

Lab 4: Introduction to Physiological Measurements - Cardiovascular

INTRODUCTION:

This lab will demonstrate cardiovascular measurements by creating an ECG with instruments used in previous labs. Students will also observe how plethysmograph measurements compare with ECG measurements.

REQUIRED PARTS AND MATERIALS:

This lab assignment is performed using:

- 1) PC computer with LabVIEW 8.5
- 2) ETH-256 bioamplifier
- 3) Isolated amplifier and three ECG leads
- 4) Alcohol swabs
- 5) 3 electrodes per student
- 6) Plethysmograph
- 7) BNC-Alligator clip cables
- 8) Elvis DAQ interface board

PRELAB:

1. Read the BACKGROUND section below. Print the Prelab Grading Sheet, and answer all of the questions, and bring it with you to lab. ***The Prelab Grading Sheet must be turned in to the TA before beginning your lab assignment.***
2. Print the Lab 4 Grading Sheet. Read through the LABORATORY PROCEDURE before coming to lab. You are not required to print the lab procedure; you can view it on the PC at your lab bench.

BACKGROUND:

Part 1

The heart is a pump that pushes blood around the body. Blood enters the heart at a low pressure and leaves at a higher pressure, and this high pressure provides the force to propel the blood through the circulatory system. Figure 1 shows the organization of the human heart and the circulatory system. Blood returning from the body is sent to the right side of the heart and then to the lungs to pick up oxygen and release carbon dioxide. This oxygenated blood is sent to the left side of the heart and back to the body, where oxygen is released and carbon dioxide is collected. The complete division of the heart insures that there is no mixing of deoxygenated blood (in the right side) with oxygenated blood (in the left side).

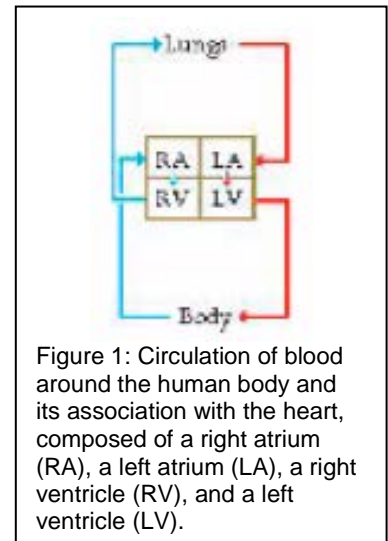


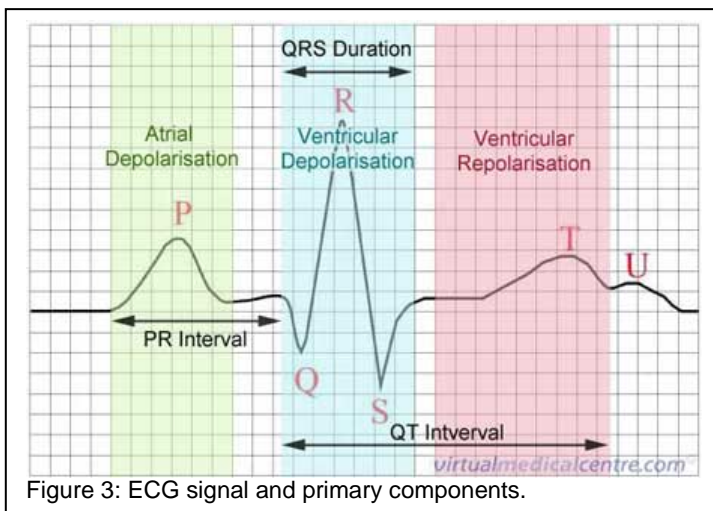
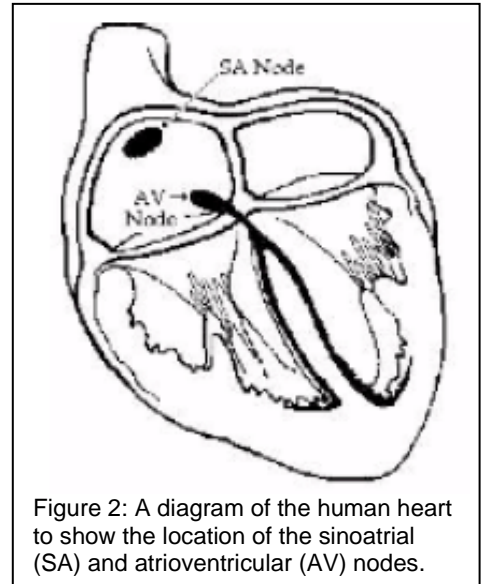
Figure 1: Circulation of blood around the human body and its association with the heart, composed of a right atrium (RA), a left atrium (LA), a right ventricle (RV), and a left ventricle (LV).

