Laboratory 4:

Electrocardiography (ECG) and Response to Breath Hold and Valsalva Breathing Maneuver

List of Downloads

Prior to coming to the lab make sure your computer has the latest versions of the following software:

Arduino IDE:

https://www.arduino.cc/en/main/software

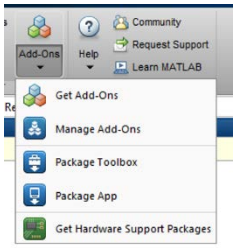
MATLAB:

https://www.mathworks.com/academia/tah-portal/university-of-toronto-676468.html

MATLAB Hardware Support Package for Arduino:

Navigate to the HOME tab of MATLAB: Go to the “Add-Ons” button

Select the “Get Hardware Support Packages” from the drop-down menu.



From the subsequent list, search for ‘Arduino’

Install the MATLAB Support Package for Arduino Hardware

Overview

In this lab, you will be examining the electrical activity of the heart by measuring the electrocardiograph (ECG). The device used in this lab detects the electrical impulses of the heart by monitoring the electrical changes on the body's surface where electrodes are attached. You will experiment with changing the rate your heart beats by activating your autonomic nervous system with holding your breath and changing the pressure inside your thoracic cavity.

Background

Your heart will respond to different stimuli that you experience. If you hold your breath chemoreceptors detect changes in oxygen, carbon dioxide, and pH. If you have ever tried to breath out forcefully with your mouth and nose closed to equalize the pressure in your ears during scuba diving or in an airplane (or increased your colonic pressure to induce a bowel movement), you have performed a Valsalva maneuver. The flexing of your chest and stomach muscles increases the pressure inside your thoracic cavity but also impedes venous blood to return to the heart and your heart rate will adjust to these conditions.

Learning Objectives

This lab will introduce you to the ECG signal using wet electrodes connected to an Arduino. At the end of this lab you will:

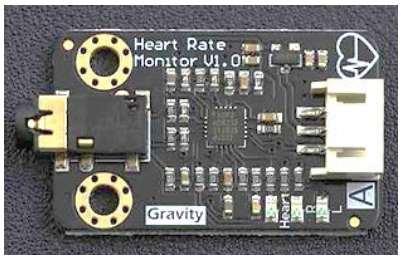
1) Identify the major features of the ECG signal
2) Record changes in heart rate with holding your breath
3) Record changes in heart rate with performing a Valsalva maneuver

General Safety

- Warning! It is strongly recommended that you do not connect the electrodes to your body while the computer or Arduino is being powered by the mains AC line (includes charging laptops and DC power supplies). Please work under battery power or isolate yourself from the power grid.
- It is recommended that you don't place the EMG electrodes near any metal plates, screws, or pins.
- If you have any medical conditions (e.g., heart arrhythmias or a pacemaker) of potential concern, please speak to the TA or coordinator to ensure that appropriate accommodations can be arranged.
- Do not overextend yourself! If you don't feel comfortable doing any of these activities, then don't do them. Also don't push yourself – this lab is not an exercise in creating maximal changes. Simply feeling and seeing how your heart responds is enough to meet the learning objectives.
- **Risks:** The primary side effect of the Valsalva maneuver is low blood pressure that may produce a lightheaded feeling.

Parts List

- Jumper wires
- Arduino UNO R3
- DFRobot Gravity: Analog Heart Rate Monitor Sensor (ECG) package (Heart rate monitor sensor, ECG leads with a PH2.0-3P cable, and 3-pin ribbon cable as shown below). More information on this sensor can be found here: Product Wiki
- Disposable ECG stick electrodes




Installing Arduino Code Library

N/A (see notes on Arduino set up below)

