Bionic Prosthetics Arm

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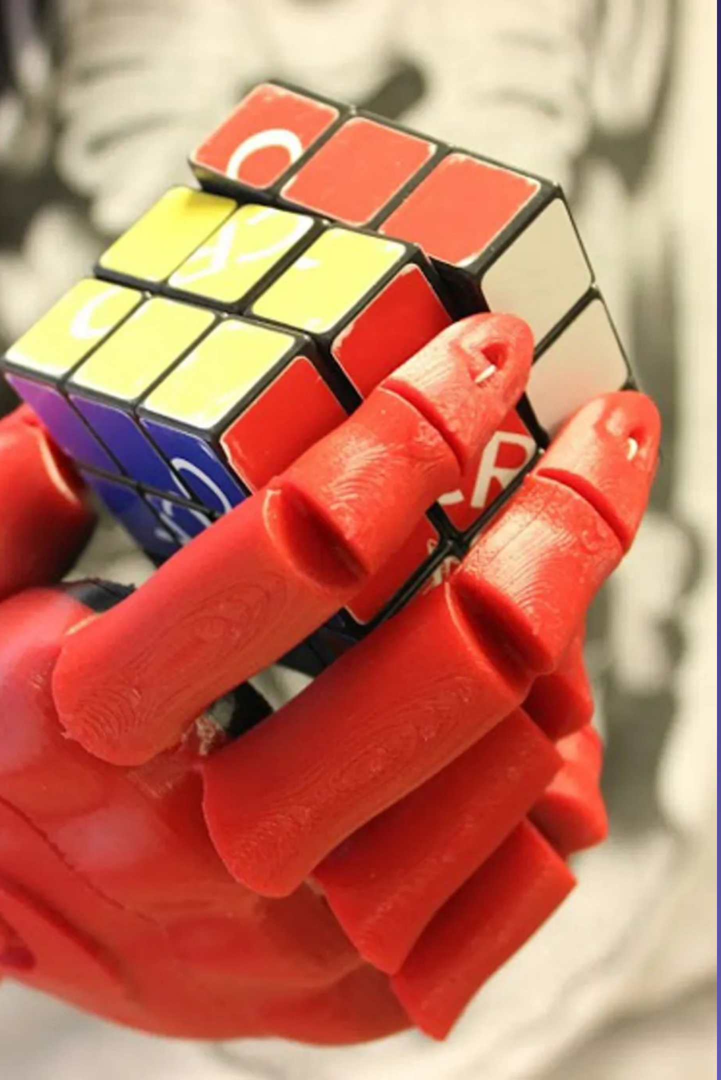


Project Overview

- Introduction of an innovative 3D printable myoelectric prosthetic arm
- Integration of electronic actuators and user-controlled movements based on muscle flexion.
- Focus on affordability and accessibility, leveraging the advantages of 3D printing technology.
- Aiming to bridge the gap in prosthetic availability, particularly in regions with limited resources.

Src: https://www.cnet.com/culture/3d-printed-robotic-prosthetic-wins-uk-james-dyson-award/

Project Overview

1. "Introducing a 3D printable myoelectric prosthetic arm, bridging accessibility gaps for amputees globally."
2. "Revolutionizing the field, this bionic arm enables user-controlled movements through muscle flexion."
3. "A response to the high cost of myoelectric technology, our design leverages the affordability of 3D printing."
4. "In the context of developing countries, where access to prosthetic solutions is limited, 3D printing emerges as a transformative force."
5. "Recent strides in 3D printed prosthetics, while mechanically simpler, highlight the positive impact on users' lives."
6. "This thesis focuses on an innovative mechanical design, integrating electronic actuators for advanced control, pushing the boundaries of 3D printing in prosthetics."
7. "Addressing a diverse audience, our work converges mechanical design, electronic control, and 3D printing technologies for a comprehensive exploration of prosthetic advancements."
8. "Key themes include the intersection of technology and accessibility, pushing the limits of mechanical design, and navigating the evolving landscape of prosthetics."
9. "This project endeavors to contribute to a future where prosthetic solutions are not just functional but also accessible, cost-effective, and tailored to individual needs."
10. "Keywords: 3D printing, myoelectric prosthetic, electronic actuators, user-controlled movement, accessibility, affordability, mechanical design, and prosthetic advancements."

