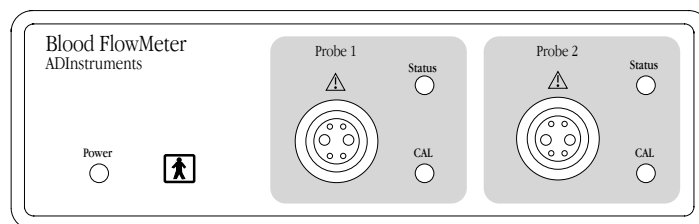


# Blood FlowMeter Owner's Guide



---

This document was, as far as possible, accurate at the time of printing. Changes may have been made to the software and hardware it describes since then, though: ADInstruments Pty Ltd reserves the right to alter specifications as required. Late-breaking information may be supplied separately.

### **Trademarks of ADInstruments**

MacLab and PowerLab are registered trademarks of ADInstruments Pty Ltd. MacLab/4, MacLab/8, MacLab/2e, MacLab/4e, MacLab/8e, MacLab/4s and MacLab/8s, MacLab/16s, PowerLab/200, PowerLab/400, PowerLab/410, PowerLab/4s, PowerLab/4sp, PowerLab/4se, PowerLab/800, PowerLab/8s, PowerLab/16s(data recording units); and Chart, Histogram, Peaks, Scope, EChem and Translate (application programs) are trademarks of ADInstruments Pty Ltd.

### **Other Trademarks**

Apple and Macintosh are registered trademarks of Apple Computer, Inc. System 7 is a trademark of Apple Computer, Inc.

Windows 95 is a registered trademark of Microsoft Corporation

---

Hardware design: Tim Spencer

Documentation: Malcolm Bowers and Tim Spencer

Document Number: U-ML192-OG-01A

Copyright © June 1998

Preliminary Document Only

ADInstruments Pty Ltd

Unit 6, 4 Gladstone Road

Castle Hill, NSW 2154

AUSTRALIA

All rights reserved. No part of this document may be reproduced by any means without the prior written permission of ADInstruments Pty Ltd.

---



# Contents

---

## Contents iii

### Important Safety

#### Instructions v

- Product Intention v
- Applicable Safety Standards v
- Cautionary Information vi
- Laser Safety vii
- Electrical Safety Instructions vii
- Safety Symbol Explanation viii

## 1 Introduction 1

- How to Use this Guide 2
  - Checking the Blood FlowMeter 2
- The Blood FlowMeter 3
  - The Front Panel 3
  - The Back Panel 4

## 2 Setting Up the Blood FlowMeter 7

- Connecting the Blood FlowMeter 8
  - Switching on the Blood FlowMeter 8
  - Probe Application 9
  - Probe Warning 9
  - Temperature Warning 10
  - Probe Calibration 10
- Using the Blood FlowMeter with Chart 11
  - Example Calibration 11

## A Care and Maintenance 13

- Cleaning 13
- Probe Sterilisation: 13
- Storage 13

## B Troubleshooting 15

## C Technical Aspects 19

- Introduction 19
- Laser Doppler Flowmetry 19
- How it Works 21
- Probe Operation 22
- What does the Blood FlowMeter Measure? 22
- The Blood Perfusion Unit (BPU) 23
- Zero BPU 23
- Motion Artefact Noise 24

## D Specifications 25

### Index 29

### Licensing & Warranty Agreement 31





## S A F E T Y

# Important Safety Instructions

### Product Intention

The Blood FlowMeter system has been designed for use in student teaching and research environments only. This product has **NOT** been designed for clinical or critical lifecare use and should **NEVER** be used for this purpose.

### Applicable Safety Standards

ADInstruments Blood FlowMeter has been designed for safe connection to humans. Considerable design effort has been undertaken to make sure that this unit conforms to international patient safety requirements. Specifically the Blood FlowMeter has been designed to conform to the requirements of IEC601.1 – “General Requirements for Safety for Medical Electrical Equipment”, and the various harmonised standards worldwide (AS3200.1 in Australia, NZS3200.1 in New Zealand and UL2601.1 in the U.S.A). 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.

---

## Cautionary Information

The Blood FlowMeter emits laser light at the end of each probe. The following safety precautions should be taken when using this instrument;

- Use **ONLY** ADInstruments or Oxford Optronics probes and cables with this instrument. Serious damage may result using other types of probes.
- **DO NOT** drop, stress, or apply mechanical shock to the probe. Probes are sensitive optical devices and may be permanently damaged by mechanical shock.
- **DO NOT** autoclave, pressure sterilise, or expose to radiation, any part of this instrument or probe. (Probes may be sterilised according to the instructions in Appendix A.)
- **DO NOT** soak or immerse the probe in any corrosive liquid solution.
- Operating this equipment above the recommended operating temperature may permanently damage the laser and lead to erroneous results. If the operating temperature is exceeded, the module will emit an audible beep every 5 seconds.
- **DO NOT** attempt to repair any part of this equipment. Repairs **MUST** be undertaken by ADInstruments trained personnel.
- The operation of this device may be affected by strong ambient lighting. Shield the probe area from direct sunlight or bright light if necessary.
- This instrument can be adversely affected by the presence of imaging equipment, such as MRI (Magnetic Resonance Imaging) and CT (Computerised Tomography) devices. Do not use the Blood FlowMeter in these environments.

---

## Laser Safety

Semiconductor lasers are used in this device, with a nominal operating wavelength of 780 nm with a maximum output power of 1.5 mW at the probe face. Due to the highly divergent nature of the laser beam, the Blood Flowmeter probes are classified as class 1 laser products (as per 21 CFR 1040-10 and 1040-11). This makes the device safe to view from a distance in excess of 20 cm from the eye. Applying the probe to any tissue **OTHER THAN THE EYE** is completely harmless, even over prolonged time periods.

