ECE Team 10 / ME Team 29
Strength Assisting Orthotic

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11/20/15

Overview

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Project Overview

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

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.

Initial Design

The Arm 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.

Strength of 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.

Inertia

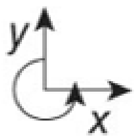
Pulls moment of inertia to the center of the body using tension

Will suspend the weight of the exo-arm

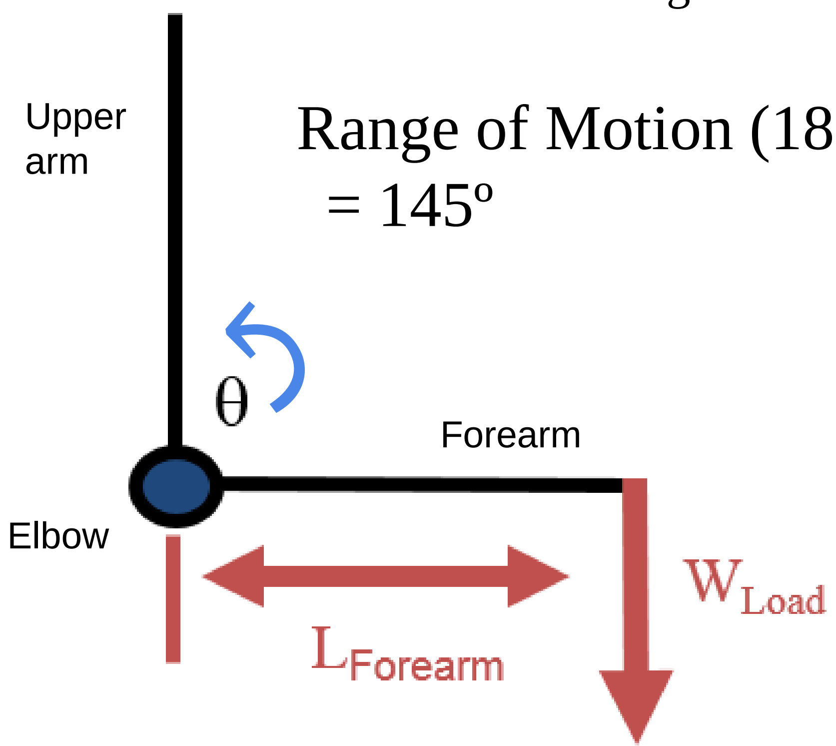
This set up is used in previous orthotic designs for rehab

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.



