ECE Team 10 / ME Team 29
Strength Assisting Orthotic

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2/18/15

Andersen

Presentation Overview

- Project Overview
- Initial and Current Design
- Mechanical System
- Electrical System
- Testing Plan
- Safety Analysis

Conclusion

Project Overview

- Our team is dedicated in designing and building a powered strength-assisting orthotic arm.
- This orthotic will have potential applications in healthcare, military, and commercial markets, and could be marketed to these groups.

What is an Orthotic?

- An orthotic is an artificial device that is used to increase bio-mechanical efficiency.
- Orthotics are different from prosthetics, which are artificial limbs.
- Previous orthotics are bulky, expensive, and hindersome to natural movements.

Goals

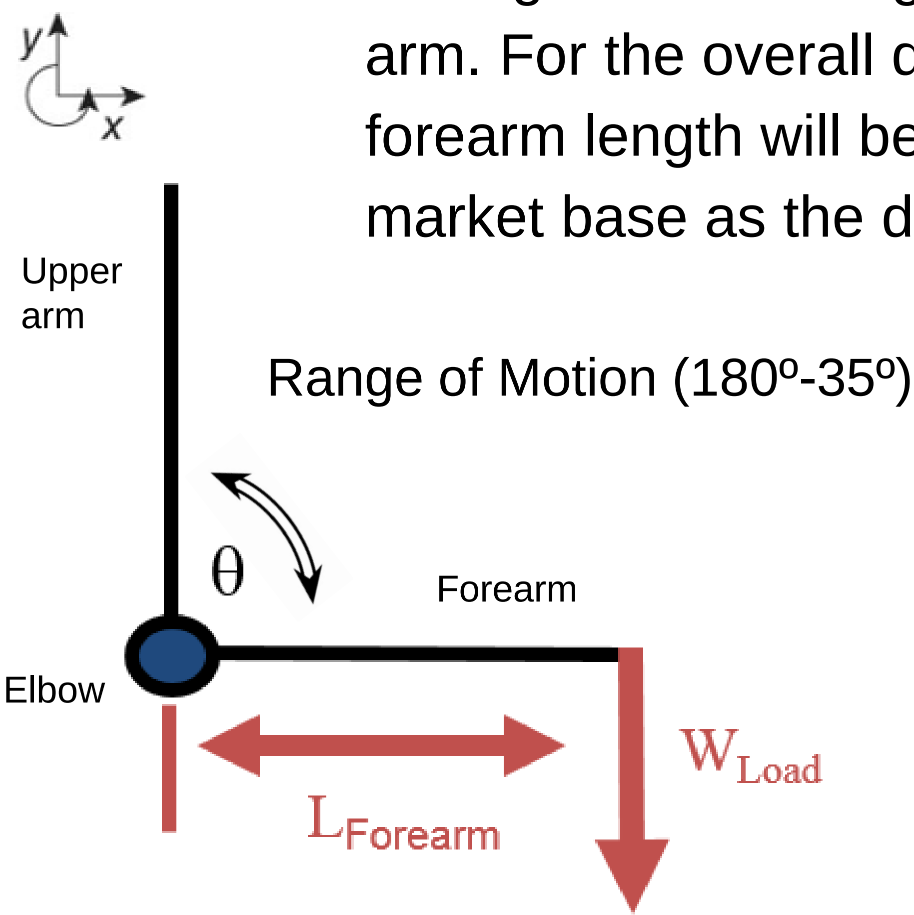
1) Providing a strength-assisting powered orthotic that will make lifting heavy objects easier.

2) Increasing endurance for holding said objects, using a form of actuation to mimic muscles and a frame to add structure.

3) Lifting at least 20 pounds with just the power of the orthotic.

Modeling the Load to be Lifted

To find the maximum torque needed, the maximum average forearm length will be used as the moment arm. For the overall design though, the minimum forearm length will be included as well to increase the market base as the design will include a sliding bar.



$\theta = 90°$

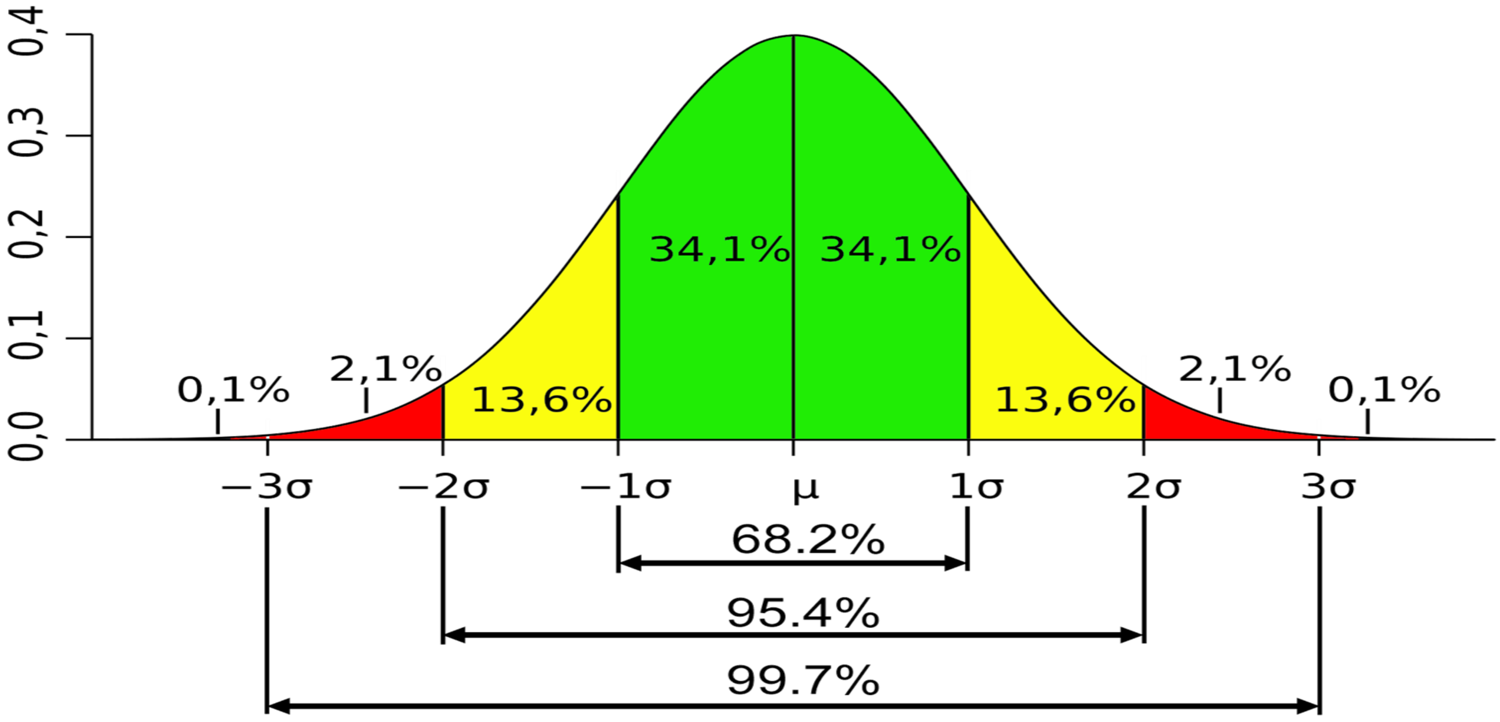
$L_{Forearm - max} = 52cm$

$L_{Forearm - min} = 38cm$

$W_{Load} = 21.lbs = 9.52\ kg$

Modeling the Load (Cont.)