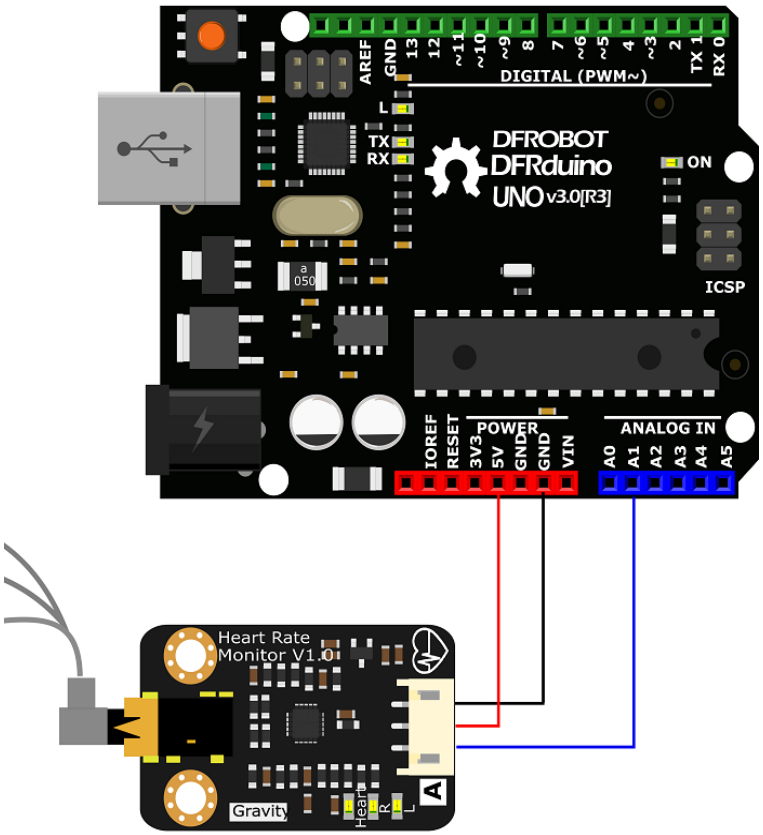
Installing MATLAB Code

The MATLAB code file (labPlotter.mlapp) can be found in the Lab 4 page in Quercus

Connecting DFRobot ECG Sensor (Dry Electrodes)

This sensor is used for Learning Objective 1

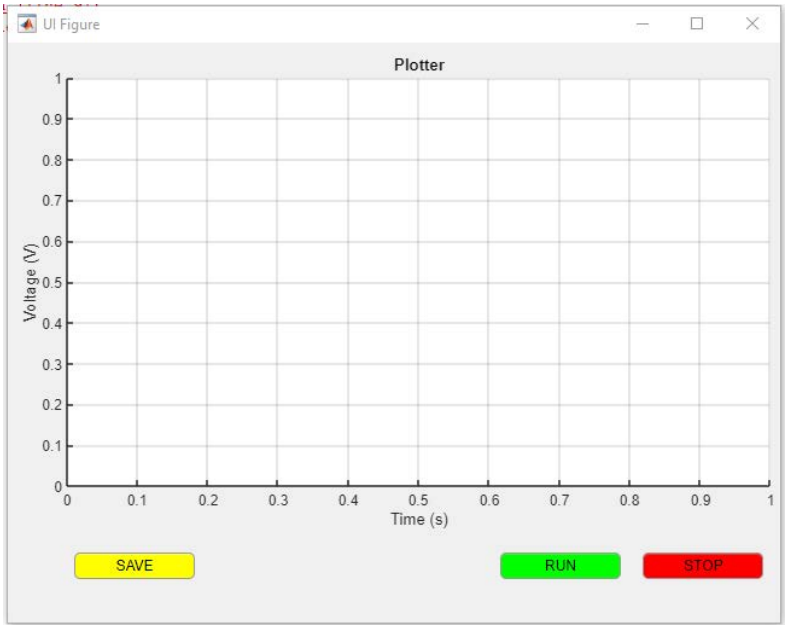
1. Connect the 3-pin cable to the ECG sensor.
2. Connect male-male jumper wires from the 3-pin ribbon cable. If possible, use jumper wires that are the same colour as the ribbon cable. (These jumper wires will be connected to the Arduino as shown by the representative figure below)



