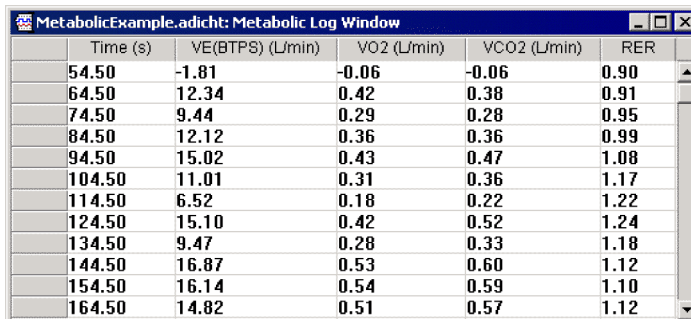
The Log window (see Figure 4–10) displays a table of calculation results for each Averaging Time period. All the other Metabolic windows display plots of calculation results. When working offline, you need to first select data from the Chart View before calculation results can be displayed.

*BTPS - Body Temperature
(36.6 °C), Ambient
Pressure, Saturated with
water vapor.*

*STPD - Standard
Temperature and Pressure
in Dry conditions: 0 °C
(273 K) and 760 mmHg,
zero humidity.*

Figure 4–10

The Metabolic Log window, with an Averaging Time period of 10 seconds.



Time (s)	VE(BTPS) (L/min)	VO2 (L/min)	VCO2 (L/min)	RER
54.50	-1.81	-0.06	-0.06	0.90
64.50	12.34	0.42	0.38	0.91
74.50	9.44	0.29	0.28	0.95
84.50	12.12	0.36	0.36	0.99
94.50	15.02	0.43	0.47	1.08
104.50	11.01	0.31	0.36	1.17
114.50	6.52	0.18	0.22	1.22
124.50	15.10	0.42	0.52	1.24
134.50	9.47	0.28	0.33	1.18
144.50	16.87	0.53	0.60	1.12
154.50	16.14	0.54	0.59	1.10
164.50	14.82	0.51	0.57	1.12

All the Metabolic windows may be opened together using the Open All Windows command from the Metabolic menu. You can open an individual window, or make an open window active, by choosing Metabolic Windows from the Metabolic menu and selecting the required window from the submenu.

The arrangement of windows in the screen can be controlled using the Cascade and Tile commands from the Windows menu. The icons for minimized windows may be organized at the bottom of the screen using the Arrange Icons command from the Windows menu.

Display controls

Display settings for individual channels in the Chart View may be customized using the Channel Settings dialog box. Please consult the *Chart User's Guide* for more detail on display controls.

The color and style of the background graticule for all channels in the Chart View may be customized using the Display Settings dialog box, opened from Chart's Setup menu.

The color and style of the signal traces in the VCO2 vs. Time and VO2 vs. Time Metabolic plot windows take the color of the signal traces of the relevant channel in the Chart View.

Axes controls

Axes in the Metabolic plot windows can be manipulated in a similar way to the channel amplitude axes in the Chart View:

- the scales of both axes can be resized (doubled or halved) using the scaling buttons for each axis, located at the bottom left of the plot
- alternatively, click and drag the axis when double arrows pointing

away from the axis midpoint appear

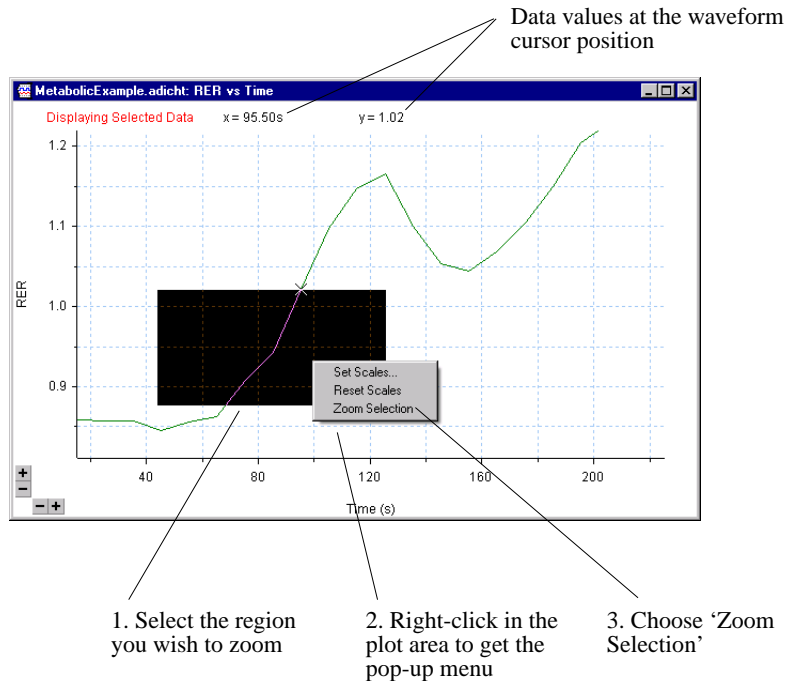
- the axis may be shifted in either direction, without resizing, by dragging the double-headed arrow
- precise limits for the axis scales can be entered into the Set Scales dialog by right-clicking in the plot and choosing Set Scales...
- axis scales can be restored by right-clicking in the plot and choosing Reset Scales.

Please refer to the *Chart User's Guide* for further details on these features.

Expanding the view

You can enlarge a region of interest in a Metabolic plot window by using the zoom feature.

Figure 4–11
Expanding a selection in a Metabolic plot window.



To zoom, click and drag to select the trace portion of interest, right-click in the plot area, and choose Zoom Selection from the pop-up menu (see Figure 4–11). The selected portion of the trace enlarges to fill the plot. You can restore the original view by right-clicking in the plot and choosing Reset Scales.

Data values

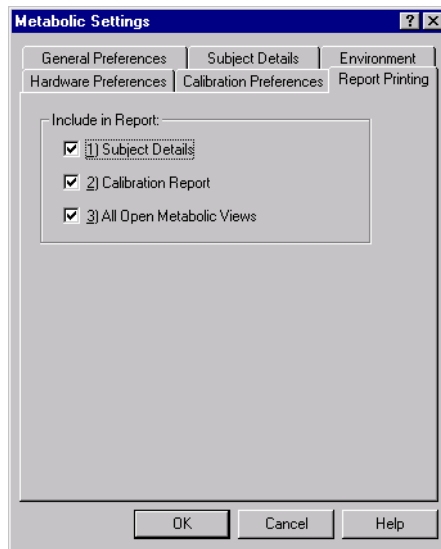
Data values at the Waveform Cursor position are displayed above the display area in the Metabolic plot windows.

Printing reports

The Metabolic Module can print a simple report of the current document. The details to be included in the report can be specified in the Report Printing pane of the Metabolic Settings dialog box (see Figure 4-12).

Figure 4-12

The Report Printing pane of the Metabolic Settings dialog box.



Note that if you wish to include all the open Metabolic windows in the report, you should have made a data selection in the Chart View first. This ensures that the windows have data displayed when they are printed.

You print the report by choosing the Print Report command from the Metabolic menu.

Printing Metabolic windows

You can print the contents of any of the Metabolic windows.

When you select a window it becomes active and the Print... command in the File menu changes to indicate the window's name.

Choosing this command causes the contents of the active window to be printed.

Copying Metabolic windows

You can copy the contents of any of the Metabolic windows.

When you select a window the Copy... command in the Edit menu changes to indicate the window's name. Either choosing the Copy command from the Edit menu or typing Ctrl+C causes the currently selected window to be copied to the Windows clipboard. Copied windows may then be pasted into another application (such as Microsoft Word). Data from the Log window is copied as text.

Viewing the recorded data

Chart provides several windows for viewing the recorded data. These include, in addition to the Chart View, the Zoom View, the X-Y View, the Data Pad and the Spectrum window.

To use any of these alternate views of the data, you first select all or a portion of the data in the Chart View.

Please refer to the *Chart User's Guide* for further details on these features.

Basics

The Gas Analyzers of the PowerLab/8M measure expired concentrations of O₂ and CO₂. If respiratory air flow measurements are made simultaneously, it is possible to calculate the rates of O₂ consumption and CO₂ production. Chart records data from the flow and gas inlet channels of the PowerLab/8M in real-time. From this data, the Metabolic Module calculates and displays a range of metabolic variables: \dot{V}_{O_2} (oxygen consumption), \dot{V}_{CO_2} (carbon dioxide production), Respiratory Exchange Ratio, and \dot{V}_E (expired flow) or \dot{V}_I (inspired flow). The module is designed for experiments in human metabolic physiology and the physiology of exercise, but not for clinical use.

Overview

The Metabolic Module is able to calculate and display metabolic data online. To operate, the module requires three channels of data with the following units: %CO₂ for CO₂ concentration, %O₂ for O₂ concentration, and L/s for flow (for Inputs 3, 4, and 7 of the PowerLab/8M, respectively).

The module also needs information about the recording conditions, such as the temperature of inspired or expired air. If these aren't measured, then default values are substituted (discussed later under Environment Details).

A Metabolic settings file was added, when the Metabolic Module was installed, to a folder called Metabolic, inside the Chart folder. It provides suitable gain ranges and units conversion settings for the PowerLab/8M and applies units conversion to some channels.

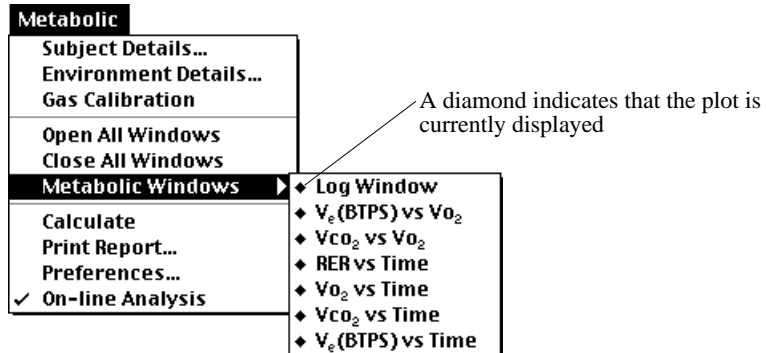
When the module is set to Online Analysis mode, it modifies the normal function of Chart. Most importantly, it will record for a fixed duration (entered into the Preferences, see below). The sampling rate is restricted to 10–1000 samples/s.

