



UNIVERSITY OF
ILLINOIS
URBANA - CHAMPAIGN

Affordable EMG Device

Electrical & Computer Engineering

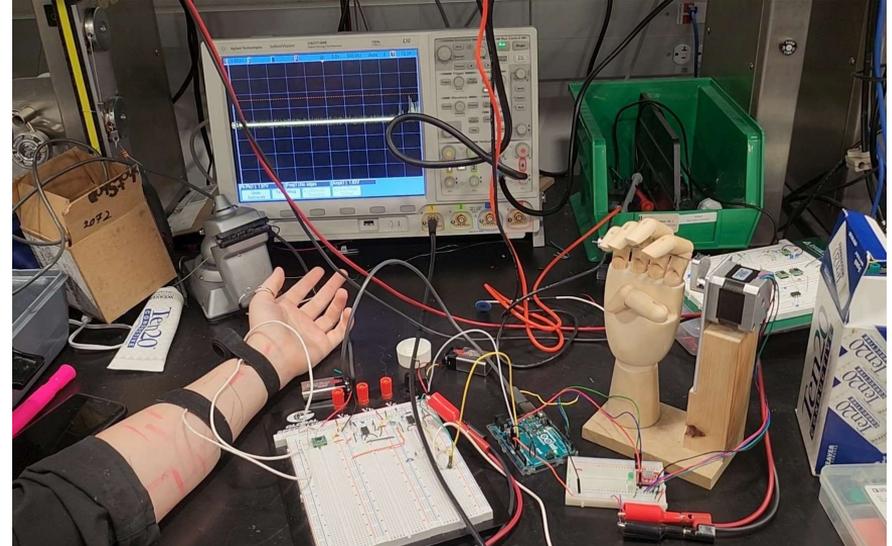
Team #9

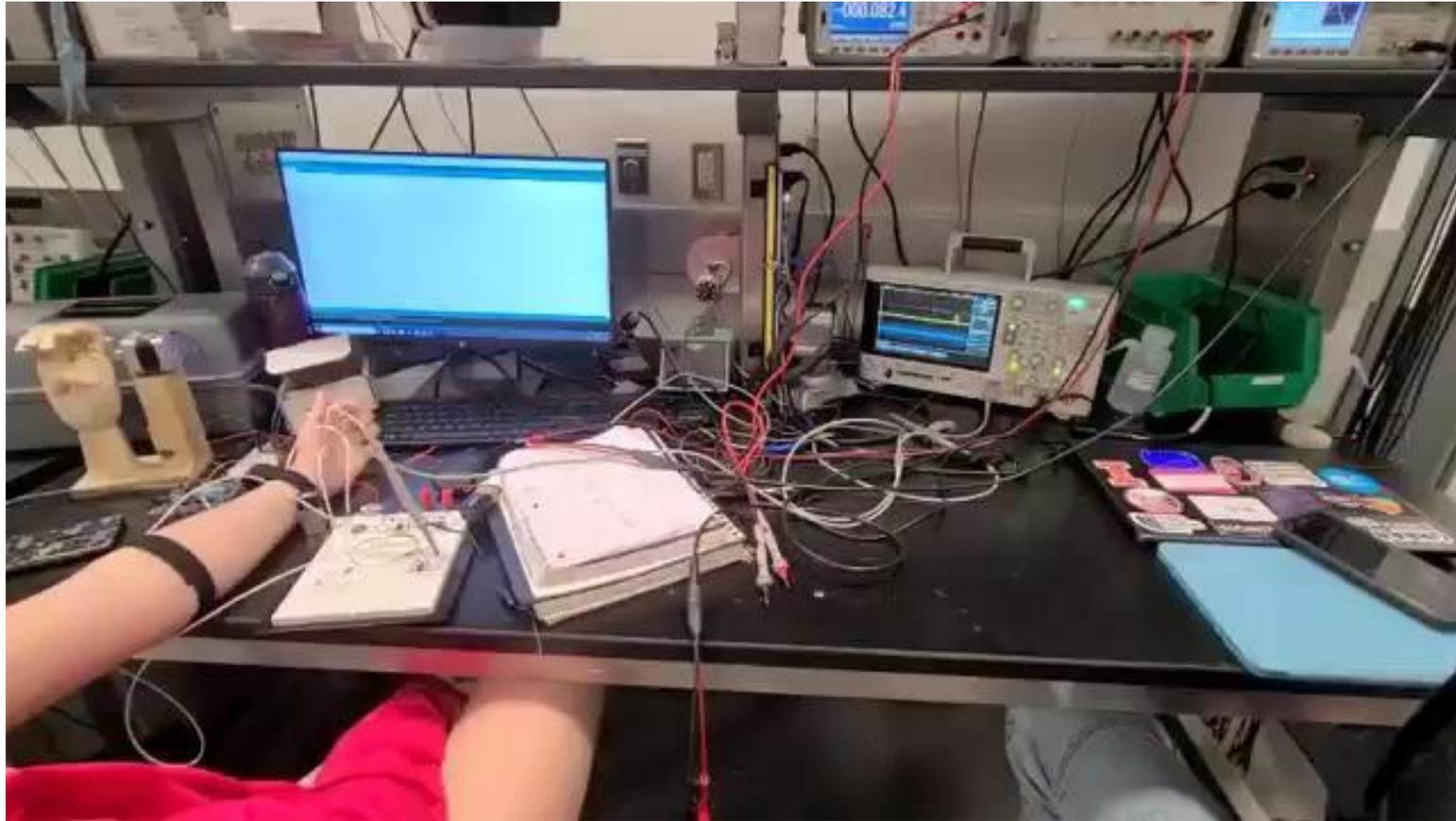
By: Leanne Lee, Minwoo Cho, and Kathleen Beetner

