ADInstruments

Application Note

# Monitoring Heart Rate in Humans

This application note discusses different methods for recording heart beat-related signals and displaying heart rate using the PowerLab system and Chart software.

Robert Purves, ADInstruments.

## Introduction

A record of beat-to-beat heart rate is required in a wide range of research settings and student laboratory classes, such as cardiovascular and cardio-respiratory physiology, exercise studies, and cardiovascular pharmacology. The PowerLab system allows a trace of the heart rate to be obtained in several different ways, each method having its own advantages and disadvantages.

## Equipment

PowerLab
ML110 Bridge Amp (for use with MLT1020)
MLT1010 Pulse Transducer
MLT1020 Plethysmograph
ML132 Bio Amp
ECG electrodes MLA1010
BioAmp cable MLA1340
Snaplead wires MLA0313

## Signal sources

The commonly used signals from which heart rate is derived are the peripheral pulse and the electrocardiogram (ECG or EKG). The pulse may be recorded with various PowerLab transducers.

### MLT1010 Pulse Transducer

The Pulse Transducer is robust and inexpensive. It requires no front-end amplifier, and plugs straight into a PowerLab unit. The best sites for recording a pulse are the fingers and toes. Alternatively, the transducer can be taped firmly over a carotid artery.

The sensing device is a mechanical accelerometer, and therefore the Pulse Transducer is inherently liable to generate movement artefacts during exercise. Also the amplitude of the Pulse Transducer signal from a digit diminishes sharply if the digit is elevated above heart level, owing to drainage of the venous circulation. These changes in amplitude make it difficult to set the threshold level for deriving heart rate. Such complications can, however, be minimised by attaching the transducer to the subject’s finger and providing a fixed bar for the subject to hold. The handlebars of an exercise bicycle can play the same role.

### MLT1020 Plethysmograph

The Plethysmograph contains an infrared light source and sensor, and requires a Bridge Amp front-end. It detects changes in infrared absorption as the blood content of the subcutaneous vascular bed changes with the pulse. Three types of plethysmograph are available. The ear-clip type is intended for attachment to an ear lobe. It also works when clipped on a finger, but is then strongly affected by variations in ambient light. The Velcro strap type can be strapped to fingers or toes, or taped on the forehead. The finger/toe spring clip type is less versatile but attaches very easily, and is screened against variations in ambient light.

The Plethysmograph transducer is inherently resistant to generating mechanical artefacts, provided that its attachment does not wobble. To prevent displacement during exercise, the lead from the Plethysmograph should be taped securely.

## ECG

Recording the ECG requires a Bio Amp with Bio Amp lead and three electrodes (see application note AN312, ‘Human Electrocardiography’). In a resting subject almost any standard ECG lead can be used that gives a good-sized QRS complex.

Life Science

In an exercising subject, the ECG will be severely contaminated by electromyographic (EMG) activity unless care is taken with electrode placement. In general, the closer the electrodes are to the heart, the less is the contamination. Adhesive electrodes must be used; the ‘clip-on’ types cannot be placed close to the heart, and tend to twist during exercise, causing severe movement artefacts.

If the exercise consists of stepping, with minimal arm involvement, satisfactory recordings can usually be made from Lead I if the two limb electrodes are placed just under the right and left clavicles, rather than more distally on the arms. The appearance of the Lead I ECG is hardly affected by this change of placement.

A better alternative is a non-standard lead, with one electrode on the sternum and the other at precordial position $V_5$ (on the left anterior axillary line, in the fifth or sixth intercostal space). The indifferent (reference or isolated ground) electrode may be connected to any convenient part of the body. With this placement, none of the major muscle groups contributes an important EMG signal, and a good ECG can be recorded even during vigorous exercise.

## Deriving the heart-rate signal

PowerLab’s Chart software provides two chief methods for analysis of periodic waveforms: computed input and the Cycle Variables extension.

### Computed Input

Computed input has the advantage that the computation of heart rate is performed in the PowerLab unit. The heart-rate signal is therefore immediately available for display on-line. Computed input can be used at sampling speeds up to 200/s on E series PowerLabs or 2000/s on S series. It is possible to use computed input in such a way that the heart-rate signal replaces the raw signal (for example by connecting the raw signal to PowerLab’s CH1 input and displaying computed heart rate on Channel 1 of the Chart window). A better choice is to retain the raw signal and display the heart-rate on a different channel, as shown in Figure 4. The advantage of this choice is that if your settings for threshold and hysteresis should prove unsatisfactory, you can recalculate heart rate by using Cycle Variables off-line (that is, after the experiment or recording is finished); the original pulse or ECG data is still available.

### Cycle Variables Extension

Cycle Variables is an off-line extension for Chart. A heart-rate trace derived with Cycle Variables does not show while Chart is recording, but is drawn after recording stops. The chief advantage of Cycle Variables is that you can record the pulse or ECG signal first, and then try different settings in the dialog box (Figure 2) to get the best record of heart rate.