Additions to the Chart interface

When you start Chart with the Metabolic Module installed, the module loads automatically, and the Metabolic menu item is added to

the Chart menu bar. The components of the Metabolic menu are shown in Figure 5–1, and discussed in detail later.

Figure 5–1
The Metabolic menu.



Setting up

The Metabolic settings file

All Metabolic Module settings, including the print options, are saved along with the data in a Chart data file. Settings can also be saved in a Chart settings file (by way of the Save As... command). Settings are restored automatically when a file of either type is opened. Settings will remain the same for all data, until the settings are changed again.

A Metabolic settings file was installed in the Metabolic folder when you installed the Metabolic Module on your system. It provides suitable range and units conversion settings for using the Metabolic Module with Chart and the PowerLab/8M. The settings applied to Channels 3 and 4 in Chart are shown in Table 5–1.

Table 5–1
The Metabolic Settings file settings for Channels 3 and 4.

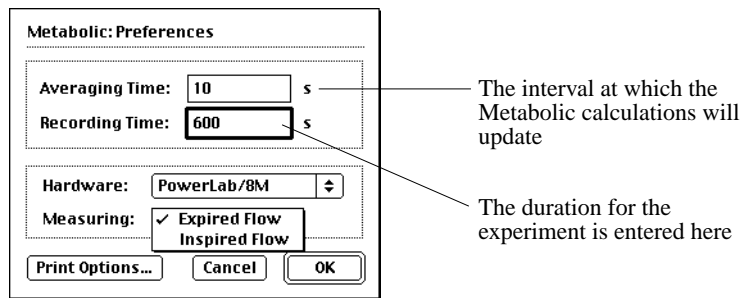
Setting	Channel 3	Channel 4
Channel on	✓	✓
Channel title	%CO2	%O2
Range	1 V	100 mV
Units	%CO ₂	%O ₂
Decimal points	2	2
Point 1	raw	0.027 V
	converted	0.03
Point 2	raw	0.6105 V
	converted	4.00
2 Point conversion	✓	✓

You use the Metabolic settings file by simply opening it. Opening the settings file automatically opens a new Chart document with all the settings applied. This new file should be saved with a new name to safeguard the original settings file. Before recording data into this new document you need to calibrate the transducers.

Preferences

Choosing the Preferences... menu item opens the Preferences dialog box (Figure 5–2). Details about the hardware, the arrangement of your breathing circuit (measuring inspired or expired flow), and values for the data averaging and recording time are entered here.

Figure 5–2
The Metabolic preferences dialog box.



In Figure 5–2, the module is expecting to see expired flow measured using the PowerLab/8M. When Chart starts recording, the module will average data at ten second intervals, for a duration of 600 seconds (ten minutes), and then automatically stop.

The Print Options... button opens a dialog box where the layout of a report can be chosen (see Copying and printing, p. 79).

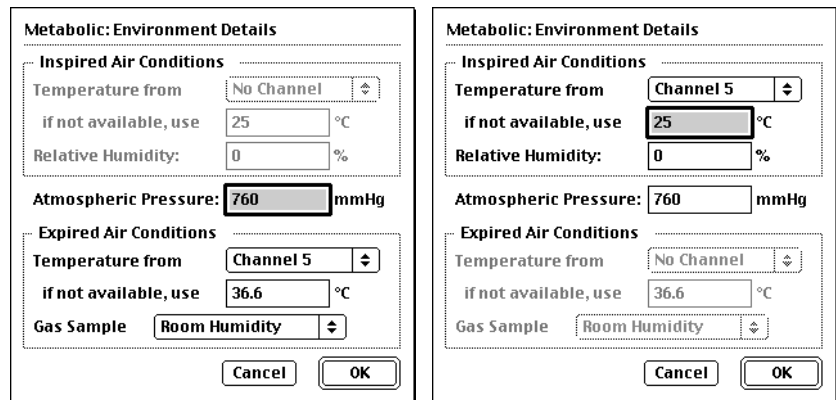
Changing the flow options in the Measuring pop-up menu allows editing of the Inspired or Expired Air Conditions in the Environment Details dialog box (see Figure 5–3).

Environment details

Choosing the Environment Details... item from the Metabolic menu displays the Environment Details dialog box (Figure 5–3). The dialog appears with some options grayed out, depending on whether inspired or expired flow is specified in the Preferences dialog box. The

Figure 5–3

The Metabolic Environment Details dialog box. When expired air is being measured (see Preferences) the options shown on the left are available; when measuring inspired air, the options shown on the right are available.



Metabolic Module calculates \dot{V}_{O_2} and \dot{V}_{CO_2} from \dot{V}_E and \dot{V}_I (expired and inspired minute volumes). To make these calculations the module needs additional information about the recording environment.

Values entered for temperature, atmospheric pressure, and relative humidity are used to convert minute volumes from ATPS or BTPS to STPD conditions (see Appendix A for more information). The values can be determined from a thermometer, barometer and hygrometer in the laboratory. Inspired or Expired Air Conditions can be modified by changing the flow Measuring options in the Preferences dialog box (see Figure 5–2).

A thermistor connected to Input 5 of the PowerLab/8M can be used to record temperature for either inspired (T_{room}) or expired (T_{breath}) air: in this dialog box choose Channel 5 from the Temperature pop-up menu. Temperature must be recorded in the units of °C, °F, or K. If the temperature signal from the dedicated channel is not available (because it exceeds the allowed limits, or Channel 5 is not used), then the default temperatures entered under the pop-up menu are substituted into the calculations.

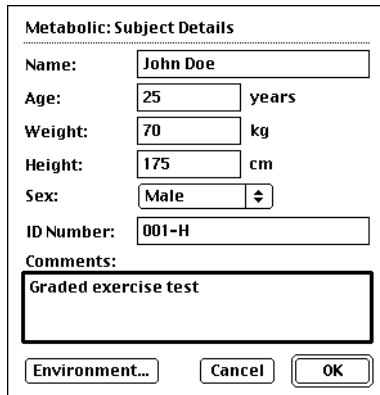
For inspired air flow measurement: the temperature is required to fall in the range of –50 °C to 100 °C, and 25 °C is the default value used if the temperature signal is not available. For expired air flow measurement: the temperature is required to fall in the range of 0–50 °C, and 36.6 °C is the default value used if the temperature signal is not available or outside this range. Atmospheric pressure is limited to a range of 0–1000 mmHg, and 760 mmHg is the default value.

Before entering the gas analyzer inlet, expired gas samples must be dried. Select the type of sample gas drying that you are using. Select Dry when passing the sample through a desiccant to remove moisture, and Room Humidity when using Nafion tubing.

Subject details

Choosing the Subject Details... item from the Metabolic menu displays a dialog box in which identifying details about the subject can be entered (Figure 5-4). The Comments field is useful for entering details such as the type of exercise protocol being performed. This field allows a maximum of 255 characters to be entered. These details do not affect any calculations, and they can be printed as part of a report. Clicking the Environment... button displays the Environment Details dialog box.

Figure 5-4
The Metabolic Subject Details dialog box.



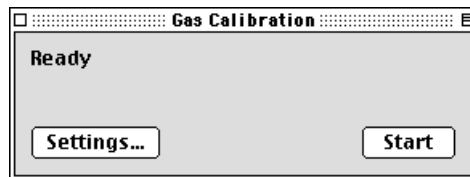
The dialog box titled "Metabolic: Subject Details" contains the following fields and controls:

- Name:
- Age: years
- Weight: kg
- Height: cm
- Sex: (dropdown arrow)
- ID Number:
- Comments:
- Buttons: Environment..., Cancel, OK

Gas calibration

Choosing Gas Calibration from the Metabolic menu displays a dialog box, from which the automated calibration procedure is controlled (Figure 5-5).

Figure 5-5
The Gas Calibration dialog box.



The dialog box titled "Gas Calibration" contains the following elements:

- Title bar: Gas Calibration
- Status: Ready
- Buttons: Settings..., Start

Click the Settings... button to open the Calibration Settings dialog box (Figure 5-6).

Figure 5-6
The Metabolic Calibration
Settings dialog box.

Metabolic: Calibration Settings	
Initial gas:	
Flush for	10 s
Sample for	10 s
O2 concentration:	20.93 %
CO2 concentration:	0.03 %
Wait for switch	5 s
Calibration gas:	
Flush for	10 s
Sample for	10 s
O2 concentration:	16 %
CO2 concentration:	4 %
Cancel OK	

The sequence in which the gas calibration is performed, and the times required, are entered here. Flushing times are required to be between 0–300 seconds. Sampling times of ten seconds or longer are needed to ensure a stable signal because the last five seconds of the flushing time are reserved for taking a reading. The Wait for Switch time must be less than 300 seconds. If no value is entered then zero seconds is used as the switching time.

Typically the initial gas will be atmospheric air, and the calibration gas will be similar in composition to expired air. Concentration values for the room air and your calibration gas must be entered in this dialog box. Room air has concentrations of $20.93 \pm 0.03\% \text{O}_2$ and $0.03 \pm 0.02\% \text{CO}_2$ at 0% humidity. These are the default values that appear for Initial gas concentrations in the Calibration Settings dialog box. Generally, a calibration gas has concentrations of around $16\% \text{O}_2$ and $4\% \text{CO}_2$ in a dry balance of N_2 . The two gases supplied during calibration must be sufficiently different that the CO_2 and O_2 transducer signals differ by at least 1% of the full scale range, otherwise the calibration routine will report an error.

