

# iBand

ECE 445 Design Document

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# 1. Introduction

## 1.1 Problem Statement

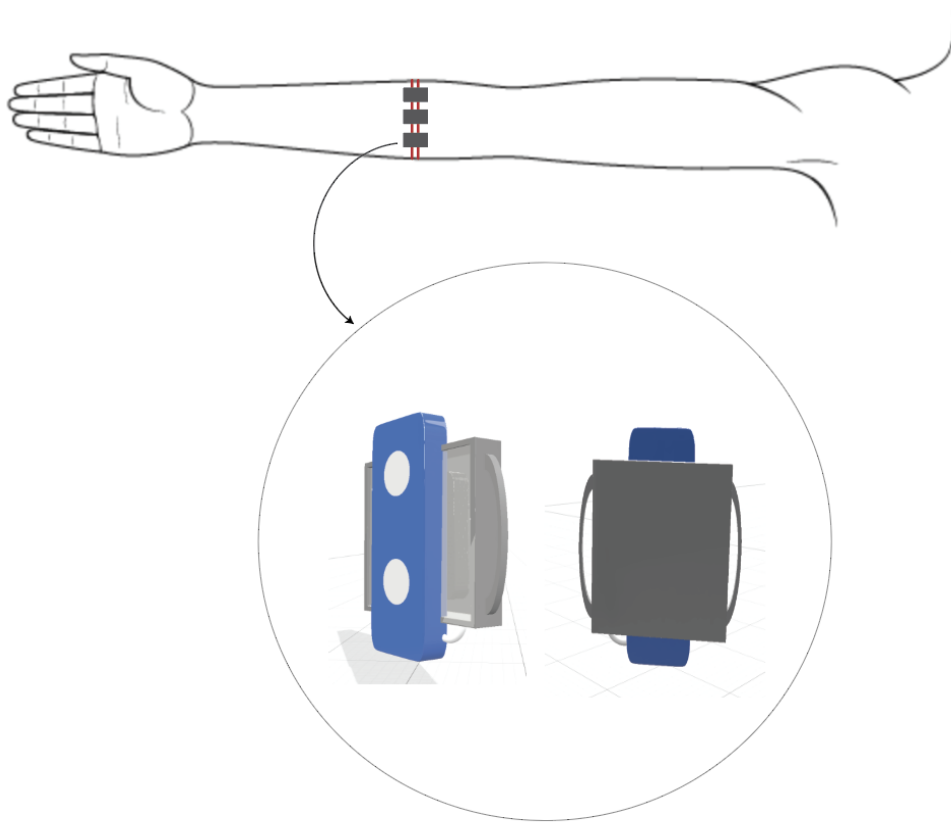
Surface electromyography (sEMG) is a non-invasive computer based technique that utilizes electrodes placed on an user's forearm to record electrical impulses produced by the nerve's stimulation of the skeletal muscle. Products that leverage the information provided through sEMG signals for rehabilitation, educational, and recreational purposes already exist in the market today. However, these devices are unable to withstand continuous use, do not provide the user with an ability to understand the data being collected and are expensive - ranging from thousands of dollars<sup>1</sup> with the cheapest option being discontinued<sup>2</sup>. Therefore, the options that are available in the market today are not ideal for rehabilitation use cases in which the nurses do not have a background in sEMG signal analysis as well as educational and recreational use cases in which an expensive device is unobtainable and used with greater frequency.

