# Muscle Activation Sensor System (MASS)

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ECE 445 Design Document – Fall 2018

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# 1. Introduction

## 1.1 Background

There are numerous protocols suggested for lifters to improve their strength and muscle size, but it can take months to learn how to perform them with proper form, or what set and rep schemes are ideal for the person at that time. Skills like the mind-muscle connection and form have to be learned by trial and error, but could be learned much faster using EMG data. Advanced lifters could determine if reducing the weight and slowing down the reps on their exercises produce equivalent or improved muscle activation, and could then confidently perform those slower reps, which provide less of an injury risk.

Additionally, people who are developing degenerative muscle diseases may not know about it for months or years after the onset of a disease. Earlier detection with EMG sensors allows for improved prognoses and reduced medical bill and insurance costs.

## 1.2 Objective

Our project is an inexpensive, reusable EMG sensor that gives user's muscle activation data for optimizing their workouts themselves, on the go. It will also be able to refer user's to see a doctor if it detects frequent fibrillations that indicate a certain class of muscular degenerative disease.

It will consist of electrodes connected to a TI microprocessor that will send data to the user's phone for viewing in an app. The microprocessor will connect to a bluetooth modem, filters, a mixer, and the electrodes so the data received in the TI chip is filtered and amplified to be comprehensible for further processing. The device will be powered by a button cell battery.

EMG requires two electrodes to detect one muscle's activation, so the electrode that is not connected to the microcontroller (instead on a bone or joint; not on the muscle belly) will connect to the rest of the sensor using flat wires. The device would come with pre-cut gauze squares and 90% rubbing alcohol for cleaning the sites of electrode placement, as well as a manual with pictures of placement for each muscle. Data visualization and a user interface will reside in the Android app.

The microprocessor and hardware filters will be used to make the raw data readable for the Android phone app. The app will take readable data and separate it into differential muscle activations, as well as display it on a graph and detect fibrillations over time.

An additional idea would be to include an LED that lights up on the main electrode (housing the microprocessor and lying on the muscle belly) whenever the user can be said to be achieving a goal muscle activation amount. Also, I have reached out to a professor at the University of Pittsburgh about his patent on a dry electrode and if it is on sale. Such an electrode would simplify the search for an appropriately reusable electrode. If those electrodes are not available,, we will include an electrolyte solution for the user to apply to their skin after the rubbing alcohol.

Another company has built a similar system (called Athos) consisting of clothes that incorporate EMG sensors and also track muscle activation, as well as calorie consumption,  and heart rate. It does not consider fibrillation detection. The suit is $696 to track the whole body, and so our project aims to make a much more cost-effective solution, in addition to tackling the problem of diagnosing some degenerative muscle diseases [1]. We are not interested in tracking calories or heart rate, though calories are important for weight-training.

## 1.3 High-level Requirements List

- Fibrillation detection rate: 7-20Hz provided by characteristic of fibrillations.
- The filtered and amplified EMG data should be +-40 Hz of 2KHz. With an overall gain of Av=100, a 10 bit A/D converter should produce 3mV discrete increases.
- Our Bluetooth modem code should successfully communicate with the phone faster than the speed of the processor so the memory in the processor does not overflow.

# 2. Design

MASS requires a power supply, Bluetooth modem, TI processor and filter system to make electrode data distinct. The power supply provides 10W of power to the processor, Bluetooth modem and flash. The power should last 2 kWh. The electrodes contains the signal generated from the muscle and use a filter system to make the signal distinct. Then the filtered signal is sent to the TI processor to format the information to be sent out to the cellphone through the bluetooth modem. The entire system should be small and portable and capable of process all information in real time.

