



ABOUT ELECTRODES

- Electrode Overview – page 1
- Using Electrodes – page 2
- Reducing “noise” – page 3
- The Body Electric – page 4
- Waveform Signal – page 5



ELECTRODE OVERVIEW

Attaching Disposable Electrodes

- For optimal electrode response, place electrodes on the skin at least 5 minutes before starting to record data.

Connecting Electrode Leads

Each lead set has three pinch leads designed to snap directly onto standard disposable electrodes (such as the EL500 series electrodes). Each pinch lead is 1 meter long. This is the general-purpose electrode cable used for almost all applications requiring the use of electrodes. These cables are used to connect the disposable electrodes that are placed on the surface of the skin to the MP40 unit. Depending on where the electrodes are placed, you can use them to measure muscle contraction, heartbeats, or even brainwaves.

Red – positive
White – Negative
Black – Ground

- Each pinch connector on the end of the electrode cable needs to be attached to a specific electrode. The electrode cables are each a different color. Follow the color code above to ensure that each cable is connected to the proper electrode.
- The pinch connectors work like a small clothespin, but will only latch onto the snap of the electrode from one side of the connector.

Removing Electrodes

- Unclip the electrode leads and peel off the electrodes.
- Throw out the electrodes (BIOPAC electrodes are not reusable).
- Use soap and water to wash the electrode gel residue from the skin. It is quite normal for the electrodes to leave a slight ring on the skin for a few hours.

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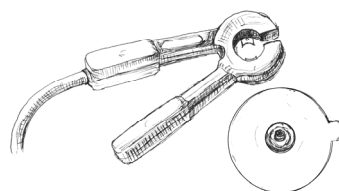
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Using Electrodes

About Electrodes

The purpose of an **electrode** is to act as a “connector” between the Subject’s skin (where electrical signals are easiest to detect) and the MP40 acquisition unit (via the 40EL **lead cable**). If an electrode makes good contact with the skin, the signals that are generated will be relatively accurate.



Electrode lead connector and electrode

Electrodes are very simple devices that consist of a small piece of metal designed to make indirect contact with the skin and a larger adhesive plastic disk. Each electrode is about 1 inch (2.5 cm) in diameter, and is sticky on one side so it will adhere to your skin.

If you look closely at the electrode, you can see that there is a small piece of plastic mesh filled with a bluish gel. Since gel conducts electricity (better than your skin, in fact) and is more flexible than the metal part of the electrode, your skin can flex and change shape somewhat without losing the electrical connection with the metal part of the electrode.

BIOPAC disposable electrodes are standard disposable electrodes and are widely used in clinical, research, and teaching applications. These electrodes come in strips of ten, and you should not remove an electrode from the backing until you are ready to use it.

The following directions will help you get good data from the electrodes by explaining how electrodes work and how to attach the electrodes and electrode leads to obtain the best signal.

Electrode placement

There are two basic methods of electrode placement: monopolar and bipolar.

- In a **monopolar** recording, an active electrode is placed over the region of interest and a “reference” electrode is attached to a more distant part of the body.
- In a **bipolar** recording, the voltage difference between two electrodes, placed over the regions of interest, is measured with respect to the third “reference” electrode. Leads I, II, and III are standard bipolar electrode configurations. The **standard bipolar limb leads** are:

lead I = right arm (-), left arm (+)

lead II = right arm (-), left leg (+)

lead III = left arm (-), left leg (+)

Preparing the Electrode Site

If signals are erratic, one way you can improve electrode connections is to gently rub the area where the electrode is to be placed. This is known as **abrading** the skin, and removes a thin layer of dead skin from the surface of the skin. Since dead skin doesn’t conduct electricity very well, removing it improves the connection between the electrode and the skin. The skin site can be lightly abraded with a clean dry cloth.



Abrading the skin surface

Attaching electrodes

To attach an electrode, peel the electrode from its backing and place it on the area indicated in the lesson. Once in place, press down firmly on the electrode with two fingers and rock the electrode back and forth for a few seconds. This will ensure that it is adhering to the skin as much as possible.

