ECG

OBJECTIVES

Students will learn basic concepts of acquiring and analyzing an electrocardiogram (ECG or ECG) by working and becoming familiar with Vernier's ECG sensor. This lab also introduces the Biosignal Logger and ECG Feature Extractor of the NI Biomedical Startup Kit.

MATERIALS

- NI Biomedical Startup Kit 3.0
- NI ELVIS II Series Benchtop Workstation
- NI ELVIS II Series Prototyping Board
- AC/DC power supply
- NI ELVISmx 4.0 or later CD
- High-speed USB 2.0 cable
- Computer
- Wires to build circuits
- Vernier Analog Proto Board Connector (order code BTA-ELV)
- Vernier ECG Sensor (order code ECG-BTA)

THEORY

Your heart is initially polarized at rest due to the excess of sodium ions (Na^+) outside of the membrane. This correlates to a resting potential of approximately 90 mV. Muscle stimulation increases the permeability of the membrane to these sodium ions. The entry of these sodium ions into the membrane alters the electric field around the muscular cells, generating an action potential and causing muscle contraction. Other ions, including potassium, calcium, and chlorine are also involved in this process. Electrodes placed on the surface of the skin record a summation of these action potentials. The resulting signal can be graphed as an electrocardiogram (ECG or ECG) and illustrates cardiac electric potential. Various deflections in the ECG waveforms correspond to the contraction of different areas of the heart. Each heart cycle is represented by a P wave, a QRS complex, and a T wave. The P wave corresponds to the depolarization of the atria, the QRS complex corresponds to the depolarization of the ventricles (repolarization of the atria also occurs during this time), and the T wave corresponds to the repolarization of the ventricles. Refer to Figure 1 below for a typical ECG signal and the typical time spans for each deflection.

(Summarized from the ECG Sensor User Guide; http://www.vernier.com)

Figure 1: Typical ECG Signal
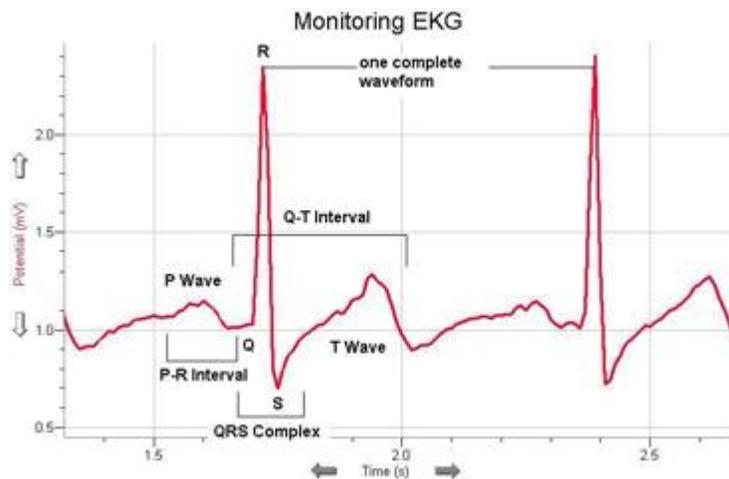
(www.vernier.com)

P-R interval: 0.12 – 0.20 seconds

QRS interval: < 0.1 seconds

Q-T interval: < 0.38 seconds

The ECG sensor used in this lab utilizes three electrodes, which are attached to the surface of the skin. There is an internal offset of 1 V within the sensor with an accuracy of +/- 0.3 V. This lab is set to account for this offset. The gain of the ECG sensor is set to amplify a 1 mV measured potential to a 1 V output. Reference the ECG sensor user guide for more information.