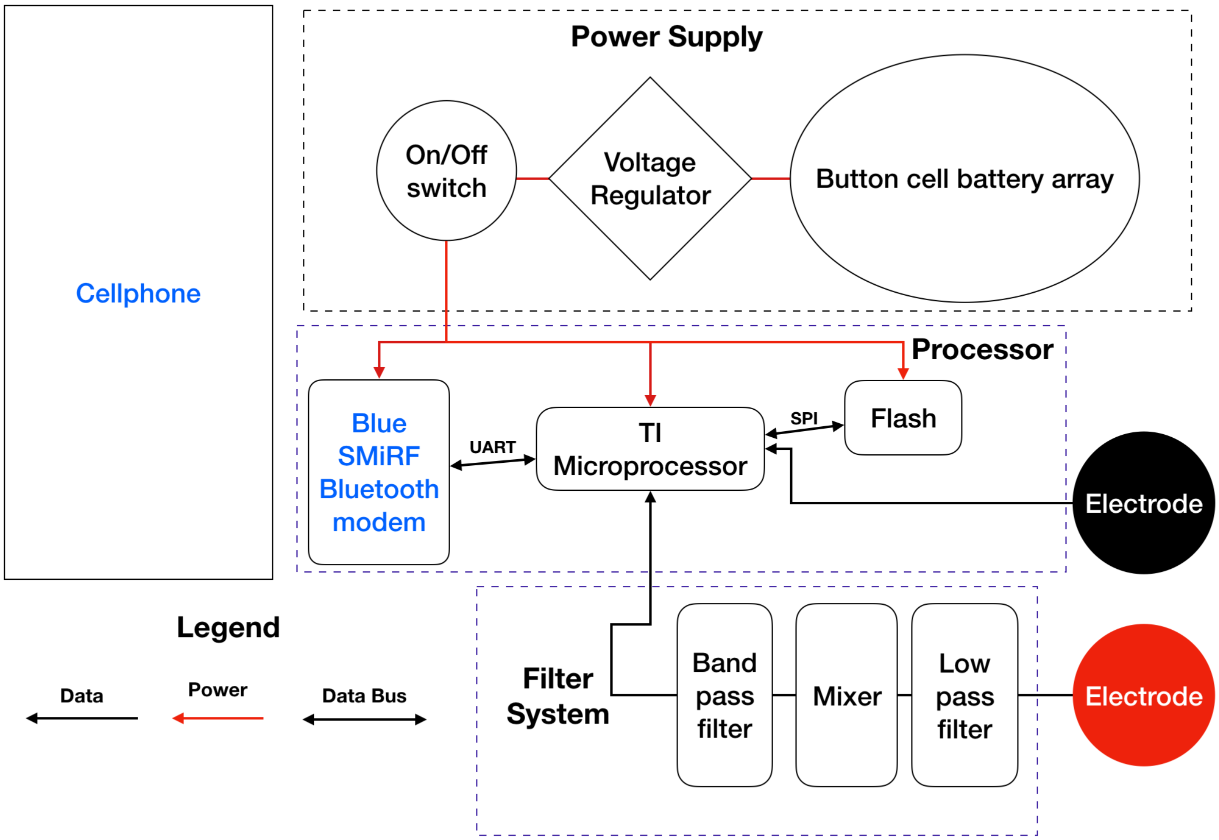



Figure 1. Block Diagram

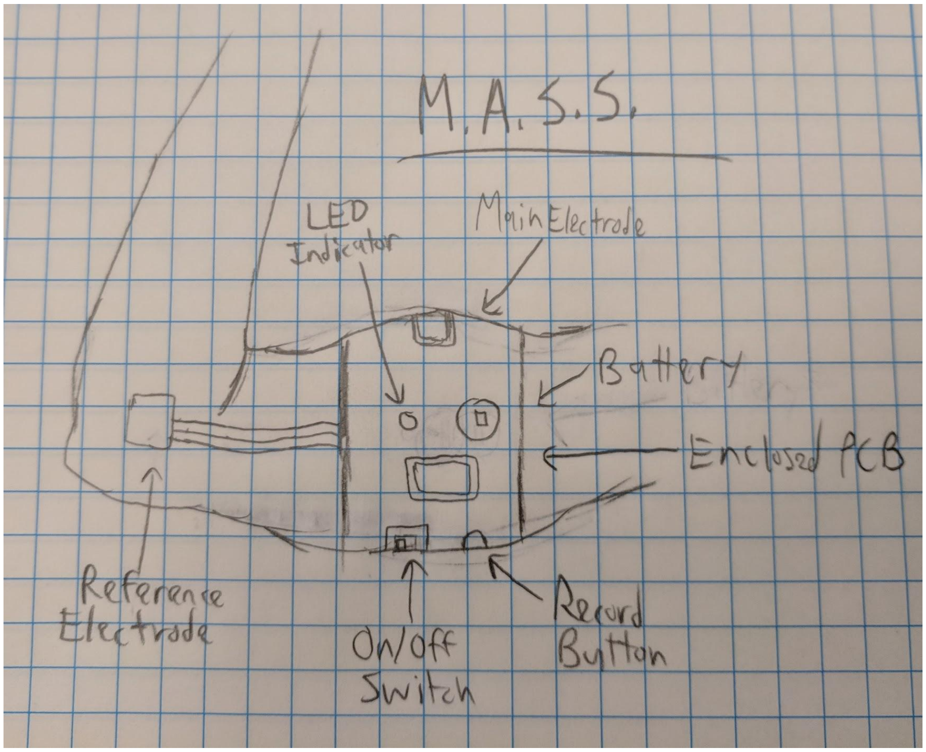



Figure 2. Physical Sketch

# 2.1 Sensor Subsystem

## 2.1.1 EMG Electrodes

The EMG circuits consist of various reusable electrodes and an electrolyte gel to measure muscle activities when the user walks in place and pass it through the filter to the microcontroller. This circuit should be designed with the idea of adjustability so it can be attached to any limb.

Requirements: electrodes should report signals between 5uV -30mV and 7-20 Hz

verification: Have a test subject work till exhaustion. Then attach electrodes in the worked area with the other ends connected to oscilloscope. If oscilloscope defects changes in voltage within domain then voltage range is established. Then change oscilloscope to measure frequency domain and if frequency is in range then all requirements are met.

