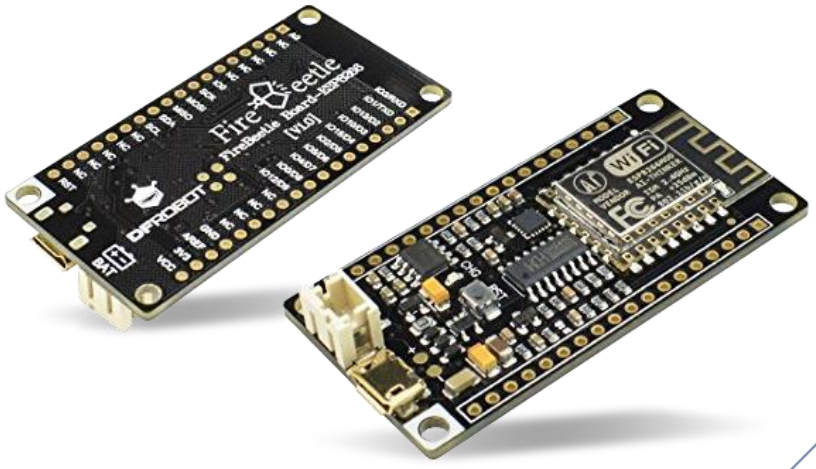
HEART RATE AND BREATHING RATE STRAP

FITNESS STRAP LAB



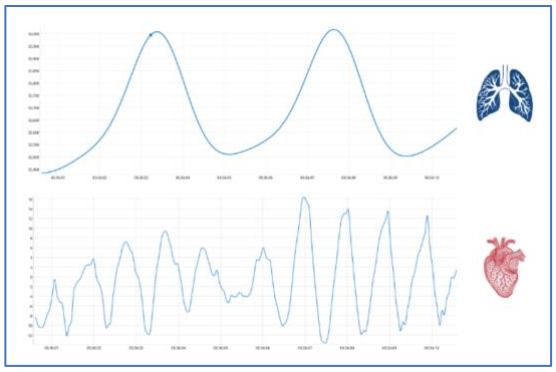
Wearable Technology Laboratory (BME/CS 479)

Spring 2022 – Lab 2

Materials:

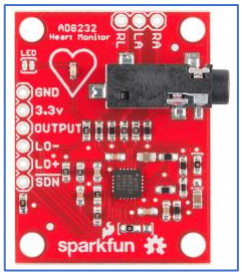
1. FireBeetle Board-328P with BLE4.1 x 2
2. Micro USB Interface Cable
3. Rechargeable Lithium Battery
4. FireBeetle Proto Board
5. AD8232 Heart Monitor
6. ECG Leads x 3
7. Snap-On ECG electrodes
8. FSR & 10 kOhm
9. Elastic Band
10. Tape or Glue
11. 3D printed FSR Backing
12. 3D Printed clasp
13. Wire and Wire wrapping tool
14. Solder and soldering iron
15. Athletic tape
16. Female Headers

Background:



Your goal in this lab is to develop a wearable chest strap that monitors the heart rate and the respiratory rate. Wearables that monitor these two vitals are used in medicine and fitness. Your wearable strap will house embedded electronics for recording the Electrocardiograph (ECG) signal using the AD8232 heart monitoring board. The chest strap will also incorporate a Force Sensitive Resistor (FSR) connected to the peripheral board in order to measure the respiratory rate.

AD8232 Heart Monitor:



Let's get familiar with the AD8232 heart monitor board, this board is designed to collect a clean ECG signal. Go over the tutorial of this board using the link provided below. The tutorial will go over the basics for getting your AD8232 board up and running. (Note that the tutorial uses a different Arduino from us, however, the connections will still be the same as the tutorial)
https://learn.sparkfun.com/tutorials/ad8232-heart-rate-monitor-hookup-guide?_ga=2.201433553.1187612062.1519059427-2036631182.1517865376

Note: Some post-processing steps might be required when dealing with biosignals. You could use time-varying or frequency domain filters to reduce the noise. Also have in mind that sometimes observing the signal in the frequency domain is the best approach for calculating a rhythmic pattern such as the heart rate.

Device Assembly:

Carefully assemble your wearable strap per instruction in the class. While assembling your device, always have in mind that you are being graded on the criteria of how "wearable", compact, and user-friendly your device design will be. Follow the following steps:

Step 1. Measure the circumference around your chest and adjust the elastic band to the appropriate size. Incorporate the 3D printed clasp so that you could create a closed wearable loop.

Step 2. Embed the ECG leads on to the elastic band so that you can record the ECG signal. The leads will be attached to the Snap-On ECG electrodes, therefore; pick the location of the leads wisely so that you have one electrode to the right of the heart and the other electrode to the left of the heart. The electrodes need to make contact with the skin in order to record signals. Place the reference electrode lead furthest away from the heart on the right side of the body on the elastic strap towards the back. Follow the Sparkfun diagram to identify the correct electrode colors for placement.

