Senior Design 2019

Deliverable: Engineering Analyses (Bit Depth, Data Transmission, Data Storage)

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Team: Notorious EMG

Team Members: Chris Anderson, Vi Tran

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 = 1.22mV. 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. Therefore, our required data transmission rate to correctly and continuously process and transmit the digital muscle signal via Bluetooth is **1.5 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.