UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

Affordable EMG Device

Electrical & Computer Engineering

Team #9
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Problem

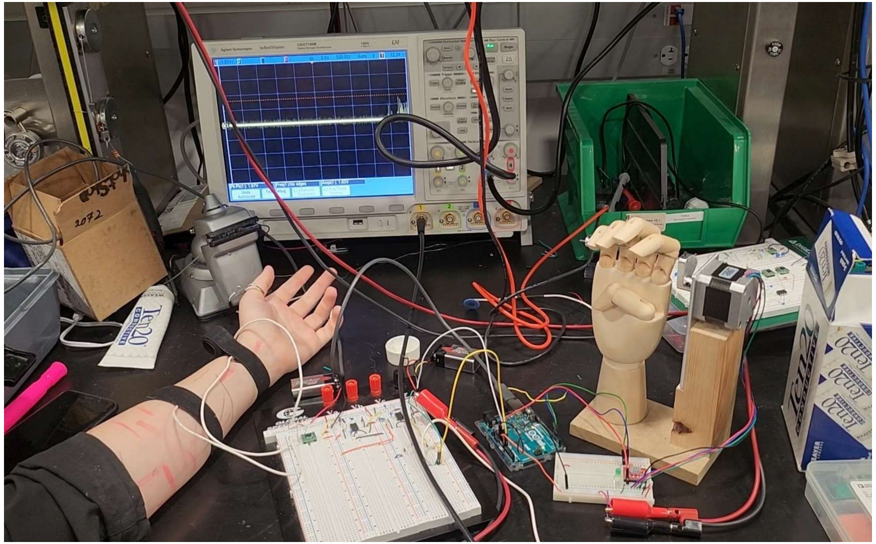
- Average myoelectric prosthetic unaffordable
  - Partial upper limb loss: $18,703
  - Total upper limb loss: $61,655