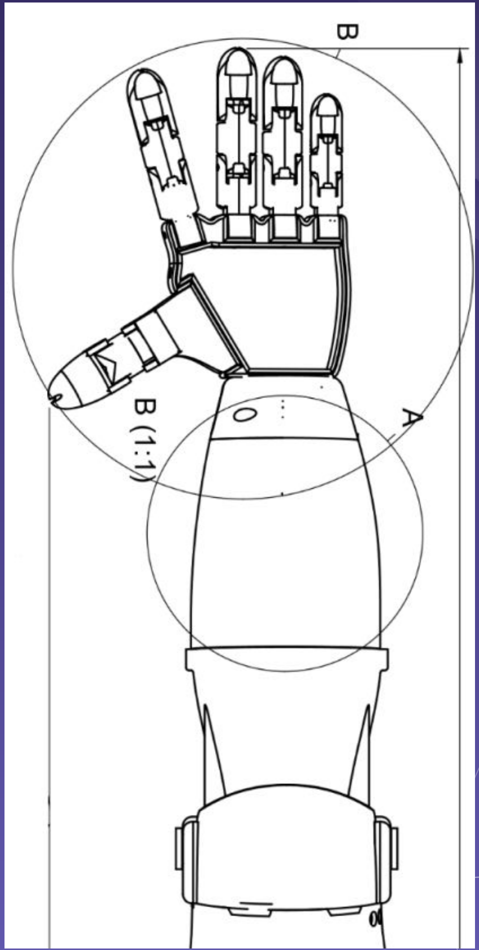
Mechanical Design

Mechanical Design

For mechanical development I will use Solidworks. Solidworks stands as a computer-aided design software specifically crafted for modeling solid mechanical components and assemblies. Widely embraced in the engineering industry, Solidworks has garnered extensive use for the design and analysis of mechanical components.

Subtopics:

1. **Fingers**
2. **Drive System**
3. **Mechanical Calculations**



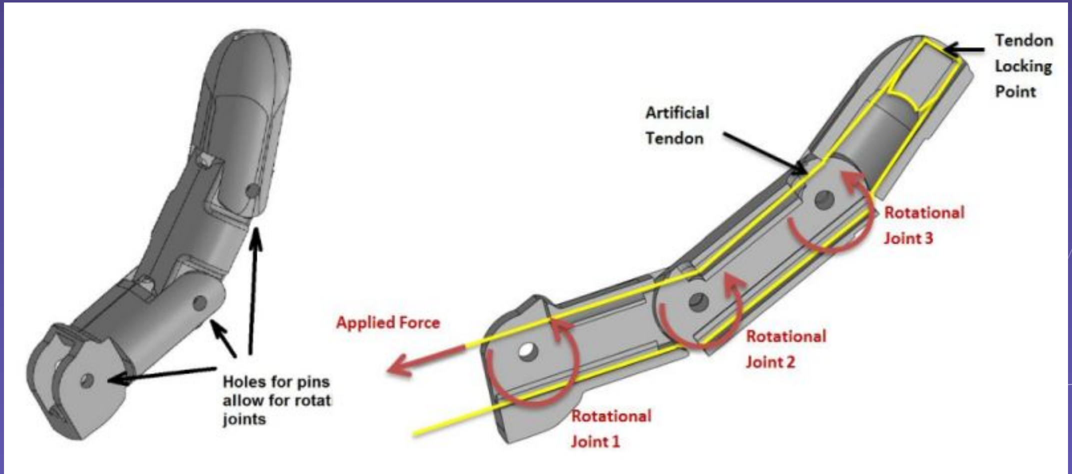
Mechanical Design

Finger

- Every finger comprises three distinct 3D-printed elements

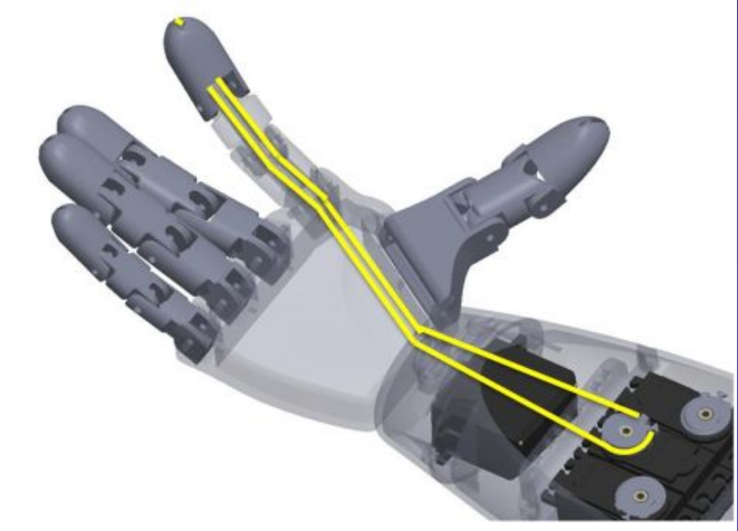
- A synthetic tendon is intricately looped around the inner tip of each finger, establishing a secure anchor point.

- Tendon navigates through internal channels within the finger



Mechanical Design

Driving System



- He tendons form closed loops

- Servo motor pulls on the tendon,

- The ring and pinky fingers share the same servo, causing them to open and close in synchronization.

Mechanical Design

Mechanical Calculations - Force in Fingers

At the point where the maximum liftable load is applied, the moments M1 and M2 balance each other out. For our calculations, we need to determine the tensile force in the tendon. The stall torque (maximum turning force) of the MG996R Servos is 10kg-cm (1 N/m).

$$\tau_{servo} d = F_2$$

$$F_2 = 1(N/m) * 10mm = 10N\ (tension\ in\ the\ tendon)$$

$$F_1 D_1 = F_2 D_2$$

$$F_1 = \frac{10(N)*4.5(mm)}{65(mm)} = 0.70N\ so\ Mass \approx 70g$$

Therefore, when fully extended, each fingertip can withstand a force of 0.7N or lift a 70g mass. It might appear relatively low, but it's crucial to understand that this doesn't represent the maximum force the finger can exert.

In this case each finger can support a mass of roughly 150g, which would give the entire hand a lifting/holding capacity of about 600g.

Mechanical Design

Mechanical Calculations - Finger Actuation Speed

The MG996R servo has an operating speed of 0.15 sec/60°. A full wrist rotation from a palm-up to a palm-down position (180°) therefore takes (0.15/60)*180 = 0.45 seconds.

$$\frac{0.15s}{60} * 180 = 0.45s$$

$$length = \frac{n}{360} * 2\pi r$$

It has been measured that a tendon must move about 2cm to move the finger from fully extended to fully flexed. Using the arc length formula, where the length is 2cm and r is the radius of the custom servo horns (7mm), we find that the servo must rotate 160° to completely open/close each finger. Consequently, the maximum time to open/close a finger is calculated as (0.15/60)*160 = 0.4 seconds.

Mechanical Design

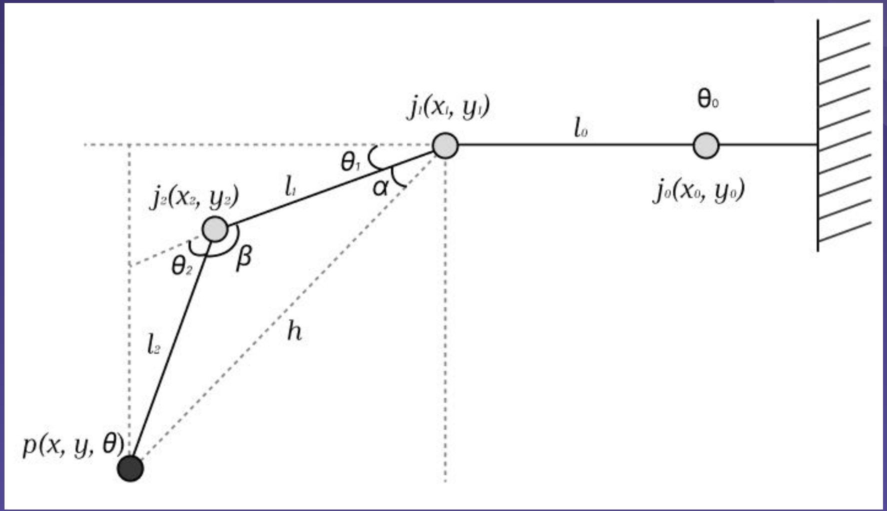
Mechanical Calculations - A Computational Model