BUILDING THE EXPERIMENT ON ELVIS II SERIES

The Vernier sensor attaches to NI ELVIS II Series through the Analog Proto Board Connector. The following steps and Figure 2 below illustrate how to connect the Analog Proto Board Connector to the NI ELVIS II Series Prototyping Board.
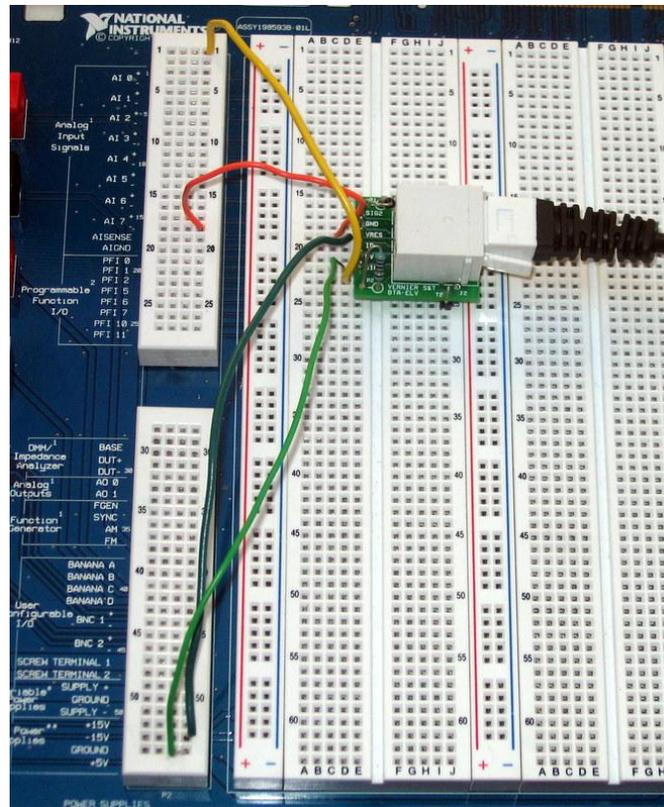
Figure 2: Connecting the Analog Proto Board Connector to NI ELVIS II Series

Connect the following pins to wire the connector:

1) AI0+ to SIG1 of the Analog Proto Board Connector
2) +5V DC power supply to 5V of the Analog Proto Board Connector
3) GROUND power supply to GND of the Analog Proto Board Connector
4) AIGND to GND of the Analog Proto Board Connector

RUNNING THE EXPERIMENT

To set up the experiment on NI ELVIS II Series:

1) Connect the USB cable from NI ELVIS II Series to your computer and plug the power supply into a power outlet.
2) Turn the prototyping board power switch located on the rear panel to the on position (see Figure 3).
3) Turn the prototyping power supply switch located on the benchtop workstation to the on position (see Figure 3).
   - A green power LED should now be lit, indicating that the full power supply is turned on.
   - A yellow USB ready LED should also be lit, indicating that the NI ELVIS II Series is properly connected to the USB host.

NATIONAL INSTRUMENTS

4) Insert the ECG sensor into the Analog Proto Board Connector connected to AI 0⁺.

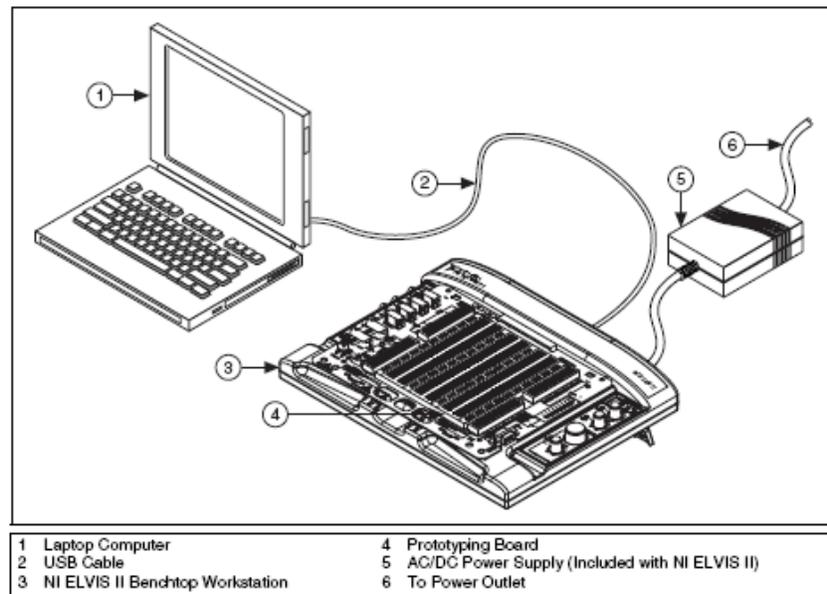| 1 | Laptop Computer | 4 | Prototyping Board |
| 2 | USB Cable | 5 | AC/DC Power Supply (Included with NI ELVIS II) |
| 3 | NI ELVIS II Benchtop Workstation | 6 | To Power Outlet |

Figure 3: NI ELVIS II Series Set-Up

To set up the experiment with the Biomedical Startup Kit:

1) If the Biomedical Startup Kit is not installed on your computer:
   - Go to https://decibel.ni.com/content/docs/DOC-12646 and download Biomedical Startup Kit 3.0
2) Once Installed, go to Start>>All Programs>>National Instruments>>Biomedical Startup Kit and Click on Biomedical Workbench. A pop-up menu should show up on your screen.
3) Select Biosignal Logger from the Biosignal Tab. A blank chart will be displayed in a separate window (Figure 4). The Biosignal Logger will display the cardiac electrical activity in Volts recorded by the ECG sensor over time.
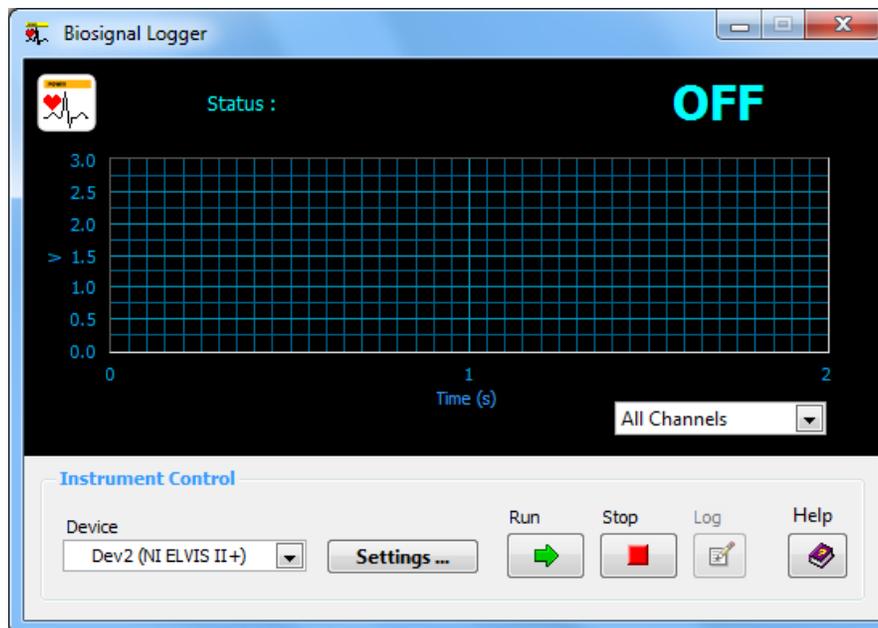
Figure 4: Biosignal Logger

4) In the Device dropdown menu, select the device corresponding to NI ELVIS II Series.
5) Click on "Settings" to view the Channel Configuration window.
   - Select the AI0 channel as the channel from which to acquire signals.
   - Place a checkmark in the "Enable" box to enable acquisition from this channel.
   - You can also specify the input range, sensitivity, and engineering unit of the channel if it needs to be scaled to a unit other than volts. For this exercise, leave these parameters as default.
   - Leave the sampling rate at the default value of 500 Hz.
   - The block size specifies the number of seconds used to acquire the signal and the number of seconds to display the signal on the waveform plot. Set the block size to 10 seconds.
   - The data acquired from the channel can be saved to a TDMS file by pressing the "Log" button. Specify the file path in the "File to" control and name the file "**Typical ECG**".

DATA COLLECTION

You will use three electrodes to record cardiac electrical activity for this lab. Figure 5 illustrates the correct electrode placement.

1) Scrub the areas of the skin with paper towels where the electrodes will be placed to remove dead skin and oil.
2) For each electrode, peel the back off of the electrode and place it firmly onto the skin.
3) Place 2 electrodes on the interior of each arm, just above the elbow.
4) Place the third electrode on the inside of your right wrist.