A one litre bottle filled from the calibration gas cylinder provides a suitable container from which to draw a sample. This bottle should have a narrow neck so that draft effects are minimal. Note that high pressure gases, for example from the calibration gas cylinder, should

never be connected (even using a regulator) to the PowerLab/8M Gas Analyzer inlets.

The O₂ sensor is very sensitive to changes in gas flow. It is important, therefore, to use the same sampling line and gas inlet port for both the calibration gas and the sample gas, so that the sampling line resistance is kept as constant as possible.

On the front panel of the PowerLab/8M, connect the supplied Nafion sampling line to the Subject Inlet (or the Calibration Inlet) of the PowerLab/8M, but leave the other end open to room air initially. Switch the Inlet Select switch to Subject (or Calibration, if you are using the Calibration Inlet).

Ensure that the gas sampling pump is switched on.

The Start button initiates the calibration sequence. The calibration is a simple flushing and reading procedure which allows time for you to switch from the initial gas to the calibration gas. During calibration, the Gas Calibration window indicates progress with messages: 'Ready', 'Flushing', 'Reading', and 'Waiting for Switch'.

When the message 'Waiting for Switch' is displayed, change from room air to the calibration gas by putting the open end of the sampling line into the 1 L bottle previously filled with the calibration gas. Sampling now occurs from the calibration gas in the 1 L bottle, to obtain the second calibration point.

This arrangement allows quick switching between gases during calibration, and maintains constant sampling line resistance. This latter point is essential because the O₂ sensor is affected by flow, so the sampling line resistance must remain constant between calibration points.

After Calibration, the Metabolic Module automatically annotates the O₂ and CO₂ traces with comments containing the time and values for the reading with standard deviations. Gas concentration values and the voltage readings from the calibration are used to automatically convert the raw voltage readings from the CO₂ and O₂ channels to %CO₂ and %O₂ using Units Conversion (see Chapter 3 of the *Chart User's Guide* for details). If Units Conversion is already applied (such as in the PowerLab/8M Settings file) then the existing values are simply modified. Calibration details can be included in a report printout by selecting the Calibration Report checkbox shown in Figure 5-9 on page 79.

Using Metabolic

Online and offline analysis

The Metabolic Module can be used to plot results during the course of an experiment. This mode is active when the Online Analysis menu item is enabled (has a tick beside it). To stop a recording before the end of the designated experiment time, click Chart's Stop button. Clicking Start again will begin recording a new set of data, overwriting the previously displayed metabolic results.

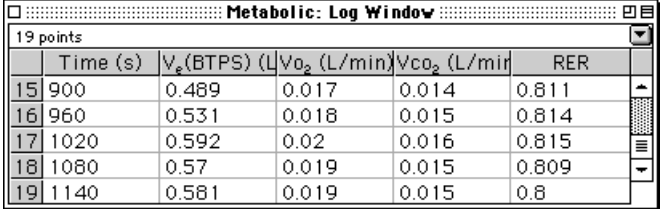
A data file can be analyzed when operating online or offline. Firstly, select a range of data (usually this will be an entire data block, for which you can use the Chart short-cut: a double-click in the time axis area). Choose the Metabolic menu command Open All Windows, then choose Calculate. From the same menu, data is tabulated using the Averaging Time entered in the Preferences. The Recording Time setting is ignored and the length of the data selection is used as the duration of the experiment.

At the end of recording, data can be reanalyzed if, for example, you are unsatisfied with the averaging time used. Simply open the Preferences dialog box, change the Averaging Time, close the dialog box, make a data selection, and choose Calculate. Note that selections across data blocks cannot be analyzed — only data contained within individual data blocks can be analyzed and displayed.

Metabolic windows

The Log window is a table of time-averaged data points used to construct the plots (Figure 5-7).

Figure 5-7
The Metabolic Log window.



The screenshot shows a window titled "Metabolic: Log Window" containing a table with 19 rows of data. The table has five columns: Time (s), \dot{V}_E (BTPS) (L), \dot{V}_{O_2} (L/min), \dot{V}_{CO_2} (L/min), and RER. The data points are as follows:

	Time (s)	\dot{V}_E (BTPS) (L)	\dot{V}_{O_2} (L/min)	\dot{V}_{CO_2} (L/min)	RER
15	900	0.489	0.017	0.014	0.811
16	960	0.531	0.018	0.015	0.814
17	1020	0.592	0.02	0.016	0.815
18	1080	0.57	0.019	0.015	0.809
19	1140	0.581	0.019	0.015	0.8

The windows are opened by choosing Open All Windows from the Metabolic menu. For online recording, open the windows either before clicking Start, or after recording has commenced. Individual

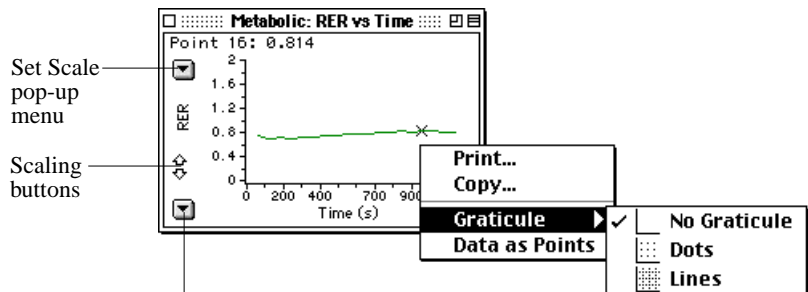
windows are opened by choosing them from the Metabolic Windows submenu. Up to six plots may be displayed, all constructed from values in the Log window:

- \dot{V}_E (BTPS) or \dot{V}_I (ATPS) vs \dot{V}_{O_2}
- \dot{V}_{CO_2} vs \dot{V}_{O_2}
- RER vs time
- \dot{V}_{O_2} vs time
- \dot{V}_{CO_2} vs time
- \dot{V}_E (BTPS) or \dot{V}_I (ATPS) vs time.

Equations used to calculate \dot{V}_{O_2} , \dot{V}_{CO_2} , and the Respiratory Exchange Ratio (RER) are found in Appendix A.

Metabolic windows float in front of the Chart window. They can be closed individually by clicking the close box, or collectively by choosing the menu item Close All Windows. The windows can be automatically rescaled back to the default size and location by holding down the Option key when selecting Open All Windows from the Metabolic menu (this action will also open any closed windows). Plot axes can be adjusted using the Set Scale pop-up menu or the Scaling buttons. Various other options, such as choice of plot graticules, can also be accessed by holding down the Control key and clicking in the display region of a plot window or by clicking the button at the bottom left of the windows (see Figure 2–7). The graticule color is determined by the settings in Chart’s Display Settings dialog box.

Figure 5–8
The Metabolic window display controls.



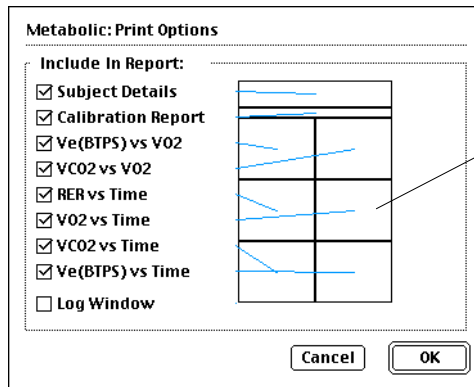
Control-clicking in the display area or clicking this button displays the pop-up menu (shown at right).

Copying and printing

The Metabolic windows can be individually printed or copied to the Clipboard. A pop-up menu with these options is available by Control-clicking in the display area or by using the button at the bottom left of the window (see Figure 5–8 above). Note that for the Log window, the button for the pop-up menu is at the top right of the window. Data from the Log window is copied as text.

The Print Report... command from the Metabolic menu prints a comprehensive report. The Print Options dialog box (accessed from the Preferences dialog box) allows the appearance of the printed report to be customized (Figure 5–9). Customize your report by selecting the checkboxes for items that you wish to include in the printout. A calibration report is only included if a calibration is performed. If you run a pre- and post-experiment calibration, then only the results of the last calibration run are printed in the report. Tabulated data from the Log window is usually printed separately from the other pages.

Figure 5–9
The Print Options dialog box.



The lines indicate where the associated item will be included in the report

General background

The rates of oxygen consumption, \dot{V}_{O_2} , and carbon dioxide production, \dot{V}_{CO_2} , are calculated as the differences between the expired and inspired minute volumes:

$$\dot{V}_{O_2} = \dot{V}_I F_{I O_2} - \dot{V}_E F_{E O_2} \quad [1]$$

$$\dot{V}_{CO_2} = \dot{V}_E F_{E CO_2} - \dot{V}_I F_{I CO_2}$$

where F_I is an inspired fraction, F_E is an expired fraction and \dot{V}_I and \dot{V}_E are the minute volumes of inspired and expired air.

The application of these equations would be straightforward if you were measuring both \dot{V}_I and \dot{V}_E . It is standard practice, however, to measure only one of these, and to calculate the other from it. This is done via the Haldane transformation, which relies on the facts that:

a) at nitrogen equilibrium

$$\dot{V}_I F_{I N_2} (STPD) = \dot{V}_E F_{E N_2} (STPD), \text{ and}$$

b) the components of dried air are such that

$$F_{O_2} + F_{N_2} + F_{CO_2} = 1.$$

The fractions of gases in dry air are listed in Table A-1.

Gas	Fraction
nitrogen and argon (inert)	0.7904
oxygen	0.2093
carbon dioxide	0.0003

Table A-1

The composition of dry air.