## 1.2 Solution Overview

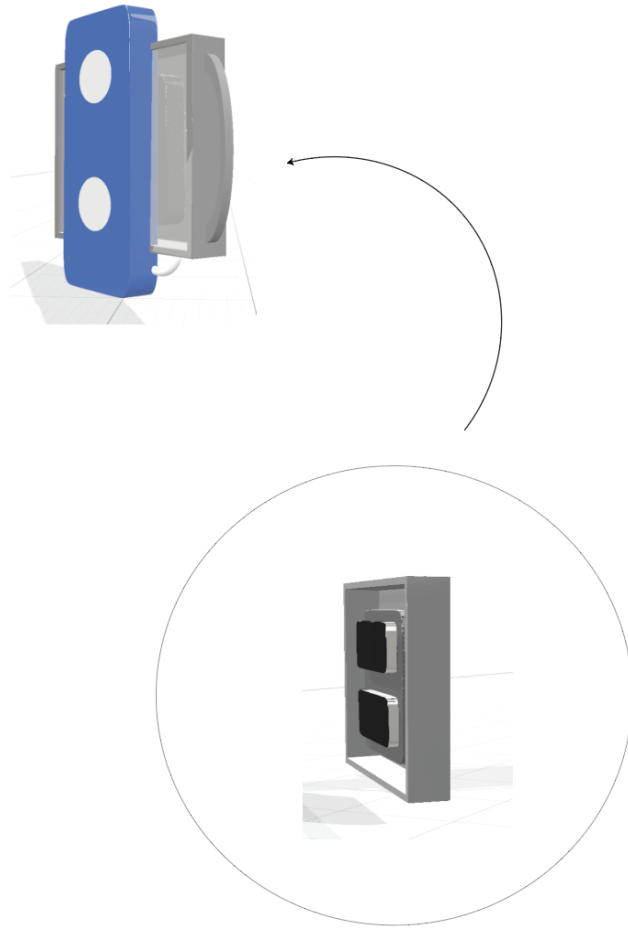
Our solution to increase public accessibility and understanding of sEMG devices is to create an inexpensive, durable, and portable replacement to the now discontinued Myo Armband. This will be done through the use of eight sEMG sensors coupled with medical grade electrodes, an Inertial Measurement Unit (IMU), a Galvanic Skin Response sensor (GSR), and a Pulse sensor. The IMU combines the use of gyroscopes and accelerometers to measure angular and linear acceleration providing information as to position and velocity. The GSR measures the skin's conductivity which is directly proportional to sweat gland activity. The Pulse sensor measures the change in the amount of infrared light being transmitted through the body as dependent on the rate of blood flow. This design will then transmit the data collected by these sensors to a built-in user interface located on the user's laptop through bluetooth.

## 1.3 Visual Aid

The implementation of this idea can be seen in the following figures below. The armband will consist of six encasings which will encompass the individual sEMG sensors and electrodes. Each of these encasings will be connected by a thin rubber pipe in which each of the sensor's cabling will be run through. The rubber pipe will have a mechanism built in which will enable the user to adjust the distance between the two sensor encasings and therefore change the circumference of the entire band.



*Figure 1 : Demonstration of how the proposed solution will look on the user's forearm*



*Figure 2 : Demonstration of how the sEMG sensor will be placed in the chassis*

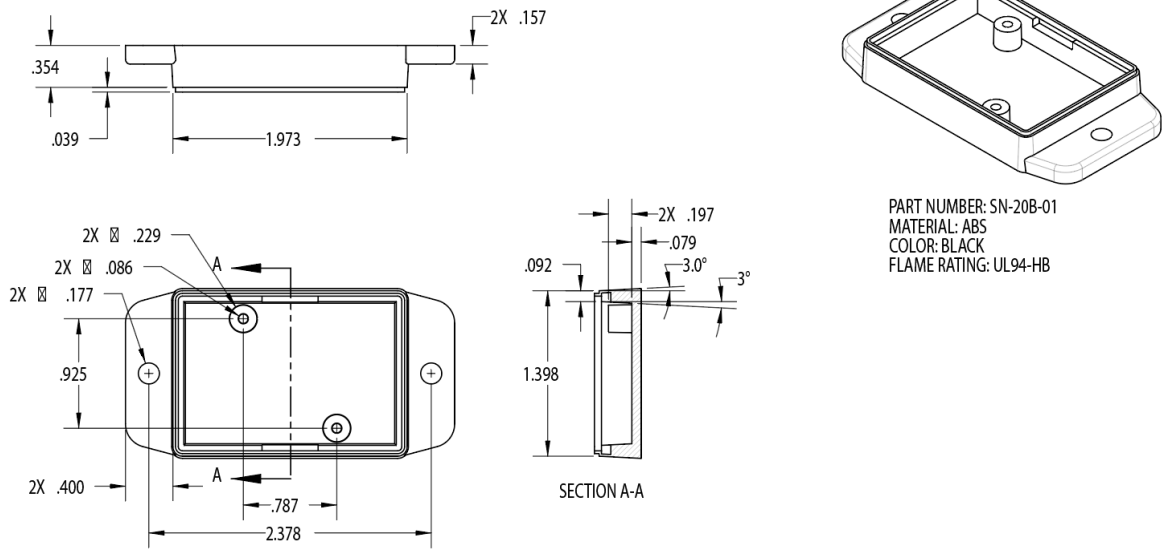


Figure 3 : CAD drawing of the base of the sEMG enclosing (gray box in the illustrations above)