- The probes should **NEVER** be used on the eye surface. Permanent damage to the retina can occur resulting in partial or total loss of vision in that eye.
- Keep the probes active surface pointing away from a subject or operators eyes at all times. **NEVER** allow the probe to come within 20 cm of anyones eyes.

## Electrical Safety Instructions

- The Blood FlowMeter is classified as Class I medical equipment which means that protection against electric shock in the event of a fault **RELIES** on a direct connection through the power cable to your buildings earth conductor. The power cable supplied with your Blood FlowMeter power supply 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 on the rear or the PowerLab to provide the ground connection to the buildings earth conductor. The ground connection is an **ESSENTIAL** part of this equipments safety. **NEVER** use the Blood Flowmeter without a ground connection.
- The Blood FlowMeter has been rated as a medically approved device only when used with the ML193 medically rated switching power supply. Using other types of power supply may damage the unit and will void its medical rating.

---

## Safety Symbol Explanation

The Blood FlowMeter carries a set of safety symbols next to the various input and output connectors that can be directly connected to human subjects. The meaning of these safety symbols is described below.



BF Protected (body protected). This means that the signal connections indicated by this symbol are suitable for connection to humans provided there is no direct electrical connection to the heart.

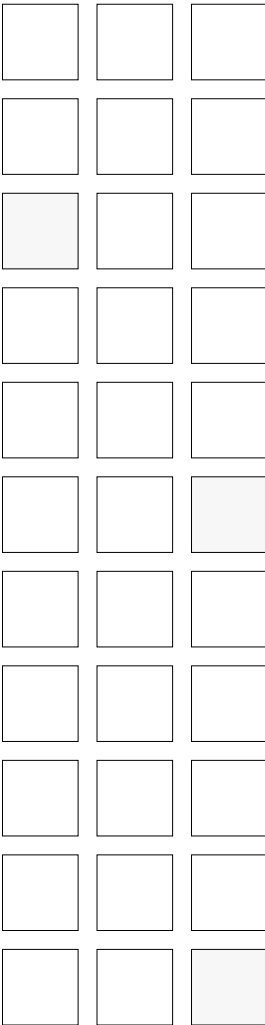


The exclamation mark symbol inside a triangle means that you should consult the supplied documentation for operating information or cautionary and safety information before using this device.

# 1

## C H A P T E R O N E

# Introduction



The ADInstruments Blood FlowMeter is one of a family of stand-alone instruments, designed to extend the capabilities of the MacLab\PowerLab system. The Blood FlowMeter is designed to measure blood cell perfusion levels in the microcirculatory beds of skin and other tissues.

This Owner's guide covers the features of the Blood FlowMeter, its operation, maintenance and safety information.

---

# How to Use this Guide

This owner's guide describes how to set up and begin using your Blood FlowMeter. The chapters discuss how to connect the hardware and perform a simple power-up test. Use of the Blood FlowMeter with the ADInstruments PowerLab system is described in the next chapter. Appendices provide technical information about the Blood FlowMeter, maintenance information, and take a look at some potential problems and their solutions.

Toward the end of this guide, you'll find an index and warranty information.

## Checking the Blood FlowMeter

Before connecting the Blood FlowMeter to anything, check it carefully for signs of physical damage.

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

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

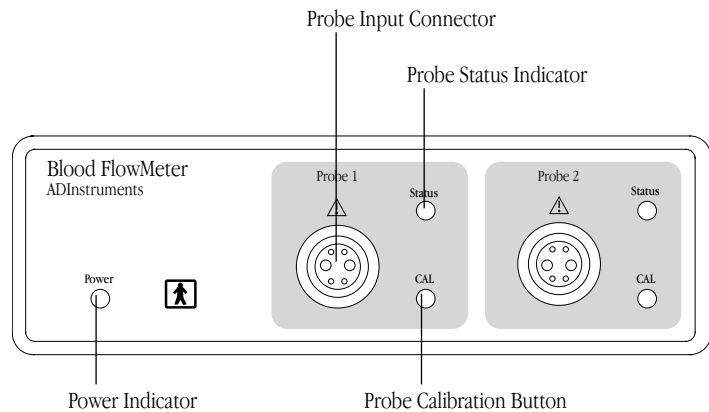
# The Blood FlowMeter

This rest of this chapter contains general information about the features, connections, and indicators of the Blood FlowMeter. More detailed information can be found in the technical appendixes.

## The Front Panel

The front panel of the Blood FlowMeter is relatively simple, with two probe input connector and three indicator lights, and two calibration buttons.

**Figure 1-1**  
The front panel of the Blood FlowMeter



## The Power Indicator

Located at the bottom left of the front panel is the power indicator. When lit, it indicates that the Blood FlowMeter has power from the external power supply.

## The Probe Input Connectors

The Blood FlowMeter is a dual channel device and provides two connectors one for each probe. Each input connector is a polarised (keyed) multipin connector with optical interfaces for the fibre optics in the probe cable. The probes are designed to push and click into these connectors. Do not touch or tamper with any part of these connectors as it may damage the optics or internal circuitry.