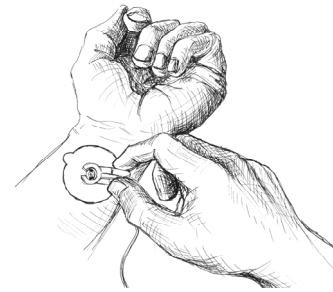
- To help insure that the electrode will make good electrical contact with the skin, you may want to squeeze a drop or two of **electrode gel** (BIOPAC GEL1 or GEL100) onto either the surface of the skin or onto the electrode, without allowing any to get on the adhesive.



Optional: apply electrode gel

Connecting the Electrode Lead

Each electrode lead cable is a different color and each pinch connector on the end of the cable needs to be attached to a specific electrode. Note that the connector is polarized and needs to be clipped on such that the metal extensions inside the clip are on the down side to make surface contact with the electrode. The pinch connectors work like a small clothespin, but will only latch onto the snap of the electrode from one side of the connector. You should follow the figure provided in the lesson to ensure that you connect each lead cable to the proper electrode.



**Clip the lead to the electrode
"snap"**

Reducing Electrode "Noise"

If an electrode does not adhere well to the skin, the signal plotted on the screen may appear "fuzzy." This is referred to as "**noise**," and although it always exists to some degree, it is best to reduce noise as much as possible. Electrodes have no moving parts, so there is nothing you have to do to get an electrode to "work" but there are several things you can do to reduce noise when electrodes are connected:

- Place the electrodes where there is the least amount of hair and/or choose the subject with the least amount of hair. A common problem is that something on the surface of the skin is interfering with the electrode contact. If there is too much hair (for instance) between the outer layer of skin and the electrode, the electrical activity taking place below the surface of the skin may not be detected.
- Make sure that everything is connected properly.
- Attach the electrodes a few minutes before you are going to use them. The best results are achieved by putting the electrodes in place about five minutes before you begin recording data. This gives the electrodes time to establish contact with the surface of the skin.
- Position the electrode lead cables such that they are not pulling on the electrodes. Connect the electrode cable clip (where the cable meets the three individual colored wires) to a convenient location (can be on the Subject's clothes). This will relieve cable strain.
- The Subject should not be in contact with nearby metal objects (faucets, pipes, etc.), and should remove any wrist or ankle bracelets.

Removing Electrodes

Once you have completed a lesson, disconnect the electrode cable pinch connectors, peel the electrode off the skin, and dispose of the electrode (BIOPAC electrodes are not reusable). Wash the electrode gel residue from the skin, using soap and water. The electrodes may leave a slight ring on the skin for a few hours. This is normal, and does not indicate that anything is wrong.

The Body Electric

Generally, people think of electricity flowing through bodies as an unusual occurrence. For instance, they may think of rather unique animals, such as electric eels, or of rare events such as being struck by lightning. What most people do not realize is that electricity is part of everything their body does...from thinking to doing aerobics—even sleeping.

In fact, physiology and electricity share a common history, with some of the pioneering work in each field being done in the late 1700's by Count Alessandro Giuseppe Antonio Anastasio Volta and Luigi Galvani. Count Volta, among other things, invented the battery and had a unit of electrical measurement named in his honor (the Volt). These early researchers studied "animal electricity" and were among the first to realize that applying an electrical signal to an isolated animal muscle caused it to twitch. Even today, many classrooms use procedures similar to Count Volta's to demonstrate how muscles can be electrically stimulated.

