

BIO-ELECTRIC MEASUREMENTS

OBJECTIVES:

- 1) Determine the amplitude of the electrical "noise" in the body.
- 2) Observe and measure the characteristics and amplitudes of muscle potentials due to the biceps.
- 3) Observe and measure the characteristics and amplitudes of muscle potentials due to the heart muscles (EKG).

INTRODUCTION

Many biological systems, ranging from the single cell to the human body, produce electrical signals that can be detected and recorded by sensitive electronic equipment. In recent years, the study of these signals has played an increasingly important role in the biological sciences, particularly in human medicine. Recently, there has been much interest in the electrical characteristics of plants. Even though research in this area is still in its infancy, there seems to be some evidence that plants change their electrical characteristics in response to changes in the environment.

While a complete explanation of the origins of electric phenomena in biological systems is not possible here, we will introduce the very basic concept of electricity produced by ionic diffusion. The weak electrical signals measured in this experiment are typical of those encountered in animal and plant cells. We hope that, through this experiment, you will gain the basic knowledge of bio-electric measurements and the precautions necessary for obtaining meaningful data from biological systems.

In this experiment, we will measure three types of bio-electric signals. 1) AC "noise" which the body picks up because the body acts as an antenna; 2) DC muscle potentials produced when a muscle is flexed; 3) cardiac signals produced by the contracting and relaxing of the heart muscles. We will use an oscilloscope and a differential amplifier to measure these signals.

SAFETY PRECAUTIONS

Any time electronic equipment is connected to a human or animal subject, the matter of electrical shock must be considered. The severity of shock depends on the amount of current flowing through the body and the frequency of that current. See figure 1 and 2. The amount of current which will flow through the body is determined by Ohm's Law, $I = V/R$, where the voltage is fixed, and the current is determined by the body resistance. The arm-to-arm resistance with contacts on dry skin is of the order of $10^5 \Omega$. Sticking your fingers in the 120-volt wall outlet would let a current of 1-2 mA flow through your body -- definitely painful. With dry skin, the maximum voltage you should even consider touching is 30 volts.