Range of Motion (180º-35º) = 145º



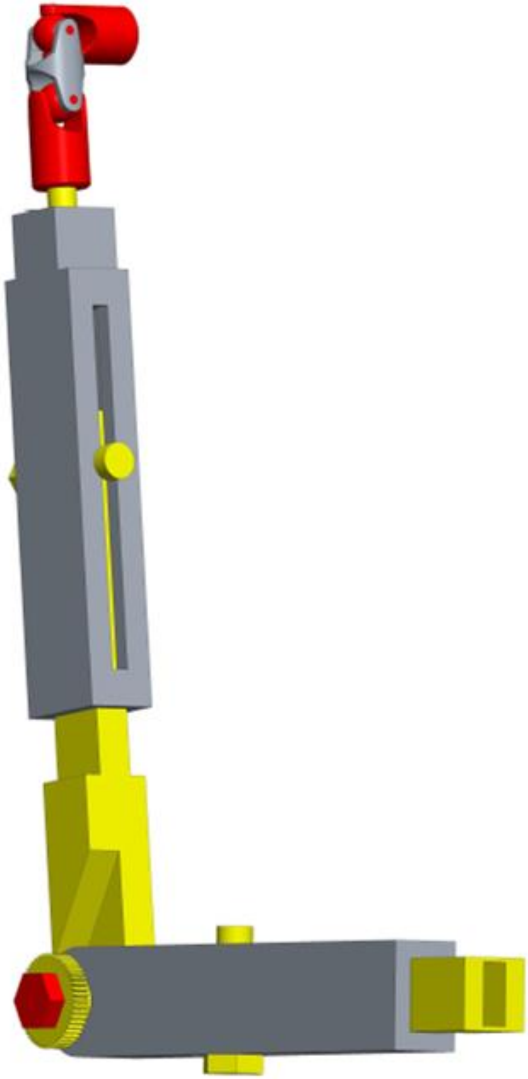
$\theta = 90°$

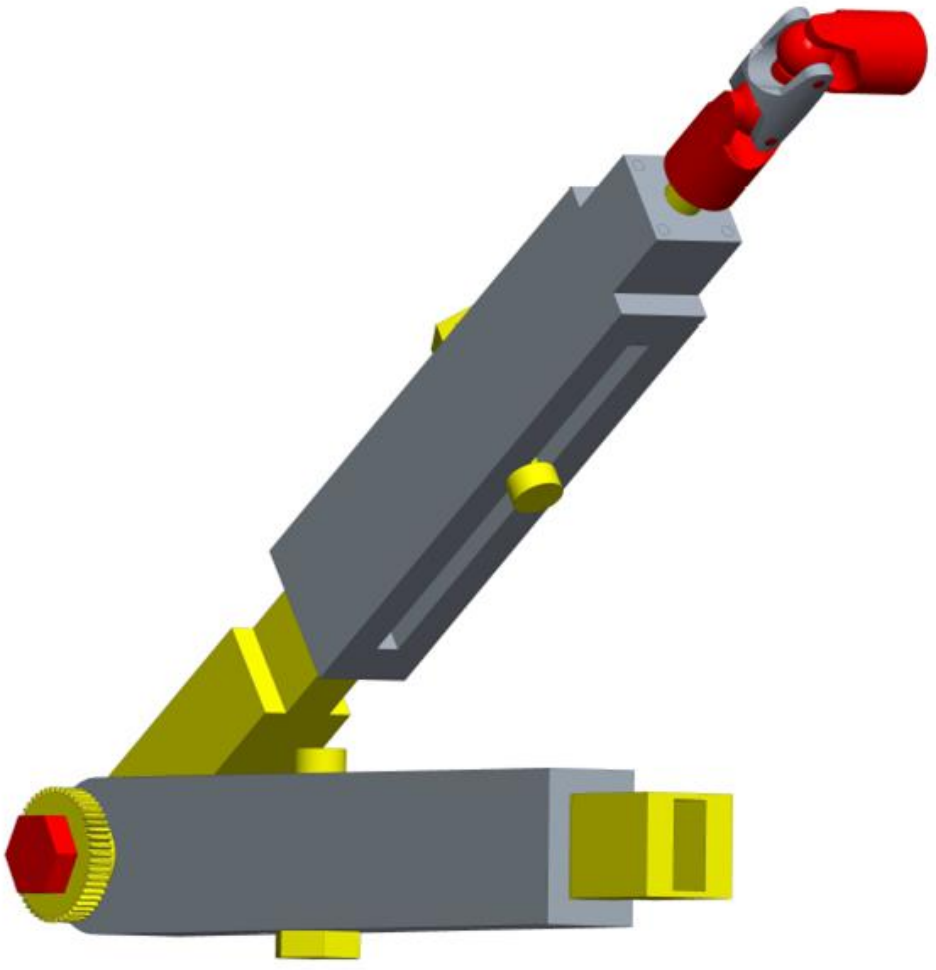
*$L_{Forearm\ -\ max} = 52cm$

*$L_{Forearm\ -\ min} = 38cm$

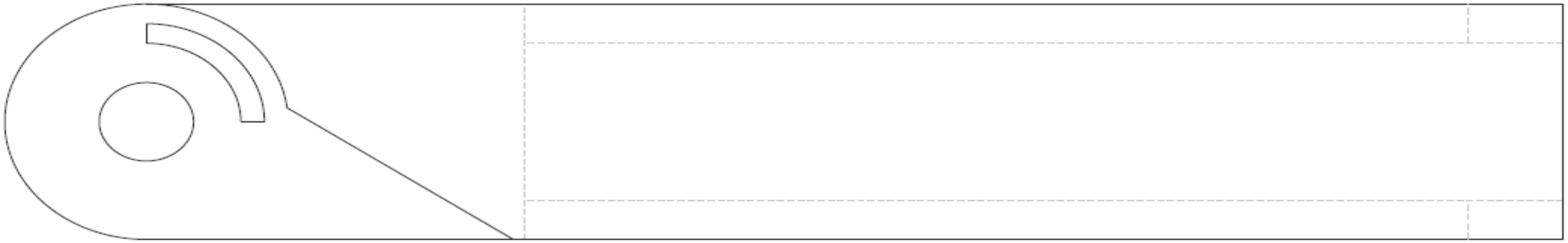
W_{Load} = 21.lbs = 9.52 kg

