Introduction

Problem:

- Many people are new to fitness workouts and do not have a proper understanding of what muscles are being used when doing specific exercises. Even if they do understand, they may not perform the exercises correctly and therefore, not be activating the muscles that they would expect to.

Solution:

- Our solution is to create a fitness device that specifically focuses on muscles in the arm including biceps(front of upper arms), triceps(back of upper arms) and forearms(lower arm). This device would be in the shape of a sleeve that the user would put on while working out their arms. This sleeve would contain multiple sensors throughout to detect various muscle activity. Additionally, each sensor would have an LED corresponding to it which would light up if the sensor recognizes muscle activity. The main goal would be for users to be able to recognize the muscles they are activating through the sleeve and to be able to make self adjustments if they realize they are not activating the correct muscles corresponding to the specific exercises they are performing.
- In order to isolate which muscle is being targeted, we plan on placing EMG sensors and LEDs near the locations of different muscles. Our goal is to create a sleeve where muscles that are being contracted and used more, have a brighter illumination compared to muscles that may not be used as much during an exercise. For example, if someone is performing bicep curls, they would be contracting and using the bicep the most, but another muscle such as the tricep could also be used to a lesser extent. In this case, the EMG sensor near the bicep would provide a larger amplitude value compared to the EMG sensor near the tricep. The amplitude returned by the sensor defines the strength and intensity of the muscle being contracted. Using this amplitude value, the LED corresponding to the bicep EMG sensor would light up brighter than the LED corresponding to the tricep EMG sensor. This method provides the user with information regarding all muscles on the arm which are activated during the exercise as well as the intensity of which they are being used.

Visual Aid:

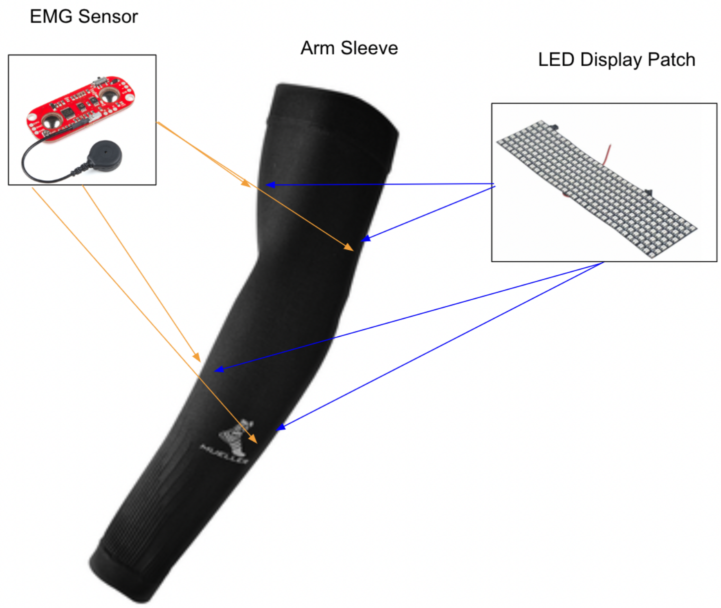


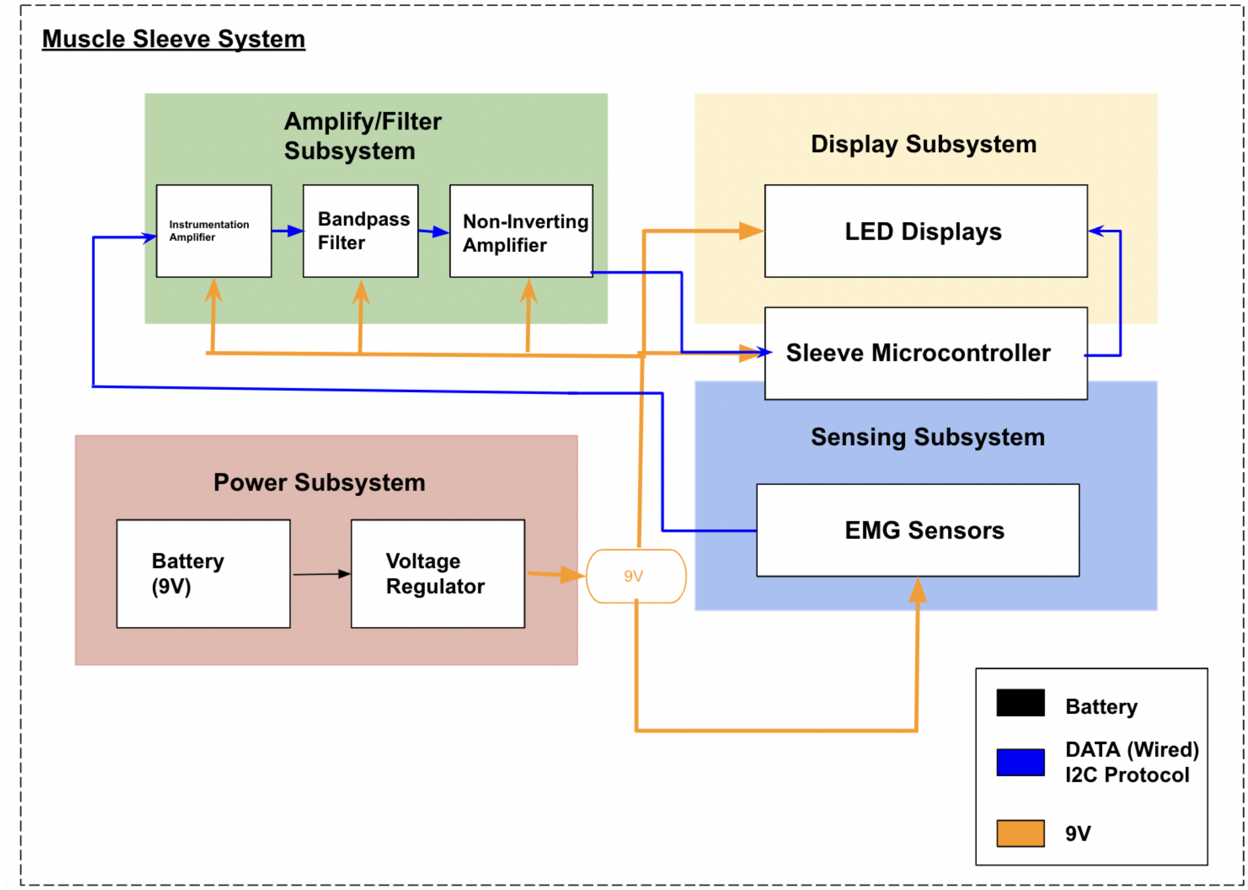
Image of the arm sleeve integrated with LED display and EMG sensors

High Level Requirements list:

- The device should function for at least one hour during workout.
- The arm sleeve is able to display all muscles being activated even if some muscles may not be used as much as others
- LED illumination should vary based on muscle activity in a specific muscle group during a performed exercise

Design

Block Diagram:



Subsystem Overview:

- The power subsystem provides the voltage to turn on all the other subsystems with 9V. The EMG sensors are the main starting point of the overall design. Once voltage is circulating, the EMG sensors detect muscle activity and generate a real time signal which is then sent to the amplifying/filtering subsystem. This subsystem amplifies the given signal from the EMG sensors to a max of 9V, and then runs a bandpass filter on the generated amplified signal to remove any noise. This filtered signal is then sent to the microcontroller where it will then perform a ranking of the amplitudes of the signal and then take the percentage difference between each ranking pair. Once these values are determined, the microcontroller will provide an input to each LED corresponding to a specific EMG sensor and light up based on a ratio compared to the input from other EMG sensors.