Volume conversions

The Metabolic Module always displays a minute volume of air as \dot{V}_E at BTPS, regardless of recording settings. When you are measuring \dot{V}_E directly, the Metabolic Module uses the averaged values of flow as measured. Alternatively, you may specify (in the Environment tab of the Metabolic Settings dialog box for Windows, and in the Preferences dialog box for the Macintosh) that you are recording inspired air flow. In this case it is \dot{V}_I that is recorded, and the Metabolic Module converts this to a value that reflects what \dot{V}_E

BTPS - Body Temperature (36.6 °C), Ambient Pressure, Saturated with water vapour.

ATPS - Ambient
Temperature and Pressure,
Saturated with water
vapour.

would have been had it been measured. This requires a conversion from ATPS to BTPS using the gas law equation:

$$\frac{PV}{T} (BTPS) = \frac{PV}{T} (ATPS)$$

which in the present case becomes:

$$\dot{V}_I(BTPS) \frac{P_{atm} - P_{sat}(T_{breath})}{273 + T_{breath}} = \dot{V}_I(ATPS) \frac{P_{atm} - P_{vap\cdot room}}{273 + T_{room}}$$

where P_{sat} as a function of T is:

$$P_{sat}(T) = 13.955 - 0.6584T + 0.0419T^2$$

Expired volumes are assumed to be at a temperature T_{breath} . This can either be measured by a thermistor placed in the stream of expired air close to the flow head, or entered as a constant value (in the Environment tab of the Metabolic Settings dialog box for Windows, or in the Environment Details dialog box on the Macintosh). In either case, the expired volume is assumed to be saturated with water vapour at a pressure P_{sat} .

P_{atm} is the atmospheric pressure in mmHg, $\dot{V}_I(ATPS)$ is the measured inspired flow, and T_{room} is room temperature in °C. The water vapour pressure is given by:

$$P_{vap\cdot room} = H_{rel} \times P_{sat}(T_{room}) / 100$$

where H_{rel} is % relative humidity.

Calculating $\dot{V}O_2$

By convention, $\dot{V}O_2$ is expressed at STPD.

The calculation differs according to whether \dot{V}_I or \dot{V}_E is measured.

If \dot{V}_I is measured then equation 1 above becomes:

$$\dot{V}O_2(STPD) = \dot{V}_I(STPD) \left\{ F_{IO_2} - \frac{F_{IN_2}}{1 - F_{EO_2} - F_{ECO_2}} F_{EO_2} \right\}$$

where

$$\dot{V}_I(STPD) = \dot{V}_I(ATPS) \frac{P_{atm} - P_{vap\cdot room}}{273 + T_{room}} \frac{273}{760}$$

STPD - Standard
Temperature and Pressure
in Dry conditions: 0 °C
(273 K) and 760 mmHg,
zero humidity.

If \dot{V}_E is measured then equation 1 above becomes:

$$\dot{V}_{O_2}(STPD) = \dot{V}_E(STPD) \left\{ F_{I_{O_2}} \frac{1 - F_{E_{O_2}} - F_{E_{CO_2}}}{F_{I_{N_2}}} - F_{E_{O_2}} \right\}$$

where

$$\dot{V}_E(STPD) = \dot{V}_E(BTPS) \frac{P_{atm} - P_{sat}(T_{breath})}{273 + T_{breath}} \frac{273}{760}$$

Calculating V_{CO_2}

\dot{V}_{CO_2} is calculated using equations that correspond to those given above for \dot{V}_{O_2} , but with the obvious substitutions.

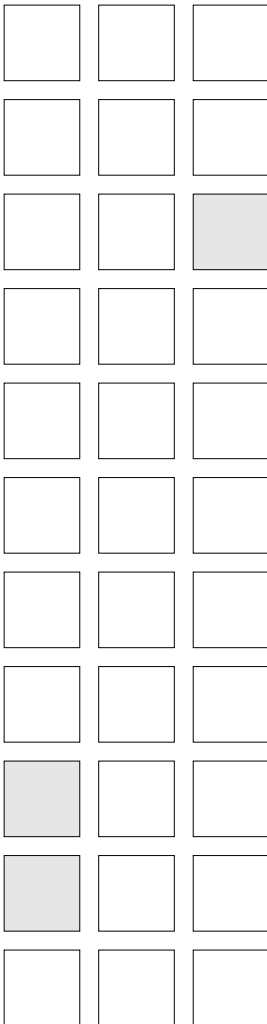
Respiratory Exchange Ratio

The Respiratory Exchange Ratio (RER) is calculated as:

$$RER = \frac{\dot{V}_{CO_2}}{\dot{V}_{O_2}}$$

B

Troubleshooting



This appendix describes difficulties that you may encounter when using the Metabolic System. It covers problems that might occur with the hardware, such as the PowerLab/8M, and the warning messages generated by the Metabolic Module. For problems to do with Chart please refer to the *Chart User's Guide*. If none of the suggestions work, then please consult your ADInstruments distributor.

Details of SCSI connections are described in Appendix C.

Hardware

Communication problems

Most connection problems that users encounter are SCSI problems. Improper connections can result in a loss of all or some of a signal. SCSI difficulties can cause data loss, failure of the computer to recognize that SCSI devices are attached to it, and difficulties using other SCSI devices. SCSI problems do apply when using USB.

The Status indicator light flashes red and orange on start-up

If the pattern is simply an alternating red flash and orange flash, then the SCSI ID has been set to the numbers 0 or 7. Only 1 to 6 are valid SCSI ID numbers.

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

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

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

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

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

- Check switches, power connections, and fuses.

Poor cable connection between PowerLab and computer, or bad cable.

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

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

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

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

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

The computer hangs while recording, or there is data loss

Poor connection between PowerLab and computer, or a bad cable.

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

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

- Check that each device has a unique ID number and that the SCSI chain is terminated correctly.

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

Poor cable connection between the PowerLab and computer, or a bad cable.

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

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

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

Partitioning problems on the hard disk (is rare but can happen even with new disks).

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

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

The correct drivers are not installed on your computer (they should be in the Essential Files folder in the Chart or Scope folder).

- Reinstall the software.

Spirometer problems

The Spirometer's trace does not zero properly when using automatic or manual zeroing

Variations in the signal during auto-zeroing may cause the software to fail to zero properly.

- Keep flow heads still while zeroing, to prevent small changes in pressure reaching the Flow Head Inlet.

The Spirometer's signal is noisy at lower ranges

This is not a fault but usually amplified noise from the transducer.

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

The Spirometer is recording a weak signal at lower ranges

There may be a leak from the tubing, or condensation in the tubing or condensation on the gauze of the flow head.

- Check that all connections are tight and there are no leaks from the tubing.
- Check that tubing and gauze is free from condensation. Dry or replace if wet. To minimize moisture build-up, record with the pipes from the flow head pointing upwards.

Bio Amplifier problems

The Bio Amp trace does not zero when adjusting high-pass filters

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

- Check the connections for proper contact and try again.

The signal appears to display a constant amplitude oscillation

Interference from mains power can appear as a superposition when measuring biological signals.

- Use the notch filter in the Bio Amp dialog box to remove interference.
- Only use the cable and leads supplied with the system or high quality shielded leads.

The Bio Amp signal is noisy at lower ranges

Noise is amplified along with any biological signal.

- Excessive noise can be removed by using a low-pass filter although important components of a biological signal may be attenuated.
- Turn off unnecessary pieces of equipment.
- Move the subject away from excessively noise environments such as the front of computer screens.

The Bio Amp signal is clipped or distorted.

This can be a combined problem of sampling, filtering or range settings.

- Check that the settings you are using are appropriate for the expected signal. Information about recording biological signals is available from our website (www.adinstruments.com).

Software

This section describes warnings specific to the Metabolic Module (Windows or Macintosh versions) as indicated by a message displayed on the screen. For other classes of problems please refer to the *Chart User's Guide*.

Windows

The following warning messages may be displayed when you are using the Metabolic Module:

“Calibration failed”

This dialog box may be displayed at the end of the Metabolic gas calibration routine.

The message indicates that the transducer signals for the first and second calibration gases did not appear to the Metabolic Module to differ by at least 1% of the full scale range.

- You should check all cable and gas connections, and work through the Calibrating the gas analyzers section.

“Insufficient selected data”

The ‘Insufficient Selected Data’ message is displayed in Metabolic plot windows when the selection made in the Chart View is of shorter duration than the averaging time.

- You should either change the selection to be of longer duration or change the Averaging Time to be of shorter duration.

“Invalid selection”

This dialog box is displayed if you make a data selection over more than one block of data when the Metabolic Module is enabled. Only the data in the last selected block is used in calculations.

“Not all required metabolic channels are enabled”

This dialog box may be displayed when you start sampling with the Metabolic Module enabled.

▼ Refer

Calibrating the gas analyzers, p. 58

▼ Refer

Reducing noise in the calculations, p. 63

▼ **Refer**

Chart settings, p. 52
Metabolic Module settings, p. 54

▼ **Refer**

Chart settings, p. 52
Metabolic Module settings, p. 54

The message indicates that one or more required Chart channels are not turned on, or that Metabolic channel associations are incorrect.

- You need to check the channel settings and channel associations for the channels indicated in the dialog box.

“Unrecognized channel units”

This dialog box may be displayed when you open a Chart file, enable the Metabolic Module, begin sampling, or make a selection in the Chart View.

The message indicates that the Chart file you are working with has Units Conversion or channel associations incorrectly set up. Calculations may still be performed, but the results may not be reliable.

- You need to check the unit conversions and channel associations for the channels indicated in the dialog box.

Macintosh

The following problems and warning messages may be encountered when using the Metabolic Module for the Macintosh:

The metabolic windows fail to update during a recording (except the RER vs time window)

The module expects inspired flow signals to be positively deflected and expired flow signals to be negatively deflected. For example, if your Preferences are set for measuring expired flow and the signal in the Spirometer Amplifier dialog box is showing a positive deflection, then any calculation using \dot{V}_E will fail to update.

- Use the Invert checkbox in the Spirometer Amplifier dialog box to change the polarity of the flow signal.
- Check that the type of breathing circuit is compatible with the Preferences you have chosen.