The mammalian heart is autorhythmic, since it will continue to beat if removed from the body (and kept in an appropriate solution). Heart contractions are, therefore, not dependent upon the brain, rather the rhythm comes from within the heart itself. The heart is composed almost entirely of large, strong muscle fibers, which are responsible for the pumping action of the heart. Other cardiac muscle cells are weakly contractile and produce or conduct the rhythm for the rest of the heart. A group of these weak muscle cells is located in the sinoatrial (SA) node (Figure 2) and acts as the pacemaker for the heart. These cells rhythmically produce action potentials, which spread via gap junctions to fibers of both atria. The resulting contraction pushes blood into the ventricles. While adjacent atrial fibers are connected by gap

junctions, the only electrical connection between the atria and the ventricles is via the atrio-ventricular (AV) node. The action potential spreads slowly through the AV node and then rapidly through the Bundle of His and Purkinje fibers to excite both ventricles.

The semilunar valves are located between the ventricle and the artery on each side of the heart. In the relaxed heart, the high arterial pressure shuts the semilunar valves and prevents blood flow from the artery into the ventricle. Ventricular contraction increases the pressure of the blood in the ventricle. When the ventricular pressure is greater than the arterial pressure, the semilunar valves open and blood flows into the artery. Then, the myocardium relaxes, the ventricular pressure declines, and the semilunar valves close.

The cardiac cycle involves a sequential contraction of the atria and the ventricles. The combined electrical activity of the different myocardial cells produces electrical currents that spread through the body fluids. These currents are large and can be detected by recording electrodes placed on the skin. The regular pattern of “peaks” produced by each heart beat cycle is called the electrocardiogram or ECG.



The action potentials recorded from atrial and ventricular fibers are different from those of nerves and skeletal muscle. The cardiac action potential is composed of three phases: a rapid depolarization, a plateau depolarization (which is pronounced in ventricular fibers), and a repolarization back to resting membrane potential. The components of the ECG can be correlated with the electrical activity of the atrial and ventricular fibers such that:

- Atrial depolarization produces the P wave.
- Atrial repolarization and ventricular depolarization produce the QRS complex.
- Ventricular repolarization produces the T wave

Part 2

The arterial system functions as a pressure reservoir. Blood leaves the arterial system continuously through the capillaries, but enters intermittently from the heart. Between contractions the heart is relaxed (called diastole) and the chambers fill with blood from the veins. During this time no blood flows into the arterial system from the heart, but blood flows out through the capillaries; as a result, the arterial pressure slowly declines. When the ventricles contract (called systole), the pressure of the blood inside the ventricles increases to close the atrioventricular valves. Further contraction increases the ventricular pressure until it exceeds the arterial pressure. At this point, when the arterial pressure is at its lowest point during the cardiac cycle (called diastolic pressure) the semilunar valves are forced open, and blood flows into the artery. Blood entering the arterial system inflates the arteries a little and increases blood pressure to a maximum - the systolic pressure. While the variation in arterial blood pressure during the cardiac cycle is smoothed out by the inherent elasticity of the major arteries, blood still exhibits pulsatile flow through the arteries and arterioles. In this lab you will measure the pulsatile flow of blood through the finger of a student volunteer and correlate it with the ECG. The pulse signal is referred to as the plethysmograph. Its prominent peak is labeled as the D wave in this lab.

LABORATORY PROCEDURE:

Important Note:

For the following experiments, groups of two should be formed. Each student will take turns making measurements on their lab partner.

If Biomedical Toolkit has not been setup for your account then before opening the LabVIEW run the "Setup Biomedical Toolkit" script from the Desktop. This should be done only once for each account in use.

Exercise 1: ECG in Resting and Active Volunteer**Data Acquisition Setup:**

- 1) Open a Blank VI on Labview.
- 2) Click on "Biomedical Applications" → Data Acquisition → Continuous Acquisition → Continuous Acquisition Shell
- 3) Drop the Shell onto your block diagram window. Have a look at the different components and try to understand what all the components do.

