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Bionic Hand Team

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Using Electromyography for Control of Prosthetics

Designing a 3D-Printed Myoelectric Hand

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Abstract

The project goal is to design a low-cost prosthetic hand controlled by a PIC18F25K22, allowing its user to perform simple tasks that require a greater dexterity than what a mechanical prosthetic can deliver. Electromyographic signals, from electrodes on a single muscle group, will be processed to control the hand's movement. Grip settings, which define open and closed positions for each digit, are used to simplify the process. This allows common actions, such as grabbing a door handle, to be accomplished while reading from only one muscle group, rather than one for each finger. Pressure sensors on the fingers provide feedback to the user, and prevent the system from damaging itself by forcing the digits into an impossible position.

Project Overview

Our design focuses on increasing the accessibility and affordability of a prosthetic hand, without sacrificing its quality. To accomplish this end, we used CAD to create all of our parts. This gave us increased flexibility in our design, and significantly decreased the cost. After numerous iterations, we settled on a design for the hand that met our needs. The various profiles of the CAD model for the final hand design are shown below in Figure 1.

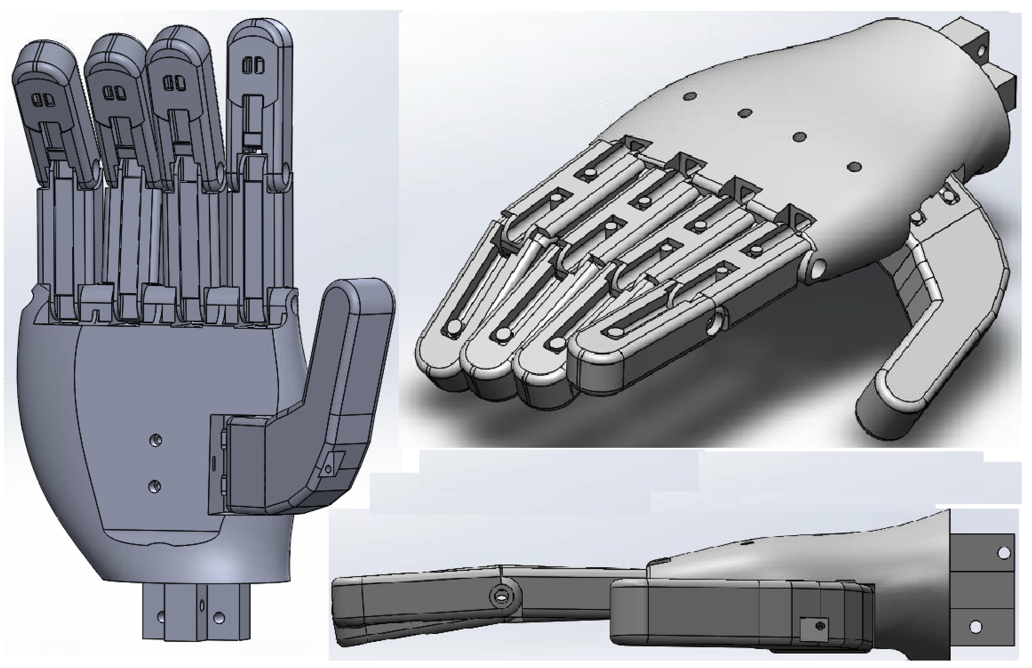

Figure 1: CAD model of the final hand design

In order to reach the design goal, our team developed a set of requirements and constraints for the project. These served as guidelines for the technical decisions, such as choosing servos over linear actuators or selecting electrodes. Some of the most important ones are listed below.

Requirements & Constraints

1. The hand will be controlled by EMG readings from the user's arm.
2. The hand will be constructed of easily replaceable, 3D-printed parts.
3. An OLED display will convey pertinent information to the user.
4. Six, preset grip configurations will determine the fingers' positions.
5. Controlling the bionic hand must be intuitive to new users.
6. The bionic hand will utilize a single PCB for its circuitry.
7. The unit cost of the hand must be less than $1000.

Hardware Overview

The hardware selections provided input to the microcontroller through sensors and a user interface, as well as output to the user through a vibrator and display.

Incorporating an Electromyography (EMG) sensor into the design allowed the user to control the movement of the prosthetic through motor control of the bicep. Pressure sensors in the finger tips allowed the system to determine when an object has been grasped and the servos need to stop closing the fingers.

The user interface consisted of four buttons in order for the user to input commands to change settings and cycle through various grip options as well as hold the prosthetic in either an open or closed position rather than responding to the EMG input.

A haptic feedback vibrator included on the PCB alerts the user to changing conditions, i.e. the hand is closed all of the way, the hand is frozen open or closed, or there is low battery.