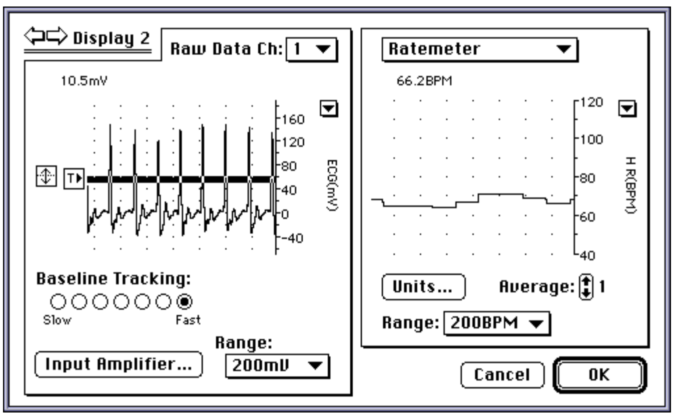


**Figure 1.** Computed Input dialog box with settings for heart-rate. The raw data here is from a Pulse Transducer connected to Channel 1. Heart rate will be displayed on Channel 2. Note that Average should be set to 1. For pulse and ECG waveforms, any setting for Baseline Tracking will work, but the Fast setting gives most immunity to movement artefacts.

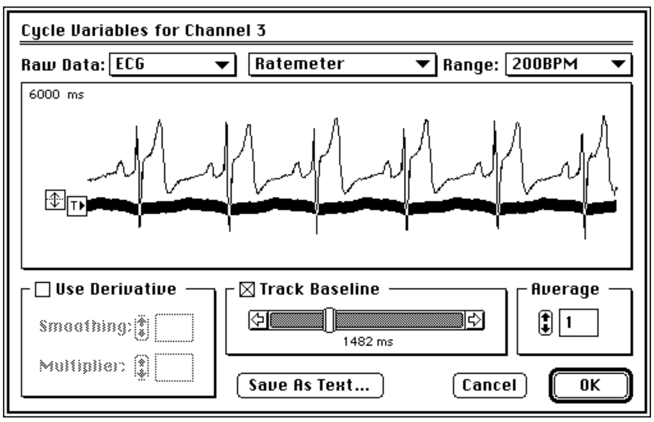


**Figure 2.** The Cycle Variables dialog box, showing settings for deriving heart rate from the QRS complex of a non-standard lead ECG. Note that Average should be set to 1. For cleanly recorded pulse and ECG waveforms, you can turn Track Baseline off, but a value in the range 1–2 s (set by the slider control) gives additional immunity to movement artefacts.

## Sampling speed

The choice of sampling speed is governed by the need to obtain adequate definition of the waveform used to trigger the ratemeter, without unduly increasing the size of saved Chart files.

The principal peak of the pulse signals has a duration of 0.1–0.15s, and a sample rate of 40/s to 100/s is adequate for teaching purposes. In a research setting a higher sample rate would be better: 200/s or 400/s.

Higher sampling speeds are needed for an ECG. The entire QRS complex is normally less than 0.1s in duration, and so to define the R wave accurately a sample rate of 200/s or 400/s is needed. In many research applications, a sample rate of 1000/s is used (see application note AN309, ‘Heart Rate Variability Extension’).

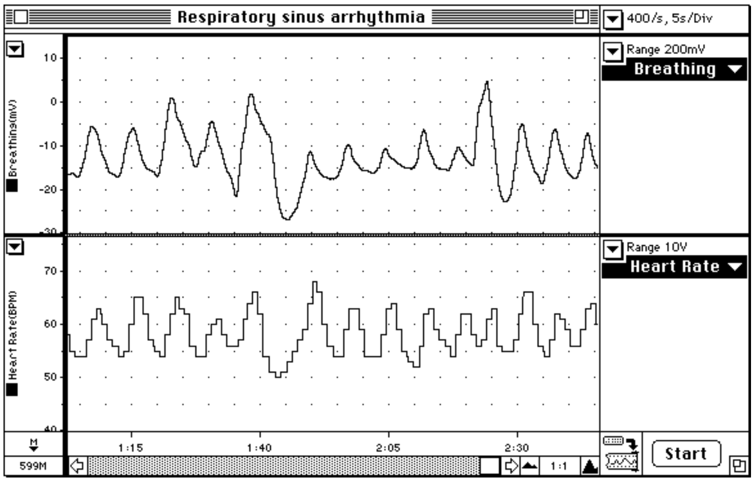


**Figure 4.** A typical application of heart rate monitoring, showing respiratory sinus arrhythmia (variations in heart rate synchronised with the respiratory cycle). Top trace: breathing movements recorded from thorax with a Pneumotrace transducer. Lower trace: heart rate derived from finger pulse recording.

