Senior Design 2018/2019

Notorious EMG
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Engineering Analyses

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◦All analyses should be complete – Fully described in documentation, general description of outcomes and impact on design in presentation

Power

An appropriately sized power supply is any such supply that allows for our design to meet final specifications for battery life and size/weight. In other words, the battery must power the device for a useful amount of time while not significantly contributing to the overall size and weight of the device. Two (2) 3.7 V rechargeable lithium-ion batteries of different capacities were selected to meet this goal. The breakdown for the arm unit is as follows:

Current Consumption (Boost Converter): Amps	
C_1 (100µF) = 0 A	0
C_5 (10µF) = 0 A	0
LM27313:	
I_{SHON} = 2 µA	2.00E-06
I_{FB} = 60 nA	6.00E-08
I_Q = 500 µA	5.00E-04
I_L = 1 µA	1.00E-06
R_3 (2kΩ) = 7.04 mA	7.04E-03
R_4 (2.2kΩ) = 335 µA	3.35E-04
C_3 (330 nF) = 335 µA	3.35E-04
L_1 (100 µH) = 581 µA	5.81E-04
D_1 = 581 µA	5.81E-04
Potentiometer (100kΩ) = 7.51 mA	7.51E-03
C_6 (220 µF) = 7.07 mA	7.07E-03
Load (typical) = 141 µA	1.41E-04
TOTAL	0.024096

Total Current Consumption for EMG Arm Unit:		
2 Boost Converters:		0.048192
1 SCU (Previously Calculated)		2.31E-02
PSoC63 BLE (PSoC6 - BLE MCU):		
Tx Current:		5.70E-03
Rx Current:	6.70E-03	
Active Mode Current Consumption (Assume Worst-Case):		
>> Active CPU Power Consumption (Coretex M4, 3.3 V Supply @ 150 MHz Clock)		
>>> 40 µA/MHz current consumption @ user-selected 1.1 V core operation		
>>> 40E-06(150):		0.006
Total Amps Consumed:		8.30E-02

Expected Battery Life (HOURS): 3.7 V, 300 mAh Li-ion Battery
3.61E+00

Since size and weight is not a constraint for our RTC unit, we chose a larger battery to meet our current specification without jeopardizing size or weight in any way. As such, a 1.2 Ah battery was selected to power the microSD card reader and the GLCD screen. By themselves, these two components are expected to consume 260 mA of current. A second MCU will receive the wirelessly-transmitted muscle signal for an expected total current consumption of 272.7 mA. Therefore, the expected battery life for the RTC box is **4.4 hours**.

Size & Weight

This device is intended to be portable, small, and lightweight for the user to use while exercising. A weight and size analysis are completed to ensure that this device is not inconvenient for the user or makes their exercise regime more difficult. The vision for this device is to be the size and weight of a typical cell phone. As it stands, the size and weight are as follows:

EMG Unit					
Item	Material	Dimensions: mm			Weight: Lbs. (g)
		Length	Width	Height	
On/Off Switch	NA	5.00	5.00	15.0	0.002 (1.09)
EMG Battery	Li Polymer	35.00	18.90	5.10	0.018 (7.93)
Electrodes	PVC, Brass	60.00	15.30	7.05	0.028 (12.60)
PCB (populated)	Epoxy Resin, Copper	167.64	80.01	1.74	0.154 (69.91)
EMG Housing	PLA	193.00	106.00	31.15	0.241 (109.54)
EMG Lid	PLA	193.00	106.00	10.00	0.093 (42.10)
Hardware	Steel	20.00	3.00	5.00	0.020 (9.10)
PSoC 6 Breakaway	Epoxy Resin, Copper	100.00	25.15	5.00	0.020 (9.07)
Electrode Sleeve	Nylon, Polyester, Polyurethane	355.60	108.00	1.00	0.051 (22.94)
				Total Weight:	0.549 (248.97)

RTC Unit					
Item	Material	Dimensions: mm			Weight: Lbs. (g)
		Length	Width	Height	
RTC Battery	Li Polymer	51.20	33.21	5.80	0.048 (21.78)
On/Off Switch	NA	5.00	5.01	15.00	0.002 (1.09)
PCB (non-populated)	Epoxy Resin, Copper	114.30	104.14	1.74	0.107 (48.37)
LCD Screen	NA	64.10	43.10	10.30	0.036 (16.37)
RTC Housing	PLA	152.60	114.24	15.10	0.156 (70.74)
RTC Lid	PLA	152.60	114.24	19.00	0.174 (78.72)
Hardware	Steel	20.00	3.00	5.00	0.020 (9.10)
PSoC 6 Breakaway	Epoxy Resin, Copper	100.00	25.15	5.00	0.020 (9.07)
SD Card	NA	25.00	20.00	5.00	0.009 (4.00)
				Total Weight:	0.564 (255.99)

