Analyzing the Heart with EKG

An electrocardiogram (EKG) is a graphical recording of the electrical events occurring within the heart. In a healthy heart there is a natural pacemaker in the right atrium that initiates an electrical sequence. This impulse then passes down natural conduction pathways between the atria to the atroventricular node and from there to both ventricles. The natural conduction pathways facilitate orderly spread of the impulse and coordinated contraction of first the atria and then the ventricles. The electrical journey creates unique deflections in the EKG that tell a story about heart function and health. Doctors and other trained personnel can look at an EKG tracing and see evidence for disorders of the heart such as abnormal slowing, speeding, irregular rhythms, injury to muscle tissue (angina), and death of muscle tissue (myocardial infarction). By looking at several beats, you can also calculate heart rate.

PROJECT DESIGN REQUIREMENTS

Write a LabVIEW program to graphically record an EKG tracing of heart activity. You will use a Vernier interface and an EKG Sensor for data collection with a sampling time of 10 seconds and a sampling rate of 100 samples per second. You should make two graphical displays – the first plotting the data in real time on a chart, and the second displaying the plot on a graph after all data have been collected. The second display should incorporate the graphical analysis tools available with the use of a Waveform Graph. After creating your VI, follow the steps in the Project Setup to properly attach the EKG to a test subject and run your program.

MATERIALS

- SensorDAQ, LabQuest, or LabQuest Mini
- USB cable
- LabVIEW computer
- Vernier EKG Sensor
- electrode tabs
PROJECT SETUP

Connect the sensor to the interface
1. Connect the Vernier EKG Sensor to Channel 1 of the interface.
2. Connect the interface to the computer.

Note: Wait until your VI is written before performing the rest of the Project Setup.

Attach the EKG electrodes to subject
1. Use three electrode tabs per subject. Place the first electrode on the right wrist, a second electrode on the inside of the right elbow, and a third electrode on the inside of the left elbow. Place each electrode so it is on the inside part of the arm (closer to the body) with the tab on the edge of the electrode patch pointing downward. This way, the wires of the sensor can hang freely without twisting the edge of the patch.
2. Connect the alligator clips from the sensor to the tabs on the electrodes. Connect the black (or ground) clip to the right wrist electrode, connect the green (or negative) clip to the right elbow electrode, and connect the red (or positive) clip to the left elbow electrode as shown in the figure below. The subject should be seated and remain relaxed.

![EKG electrode placement for heart activity](image)

PROJECT BACKGROUND INFORMATION

The EKG sensor measures cardiac electrical potential waveforms (voltages produced during the contraction of the heart). A typical tracing consists of a series of waveforms occurring in a repetitive order. These waveforms arise from a flat baseline called the isoelectric line. Any deflection from the isoelectric line denotes electrical activity.

The five major deflections on a normal EKG are designated by the letters P, Q, R, S, and T. One heart cycle is represented by a group of waveforms beginning with the P wave, followed by the QRS wave complex, and ending with the T wave (see Figure 2). The P wave represents the depolarization of the atria and is associated with their contraction. Ventricular activation is
represented by the QRS complex. The T wave results from ventricular repolarization, which is a recovery of the ventricular muscle tissue to its resting state.

![Monitoring EKG](image)

**Figure 2  EKG waveform**

In order to zoom in and analyze a two-beat EKG tracing like the one shown above, you will need to enable the graphical analysis tools of the Waveform Graph. Right-click a Waveform Graph and select Properties to view the configuration window. The options to make the graphical analysis tools visible are found under the Appearance tab.

![Graph Properties: EKG](image)

**Figure 3  The graphical analysis tools configuration window**
To enable a cursor that can be used for examining your waveform, you must set up its properties under the Cursors tab as shown in the figure below.

![Figure 4 The graph cursor configuration window](image)

Once you have collected a set of data and enabled the graphical analysis tools, you can examine your data with a cursor. If you configured your cursor like that shown above, a dashed vertical line will appear at the beginning of your Waveform Graph (if you do not see the cursor, right-click on the cursor legend and select Bring to Center). Click and drag on this vertical line to examine your data.