These images were taken from Polycase. com

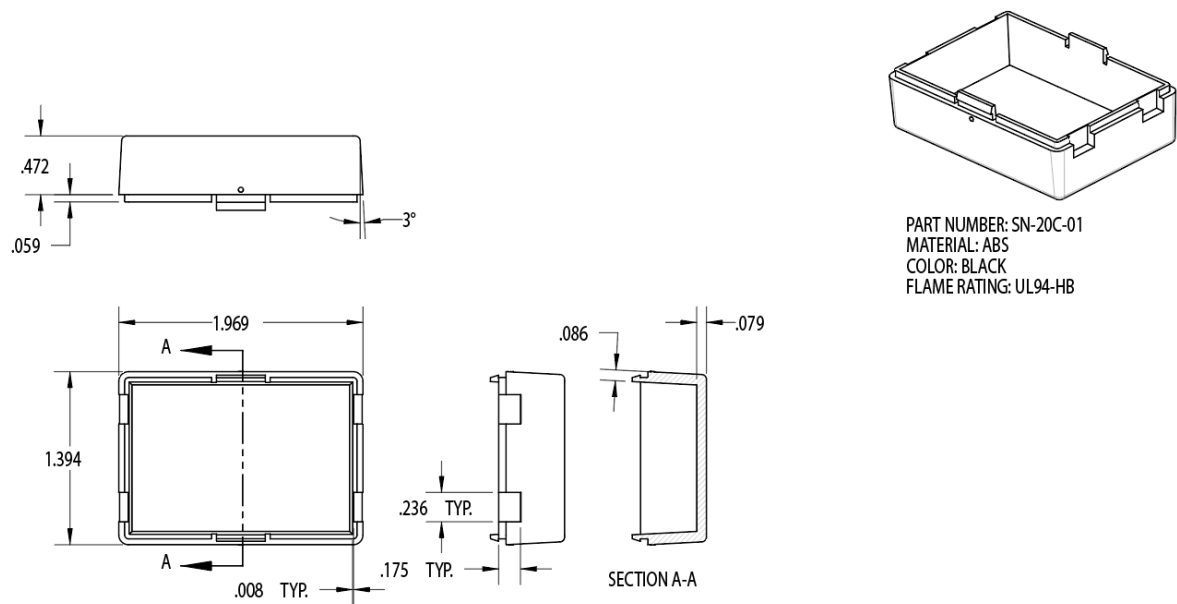


Figure 4 : CAD drawing of the cover of the sEMG enclosing (gray box in the illustrations above)

These images were taken from Polycase. com

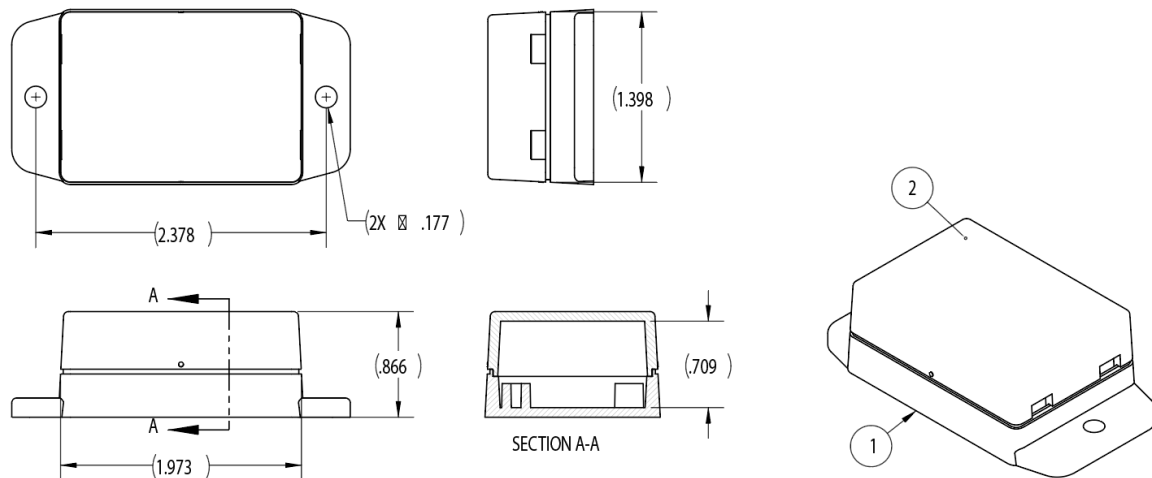


Figure 5 : CAD drawing of the entire enclosure assembled

*These images were taken from Polycase. com*

This design at the moment only showcases how we will design the chassis for the electrode and sEMG sensors. We are currently iterating on the overall band design in order to include our PCB, IMU sensor, and GSR sensor.

#### 1.4 High - Level Requirements

1. **Sensing and Size:** The length of the armband must be between 22 cm and 44 cm and have the ability to change circumference without the relative position between sensors changing. Our six sEMG sensors (each 22mm long) , IMU sensor (25.4 mm long), GSR sensor (24mm long), and a Pulse sensor (15mm long) must fit within the constraints of the armband length.
2. **Compact Size:** The next quantitative characteristic this project must exhibit is that the new design must be smaller and more compact than the current design, which has the dimensions of 14.8cm wide x 14.5cm long x 1cm tall. To prevent a bulky design, the maximum size of the printed circuit board (PCB) must be less than half of this at 10 cm.
3. **Data Collection:** This project must be able to collect data for at least two hours with minimal to no discomfort put onto the user. The raw data from the sensors must be displaced in real-time and provide the user with some feedback as to how to obtain the most accurate data - such as where to place the armband.