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

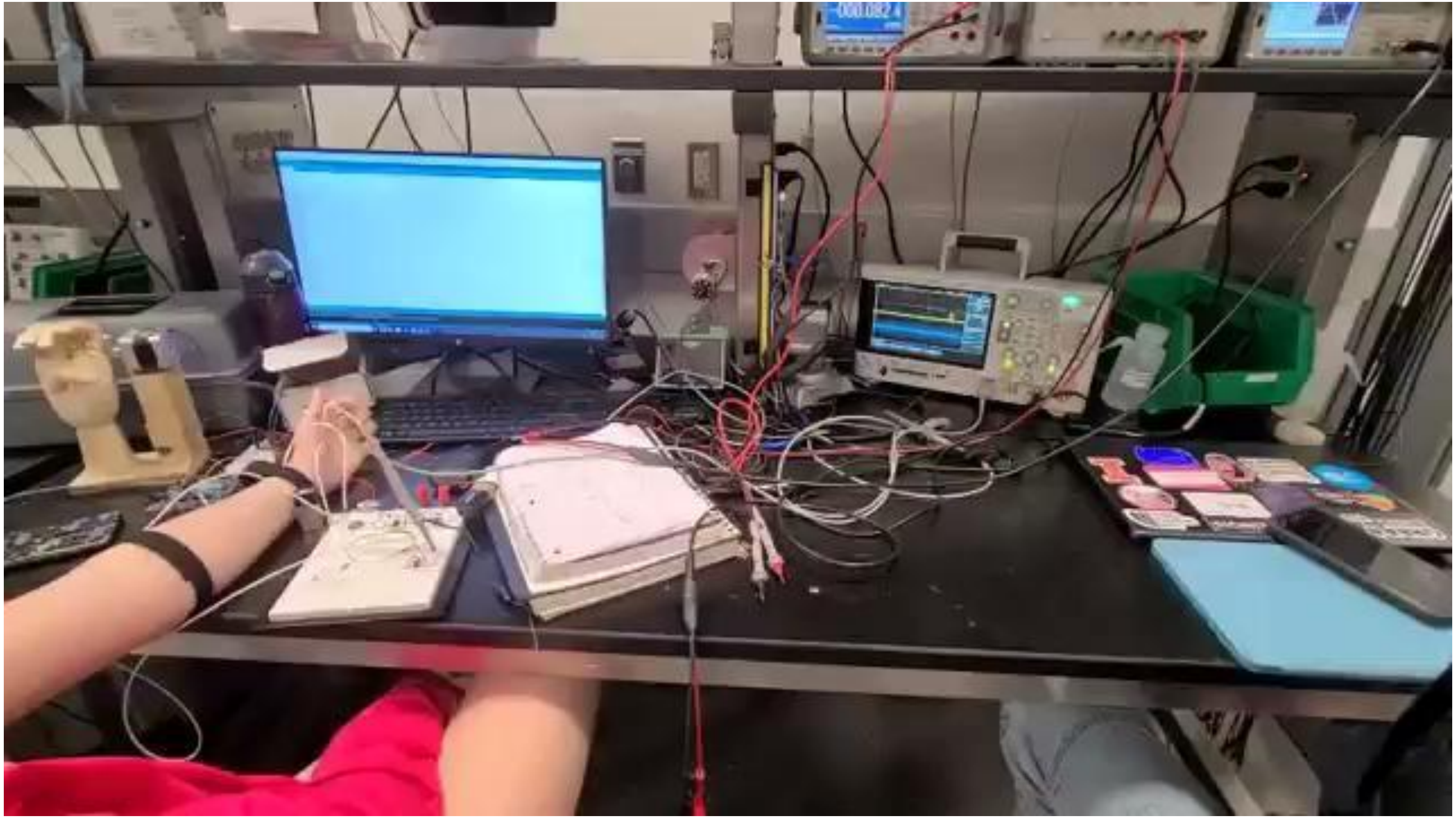
Solution

- 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

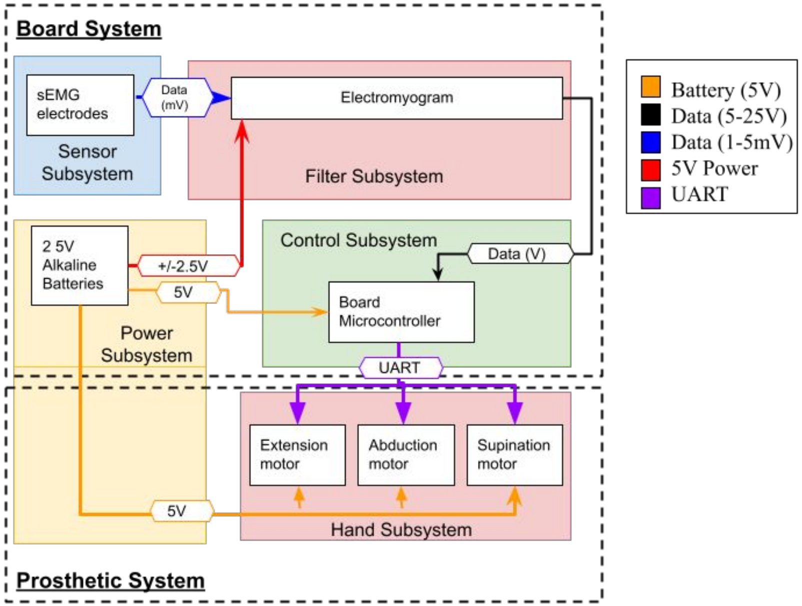


Solution - Demonstration

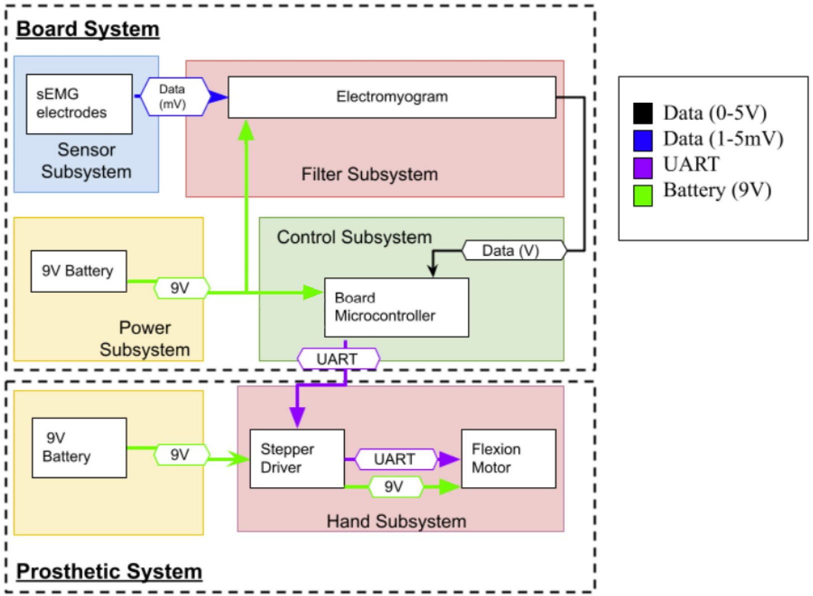


Design Changes

Block Diagram

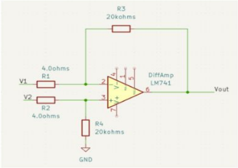
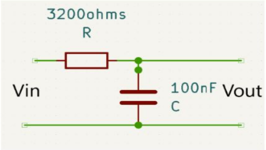