![Figure 5 Waveform Graph cursor selector](image)
To zoom in on a portion of the graph, click the Zoom selector (found in the Graph Palette) and drag across two complete waveforms.

![Zoom selector](image)

**Figure 6  Zoom selector**

### PROJECT TIPS

1. The Waveform Chart terminal should reside within the While Loop. Wiring the data to the Waveform Graph requires the data as an array. The easiest way to do this is to locate the Waveform Graph outside the data collection While Loop. Wire the data output terminal of the Analog Express VI through the border of the While Loop to the Waveform Graph, and then right-click on the tunnel created at the border of the While Loop and select Enable Indexing. The data will automatically be gathered into an array that will be plotted to the graph when the loop has finished executing.

2. For best results, do not reuse electrode tabs on different subjects.

3. Because the electrical signal produced by the heart and detected at the body’s surface is so small, it is very important that the electrode patches makes good contact with the skin. You may need to scrub the areas of skin where the patches will be attached with soap and water to remove dead skin and oil.

4. Refer to *Appendix E* for additional information about the Vernier EKG Sensor.

### PROJECT TROUBLESHOOTING

1. EKG waveforms should show a positive deflection from the isoelectric line. A positive deflection represents electrical activity moving toward the positive lead (the green lead in this exercise). If your waveforms are showing a negative deflection, make sure the positive lead is connected to the electrode on the right elbow, and the negative lead (red) is connected to the electrode on the left elbow.

2. The EKG Sensor leads are not shielded and can pick up electronic interference from computers, monitors, cell phones, and power cables. This can cause a noisy waveform making it somewhat difficult to plot an accurate tracing of heart activity. Proper electrode placement, avoidance of electronic equipment, and minimizing the area between the electrode leads (e.g., by twisting them together) can reduce noise somewhat.
CHALLENGE DESIGN REQUIREMENTS

**Note:** Do not attempt the Challenge until you have completed the Project Design Requirements.

Modify your VI created in the Project to compute and display heart rate in beats per minute (bpm) from the signal readings of the EKG Sensor.

**CHALLENGE BACKGROUND INFORMATION**

In a normal EKG, the waveforms repeat at regular intervals. The time between waveforms can be used to determine the subject’s heart rate measured in beats per minute (bpm).

There are several subVIs that can be used to help with calculating the heart rate. One option is to use the Peak Detector subVI (found in the Signal Processing ► Signal Operation function palette). This subVI requires the data are input as an array. The width and threshold inputs are important parameters that may take some experimentation to determine proper values. Use the # found output of this subVI to calculate beats per minute. For example, multiplying the number of peaks in a 5 second sample by 12 will give you the heart rate in beats per minute.

![Peak Detector subVI](image)

*Figure 7  Peak Detector subVI*

**CHALLENGE TIPS**

1. The Project Tips describe a method of creating an array at the border of a While Loop. This array can be used as input into the Peak Detector subVI.

2. Since the exact placement of the electrodes will affect the size of the signal detected by the EKG, you will need to experiment to find the proper threshold value.

3. If your waveform does not have strong, easy-to-detect peaks, you may have to include some signal processing. The goal of this processing would be to reshape the waveform to have a distinct peak for every beat of the heart.
EXTREME CHALLENGE DESIGN REQUIREMENTS

While an EKG sensor is normally used to record the muscle activity of the heart, it can also detect other electrical changes in your body, even motion of your eyes. Build a device that switches a bipolar LED from one color to another when you look left or right. Use the EKG Sensor to detect the motion of the eyes, and the Vernier Digital Control Unit (DCU) to power the LED.

ADDITIONAL MATERIALS

- Vernier Digital Control Unit (DCU)
- 220 Ω resistor
- Vernier LabQuest or LabPro power supply
- breadboard
- bipolar LED
- jumper wires
- breadboard
- jumper wires

EXTREME CHALLENGE SETUP

Connect the sensor to the interface
1. Connect the EKG Sensor to Channel 1 of the interface.
2. Connect the interface to the computer.