## 2. Design

### 2.1 Block Diagram

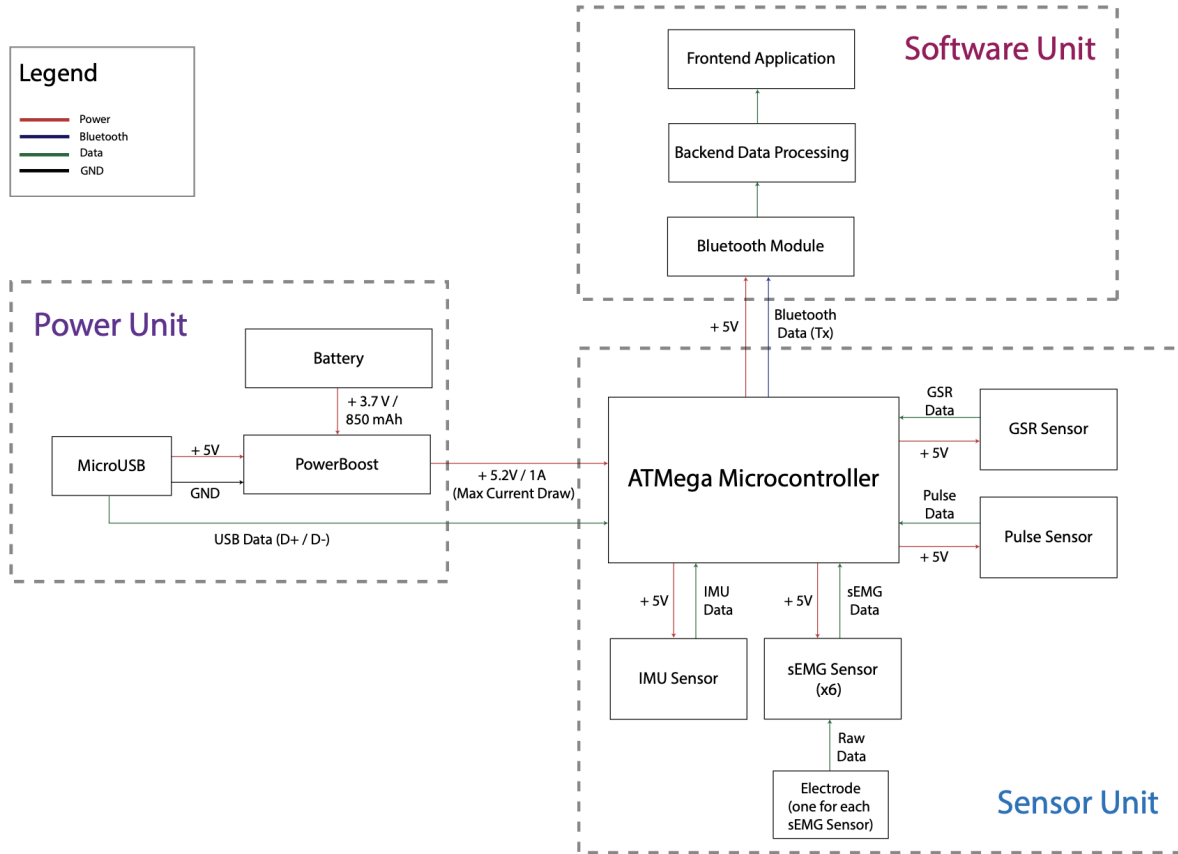


Figure 5 : Block Diagram of the Subsystems in our Proposed Solution

### 2.2 Subsystem Description

#### 2.2.1 Power Delivery Unit

This subsystem supplies power to the microcontroller in the software subsystem and recharges the lithium-ion battery. It includes a boost converter and battery charge management controller, referred to as a PowerBoost, which handles both supplying power to the microcontroller and charging the battery. It has a voltage regulator which steps up the voltage, and a battery management system that is able to regulate the temperature and current of the battery to prevent overheating. The PowerBoost is powered by a 5V input and a lithium-ion battery at 3.7V for 850mAh. It is able to step up the voltage to provide an output voltage of 5.2V with a maximum current draw of 1A. A limitation of the PowerBoost is that it does not pass through the data bus lines from the MicroUSB header to the USB Power Out port. In order to alleviate this problem, we are directly connecting the D+/D- bus lines to the microcontroller. This allows us to use one single USB port for both charging and reprogramming the microcontroller.