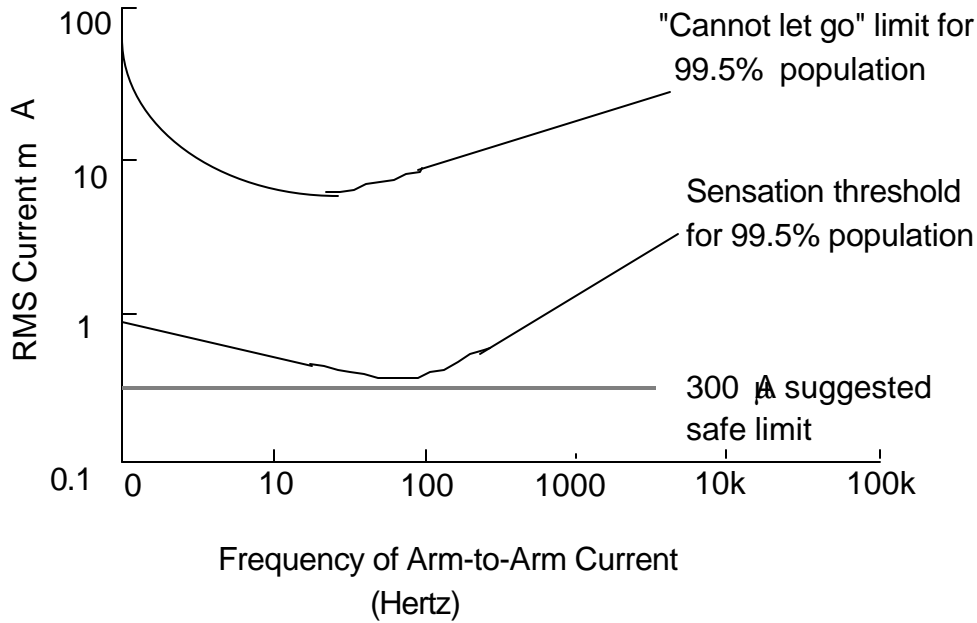


Figure 1

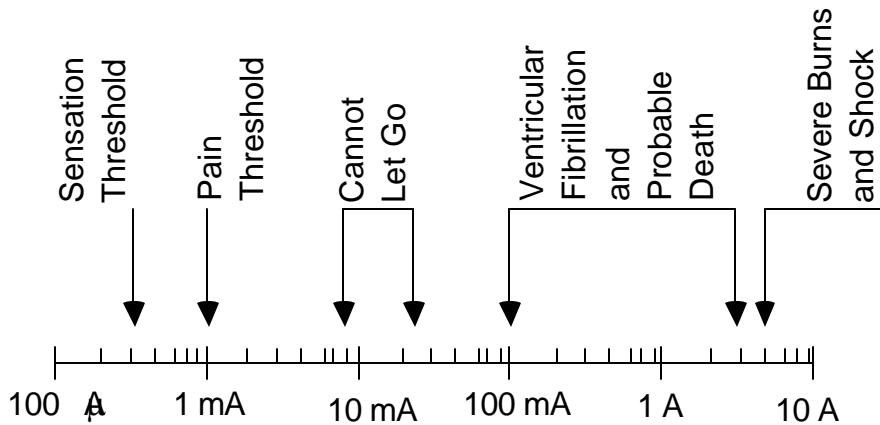


Figure 2

In order to detect small signals, it is necessary to reduce the body resistance by reducing the skin resistance. This can be done with a conducting paste between the electrode and the skin. Using this paste, a skin resistance as low as 5×10^{-3} ohms is possible. Such a reduction in body resistance significantly raises the possibility of severe injury from an electrical shock.

Electronic instruments used to amplify and measure voltages have no potential differences across the inputs, and therefore present no risk of shock. However, if some malfunction of the equipment were to transpire which allowed a high voltage to be present at the inputs, the result could be a severe shock to the subject. The probability of such a malfunction is very small. However, even one incident of shock in thousands of subjects would be unfortunate, therefore, we have devised a system that completely precludes the possibility of large voltages being present at the inputs of the differential amplifier. This ultimate safety device is known as an optical coupler.

The differential amplifier is powered by 2 batteries, which, even if shorted directly across the inputs, would not allow sufficient current to flow to produce even a sensation. Unfortunately, measuring equipment such as oscilloscopes and chart recorders require line voltages to operate. The optical coupler measuring isolates the measuring device (and thus the subject) from the amplifier.

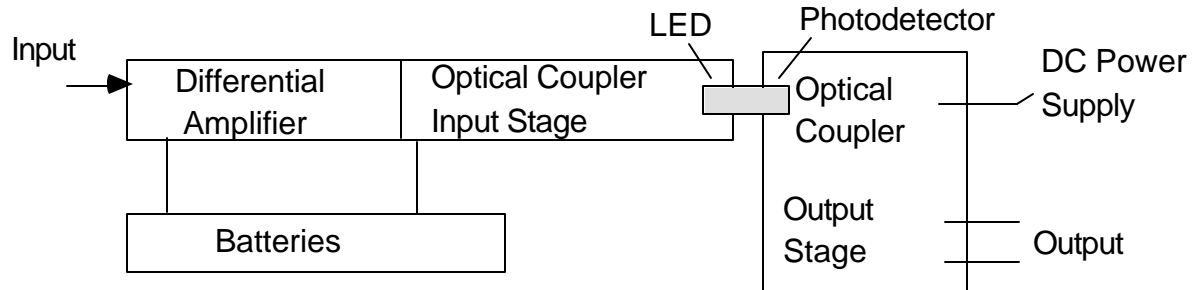


Figure 3

The output of the differential amplifier goes to the input stage of the optical coupler, which converts the electrical signal to a light signal by pulsing a light-emitting diode (LED). The light signal is detected by a phototransistor and converted back to an electrical signal in the output stage. The signal now goes to the measuring device. There is no electrical path between the differential amplifier and the measuring device. Even the case of the differential amplifier/optical coupler is made of non-conducting Plexiglas. The differential amplifier/optical coupler is an integrated unit housed in a Plexiglas box. Looking at the bottom of the circuit board, you will notice a distinct separation of the input circuit and the output circuit. The device that spans this gap on the top of the board is the LED/Phototransistor. (There also can be two jumper wires spanning the gap. These bring power from the power supply to the differential amplifier and input stage of the optical coupler. This arrangement saves the batteries when the device is being used to amplify non-biological signals. When the unit is used for actual biological signal detection, the jumpers are removed, thus totally isolating the subject from potential hazard.)