An OLED display presents the current status of the hand in a clear concise way, allowing the user to navigate through the menu and settings using the buttons to change grips, EMG sensitivity, and brightness.

Software Overview

The prosthetic is being controlled by a PIC18F25K22 microcontroller programmed using the MPLAB IDE with C. The PIC18 will receive the signals from the EMG sensor using the internal ADC and will then use that data to move the corresponding servos via PWM signals. The EMG threshold value can be chosen by the user and will be stored in the PIC18's EEPROM so that it can retain its value even when the hand is powered off. The user can choose to auto-calibrate the threshold value which will give them a result somewhere in between the relaxation and the flexion muscle states.

EMG

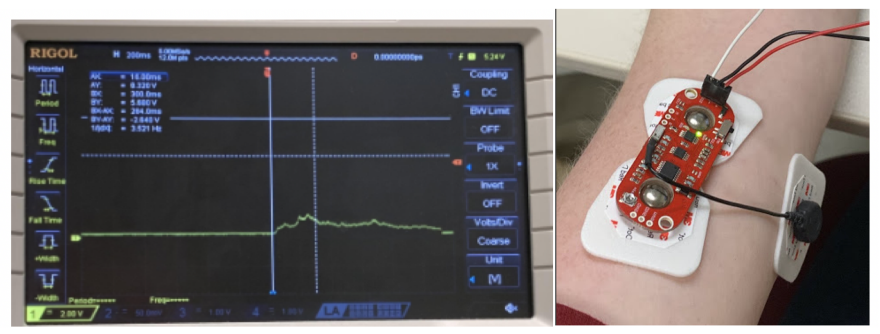

Figure 2: Example EMG wave and electrode placement

Electromyography (EMG) measures the electrical activity across a muscle. In this application, an EMG sensor is used to measure when the bicep is being flexed in order to have motor control of the prosthetic. Flexing the bicep in order to close the hand, while relaxing the bicep opens the hand gives an intuitive operation of the hand to the user.

The EMG sensor requires three electrodes to measure the voltage at either end of the muscle and on a different muscle in the arm as reference. These three signals are measured through a series of differential operational amplifiers and buffers to output the envelope of a single rectified signal, which increases as the muscle is contracted and decreases as the muscle is relaxed.

The output of the EMG sensor is converted to a digital value through an ADC on the PIC18 microcontroller to be compared to a set threshold level. After the EMG signal goes above a certain threshold, the servos will close the fingers. When the signal passes back below the threshold level, the fingers will open.

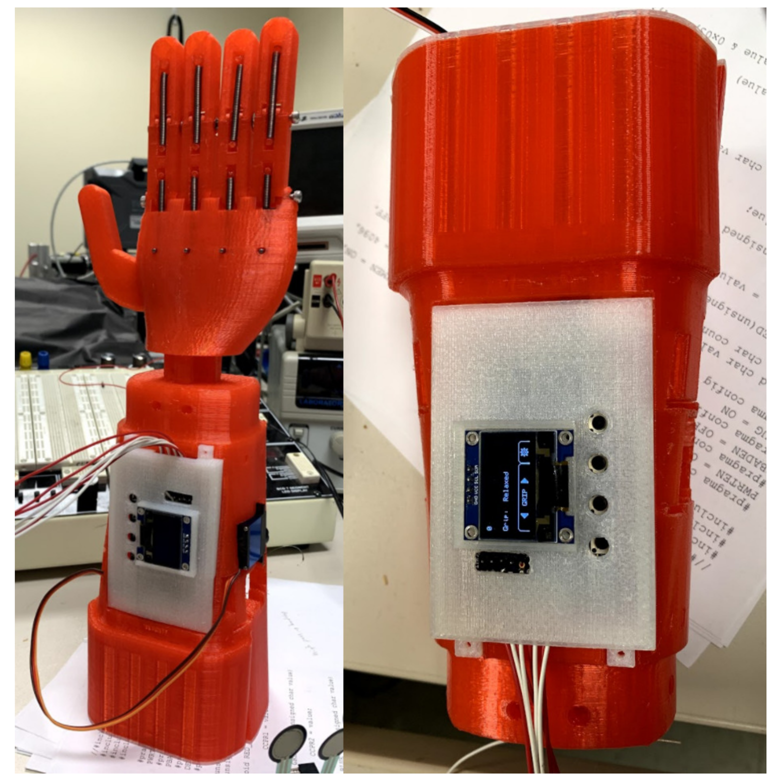

Figure 3: Assembled Hand Prototype

Acknowledgements

This project was undertaken in partnership with the Hands of Hope Foundation, and we are extremely thankful for their assistance in printing our components and making design choices. Additionally, this project would not have been possible without our advisor, Dr. Fang, who has been a source of knowledge and encouragement through the whole process.