Requirements	Verification
<p>At an input voltage of 5V, the PowerBoost will charge the lithium-ion battery at <math>3.7V \pm 50mV</math> for 850 mAh.</p>	<ol style="list-style-type: none"> <li>1) Discharge the 3.7V lithium-ion battery.</li> <li>2) Connect the microUSB to the Printed Circuit Board (PCB) to provide an input voltage of 5V and recharge the battery completely. Verify that the output voltage of the lithium-ion battery is between 4.2V and 4.5V.</li> </ol>
<p>The PowerBoost will provide an output voltage of <math>5.2V \pm 50mV</math> and output current ranging between 0A to 1A.</p> <p>It will have an input voltage of 3.7V-4.5V from the lithium-ion battery.</p>	<ol style="list-style-type: none"> <li>1) Connect the lithium-ion battery to the PowerBoost. Verify that the output voltage of the PowerBoost is <math>5.2V \pm 50mV</math> using an oscilloscope and voltage probe.</li> <li>2) Connect the output of the PowerBoost to the microcontroller and use the oscilloscope and current probe to verify that the output current is <math>1A \pm 50mA</math>.</li> </ol>
<p>The power subsystem will include a rechargeable battery which supplies voltage for at least 3 hours.</p>	<ol style="list-style-type: none"> <li>1) Discharge the battery to <math>3.0V \pm 50mV</math>. Then charge it completely until the voltage of the lithium-ion battery is between 4.2V and 4.5V.</li> <li>2) Connect the battery to the PowerBoost for 3 hours to discharge it. Check that the voltage of the lithium-ion battery is between <math>4.2V \pm 50mV</math> to <math>4.5V \pm 50mV</math>.</li> </ol>

*Table 1 : Requirements and Verification Table for Power Delivery Subsystem*

### 2.2.2 Software Unit

This subsystem consists of a bluetooth module, some backend processing, and a frontend user interface. The bluetooth module will receive a stream of serial information from the microcontroller through the connection from the R<sub>x</sub> to T<sub>x</sub> pin connection found on the bluetooth module and the microcontroller, respectively. This information will then be processed and cleaned by python scripts found in our backend system in order to enable a clear depiction of the individual signals produced by the sEMG, IMU, GSR, and Pulse sensors.

Requirements	Verification
The serial communication between the microcontroller and bluetooth module must occur at a rate of at least 9600 bauds <sup>3</sup> (104.167 μs).	<ol style="list-style-type: none"> <li>1) Connect an oscilloscope to the T<sub>x</sub> pin of the microcontroller.</li> <li>2) Set the oscilloscope to trigger on a pulse.</li> <li>3) Take the reciprocal of the shortest pulse.</li> <li>4) Verify that it is 104.167 μs.</li> </ol>
The input voltage to the bluetooth module must be 5 V ± 1V <sup>4</sup>	<ol style="list-style-type: none"> <li>1) Connect one lead of the voltmeter to the input T<sub>x</sub> pin of the microcontroller</li> <li>2) Connect the other lead of the voltmeter to the R<sub>x</sub> pin of the bluetooth module</li> <li>3) Verify that there is an electrical potential difference of 0 V ± 1V</li> </ol>
Bluetooth connection must be enabled and exposed to external devices <sup>5</sup>	<ol style="list-style-type: none"> <li>1) Prior to any external device connecting to the bluetooth module, the red LED should blink continuously.</li> <li>2) Once connection to an external device is successful the red LED's blinking rate decreases.</li> </ol>

*Table 2 : Requirements and Verification Table for Software Subsystem*

### 2.2.3 Sensor Unit

This subsystem consists of all the sensors - six sEMG sensors, one IMU sensor, one GSR sensor, and one Pulse sensor - that will be used in this project. The EMG sensors, as alluded to earlier, will be measuring electrical impulses from the muscles in the forearm. Using six sensors, several muscle groups can be targeted, which allows the iBand to measure several different kinds of gestures. The IMU sensor aids in gesture recognition by providing the spatial position of one's arm. The GSR sensor allows the iBand to monitor the user's perspiration levels - an indirect indicator of one's emotions and stress levels. Lastly, the Pulse sensor aids the GSR sensor as heartbeats per minute can be added as an additional datapoint to measure a user's stress levels and emotions.