The min and the max arm lengths have a difference of more than two standard deviations of the median. Meaning that over 95.4% of the human population should be able to use the orthotic.



Moment of Inertia

Pulls moment of inertia to the center of the body using tension

Will suspend the weight of the orthotic

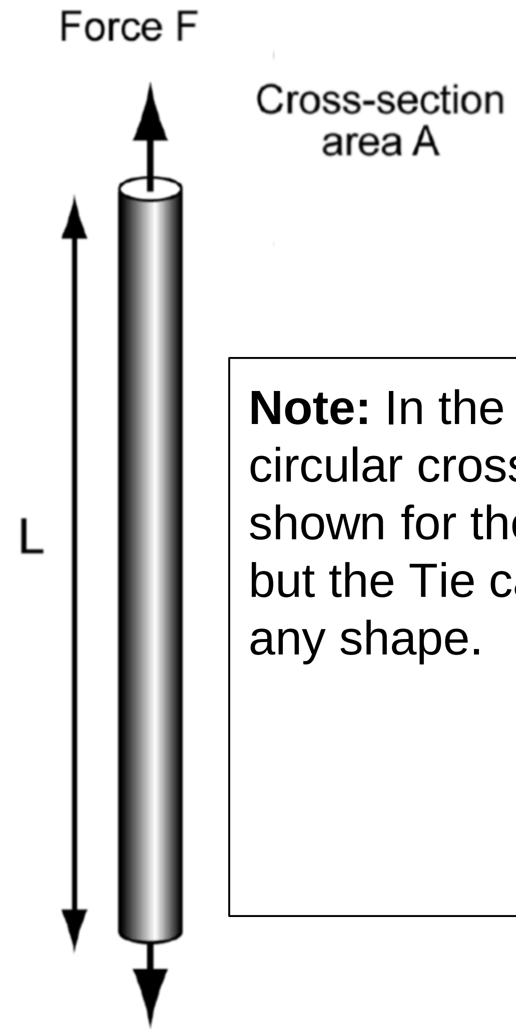
This set up is used in previous orthotic designs for rehab

Material Selection

For the general design of our orthotic we simulate the arm as a light, strong, stiff Tie rod when the arm is at 180 degrees to obtain the coupling equation.

$$\frac{E}{\rho} = \left(\frac{L}{\delta}\right)\left(\frac{\sigma_y}{\rho}\right)$$

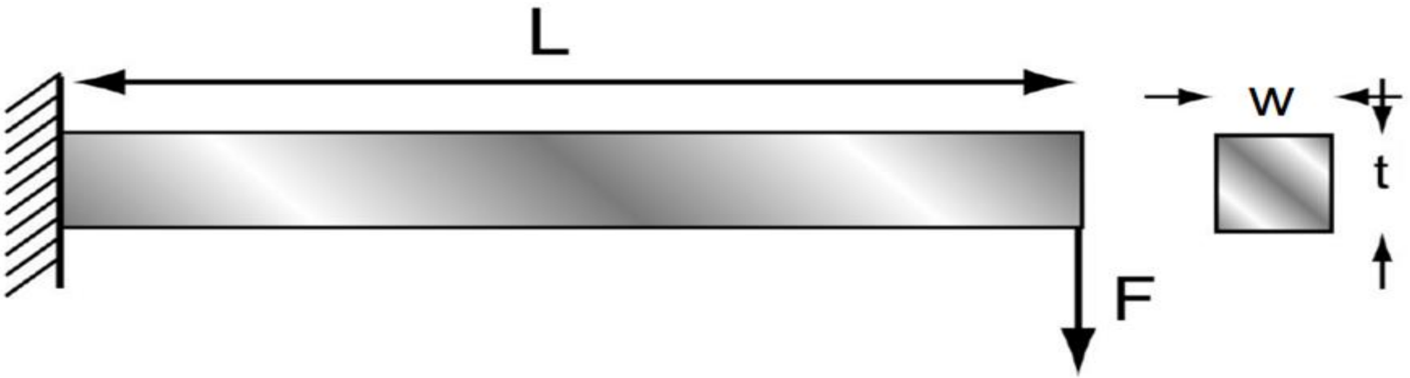
Where E is the young's modulus, ρ is the density, δ is the deflection of the tie rod, σ is the yield strength for the material the tie rod, and L is the length of the rod.



Note: In the diagram a circular cross section is shown for the Tie rod, but the Tie can be of any shape.

Material Selection (cont.)

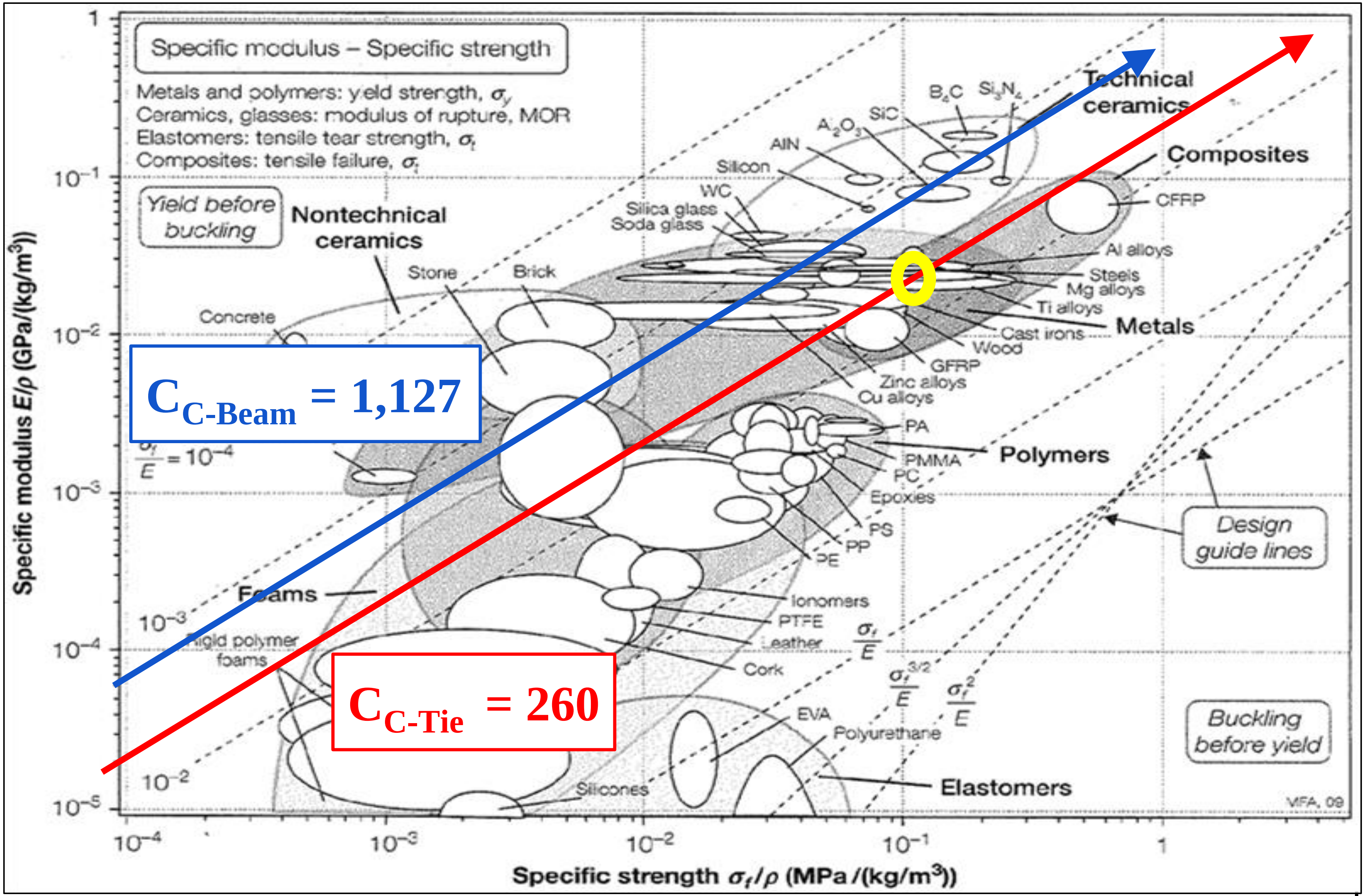
Also for when the arm is in movement we can simulate the arm as a light, strong, stiff cantilever beam which is end loaded and the thickness(t) of the beam is known to get its coupling equation.