Connect the DCU to the interface
1. Connect the DCU to the DIG port on the interface.
2. Connect a power supply to the DCU.

Construct a bipolar LED circuit
1. Plug the 9-pin cable into the side of the DCU.
2. Insert the bipolar LED and resistor into a breadboard, and then wire the components to the DCU cable as shown in the figure below. You can find the color-coded pin-out for the DCU cable on the label attached to the cord.

![Figure 8 Wiring diagram for connecting a bipolar LED to the DCU cable](image)
**Attach the EKG electrodes to subject**

1. Place three fresh electrode tabs on the subject as shown in the figure below. Place a tab to the side of each eye, and then place a third tab on the neck.

![EKG electrode placement for eye movement](image)

2. Connect the red (or positive) alligator clip to the right eye electrode, connect the green (or negative) clip to the left eye electrode, and connect the black (or ground) clip to the neck electrode. The subject should be seated and remain relaxed.

**EXTREME CHALLENGE BACKGROUND INFORMATION**

The retina of the eye is a complex layered structure of neurons, and as such, it maintains a charge across its surface giving the eyeball a small electrical dipole moment. The EKG Sensor is capable of detecting changes in this dipole moment as the eyes rotate. If the eyes rotate to the right a voltage pulse is produced in the EKG Sensor and if they rotate to the left a pulse of opposite polarity is produced.

In the Extreme Challenge, you are asked to control the color of a bipolar LED with eye movement. The behavior of a bipolar LED depends on the direction of current flow. If the current flows in one direction, the bipolar LED will appear green. If the current flows in the opposite direction, the bipolar LED will appear red. Since an LED can be destroyed if too much current flows through it, you should wire it in series with a current-limiting resistor.

The Vernier Digital Control Unit (DCU) can be used to switch between colors in the bipolar LED. The DCU is an electronic device that allows you to control up to six digital output lines for on/off control of LEDs and other DC electrical components. The DCU plugs into the DIG port on the interface and is powered by a separate DC power supply. A 9-pin, D-sub socket cable is supplied with the DCU, with bare wires on one end, for use in building projects. There are connections for all six digital lines, plus a power connection and two ground connections. The color code of the wires is identified on a label attached to the cable.

The bipolar LED should be connected in series with a current-limiting resistor between DCU lines D1 and D2 (there is no ground connection in this setup). To illuminate each color, you must send a numeric output pattern to the DCU to turn on one of the digital lines. The Digital Express VI found in the Vernier functions palette can be used to send these output patterns.
EXTREME CHALLENGE TIPS

1. A good first step might be to record some data and analyze the waveform. Then you can determine what events occur in the waveform, such as peaks, that can be used in your program to control the output to the DCU.

2. For best results, do not reuse electrode tabs on different areas of the body.

3. Since the exact placement of the electrodes will affect the size of the signal detected by the EKG, you will need to experiment to find an upper and lower threshold to change the LED color that works for your apparatus. You will find the Waveform Graph on your front panel very helpful for this process.

4. When the Analog and Digital Express VIs are used together in the same loop, you should make sure they are connected together via their “stop (F)” and “stopped” terminals.

5. Avoid using the Abort Execution button to stop your VI because some of the DCU lines may remain on.

6. Refer to Appendix E for additional information on the Vernier DCU.

EXTREME CHALLENGE TROUBLESHOOTING

1. Make sure the DCU is receiving power. The green LED in the top of the DCU box will be lit when the DCU is powered on.

2. Make sure you are sending the proper output pattern to turn on a digital line. Use the Digital Express VI configuration window to test your pattern and hardware.
Vernier Lab Safety Instructions Disclaimer

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This copy does not include:

- Safety information
- Essential instructor background information
- Directions for preparing solutions
- Important tips for successfully doing these labs

The complete Engineering Projects with NI LabVIEW™ and Vernier manual includes 12 projects as well as essential teacher information. The full lab book is available for purchase at: http://www.vernier.com/cmat/epv.html