The equation of the Lagrange formulation method is shown

$$\frac{d}{dt}\frac{\partial L}{\partial \dot{q}} - \frac{\partial L}{\partial q} = \tau$$

$$KE = \sum_{i=1}^{n} KE(\theta), \quad PE = \sum_{i=1}^{n} PE(\theta)$$

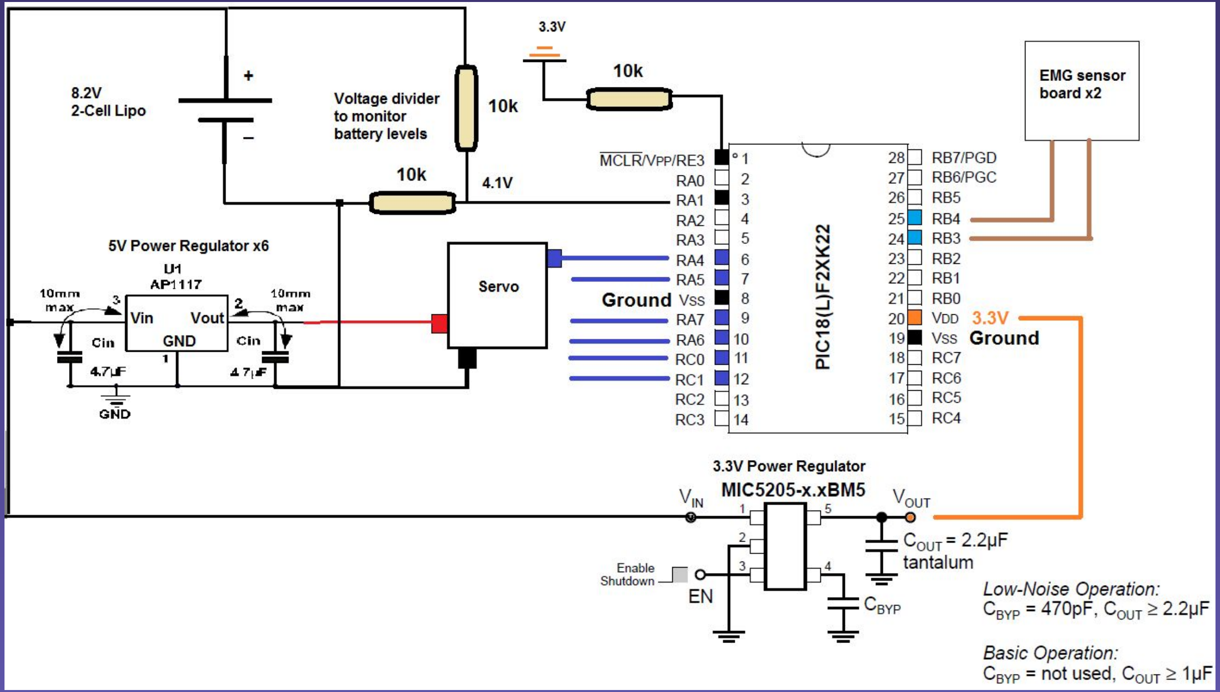
$$\sum_{i=1}^{n} KE(\theta) = KE_{l_0} + KE_{l_1} + KE_{l_2} \text{ and } \sum_{i=1}^{n} PE(\theta) = PE_{l_0} + PE_{l_1} + PE_{l_2}$$



Joints	Torque	Value
J0	τ_0	$I_0\ddot{\theta}_0$
J0	τ_1	$(m_1+m_2)l_1^{\,2}\ddot{\theta}_1 + m_2 l_1 l_2 \ddot{\theta}_2 \cos(\theta_1 - \theta_2) - m_2 l_1 l_2 \dot{\theta}_2^{\,2} \sin(\theta_1 - \theta_2) + (m_1+m_2) g l_1 \cos\theta_1$
J2	τ_2	$m_2 l_2^{\,2}\ddot{\theta}_2 + m_2 l_1 l_2 \ddot{\theta}_1 \cos(\theta_1 - \theta_2) - m_2 l_1 l_2 \dot{\theta}_1^{\,2} \sin(\theta_1 - \theta_2) + m_2 g l_2 \cos\theta_2$