## Probe Status Indicators

Each probe input has an associated status indicator. This indicator is used to indicate what is happening to that channel at any given time. Flash and colour indications are listed below;

- Green (continuous) Channel OK - no probe connected
- Red/Green flashing Calibration in progress
- Amber (continuous) Probe connected and laser operating

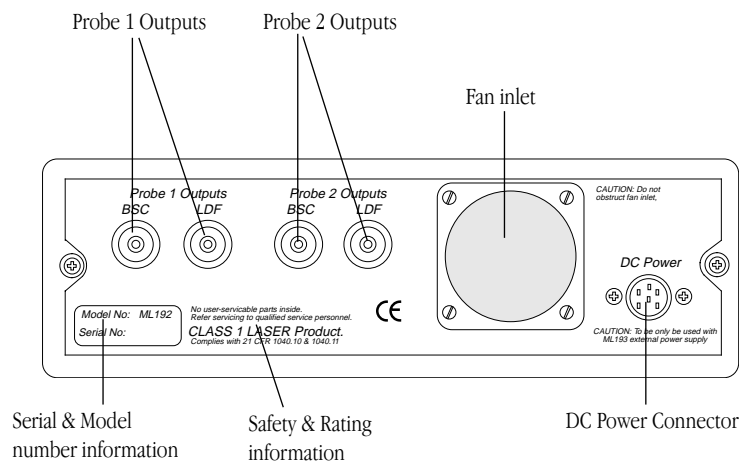
## Probe Calibration Buttons

The Blood FlowMeter is designed to automatically configure and calibrate itself for specific probes. To perform this operation you will need a Blood FlowMeter calibration kit which includes a controlled concentration of latex spheres in solution. This process is discussed later in this guide.

## The Back Panel

The back panel of the Blood FlowMeter provides all the sockets that produce the output signals. It also has a fan opening and power supply connection.

**Figure 1–2**  
The back panel of the Blood FlowMeter



---

## Signal Output Sockets

There are four BNC output connectors on the rear panel two for each probe. All signals are analog and are designed to be suitable for connection to a variety of data recording systems including MacLabs or PowerLabs.

The LDF outputs are the Laser Doppler flowmetry output signal, which is an analog signal between 0 and 4 volts. This signal represents the relative Blood Perfusion with 1 perfusion unit equalling 4 mV.

The second output for each channel is marked BSC and is an analog output representing the percentage backscatter (tissue remittance). This output swings between 0 and 4 volts with 1% remittance equivalent to 40 mV.

## Power Supply Socket

Power to the Blood FlowMeter comes from an external, medically rated, switching power supply. This unit is designed to connect to a wide variety of A.C supplies. Connection of power to the Blood FlowMeter is via a mini DIN connector. All power at this point is low voltage.

**WARNING** The Blood FlowMeter's medical rating is only valid when used in conjunction with the ML193 power supply. Using any other type of supply will not guarantee medical approval.

## Fan Opening

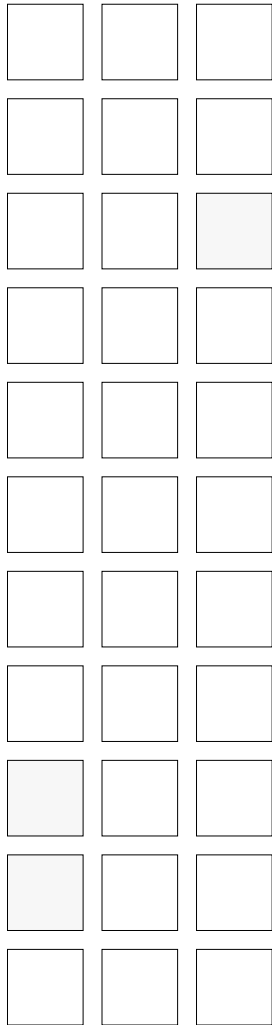
In order to maintain the internal laser diode temperature, the Blood FlowMeter utilises a thermostatically controlled fan to supplement cooling when required. The fan opening must remain clear of obstructions at all times while operating to ensure correct operation.



# 2

## C H A P T E R T W O

# Setting Up the Blood FlowMeter



This Chapter guides you through connecting your Blood FlowMeter and subsequent operation of the instrument. It is advised that you read this chapter carefully before attempting to use your Blood FlowMeter.

---

# Connecting the Blood FlowMeter

Before connecting anything make sure that the power outlet and the switch on the external power supply are turned off.

Connect the power supply output of the external supply to the power input of the Blood FlowMeter. Make sure that this connector is pushed all the way in as it does not have a locking facility.

Connect the outputs of the Blood FlowMeter that you wish to record to the signal inputs of you recording device. Note that the Blood FlowMeter has four signal outputs, two per probe. Not all four signal outputs need to be used. You only need to connect the output signals that you wish to record.

## Switching on the Blood FlowMeter

When the power has been connected, turn on the power outlet and then turn on the power switch on the top side of the external power supply. The power indicator on the front of the Blood FlowMeter should glow green and you should hear a double beep from the unit to indicate it has initialised.

You should wait at least five minutes before making any measurements because the system will need time to temperature stabilise.

## Connecting the Laser Doppler Probes

Very carefully remove the probes from their protective cases and check that the probe connector is clean and free from dust. To connect the probes to the probe connectors on the front of the Blood Flowmeter, orientate the plug with respect to the sockets until they are aligned correctly. The sockets and plugs are designed to only accept the plug in one particular orientation. Once aligned, carefully push the plugs into the sockets until the lock in position.

---

If everything is OK then the status indicators for both probes will glow amber. If there is something wrong with the probe or connection then the status indicators will remain green.

For safety reasons the Blood Flowmeter will not operate until both probes are connected. If only one probe is inserted then the status indicators will remain green and no laser power will be provided.

## **Probe Application**

If you are using a surface probe, it can be attached to tissue using a self adhesive ring. These have adhesive on both sides with a small hole in the centre. If you are using needle electrodes they can be secured by using a micro-manipulator or some similar device.