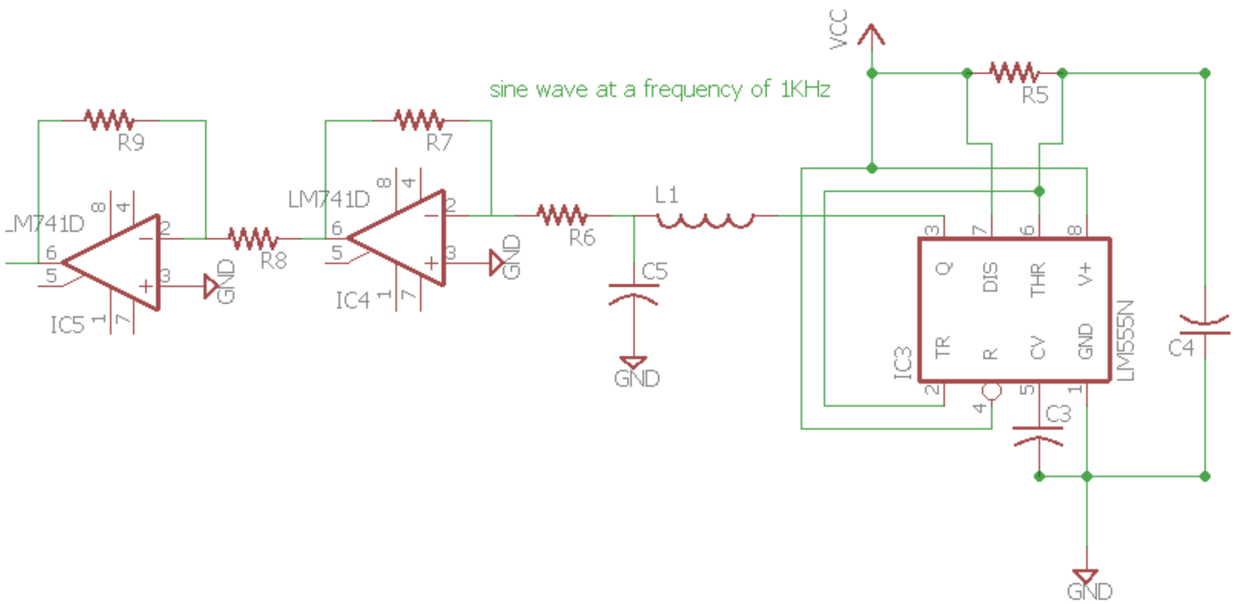
# 2.2 Processing Subsystem

## 2.2.1 Filtering and Amplification Circuit

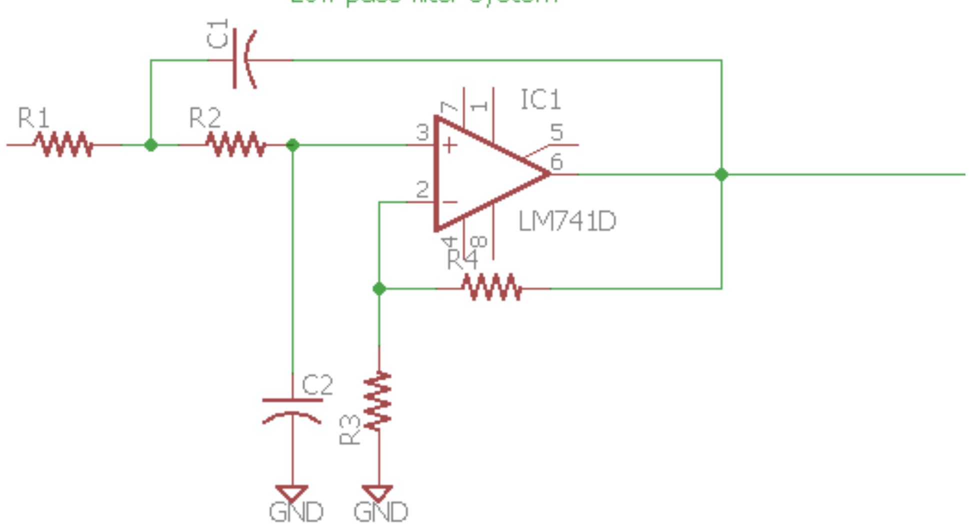
Will use linear components to handle signals through the low pass, band pass and mixer.

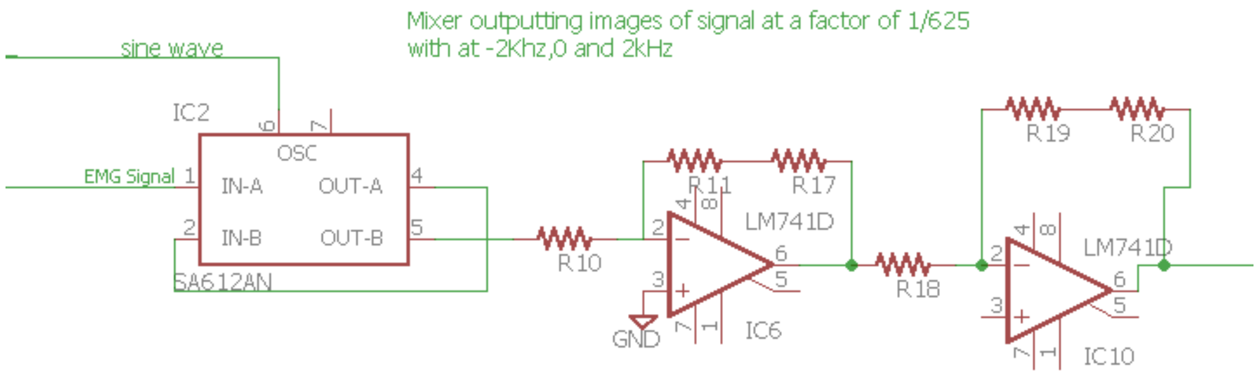
Requirements: The components have to handle signals with a voltage range of 50uV-30mV and frequency range of 7-20 Hz, and produce gain  Av=100 and a frequency response centered at 2kHz.