$$\frac{E}{\rho} = \left(\frac{4L^2}{6t\delta}\right)\left(\frac{\sigma_y}{\rho}\right)$$

Where E is the young's modulus, ρ is the density, δ is the deflection of the beam, σ is the yield strength for the material the beam, t is the thickness and L is the length of the beam.

Material Selection (cont.)



Initial Design

The orthotic will be modular (have easily replaceable parts).

The orthotic will have an aluminum frame.

The frame includes a sliding bar to change distance of forearm and upper arm, which will allow for over 95.4% of the human population to be able to use the orthotic.

The aluminum frame can’t plastically deform.

Range of Motion for the orthotic is 180º-35º

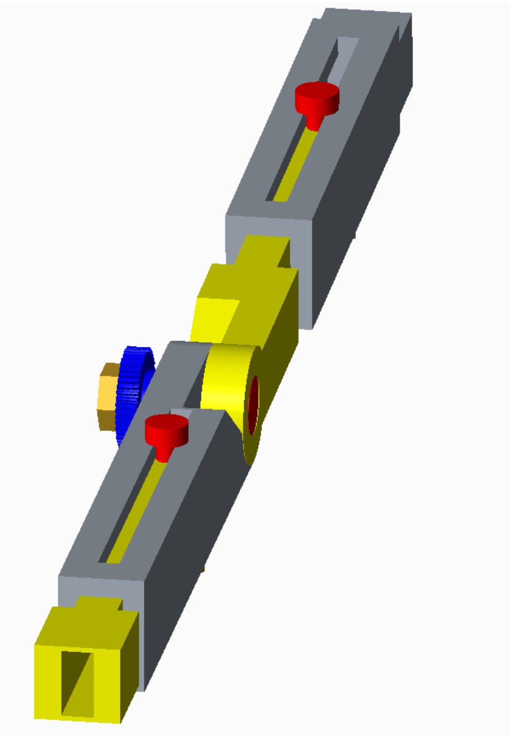
A motor will be used as the method of actuation.

Updated Design

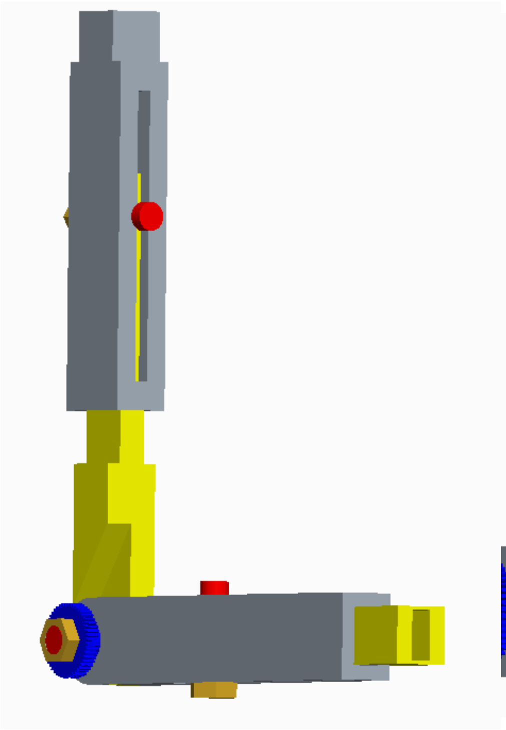
First prototype may be ABS.

Increased safety and fail safes.

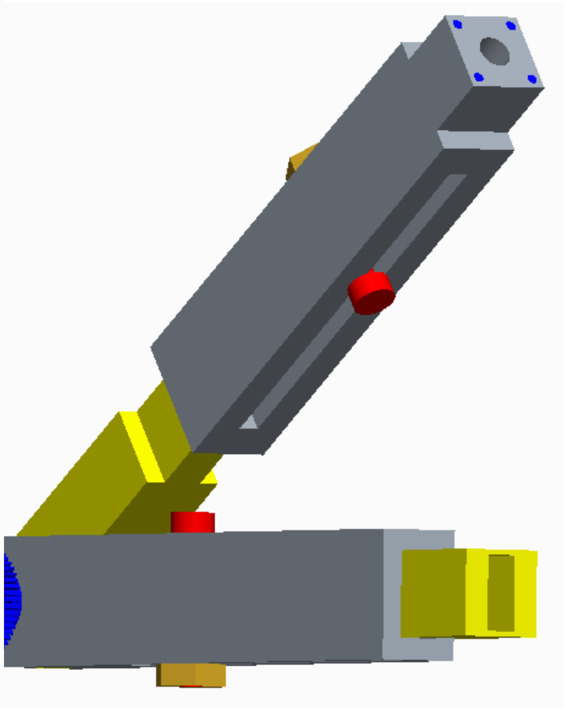
Frame - Circular Elbow Joint



Arm at 180 degrees.

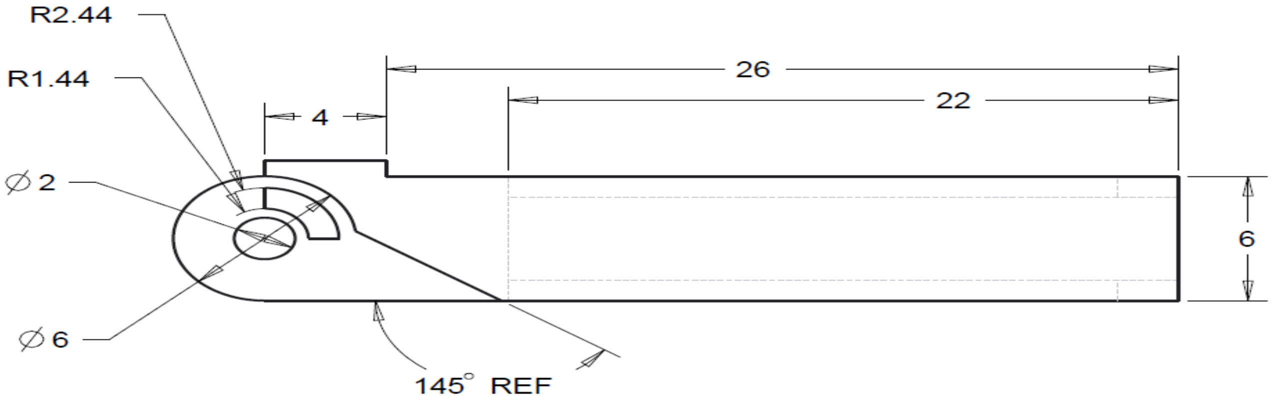


Arm at 90 degrees.