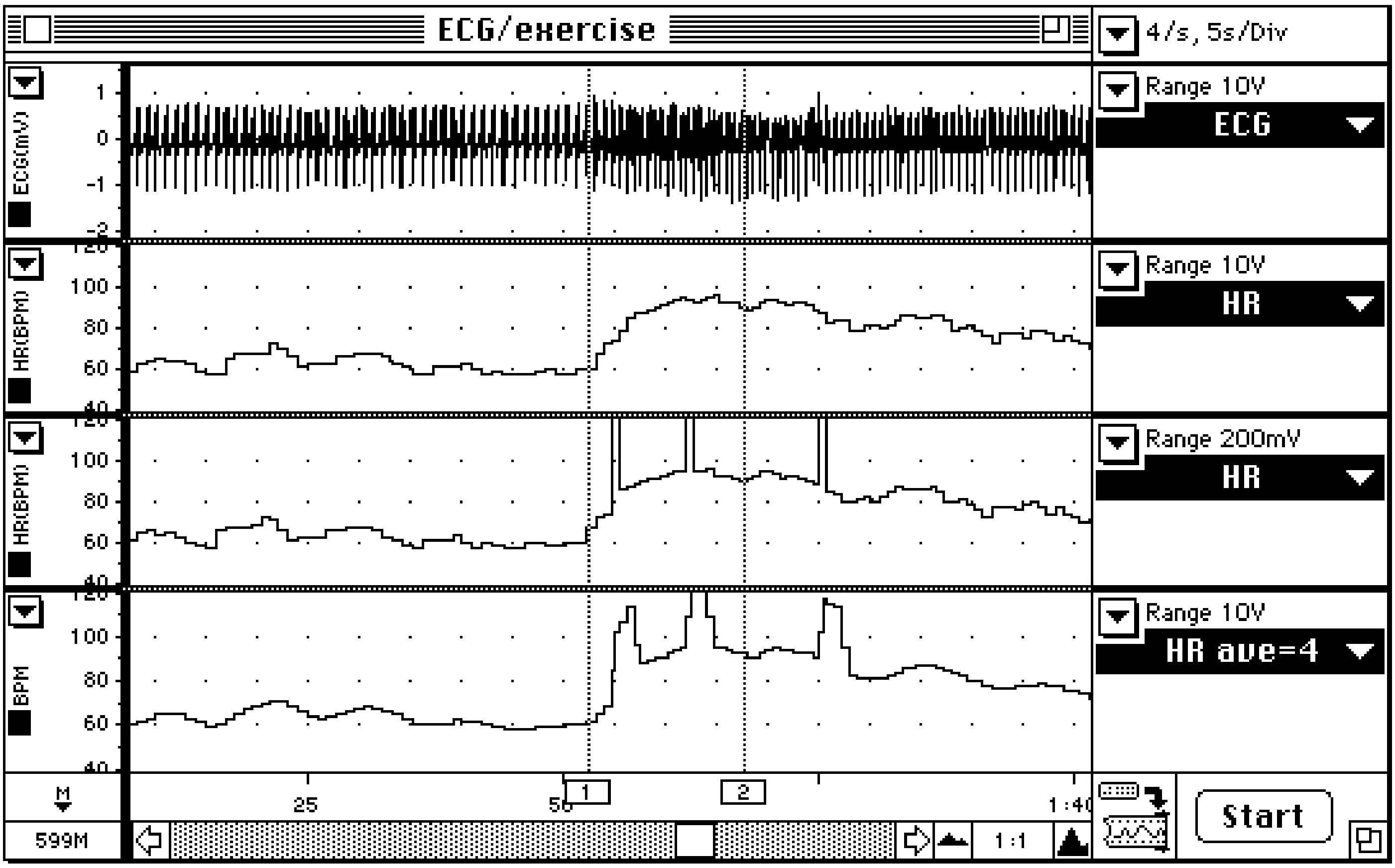


**Figure 3**. ECG and heart rate during exercise. Channel 1: the raw ECG signal recorded between sternum and V5 electrode position. Channel 2: heart rate derived on-line by Computed Input. Channel 3: heart rate derived off-line by Cycle Variables, with deliberate maladjustment of threshold so that some T waves trigger waveform recognition. Note that the data trend is clear in spite of occasional mistriggering. Channel 4: As for Channel 3 but with Average set to 4.

# Notes

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Addresses

International
ADInstruments Pty Ltd
Unit 6, 4 Gladstone Road
Castle Hill, NSW 2154
AUSTRALIA
Phone:+61 (2) 9899 5455
Fax:+61 (2) 9899 5847
Email:enquiries@adi.com.au
Web:
http://www.adinstruments.com

North America
ADInstruments Inc.
1949 Landings Dr
Mountain View CA 94043
U.S.A.
Phone:+1 (650) 965 9292
Fax: +1 (650) 965 9293
Email:
info@adinstruments.com

Europe
ADInstruments Ltd
Grove House
Grove Road, Hastings
East Sussex, TN35 4JS
UNITED KINGDOM
Phone: +44 (1424) 424 342
Fax: +44 (1424) 460 303
Email:enquiries
@adi-europe.com

Japan
ADInstruments Japan Inc.
Okajima Bldg 2-10-1
Iwamoto-cho
Chiyoda-ku, 101 Tokyo
JAPAN
Phone:+81 (3) 5820 7556
Fax:+81 (3) 3861 7022
Email:adijapan@po.iijnet.or.jp

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