- Average myoelectric prosthetic unaffordable
 - Partial upper limb loss: \$18,703
 - Total upper limb loss: \$61,655

- High costs prevented 9 out of 10 people worldwide from accessing the prosthetics they need

- Affordable electromyography (EMG) device to control prosthetics
 - EMG: Technique used to record electrical activity in muscles
- Universal and easily removable design to fit all designs

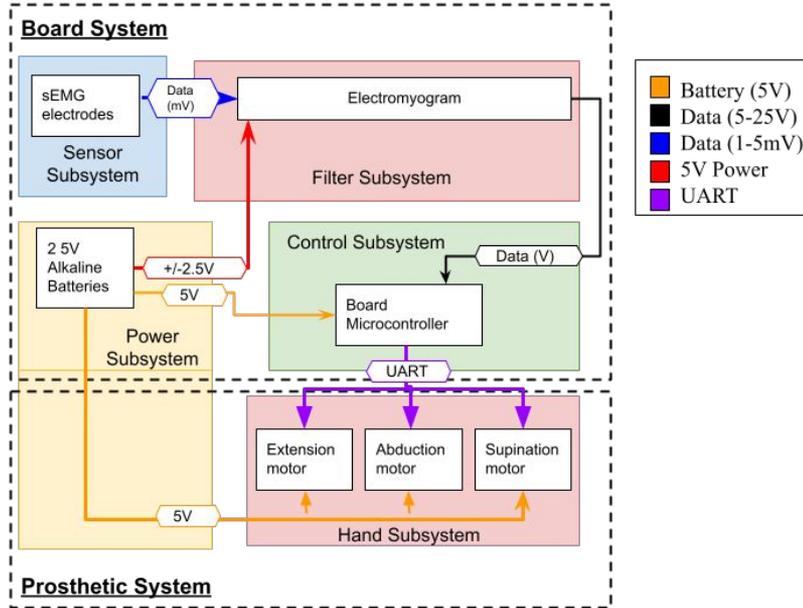




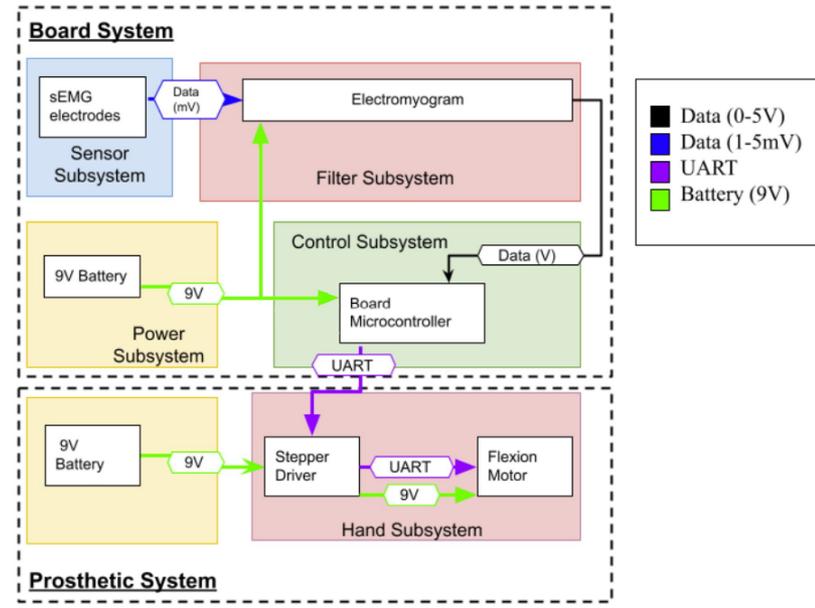


Design Changes

Block Diagram



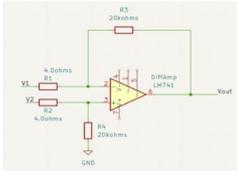
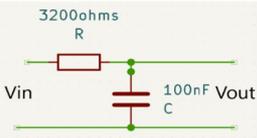
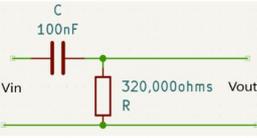
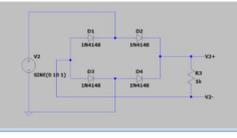
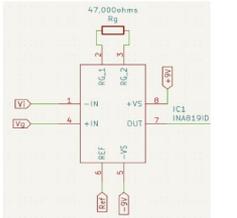
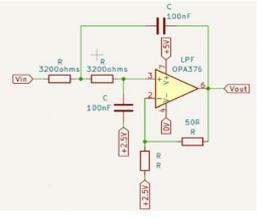
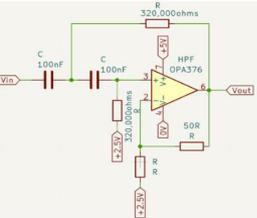
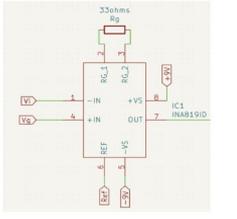
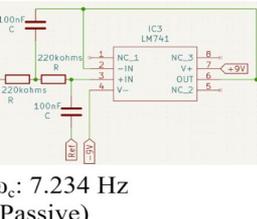
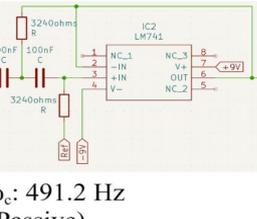
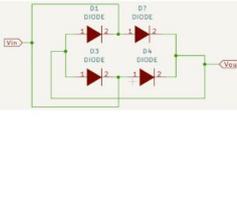
a.



b.