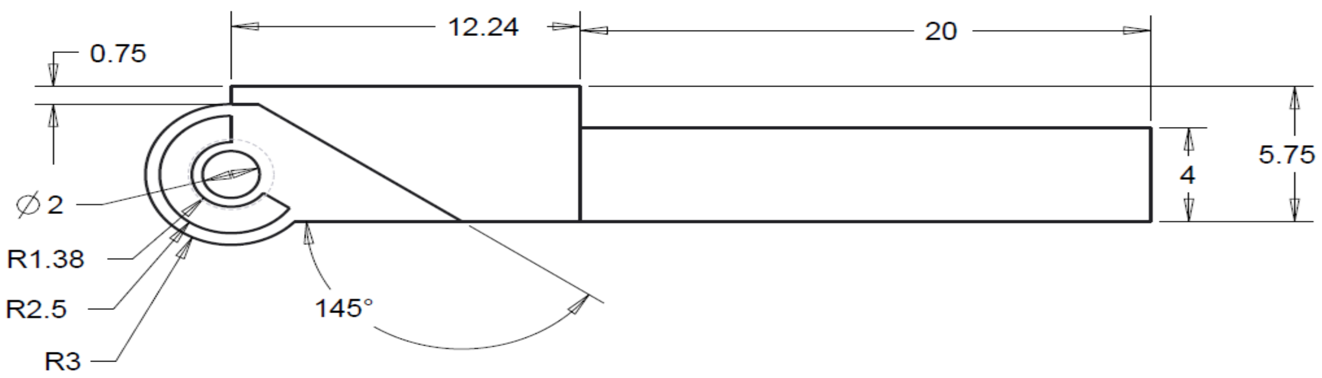


Arm at 35 degrees.

Frame - Circular Elbow Joint Pt. 2



Forearm Piece

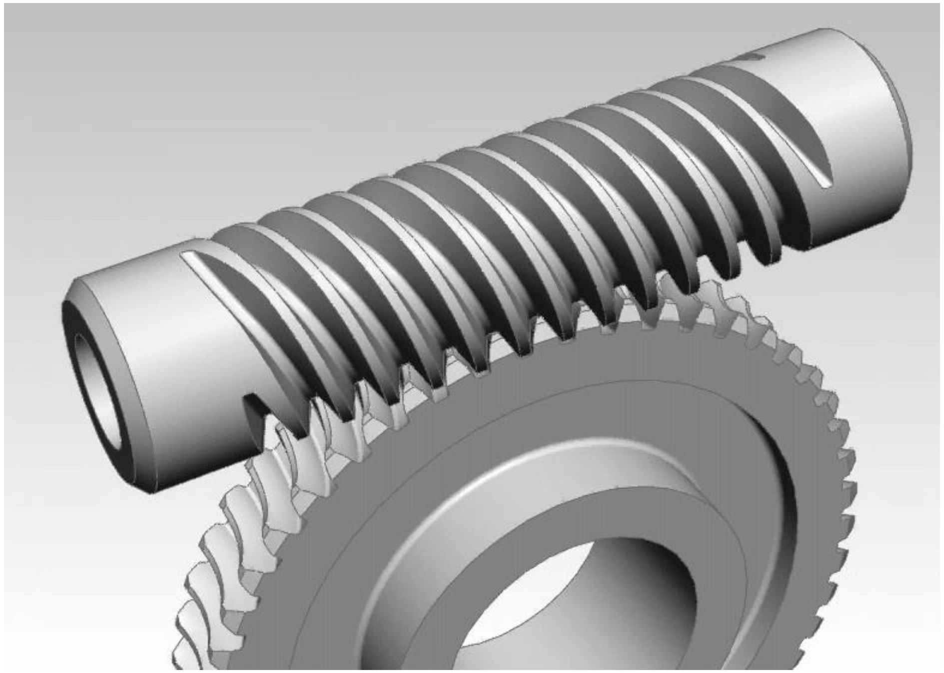


Upper Arm Piece

Worm And Worm Gear

We chose to apply torque through a worm and worm gear system for several reasons:

- Reduces motor speed
- Increases torque
- Easier to mount the motor and apply torque through the motor
- Locks the user's arm into position when the motor is not activated



Backpack

Utilize both straps to spread weight evenly across the back

Evenly spread moment of inertia

Adjust straps so that the bag fits closely to the body and does not sit low below the hips

Houses the microcontroller, motor driver, and battery.

Machining the Frame

Frame will be cut in half initially in order to make machining easier. It will then be spliced back together.

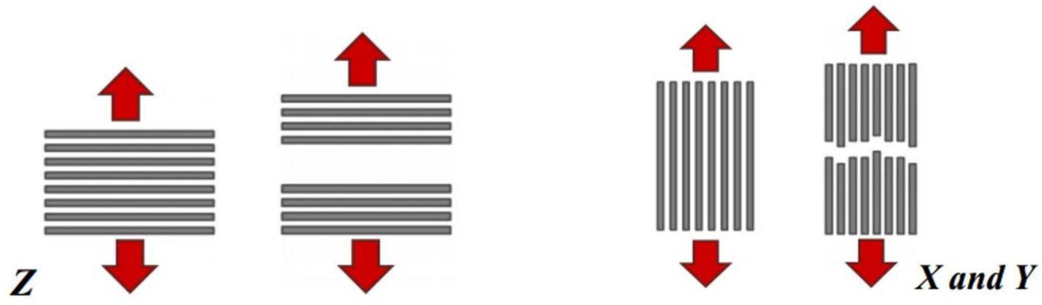
Machining of the arm will be performed by the COE machine shop

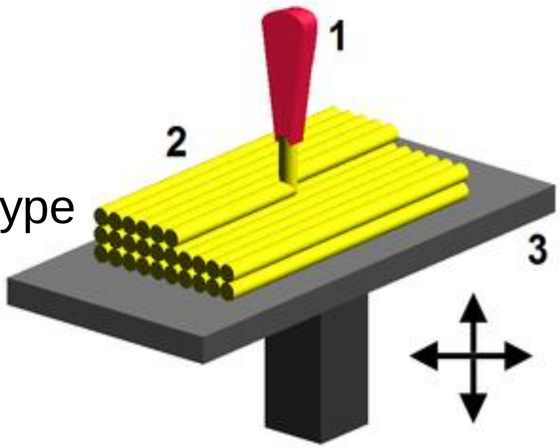
Back mounted frame will be obtained and modified from externally av

3D Printing

Problems with 3D Prototyping:

- Low bonding between layers
- Strength of material limited by bonding
- Metal printing expensive and not readily available
- Plastic tensile strength not good enough for our prototype





