ADInstruments

Application Note

Human Electrocardiography

This note discusses electrodes and connections for recording the electrocardiogram (ECG, EKG) with the PowerLab system and Chart software. Most of the experiments described are suitable for an introductory course in physiology.

Robert Purves, ADInstruments

Introduction

ECG recording is required in a wide range of research settings and student laboratory classes, for studies in cardiovascular, cardio-respiratory and exercise physiology, and cardiovascular pharmacology.

Equipment required

- Any PowerLab unit with Chart software
- ML132 Bio Amp and MLA1340 Subject cable (two required for simultaneous six frontal leads ECG)
- MLA1092 Abrasive pad
- MLA1090 Electrode cream

Electrodes

- MLT YDG Dry Earth Strap (optional)
- MLA700 reusable large clamp ECG electrodes with MLA0313 snap-connect wires

or

- MLA1081 reusable electrodes with MLA1080 adhesive disks and MLA0313 snap-connect wires

or

- MLA0415 disposable Biotabs electrodes with MLA0213 clip-on wires

or

- MLA1010 disposable ECG electrodes with MLA0313 snap-connect wires

The MLA700 large clamp electrodes are especially easy to connect, and are suitable for many student lab classes. They are, however, liable to generate movement artefacts. The other ECG electrodes listed are adhesive, and are preferred for stable low-noise recording.

Electrode attachment

Connections should be made according to Table 1. Figure 1 illustrates connections for Lead I.

High-quality recordings can only be made if the resistance of the electrode connections is sufficiently low. Since most of the resistance resides in the stratum corneum of the skin, it is a good idea to abrade the skin lightly before attaching electrodes. Two or three strokes of the abrasive pad suffice. A small quantity of electrode cream, just enough to ensure contact, should then be applied to reusable electrodes before attachment. Disposable electrodes do not normally need electrode cream.

The common electrode may be of the same type as the two ECG electrodes proper, or it may be a Dry Earth Strap attached firmly around the right ankle. The Dry Earth Strap does not need skin abrasion or electrode cream.

Lead	Neg	Pos	Common
I	right arm	left arm	right leg
II	right arm	left leg	right leg
III	left arm	left leg	right leg

Table 1. The standard limb leads and their electrode connections to the Subject cable.

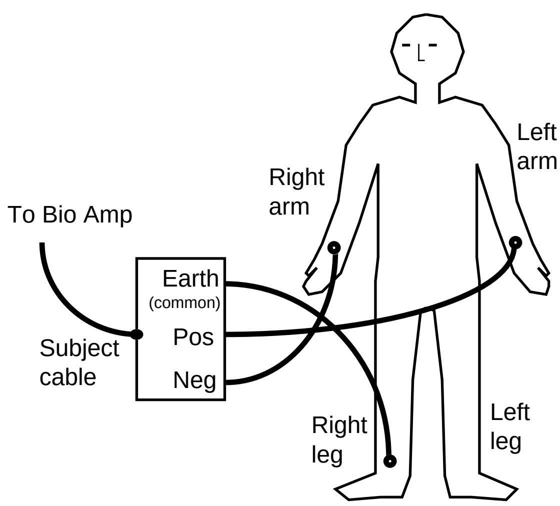

Figure 1. Connections for ECG recording, Lead I.

Life Science

To reduce 50/60 Hz interference, the subject and the connections from electrodes to the Subject cable should be kept away from mains power wires and computer screens.

Exercise studies

In an exercising subject, the ECG will be severely contaminated by electromyographic (EMG) activity or movement artefacts unless care is taken with electrode placement. The required precautions are described in application note AN311, ‘Monitoring Heart Rate in Humans’.

Safety

The Bio Amp is a specially designed isolated amplifier with no direct electrical connection to ground. This means that it cannot become a source of potentially fatal currents, even under fault conditions. To maintain this protection, never connect the subject directly to the PowerLab hardware unit itself or to any other grounded equipment. The Bio Amp is supplied with an approved Subject cable and leads. The safety of the device is guaranteed only when used in conjunction with these leads.