Requirements	Verification
<p>The sEMG sensor outputs a filtered sEMG signal between 0-1000 units<sup>6</sup>.</p>	<ol style="list-style-type: none"> <li>1) Connect the sEMG sensor to an Arduino and place the electrode longitudinally over a team member's forearm.</li> <li>2) Open the Serial Plotter in the Arduino IDE to view the signal.</li> <li>3) Verify the signal by observing the max values of the peaks generated.</li> <li>4) If the output is above 1500, or has noise (values might go up to <math>4 \times 10^9</math>), check the connection to the board and check the placement of the sensor over the arm.</li> </ol>
<p>The IMU sensor needs to correctly reflect changes in spatial position and the changes should be within <math>\pm 3\%</math> of the expected value<sup>7</sup>.</p>	<ol style="list-style-type: none"> <li>1) Connect the IMU sensor to an arduino and place it on a flat surface.</li> <li>2) Open the serial monitor in the Arduino IDE to view the signal.</li> <li>3) Rotate it by 90 degrees in each axis (x, y, z) and check the changes in spatial angles.</li> <li>4) Check if the changes in spatial position are within <math>\pm 3\%</math> of the expected value (here, 90 degrees).</li> </ol>
<p>The Pulse sensor's BPM (Beats Per Minute) output should be within <math>\pm 5\%</math> of the actual heart rate of the user.</p>	<ol style="list-style-type: none"> <li>1) Connect the Pulse sensor to an arduino and place it over a team member's forearm.</li> <li>2) Open the serial monitor in the Arduino IDE to view the signal.</li> <li>3) Either manually count or use medical grade equipment to measure the user's heartbeat.</li> <li>4) Check if the value measured by the sensor is within <math>\pm 5\%</math> of the value obtained from manual counting / medical equipment.</li> <li>5) Repeat Steps 3-4 five times to verify the accuracy of the result.</li> </ol>