Chart stops recording automatically after a period of time

The Recording Time in the Preferences dialog box automatically stops Chart recording after the duration specified has elapsed.

-
- Disable the On-line Analysis menu item if you don't require the metabolic plots to update online, and for experiments that do not require the control of the Metabolic Module.

“Metabolic extension: Incorrect temperature unit specified (<unit>)”

The temperature unit for Input 5 has been incorrectly specified. In most cases this is a keyboard entry error.

- Specify the signal for Input 5 in units of °C, °F or K.

“Metabolic extension: Temperatures are not in the range 0-50° C”

This alert informs the user that non-physiological average temperatures are being recorded from Input 5 for expired flow measurements. Temporary temperature spikes do not trigger the alert. Calculations will still proceed if temperatures are outside this range using the specified value in the Environment Details dialog box.

“Metabolic extension cannot find channel(s) with correct units”

Three channels (recording in units %CO₂, %O₂, and L/s) are needed to calculate \dot{V}_{CO_2} and \dot{V}_{O_2} . If the units for the channels recording these parameters are incorrect or not specified then this message appears.

- Specify the units for Channel 3 as %CO₂, for Channel 4 as %O₂ and for the Spirometer (Channel 7) as L/s.

“Calibration failed: The concentration values are too close”

For a gas calibration to be accepted, a signal difference greater than 1% of the full range between the concentrations of the calibration gas and air is expected.

- Adjust the gain range setting to be more sensitive.
- Increase the concentration difference of the calibration gas from air.

“Metabolic extension cannot calibrate: at least one of the gas channels should be on”

A calibration has been attempted with both the CO₂ and O₂ channels turned off. At least one of the gas inlet channels needs to be turned on for the calibration routine to finish.

- Turn on Channel 3 (CO₂) and /or Channel 4 (O₂).

“Averaging time is too short (should be no less than 5 sec)”

The Averaging Time that you specified in the Preferences dialog box is either zero, a negative value, or shorter than five seconds.

- Specify a positive value longer than five seconds.

“Duration of the experiment is too short (should be no less than Averaging Time)”

You have specified a longer Averaging Time than the Recording Time in the Preferences dialog box. The experiment duration should be longer than the Averaging Time.

- Specify a Recording Time longer than the Averaging Time.

“Selection is too short”

You have selected a length of data shorter than the Averaging Time specified in the Preferences dialog box, and the module cannot calculate \dot{V}_{CO_2} and \dot{V}_{O_2} .

- Select a length of data longer than the Averaging Time for display, or reduce the Averaging Time.

“Metabolic extension works only when ADInstruments spirometer is connected”

You have attempted to use the Metabolic Module without a PowerLab/8M, or PowerLab and Spirometer connected. The module requires either a PowerLab/8M or a PowerLab and an ML140 Spirometer to collect data.

“Metabolic extension cannot sample: invalid sampling rate (should be between 10 and 1000 samples/sec)”

With On-Line Analysis active, sampling rates are limited to the range of 10 to 1000 samples/s. If you require rates greater than 1000 samples/s, make Metabolic offline and use the module to analyze your data at the end of the experiment.

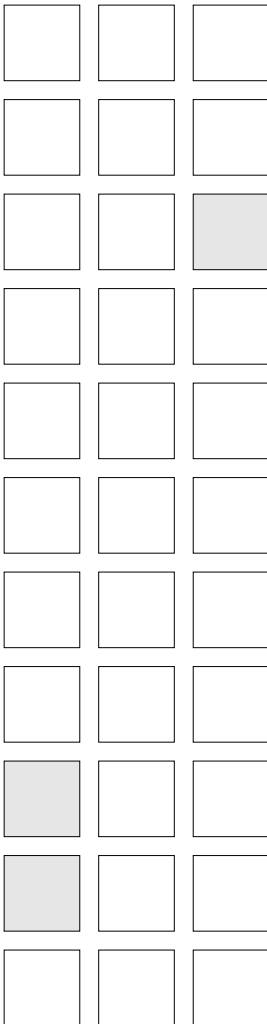
- When using Metabolic online, reduce the sampling rate to 1000 samples per second or less.

“Metabolic extension: the selection has included more than one block of data. Only the first block is processed”

A selection over two or more blocks of data has been made. The module requires a continuous time line to display a selection. Data can be divided into blocks if Chart is stopped and started during a recording or data has been deleted from the file. In this case, data from the first selected block is calculated and displayed by the Metabolic Module.

C

USB and SCSI



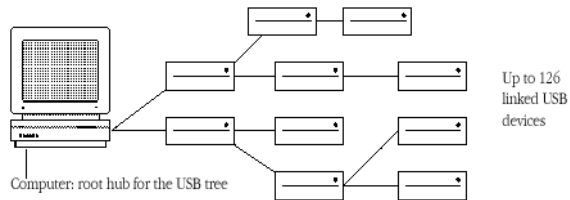
This Appendix provides information about making USB and SCSI connections between a computer and other devices, such as the PowerLab/8M.

The USB connection

USB devices are connected in a tree-like structure, with the host (the computer) forming the root of the tree, and hubs, allowing multiple devices to connect to them, like the branches of the tree. A hub is simply a device that lets you extend the USB tree. It connects to a USB device such as the computer, and allows multiple USB devices (including other hubs) to connect to it in turn. It provides power for up to 126 linked USB devices.

Figure C-1

A USB tree allows up to 126 devices to be connected to the computer.



USB connection rules

1. *Cable length should be less than 5 meters (16 feet) between devices.*

Devices include USB hubs. There can be a maximum of five hubs on any branch, so the maximum distance between the computer and the PowerLab is 30 meters (98 feet). Do not use extension cables. Use hubs connected by approved high-speed cables.

2. *Never attempt to make your own USB cable, or modify one.*

USB is sensitive to cable impedances and cable lengths. Only use a certified USB cable from a reliable supplier. The PowerLab is supplied with an approved USB cable. Additional USB cables should be high-speed cables (fully shielded, twisted-pair, and with standard USB connections) for reliable results.

3. *Don't disconnect the PowerLab while a program is using it.*

Stop sampling and quit the application program before disconnecting the PowerLab from USB.

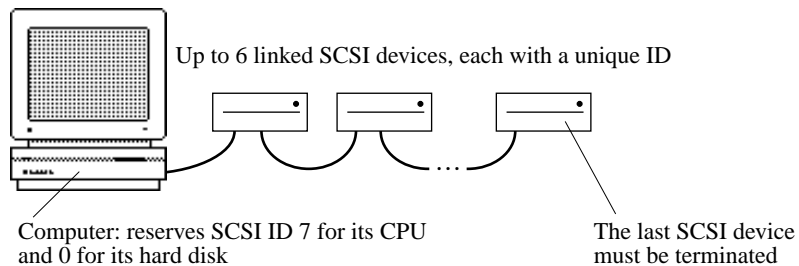
You can disconnect or reconnect a PowerLab using USB while the computer remains on as long as Chart is closed when you do it.

The SCSI connection

Small Computer System Interface (SCSI pronounced as 'suzzy') is a communication standard for connecting SCSI devices together on a common high-speed communication pathway. The PowerLab/8M can communicate with your computer using SCSI, by connecting it directly to the SCSI port of the computer, or at the end of the SCSI chain (see Figure C-2). A SCSI connection can handle up to the 4 megabytes per second maximum data transfer rate. Generally the SCSI connection is used on older computers that do not support USB.

Figure C-2

A chain of SCSI devices and a computer linked to form a SCSI chain.



SCSI devices can be linked together to form a SCSI chain and generally, except for computers, SCSI devices will have two connectors. The maximum number of devices within the same SCSI chain is eight. This includes the computer and its internal hard disk, which leaves six other SCSI devices that can connect to most computers. Each device in the chain must have a unique SCSI identification number assigned to it. The numbers range from 0 to 7, with 7 the highest priority device. The computer CPU reserves a SCSI ID number of 7 for itself. An internal hard disk takes a SCSI ID of 0 (zero), and an internal CD-ROM, usually takes a SCSI ID of 3. It is recommended to give higher numbers to more frequently used devices, however only one SCSI device communicates with the computer at any one time. The PowerLab/8M unit will register an error at start-up if its ID is set to 0 or 7.

SCSI connection rules

1. *The SCSI chain must be terminated correctly.*
This is the most important rule. Failure to terminate the chain properly can result in intermittent communication, no communication, or failure of the computer to boot up.

-
2. *Each SCSI device must have its own unique SCSI ID number.*
No two SCSI devices can have the same SCSI ID number. In the Mac OS environment, SCSI ID 7 is reserved by the computer, SCSI ID 0 is usually reserved by an internal hard disk, and SCSI ID 3 by an internal CD-ROM, if present. External devices can have ID numbers from 1 through 6. Set the PowerLab/8M to these numbers when using SCSI to communicate with your computer.
 3. *Turn SCSI devices on and off in the right sequence.*
Turn on all external SCSI devices before the computer, and turn off the computer before turning off other devices. Turning other SCSI devices on before your computer ensures that the SCSI bus is stable before your computer tries to use it. Similarly, turning your computer off first prevents external SCSI devices from ‘hanging’ the SCSI bus and preventing access to the internal hard disk. Do not operate with some devices in a chain turned off, as this degrades performance and signal quality.
 4. *Never attempt to make your own SCSI cable.*
SCSI is sensitive to cable impedances and cable lengths. Only use an approved SCSI cable or cables from a reliable supplier.
 5. *Total cable length should be less than 6 meters.*
SCSI circuits can only transmit data reliably over short lengths of cable. The total length of the chain, not the length between devices, is important. This includes the short lengths of cable inside the computer and other SCSI devices.
 6. *Never alter the SCSI chain while any SCSI devices are on.*
Disconnecting a SCSI device while there is hard disk activity may cause data loss or electrical damage. Switch all devices off, including the computer, before adding or removing SCSI devices.
 7. *Avoid mixing cable types, brands, and styles.*
Mixing poor-quality SCSI cables with approved high-quality SCSI cables can result in problems. Different cable types or brands may have different types of construction, impedance, and wire placement. Avoid using cable joiners and junctions to extend cable lengths.