Frame - Circular Elbow Joint Pt. 1

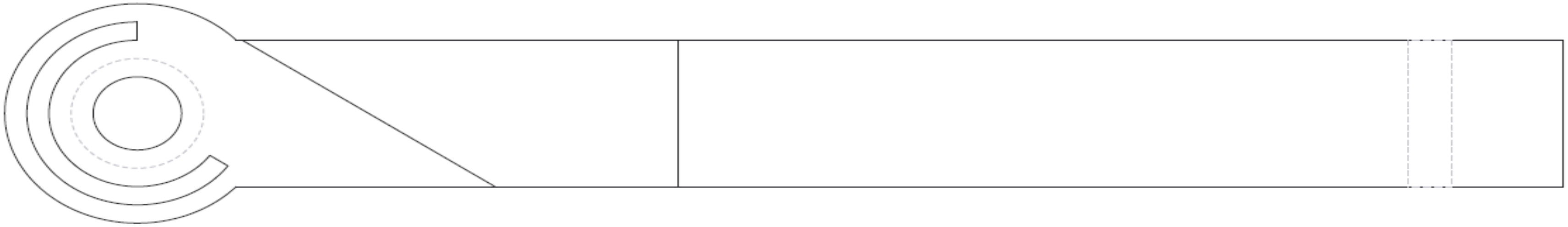




Frame - Circular Elbow Joint Pt. 2

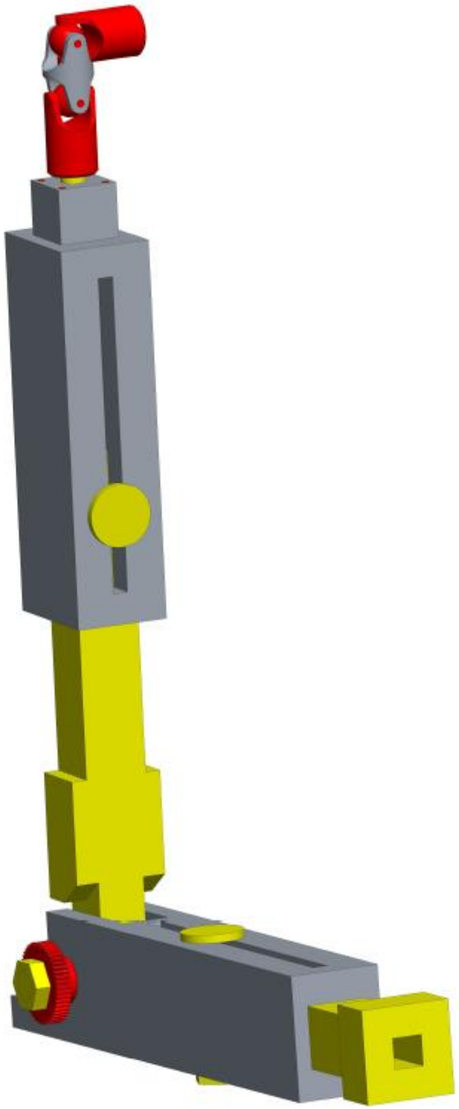


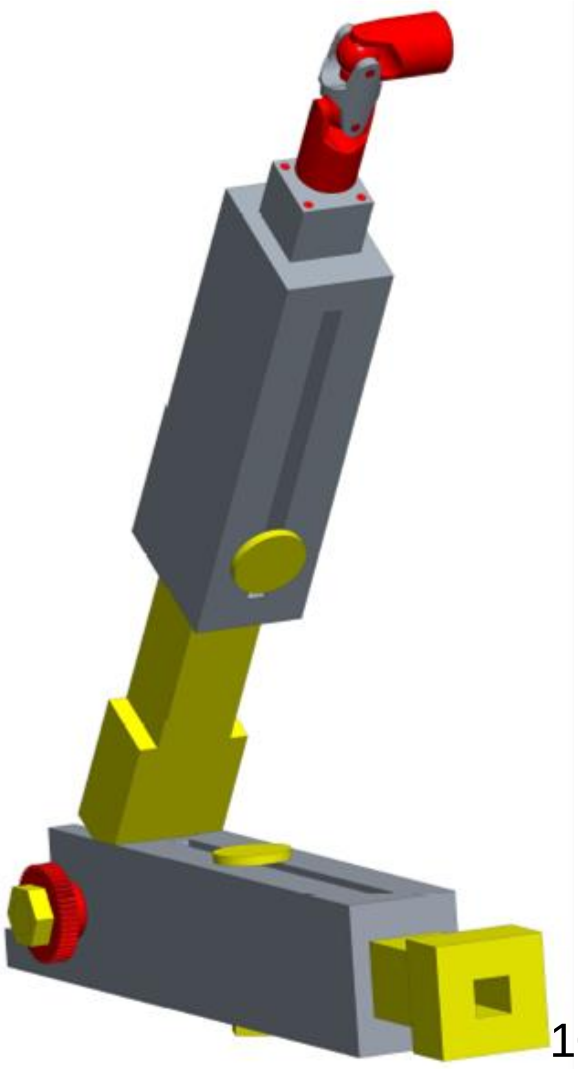
Forearm Piece



Upper Arm Piece

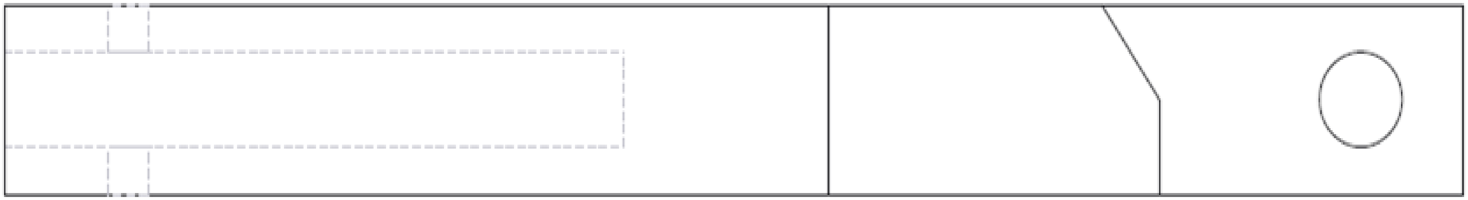
Frame - Square Elbow Joint Pt. 1





