EXPERIMENT 8
Bio-Electric Measurements

Objectives

1) Determine the amplitude of some electrical signals in the body.
2) 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. Through this experiment you will gain the basic knowledge of bio-electric measurements and the precautions necessary for obtaining meaningful data from biological systems.

When the heart is at rest, the inside of the heart muscle cells are negatively charged and the exterior of the cells are positively charged. The cells are said to be polarized. Depolarization and repolarization of the heart muscle cells causes the heart to contract and blood to be pumped throughout your system. Depolarization is accomplished when some of the positively charged ions move through the cell membrane, resulting in a lower potential difference between the exterior and interior of the heart muscle cells. Shortly after depolarization, positive ions move back to their original location and the heart cells are repolarized. Figure 1 is an electrocardiogram (EKG) two successive heartbeats. The P-wave represents the depolarization of the two atrium chambers of the heart. The Q, R and S waves represent the depolarization of the two ventricle chambers of the heart. The T wave represents the repolarization of the two ventricle chambers. The atria are repolarized at the same time as the ventricles are depolarizing and are therefore obscured by the much larger ventricle depolarization.

The EKG can be measured by placing electrodes on the surface of your body. However, the resistance of dry skin is fairly high and it is necessary to reduce this resistance in order to obtain any measurements. This can be done by applying a conducting paste or gel to the skin. In this lab you will use adhesive, disposable foam, single use EKG electrodes which contain a hydrogel to reduce the resistance of your skin.

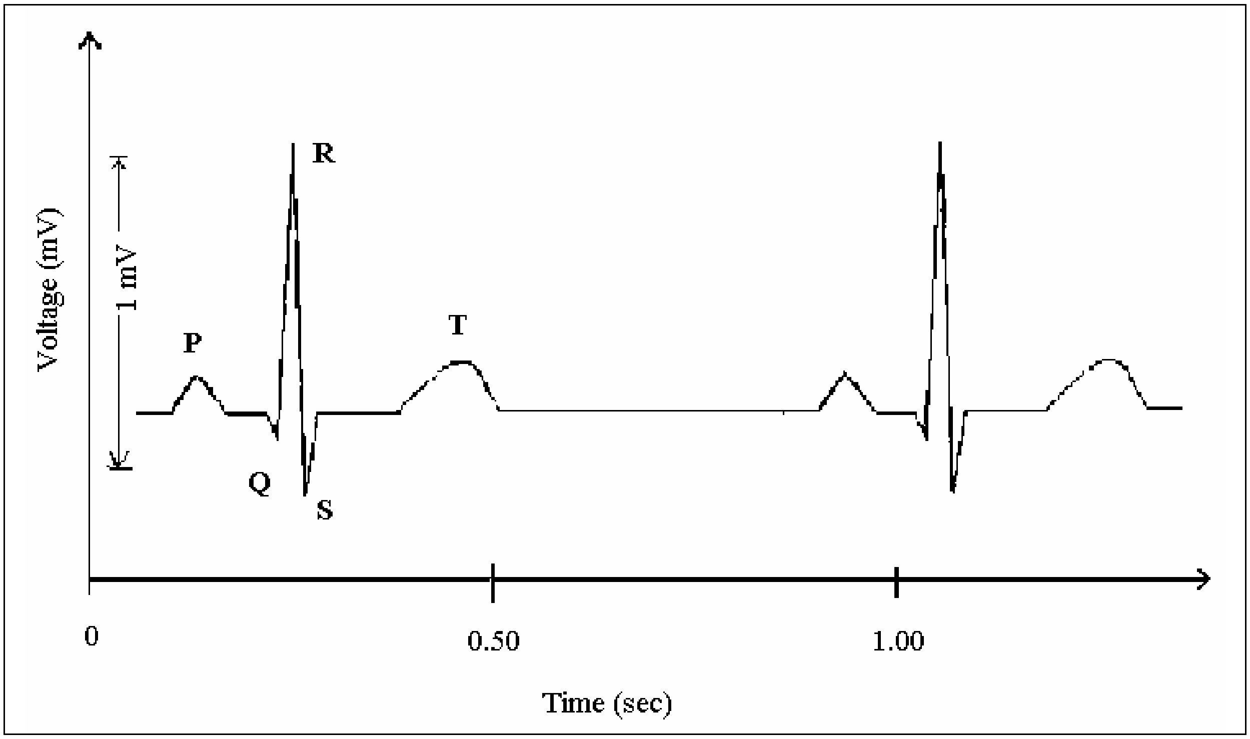

Figure 1

In addition to measuring cardiac signals in this experiment, you will observe AC noise which your body picks up because it acts as an antenna and measure DC muscle potentials produced when you flex your muscle. You 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.