It is important to control, the relative movements of the tissue (especially that induced by breathing) with respect to the probe. Relative movements will produce artefacts in the perfusion signal. These can be reduced by allowing the supported probe to lightly contact the surface of the tissue. Under some conditions it may be desirable for the probe to be held in position by hand. It is essential to ensure that the pressure on the tissue is minimal, otherwise local occlusion of the microvasculature may result.

Excessive ambient lighting at the probe site can disturb the blood perfusion reading. Avoid direct illumination of the measurement site especially direct sunlight. If erroneous readings of the measurement site from external lighting levels are suspected, cover the attached probe and measurement area with a light piece of opaque material.

## **Probe Warning**

If a new or unrecognised probe is connected to the Blood FlowMeter, you will hear a double beep every two seconds. The probe status indicator will also flash amber/red for the probe channel not recognised. The probe must be recalibrated in order to use it. Refer to the probe calibration section.

---

## Temperature Warning

If the internal temperature of the Blood FlowMeter rises above the maximum operating temperature range of the device, then it will emit a double beep every five seconds. If this occurs, the instruments should be moved to a cooler location environment for proper operation. With the temperature out of range, output signals will continue to be generated but may no longer be within the calibrated tolerance of the system and should be interpreted with caution. If the environmental temperature is below 25°C and this error occurs repeatedly soon after power-on, then a fault may have occurred and you should contact your distributor for further advice.

## Probe Calibration

The Blood FlowMeter is designed to automatically configure and calibrate itself for a new probe. To perform this operation, you will require the probe calibration kit which includes a dedicated solution of latex spheres at a controlled concentration. Calibration is not possible without this kit and should not be attempted.

Before starting this it is advisable to have a stable workbench free from vibration and a clamp to hold the probe reliably in the solution. Set up the probe in the centre of the solution, with the measuring surface of the probe at a maximum distance from all edges of the vessel. Follow the procedure below to calibrate the probe. Note that calibration can be abandoned at any time by simply turning off the power.

- 1) Plug the probe to be calibrated into one of the probe inputs.
- 2) Press the CAL button once. A single beep followed by a double beep will sound and the indicator flashes red and amber. During this time place the probe into the centre of the container.
- 3) After placing the probe in the solution press the CAL button again. A long beep will sound and red and amber lights flash.
- 4) After thirty seconds, a double beep indicates the end of the calibration. After five seconds, the red indicator light returns to amber and the unit is ready for use. Repeat for the second channel.

During calibration keep the bench free of vibration and movement as this may invalidate the result. Generally a probe does not require recalibration unless a new or replacement probe is introduced.

## Using the Blood FlowMeter with Chart

The Blood FlowMeter has been designed to be used in conjunction with any analog recording device such as paper chart recorders or ADInstruments MacLab or PowerLab systems.

The following section details the use of the Blood Flowmeter with either a MacLab or PowerLab system and Chart software. For this example only one channel has been used with both the BSC and LDF signals being recorded. It assumes that you know how to connect the Blood FlowMeter to you MacLab or PowerLab system and are familiar with the Chart software

### Example Calibration

Both the LDF and BSC outputs have been factory calibrated to give a certain voltage output to calibrated unit. The LDF output produces 4 mV for each blood perfusion unit. As the maximum output of the Blood Flowmeter is 9999 perfusion units or 4 V then you should set the corresponding MacLab or PowerLab input channel to the 5 V range or more sensitive depending on your requirements. As LDF output only produces an output between 0 V and 4 V you can also select the unipolar axis on the input channel so that negative values do not get used.

To calibrate the system, open the input amplifier dialog box for the LDF channel. Click the Units button to bring up the Units conversion dialog box.

**Figure 2–1**  
Entering units conversion information for the LDF channel

**Units Conversion for Channel 1**

---

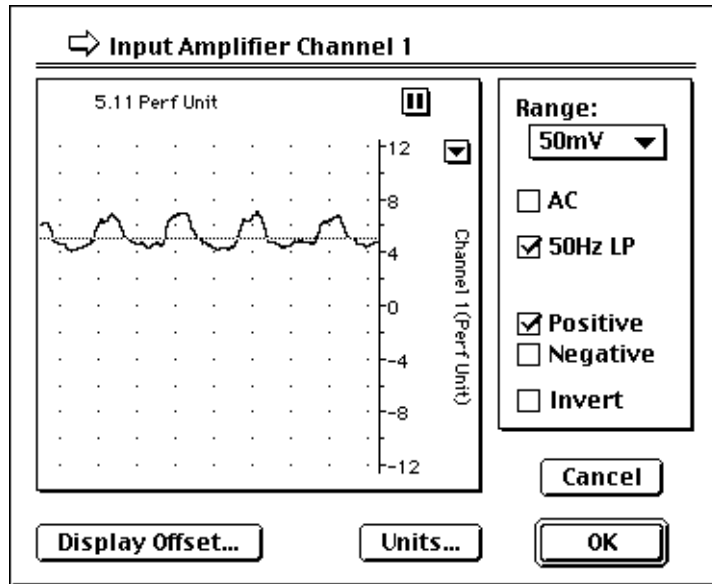
2 Point Calibration ▾

Point 1	➡	0mV	➔	0.00
Point 2	➡	4mV	➔	1.00

At the top of the box type in the values shown below. Note that you must enter the numbers on the left as mV in order to get the correct scaling. Click the OK button to make sure that the units conversion is applied to that channel. Check to see if it has been applied by looking at the scale of the Input amplifier window. An example of what you should see is shown in Figure XX. This figure also shows a typical waveform from the LDF output. You can use the low pass filter setting of the channel to remove any unwanted noise. You should not use the AC coupling feature as this will result in an incorrect measurement of blood perfusion units.