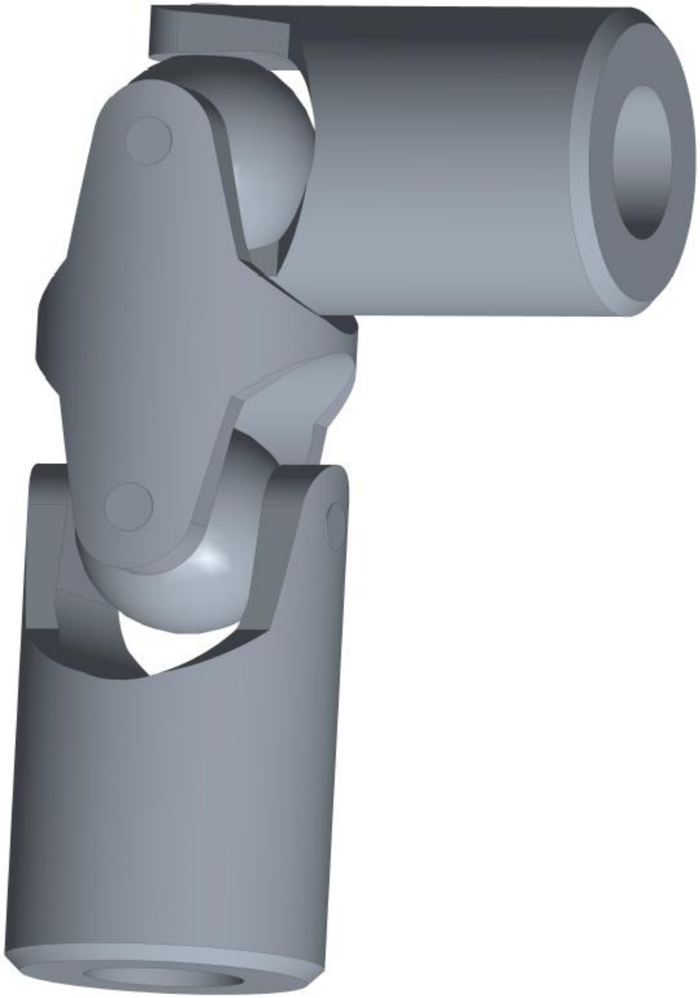
Frame - Square Elbow Joint Pt. 2

Forearm Piece



Upper Arm Piece

Shoulder Joint



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 c than other motors
  - Need to be used at > than 40 kHz due to decreased induction