3. Connect the jumper wires from the ECG signal transmitter board to the correct Arduino ports. The **blue** wire corresponds to the analog input of the sensor and should be connected to the header labeled **A0**. The **red** wire corresponds to the power supply of the sensor and should be connected to the header labeled **5V**. The **black** wire corresponds to the ground and should be connected to the header labeled **GND**.) See the image below to see schematically how the blue wire will need to connect to A0, the red wire to 5V, and the black to GND.
4. Connect the ECG-lead electrode cable to the ECG sensor board.
5. Connect the electrode pads to the electrode without removing the protective plastic.
6. Connect the Arduino to the USB port of the computer using a USB cable and turn your computer ON.

MATLAB Setup

- You should have downloaded the labPlotter.mlapp code to a folder on your computer.
- Open MATLAB and make sure that your file path displays the “labPlotter.mlapp” file in your “Current Folder” window. You can then double click on this file or type the name of the file in the “Command Window” to run the code.
- A new window will pop up and the Plotter will start showing a graph of data when you click on the green “Run” button to acquire data. (Click the red “Stop” button to stop acquiring data and then the yellow “Save” button to save the data just acquired)

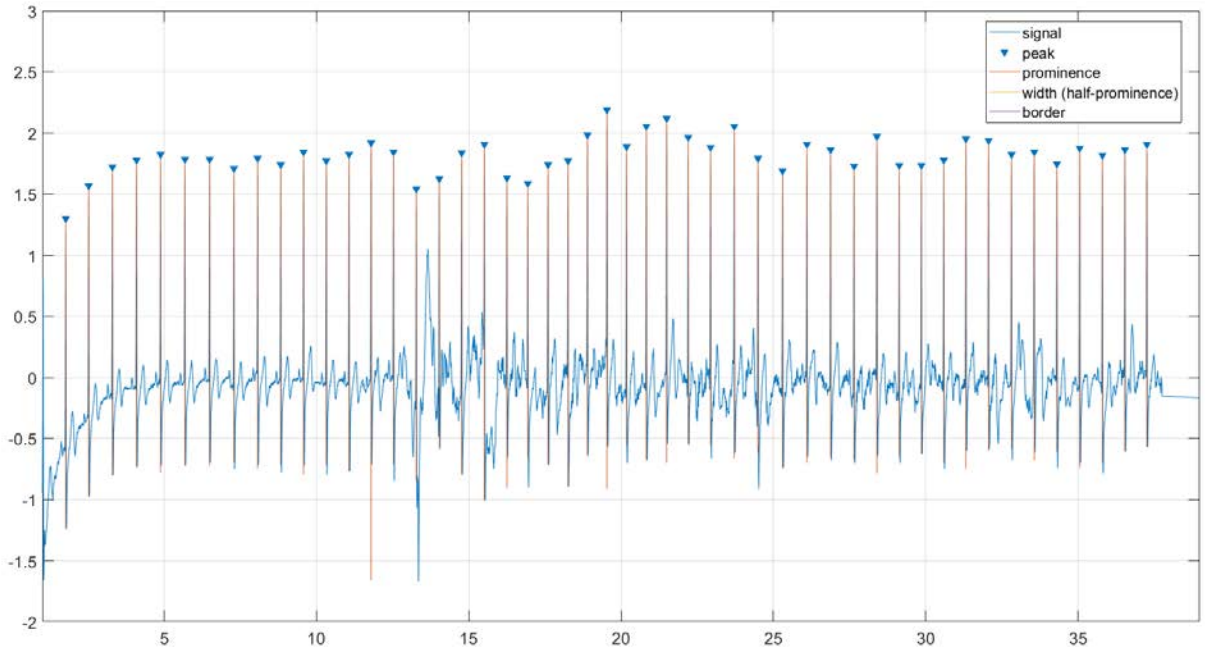


MATLAB Data Analysis

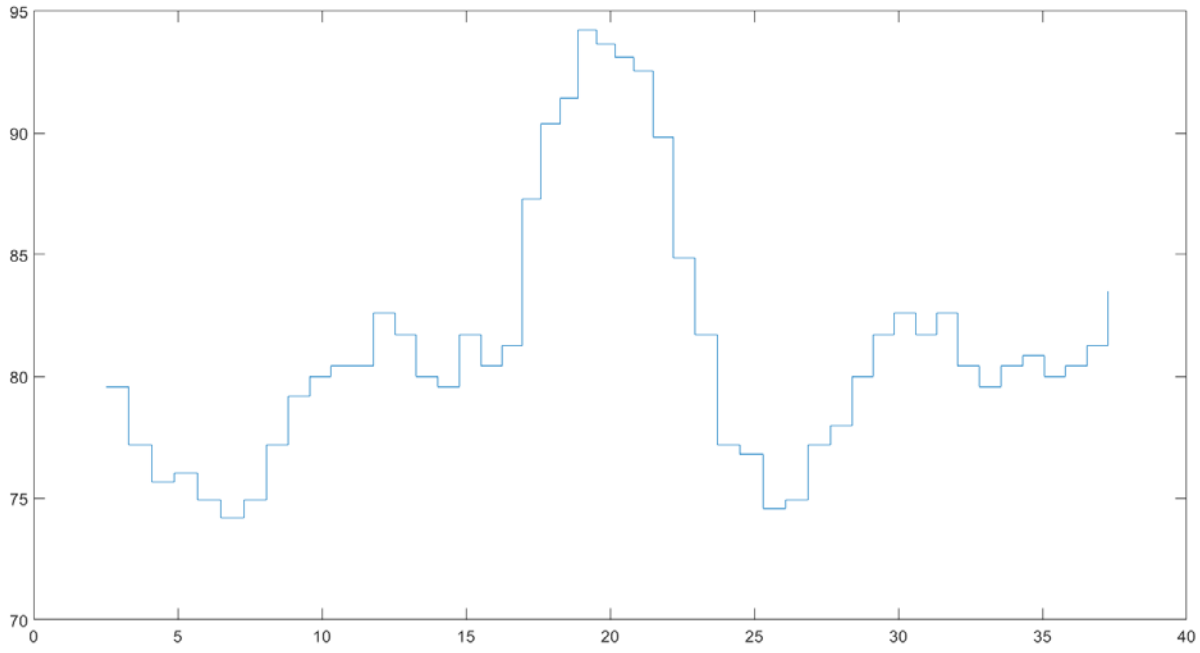
- You will use the findpeaks function to help you quickly calculate the heart rate. The findpeaks function will help you identify the time of every R wave and then calculate the R-R interval. The R-R interval represents the time it takes for your next heart beat to arrive and can be used to calculate the changes in heart rate that you will experience.
- For information on how to use the findpeaks function, you should look at the MATLAB documentation for this fuction.
- To test the findpeaks function quickly, you may use the testdata.txt file provided in the Lab 4 page in Quercus
- As an example you can use the following code (see next page):

```
% Basic MATLAB script to plot peaks of your data:

ecg_signal=load('testdata.txt');

t=ecg_signal(:,1); %this is the time stamp of each sample

y=ecg_signal(:,2); %this is the ECG signal

% You may need to apply a filter to the ECG signal or smooth it to reduce noise

[pks,locs]=findpeaks(y,t,'MinPeakProminence',2);

findpeaks(y,t,'MinPeakProminence',2,'Annotate','extents')
```