*Table 3 : Requirements and Verification Table for Sensor Subsystem*

### 2.3 Circuit Schematic

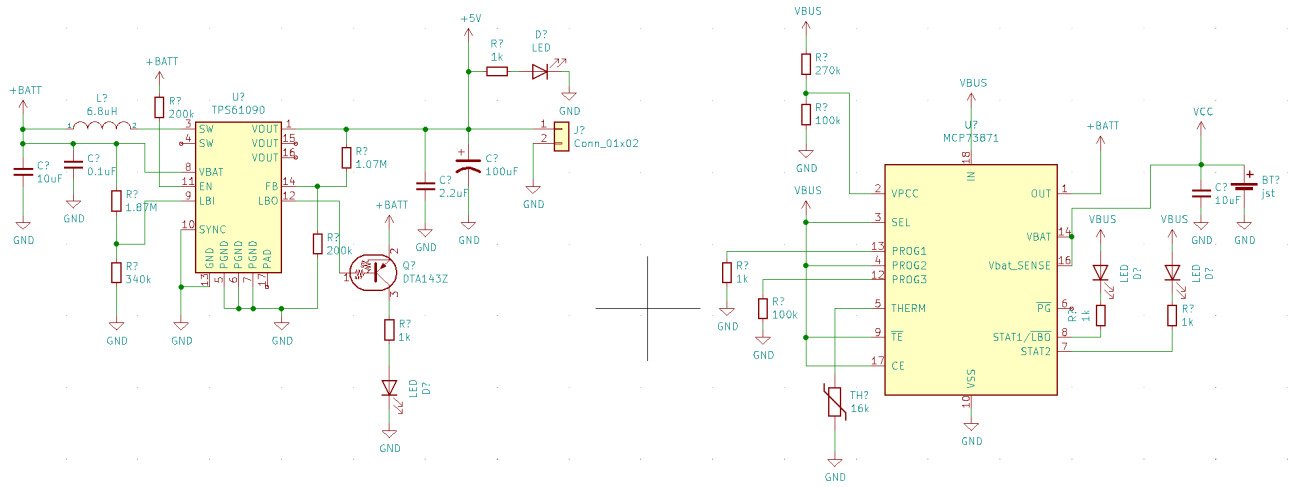


Figure 6 : Boost Converter and Battery Management System Schematic

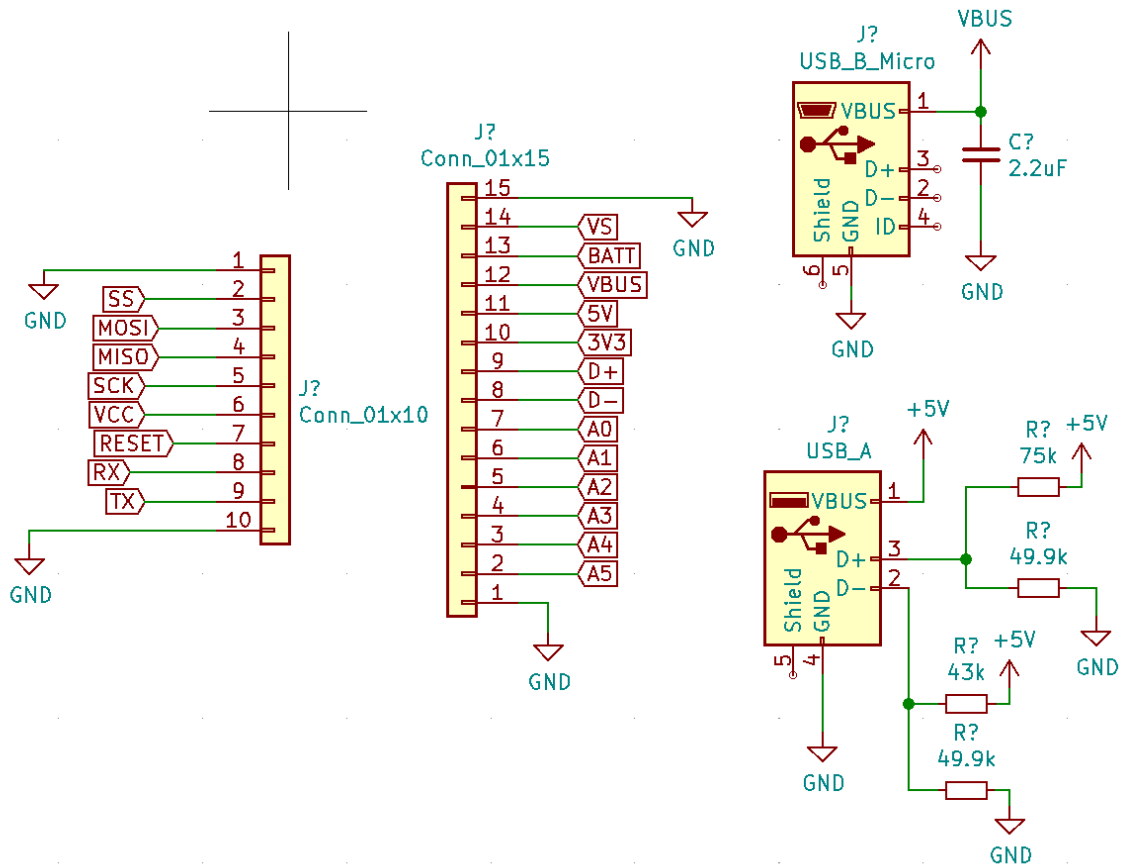


Figure 7 : USB-A, USB-micro, and Connectors Schematic

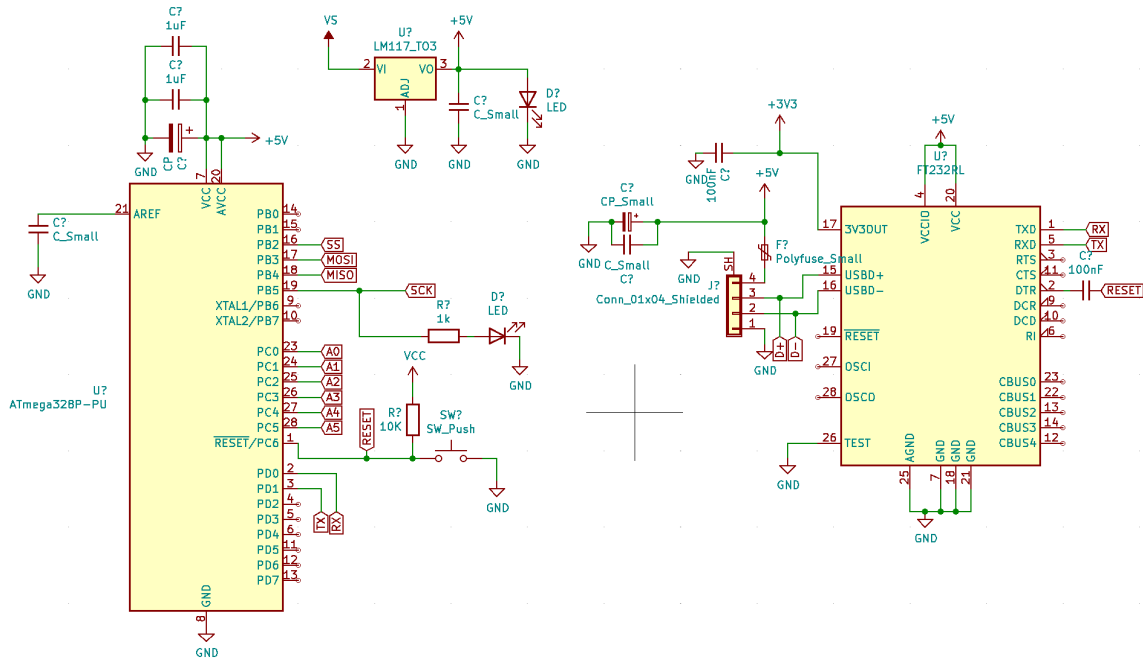


Figure 8 : Microcontroller, Voltage Regulator, and USB UART IC Schematic

## 2.4 Tolerance Analysis

The placement of the sEMG sensors on the forearms of the user plays a very important role in determining the accuracy of its data. As alluded to in the article published in Journal of Electromyography and Kinesiology<sup>8</sup>, the electrodes of the sensor must be placed “halfway between the (most) distal motor endplate zone and the distal tendon”. Additionally, according to guidelines published by under the SENIAM (Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles)<sup>9</sup> project, the electrodes should be longitudinally across the muscle, and should be at the center with respect to the width. These conditions are as such because placing the electrodes elsewhere can lead to an increase in noise due to crosstalk between active muscle groups, and so on.

