Senior Design 2019

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Team: Notorious EMG

Team Members: Chris Anderson, Vi Tran, Marshall Kabat, Jacob Gamboa

FUNCTIONAL SPECIFICATIONS FOR MUSCLE GUIDE SYSTEM

PROJECT DEFINITION

Team Notorious EMG's goal is to design a device that will increase the overall effectiveness of athletic-conditioning workouts. The device will assist athletes in targeting areas that are experiencing muscle fatigue, and this will decrease the amount of time spent unnecessarily training fully-conditioned muscle groups.

a. The device will have three main components attributed to the system. It will consist of a Signal Conditioning Unit (SCU), a conductive sleeve of electrodes, and the PSoC6 BLE break-a-way board.
b. Users will be able to detect muscle signals and transmit the data via Bluetooth 5.0 to a terminal for further analyzing.
c. The physical device will have conductive pieces of fabric sewn into a wearable sleeve that will be attached to three connecting snaps to allow for a wired connection between electrodes and a break-a-way board.
d. The device will be designed to be small, light, and wireless to improve usability and enhance safety by eliminating the risk of tangled wires.

GOALS

1. Safety (S)

The safety of the consumer is not just a goal, but a responsibility. A safe product is a desirable product and meeting the following specifications will also ensure that the product will be useful by eliminating the risk of injury and liability. Our device will be designed to be standard-compliant with the FDA's 510(k) review process for marketing clearance.

S001: Wire length: **The device shall be designed to minimize any loose or hanging wires. The device should be designed without any external wires to eliminate hazards associated with tangled wires.** *A conductive sleeve with external electrode snaps will interface with the PCB through the shortest wired connection possible, and the entire package will be contained within the wearable sleeve.*

S002: Sleeve Conductivity: **The device will utilize three (3) conductive strips of fabric sewn into a wearable sleeve for the purpose of detecting muscle signals through surface electromyography (SEMG). The conductive strips will be electrically connected to external snaps for the purpose of interfacing with the PCB.** *Skin irritation and other complications resulting from the removal of disposable adhesive SEMG electrodes will be avoided by utilizing a re-usable conductive sleeve. Continuity will be verified with a multimeter.*

S003: Current Exposure: **The device shall not expose the user to current exceeding 3 mA, which is the threshold for sensation. The device should not expose the user to more than 1 mA.** *This is a passive device that detects a voltage through a time-changing magnetic field, but current protection will be added by placing a diode to restrict the backflow of current through the EMG snap electrodes and into the conductive sleeve to ensure that the user is not exposed to unsafe current levels due to fault conditions.*

S004: Ease-of-Use: **The Muscle Guide shall be conveniently embedded into a wearable garment, as part of daily clothes, and worn unobtrusively by the operator. No extra setup time is required for placement of individual electrodes, fine alignment, etc. The device should be designed to eliminate interference with equipment and range-of-motion issues that could result in risk of injury.** *The unit must fit snug to ensure that it does not become tangled or pinched on or between moving parts. A poorly-fitting device could result in missed data collection. Testing/verification will take place through research, consulting with subject-matter experts, as well as through testing on ourselves.*

S005: Marketing Clearance: **The device is designed to be standard-compliant with the Food and Drug Administration's (FDA) 501(k) review process for marketing clearance.** *Determining the likelihood of receiving marketing clearance will be verified by consulting previously-completed FDA 501(k) approval process requirements.*

S006: Battery/Electrical Safety: **The device will be designed to be standards-compliant with UL 4200A and UL 1642 to protect the user from fault-current conditions and hazards associated with fire.** *Protective devices will be incorporated into the design to ensure that the user is not exposed to dangerous fault current. Improving battery technology has allowed for increased energy densities in smaller packages, and it is essential that protective measures are taken to prevent fires resulting from irreversible chemical reactions.*

2. Customer Appeal (CA)

The importance of customer appeal for the Muscle Guide is so it can provide interest to the consumer, which results in more engagement with the product. Customer appeal highlights the importance of drawing the customer towards the device to promote returning customers as well as encouraging users to share their experience with others. Having a strong customer appeal for the Muscle Guide is the difference between it being successful or a failure. Ergonomic design of the device is at every stage, thought thoroughly about. Natural movements of the athlete will impede on the overall effectiveness of the data being acquired. Factors such as weight and size of the product will distract the athlete from moving organically. By creating the product in such a way, the athlete will be able to perform naturally and will result in better feedback, data, and usability from the user.