Unfortunately, isolating systems such as the optical coupler are not in general use in the measurement of human or animal bio-electric potentials. We are encouraging the widespread use of such systems and we hope that you, as future professionals in the bio-sciences, will also insist on their use. The incidence of electrical shock in bio-electrical measurements is indeed small, but we have the technology to virtually eliminate the hazard.

Partners _____

Name _____
 Section _____

PROCEDURE:

1. AC noise signal

First, we shall view AC noise voltages, which the body picks up from the surrounding power lines and cables. This forms a large portion of the signal which you would detect if you were to connect a set of electrodes from your body to the oscilloscope.

- a) To observe the AC noise signal, connect AC output to channel A of the oscilloscope and set the amplifier switch to AC.
- b) Set the amplifier and the scope for AC coupling.
- c) Touch one of the red input clip with your finger (see figure 4).
- d) Adjust voltage sensitivity and the time base on the scope to get a reasonable view of the signal.

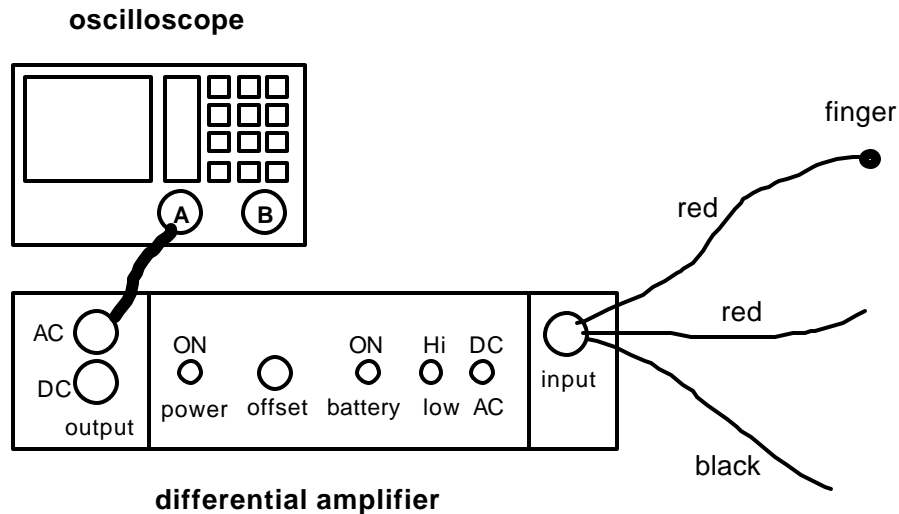


Figure 4

- e) Sketch the noise signal that you see on the scope: (You may want to freeze the trace by pressing the LOCK button on the scope.)

- f) Measure the peak-to-peak voltage and the frequency of the noise signal. Remember: the differential amplifier has a gain, so you must take that into account when computing the actual voltage.

V_{pp} reading from the scope = _____ mV

Actual V_{pp} = _____ mV

Gain=_____ (From last weeks experiment.)

Frequency = _____ Hz

2. DC muscle potential

In order to view the DC muscle potential and the cardiac signal, it will be necessary to remove the AC noise signal. This is accomplished by using the differential amp. As was stated in last week's experiment, the Amplifier, if two signals, A and B are sent to the inputs of the differential amp the output of the differential amp will be the difference between these two signals, $A - B$. If there are any noise signals common to both of the inputs of the differential amp, then the noise signal will be subtracted out and thereby eliminated.

Now we will measure the DC voltage generated when a muscle is flexed. It has been shown that the voltage difference across a muscle is directly proportional to the force applied by the muscle. In order to make this measurement, it will be necessary to use the electrodes which can be attached to the skin with a thin layer of contact cream to make a better electrical connection. The electrodes will be connected as pictured in figure 5.