Method 1 = 40%

Method 2 = 60%

Types of Electric Motors

Brushless Motor

- DC Brushless
    - Higher efficiency due to no loss of energy from friction
    - A lower EF and RF noise
    - Output less heat

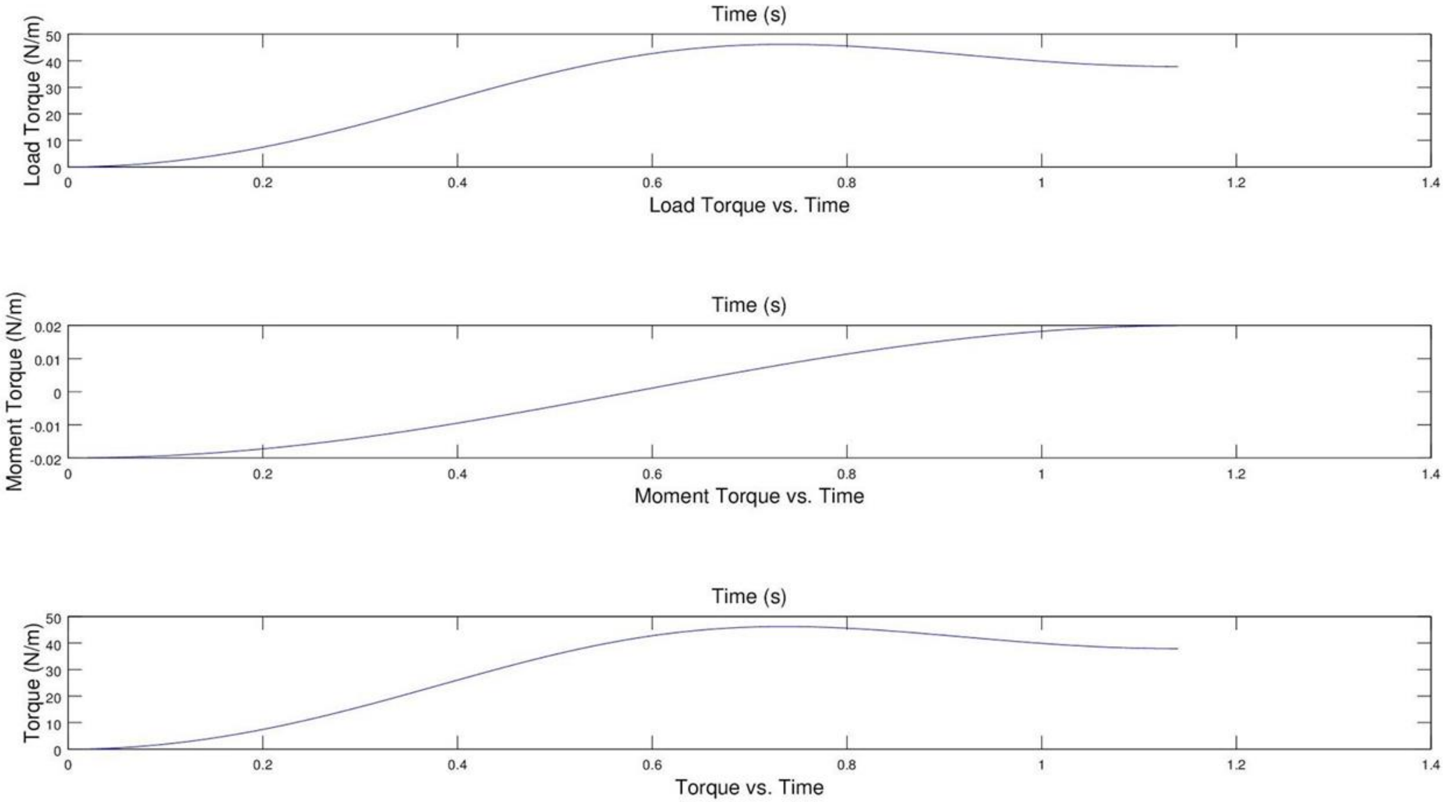
Pancake Motor

- Pancake Motor
    - Designed to be flat, use windings around a disc to provide the EM field.
    - The design allows for the motor to be much more compact than other motors
    - Need to be used at > than 40 kHz due to decreased induction

Brushed DC Motor

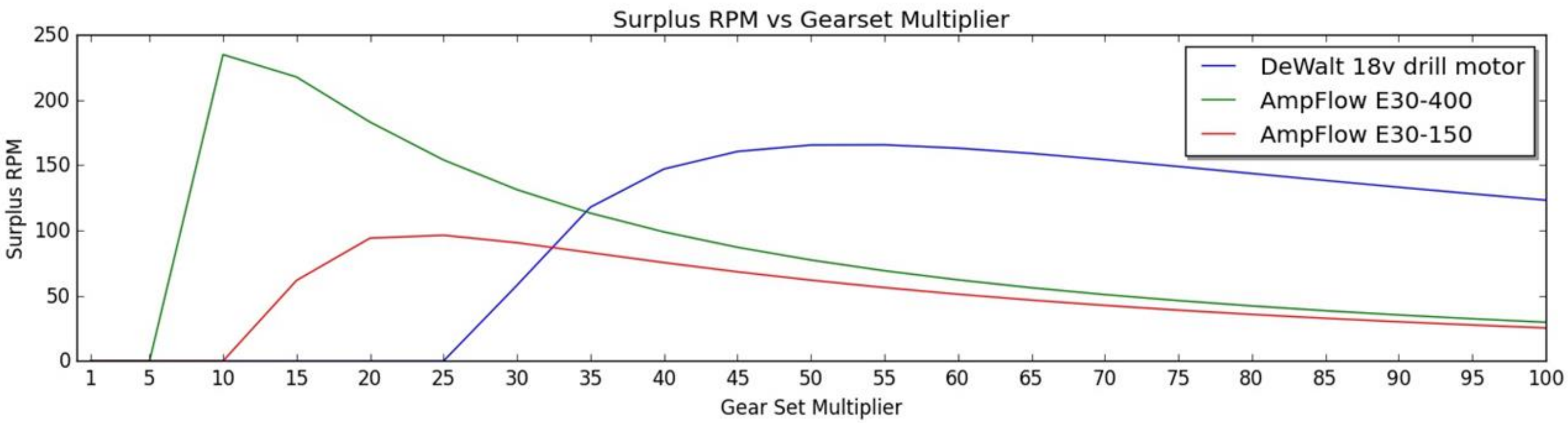
- Brushed DC Motor
    - Moderate level of control