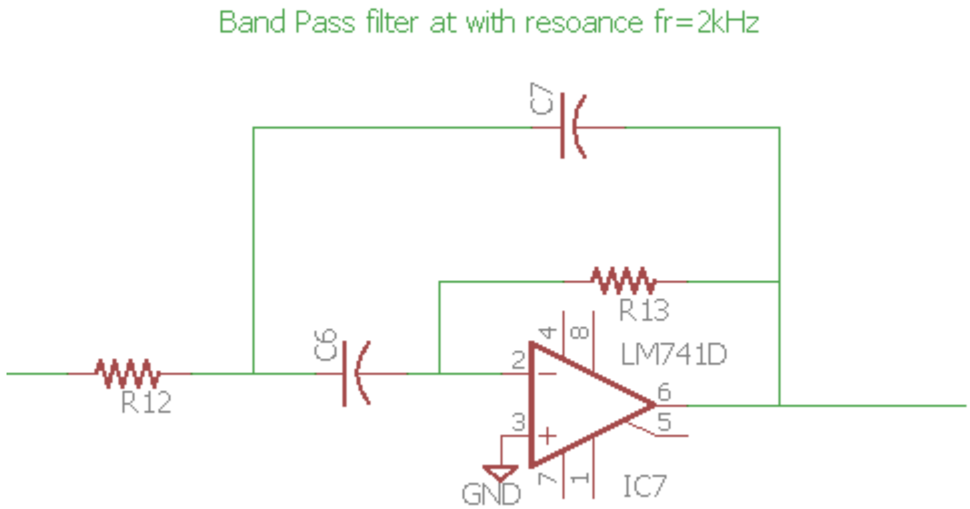
Verification: have test points set at voltage out points of the four circuits depicted below. use oscilloscope to determine if each circuit has the correct frequencies specified in the diagrams below. In addition send 10mV input into the electrode and after the first filter measure a Vout of 20mV. Then after the mixer a Vout of -0.8mV and the final output hold be 1V.