% See the findpeaks documentation to understand the different name-value pair arguments to help you identify peaks. MinPeakProminence was set to “2” in the line of code above. Below is the figure generated that shows the detected peaks.



```
% Basic way to calculate the RR interval

RR = diff(locs);

HR = 60./RR; %convert to beats per minute

HRplot = cat(1,nan,HR); %concatenate the HR array to have the first row equal to
not-a-number

stairs(locs,HRplot) %Plot the instantaneous changes in HR using the same time scale
as the acquired data

%Below is the resulting graph of the heart rate changes plotted against time using
the stairs function because each RR interval is calculated by comparing to the last
R wave detected – therefore the jagged line represents the “instantaneous” changes
in heart rate. Using a consistent time scale allows you to compare the instantaneous
HR changes to events in real time.
```



Wearing the ECG Electrodes[1]

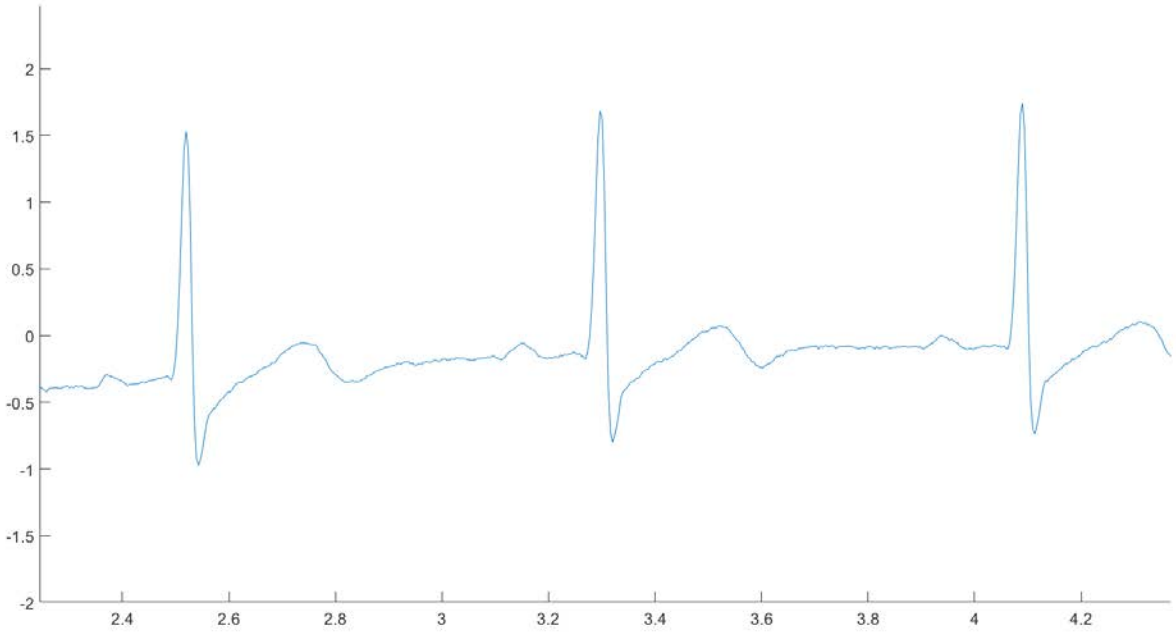
- Thoroughly clean the intended area of measurement of any excess dirt or oil. Alcohol-based wipes can be used clean your skin and may improve signal quality.
- The bottom of the ECG sensor attaches to snap electrodes. These snap electrodes have a sticky side that can be attached on a muscle of interest.
- NOTE: While you can snap the sensor to the electrodes after they've been placed on the muscle, we do not recommend doing so due to the possibility of excessive force being applied and bruising the skin.
- Remove the protective paper on the electrode pads and place them on the subject as follows:
  Primary approach:
  RED: under right clavicle near the right shoulder within the rib cage.
  YELLOW: under left clavicle near the left shoulder within the rib cage frame.
  GREEN: on the left side, placed on your hip bone (below pectoral muscles and the lower edge of the rib cage) to eliminate interference from respiratory muscles as much as possible.
  Or alternatively:
  RED: on the right forearm.
  YELLOW: on the left forearm.
  GREEN: on the left leg/thigh.
- In order to obtain a clear ECG signal, it is important that the you:
  - Remain still during the recording.
  - Refrain from laughing or talking during the recording.
  - Keep arms and legs steady and relaxed.
  - Remove metal watches and bracelets.
- It may be that an ECG signal is not easily acquired due to individual differences. If the first electrode placement does not yield good results, you may get new electrode pads and try the alternative arrangement.