**Figure 2-2**

The Input Amplifier dialog box after showing the LDF waveform after units conversion has been applied



Calibrating the BSC channel is a similar process but with different values required. As the BSC output represents the relative strength of the returned signal it is a voltage that represents the percentage of backscattered light. A 100% backscattered signal is represented by a voltage of 4 V. Zero backscattering corresponds to 0 V. This gives an output that corresponds to 40 mV per % backscattering.

### Removing the probes

To remove a probe from the instrument, gently pull the outside of the probe connector (the knurled sleeve). This will disengage the locking mechanism and the connector should just pull out. Do not attempt to force the connector

---

# A

## A P P E N D I X A

# Care and Maintenance

---

### Cleaning

To clean the outside cover of the Blood Flowmeter or remove spills, wipe the device with a soft, lint free cloth. Do not use alcohol or abrasive based cleaners as this may damage the external surfaces of the device.

Do not use water or submerge the unit in liquid.

### Probe Sterilisation:

The fibre optic probes may be sterilised by immersion in a non-corrosive sterilising solution such as 2% Glutaraldehyde (Cidex) or in a low-temperature ethylene oxide gas sterilisation chamber. The maximum temperature to which the probes can be exposed is 60°C.

NOTE DO NOT immerse the electrical connector in sterilising solution.

### Storage

It is suggested that the instrument and probes be stored at temperatures in the range 0 – 50°C. If the instrument has been stored in extremes of temperature, allow the instrument to stabilise at room temperature before use.



---

# B

## A P P E N D I X B

# Troubleshooting

---

This appendix describes some problems that may arise when using the Blood Flowmeter. If you have any trouble getting the Blood Flowmeter to work, use this section to try and isolate and cure the problem. If you cannot find a solution to your problem in this appendix, and those in your MacLab/PowerLab and application guides, please contact your MacLab/PowerLab dealer.

Although the Blood Flowmeter was designed to be very reliable, there may be occasions when they do not appear to function correctly. In the majority of cases, the problem can be fixed by checking connections and or resetting the Blood Flowmeter. Very rarely will there be an actual problem with the Blood Flowmeter. This appendix will help you determine what kind of fault you have and the appropriate solution.

***The Power indicator fails to light when the unit is turned on***

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

- Check switches, power connections, and fuses.

The power cable from the external power supply is loose.

- Check that the power supply cable is firmly connected to the power input connector on the back of the Blood Flowmeter.

An faulty power supply unit.

- 
- If you suspect the power supply unit or the Blood Flowmeter itself then contact your MacLab/PowerLab dealer for advice. Do not attempt to fix these yourself as it will void the warranty and may compromise the safety aspects of the system.

***The power indicator is lit but pluggin in the probes status indicators do not operate***

You are only pluggin in one probe.

- Both probes must be connected for the system to work.

A faulty or damaged probe connector.

- Check to see if all of the connection pins are unbent. If one or more is bent do not attempt to bend them back. Contact your MacLab/PowerLab dealer for help.

The Blood Flowmeter internal processor is not working.

- Turn off the power, wait five seconds and turn on the power again. If the probe status lights do not show the appropriate thing then the main processor circuitry may be faulty. Contact your MacLab/PowerLab dealer for help.

***The Blood Flowmeter does not produce any laser output when the power is on***

You only have one probe connected.

- Make sure both probes are connected even if one is not being used.

A faulty probe connection.

- Make sure both probes are properly connected to the system by pushing their connectors firmly into the front panel sockets. If this fails to correct the problem remove each probe in turn and check the connector pins to verify that they are unbent. If any of the pins are bent do not attempt to fix them, contact your MacLab/PowerLab dealer for assistance.

---

A faulty optic fibre in the probe.

- If the probe cable has been subject to undue mechanical stress then the internal optic fibre might be damaged. Although this is unlikely the probe should not be used. A replacement will need to be purchased.

A faulty laser diode.

- Very unlikely but if everything else has been checked and there is still no laser output then you should contact your MacLab/PowerLab dealer for service.

***There is no signal output from the Blood Flowmeter***

No power to the Blood Flowmeter

- Check that the power indicator on the Blood Flowmeter is on.

You only have one probe connected

- Make sure that you have both probes connected.

A probe is not plugged in correctly.

- Check that both probes are connected correctly.

A loose or missing output connection to your recording equipment

- Make sure that the appropriate output signals from the Blood Flowmeter are connected properly to your recording equipment.



---

# C

## A P P E N D I X C

# Technical Aspects

---

## Introduction

Blood flow in the skin performs an essential role in the regulation of the metabolic, haemodynamic and thermal state of the individual. Despite the fact that the skin is the body's largest and most accessible organ, the measurement of cutaneous microcirculatory blood perfusion has until quite recently proved a formidable task.

By far the largest proportion of the body's dermal vasculature is involved in regulating body temperature and controlling systemic blood pressure. A smaller but significant proportion of the bulk skin blood perfusion also fulfils the skin's metabolic requirements. It is the upper dermis (i.e the first 1.5 - 4.0 mm of tissue- depending on the site) that is chiefly responsible for providing a nutritional supply of blood to the avascular epidermis, the integrity of which is essential for the well-being of the individual. The degree of blood cell perfusion in this region of the microvascular tree, over both long and short time periods, can provide a reliable indicator of peripheral vascular disease or injury. Reduction or even complete occlusion of blood perfusion in the microcirculatory blood vessels can often be attributed to a variety of cutaneous vascularisation disorders.

## Laser Doppler Flowmetry

Laser Doppler flowmetry (LDF) offers a continuous measurement of blood cell perfusion in the microcirculatory beds of skin tissue and other tissues without influencing the blood perfusion. LDF is established as an effective and reliable clinical medicine and

---

microvascular research. This has been achieved largely because LDF satisfies the need for continuous, non-invasive and real-time measurement of blood perfusion in the microvasculature.