Electronic Design

Electronic Design

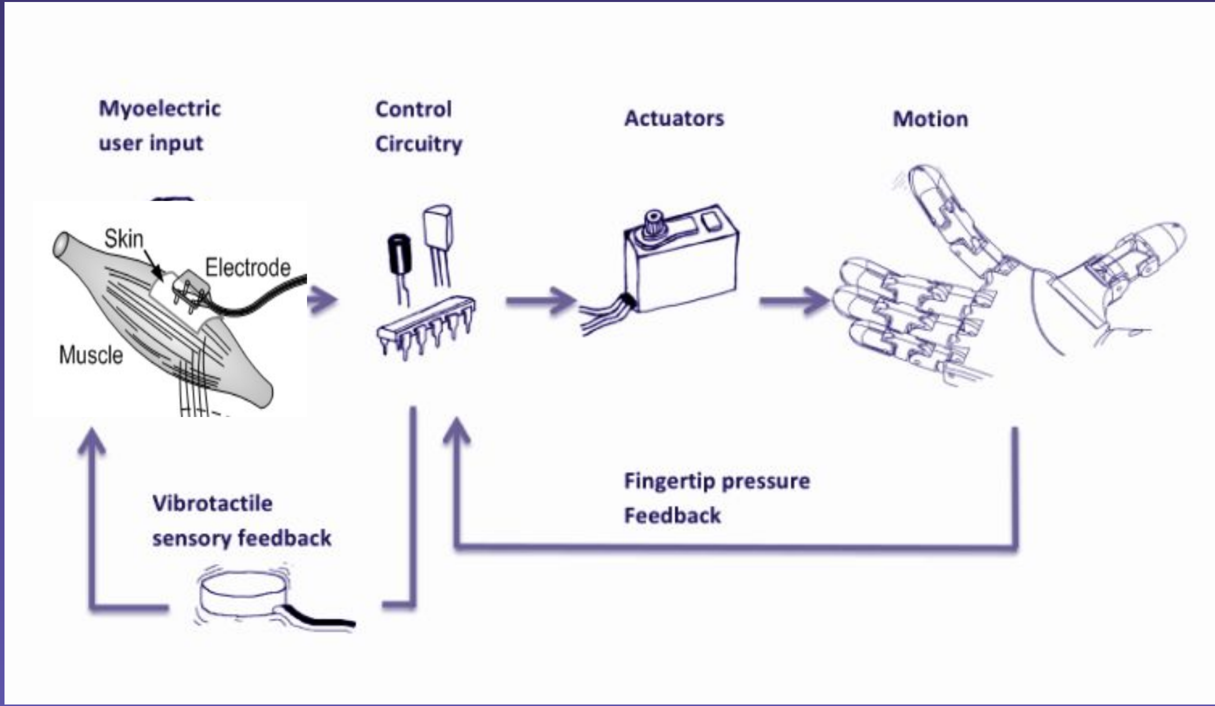


Subtopics:

1. Signal Flow Overview
2. Actuation
3. Microprocessor
4. Voltage regulators
5. Power Supply

Electronic Design

Signal Flow Overview



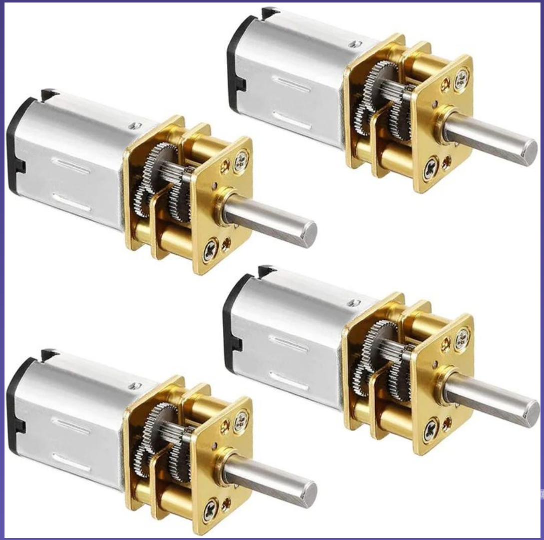
- An analog signal is produced
- Smoothing by the EMG sensor board.
The microcontroller utilizes analog signal
- Microcontroller generate a pulse-width-modulated signal.