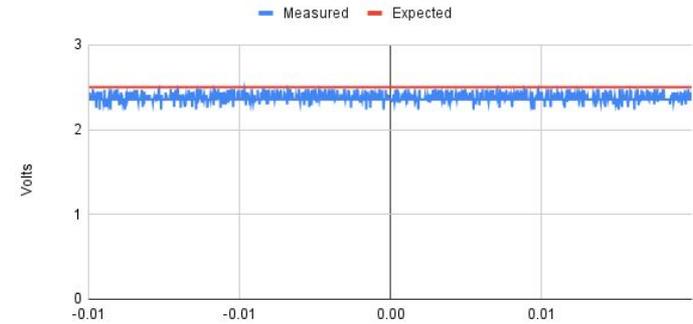
Board - Filter Subsystem Design Changes



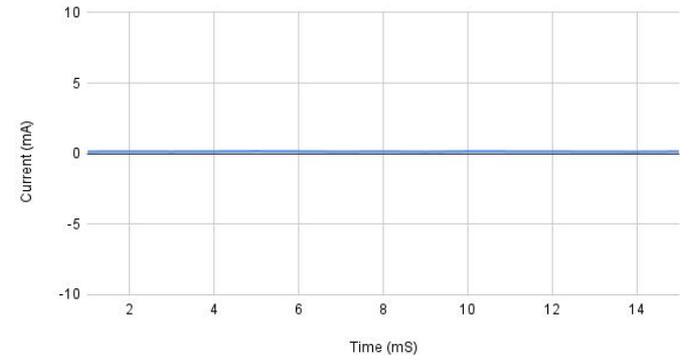
	Amplifier	Low-Pass Filter	High-Pass Filter	Rectifier
Original Design	 <p>Gain: 5,000 V/V</p>	 <p>ω_c: 497 Hz (Passive)</p>	 <p>ω_c: 4.97 Hz (Passive)</p>	
Potential Design	 <p>Gain: 2 V/V</p>	 <p>ω_c: 497 Hz Gain: 50 V/V</p>	 <p>ω_c: 4.97 Hz Gain: 50 V/V</p>	Not Needed
Current Design	 <p>Gain: 1,516 V/V</p>	 <p>ω_c: 7.234 Hz (Passive)</p>	 <p>ω_c: 491.2 Hz (Passive)</p>	

- Change in operational amplifier
 - New power rails +/-9V
 - 2.5V step down not needed

9V -> 2.5V Step Down



9V -> 2.5V Output Current



Microcontroller - Design Changes



Original design:

ATmega328P with machine learning

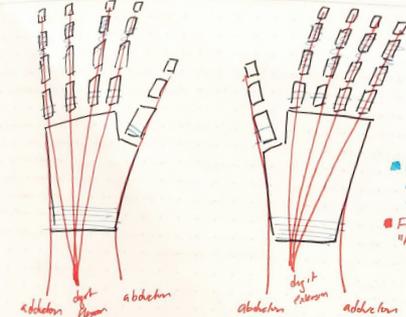
Altered design:

Arduino Uno with rolling average



Prosthetic Hand Design Changes





Scope of Project:

The team has chosen to focus on six primary movements that involve superficial (easily accessed) forearm muscles:

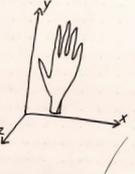
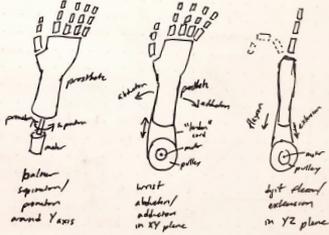
- wrist abduction
- wrist adduction
- digit flexion
- digit extension
- palmar supination
- palmar pronation

In the diagram at left, the region of a hand model is shown in the supinated and pronated positions so to how this will be mechanically fulfilled. A screw is fixed on a pulley which has a [-1,0,1] positional range for digit flexion/pronation/extension and wrist adduction/pronation/abduction. A flawed

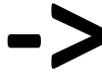
Prototypal Motor Attachments

servo controls the supination/pronation of the base. The EMG unit is mechanically separable from the prosthesis since the hand is primarily a proof-of-concept and not a focus of the project. The motor/pulley set-up is described in the diagram to the below right of this text. Limiting the number of motors reduces the cost and power of the mechanical design which allows more focus on the PCB and electrical aspect of the project. The anticipated movements occur in 3 separate planes.

The project is required to demonstrate complexity, but achieving a large range of hand motions within the semester feels unrealistic.