Laser Doppler flowmeters produce an output signal that is proportional to the blood cell perfusion (or flux). This represents the transport of blood cells through microvasculature and is defined as;

Microvascular Perfusion = # of blood cells x Mean velocity

Microvascular perfusion, therefore, is the product of the mean cell velocity and mean blood cell concentration present in the small volume of tissue under illumination from the laser beam.

### **LDF Theory**

LDF makes use of the fact that when tissue is illuminated by a coherent, low powered laser, light is scattered by both moving and static structures within the microcirculatory beds. Photons, scattered by moving blood cells are spectrally broadened according to the Doppler effect. Maximum Doppler shifts occur when blood cells are moving in a direction parallel to the incident light beam and the detected light (scattered light) from the cells is detected in a direction opposite to its origin. For example, a Doppler shift of about 4 kHz is obtained when laser light (of a wavelength of 780 nm) is backscattered from a particle in water moving at 1 mm/s parallel to the light beam. In general a continuous range of Doppler frequency shifts is expected. Photons scattered by static structures alone do not undergo Doppler shifting.

In order to detect these small frequency shifts (~10-12 metres) it is necessary to use a technique called "optical beating". This basic means that the original output light is mixed with the backscattered light to effectively add the signals. (In technical terms this is referred to as heterodyning). When these signals are presented to the detector the result is an output which contains a fluctuating component related to the difference between the two beams.

This is performed using a photo diode detector. The frequency and magnitude of the alternating component of the photocurrent from this device (i.e. the power spectral density) is related to the mean

velocity and number concentration of blood cells present in the measuring volume.

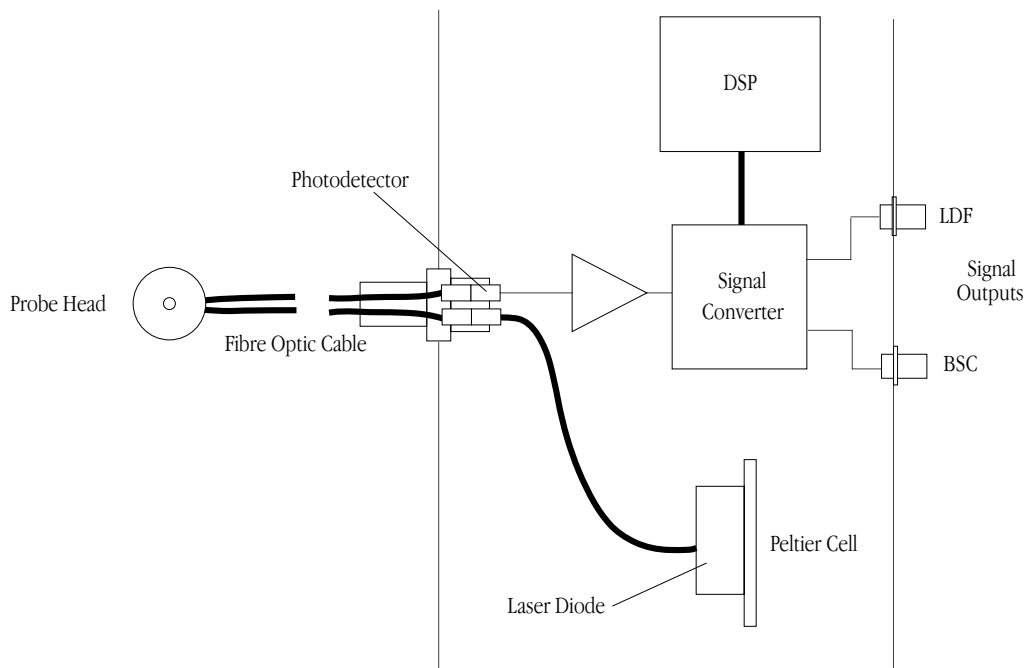
The signal from the photodiode is converted to digital information and then processed using a DSP (Digital Signal Processor). This device performs the spectral analysis and produces an LDF signal.

## How it Works

The Blood FlowMeter determines the blood flow perfusion by illuminating the surface of the skin with laser light and measuring the backscattered light. Various calculations are then performed on the returned signal which is then turned into a continuous signal that represents the blood perfusion in the illuminated area. The block diagram below shows a very basic outline of the fundamental components and their function.

**Figure C-1**  
Block diagram of the Blood FlowMeter (only one channel shown)

Both channels are supplied with laser light at a wavelength of 780 nm (visible red light) from an internal semiconductor laser diode which is temperature controlled by means of a Peltier cell and fans.



---

The laser light is transferred to the probe connectors by optic fibre. No laser light is supplied to the probe connectors unless both probes are present. This is for safety reasons.

When both probes are connected the system will turn on the laser therefore passing red light down the length of the probes fibre optics to the probe head. The probe head has an optical lens that allows light to be transmitted to the skin surface as well as allowing the transmission of backscattered light via a separate optic fibre. The returned or backscattered light travels up to the probe cable to a photodiode assembly attached to the input connector. The photodiode generates an electrical signal proportional to the light it receives.

The returned signal will be a combination of the original light and backscattered light which results in a signal with a varying frequency content. This varying signal content is the signal we are interested in as it represents the Doppler shift as a result of light being backscattered off moving blood cells.

This photodiode signal is digitised and a digital signal processor is used to perform a spectral analysis of the signal to determine the mean velocity of the blood cells and thus generate an LDF signal. The result is converted back into an analog signal that is proportional to the blood perfusion in the area of measurement.