5) Attach the black (ground) alligator clip from the ECG sensor to the electrode on your right wrist (see Figure 5).
6) Attach the green (negative) alligator clip from the ECG sensor to the electrode above your right elbow (see Figure 5).
7) Attach the red (positive) alligator clip from the ECG sensor to the electrode above your left elbow (see Figure 5).
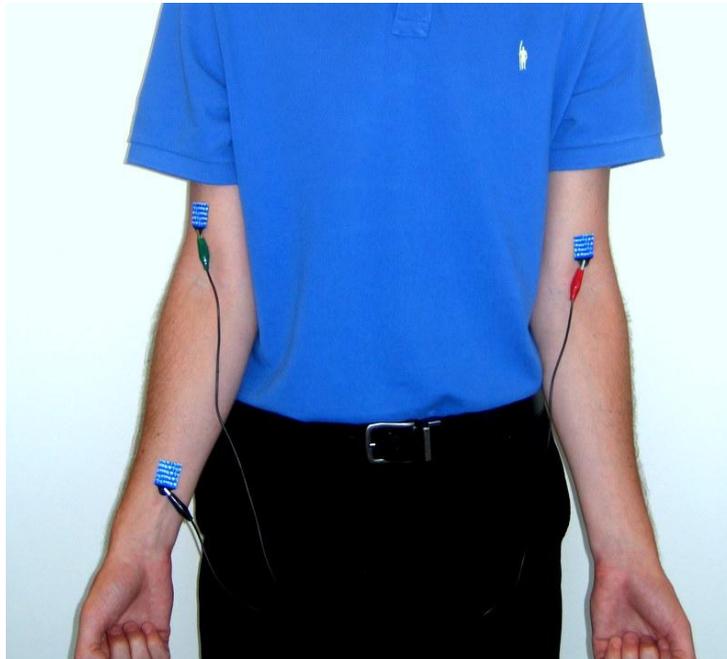
You are now ready to begin collecting data.

Figure 5: Proper ECG Placement

Part 1: Typical ECG Recording

The first part of this lab is designed to familiarize you with the ECG sensor and a typical ECG waveform. Figure 6 below illustrates an example of a typical ECG for this experiment.

Acquire Waveform

1) The volunteer should remain seated for the duration of the experiment. To ensure accuracy, the volunteer should also remain quiet and still throughout the experiment.
2) Press the green "Run" arrow on the Biosignal Logger window to begin collecting data.
3) Press the "Log" button to log the data to the TDMS file you specified in "Settings".
4) Press the "Stop" button when you are done collecting and logging 10 seconds of data.
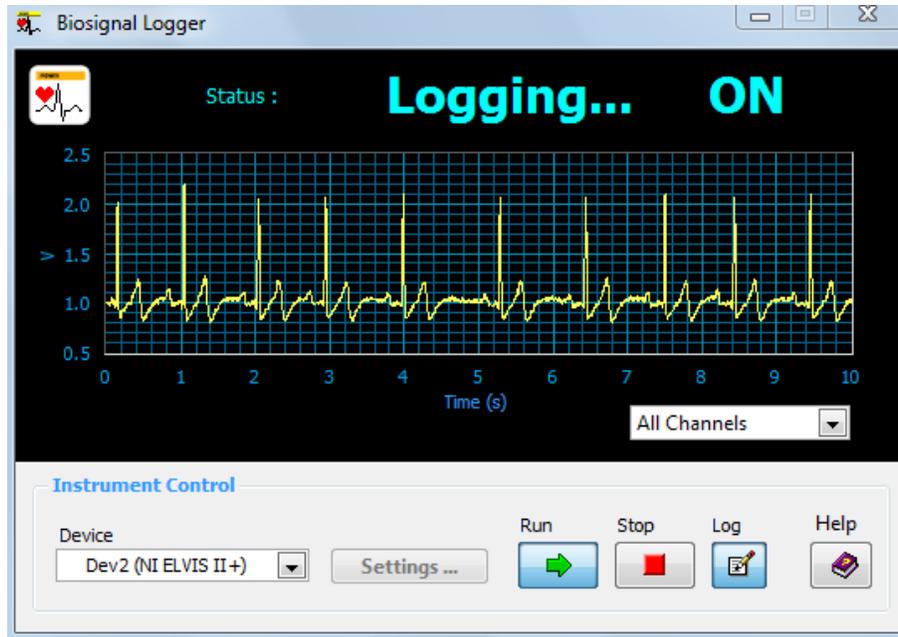5) Do not close the Biosignal Logger.