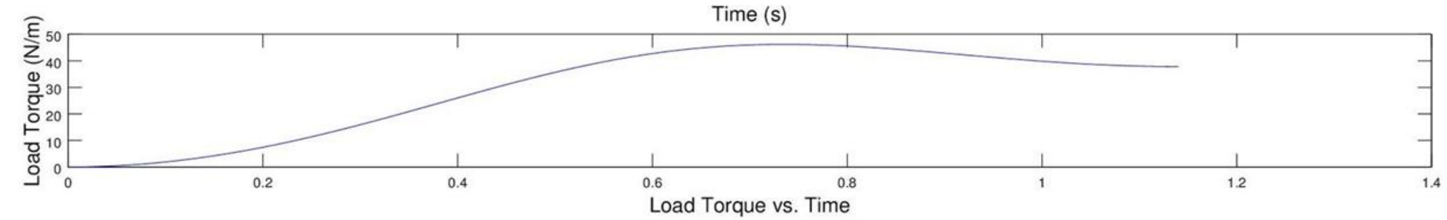
Brushed DC Motor

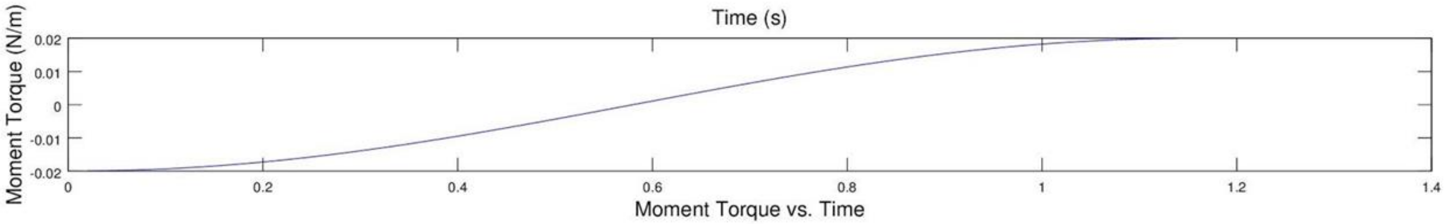
- Brushed DC Motor

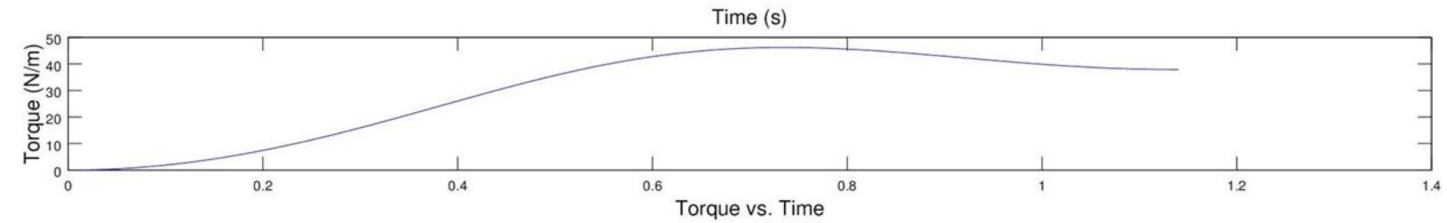
Motor Selection - Gearset Samples

Worm Gear Reduction	Torque Needed (Nm)	oz-in	RPM Needed	Torque (max-min required)	57.00 - 0.57
1	57.00000000	8071.20	130.00	Speed (RPM max-min required)	13000 - 130
5	11.40000000	1614.24	650.00		
10	5.70000000	807.12	1300.00		
15	3.80000000	538.08	1950.00		
20	2.85000000	403.56	2600.00		
25	2.28000000	322.85	3250.00		
30	1.90000000	269.04	3900.00		
35	1.62857143	230.61	4550.00		
40	1.42500000	201.78	5200.00		
45	1.26666667	179.36	5850.00		
50	1.14000000	161.42	6500.00		