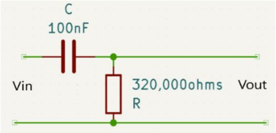
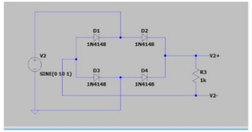
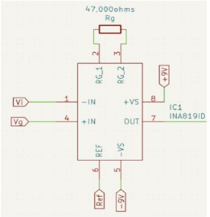
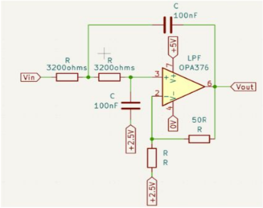
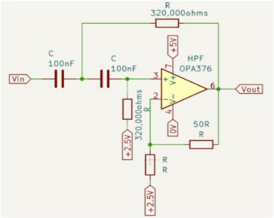
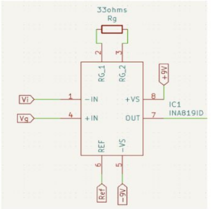
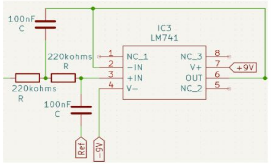
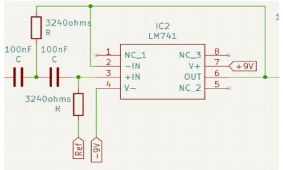
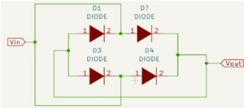


a.



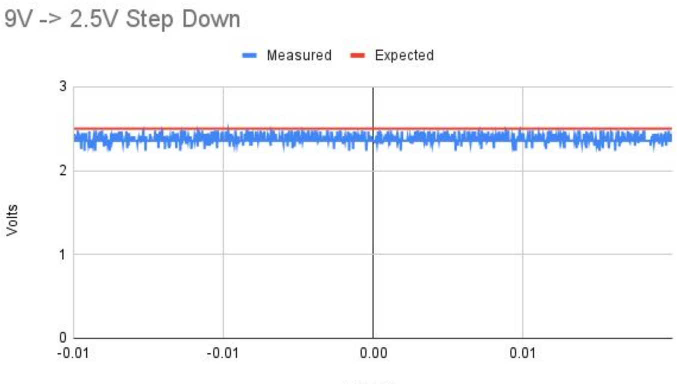
b.