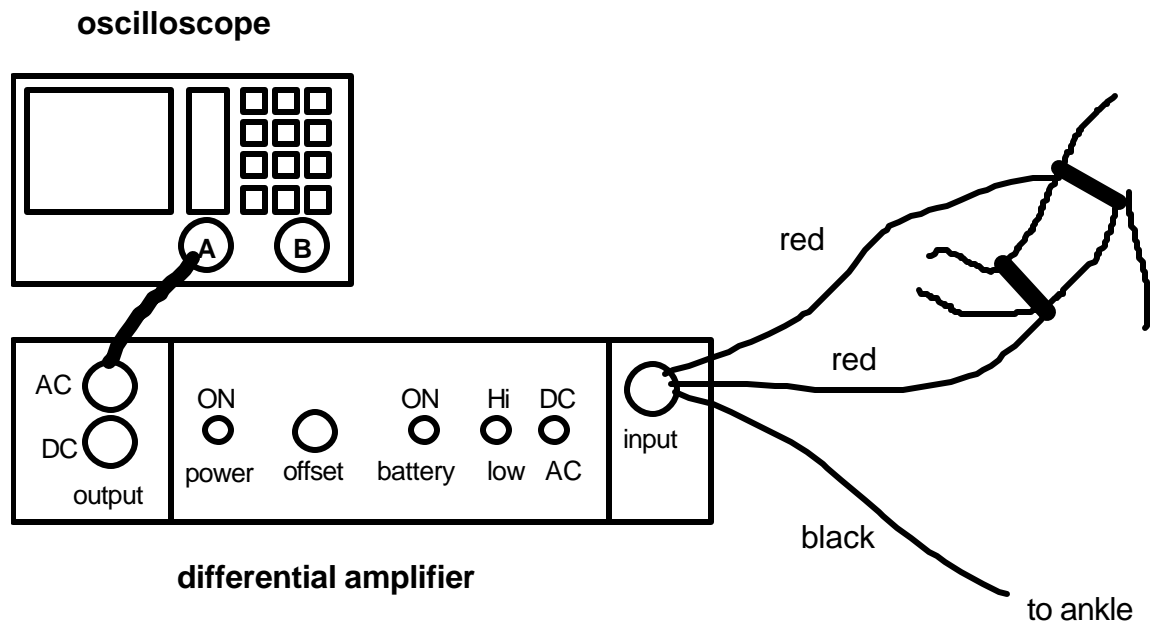


Figure 5

- Attach the electrodes to the upper and lower part of the biceps muscle. Place the upper lead as high as practical. Clip the two red leads to each electrode. Attach one electrode to the ankle. Clip the black lead to that electrode.
- Set both the scope and the amplifier to DC coupling.
- Connect DC output to channel A of the scope, and turn on both the power switch and the battery switch on the amplifier.
- Set the time base to 10 ms.
- With your biceps muscle relaxed, adjust the OFFSET knob on the amplifier to produce a zero DC output. (Verify this by pressing the GND (ground) button on the scope and see if their vertical positions are the same.)
- Set the time base to 1 s.

- g) Now, as the trace starts across the screen, flex your bicep as hard as you can and hold it there. You should notice that the signal, although noisy, does level off at a different level than it began.
- h) Sketch below the muscle potential that you see on the scope. (You may want to freeze the trace by pressing the LOCK button.)

- i) Determine the voltage change when the muscle is flexed and when the muscle is relaxed.

Voltage change read from the scope = _____ mV

Actual voltage change = _____ mV

(Use the GAIN value that you determined in last week's experiment.)

3. AC cardiac signal

Finally, we wish to observe and measure the cardiac signal (EKG). The connections to be made for this section are shown in figure 6.