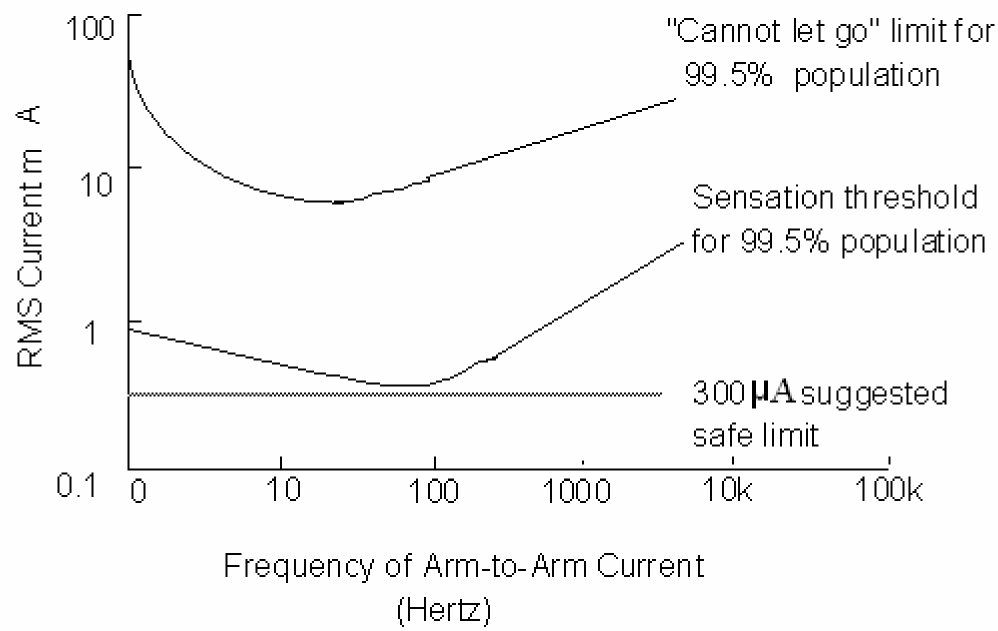

Figure 2

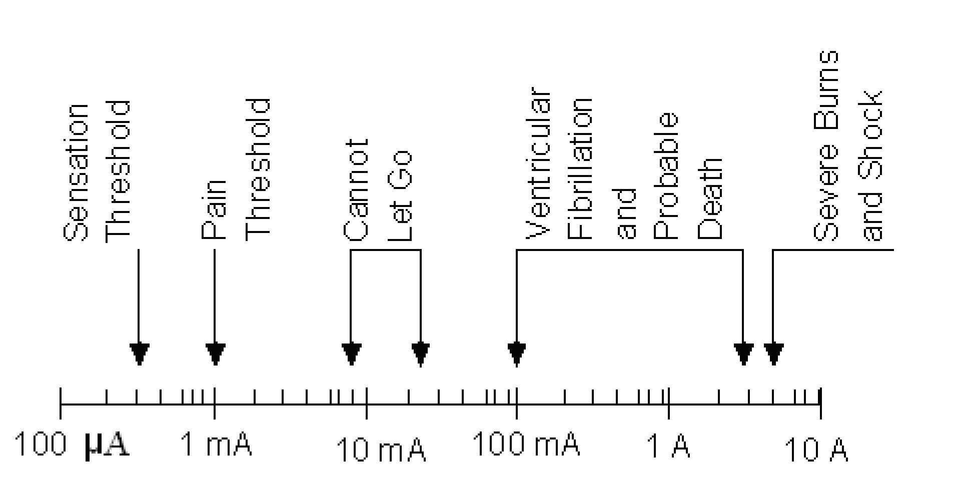

Figure 3 Effects of current (60 Hz)

Using the disposable electrodes can reduce your skin resistance as low as $5 \times 10^{-3}\,\Omega$. Such a reduction in body resistance significantly raises the possibility of severe injury from an electric shock.

Electronic instruments used to amplify and measure voltages have no potential difference across their inputs, and therefore present no risk of shock. However, if some malfunction of the equipment were to transpire and allow a high voltage to be present at the inputs, a severe shock to the subject could result. Although the probability of such a malfunction is very small, even one incident of shock in thousands of subjects would be unfortunate. Therefore, the system you will use completely precludes the possibility of large voltages being present at the inputs of the differential amplifier. The safety device used is known as an optical coupler. Essentially what the optical coupler does is convert the output of the differential amplifier to an optical signal; this optical signal is then detected and converted back to an electrical signal which can be displayed on the oscilloscope. Therefore, <u>no electrical path</u> exists between the differential amplifier and the measuring device.

WORKSHEET
Bio-Electric Measurements
Experiment 8

Name__________________________

Lab Partner_____________________

Section__________________________

Date____________________________

Procedure

You will not use an Excel spreadsheet to record your data. In its place, you will use this worksheet.