Bio Amp settings

Recommended Bio Amp settings for ECG recording are shown in Figure 2. Mains frequency (50/60 Hz) interference can be minimised by turning the Notch filter on. Movement artefacts can be made less intrusive by setting the High Pass filter to 0.3 Hz. These alternative settings will affect the ECG waveform, but only very slightly.

Sampling speed

The choice of sampling speed is governed by the need to obtain adequate definition of the QRS complex, without unduly increasing the size of saved Chart files. The entire QRS complex is less than 0.1 s in duration, and so to define the R wave accurately a sample rate of at least 200/s is needed. For most research applications, a sample rate of 400 or 1000/s is used (see application note AN309, ‘Heart Rate Variability’).

Suggestions for student lab classes

When students are first gaining experience with ECG recording, many teachers prefer not to confuse them with a multiplicity of leads, but to restrict the recording to one (for example Lead I). Suitable experiments for single-lead recording include:

(1) Exploring different placements of the Left and Right Arm electrodes (wrists, upper arms, thorax just below clavicles). These differing placements have virtually no effect on the ECG waveform.

(2) Simultaneous recording of peripheral pulse or heart sounds or both, along with the ECG (Figure 3).

(3) Determination of heart rate. For elementary teaching purposes, students can measure the RR interval and calculate the rate (Figure 4). A continuous beat-to-beat display of heart rate is also easily obtained. See application note AN311, ‘Monitoring Heart Rate in Humans’.

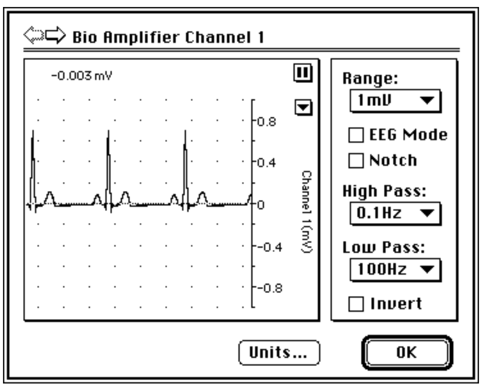

Figure 2. Recommended Bio Amp settings for ECG recording.

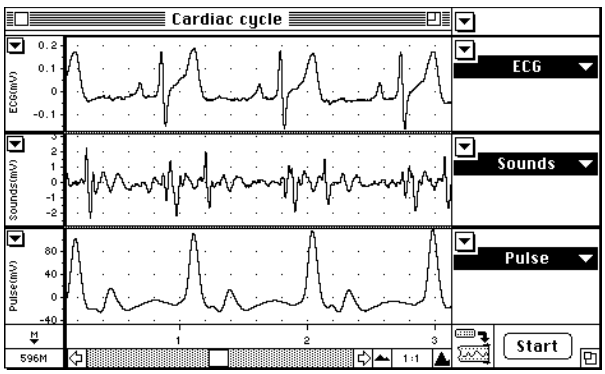

Figure 3. ECG, heart sounds and finger pulse. Heart sounds recorded with MLT 201 Cardiac Microphone. Pulse recorded with pulse transducer. The sequence is clear: QRS complex, first heart sound, arterial pulse.

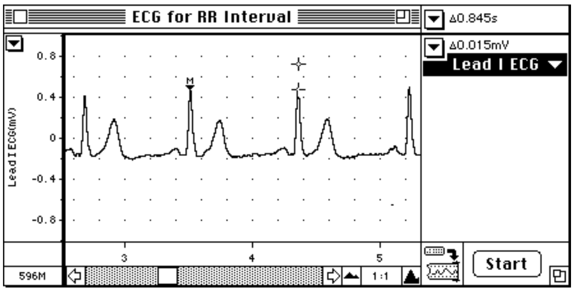

Figure 4. Determination of RR interval. The Marker has been dragged to the peak of one R wave, and the cursor placed at the peak of the next. The RR interval (0.845s) is displayed at top right of the window. The heart rate corresponding to this RR interval is 60/0.845 ≈ 71 BPM. Direct determination by counting the pulse for 1 minute gave 74 BPM.

More advanced work

The six frontal-plane leads

If you have two Bio Amps or a dual Bio Amp and Subject cables, you can record Leads I and II directly in Channels 1 and 2. Duplicate electrodes are required on the right arm and leg. Use the Arithmetic extension to derive the remaining four frontal leads (Figure 5).