Motor Torque Simulation







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

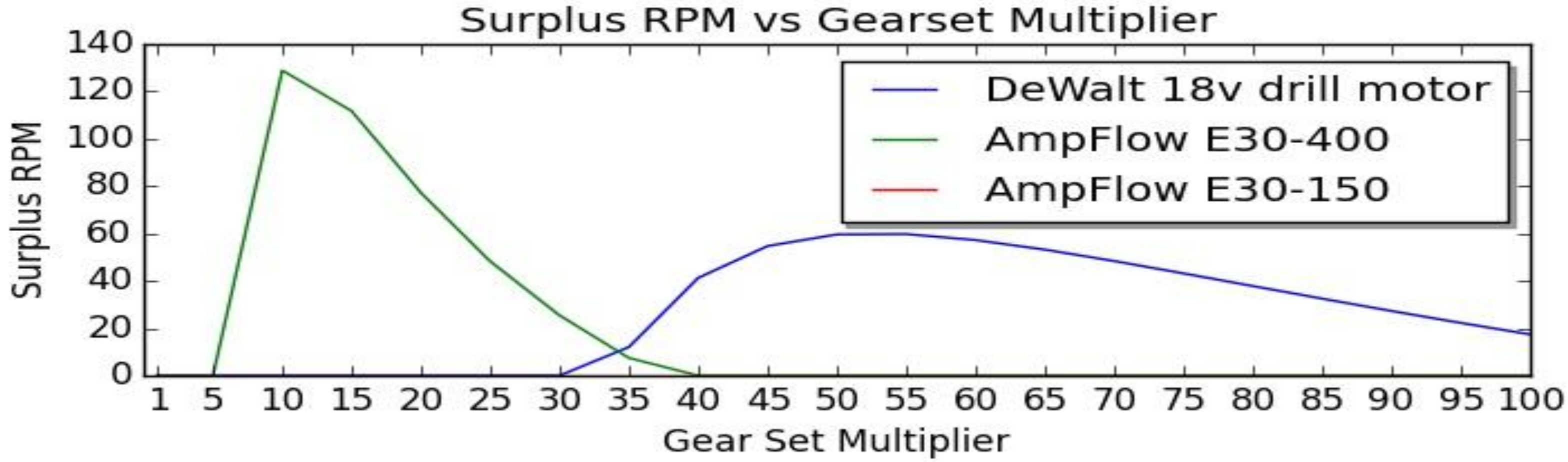
Whitney

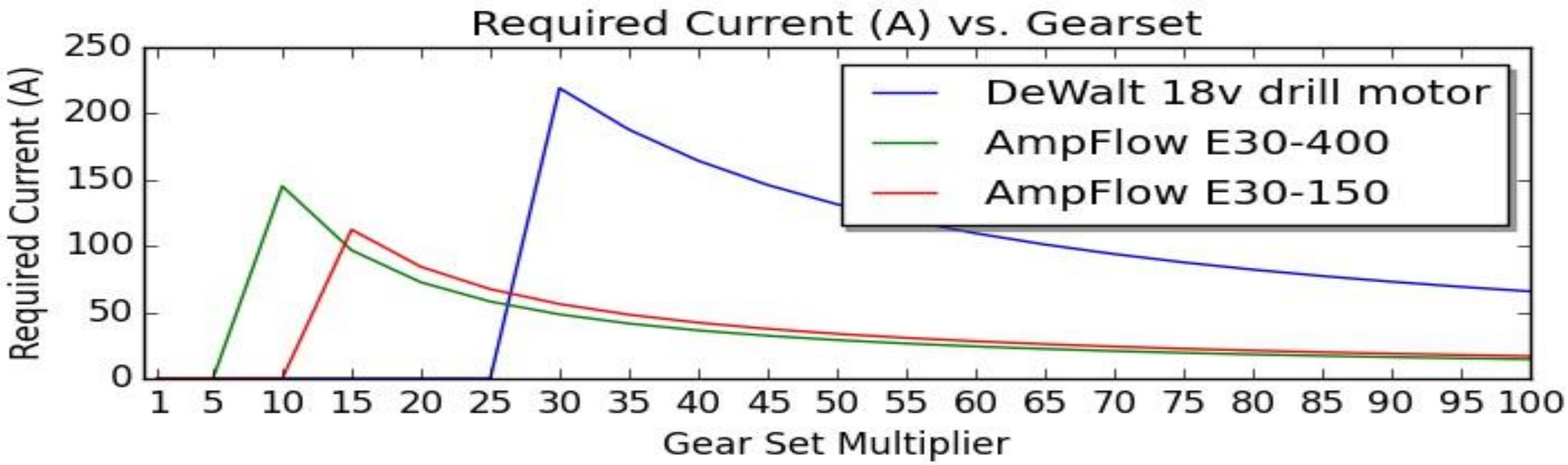
Motor Selection (Cont.)