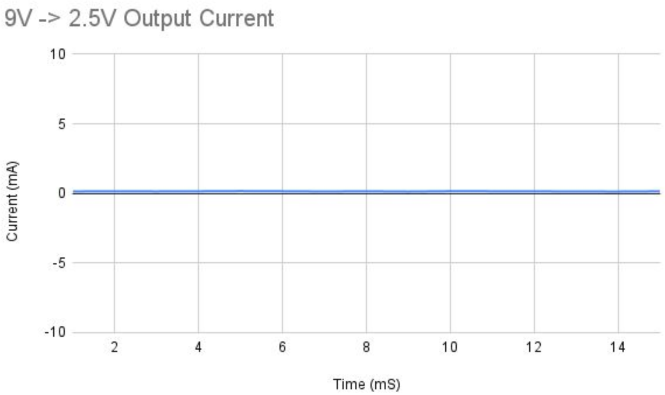
Board - Filter Subsystem Design Changes

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

Board - Power Subsystem Design Changes

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





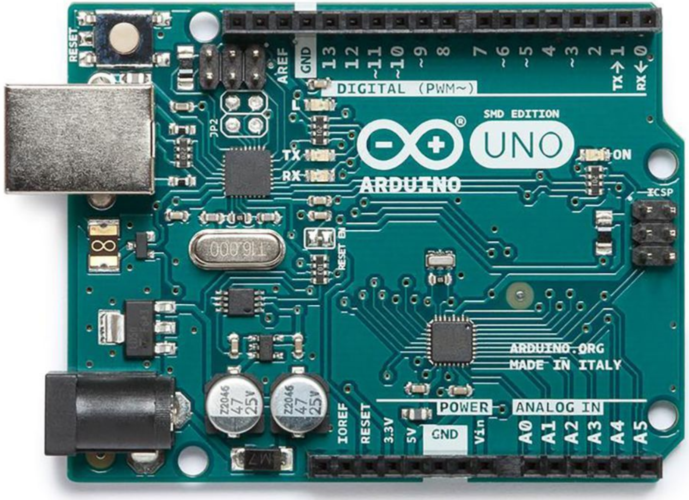
Microcontroller - Design Changes

Original design:

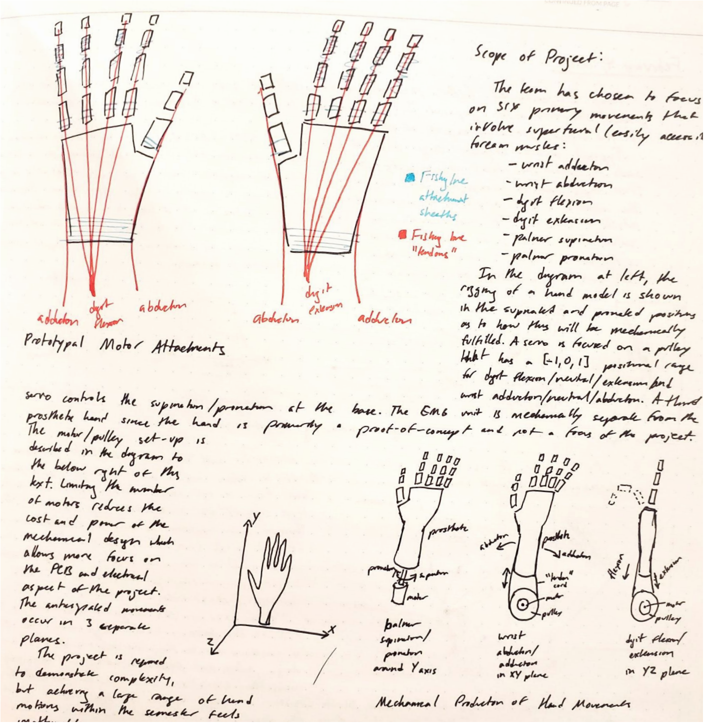
ATmega328P with machine learning

Altered design:

Arduino Uno with rolling average



Prosthetic Hand Design Changes



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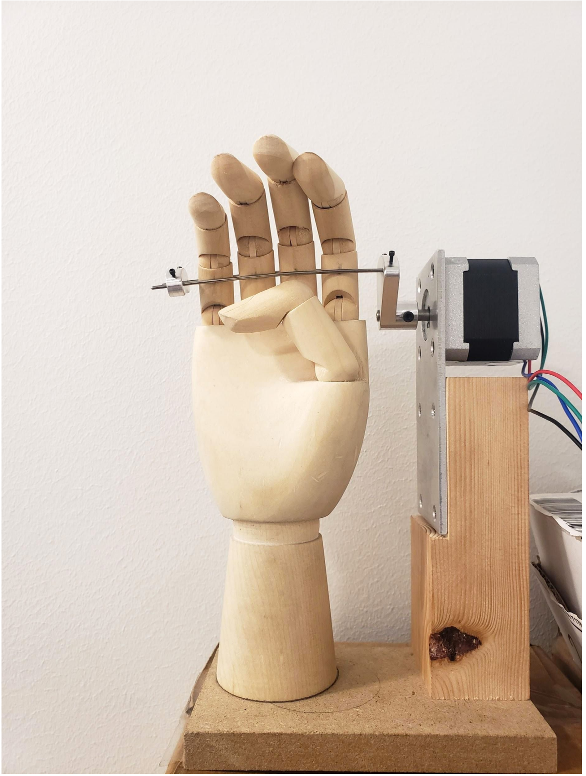
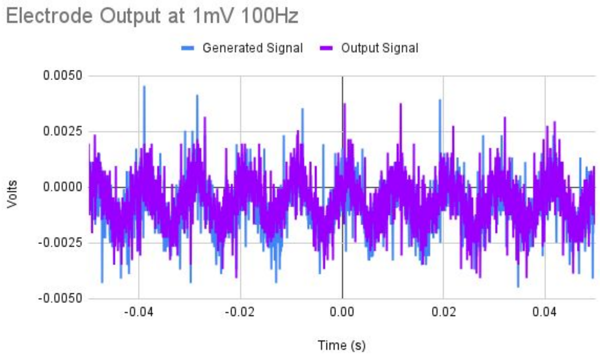
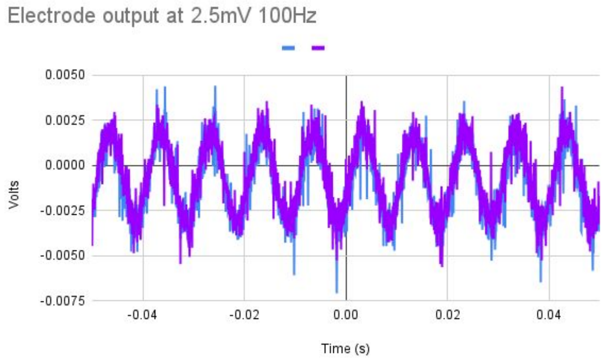