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, touch the red end of the cable connected to the oscilloscope with your finger.
b) Adjust the voltage sensitivity and the time base on the scope to get a reasonable view of the signal.
c) 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.)

d) 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

Frequency = __________±_____ Hz

Question 1: Is the frequency of the noise signal consistent with 60 Hz (i.e. the frequency of electrical signal throughout the room)?

2. 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 4.

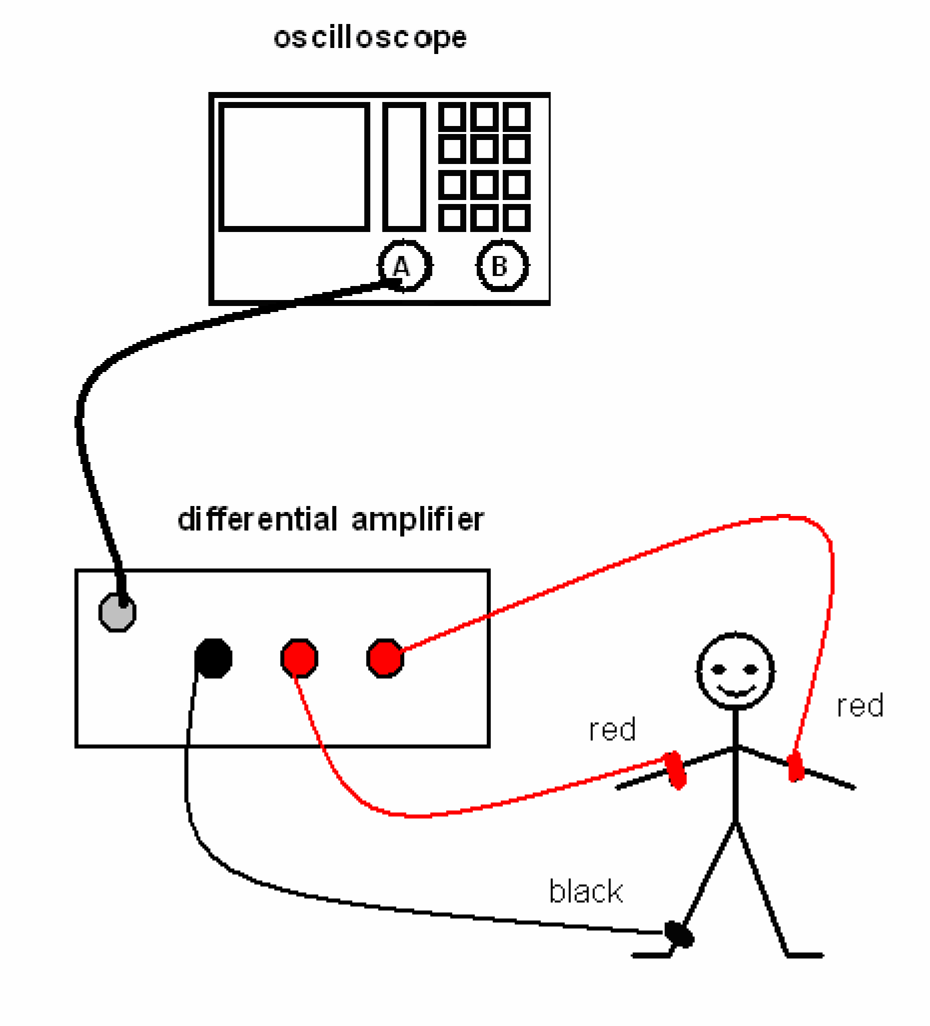

Figure 4

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. (You may want to freeze the trace by pressing the LOCK button on the scope.)

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

V_{pp} read from the scope = __________±_____ mV

Gain (from last week) = __________±____

Actual V_{pp} = __________±_____ mV

Frequency = ___________±____ Hz

The uncertainty of the peak to peak voltage of the actual cardiac signal is given by:

$$\delta V_{PP(actual)} = \delta V_{PP(actual)} = V_{PP(actual)}\left(\frac{\delta V_{PP}}{V_{PP}} + \frac{\delta GAIN}{GAIN}\right)$$

Show you calculations below:

Question 2: Predict what should happen to the output of a differential amplifier when its input leads are exchanged, recalling $C = k(A - B)$. Justify your prediction.

f) 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:

Question 3: Does the result from part f agree with your prediction?

Question 4: 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.)

g) 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:

Question 5: Does the result from part g agree with your prediction?

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Measure the cardiac signal for the other member(s) in your lab group. Record your results below:

Student 2:

V_{pp} read from the scope = __________±_____ mV

Actual V_{pp} = __________±_____ mV

Frequency = ___________±____ Hz

There should be no more than one group of three students in a lab session. If applicable record the third student's results below:

Student 3 (if applicable):

V_{pp} read from the scope = __________±_____ mV

Actual V_{pp} = __________±_____ mV

Frequency = ___________±____ Hz