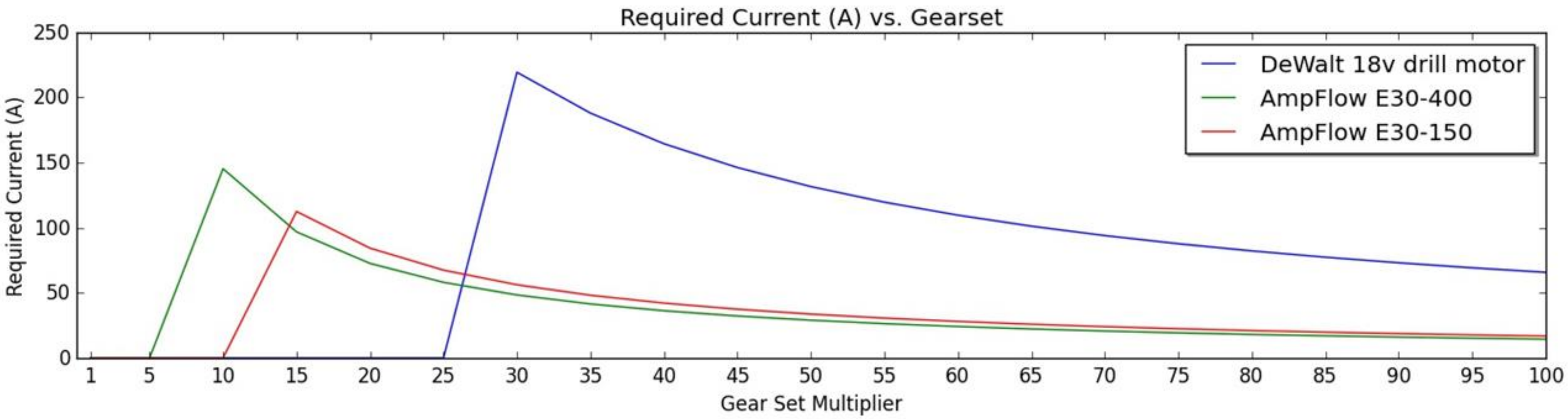
Motor Torque Simulation



- Equations used:
  - $\tau = \tau_{load} + \tau_{moment}$
  - $\tau_{load} = m*g*\sin(\theta)*r$
  - $\tau_{moment} = I\theta''$
  - $I = mr^2$

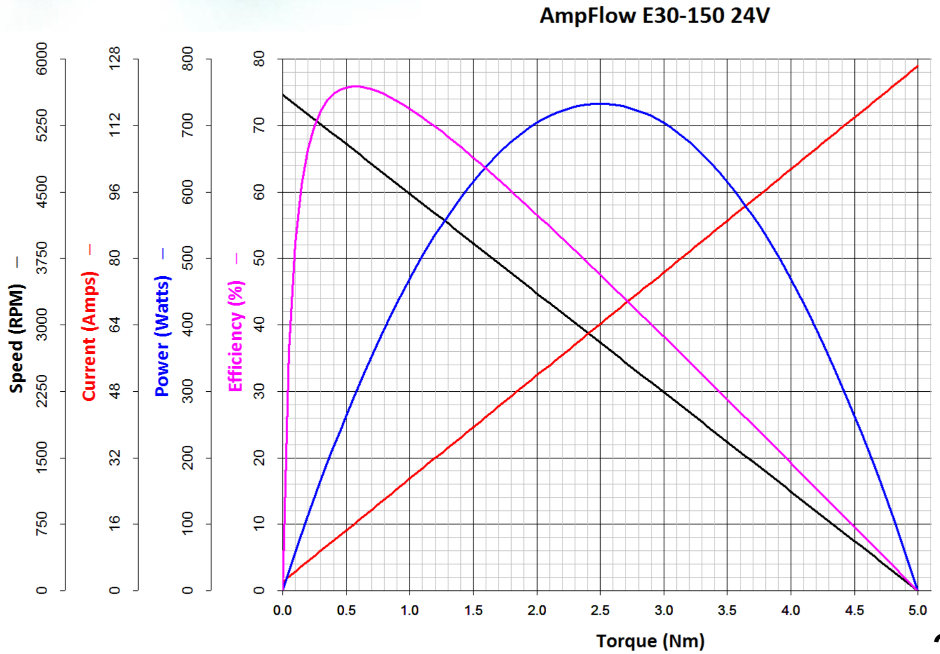
Fitness Charts



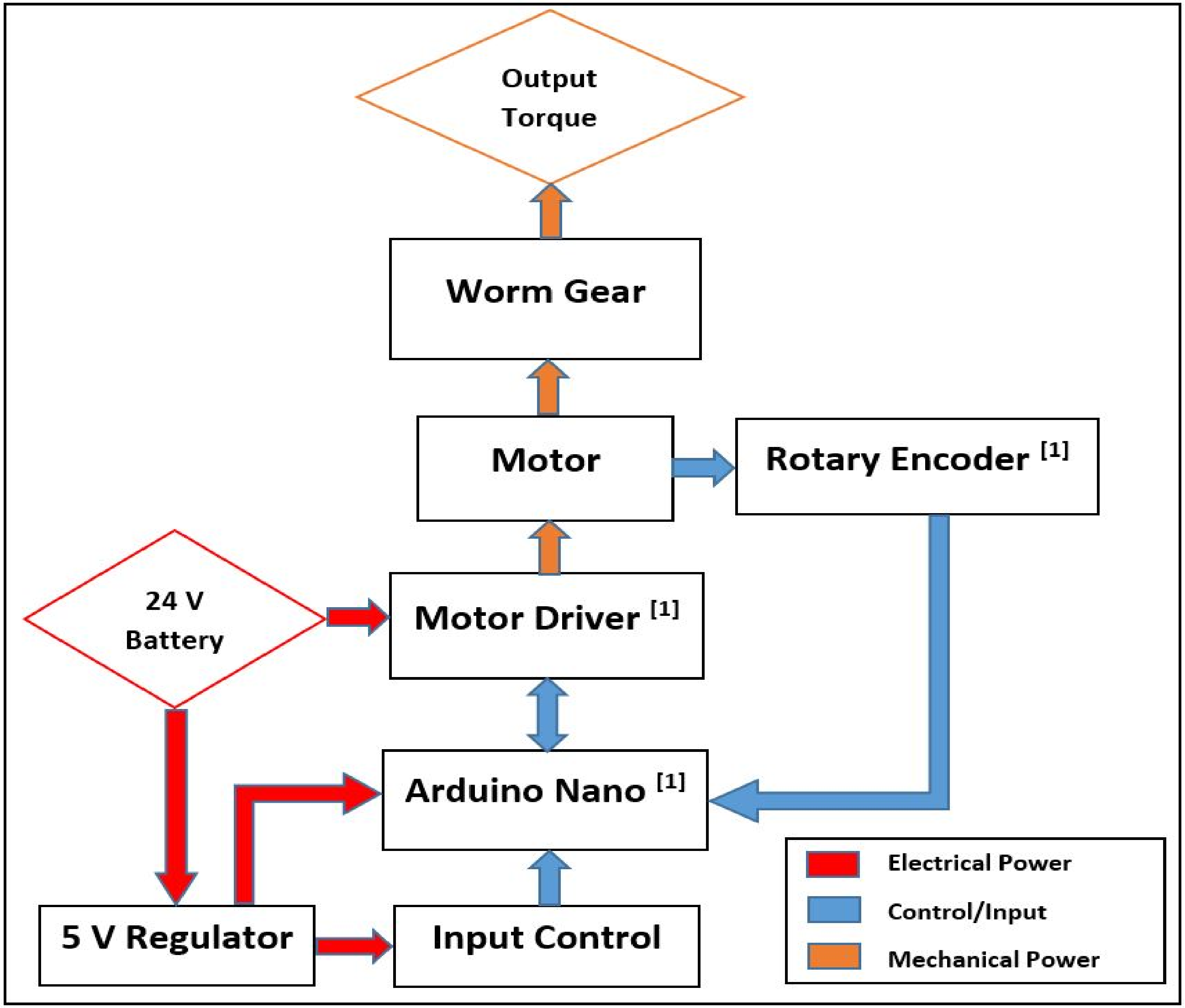


Motor Choice - AmpFlow E30-150

- Brushed DC Motor
- Stall Torque (Nm)
  - 5.014
- Max Rpm
  - 5600
- Operating Point
  - .95 Nm
  - 1450 rpm
  - 20 A
  - 24 V peak, 7.73V average
- Price