Requirements and Verifications

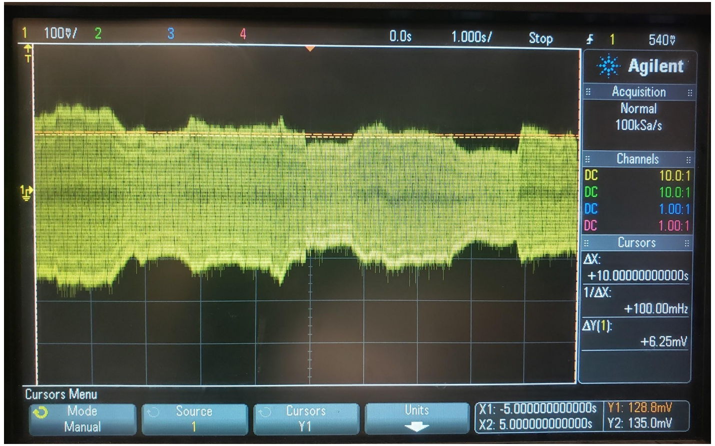
Functionality of Sensor Subsystem

- Noisy
- Low cost





Filter Input -> Output



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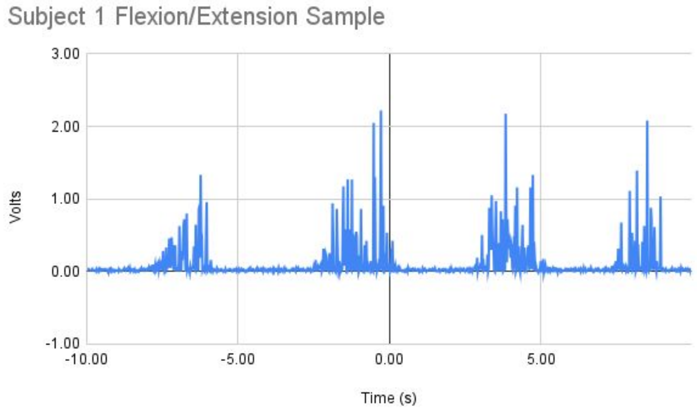


Functionality of Filter Subsystem

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

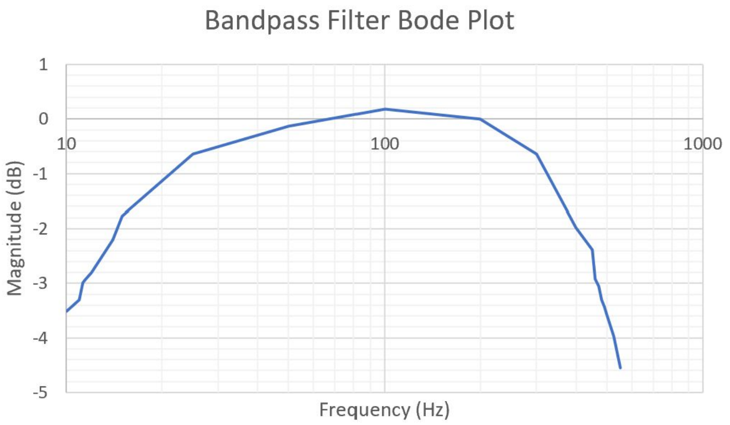
Equations Used:

Amplifier

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

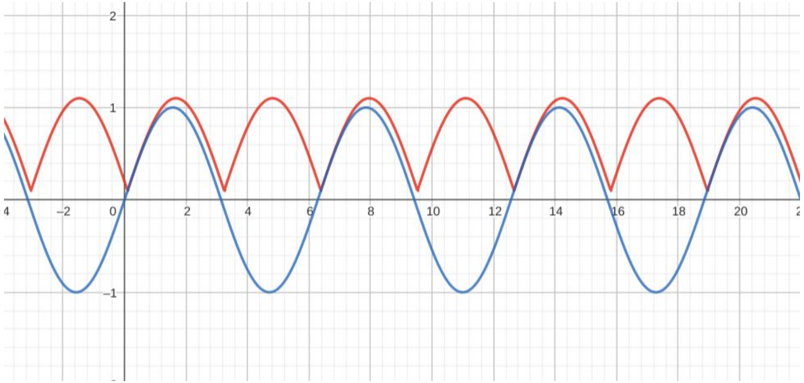
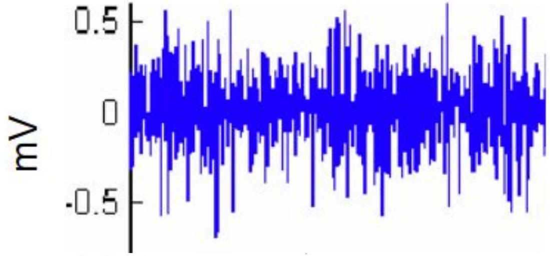
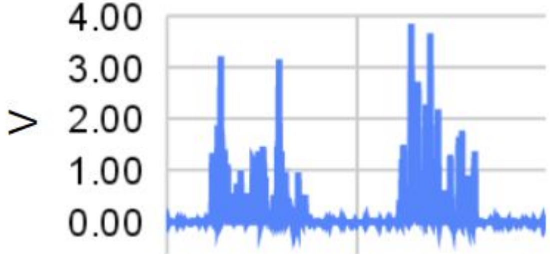
Bandpass Filter