Src: https://www.bu.edu/ids/research-projects/muscles-alive/

Electronic Design

Actuation

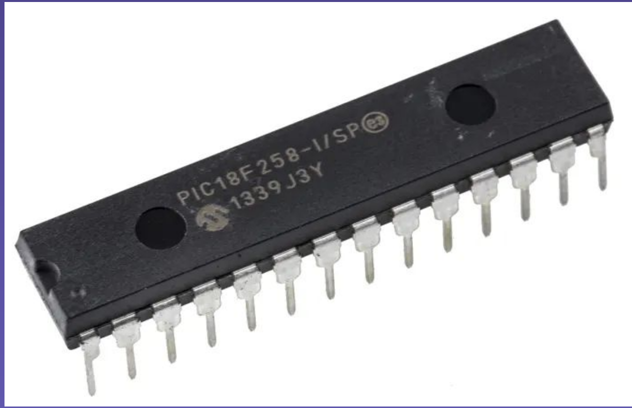
- The actuators are standard servo motors.
- Small movements to open and close each finger
- Higher-quality servos would also entail a substantial increase in costs.

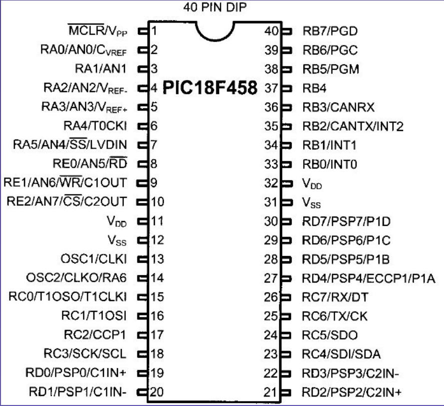


Electronic Design

Microprocessor

- The central processing unit for this system is an 8-bit microcontroller selected from the Microchip PIC18F series.
- While processors from this family have computational power limitations, they prove to be more than sufficient for the requirements of this design.
- To program the device, a Pickit3 debugger/programmer is connected to the microcontroller circuitry, receiving data through a USB connection to a PC.

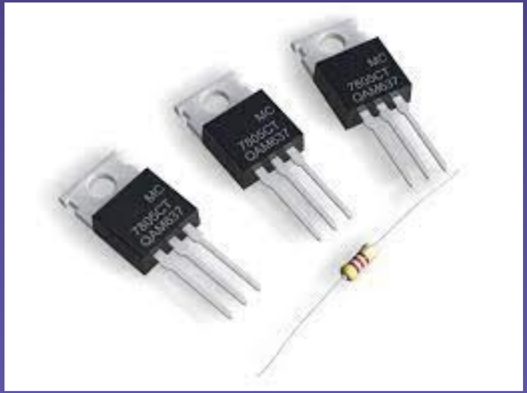




Electronic Design

Voltage regulators

- Manage the voltage and power supplied
- Drawing excessive current from the battery.
- Drawing potentially lead to damage to the electronics
- 5V for servos and 3.3V for Microcontroller.
- The chosen regulators offer a maximum current output of 1A