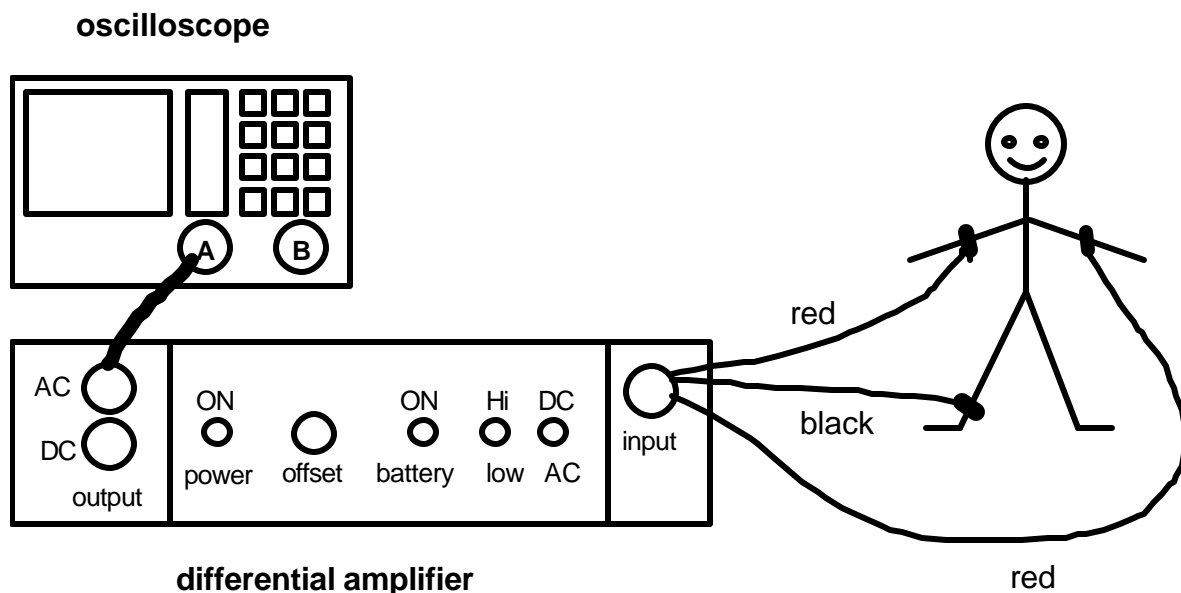


Figure 6

- a) Attach one electrode to each arm and attach one electrode to the ankle. Clip the red leads to the arm electrodes, and the black lead to the ankle electrode.
- b) Connect AC output to channel A of the scope. Set both the scope and the amp to AC coupling. Because the heart muscle is constantly flexing and relaxing, the cardiac signal is a constantly changing voltage. Hence, for this measurement the amplifier should be in AC coupling mode to eliminate offsets due to steady DC potentials.

- c) Adjust the voltage sensitivity and the time base on the scope to obtain a reasonable trace.
- d) Sketch the cardiac signal that you see on the scope twice: once where you see several heartbeats and once where you can see the detail of a single heartbeat.

- e) Determine the peak-to-peak voltage and the frequency of the cardiac signal.

V_{pp} read from the scope = _____ mV

Actual V_{pp} = _____ mV

Frequency = _____ Hz

- Q: Which is larger, the cardiac signal or the biceps signal in 2(i)?

- f) Predict what should happen to the output of a differential amplifier when its input leads are exchanged, recalling $C = k(A - B)$.
- g) Interchange the two red leads. Readjust the amplifier OFFSET knob and observe the heart signal. Sketch what you see on the scope when set up to look at detail of a single heartbeat:
- h) Predict what would happen if you exchanged the lead on the left arm with the lead on the ankle. Should the signal get noisier or more clear, larger or smaller? Why? (Here it is important to consider that the two paths, between one red and the black and between the other red and the black, should be of about the same length to cancel the most noise. Also consider which, if any, paths actually go through the heart. Finally, consider that the farther away from the heart you are, the more the signal has dropped off.)

- i) Place the black lead on the left arm, one red lead on the ankle, and the other red lead on the right arm. Readjust the amplifier OFFSET knob and observe the cardiac signals. Sketch what you see on the scope:

- j) Predict what would happen if you exchanged the leads on the two arms. Should the signal get noisier or more clear, larger or smaller? Why?

- k) Exchange the arm electrodes (black on right arm). Observe and sketch the signal from the oscilloscope.