- $2\pi f = 1/(R_1R_2C_1C_2)^{1/2}$

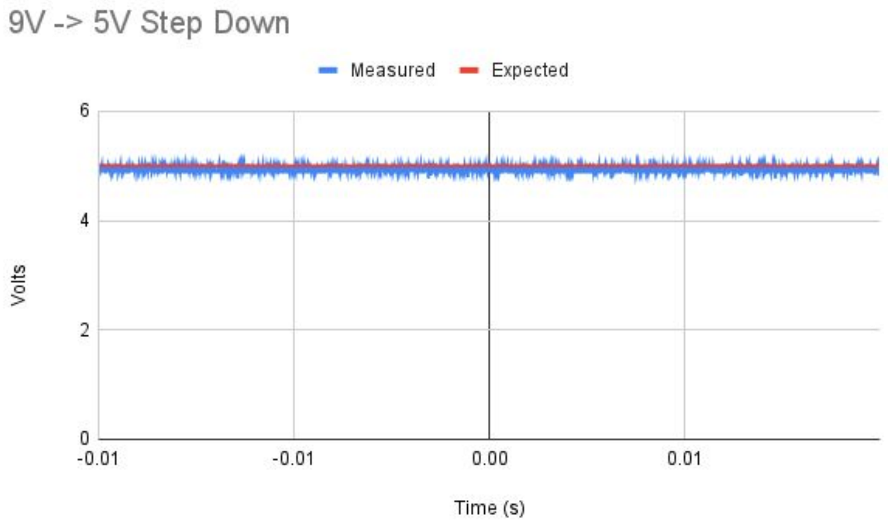


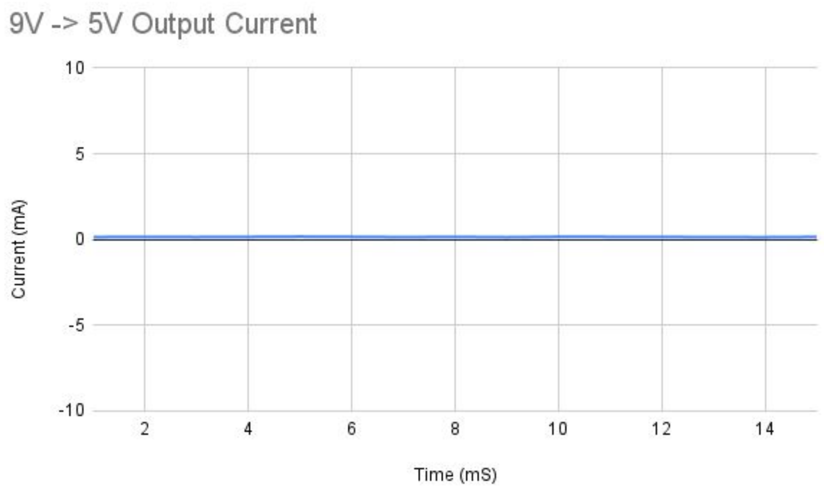
$$Gain_{dB} = 20\log_{10}(V_{out}/V_{in})$$