In this analysis, we will be focusing on the error margins of the electrode placement with respect to the width of the muscle group in consideration. The muscle group in consideration for this analysis is the *Flexor Carpi Radialis*. As seen from a study performed by *B K Potu et al*<sup>10</sup>, the average width of the muscle belly towards the distal end is about  $1.99 \pm 0.72$  cm. Given that the electrodes that will be used in this project have a width of 1.545 cm, the error in the placement of the sensor with respect to the center of the muscle can vary from:

$$\begin{aligned}
 &= \pm (1.99 - 1.545) / 2 \text{ cm to } \pm ((1.99 \pm 0.72) - 1.545) / 2 \text{ cm} \\
 &= \pm 0.2225 \text{ cm to } \pm 0.5825 \text{ cm.}
 \end{aligned}$$

However, as the diameter of the leads of the electrode is 0.9017cm, the maximum range of permissible error before the leads are not in contact with the center of the muscle (with respect to the width) is:

$$\begin{aligned}
 &= \pm 0.9017 / 2 \text{ cm} \\
 &= \pm 0.4509 \text{ cm}
 \end{aligned}$$

If the electrode is outside this range, the data collected from the sensor can produce data with high levels of noise, leading to substantial inaccuracies.

Tolerances of other sensors are not accounted for in this analysis because they are not sensitive to their placement on the user's arm as compared to the sEMG sensor. Both the GSR and the Pulse sensor obtain their data by interacting with the user's skin on their arm.

### 3. Cost and Schedule

#### 3.1 Cost of Materials

<b>Part</b>	<b>Quantity</b>	<b>Cost per Item</b>
Microcontroller (ATmega328P-PU)	1	\$2.82
Voltage Regulator (LM117 TO3)	1	\$20.94
USB UART IC (FT232RL)	1	\$4.70
Synchronous Boost Converter (TPS61090)	1	\$0.87
Battery Charge Management Controller (MCP73871)	1	\$2.19
<b>Total</b>	5	\$31.52

*Table 4 : Cost Analysis*

### 3.2 Schedule

Date	Saaniya	Rutu	Panav
2/21	Design Document	Design Document	Design Document
2/28	Design Review	Design Review	Design Review
3/7	Finalizing Armband Design	PCB Modifications	Digital Filtering
3/14		Spring Break	
3/21	Web Application	Final PCB Modifications	Web Application
3/28	Software + Hardware Integration	Software + Hardware Integration	Software + Hardware Integration
4/4	Testing + Validation	Testing + Validation	Testing + Validation
4/11	Prepare Demo	Prepare Demo	Prepare Demo
4/18	Prepare Presentation + Modify Demo	Prepare Presentation + Modify Demo	Prepare Presentation + Modify Demo
4/25	Final Touches + Modify Presentation	Final Touches + Modify Presentation	Final Touches + Modify Presentation
5/2	Final Presentation	Final Presentation	Final Presentation

*Table 5 : Schedule and Individual Tasks for the Spring Semester of Senior Design*

## 4. Ethics and Safety

In this section we will address some possible ethical and safety concerns that we have to account for in our proposed solution. The first being that HIPAA (Health Insurance Portability and Accountability Act of 1996)<sup>[1]</sup> prevents the disclosure of a patient’s medical data without consent. As we collect data from sensors, we must make sure that all data is locally processed and is not used in any way that violates the HIPAA act.

Furthermore, the housing needs to have adequate safety measures to prevent perspiration or other conductive material from seeping in. This is done to prevent short circuits and other electrical hazards. The power management module must also be designed correctly to prevent overcharging and overheating the batteries. The communication protocol must also be designed correctly with security measures taken into consideration. Security concerns, such as unencrypted data transmissions, and so on, are among the problems that need to be addressed.

Additionally, the device must make sure that it is transmitting data to the correct Rx module if there are multiple Rx devices in the vicinity. This needs to be done to protect the user’s privacy. Lastly, in terms of

our safety, we must be careful when making connections between devices to avoid accidental short circuits and destroying equipment.



## 5. Citations

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