SCSI chain termination

Terminating the SCSI bus is essential to preserve the integrity of the high-speed signals present on the bus. Termination helps keep these

signals free from noise and prevents unwanted signal reflections up and down the bus.

Possible dangers of not following the SCSI device connection protocols include loss of data, intermittent communications, corruption of data on the hard disk, failure of the computer to boot from a SCSI drive, and failure of the computer to recognize SCSI devices connected to it.

Terminate the SCSI chain by placing terminators at each end of the chain. The computer is terminated internally, so forming one end of the chain. The PowerLab/8M unit can be anywhere in the SCSI chain, and an external terminator should be connected to the last SCSI device in the chain, whatever it is (or if the device has internal SCSI termination, this should be switched on).

If you wish to use multiple SCSI devices with the computer, the internal, terminated hard disk of the computer is the start of the chain. The last device in the chain needs to be terminated and ensure that each device in the SCSI chain has a unique SCSI ID number. Do not use SCSI ID number of 0 (internal hard disk), a SCSI ID of 7 (computer) and a SCSI ID of 3 (CD-ROM). The remaining SCSI IDs of 1 through to 6 can be used by the external devices.

PowerLab/8M

(As tested at the time of printing and subject to change.)

General inputs

Number of input channels:	2	
Input configuration:	Single-ended	
Amplification range:	± 2 mV to ± 10 V full scale in 12 steps:	
	<i>Range</i>	<i>Resolution</i>
	± 10 V	0.30 mV
	± 5 V	0.15 mV
	± 2 V	60 μ V
	± 1 V	30 μ V
	± 0.5 V	15 μ V
	± 0.2 V	6.0 μ V
	± 0.1 V	3.0 μ V
	± 50 mV	1.5 μ V
	± 20 mV	0.60 μ V
	± 10 mV	0.30 μ V
	± 5 mV	0.15 μ V
± 2 mV	0.06 μ V	
Maximum input voltage:	± 15 V	
Input impedance:	≈ 1 M Ω 47 pF @ DC	
Low-pass filtering:	20 kHz to 1 Hz in 13 steps	
AC coupling:	DC or 0.16 Hz (software-selectable)	
Frequency response (-3 dB):	20 kHz @ ± 10 V full scale, all gain ranges	
DC drift:	Software corrected	
CMRR (differential):	96 dB @ 50 Hz (typical)	
Channel crosstalk:	-110 dB typical	
Input noise:	< 2.4 μ V _{rms} referred to input	

Sampling

ADC resolution:	16 bits (312.5 μ V resolution at 10 V range)
Linearity error:	± 1 LSB (from 0 $^{\circ}$ C to 70 $^{\circ}$ C)
Maximum sampling rates:	200 kHz on one channel
	100 kHz on two channels
	40 kHz on three to five channels
	20 kHz on six to eight channels
Available sampling rates:	200 kHz down to 0.03 Hz in Chart
	200 kHz down to 2 Hz in Scope
	Sampling on USB may limit maximum sampling rate.

Output amplifier

Number output channels:	2	
Output configuration:	Single channel (complementary) or two independent outputs	
Output resolution:	14 bits (0.6 mV resolution at 10 V range)	
Maximum output current:	± 12 mA	
Output impedance:	0.1 Ω typical	
Slew rate:	6 V/ μ s	
Settling time:	2 μ s (to 0.01% of FSR for LSB change)	
Linearity error:	± 1 LSB (from 0 $^{\circ}$ C to 70 $^{\circ}$ C)	
Output range:	± 200 mV to ± 10 V full scale in 6 steps	
	<i>Range</i>	<i>Resolution</i>
	± 10 V	5 mV
	± 5 V	2.5 mV
	± 2 V	1 mV
	± 1 V	500 μ V
	± 500 mV	250 μ V
	± 200 mV	100 μ V

External trigger

Trigger threshold:	$3.3 \pm 0.4 \text{ V}$
Hysteresis:	$> 0.2 \text{ V}$
Input load:	$1.2 \text{ k}\Omega$
Maximum input voltage:	$\pm 12 \text{ V}$
Minimum pulse duration:	$5 \mu\text{s}$

Bio Amplifier

Connector type:	6-pin DIN/MS socket to fit 3-Lead Bio Amp Cable	
Input configuration:	High impedance, differential (floating), electrically isolated	
Amplification range:	$\pm 5 \mu\text{V}$ to $\pm 100 \text{ mV}$ full scale in 14 steps (combined PowerLab and Bio Amp)	
	<i>Full Scale</i>	<i>Resolution</i>
	$\pm 100 \text{ mV}$	$50 \mu\text{V}$
	$\pm 50 \text{ mV}$	$25 \mu\text{V}$
	$\pm 20 \text{ mV}$	$0 \mu\text{V}$
	$\pm 10 \text{ mV}$	$5 \mu\text{V}$
	$\pm 5 \text{ mV}$	$2.5 \mu\text{V}$
	$\pm 2 \text{ mV}$	$1 \mu\text{V}$
	$\pm 1 \text{ mV}$	500 nV
	$\pm 500 \mu\text{V}$	250 nV
	$\pm 200 \mu\text{V}$	100 nV
	$\pm 100 \mu\text{V}$	50 nV
	$\pm 50 \mu\text{V}$	25 nV
	$\pm 20 \mu\text{V}$	10 nV
	$\pm 10 \mu\text{V}$	5 nV
$\pm 5 \mu\text{V}$	2.5 nV	
Gain accuracy:	$\pm 1.5\%$ all ranges	
Non-linearity:	$< 0.1\%$ within range	

Noise at various bandwidths:	
1 Hz to 5 kHz:	< 1.3 μ V rms (<8 μ V peak to peak)
0.3 Hz to 1 kHz:	< 0.6 μ V rms
0.1 Hz to 100 Hz:	< 0.35 μ V rms (at 200 samples/s)
CMRR:	> 76 dB (to isolated earth, 10 Hz to 1 kHz)
IMRR:	> 130 dB (to true earth, 50 to 100 Hz)
Input impedance:	200 M Ω differential, 30 pF (no cable) or 200 pF (supplied Bio Amp Cable and Leads) to isolated ground
Input leakage current:	< 3 μ Arms at 240 V, 50 Hz
	< 2 μ Arms at 120 V, 60 Hz
Isolation voltage:	3.75 kV rms (50 Hz for 60 seconds)
DC blocking:	\pm 1 V
Baseline restore:	Automatic
Low-pass filter:	Fourth-order Bessel, \pm 3% accuracy (software-selectable)
Standard:	50, 100, 200 and 500 Hz, and 1 and 5 kHz (all at -3 dB)
EEG mode:	3, 10, 30, 60 and 120 Hz
High-pass filter:	First-order Bessel, \pm 0.25% accuracy (software-selectable)
Standard:	0.1, 0.3, 1, 3 and 10 Hz (all at -3 dB)
EEG mode:	0.03, 0.1, 0.3 and 1 seconds
Notch filter:	Second-order filter, -32 dB attenuation 50 or 60 Hz frequency (automatic sensing)

Spirometer

Input:	Differential pressure ± 12.5 cm (5") H ₂ O (9.3 mmHg, 1240 Pa)
Amplification range:	± 10 V to ± 2 mV in 12 steps
Maximum input pressure:	± 5 psi (34.5 kPa)
Pressure sensitivity:	1.27 V per cm (0.5 V per inch) H ₂ O
Low-pass filtering:	1 Hz, 10 Hz and 100 Hz (software-selectable) using fourth-order Bessel
Amplifier noise:	<3 μ V rms at 10 kHz bandwidth
	<1 μ V rms for 100 kHz bandwidth and lower
Zeroing and offset:	Manual or automatic software controlled. Controlled by internal 12-bit DAC; resolution ± 2048 steps about 0 V

CO₂ and O₂ inlets

Sampling system:	One CO ₂ and one O ₂ transducer fed from a damped, micro-vacuum pump. Moisture must be removed prior to sampling.
Gases:	Must be non-corrosive and non-flammable. O ₂ measurements affected by NO and NO ₂ above trace amounts.
System sampling flow rate:	100 mL / minute fixed
Desiccant material:	Drierite, indicating 0.8–2 mm granules
	Nafion tubing
Inlet connector:	Plastic luer
Bacterial filter:	Internal bacterial filter fitted before transducers (5 micrometer, teflon hydrophobic membrane filter)

Materials in contact with gas:	316 stainless steel, sapphire, nylon 66, borosilicate glass, platinum, platinum/iridium alloy, silicone rubber, epoxy varnish
Operating temp range:	+5 to 40 °C
Humidity:	0 to 90% non-condensing
Operating pressure range:	±5 psig
Warm-up time:	5 minutes at 20 °C

CO₂ system

Type:	Infrared, optical
Range:	0 to 10% CO ₂
Output:	Linear 0 to 1 V (0 to 10% CO ₂)
Resolution:	0.1% CO ₂
Linearity:	0.1% CO ₂
Drift:	0.1% CO ₂ over 8 hours
Response time:	120 ms at 100 mL/min
Temp coefficient:	Zero: <0.01% CO ₂ /°C
	Span: <0.02% CO ₂ /°C

O₂ system

Type:	Paramagnetic, dumb-bell system
Range:	0 to 100% O ₂
Output:	Linear offset so that -0.2 to 0.8 V (0 to 100% O ₂) Directly proportional to atmospheric pressure
Offset:	-0.2 V, such that ~20% O ₂ is ~ 0 V output
Linearity:	±0.2% O ₂
Drift:	±0.01% O ₂ /hour
Response time:	<0.5 s (100 mL/minute)
Temperature coefficient:	Zero: ±0.05% O ₂ /°C
	Span: ±0.25% O ₂ /°C

Temperature input

Input connector:	3-pin mini-audio connector
Thermistor type:	10 k Ω at 25 °C
Non-linearity:	< 0.4 °C (25 to 45 °C)
Output voltage:	50 mV/°C (0 mV = 25 °C)
Temperature accuracy:	\pm 0.2 °C absolute (25 to 45 °C)
DC drift:	3 μ V/°C
Response time:	< 150 ms (5 to 95%). Overall response dependent on thermistor probe.
Temperature offsetting range:	50 °C overall (-5 to 45 °C absolute)

Microprocessor and data communication

CPU:	PPC403GCX (60 MHz)
Internal memory:	4 MB DRAM
Data communication:	USB (up to 800 kilobytes/s, dependent on setup)

Instrument connection port

Instrument connection port:	20-pin port. Accepts strip terminal.
Strip terminal:	Plugs into Instrument port. Allows easy connection.