Figure 6: Example ECG Experiment Window

Find Average Interval Duration and Deflection Height

6) Now open the ECG Feature Extractor from the Biosignal tab of the Biomedical Workbench window. The ECG Feature Extractor (Figure 7) imports data and extracts ECG features such as the QRS complex, P wave, and T wave.
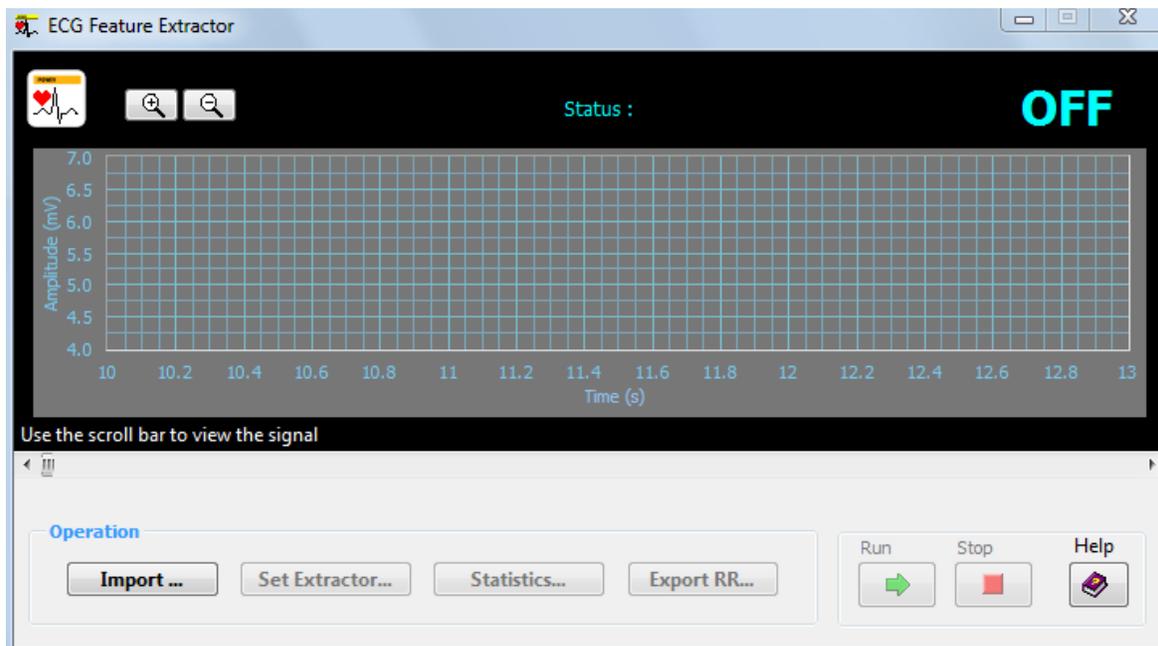

Figure 7: ECG Feature Extractor

7) Click the "Import" button. In the File Path section, browse for the file **Typical ECG.tdms** that you saved in the previous part of this exercise. Once you select it, you should see the ECG waveform appear on the right side of the window in the Waveform tab.

8) Click "OK". The ECG waveform should now appear on the ECG Feature Extractor window.

9) Click on the "Set Extractor" button to view the settings for the extraction. Check out the settings in each tab. For this exercise, leave all the settings at their default values and click "OK". Press the "Help" button on the ECG Extractor window to pull up a Help window that explains the details about each of these settings.

10) Press the green "Run" arrow and wait for the ECG Feature Extractor to completely extract from and refine the ECG signal. When the word "OFF" appears on the top right of the graph, the Extractor is finished.

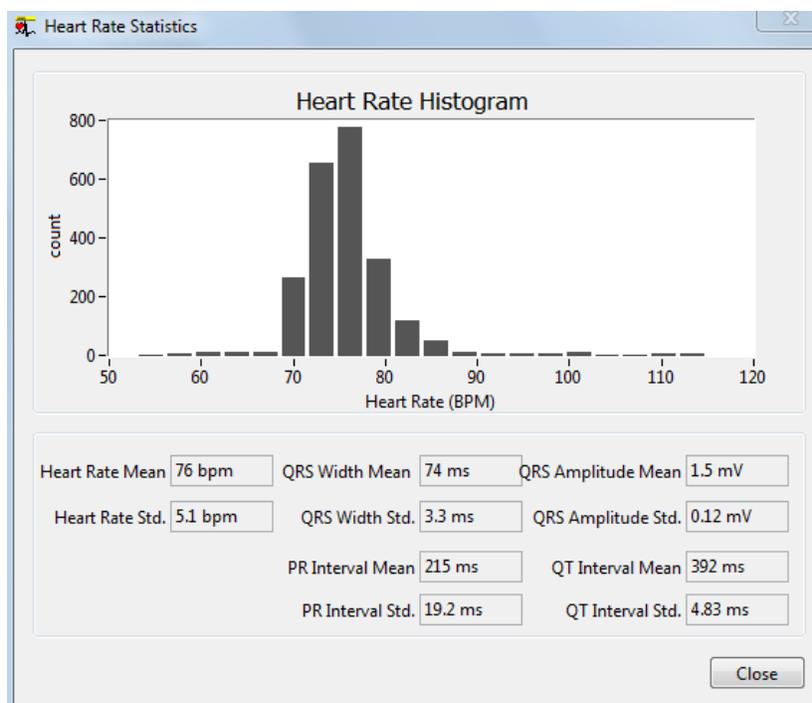11) Click the "Statistics" button to pull up a window with information about the extracted features (Figure 8).