CA001: Weight: **The EMG sleeve shall weigh no more than 1.1 pounds to allow the user to participate in exercise without hindrance. The off-board RTC unit shall weigh no more than 2 pounds. The EMG sleeve should weigh less than 0.9 pounds, while the off-board RTC unit should weigh less than 1.1 pounds.** *This will be tested using* **s***cientific scale. The athletic sleeve along with the integrated electronics should allow the user to wear it without hindering performance.*

CA002: Size: **The EMG device shall be designed to have an area of 125 x 55 x 25 (mm^3) to optimize performance.** *The electronics of the device will be compact to fit onto the athletic sleeve without affecting the user's performance. The sleeve itself will fit on 2/3 of the user's arm starting from the bicep ending at the wrist.* **The EMG sleeve unit should be able to fit on people of all statures.** It will be tested using SolidWorks dimensioning.

3. Durability (D**)**

It is important for this product to be designed for long, sustainable amounts of time. The important physical durability features of the Muscle Guide include multiple uses in the field. With high times of rain and sweat susceptibility, as well as impact forces from use, the product must be durable to withstand these outside forces. Due to this rough environment, the product needs to sustain itself through these trials. If the product breaks in any way, there is a chance data will be lost and therefore making the product undesirable. This product is intended for prolonged use, and thus, needs to last.

D001: Water Resistance: **The electronics shall be water, sweat, and dust resistant to a rating of IP56. This should entail an enclosure to separate electrical components, so the device does not fail when water may be in contact with the product.** It is imperative that the device is water resistant, as to the safety of the user and the longevity of the product itself. Our product will likely encounter vast amounts of water and sweat. Given that it will be used in the field repetitively, the device must not be altered by this magnitude of exposure.

D002: Strength: **The housing enclosure for the electronics shall have the strength to withstand a drop of up to 1 meter onto concrete flooring to withstand functional damage to internal components.** This height is an average height the product will likely fall from. **The enclosure system should have built in rib supports for force distribution dissipation and should survive a drop from 2 meters on concrete.** The height was chosen based on realistic drop heights in the field the device may encounter. The device needs to not break if dropped from this height. This will be tested using drop tests of variable orientations. This device will pass the test, if after the drops, the device still functions as intended. May obtain materials to dampen shock effects, if cracks have developed after testing.

4. Reliability (R)

To ensure that the device is useful to users, specifically athletes, the device must successful acquire the correct EMG signals from the user's muscle activities then process and report the data wirelessly through Bluetooth at a sufficient rate for the user to analyze and utilize to enhance their performance.

R001: Integration: **The EMG contacts from the snap buttons will be read through a signal conditioning unit and integrated with the MCU 1 to read and transmit data.** *Through direct contact, the conductive fabric will successfully detect a voltage signal and then transmit the data via Bluetooth 5.0 to the MCU 2 to be written to memory.*

R002: Acquisition: Wireless Data Acquisition: **MCU 2 shall receive detected muscle activity from the signal conditioning unit wirelessly from 20 feet. MCU 2 should receive detected muscle activity from the signal conditioning unit wirelessly from 30 feet.** *Wireless capability will make the device more user friendly, and it will also decrease the chance of damaging the device by entanglement of loose wires.*

R003: Signal Conditioning: **The detected muscle activity shall be noise-reduced and amplified to 30 mV. The detected muscle activity should be noise-reduced and amplified to 50 mV.** *Noise reduction and signal amplification is essential for the detection of muscle activity. Testing and verification will take place by taking measurements of the conditioned signal.*

R004: Data Processing & Reporting: **The microcontroller will process incoming data and output the results correctly and continuously.** *Correctly processing the data will require the MCU to process incoming signals in the range of 7 µV - 60 µV. The purpose of this device is to allow users to analyze their muscle activity during athletic performances, therefore processing the incoming data is a necessity.*

R005: Sampling Rate: **The software shall sample from 500Hz to 750Hz. The software should sample from 750Hz to 1,000 Hz.** The sampling rate of an EMG signal ranges from 1,000 to 2,000 Hz. The software utilizes a delay to reduce the sampling rate and improve storage.