Mechanical Projection of Hand Movements





Requirements and Verifications

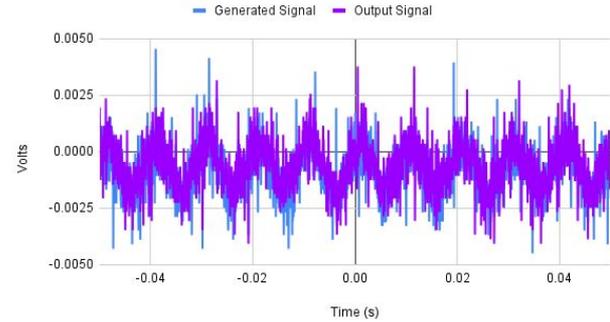
Functionality of Sensor Subsystem



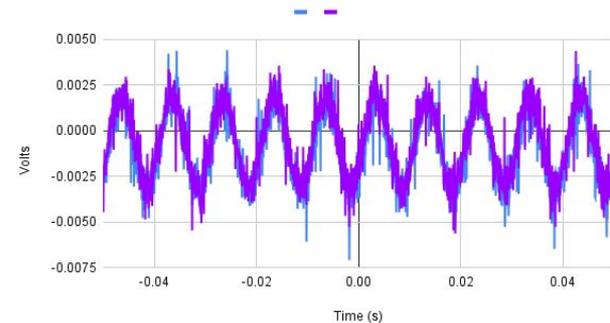
- Noisy
- Low cost



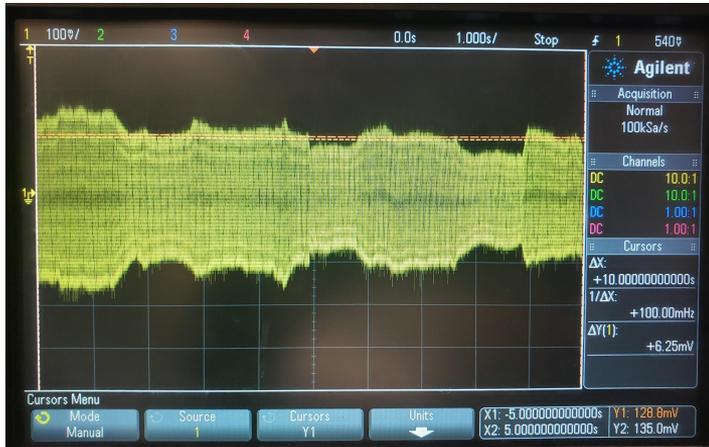
Electrode Output at 1mV 100Hz



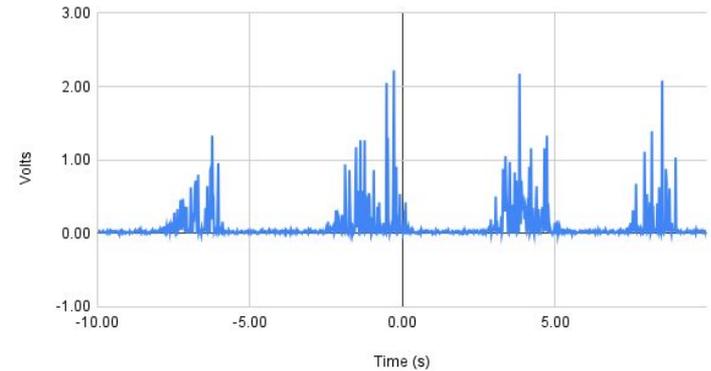
Electrode output at 2.5mV 100Hz



Filter Input -> Output



Subject 1 Flexion/Extension Sample



Functionality of Filter Subsystem



Amplifier	Input Sinusoidal wave	Mean Input Amplitude (mV)	Mean Output Amplitude (V)	Gain (V/V)
	2.0 mVpp	4.52	5.50	1216
	2.1 mVpp	4.72	5.49	1163
	2.2 mVpp	4.80	5.50	1145
	2.3 mVpp	4.88	5.47	1120
	2.4 mVpp	4.99	5.46	1094
	2.5 mVpp	5.07	5.49	1082
Average Gain for Instrumentation Amplifier : 1137 V/V				

Low-Pass Filter	Input Voltage (V)	Output Voltage (V)	Ratio of Output to Input (V/V)	Frequency (Hz)
	1.96	1.56	0.796	400
	1.96	1.49	0.760	450
	1.96	1.40	0.714	460
	1.96	1.38	0.704	474
	1.96	1.34	0.684	480
	1.96	1.32	0.673	490