Waveform Graph:

- 4) Switch to the front panel and place a 'waveform graph'. Fix the scale on the graph from -5 to +5
- 5) On the block diagram, drag the graph into the while loop. Then connect the data output of the DAQmx read VI to the graph.
- 6) On the DAQmx read VI, right click on "sample per channel" input and select Create→Control.
- 7) On the DAQmx timing VI, delete the 1000 input to the "sampling rate" and right click and selecting Create→Control.
- 8) You can now control the sampling rate and # of samples on the control panel.
 - Set the number of samples to 500
 - Set the sampling rate to 1000 Hz.

Physical Channel:

- 9) On the block diagram, double click on the Physical Channel indicator located at the far left of the blocks. You will be taken to the front control panel. Click on the drop down menu of the physical channels and select Dev1/ai0.
- 10) Save your block diagram to a descriptive name. You will be using this VI in the next the Lab also.

Bioamplifier:

- 11) Turn the ETH-256.Bioamplifier on. Switch is in the back.

- 12) Connect a BNC to banana cable from the output channel 1 of the amplifier to the ACH0+ and AIGND of the Elvis Board.
- 13) On the amplifier, set the following parameters: HF = 0.3 , LF = 50, Gain = 5x
- 14) Connect the ECG Isolating amplifier to the Channel 1 input.

ECG Leads and electrodes:

- 15) There are two options for electrode placement, the 'chest' placement and the 'wrist-ankle' placement. In this lab you will use Option 1 on one student and Option 2 on the other student in the group.

16) Option 1:

Take an alcohol cotton swab and swipe the wrists and inside right ankle. Allow the areas to dry. This area will read the ECG signal but noise due muscle interference may also be visible. (Electromyogram).

- the white "Pos (+)" lead is attached to the right wrist
- the brown "Neg (-)" lead is connected to the left wrist
- the green "Gnd" lead is connected to the right leg

17) Option 2:

Take an alcohol cotton swab and swipe the chest areas as shown in Fig. 4. Allow the areas to dry. This arrangement is expected to provide better ECG trace with minimal noise.

- the white "Pos (+)" lead on patient's bottom left
- the brown "Neg (-)" lead on patient's top right
- the green "Gnd" lead at the top left

- 18) Peel the electrodes off the plastic strip and press onto the designated areas of the body. **Do not remove the yellow strip on the elongated corner of the electrode.**
- 19) Stick the electrodes on by pressing the center and moving outward. This optimizes the chance that the majority of the electrolytic gel is in contact with the skin. **Do not remove and reapply an electrode.**

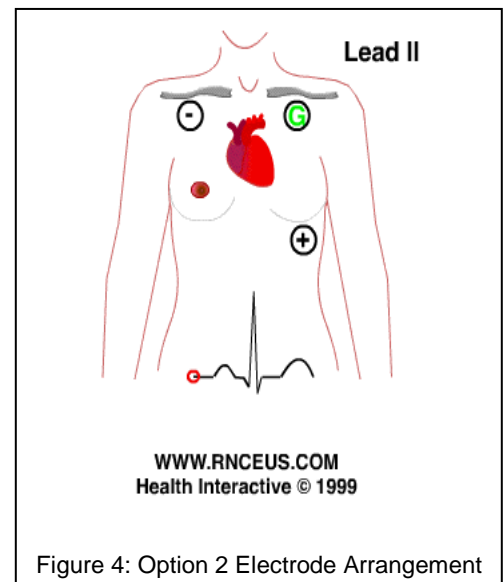


Figure 4: Option 2 Electrode Arrangement

- 20) Attach the cables to the 3 electrodes on the plastic strip.
- 21) Call over the TA to make sure everything is set up properly before moving on.

ECG of Patient at Rest

- 22) Lab Partners will take turns being the "patient" and the data analyzer.
- 23) Patient needs to sit up straight in the chair with both arms resting on the table in a comfortable position. Minimize any movement during the recording process.
- 24) The lab partner analyzing the data will then press the Run arrow.

Signal Quality:

- 25) The recorded signal should look like the one shown in Fig. 3. If it is noisy then you must adjust the settings (and environment) to get a clean signal. For example
- Change the posture of the patient,
 - Change the offset of the amplifier. Try changing it from one extreme to other
 - Adjust the LPF, HPF and the gain of the amplifier
 - Recheck physical connections
 - Change the sampling frequency and number of samples
 - Think of any external noise sources; long wires? Loose wire connections?
 - Try anything and everything to get a clean signal.
- 26) Call over the TA to view the ECG trace that was recorded.