R006: Power Supply: **The system will be designed with all rechargeable lithium-ion batteries.** *The SCU will be powered by two, 3.7 V batteries, and one CR2032 coin cell that supplies the break-a-way board. Enough battery capacity is an important design consideration that will affect the user's interaction with the device. If the device does not sufficiently power the system, data will be skewed, and results may vary.*

R007: Battery Life: **The system shall be designed with a battery life of 4 hours. The system should function for 6.5 hours.** *The SCU and boost converter will consume more power than the break-a-way board, so battery life will be determined by this subsystem. Verification will take place through life testing and through power analysis.*

R008: Data Storage: **The system will be designed to have 1.5 GB of available storage to write and store EMG data. The system shall have 2.0 GB available for data storage.** *Data will be written and stored to a micro SD card to write to and store data for user access. Verification will be done through running the program to test and see if it reads the data files in the correct directories and if it reserves an amount of storage so that unexpected terminations does not occur due to a shortage of data storage space.*

R009: Data Rate: **The EMG signal read in by MCU 2 via Bluetooth shall be transmitted at a rate of 700kbps. The signal should be transmitted at 2Mbps.** The sampling bit depth corresponds to R005 in that the faster the data rate, the larger sampling bit depth.

5. Logic (L)

A series of specifications relating to the logic needed to calculate values to the RTC box and display to a GLCD screen.

L001: Array Size: **The values of the maximum and minimum voltage potentials stored will not exceed the size of the array of 50.** *EMG signals sample at a rate of 1,000-2,000 Hz. Assuming that one rep takes about 1 second, the software is written for the user to take in samples up to 50 reps over a single period of time. Verification will take place during output analysis following code execution.*

L002: EMG Signal Display: **The change in muscle potential will be displayed graphically along an x and y axis as a waveform.** *The display of the waveform will not exceed the limits of the GLCD screen. Change in muscle potential will be seen along the y-axis. Verification will take place during output analysis following code execution.*

L003: Data Calculation: **The power calculated by the RTC algorithm is within 5% of 60mV. The power calculated should be within 2.5% of 60mV.** *The average power output of a muscle rep is approximately 65mV. Verification will take place during output analysis following code execution.*

L004: SD Card: **The initial maximum voltage potential value and the absolute maximum voltage potential value will be written and saved to an SD card.** *The initial and absolute maximum values will be used to compare power and muscle fatigue to a later session. Verification will take place during output analysis following code execution.*

Spec ID	**Requirement**	**Threshold (Shall)**	**Objective (Should)**	**Validation Method**	**Notes**
S001	Wire Length	Loose Wires Minimized	Loose Wires Eliminated	Lab	
S002	Sleeve Conductivity	Three re-usable conductive strips	N/A	Multimeter	
S003	Current Exposure	≤ 3 mA	≤ 1 mA	Multimeter	Passive Device (SEMG)
S004	Ease-of-Use	Worn Unobtrusively	Eliminate Equipment Interference	Survey's and Research on Design	
S005	Marketing Clearance	Standards Compliant with FDA 501(k) Review Process	N/A	Follow Previously-Completed FDA Research	
S006	Battery / Electrical Safety	UL 4200 A and UL 1642	N/A	Lab/Testing and Analysis	

		Standards Compliant			
CA001	Weight	EMG = 1.1 lbs RTC = 2.0 lbs	EMG = 0.9 lbs RTC = 1.1 lbs	Digital Scale	
CA002	Size	6.0” x 3.5” x 1.5”	5” x 2.8” x 0.75”	SolidWorks Dimensioning	
D001	Water Resistance	Expel Water and Dust - IP56 Rating	Eliminate a Safety Hazzard	Sweat Test or Water Pour	Further Research
D002	Strength	Withstand Vertical fall of 1 m (Concrete)	Rib Supports	Load Cell Experiment or a Drop Test	Advice
R001	Integration	Signal conditioning unit integrated with MCU 2	N/A	Oscilloscope	
R002	Acquistion	20 ft	30 ft	Tape measure	
R003	Signal Conditioning	30 mV	50 mV	MyoWare Muscle Sensor comparison	
R004	Data Processing and Reporting	Accurate, continuous processing	N/A	Experimental Data Capture	
R005	Sampling Rate	500 Hz – 750 Hz	750 Hz – 1000 Hz	Code Syntax	Array Sample Size
R006	Power Supply	Rechargeable	N/A	Parts acquisition	
R007	Battery Life	4hrs	6.5hrs	Power analysis, lab testing	
R008	Data Storage	1.5 GB	2.0 GB	Program execution and observation of storage routine	
R009	Data Rate	700 kbps	2.0 Mbps	Test plan developed during Fall quarter	Throughput = payload size/transaction time
L001	Array Size	50 elements	N/A	Code Output Analysis	
L002	EMG Signal Display	Bound of 1027 on the x and y axis	N/A	Code Output Analysis	
L003	Data Calculation	Within 5% of 60 mV	Within 2.5% of 60mV	Code Output Analysis	

L004	SD Card	500Hz	1000Hz	Code Output Analysis	

Table 1. Specifications