[1] Minor edits made to use of alcohol wipes and suggested placement of green electrode (from below rib cage to hip bone)

Learning Objective 1: ECG Signal Baseline and Feature Identification

Your objective is to collect a short recording (~10 second) of baseline data that will allow you to choose a representative heart beat to annotate ECG features correctly. See the figure below for an example of representative beats that will allow you to annotate the following markers:

- P Wave
- Q Wave
- R Wave
- S Wave
- T Wave



The outcome for each individual is:

Figure 1: Your best representative raw ECG data with labels of all landmarks of the waveform that you can identify

Learning Objective 2: Heart Rate Changes with Breath Hold Maneuver

Your objective is to record how your heart rate changes when you hold your breath. Holding your breath for maximum effect is not necessary and you should only hold your breath for as long as you feel comfortable. You should be able to see the effects after 30 seconds and definitely by 1 minute. To prepare for the breath hold you may take a few deep breaths or just breath normally as long as you record this "preparation" as you baseline before your breath hold. It is suggested that a lab partner helps you by noting the exact time in your data acquisition recording when you began and ended your breath hold. You should collect at least another 20 seconds of data to show your heart rate return to baseline.

The outcome for each individual is:

Figure 2: Heart rate as a function of time for your breath hold (show the start and end of the breath hold)

N.B. Use the staircase figure shown earlier to show these changes.

Learning Objective 3: Heart Rate Changes with Valsalva Maneuver

Your objective is to record how your heart rate changes when you try to breath out against a closed mouth. See this YouTube video for a demonstration of this breathing maneuver. You should take a deep breath and try to breath out, with an increasing force, over 2 to 3 seconds and sustain the forceful pressure for another 5 to 10 seconds. Only use as much force as you feel comfortable with, for as long as you feel comfortable with but do not extend this maneuver too long as light-headedness can happen as a result. It is suggested that a lab partner helps you by noting the exact time in your data acquisition recording when you began and ended your breath hold. You should collect at least another 20 seconds of data to show your heart rate return to baseline.

The outcome for each individual is:

Figure 3: Heart rate as a function of time for your breathing maneuver (show the start and end of your breathing maneuver)

N.B. Use the staircase figure shown earlier to show these changes.

Tasks Required to Complete the Lab

See the Lab 4: ECG module for links to complete the Lab 4 Questionnaire and Submission. You must register your attendance with the TA and complete these tasks before gaining access to the next module.

Submission

Submit a PDF file that contains your collection of data and reflection.

Include labelled screen shots of:

- Figure 1: Your best representative raw ECG data with labels of all landmarks of the waveform that you can identify
- Figure 2: Heart rate as a function of time for your breath hold (show the start and end of the breath hold with figure annotations)
- Figure 3: Heart rate as a function of time for your Valsalva breathing maneuver (show the start and end of your breathing maneuver with figure annotations)

Include a brief summary that answers the following questions:

1. How would you qualitatively describe the pattern of heart rate changes after you performed your breathing maneuvers?
2. How closely did your data match an example from established literature? (Provide the citation and exact figure number that you are comparing your data to)
3. What key words and database did you use to find your source?

Questionnaire

1) Prior to your breath hold intervention, what was your resting heart rate (measured in beats per minute)?
2) What was the maximum heart rate you reached with your breath hold?
3) Prior to your Valsalva maneuver intervention, what was your resting heart rate?
4) What was the maximum heart rate you reached with your Valsalva maneuver?
5) What was the minimum heart rate you reached with your Valsalva maneuver?