Step 3. We will use a Force Sensitive Resistor (FSR) as a sensor to measure the respiratory rate. The FSR changes its resistance due to the expansion and contraction of the diaphragm during the inhalation and exhalation. This variation in resistance could be used to calculate the respiratory rate, and the inhalation/exhalation phase. Create a voltage divider that could be used to identify changes in voltage that results from the inhalation and exhalation. Secure the FSR sensor on the 3D printed backing and place the FSR on the elastic strap towards the right side of the body.

Step 4. Connect all the wires to the FireBeetle protoboard accordingly and assemble the wearable.

After device assembly, place the electrodes on the leads attached to the strap and start recording your live ECG and breathing signal. Write a code that would calculate the heart and respiratory rate, the inhalation period, the exhalation period, and display it on your interface.

Data Collection:

Time to put the device to test. Design and develop a user interface that offers the user a selection from 3 modes of operation: 1) Fitness Mode, 2) Stress Monitoring Mode, 3) Meditation Mode.

Section I: Fitness Mode

1) In the fitness mode, your interface should always collect 30-sec of baseline from the user. The baseline data would display the resting heart rate and the resting respiratory rate.
2) After the initial 30 sec data collection, the interface should display the cardio zone that the user is experiencing.
3) Perform a physical task, for example jumping jacks, this task should be vigorous enough to change your cardio zone. Analyze the collected ECG signal, and have the interface display an activity graph. The activity graph should be color-coded according to the period of the time that the user was at each cardio zone (consult Fig 1). The maximum heart rate for each user is roughly equal to the user's age subtracted from 220.
4) For each cardio zone, your interface, should display the change in the respiratory rate, and the inhalation and respiration duration.

Fig 1: Heart rate zone as a percentage of the user's maximum heart rate.

Section II: Stress Monitoring Mode

1) For this mode, your interface should always collect 30-sec of baseline data from the user. The baseline data will be used to calculate the resting heart rate and the respiratory rate.
2) Play relaxing music and measure your heart rate and the respiratory rate for the entire duration of the song. Can you conclude that the music actually made you more relaxed?
3) Now perform a difficult task or try to solve a hard riddle. Measure your heart rate and respiratory rate during the entire duration of this activity. Can you conclude that the activity actually made you anxious?
4) Discuss with your team on how to improve your interface so that it could detect if the user is stressed or calm. Incorporate these steps into your interface so that it would be able to automatically detect these two emotional modes.

Section III: Meditation Monitoring Mode

1) For this mode as well, your interface should always collect a 30-sec baseline data from the user. The baseline data will display the resting heart rate and the respiratory rate of the user.
2) Now imagine that you want to do meditation, breathe so that your inhalation period is one third of your exhalation period.
3) Your interface should continually check to make sure if this breathing pattern is achieved. If for 3 consecutive breaths this criterion is not met an indicator on your interface should be activated.

Section IV:

Simulate an innovative application for this wearable in order to make it more interesting.

Module Requirements:
You will be graded on:

- *A working prototype at the end of the module.*
- *A well organized and scientifically composed presentation in which you present the required presentation elements. An individually composed report on the user interface.*
- *All team members are knowledgeable able to build and use the circuit and accompanying interface.*
- *Your creativity in representing your data.*
- *The uniqueness of your extra application for your device.*

Grading Rubric

Hardware:

- *Does the device work?*
- *How compact and easily wearable is the device?*
- *Size constraints consideration*
- *Are the soldering and arrangement of the parts efficient and clean?*
- *How user friendly is the device?*

Interface & data processing:

- *User-friendly (effectiveness in data communication/ legibility of the User Interface)*
- *Accuracy of the data*
- *Noise reduction & signal processing algorithms*

Lab specific Calculations:

- *Parameters that needed to be calculated, and the appropriate graphs:*
  - *Resting heartrate and resting respiratory rate for different modes*
  - *Cardiac zone identification*
- *Graphs for different zones*
  - *ECG*
  - *Cardio Zone*
  - *Respiratory (inhalation and exhalation duration. respiratory rate)*
- Stress Monitoring Mode
  - Mode identification based on the input analysis
- Meditation Monitoring Mode
  - Interface indicator

Part IV:

- Simulation of an innovative application

Presentation style in the video submission:

- *Each group member presented.*
- *Does everyone understand the concepts and demonstrate knowledge of the design?*
- *Are the figures and graphs logically designed and presented?*
- *Are the parameters clearly calculated?*
- *Is the data presentation clear and concise?*
- *Is the presentation within the time limit?*

Partner Evaluation (each group member is evaluated by other group members)