High-Pass Filter	Input Voltage (V)	Output Voltage (V)	Ratio of Output to Input (V/V)	Frequency (Hz)
	1.96	1.52	0.776	14
	1.96	1.42	0.724	12
	1.96	1.40	0.714	11.5
	1.96	1.39	0.709	11.3
	1.92	1.34	0.684	11
	1.92	1.28	0.667	10

Equations Used:

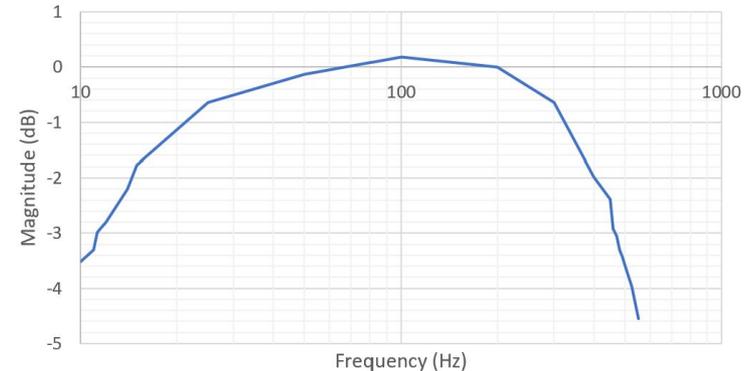
Amplifier

- $\text{Gain} = 1 + (50\text{k}\Omega)/R_g$

Bandpass Filter

- $2\pi f = 1/(R_1 R_2 C_1 C_2)^{1/2}$

Bandpass Filter Bode Plot



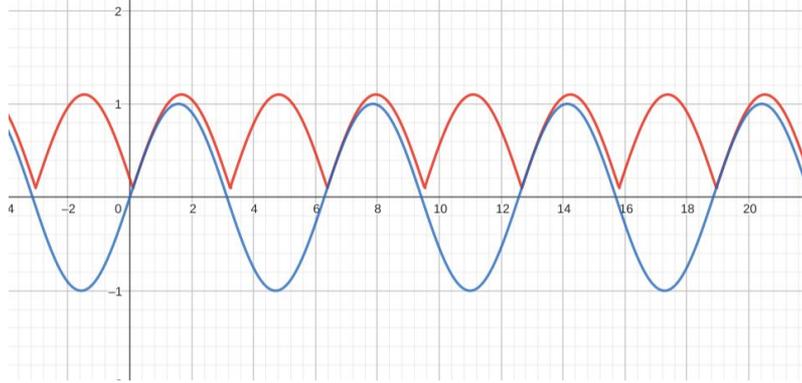
$$\text{Gain}_{\text{dB}} = 20 \log_{10} (V_{\text{out}} / V_{\text{in}})$$