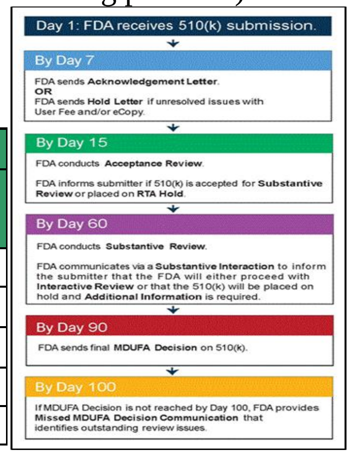
As the size and weight stands, we have met both our specifications. For the EMG unit, we have almost hit our threshold target of 0.5 lbs. As we go through the process of revising our PCB design, we are more than confident we can achieve our specifications for weight. With some new improved CAD, it is probable we will also achieve our objective of 0.35 lbs. for the EMG unit.

As for the RTC unit, we have fully met and satisfied specifications pertaining to the RTC unit. We set out to achieve a threshold of 0.85 lbs. with an objective of the RTC weighing less than 0.6 lbs. With our current weight at 0.564 lbs. we are not worried about this moving forward. In fact, this gives us additional room to add a larger LCD if we feel the need to.

FDA Compliance

In accordance with 21 CFR 807.87(h) and 21 CFR 807.92 the Muscle Guide is a portable surface electromyography (sEMG) monitoring device that records the summation of muscle electrical activity from groups of muscles. Hence, the need for medical device clearance by order of the 510(k)-submission process with the FDA. Surface electromyography (SEMG) devices approved by the U.S. Food and Drug Administration (FDA) include those that use a single electrode or a fixed array or multiple surface electrodes. Examples include but are not limited to: CMAP Pro (Medical Technologies), TeleEMG LLC Focus (Focus EMG), and GRINDCARE MEASURE (Dental Muscle Monitoring). The Muscle Guide must also comply with the marketing clearance set forth. Specifically, the Muscle Guide must comply with CFR Code of Federal Regulations Title 21. The conditions set forth by Title 21 states that the Muscle Guide must also meet Title 21 Part 890 – Physical Medicine Devices. The Muscle Guide meets requirements of FDA CFR 21 Title 21, Part 890 Subpart B (890.1175 - Electrode cable), (890.1375 - Diagnostic electromyography), and (890.1575 - Force-measuring platform).

FDA Compliance via 510(k) – Marketing Clearance		
Federal Code Regulation Number (Title 21):	Device Class (I,II, or III)	Summary: Approved or Denied
21 CFR 807.87	N/A	Approved
21 CFR 807.92	N/A	Approved
21 CFR 890.1175	II	Approved
21 CFR 890.1375	II	Approved
21 CFR 890.1575	II	Approved



Wireless Data Acquisition

One of the largest parts of this design is its capability to relay the information from the arm unit to the RTC unit wirelessly. Because this is geared towards athletes, we expect there to be a second person nearby, be that a spotter or professional trainer to assist them as they go about their sets. A trainer will want to be close enough to help, but far away enough so they do not interfere. Based off this, we can estimate that the average trainer will stand roughly 4.5 feet away from their client. This is our baseline then. Using the PSOC 6's RSSI resolution of 4 dB (which in the calculations becomes –4 dB, just because of how Cypress sets up their datasheets), we can use the equation $d = 10^{(Tx - RSSI) / 20n}$, where n = path loss value = 2 for free space. With a transmission power of 4 dBm, the maximum distance works out just over 2.5 m. However, because both antennae are in boxes and because people are imprecise, we want to set the max range to 6 feet.

EMG Data Analysis

An important function of EMG is to measure how well a muscle can be activated, therefore we plan to use this aspect of EMG to evaluate weight lifters. Medical professions practicing electromyography use the term maximum voluntary contraction, which is used to analyze the peak force generated by muscles, specifically in core-related exercises. Therefore, the amplitudes of the EMG signal have the potential to provide a measure of the magnitudes of the muscle force. Another value that medical professionals practicing EMG analyze is the average rectified EMG, or AVR. AVR is used to detect muscle fatigue in users. Muscle fatigue can be detected through electromyography through an increase in the mean absolute value of the signal, increase in the amplitude and duration of the muscle action potential and an overall shift to lower frequencies. We plan to detect increases in amplitude and calculate the potential difference between the initial reps with the final reps to represent how much muscle fatigue the user has experienced during use.