Injection signal input

Input type:	Contact closure (available through Instrument Connection port)
Closure registration:	Contact closure must be longer than 10 ms to be registered as inject signal.

Digital output controls

Signals provided:		
4 digital outputs:	available through Instrument Connection port; contact closure or TTL level (set by Contact/TTL switches near instrument port)	
Contact closure outputs:	Maximum current 300 mA	
	Maximum voltage 250 V	
	Switching time: Close 2 ms; Open 1 ms	
Digital level outputs:	TTL level outputs. Designed to drive 1 TTL input load (1 mA)	

Physical configuration

Dimensions (w × h × d):	200 mm × 65 mm × 250 mm (7.9" × 2.6" × 9.8")
Weight:	2.13 kg (4 lb 11 oz)
Operating voltage:	90 – 260 V AC 50/60 Hz
Nominal power needs:	6 VA (25 mA at 240 V or 52 mA at 115 V)
Operating temperature range:	0 to 35 °C, 0 to 90% humidity (non-condensing)

Thermistor

Thermal response time:	Still air 15 seconds	
	Water 2 seconds (plunged from 25 °C air to 5 °C water)	
Tolerances:	<i>Range (°C)</i>	<i>Tolerance (±°C)</i>
	[0 , 20]	0.20
	[20 , 35]	0.15
	[35 , 39]	0.10
	[39 , 45]	0.15
	[45 , 50]	0.20
Nominal resistance at 25 °C:	10 kW	
Maximum excitation:	2 V	
Length and diameter:	9.5 and 2.0 mm	
Cable length:	90 cm	
Connector:	3-pin mini audio	

PowerLab/8M

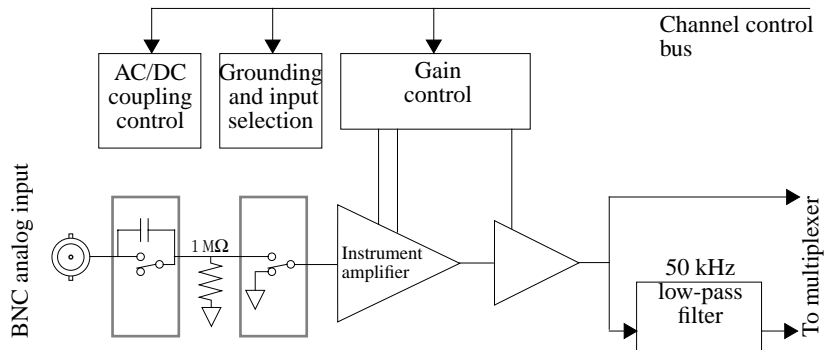
Analog inputs

Each analog input is a separate DC amplifier, with an independently programmable gain amplifier with its own filtering and AC/DC coupling (Figure E-1). Each channel can be set up independently using the Chart software.

- Do not apply more than ± 15 V to the inputs as this can damage the circuitry.

The input amplifiers have an impedance of $1\text{ M}\Omega$, and can be set to pass both DC and AC signals.

Figure E-1
Schematic of the analog input circuit.



Any DC drift due to age and temperature is measured and compensated through software each time a recording is manually started or the gain is changed. This process is transparent to the user.

Gas analyzer inputs

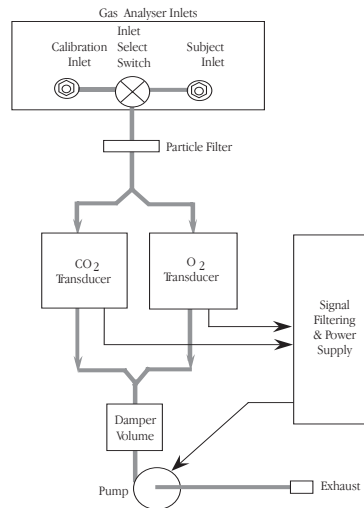
The gas analyzer inputs connect to an infrared carbon dioxide sensor and a paramagnetic oxygen detector, which are fed by a damped micro-vacuum sampling pump. Moisture must be removed before sampling. The gas analyzer transducers have response times of less than 0.5 seconds when sampled at 100 mL/min . Carbon dioxide and oxygen concentrations are measured simultaneously. An internal filter removes potentially damaging particulates (see Figure E-2).

The O₂ transducer has been offset so that 0 V is approximately equivalent to the O₂ concentration in room air. This has been done so that small changes in O₂ can be measured on the lower gain ranges of the channel.

- To minimize noise in the O₂ channel keep the PowerLab/8M free from vibrations and movement as much as possible.

Figure E-2

Diagram showing the relation of the Subject and Calibration ports to the Gas Analyzer transducers.



Temperature input

The temperature input is a 3-pin mini-audio socket (Figure E-3). Resistance changes are converted to a voltage which is amplified to produce 50 mV/°C within 0–50 °C. A hardware 3-pole 10 Hz low-pass filter reduces noise. A switchable offset circuit provides a moveable zero for relative temperature measurements. The offset can be adjusted using the 10 turn zero offset knob (Figure E-4).

Figure E-3

Pinout for the mini-audio socket.

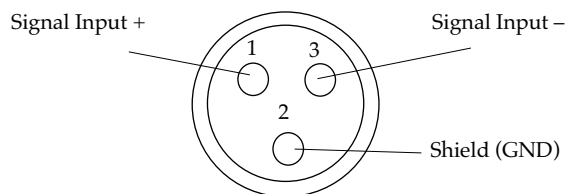
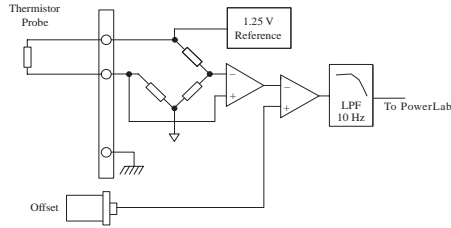


Figure E-4
Schematic of the temperature input circuit.



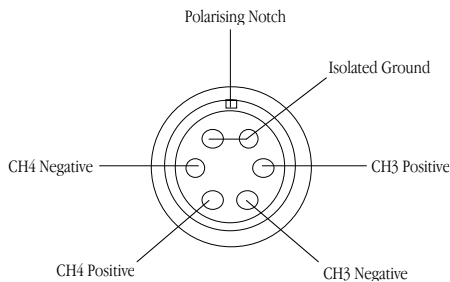
The data in Table 3-1 on page 35 lists the temperature versus output voltage for a standard 10 k Ω thermistor. Use these values with the Units Conversion feature of Chart to convert voltage to temperature. Below 20 °C non-linearity in the thermistor causes increasing errors in the readings.

Bio Amplifier input

The input is a six pin connector, with the connector physically and electrically isolated for subject safety. Please refer to the Bio Amplifier safety instructions, p. 9. Two pins of the input provide a differential input and two pins connect to the isolated ground (Figure E-5).

A 3-lead Bio Amp subject cable and lead wires are supplied. The cable connects to the lead wires through shrouded 1.5 mm sockets. The lead wires connect to snap-on ECG electrodes.

Figure E-5
Pinout for the six-pin connector of the Bio Amplifier subject cable.



- The Bio Amp is unsuitable for use with high impedance electrodes or very high bandwidth applications, such as needle EMG or microneurography. This technique requires a low capacitance input and preamplification before recording.

When recording a biological signal, pay special attention to ensure good electrode contact and minimize movement artifacts. Good contact can be made by gently abrading the skin before attaching electrodes. Movement artifacts can be minimized by preventing unnecessary movement of the lead wires and subject cable. Support the subject cable by attaching it to a piece of clothing using the clip provided.

Flow Head Inlet

The Flow Head Inlet connects to the integrated Spirometer. The Spirometer is a precision differential pressure transducer for measurements of respiration flow rates. With a flow head of suitable size, the Spirometer can be used with animals of all sizes, from mice and rats, to large animals and humans. The Spirometer and an attached flow head function together as a pneumotachometer, with an output signal proportional to airflow.

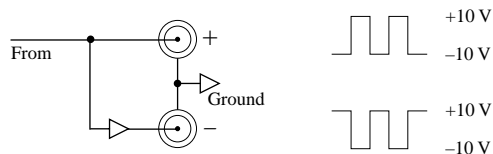
Stimulator (Analog) outputs

The output voltages are set up using the Stimulator option from the Setup menu in the Chart and Scope Applications (see the *Chart User's Guide* and *Scope User's Guide* for more information).

When the Differential option is selected in the Stimulator Constant Output dialog box, Output 2 is the complement of Output 1 (so that +3 V on one gives -3 V on the other). The output voltage has a maximum range of ± 10 V, so with this combination it is possible to generate a 20 V pulse using a ± 10 V stimulus.

When the Independent option is selected in the Stimulator Constant Output dialog box, you can set independent constant output voltages for Output 1 and Output 2.