Subsystem requirements:

Filter Subsystem

- For this device, using a bandpass filter can be a useful technique in order to filter out the noise in the EMG muscle activity sensor system.
- We learned that EMG signals are low in amplitude and therefore, they can be susceptible to a lot of interference and noise due to people's movements in a workout environment. This bandpass filter can help us improve the accuracy of the EMG signals. We learned that EMG signals range from 20 Hz to 500 Hz, with the most relevant information that we would require falling between the frequencies of 20 Hz and 250 Hz. Thus, we would be using the bandpass filter to focus on this specific frequency range within the EMG signal and cutoff frequencies to capture the relevant signal components. We would be using real time filtering which is applied as the signals are acquired. Lastly, after filtering, these signals would be processed by the microcontrollers on the sleeves so that the LED displays would be illuminated with the intensity level corresponding to the muscle that is getting worked out the most.
- We decided to use a bandpass filter over a Lowpass filter as a Lowpass filter would allow frequencies under a certain cutoff frequency. This would not be ideal for data collection using an EMG sensor as most of the relevant information that we would receive from the muscle activity is in the higher frequency range(20Hz - 250Hz). In contrast, a BandPass filter can allow us to fine tune the frequency settings of the filter and help us target the specific arm muscles we would be monitoring.

Amplifying Subsystem

- We believe that we would require some special techniques in order to eliminate the noise in the system and to amplify the relevant information we obtain from the sensors. It could happen that, due to excess noise from the movement during workouts we are unable to eliminate noise from the signal and are not able to accurately access the muscle activity taking place.
- Due to this, we would be using an instrumentation amplifier which is a circuit with high impedance which amplifies the difference between two input signals. Because skin has high output impedance, its voltage is easily understood by thinking of the skin impedance and circuit impedance as resistors in a voltage divider. If both resistors are of equal value, only half of the input voltage will be measured across the circuit impedance. As the circuit impedance is increased above the skin impedance, more voltage will be applied across the circuit. We want to maximize the voltage going into the circuit. After the signal then goes through the BandPass filter with the cutoff frequencies between 20 - 500 Hz, we can increase the output signal to be read on an oscilloscope by using a non-inverting amplifier.

- For this project we decided to use instrumentation and non-inverting amplifiers over operational amplifiers as we realized that they might not have the ideal input impedance needed for EMG sensors. We learned that EMG sensors require high impedance so that they avoid loading the electrodes. However, op-amps could degrade the EMG signal quality due to their lower input impedance compared to instrumentation amplifiers.

EMG Sensor Subsystem

- The electromyogram (EMG) sensor is used to detect electrical activity from a muscle using conductive pads that are placed directly on the skin. It is able to capture muscle contractions.
- For this device, we plan on creating a sleeve where we would be placing EMG sensors on the main muscles of the arm such as the biceps(front of upper arms), triceps(back of upper arms) and forearms(lower arm) so that it is able to detect muscles being contracted while people work out those specific muscles in the arm using surface electrodes. The sensor would be able to clearly show significant differences in electrical activity when different weights are used. Electrical activity that is detected by the EMG sensors is displayed on an oscilloscope.
- The raw output voltage of the EMG sensor would be .5 mV however, when we pass this signal through our amplification subsystem consisting of the instrumentation amplifier and the non-inverting amplifier with an amplification factor of 100 for each, the final amplified voltage we would obtain would be 5 V. This final output signal could then be analyzed using the oscilloscope for clear EMG signal analysis.
- Additionally, the most relevant information required from the sensors would fall between the frequencies of 20 Hz and 250 Hz. The EMG circuit would require three electrodes: positive input, negative input and ground. For example, in order to measure the activity of the bicep, the elbow would be a suitable placement for ground and the positive and negative electrodes should be placed on the upper arm. Using the data that is provided to us by each sensor, the microcontroller would be used to rank their outputs based on amplitude value from greatest to least so that we are able to understand the order of intensity in which the muscles are being worked out.
- A EMG sensor model used is DEV-18425 from MYOWARE because it provides a rectified signal which will be effective to reduce the noise while it is compatible with 3.3-5V. Moreover, it is suitable for wearable projects since it has a great portability compared to other models. We decided to use EMG sensors over other sensors such as accelerometers because we learned that accelerometers function based on the detection of changes in motion, that is, they primarily detect changes in velocity over time. However, muscle activity is measured through muscle

contractions that generate electrical signals which are best measured using EMG sensors.