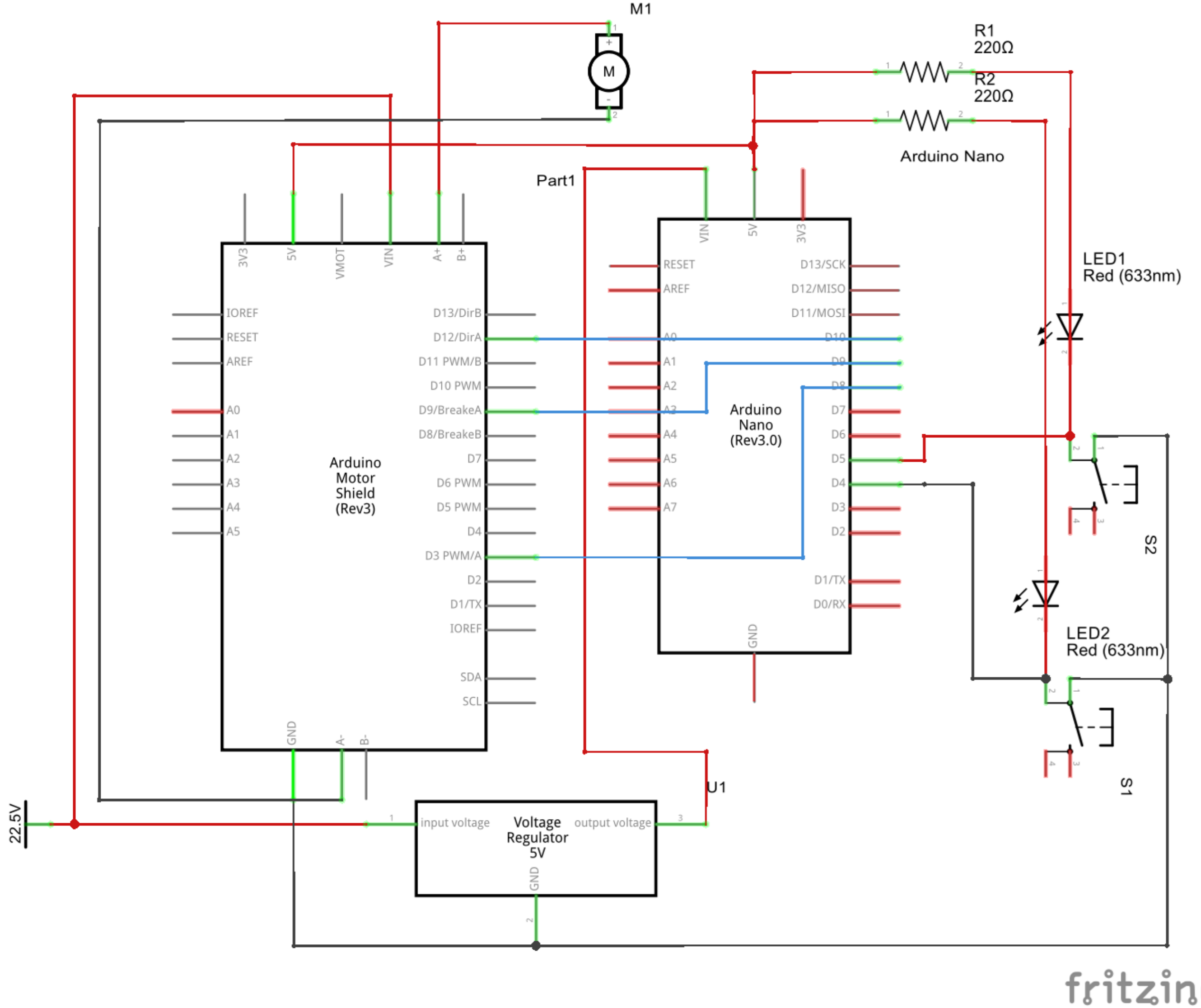


Block Diagram



[1] Indicates presence of a safety mechanism

Circuit Schematic



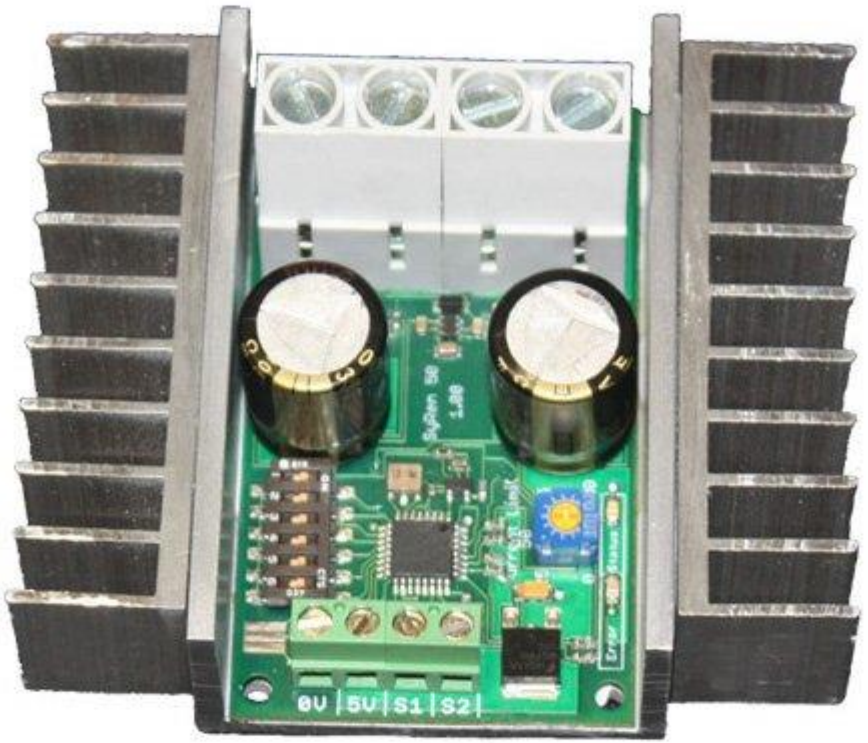
Battery - 4000 mAh LiPo, 24V

- Required current: 20 A
- Estimated lifting time: 1.14 s
- Approximately 631 lift cycles

Weight: 1.72lb

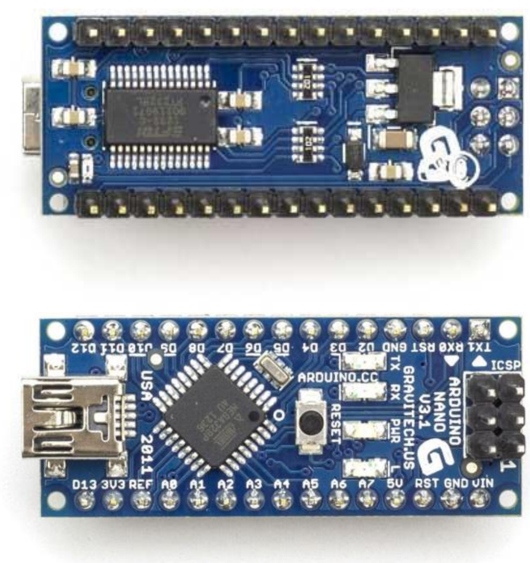
Motor Driver - SyRen 50

- 50 amp continuous current rating
- 100 amp peak current rating
- 30 volt max without additional heatsinking
- Integrated lithium cell over discharge protection
- Integrated thermal and adjustable overcurrent protection
- Multiple control protocols



Why Choose Arduino Nano?