Low pass filter system






### 2.2.2 TI Microprocessor

We are considering the TI TMS320C5505AZCH10 processor that process information at 32 bits and can act as a microcontroller. It is meant to process the information sent after filtration process to be formatted in some type of array or data type acceptable for the Bluetooth modem.

Requirements: Handle float data types, have a 10 bit Analog to digital converter, that have over 512Mb of memory, which is data for 2.84 hours. In addition the processor needs to use UART and SPI connection.

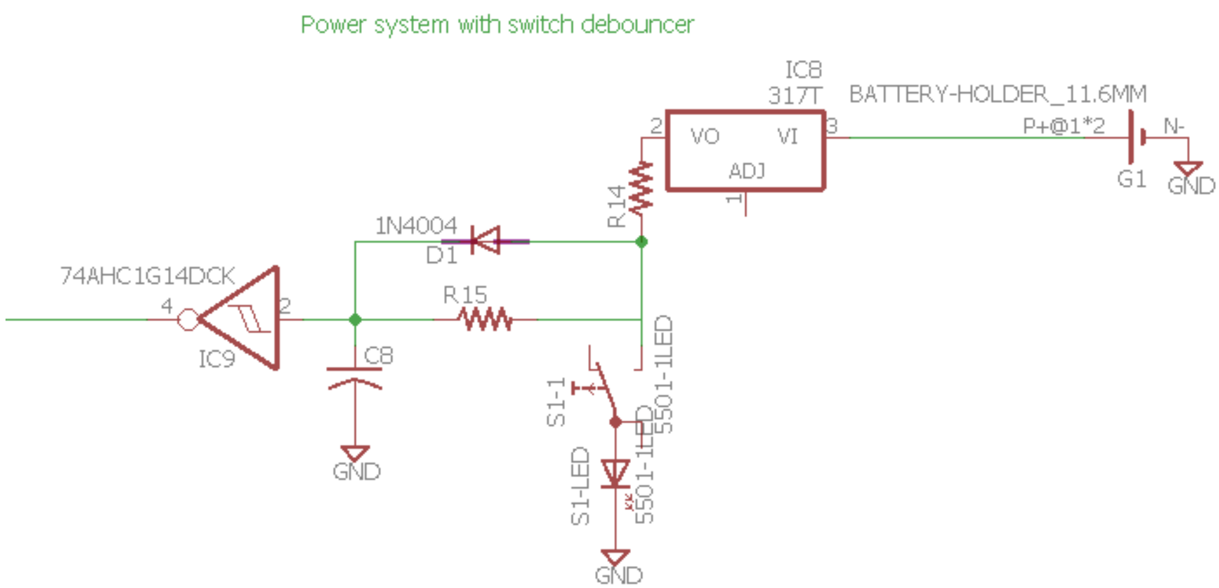
### 2.2.3 Button Cell Battery

Main source of power for device.

Requirements: The system should last a few weeks on one battery, assuming 2 hours of use 5 days a week.

### 2.2.4 Control Buttons

There will be an on/off switch, a single start/stop recording button, and a debouncing circuit to preserve battery and keep the final graphs readable to the user. An LED will indicate if the device is recording.




## 2.3 Data Transfer Subsystem

Output from the microprocessor will be sent to the user's phone app via a Bluetooth connection.

### 2.3.1 BlueSMiRF Bluetooth Modem

The Bluetooth modem will be connected to the microprocessor through a UART connection and will upload data at a rate of 2.4 GHz to the phone.