Continued Functionality of Filter Subsystem

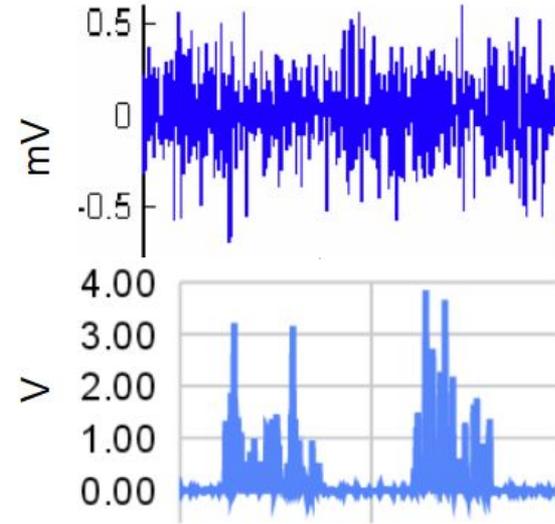


Simulation

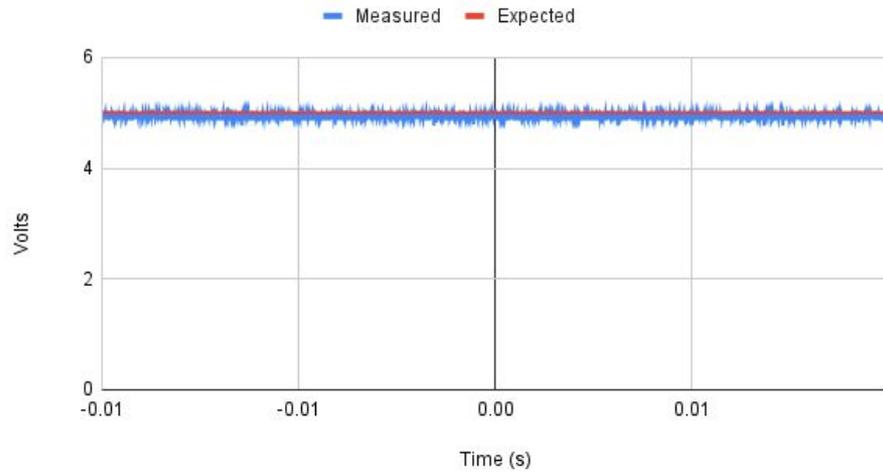
Rectifier



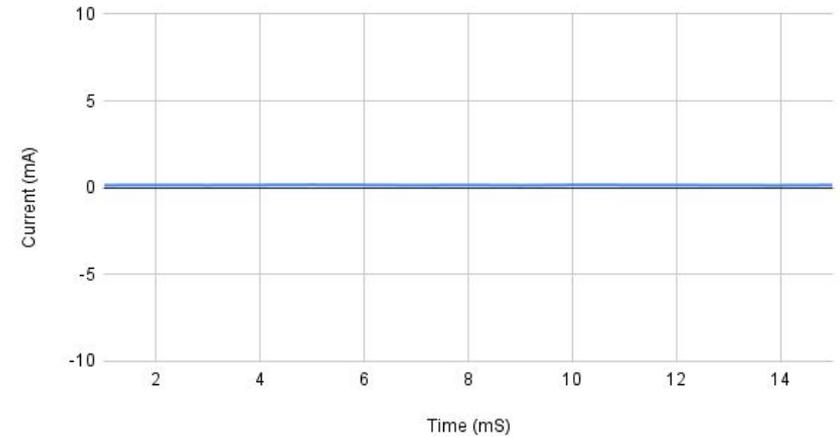
Implementation



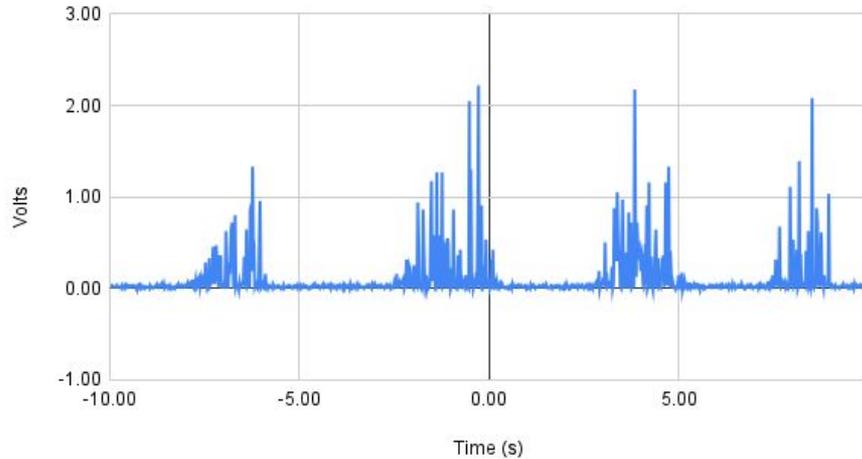
9V -> 5V Step Down



9V -> 5V Output Current

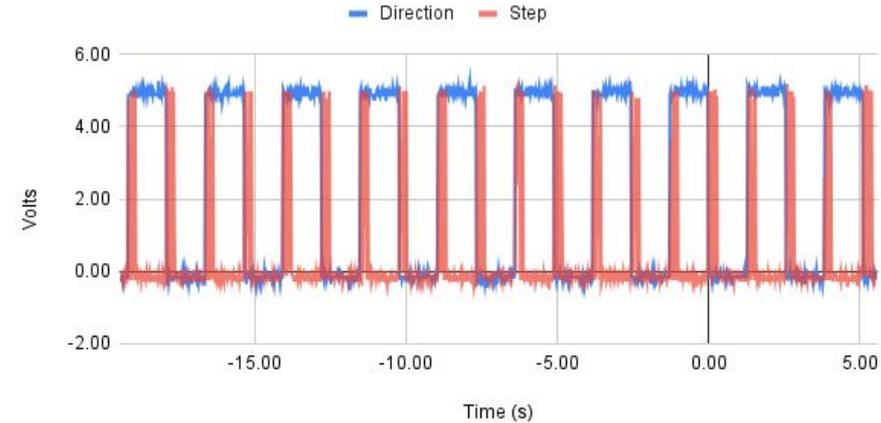


Subject 1 Flexion/Extension Sample



Stepper Motor Control

Delay between actions: 1.000 seconds



Less than 1 second delay in classification

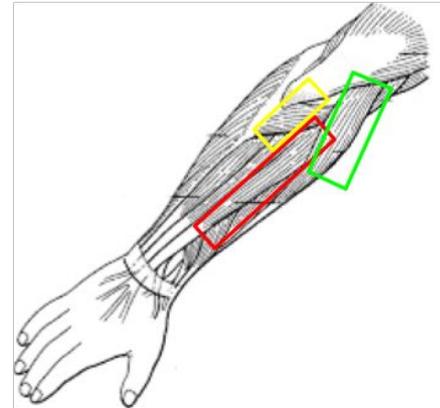
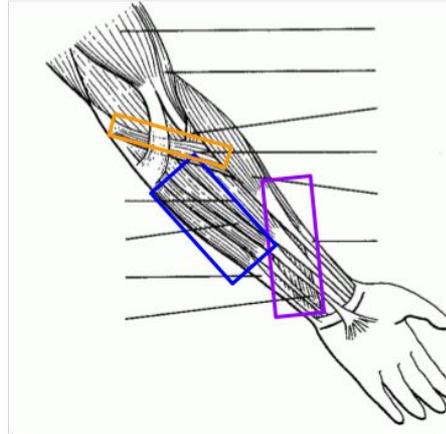
50 pulses with 4.5 ms delay = 225 ms



Successes and Challenges

- Finding optimal electrode placement for signal detection
- Functioning filter design without a rectifier
 - Damaged Op-Amps while biasing
- Different power requirements between components

Movement	Key
Digit Flexion	Purple
Digit Extension	Red
Palmar Supination	Yellow
Palmar Pronation	Orange
Palmar Flexion	Blue
Palmar Extension	Green



High Level Requirements

- Prosthetic hand was precise and accurate
- Design correctly interpreted digit flexion/extension
- EMG device was able to operate with 2 unique subjects

Other Successes

- All subsystems except sensors were stable and consistent
- Total cost for final design of EMG was less than \$40



Conclusions

- We will not store nor share any patient data as to protect the privacy of others and to prevent any conflicts of interest
- We will accept criticism of our work, and be honest in stating claims or estimates regarding our device
- We will treat all persons fairly and strive to ensure the code of ethics is upheld by colleagues
- We hold paramount the health and welfare of the public

Safety

- Dry cell batteries
- Low power motor
- Low voltages
- Passive electrodes

- Consider compatibility between components.
 - Voltage ratings between instrumentation amplifiers, operational amplifiers, and microcontroller
- When possible, extensively simulate and test subsystems on software like LTspice or on the breadboard.

- Invest more time and research EMG signal detection using electrodes
 - Optimal electrode placement
 - Physical factors affecting signal detection with electrodes

- Modularly implement the PCB design

- Design and create casing for PCB, microcontroller, and motor circuit

- Finish PCB design
 - Make it smaller, neater
- Add more electrodes
 - Complex and specific movements
- Lower power requirements
 - Replace two 9V batteries with something smaller
 - Increase battery life



The Grainger College of Engineering

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