## **Probe Operation**

There are several types of optic probes that can be used with the system, each one having its own optical characteristics. In order to make sure that different probes will produce consistent results, each probe contains a means of identifying itself to the system. In this way you can change probes without having to recalibrate your system.

## **What does the Blood FlowMeter Measure?**

The Blood FlowMeter is a laser Doppler flow meter whose primary purpose is to measure real-time microvascular red blood cell (RBC) perfusion (otherwise known as RBC flow or RBC flux). Laser Doppler signals are recorded in BPU which is a relative units scale defined using a carefully controlled motility standard.

---

## The Blood Perfusion Unit (BPU)

The Blood FlowMeter has been factory calibrated with a constant, known motility standard so that, for a given perfusion situation, all probes will read the same value of BPU. It should be noted, however that the blood perfusion value (BPU) is not an intrinsic physiological definition of blood perfusion. The notion of a universal physiological standard, valid for all types of tissue is scientifically inconceivable. Such activity rests on the assumption that microcirculatory blood perfusion is essentially homogeneous for all tissue structures over the human body. This assumption is seriously flawed since the regional complexity of the skin's microvasculature, its global variability over the human body and the complex nature of light scattering in tissue makes LDF suitable for characterising only relative changes in blood perfusion. So, although the Blood FlowMeter can be absolutely calibrated using an in vitro model, the complex and variable geometry of the vascular tree precludes absolute calibration in vivo applications. This means that even though the Blood Perfusion Unit (BPU) can be traced to a physical standard, the measurements expressed in BPU must be considered as strictly relative.

### Zero BPU

The zero reading of the Blood FlowMeter has been obtained by calibrating the system against a special static scattering material where no movements occur. In such cases the back-scattered light processed by the Blood FlowMeter contains no Doppler shifted frequencies and a true zero is obtained. A zero reading therefore indicates zero motion both in the measuring volume under examination and artefactual motion arising from relative movements between the probe and the measuring volume. During in vivo measurements rarely is an absolute zero obtained. Even during total occlusion of the tissue blood perfusion, there is often some small, residual motion of blood cells trapped in the vessels, as well as some small muscle and tissue movement in the measuring volume. Even after surgical removal of tissue, localised cell movement and Brownian motion may still occur in the severed blood vessels.

The Blood FlowMeters internal software allows the zeroing of the laser Doppler signal when there is insufficient light returning from the tissue to the probe. In the default condition (power on), the cutoff

---

threshold is set to 1%. This means that if the backscatter signal falls below 1%, the laser Doppler signal is automatically zeroed.

## **Motion Artefact Noise**

Laser Doppler studies sometimes reveal changes in the blood perfusion signal which are often unrelated to actual physiological changes in blood perfusion. These artefacts in the blood perfusion signal can often be attributed to the movement of the optical fibres in the beam delivery/collection system and are noticeable in situations where the subject moves or twitches. This type of artefact may be worse in situations where the probes moves with respect to the tissue. This effect can therefore be minimised by using a probe which is connected to, rather than clamped over the tissue, for example by using the standard right angle or saturable probes.

Spurious motion artefact may occur when a ventilator, or other mechanical device is employed. Under these conditions, artefact should be minimised by controlling vibration reaching the measurement site and the Blood FlowMeter. This may be achieved by placing the ventilator on a separate table and on a vibration absorbing medium.

# D

## A P P E N D I X D

# Specifications

### Doppler Flow Specifications

Mode:	Continuous laser Doppler flowmetry
Primary Measurand:	Microvascular blood flow (Relative RBC Flux)
LDF Units:	Relative units (0-9999 Blood Perfusion Units - corresponding to 0 - 4 V output)
BSC Units:	Relative units (0-100%) corresponding to 0-4 volts output
Laser Type:	Semiconductor laser diodes (temperature stabilised)
Laser wavelength:	780 nm $\pm$ 10 nm
Laser Power:	0.5 - 1.0 mW per probe (at probe end)
Laser Class:	Class 1 (per 21 CFR 1040 and 1040-11)
Doppler signal bandwidth:	10 Hz - 22 kHz
Linearity Range:	up to 0.35% P.C.V
Flow Response time:	0.2 s

---

Reading stability:	1.5% (measured with standard motility solution)
Zeroing:	Factory set using static scatterer
Flux Calibration:	Factory set using a motility standard (concentration of latex spheres undergoing Brownian Motion)

### **Power Supply**

Supply type:	Medically approved (IEC601.1) switching power supply in external enclosure
Voltage range:	100-240 V A.C (50 – 60 Hz), 1.3 A - 300 W
Output Power:	+5 V, $\pm 12$ V DC (maximum 45 W rating)
Approvals:	UL2601, CSA 601.1, IEC601.1, CE
Fusing:	Internal, 2 A 240 V resetable

### **Physical Configuration**

Dimensions:	225 x 50 x 260 mm
Weight	3kg
Power requirements:	240V or 120V (internally set) @ 15W
Operating temperature range:	0 to 35°C, 0 to 90% humidity (non-condensing)

---

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



---



# Index

---

## A

Analog outputs 5  
artefacts 24

## B

back panel 4  
Backscatter output 5  
blood cell perfusion 19  
Blood Flowmeter  
    checking for damage 2  
    connecting to other equipment 8  
    operating principles 19  
    product intention v  
    troubleshooting 15  
Blood Perfusion Units 23  
BPU  
    limitations 23  
    zero readings 23  
BSC Output 5

## C

calibration button 4  
cautionary information vi  
checking the Blood Flowmeter 2  
cleaning of probes 13  
connecting probes 8  
connectors  
    analog output 5  
    back panel 4  
    front panel 3  
    probe inputs 3  
cooling requirements 5