Figure 8: Example Heart Rate Statistics from the Extracted ECG Features

12) Notice that the "Statistics" window displays the mean value and standard deviation of the heart rate, QRS width (QRS interval), PR interval, QT interval, and QRS amplitude of the imported ECG data.

13) Record these mean values in Tables 1 and 2.

14) Repeat steps 1-13 for each student (refer to the above steps and Figure 5 for attaching the electrodes and alligator clips). Do not remove the electrodes as they will be used in Part 2.

Part 2: ECG Recording after Physical Activity

The second part of this lab will investigate the effect of physical activity on your ECG signal.

Acquire Waveform

1) Pull up the Biosignal Logger window again. Click "Settings" and in the "File to" control, change the name of the file in the file path from **Typical ECG** to **Physical ECG**. This will save the following data as a new file. Ensure that the other settings are still the same as described in the beginning of this lab.
2) Ensure that the three electrodes from Part 1 are still in place.
3) Instruct the volunteer to run in place for 3 minutes.
4) Attach the red, green, and black alligator clips to the volunteer (refer to Figure 5).
5) Press the green "Run" arrow on the Biosignal Logger window to begin collecting data.
6) Press the "Log" button to log the data to the TDMS file you specified in "Settings".
7) Press the "Stop" button when you are done collecting and logging 10 seconds of data.

Find Average Interval Duration and Deflection Height

8) Follow steps 6-12 from Part 1 but import **Physical ECG.tdms** in the ECG Feature Extractor.
9) Record the mean values displayed in the Statistics window in Tables 3 and 4.
10) Repeat steps 1-9 for each student.

DATA ANALYSIS

Part 1: Resting ECG Recording

Table 1: Average Resting Interval Duration

Student Name	QRS Interval (ms)	P-R Interval (ms)	Q-T interval (ms)

1) Analyze the durations of each interval. Do your numbers correspond to the expected values outlined in the theory section of the lab report? If not, can you think of an explanation?
2) Compare the data recorded from each student. Do you notice a difference based on gender? What about fitness level?
3) List various factors and/or diseases that could influence the length of each interval. Would each of these factors increase or decrease the interval length? Why?

Table 2: Average Resting Maximum Amplitude and Heart Rate

Student Name	QRS Amplitude (V)	Heart Rate (BPM)

4) Analyze the potential of each deflection for each student in your group. Do you notice a trend for the collected data?
5) Do you notice a difference based on gender? What about fitness level?
6) Explain one heart cycle in terms of blood flow. Be sure to note the blood flow through each deflection (P wave, QRS complex, and T wave).
7) List various factors and/or diseases that could influence blood flow. How would each of these affect the potential detected by the ECG sensor?

Part 2: ECG Recording after Physical Activity

Table 3: Average Interval Duration after Physical Activity

Student Name	QRS Interval (ms)	P-R Interval (ms)	Q-T interval (ms)

8) Compare the data in Table 3 with that from Table 1. Did physical activity affect the duration of any of the intervals? Why or why not?
9) Were the trends noted in the question above consistent for each member in your group?

Table 4: Average Maximum Amplitude and Heart Rate after Physical Activity

Student Name	QRS Amplitude (V)	Heart Rate (BPM)

10) Compare the data in Table 4 with that from Table 2. Did physical activity affect the amplitude of the QRS complex? Why or why not?
11) Were the trends noted in the question above consistent for each member in your group?
12) Did your heart rate increase or decrease from your resting value calculated in Part 1? Why or why not?

REFERENCES

EKG Sensor User Guide. Vernier Software & Technology. Rev. 2/16/10. Accessed 7/19/11. www.vernier.com.

NI Educational Laboratory Virtual Instrumentation Suite II Series (NI ELVIS II Series) User Manual. National Instruments. Austin, TX: National Instruments Corporation. 1/09. www.ni.com.