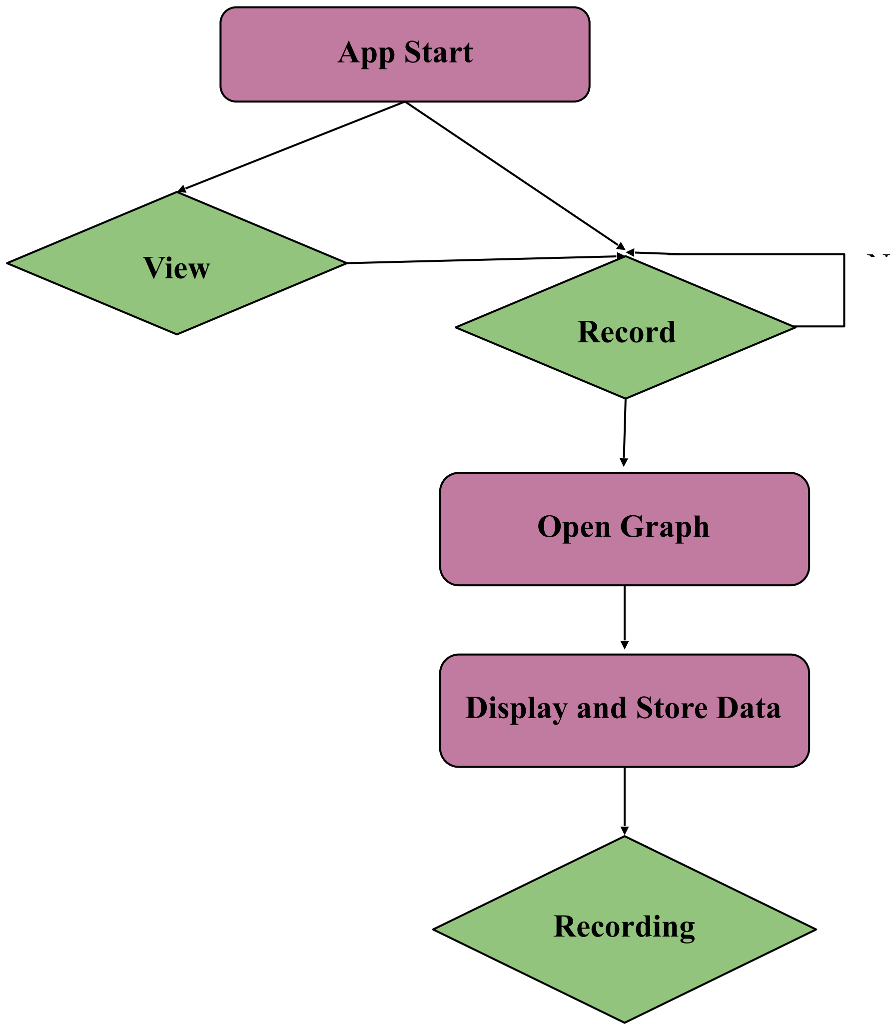
Requirements: The modem should send filtered readings at least 5 times a second.

### 2.3.2 Flash Memory

The measurements from the EMG sensors reside here post-process, then are sent via Bluetooth to the computer.

## 2.4 Phone App Software

There will be a graph that use floating point values and will be a time versus fibrillation scatter plot with a parabolic line of best fit.



## 2.5 Risk Analysis

The most important part of this project is the filtering and processing of the original signal. So there is high risk of failure if the signal can not be detected after filtration. Then if filtration is successful, the next hurdle is being able to process raw analog data to be displayed. If any part of these areas fail, the project could fail to function.

The next highest risk area in the project is displaying the data. The current method after processing is to have the data sent through the Bluetooth modem and have the phone display it as a graph. If the modem or phone app is insufficient then the back up plan of displaying the data on a screen attached to the processor will require more memory space along with a larger power supply to handle the hardware changes.

The smaller risk side of the project is the method of how to display the fibrillations on the device and power supply usage. These issues are small and can be fixed through program and wiring changes respectively.

Our solution should be able to detect electrical potentials roughly between 50uV and 30mV [2] at a rate of 7-20Hz [3], sending it to the user's phone at 10 samples per second (subject to change). Fibrillations come in at amplitudes of 20uV to 300uV at rates of 2 to 20Hz, so not all fibrillations will be detected, but depending on the frequency with which we can poll the Network Subsystem, we hope to detect a significant percentage of fibrillations.