## D

Doppler effect 20  
Doppler shift 20

## E

Electromagnetic Compatibility v

## F

fan 5  
front panel 3

## I

indicator lights  
    probe status 4

## L

Laser Doppler Flowmetry 19  
laser illumination 20  
Laser Safety vii  
LDF outputs 5  
LDF Theory 20

## M

Microvascular perfusion 20  
motion artefacts 24

## O

optic fibre 22

## P

power connector 5  
Power Indicator light 3

---

Power Supply Socket 5  
probe  
    calibration buttons 4  
    cleaning & sterilisation 13  
    connection 8  
    input connectors 3  
    operation 22  
    removing 12  
    safety instructions vi  
    status indicator lights 4  
    storage 13  
Product Intention v

## **R**

RBC 22  
red blood cell perfusion 22  
removing probes 12

## **S**

safety  
    applicable standards v  
    electrical vii  
    Instructions v  
    lasers vii  
    symbol meaning viii  
signal connection 8  
sterilisation of probes 13  
storage of probes 13

## **T**

technical aspects 19  
troubleshooting 15

## **U**

Using this guide 2

## **Z**

zero BPU readings 23

---



# Licensing & Warranty Agreement

---

This Agreement is between ADInstruments Pty Ltd. [ADI] and the purchaser [‘the Purchaser’] of any ADI software, hardware, or both. The Purchaser is deemed to have consented to the terms of this licensing and warranty agreement by using the hardware or software created by ADI.

ADI develops proprietary computer programs and hardware, including MacLab and PowerLab units and ancillary hardware. All ADI software programs, hardware designs, and associated documents are protected by copyright.

1. The Purchaser is authorised to make as many backup copies of ADI software as is deemed advisable. Each separate purchase of a software program, however, licenses the Purchaser to use the software on only one computer at any given time: although there may be multiple copies of a purchased program in existence, two or more copies must not be used simultaneously. If only one set of disks is provided with a site license, the software can be used on more than one computer at once, as if a number of copies were purchased separately (five unless otherwise specified).
2. The Purchaser is not permitted to distribute copies of the programs, libraries, or documentation supplied with the MacLab hardware and software to any other person or institution, or knowingly allow others to do so, without the prior written consent of ADI.

3. The Purchaser has the non-exclusive right to use the supplied ADI hardware and software. (The Purchaser’s employees or students, for instance, are entitled to use the hardware and software, provided the licensing agreement is adhered to.)

4. The Purchaser may not attempt to decipher, decompile, disassemble, or reverse-engineer any of the hardware, software programs or libraries, or in any other way gain access to the source code, or knowingly allow others to do so. Neither may software programs or libraries or documentation be in any way modified or translated without the prior written consent of ADI.

5. ADI warrants to the original Purchaser that the hardware supplied, including its components and parts, shall be free from defects in material and workmanship for a period of one year from the date of shipment. A dated receipt signed by an authorised Distributor shall be taken as proof of date of purchase.

6. ADI’s obligation under this warranty is limited to repair or replacement, at the option of ADI or its authorised Distributor, of the equipment or defective component or parts upon receipt of the hardware at the Distributor’s premises.

7. This warranty is contingent upon normal usage, which means that the hardware has been used within its operating specifications. This warranty does not cover hardware that has been modified without the prior written approval of

---

ADI or an authorised Distributor; units that have been subjected to unusual physical or electrical stress; units that have been used with incorrectly wired or otherwise substandard connectors or cables; or units with the original identification marks removed or altered.

8. This warranty does not apply if adjustment, repair, or parts replacement is required because of accident, neglect, or misuse; failure of electric power, air conditioning, or humidity control; transportation; or any causes out of the ordinary, such as earthquakes, war, and so on.

9. This warranty is in lieu of all obligations and liabilities, including all warranties of merchantability or otherwise, expressed or implied or statutory. This Agreement states ADI's entire and exclusive liability and the Purchaser's exclusive remedy for any claim of damages in connection with the sale or furnishing of the hardware and software, including design, suitability for use, operation, or installation.

10. The Purchaser acknowledges that ADI provides a limited warranty only in respect of the hardware, software, and documentation provided pursuant to this Agreement. The entire risk as to the results, performance, and reliability of the MacLab system or its hardware and software components is assumed by the Purchaser. ADI does not warrant, guarantee, or make any representations regarding the use, or results of the use, of the MacLab system or its hardware and software components in terms of correctness, accuracy, reliability, currentness, or other factors.

11. Neither ADI nor anyone else who has been involved in the creation, production, or delivery of ADI products, including hardware, software, or documentation, shall be liable for any direct, indirect, consequential, or incidental damages arising from the use of, results of the use of, or inability to use any product or part thereof, even if ADI has been advised of the possibility of such damages or claims.

12. The Purchaser agrees that ADI retains the exclusive ownership of the trademarks represented by its company name, logo, and product names.

13. The rights and privileges of the Purchaser under this Agreement remain effective until the Purchaser returns the products to which it relates, or fails to comply with any of its terms and conditions. The rights and privileges of ADI under this Agreement, however, shall continue in force and be actionable by ADI at all times.

14. If ADI or the Purchaser need to enforce the terms of this Agreement, the enforcement shall be governed by the laws of New South Wales in Australia, and any proceedings concerning this Agreement shall be heard, determined, and resolved by the Supreme Court of New South Wales in Australia. The Purchaser and ADI submit to the jurisdiction of this court for the purposes of the enforcement of the rights and privileges of each pursuant to this Agreement.

15. This Agreement, in fifteen parts, constitutes the entire Agreement between the Purchaser and ADI, and can be changed only by the mutual written consent of ADI and the Purchaser.