Electronic Design

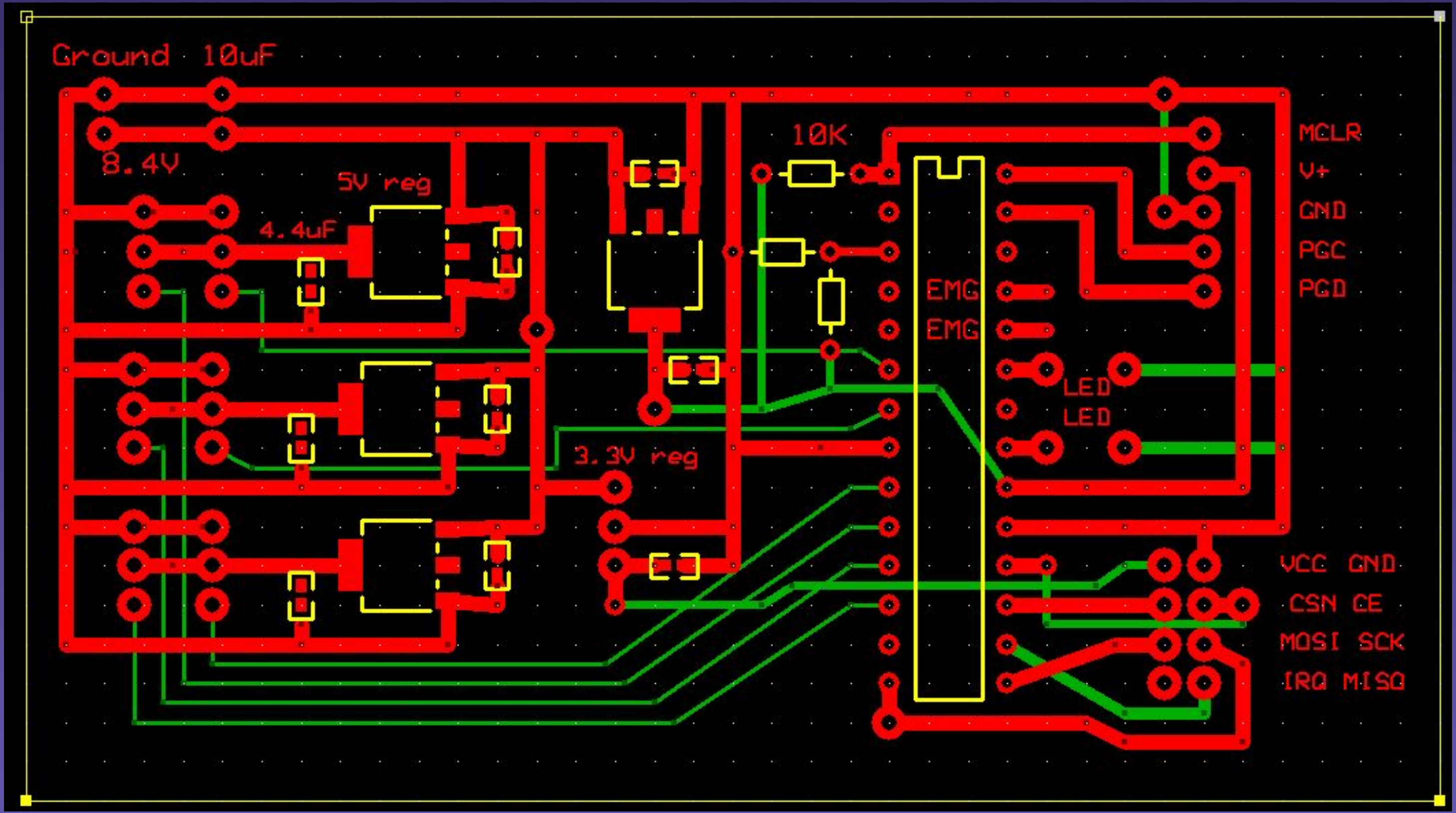
Power Supply

- System is designed to be entirely powered by internal sources
- Servo motors consume a substantial amount of current during operation
- Rendering disposable batteries impractical due to their quick drainageleitung
- Polymer (LiPo) batteries emerge as a favorable solution,