# 3. Cost and Schedule

<table>
<tr><th colspan="5">Labor</th></tr>
<tr><th>Salary/Hr</th><th>Hrs/Week</th><th>Weeks</th><th>Persons</th><th>Total Labor</th></tr>
<tr><td>$44</td><td>10</td><td>10</td><td>2</td><td>$8,800</td></tr>
<tr><th colspan="5">Parts</th></tr>
<tr><th colspan="2">Part</th><th>Part Price</th><th>Quantity</th><th>Total Price</th></tr>
<tr><td colspan="2">Reusable Norco© EMG Electrodes</td><td>$1.90</td><td>8</td><td>$15.20</td></tr>
<tr><td colspan="2">Electrolyte Solution</td><td>$4.90</td><td>1</td><td>$4.90</td></tr>
<tr><td colspan="2">Gauze Pads Pack</td><td>$4.00</td><td>1</td><td>$4.00</td></tr>
<tr><td colspan="2">Blue SMiRF Bluetooth Modem</td><td>$25.00</td><td>1</td><td>$25.00</td></tr>
<tr><td colspan="2">TI TMS320C5505AZCH10 Microprocessor</td><td>$7</td><td>2</td><td>$14</td></tr>
<tr><td colspan="2">Armband</td><td>$2.00</td><td>2</td><td>$4.00</td></tr>
<tr><td colspan="2">Button Cell Battery</td><td>$2.13</td><td>4</td><td>$8.52</td></tr>
<tr><th colspan="2">Parts Total</th><th colspan="3">$75.62</th></tr>
<tr><th colspan="2">GRAND TOTAL</th><th colspan="3">$8,875.62</th></tr>
</table>

| Schedule | | |
|---|---|---|
| **Week** | **Caleb** | **Branden** |
| **10/15** | Order parts for PCB and test electrodes | Order EMG electrodes and electrolyte solution and finalize software flow charts |
| **10/22** | Finalize PCB design if possible | Begin writing and testing microprocessor and Android app code. Start search for volunteers to test |
| **10/29** | Assemble and verify overall circuit | Continue developing code |
| **11/5** | Finalize PCB design if not yet finished | Finish debugging microprocessor code |
| **11/12** | Test the circuitry | Finish debugging Android app |
| **11/19** | Collect data with participants | Collect data with participants |

# 4. Safety and Ethics

We will strictly follow the IEEE Code of Ethics in bringing our engineering work to fruition. This product can be both a useful tool for weightlifters everywhere, as well as a potential way to alleviate discomfort for many with early-onset muscle degenerative diseases.

Because our product uses electrodes that adhere to the user's skin, we must make it clear to the user that the adhesive gel may produce an allergic reaction. Users should know to test the product out before wearing it for a prolonged period of time, and after market, we would allow refunds due to allergies. The plastic in the electrodes we are using is not made of latex, so theoretically only the gel is a potential issue.

We must also specify in our product description that users with pacemakers, implanted defibrillators, and lymphedema are not able to safely use M.A.S.S. These decisions are consistent with code #1 of the IEEE Code of Ethics: "to accept responsibility in making engineering decisions consistent with the safety, health and welfare of the public, and to disclose promptly factors that might endanger the public or the environment" [4].

In providing the users info on possible fibrillation detections, we must follow the IEEE Code of Ethics code #4, "to be honest and realistic in stating claims or estimates based on available data" [4]. We must make it clear to the user that our detection of fibrillations is not a diagnosis, and that we are not medical professionals.

# 6. References

[1] “MEN'S FULL BODY KIT - with two Cores,” *Athos*. [Online]. Available: https://www.liveathos.com/products/mens-full-body-kit-dual-core-v3.

[2] R. Berlia, S. Kandoi, S. Dubey and T. R. Pingali, "Gesture based universal controller using EMG signals," *International Conference on Circuits, Communication, Control and Computing*, Bangalore, 2014, pp. 165-168.

[3] Patterson, John R. "Fitwise". Castillo. Brian T. Retrieved 24 June 2009.

[4] “IEEE Code of Ethics,” *Encyclopedia of Software Engineering*, 2002.