The expressions that should be entered in the Waveform Arithmetic dialog box for each derived lead are listed in Table 2. Figure 6 indicates how the expression for computing Lead III is entered. Note that in Chart v3.4, you should type "Channel2" instead of "Rawchannel2", and correspondingly for other channels. Remember also that you can just click the buttons rather than having to type "Channel1" and so on.

This experiment shows the redundancy in conventional multi-lead ECG recording: all the information in the six frontal plane leads is contained in any two of them.

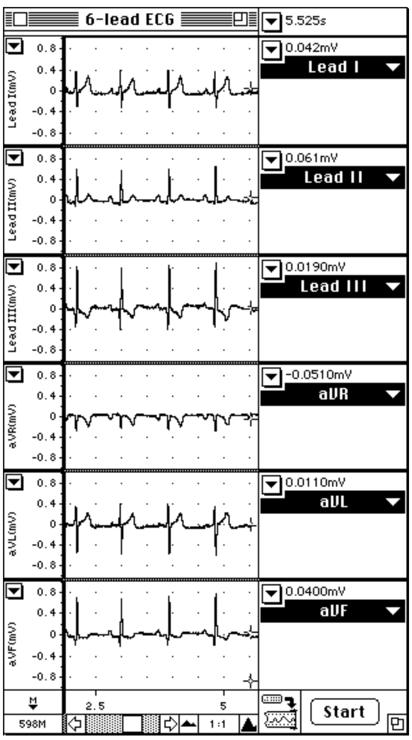

Figure 5. The six frontal leads. Leads I and II were recorded directly with two Bio Amps, and the remaining leads derived with the Arithmetic extension as described in the text.

Lead	Expression
III	(Rawchannel2 – Rawchannel1)*1000
aVR	–(Rawchannel1 + Rawchannel2)*500
aVL	(Rawchannel1 – Rawchannel2/2)*1000
aVF	(Rawchannel2 – Rawchannel1/2)*1000

Table 2. Waveform Arithmetic expressions for derived leads.

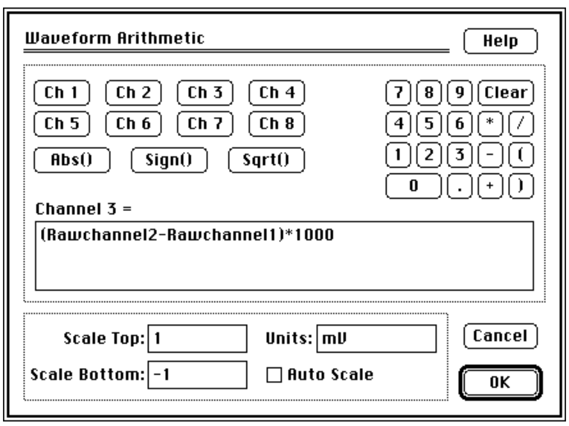

Figure 6. Waveform Arithmetic settings to compute Lead III from Lead I (Channel 1) and Lead II (Channel 2).

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Vectorcardiography

Vectorcardiography is a technique for recording electrical activity of the heart in the form of closed loops. The displays are derived from three orthogonal leads recorded with the Frank electrode placement. This arrangement is complicated and not often used in student lab classes.

You can, however, easily approximate the frontal plane Frank vectorcardiogram from the six-lead display described above. Since Lead I is horizontally directed and aVF is vertically directed, an X–Y plot of these leads is a vectorcardiogram (Figure 7). The QRS loop (outermost in Figure 7) and T-wave loop are easily distinguished. The P-wave loop is the central dark region.

For strict accuracy in the vectorcardiogram display, the factor of 1000 in the expression for Lead aVF (Table 2) should be changed to 1155. For demonstration purposes, however, the 15% error is of no consequence.

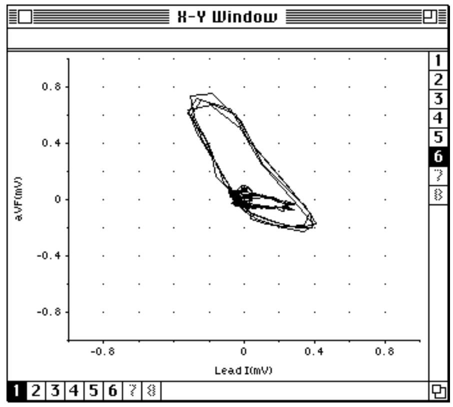

Figure 7. X–Y plot of Lead I against aVF, over several cardiac cycles.