LED Display Subsystem:

- For this device, we wanted to use an LED illumination display for the users to be able to recognize the muscles they are activating through the sleeve and to be able to make self adjustments if they realize that they are not activating the correct muscles corresponding to the specific arm exercises they are performing.
- The signal from the EMG would be sent to the microcontroller. As mentioned above, the microcontroller would be programmed to rank the outputs of the sensors of the different arm muscles based on their amplitude value from greatest to least. In order to provide an accurate illumination for the LEDs for each sensor, we plan on taking the percentage difference from each pair ranking and using that to determine the LED intensity output. For example, in the exercise: a close grip chin up both the bicep and tricep muscles are activated. The bicep sensor data through the EMG shows a frequency of about 80 Hz whereas the tricep sensor data through the EMG shows a frequency of about 100 Hz. Their percentage difference is 22% so, the LED illumination for the tricep would be 22% more intense than for the bicep.
- Using Digital Potentiometer to manipulate the brightness by software since we have to sort the order of the muscle parts by activation intensity. We are using Digital Potentiometer instead of other methods such as giving delay to the LED because delay to a LED will cause some delay to other LEDs as well, causing the delay of the whole system. Equation for Resistance for each LED: R = Minimum Resistance * (Max Frequency/Each Frequency)

Power Subsystem :

- The power subsystem interacts with all other components in other subsystems as it provides a constant voltage of 9V to the rest of the device. Power needs for LED: Since the power for LED is not fixed, the max power the LED makes will be calculated

Tolerance Analysis

- One subsystem that poses a risk for successful completion is the sensor subsystem. When the EMG sensors are stand alone with no muscle detection, they output a voltage around 0 microvolts and when the muscle is activated they detect a voltage of about 0.5mV before amplification and 5V afterwards. If the sensors do not detect a proper muscle activation even when one is occurring, there can be a failure in the product working as the LEDs may not light up accordingly. Considering 5V is the maximum output of the sensors after amplification when it does detect muscle activation, we can say that there is a 10% tolerance on the sensor output to check if a muscle is activated. This means any output within 4.5-5.5V is considered muscle activity.

- Another subsystem to take into consideration is the power subsystem. We require the battery to provide power for one hour, the length of an average workout. Below are the calculations for the total power and voltage required for the overall system:
- 9V * 1µA (max current from data sheet) * 64 (# of led for each pad) * 3 (# of pads) = 1.728 mW
- Power needs for EMG sensor: 9V * 9mA(current from data sheet) * 3 (count) = 243 mW
- Power needs for Amplifier: 9 V * 0.3 mA (Quiescent current per amplifier) * 1 (count) = 2.7 mW
- Power needs for Filter: 0 W since it does not use power.
- Total power needed: (1.728 + 243 + 2.7) mW * 1hr = 247.428 mW
- Total Voltage/Current needed: 9V at 0.0274 amps

Ethics and Safety:

- The IEEE Code of Ethics details how there should be a responsible and respective working environment during professional activities. As a group we will make sure to follow this guideline by respecting each other's opinions and treating everyone equally. Additionally, we will be mindful of each other's schedules and make sure to create a good working environment so we can all feel welcome. Our project requires us to solder which means we will need to use the senior design lab a couple of times. During these scenarios, we plan to keep each other accountable and work together when soldering. We will ensure the safety of each teammate and follow all regulations in place in the senior design lab.

Citations

"IEEE Code of Ethics." *IEEE*, www.ieee.org/about/corporate/governance/p7-8.html. Accessed 26 Sept. 2023.

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