Brian Celeste

Claire Gaffney

Thomas Kalil

Matthew Lin

November 2, 2017

**Senior Design Proposal: Work Smarter Not Harder**

**Introduction**

This project will expand upon a project from last year’s senior design class, which used photoplethysmography to monitor heart rate and blood oxygenation in order to detect the symptoms of cardiomyopathy. Cardiomyopathy, also known as enlarged heart syndrome, is the condition caused by the thickening of the heart walls, which constricts blood flow. This can lead to unexpected cardiac arrest. Since cardiomyography is not tested for in physicals, it often goes unnoticed. Our version will retain the functionality of last year’s project while adding several new features. We hope that the additional features will allow this device to serve as a high performance activity monitor that provides a robust and detailed assessment of health and well-being during strenuous activity. The type of data obtained and analyzed by our device and data processing tools could help provide a greater understanding of the body during such activity and how to optimize health and well-being.

# **Problem Description**

While several commercial devices can measure heart rate, there is nothing on the market to monitor other aspects of a person’s health during a workout. We intend to take a pre-existing board that uses photoplethysmography (PPG) to measure a person’s oxygenated and deoxygenated red blood cells and expanding its functionality by addressing its shortcomings and adding new features. The problems on the current board include the inability to determine if movement of the board causing incorrect data, the inability to measure more than two wavelengths, the necessity of physical memory, and the board being too large to be easily worn. Additional problems that may arise include board fragility or short battery life preventing its use during a workout.

# **Proposed Solution**

To account for possible noise generated by small movements of either the device or the body, we plan on including an accelerometer, and using the data the accelerometer gives to produce more accurate results.

In order to test for a wider variety of molecules, we need to scatter more wavelengths. To achieve this, we want to include 2 more LEDs of different wavelengths, and these will be supported by an additional AFE photodetector chip. This would allow us to test an area of tissue for lipids and water in addition to the currently implemented tests.

To improve the ease with which the data can be sent to a computer for further analysis, our proposed solution is to supplement the currently implemented SD card system with a bluetooth transmitter to transfer the completed data file wirelessly, which would be a much quicker method.

Wearability of the device would be enhanced with a strap, and to ensure that the device is compact enough to be portable, we would first verify that Brendan’s compact design is functional, and then expand on that.

To improve durability, we could place the device in some fabric container, and to ensure longevity we will include a large capacity battery for the device to run off of.

# **Demonstrated Features**

There are several enhancements and additions to the current device that we’d like to implement. The features that we hope to demonstrate improve upon and supplement many of the features of last year’s device. First, we’d like to add additional wavelength functionalities. The current device measures changes in blood volume by looking at the absorption and reflection of red and infrared light in hemoglobin, which describes the content of deoxygenated and oxygenated blood. We hope to add wavelengths to determine the concentration of other key tissue constituents, such as water and lipids. This would allow the device to be used for a broader range of applications, such as high performance and strenuous activity, and would provide a more thorough assessment of health.

Additionally, the old device required a microSD card and a manual transfer of data from the device to the computer in the form of a text file, which was then processed and analyzed in a MATLAB GUI. We’d like to create a more robust data analysis tool, with a comprehensive testing of the data processing and a few more features in the GUI such that the data presentation, including the new data that matched with the new wavelengths, could provide a clear and organized evaluation of health. Further, we’d like to include wireless or bluetooth capabilities to ease the burden of the user and allow for live transfer of data. An additional capability could be a phone application to livestream the data to allow the user or other stakeholders to follow and analyze the information in real time.

Other features we’d like to demonstrate include improving the wearability and portability of the device. We’d like to make sure it fits comfortably and has a reasonably long battery life for use.

Finally, we’d like to incorporate an accelerometer in conjunction with the device’s capabilities. This addition would help to measure the movement of the board to account for rapid and unanticipated movements.

# **Available Technologies**

The most important component for this project is the AFE4490 chip, which controls the LEDs and the photo sensors, as well as measuring the timing between detected photons and converting the results to a digital signal to be sent to the PIC microcontroller. This can be obtained for free by requesting samples from the manufacturer, though they will cost $17 dollars each if we somehow break the free samples.

The PIC microcontroller will handle the receipt of the data from the AFE and accelerometer, as well as managing the data transmission. It can be purchased for about $20.

An accelerometer will measure the movement of the board to determine if it caused unusual results. If the accelerometer stocked in the closet does not work we can order a surface-mount accelerometer for less than a dollar.

The wireless communications can be handled by a bluetooth transmitter. This can be purchased for about $10.

The LEDs necessary to measure the water and lipid molecules can be purchased for less than a dollar each.

All other parts (capacitors, resistors, inductors, LEDs to show power and data transmission) can be found in the closet.

The board itself will be fabricated for about $50.

# **6 Engineering Content**

* Data acquisition (hardware)
  + Light emitters/sensors: wave emission (photodiode) and capture (sensor) at specific wavelengths
  + Accelerometer: detect motion so that light data can be properly adjusted
* Data writing/transfer (hardware)
  + On-board memory (if space allows): collect acquired data on SD card
  + Wireless communication: transfer/stream data (using Bluetooth or similar technology) to specified computer/mobile device as CSV file for saving and manipulation
* Data manipulation (MATLAB)
  + Extract/calculate and save useful information from data
  + Display useful information (blood concentrations of oxy- and deoxyhemoglobin, lipids, and water) in user-friendly GUI

# **7 Conclusions**

The first step to completing this project is to get the final board design from last year to work. After the board was demonstrated it was redesigned to be much smaller and add some functionality. This board is untested and will likely have errors that will need to be corrected before any progress can be made. Following this, we hope to incorporate more wavelengths to obtain information about key constituents such as water and lipids. Additionally, we’d enhance the board’s capabilities by allowing wireless data transfer and adding an accelerometer to account for movement when wearing the device. The data collected by the device, following robust analysis using our MATLAB GUI, could provide someone performing high intensity activity to fully understand the effect that it has on their body, and allow them to optimize their performance accordingly.