Bit Depth

The bit depth, or resolution, is used to demonstrate the performance or accuracy of a device. The Muscle Guide uses an analog-to-digital converter to transform the analog EMG signal to a digital number. It does this by first transforming the analog voltage to a binary number before fully converting it to a digital signal. This number of binary bits that represent the final digital signal is what determines the ADC resolution, or bit depth. Therefore, by calculating the resolution of the ADC, it tells us how accurate, or how close the digital output is to the theoretically expected analog inputs, in this case the EMG signals. Keep in mind that the digital signal is purely an approximation of the actual EMG signal at a certain point in times because voltages can only be accurately represented as analog signal. The number of bits an ADC handles can be used to calculate the resolution. An n-bit ADC has a resolution of one part in 2^n, therefore with the PSOC6's 12-bit ADC, it will have a resolution of one part in 4,096, where $2^{12} = 4{,}096$. Both the MCU used for the EMG device and the RTC box have a maximum input of $5V_{DC}$ can resolve the measurement into $5V_{DC}/4{,}096 = 1.22$mV/bit. This value of 1.22mV is specified with respect to the full-range reading of the ADC. Therefore, the absolute minimum level that the ADC can measure is represented by 1 bit of the ADC voltage range. In other words, this value tells you how many bits of the digital output represents useful or accurate information from the input signal.

Data Transmission

The analog muscle signal is converted to a 12-bit digital signal that is sampled at 1,000 Hz. This yields 12 kb/s or 1.5 kB/s. Overhead and error correction packets must also be accounted for to ensure that data is not lost. The value that we are interested in is the size in bytes of the attribute used to respond to exchange requests from the GATT Client. The Maximum Transmission Unit (MTU) size of an attribute has a valid range of 23 – 512 bytes. Assuming the worst-case scenario, our required data transmission rate to correctly and continuously process and transmit the digital muscle signal via Bluetooth is 16.1 kb/s or 2.01 kB/s.

Data Storage

The data that the Muscle Guide must store are IMU data, timestamps, and the calculated results of muscle fatigue and maximum power. The Muscle Guide will store the EMG data to a MicroSD card embedded with the MCU. Using either three or four digital pins to read or write, the MicroSD has 2.0GB of available storage. EMG signals are typically sampled at 1,000-2,000 Hz. In other words, a single muscle voltage value is recorded 1,000-2,000 times per second. The Muscle Guide uses an analog-to-digital converter within the PSoC6 MCU to convert the raw analog EMG muscle potential signal to a digital signal that can then be read and analyzed by the PSOC. The built-in ADC of the MCU outputs 12-bits. Therefore, because the EMG signals sample at 1,000-2,000 Hz, the ADC will output 12,000 bits of EMG data per second at the least and 24,000 bits of EMG data at the most. Ideally, the Muscle Guide has a full capacity to read and store constant EMG data for a maximum of 6 hours. Therefore, it must read a total of 259,200,000 bits over a period of 6 hours. Because there is a total of 8 bits in a byte, the necessary space to store 259,200,000 bits of IMU for 6 hours is 32.4MB.

Aside from the IMU data, the Muscle Guide will also need to store timestamps. Time space are used to track changes in data and updates every time the data changes. In this case, the Muscle Guide will use timestamps to keep track of when the muscle signal changes, in this case at a rate of one second. A single timestamp takes up a total of 4 bytes. Again, the Muscle Guide is to operate to store data continuously for a total for 6 hours. Therefore at 6 hours, a total of 21600 seconds, at 4 bytes per timestamp taken per second, the timestamps will require a total of 86.4kB.

Lastly, the device will store muscle fatigue data and maximum power values. 4 bits are represented by a single digit. Predicting that a weight lifter takes approximately 4 seconds to complete one rep with rate, the Muscle Guide will calculate and report muscle fatigue values in 4-seconds intervals to successfully record multiple repetitions at the same point. By doing so, we can assure that the muscle fatigue values and maximum values are accurately compared at these same points. The Muscle Guide intends to report muscle fatigue and power values as 4-digit values, carrying to the second decimal value. Therefore, to report two 4-digit values every 4 seconds for 6 hours, the Muscle Guide is essentially reporting a total of 43,200 digits. Because 4 bits are represented by a single digit, 43,200 digits would take up a total of 172.8kB of data. Additionally, 10MB will be allocated for BLE overhead.

In conclusion, for the Muscle Guide to store all necessary IMU data, timestamps, and calculated values, it requires a total of 32.66MB storage. Based on this analysis, we can confirm that the 2.0GB of storage on the MicroSD card can easily accommodate for the needed 42.66MB of storage for the Muscle Guide.