Add Cursors:

- 27) Right click on the graph and select "Properties" followed by the Cursors tab. Click Add. Click Add once more. Go to the Cursor Color and change it to another color. Press ok. There should be two vertical and two horizontal cursors on the graph display.
- 28) Right click the graph, click "Visible Items" → Cursor Legend. A box with values indicated by the cursors should appear.

Take Measurements

- 29) Using the cursors, find the following values for 3 ECG waveforms. Note the values in the grading sheet
- Peak to Peak Amplitude:
 - i. P wave
 - ii. QRS complex
 - iii. T wave
 - Period between waveforms
 - i. P-P
 - ii. R-R
 - iii. T-T
 - Time interval between peaks within each waveform
 - i. PR
 - ii. QRS
 - iii. QT
- 30) Calculate the Average Amplitude and Average Period of the ECG waveforms you just analyzed. For the average Period, average together the R-R periods only. Note the values in the grading sheet.
- 31) Calculate the Heart Rate based on the average period. Multiply 60 by the average number. That is the average heart rate for the current "patient at rest" in beats per minute. Note the values in the grading sheet.

ECG of Patient after Exercise

- 32) Have the patient stand up and jog in place for 30 seconds.

- 33) Have the patient sit down again and rest. Immediately click the Run button again. Click stop when you feel a good clean measurement is acquired.
- 34) Repeat the measures in steps 29 – 31.
- 35) Call the TA and show the waveform

Repeat: Switch Patients and Electrode Placement

- 36) Do NOT remove the electrodes from the first patient, remove the leads only. You need the electrodes in the next exercise.**
- 37) Repeat Exercise 1 with the roles of the lab partners switched.
- 38) Use the other option for electrode placement.**
- 39) Follow steps 17 -35.

Exercise 2: ECG and Peripheral Circulation

Physical Channels:

- 1) Go to the control panel of the VI. Click onto Physical channels. Choose Browse. Hold the Ctrl key down and click on ai0 and ai1. Click OK.
- 2) Go to the block diagram and click on the DAQmx Read drop down menu. Select Analog→Multiple Channels→Multiple Samples→2D DBL.

Bioamplifier:

- 3) Attach a BNC to alligator clip cable from Output Channel 2 of the amplifier to the ACH1+ and AIGND. The connection from the first experiment should still be present for Output Channel 1.
- 4) Attach the Plethysmograph sensor into channel 2 of the amplifier.
- 5) Set the parameters for channel 2 as follows: HF = DC , LF= 50 , Gain = 5x.

Plethysmograph:

- 6) The patient with the ECG electrodes currently attached should strap the plethysmograph sensor to the finger.
- 7) The patient should rest with both arms on the table and minimize any movements.

Data Acquisition:

- 8) The other lab partner should click on the Run button. Both the ECG and Plethysmograph should appear on the chart.
- 9) Click stop when it looks like a clean signal is being acquired from both channels. The patient should not move during recording.

10) Call over the TA to view the traces that were recorded.

Add Cursors:

- 11) Right click on the graph and select "Properties" followed by the Cursors tab. Click Add. Click Add once more. Go to the Cursor Color and change it to another color. Press ok. There should be two vertical and two horizontal cursors on the graph display.
- 12) Right click the graph, click "Visible Items"→Cursor Legend. A box with values indicated by the cursors should appear.

Take Measurements:

- 13) Using the cursors, find the following values for 3 periods of the waveforms.
- Time Intervals between ECG and Plethysmograph waveforms
 - i. P-D
 - ii. R-D
 - iii. T-D
 - Time interval between peaks within ECG and Plethysmograph waveform
 - i. D-D
 - ii. R-R
 - Calculate the difference between each D-D interval with its corresponding R-R interval.
- 14) Calculate the Average Amplitude and Average Period of the waveforms you just analyzed. For the average Period, average together the R-R periods in ECG and D-D periods in plethysmograph.
- 15) Calculate the Heart Rate based on the average period for the ECG and the Plethysmograph. Multiply 60 by the average number. That is the average heart rate for the current patient at rest in beats per minute. What is the heart rate from each type of waveform?

Repeat: Switch Patients

- 16) Call the TA to show the waveforms
- 17) Disconnect the first patient and connect the second patient with ECG leads and plethysmograph
- 18) Repeat Exercise 2 for the second patient.
- 19) Call the TA to show the waveforms

This completes the lab procedure. Please remember to clean up your lab station before leaving.