Cardiac Axis Chart extension

The Chart extension Cardiac Axis automates the calculation of frontal plane ECGs and vectorcardiogram, and can give an animated display of the instantaneous cardiac vector. Figures 8 and 9 illustrate the use of Cardiac Axis with a Chart file in which Leads I and II have been recorded at 1000 samples/s.

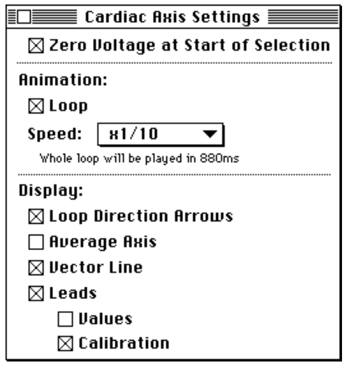

Figure 8. Cardiac Axis settings dialog box. The check-box at top has the effect of forcing the start of the selection to be isoelectric. A display with these settings is shown in Figure 9.

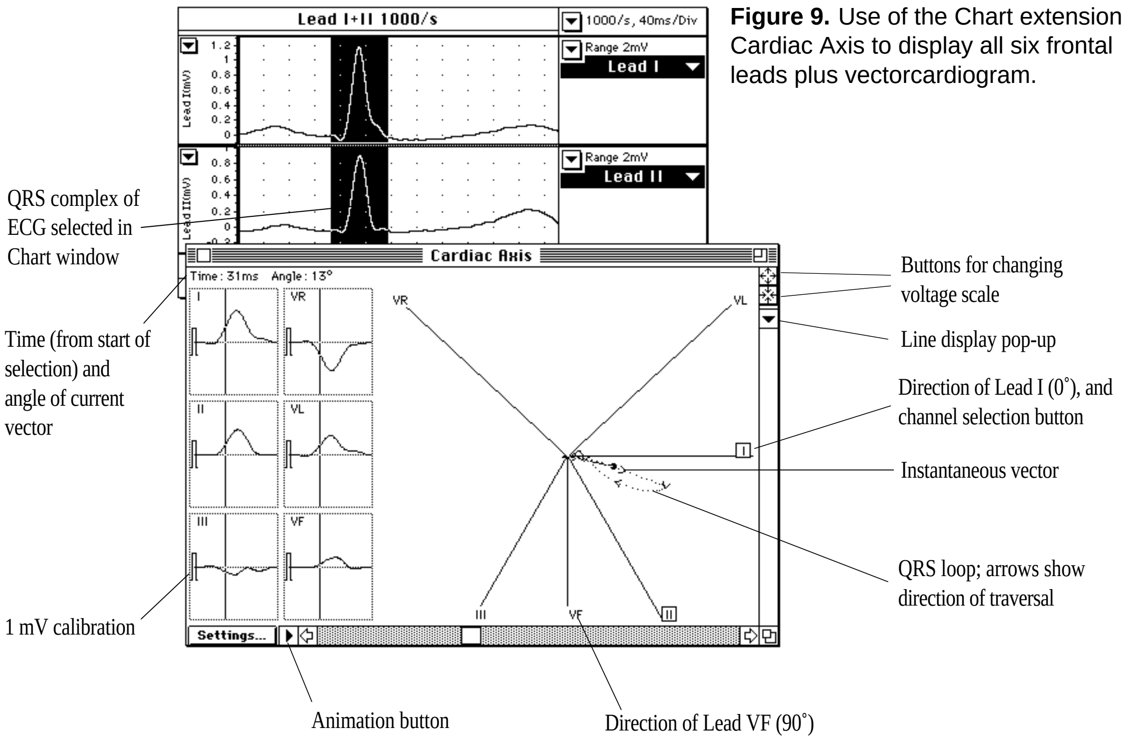

Figure 9. Use of the Chart extension Cardiac Axis to display all six frontal leads plus vectorcardiogram.