- The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328 (Arduino Nano 3.x) or ATmega168 (Arduino Nano 2.x).
- It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one.
- It can be powered via the Mini-B USB connection, 6-20V unregulated external power supply (pin 30), or 5V regulated external power supply (pin 27).



Budget Analysis

Budget for the project is $1,400.

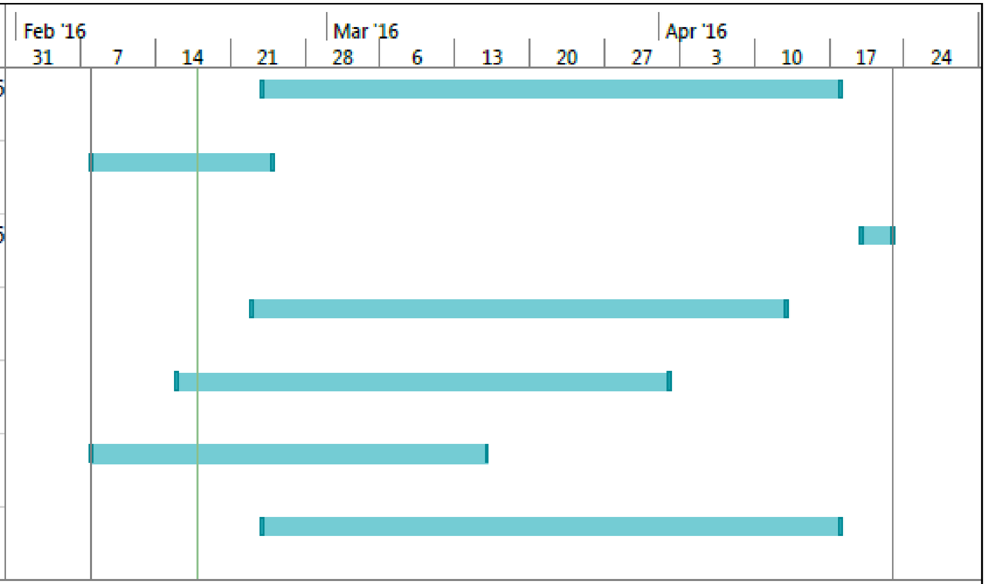
Part	Price	Time
Arduino Uno Nano	$8.88	Here
DC Voltage Step-down Regulator	$8.36	Here
Two Wire DC Voltmeter	$10.99	Here
AmpFlow E30-150 24V	$79.00	Here
Driver Board	$110	Here
Aluminum	$200	Not Ordered
Steel Double U joint	$120	Not Ordered
24V Battery	$83	Not Ordered - 1 week
Push Buttons	$4	Ordered
High Current Wire	$10	Here
Wire	$0	Here
Solder, Glue, Aluminum Tape	$0	Not Ordered
Worm Gearset	$100	Ordered
Bushings	$0	Not Using Anymore
Axle Bearing	$60	Not Ordered
Heat Sink	$20	Ordered
Back Mounted Frame	$100	Not Ordered
Total Cost:	$914.23	
Money Leftover	$485.77	

There are some things we did not order so far, but we have put them into our total cost,and compare the total cost with our budget, we still have some money left.

Cai

Gantt Chart

ID		Task Mode	Task Name	Duration	Start
1			Build Frame	39 days	Wed 2/24/16
2			Test electrical subsystems	13 days	Mon 2/8/16
3			Final Tests	3 days	Wed 4/20/16
4			Test mechanical susbsystems	36 days	Tue 2/23/16
5			Order mechanical parts	34 days	Tue 2/16/16
6			Order electrical parts	27 days	Mon 2/8/16
7			Program microcontroller	39 days	Wed 2/24/16



Development Tests

Basic motor torque/speed tests with electrical power and mechanical load

Test arm under static load.

Final Tests

A user will be asked to

1. Flex their arm under no load to test strain on the muscles.
2. Flex their arm under half load to test strain on the muscles.
3. Flex their arm under full load to test strain on the muscles.

Exertion of the arm will be calculated using the average current consumption.

Safety Analysis

- Potential Problems - Fire hazards
  - Motor Overloading
  - Battery Overloading
  - Driver Overloading
- Solutions
  - All tests performed in fire extinguishers present

Safety Analysis (Cont.)

- Potential Problem - User Hazards
  - Movement too fast/slow
  - Movement of arm outside of designated parameters
- Solution
  - Meticulous testing of set up under multiple test conditions to simulate different use cases
  - Multiple failsafes on multiple levels to ensure immediate shutdown upon abnormal operating conditions

Safety Analysis (Cont.)

- General Safety Protocols
  - At least three testers present during mechanical tests: one to perform, one axe man, one additional to help the tester if necessary
  - At least two testers present during electrical tests: one to perform, one axe man
  - Driver circuit will include multiple electronic failsafes to prevent unsafe power surges

Rubber Safety Addition

Adding a rubber stopper to the elbow safety stop will allow a more controlled fail stop. Damage due to the pinching of wayward extremities will also be minimized.

It is suitable for various kinds of shock absorption and reduced vibration.

Future Plans

Finish ordering parts

- Continue to iterate and refine mechanical design
- Construct the subsystems
- Design a back chassis to support the battery
- Build a prototype
- Program the microcontroller
- Begin testing subsystems

Conclusion

- Construction of the mechanical drive has begun.
- The electromechanical systems are mostly complete.
- Machining of the prototype is being started soon.
- Final design of the prototype is complete.
- Safety clearance for human use is processing.

Questions?

[1] Breg Inc., 'Aligner PHX Humeral Fracture Brace', 2015. [Online]. Available: http://www.breg.com/products/fracture-bracing/aligner-phx-humeral-fracture-brace. [Accessed: 14- Nov- 2015].

[2] Amazon.com, 'Turnigy Heavy Duty Series 4000mAh 6S 60C - 120C Lipo RC Battery

', 2015. [Online]. Available: http://www.amazon.com/Turnigy-Heavy-Duty-4000mAh-60C/dp/B01A07QMUE/ref=sr_1_16?ie=UTF8&qid=1455775966&sr=8-16&keywords=6s+lipo. [Accessed: 18- Feb- 2016].

[3] Amazon.com, 'SyRen 50A Regenerative Motor Driver: Electric Motor Controls: Amazon.com: Industrial & Scientific', 2015. [Online]. Available: http://www.amazon.com/SyRen-50A-Regenerative-Motor-Driver/dp/B00CJ0BEE0/ref=sr_1_3?ie=UTF8&qid=1412717255&sr=8-3&keywords=syren%20dimension%20engineering. [Accessed: 15- Nov- 2015].

[4] Arduino.cc, 'Arduino - AnalogWrite', 2015. [Online]. Available: https://www.arduino.cc/en/Reference/AnalogWrite. [Accessed: 18- Nov- 2015].