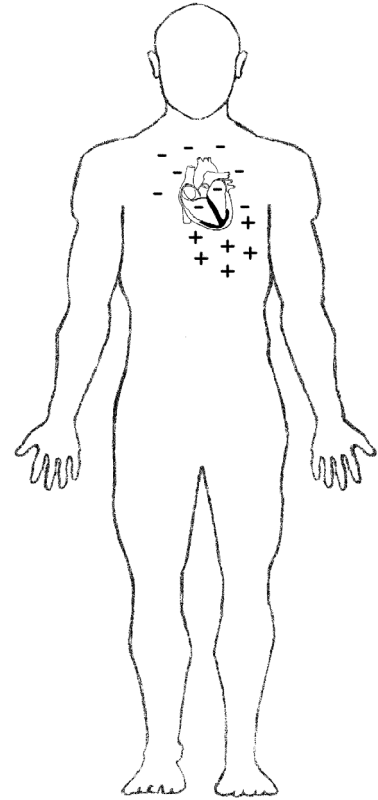
Over the next few weeks, you will likely see how your body generates electricity while doing specific things like flexing a muscle or how a beating heart produces a recognizable electric "signature." Many of the lessons covered in this manual measure electrical signals originating in the body. In order to fully understand what an electrical signal is requires a basic understanding of the physics of electricity, which properly establishes the concept of **voltages**, and is too much material to present here. All you really need to know is that electricity is always flowing in your body, and it flows from parts of your body that are negatively charged to parts of your body that are positively charged.

As this electricity is flowing, sensors can "tap in" to this electrical activity and monitor it. The volt is a unit of measure of the electrical activity at any instant of time. When we talk about an electrical signal (or just signal) we are talking about how the voltage changes over time.

The body's electrical signals are detected with transducers and electrodes and sent to the MP40 acquisition unit computer via a cable. The electrical signals can be very minute—with amplitudes sometimes in the microVolt (1/1,000,000 of a volt) range—so the MP40 amplifies these signals, filters out unwanted electrical noise or interfering signals, and converts these signals to a set of numbers that the computer can read. The Biopac Science Lab then plots these numbers as waveforms on the computer.

The body contains fluids with ions that allow for electric conduction. This makes it possible to use electrodes on the surface of the skin to detect electrical activity in and around the heart and use an electrocardiograph to record the activity. Conveniently, the legs and arms act as simple extensions of points in the torso, allowing the recording and ground electrodes to be placed on the wrists and ankles. The electrocardiogram is a record of the overall spread of electric current through the heart as a function of time in the cardiac cycle. The direction of polarity (+ or -) of the recorded waveforms depends upon the location of the recording electrodes on the surface of the body and whether the electrical activity during the cardiac cycle is coming toward or going away from the surface electrode. In general, as a wave of depolarization approaches a positive electrode, a positive voltage is seen by that electrode. If the wave of depolarization is traveling toward a negative electrode, a negative voltage will be seen.

The term "lead" is defined as a spatial arrangement of two recording electrodes on the body. One lead is labeled + and the other -. The electrode placements define the recording direction of the lead, which is called the *lead axis* or angle. The axis is determined by the direction when going *from the negative to positive electrode*. The electrocardiograph computes the voltage difference (magnitude) between the positive and negative electrodes and displays the changes in voltage difference with time.

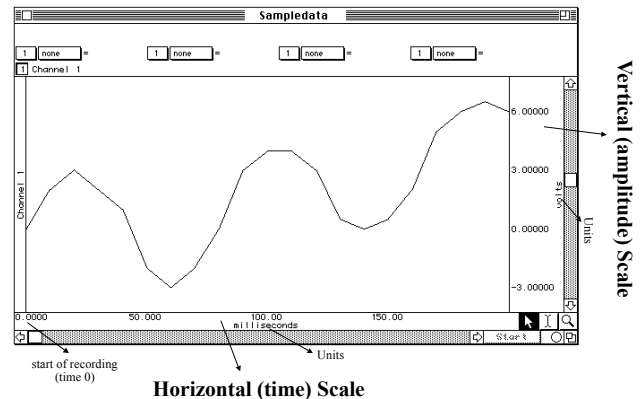


Waveforms

The BIOPAC software takes the signal input and plots it as a waveform on the computer screen. The waveform of the signal can be either a direct reflection of the electrical signal from the MP unit channel (amplitude is in Volts) or a different waveform which is based on the signal coming into the MP unit. For example, the electrical signal into the MP unit may be an ECG signal, but the software may convert this to a Beats Per Minute (BPM) waveform).