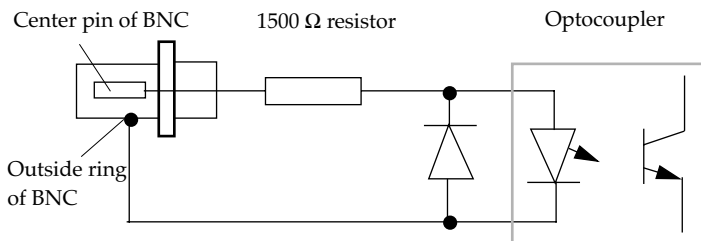
Figure E-6
Schematic of Stimulator constant output voltage in differential mode.



Trigger

An external Trigger input allows a TTL pulse to synchronize recording to an external event. The Trigger input is optically isolated to remove ground and current problems (see Figure E-7). A successful trigger is shown by a lit indicator. This input can handle voltages up to ± 12 V. The threshold voltage (the voltage above which the trigger circuit activates) is approximately 2.9 ± 0.25 V, and the trigger is ready again after the voltage falls below 1.8 ± 0.25 V. See the *Chart User's Guide* for more details.

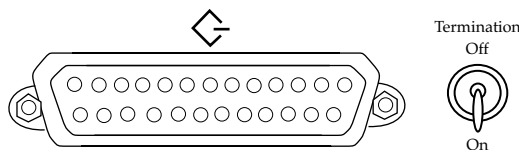
Figure E-7
Schematic of the trigger input circuit.



SCSI

The SCSI port has a 25-pin D-type female connector. We recommended that the PowerLab/8M be connected at the end of a SCSI chain. The termination switch should be left on, when the PowerLab/8M is at the end of the chain. Turn this switch off when using a SCSI T-piece if you require the PowerLab/8M to be in the middle of the chain.

Figure E-8
Diagram of the SCSI port and the termination switch.



SCSI ID switch

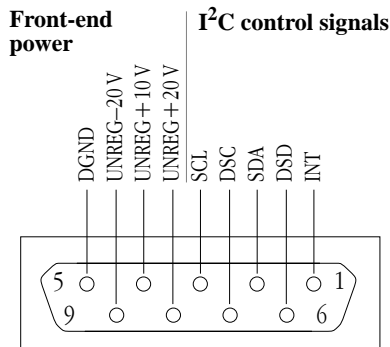
The PowerLab/8M is factory-set to an ID number of 4. The SCSI ID can be changed simply by pressing the control buttons when the PowerLab/8M is turned off. The new ID takes effect when the PowerLab/8M is turned on.



I²C output

The I²C output allows multiple front ends to be connected to the PowerLab recording unit in a daisy-chain structure. The I²C output provides both power and control signals for these front-ends. A PowerLab can have as many front-ends connected to it as it has analog inputs. Two front-ends can be connected to a PowerLab/8M. Do not attempt to run other external devices from the I²C port: it is designed for use only with ADInstruments front-ends, which draw a low current.

Figure E-9
Pinout for the I²C output.



Digital output and input

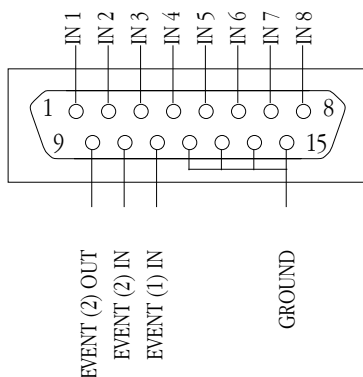
The digital input monitors state changes. For example, a predefined comment can be automatically inserted during recording when a digital input changes to a particular state (Chart for Macintosh only). The eight lines of the connector allow monitoring of up to eight devices.

The digital outputs provide logic control signals (TTL level) to turn on and off external devices, for example pumps, relays, and indicator lights, or to signal to some other device. The eight lines of the connector allow control of up to eight devices. See the *Chart for Macintosh User's Guide* for more information.

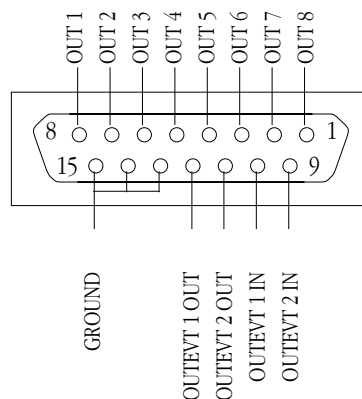
The digital input port is a 15 pin male D-type connector, and the digital output port is a 15-pin D-type socket. The eight digital input lines respond to standard TTL signals with a threshold of 2.2 V. The eight digital output lines are capable of driving TTL loads (20 mA maximum load per line).

Figure E-10
Pinouts for the digital input
and output ports.

Digital Input



Digital Output



Ground connection

The ground connection is an equipotential bonding connection post compatible with the DIN 42801 standard. If the ground connector post is used, the power cord ground connection should not be used: a power cord with no ground connection should be used instead. The ground connector post on the rear panel is used as a primary earth connection (equipotential connection point) in situations that require this type of connection, or if there is no ground provided via the power cord. Safety standards in laboratories and similar environments may require additional grounding protection when connecting equipment to human subjects. In such cases, an equipotential connection may be used for all linked equipment to prevent ground loops; correspondingly power cords with no ground connections should be used.

Gas Mixing Chamber

The MLA245 Gas Mixing Chamber provides a volume of 5.9 L for sampling expired respiratory gases in a 19-inch rack mounted casing. Two 2 mm male Luer lock connectors are provided to allow a sampling line to be connected from the gas mixing chamber to the Subject inlet port on the front panel of the PowerLab/8M. Two 35 mm OD ports allow attachment of clean bore tubing from breathing valves, or a respiratory flow head.

The chamber is made from Perspex and can be separated for washing by undoing the clips. It is recommended that the chamber be washed with hot soapy water and a soft cloth between uses. Using harsh abrasive cleaners may scratch the front panel and chamber.

Flow Head

The MLT1000L Respiratory Flow Head contains a fine gauze mesh. Laminar airflow through the mesh produces a pressure differential which is linearly proportional to the velocity of the airflow. The fine gauze mesh rapidly equilibrates in temperature with air to reduce problems of condensation. It can be cleaned by washing and cold sterilization.

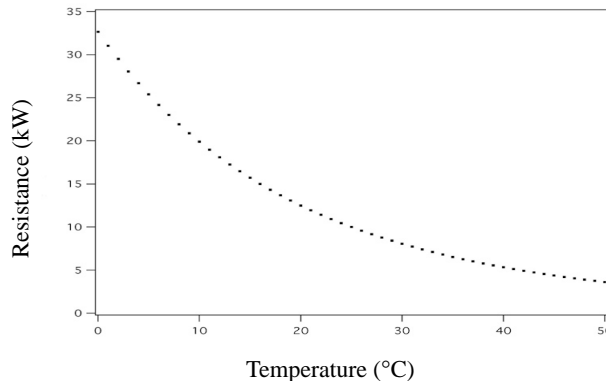
Thermistor

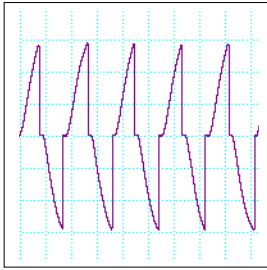
The thermistor in the MLT415 Nasal Temperature Probe supplied with the Metabolic System is a small, ceramic-encapsulated metal-oxide semiconductor. It exhibits a characteristic non-linear inverse relationship between resistance and temperature (see Figure E-11) that allows its use as a temperature sensor. The relatively large change in resistance as a function of temperature (of the order of 4% per °C) gives a signal response far greater than thermocouples and RTDs.

The thermistor can be cold-sterilized between subjects. Do not apply an excitation voltage greater than 2 V.

Figure E-11

Graph of resistance against temperature for the MLT415 Nasal Temperature Probe.





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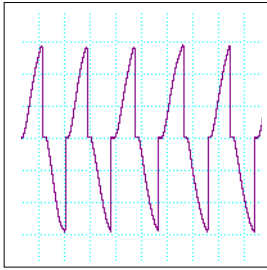
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Licensing & warranty agreement

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This Agreement is between ADInstruments Pty Ltd ['ADI'] and the purchaser ['the Purchaser'] of any ADI product — 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. Any changes to this Agreement must be recorded in writing and have ADI's and the Purchaser's consent.

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ADI products are produced to high standards, and should perform substantially as described in the supplied documentation. There is a limited hardware warranty, and technical support is provided for all products.

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No claim for damages of any sort arising from the use or misuse of ADI products can be made against ADI or its agents or employees.

Hardware warranty

ADI warrants that PowerLab Recording Units¹, all ADI Front-end Signal Conditioners and all ADI Pod Signal Conditioners purchased by the Purchaser shall be free of defects in material and workmanship for three years from their date of purchase. ADI also warrants that some other ADI instruments² and most ADI transducers³ purchased by the Purchaser shall be free of defects in material and workmanship for one year from their date of purchase. If there is such a defect, 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 PowerLab Distributor of the defect before the warranty expires. The ADI office or Authorized PowerLab Distributor 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.

This warranty applies only to hardware specified here and used normally within its operating specifications. It 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.

1. ML750 PowerLab/4SP, ML785 PowerLab/8SP, ML795 PowerLab/16SP, ML760 PowerLab/4ST, ML820 PowerLab 2/20, ML840 PowerLab 4/20, ML860 PowerLab 4/20T and ML850 PowerChrom.

2. ML191 Blood FlowMeter, ML205 Gas Analyser, ML125 NIBP System, ML275 Kerr Brain Slice Chamber, ML175 STH Pump Controller and other third party instruments.

3. All ADI transducers except disposable blood pressure transducers.

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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 Instruments web sites.

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This Agreement shall be governed by the laws of New South Wales in Australia, and any proceedings concerning it shall be heard and resolved by the Supreme Court of New South Wales in Australia.