Continued Functionality of Filter Subsystem

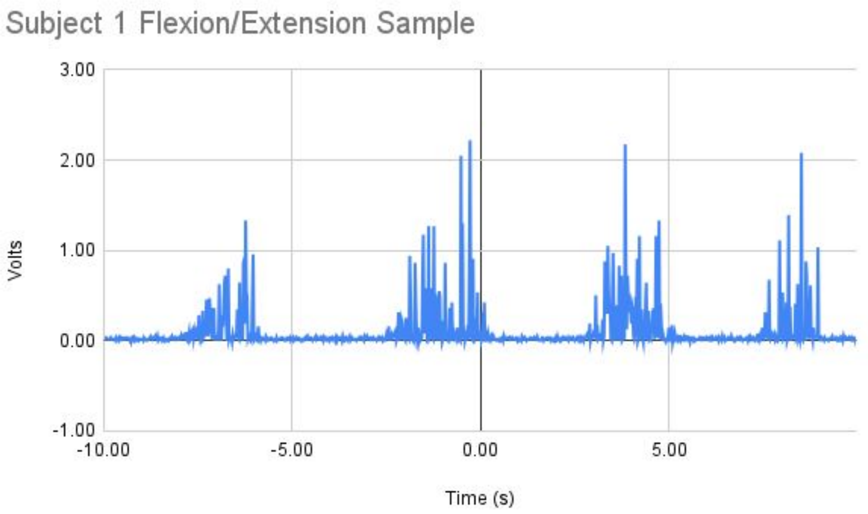
	Simulation	Implementation
Rectifier		

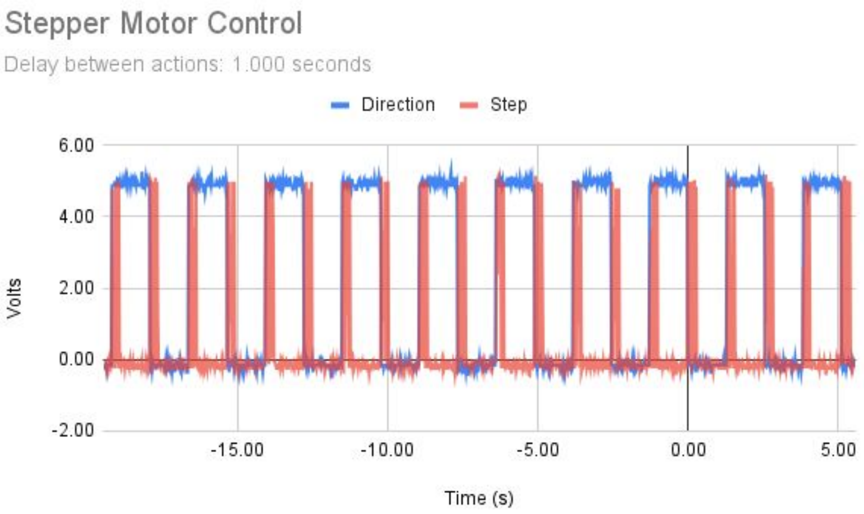
Functionality of Power Subsystem





Functionality of Prosthetic Hand





Less than 1 second delay in classification

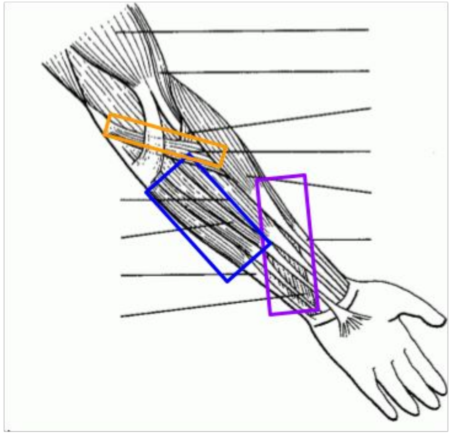
50 pulses with 4.5 ms delay = 225 ms

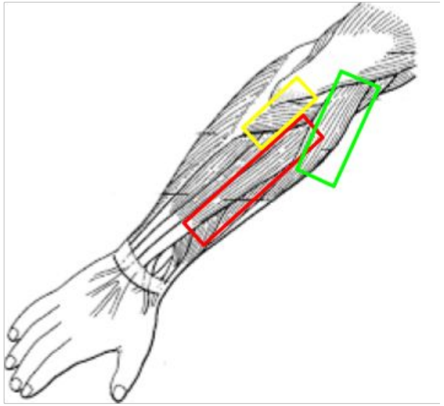
Successes and Challenges

Challenges of the Project

- 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)





Successes of the Project

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

Discussion of Ethics and Safety

- 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

What did we learn?

- 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.

What would we do differently?

- 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

Recommendations for Further Work

- 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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