Electronic Design

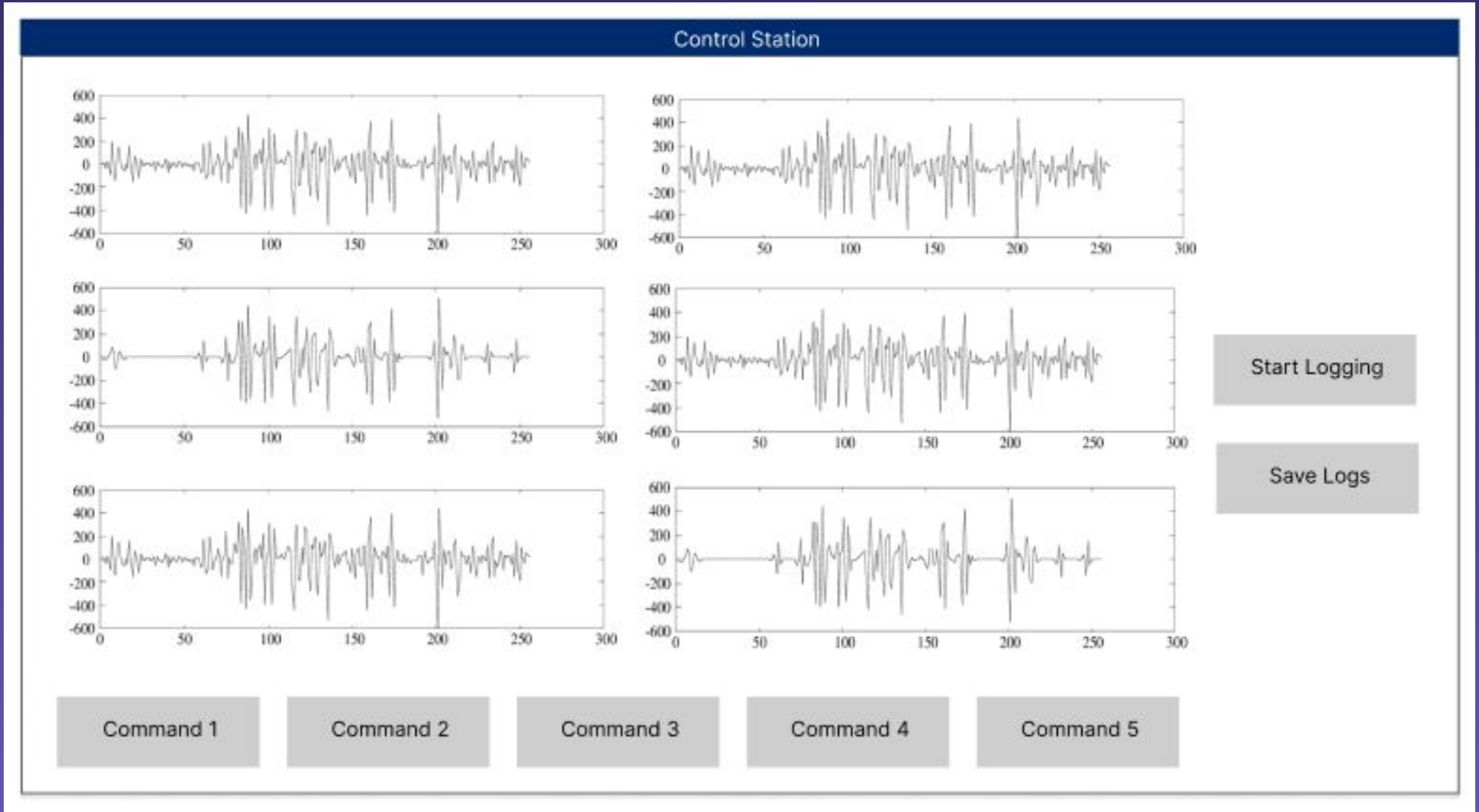
PCB Design

ExpressPCB

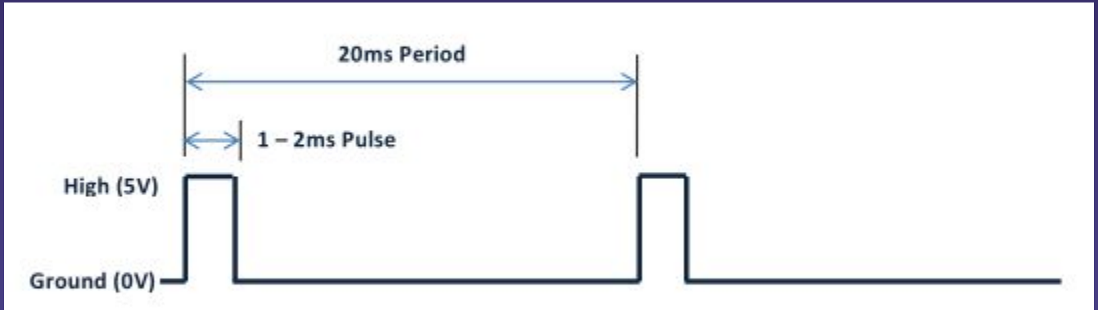


Software Design

Software Design



Software Design



A 1.5ms pulse rotates the servo shaft to its central position. Different pulse widths correspond to different motor shaft positions.

$$w_{PWM}(t) = a + k|emg(t)|$$

W_{PWM} = servo signal pulse width

a = arbitrary offset (servo PWMs start at 1ms)

k = Scaling factor

emg = EMG signal magnitude

Project Schedule

No	Works	Months and Weeks															
		February				March				April				May			
		6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.
1	Design Completion																
2	Perform Simulation and Mechanical Analysis																
3	Prototype Extraction																
4	Computer aided UI controller development																
5	EMG Data Collection and Classification																
6	Computer Aided EMG Tests																
7	Prototype Tests																

About Presentor

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Thanks for listening!