When you use any BIOPAC software, it is important to at least have a basic understanding of what the waveforms on the screen represent. The waveform below is a plot of Amplitude versus Time. As shown, the earliest data appears at the left edge of the screen, and the most recent data at the right edge.

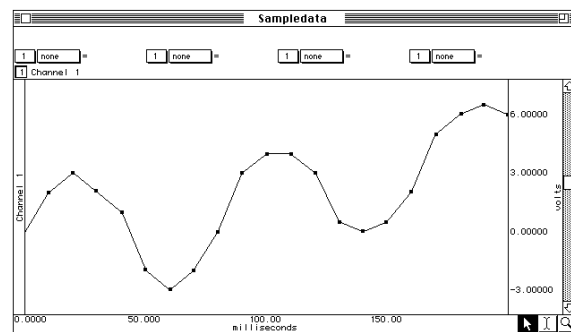
- **Amplitude** is determined by the MP unit hardware according to what it senses at one of its inputs, which is actually the signal output from a transducer, set of electrodes, or other device. The units are shown in the vertical scale region; the unit for this example is Volts.
- **Time** is the time from the start of the recording, which is to say that when the recording begins it does so at what the software considers time 0. The units of time are shown in the horizontal scale region; the unit for this example is milliseconds (1/1,000 of a second).



Waveform plot of Amplitude vs. Time

Diving a little deeper into what a waveform represents, you are actually looking at **data points** that have been connected together by straight lines.

These data points are established by the BIOPAC system hardware by sampling the signal inputs at consistent time intervals. These data points can also be referred to as **points**, **samples**, or **data**.



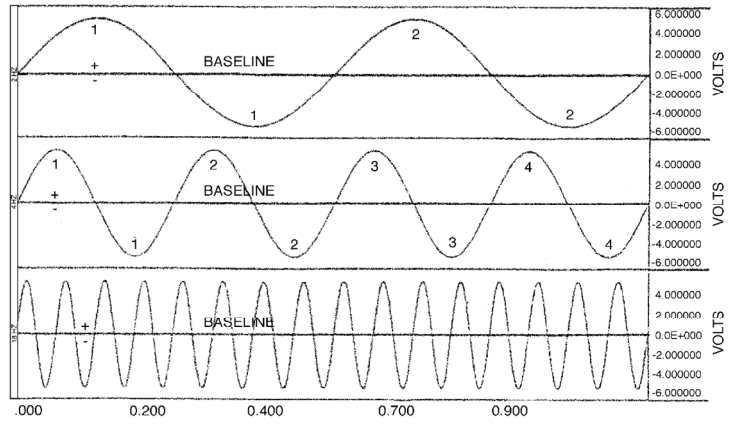
Data points of a waveform

The time interval is established by the **sample rate** of the BIOPAC software, which is the number of data points the hardware will collect in a unit of time (normally seconds or minutes). The BIOPAC software stores these amplitude values as a string of numbers. Since the sample rate of the data is also stored, the software can reconstruct the waveform.

Since BIOPAC software can simultaneously record signals from up to four (education units) or more inputs, there may often be more than one waveform on the screen. It is worth noting that the BIOPAC software always uses the same sample rate for all channels on the screen, so the horizontal time scale shown applies to all channels, but each channel has its own vertical scale. A channel's vertical scale units can be in Volts, millivolts, degrees F, beats per minute, etc.

A **baseline** is a reference point for the height or depth ("amplitude") of a waveform.

- Amplitude values above the baseline appear as a "hill" or "peak" and are considered positive (+).
- Amplitude values below the baseline appear as a "trough" or "valley" and are considered negative (-).



Baseline Samples