Motor ID	Stall Torque (Nm)	No-load Speed (RPM)	No-load Current - Stall Current (A)	Voltage (V)	Efficiency	Price ($$$)
22N78 Athlonix (Brushed)	45m	6860.00	10	9	90%	110
EMS-075Q2015 (Brushless)	0.71	3200.00	11	12	x	210
~~Leeson M1110006~~	0.20	1750.00	0.7	12 to 24	68.70%	189
~~Leeson M1120046~~	0.47	2133.00	1.7 - 120	12 to 24	80%	295.99
DeWalt 18v drill motor	2.20	20000.00	2.6	18	81%	86.99
AmpFlow E30-400	10.60	5600.00	3.10 - 266	24	79%	109
AmpFlow F24-150	1.48	2600.00	0.3	24	75%	67
AmpFlow A23-150	4.03	6400.00	1	24	82%	280
AmpFlow E30-150	5.01	5600.00	2.1	24	76%	79

Whitney

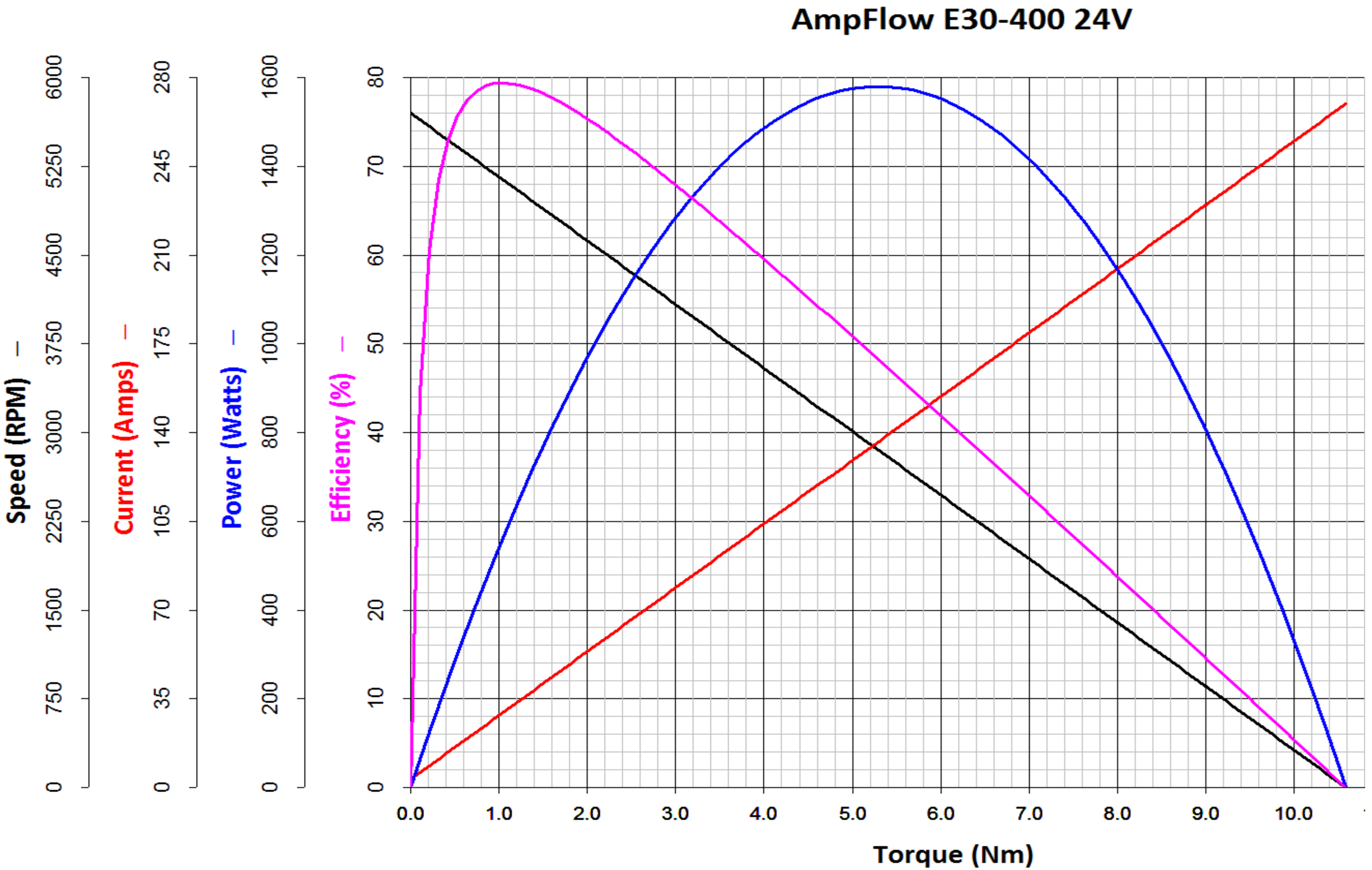
Fitness Charts



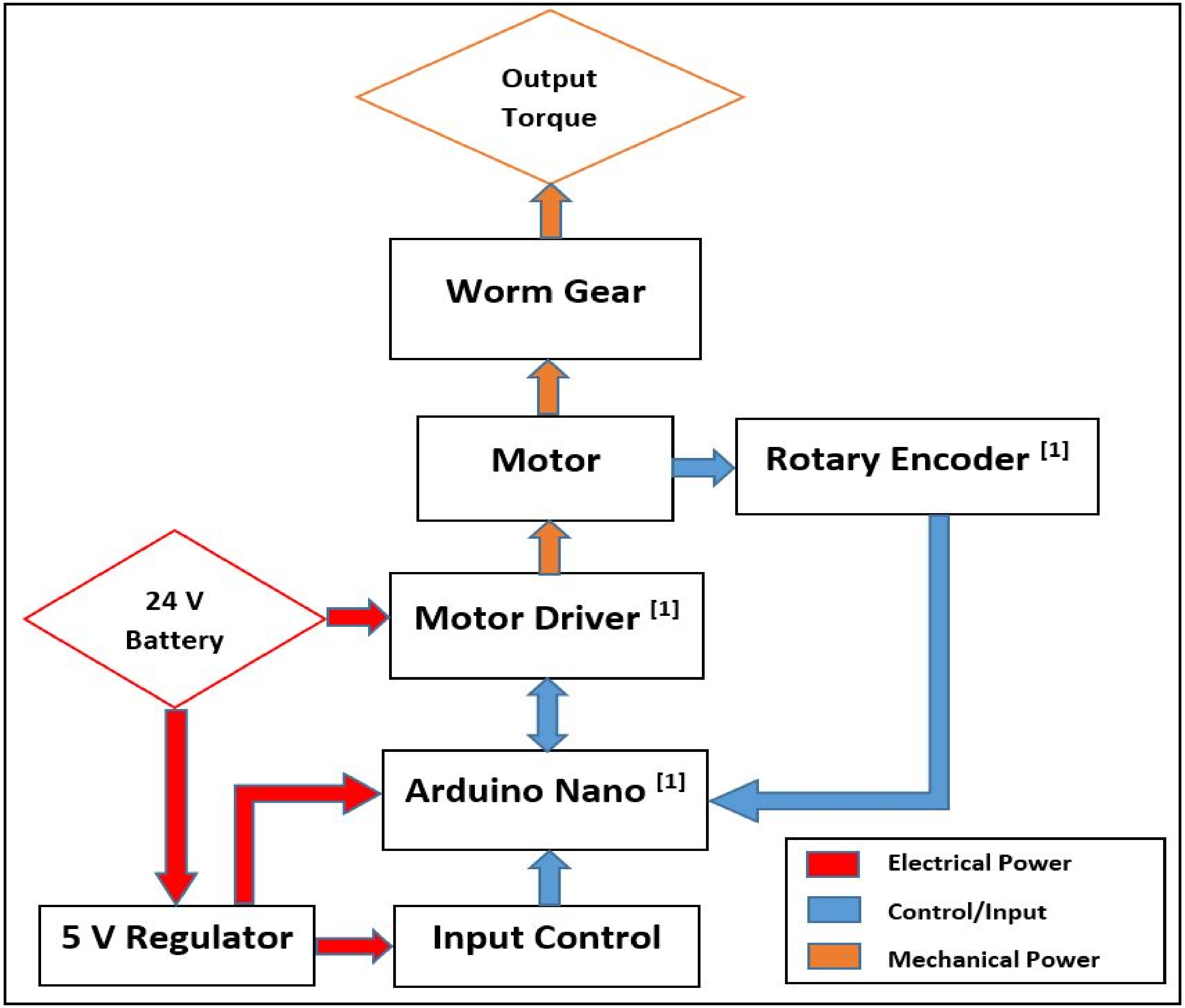


Motor Choice - AmpFlow E30-400

- Brushed DC Motor
- Stall Torque (Nm)
  - 10.6
- Max Rpm
  - 5600
- Operating Point
  - 1.9 Nm
  - 5060 rpm
  - 47 A
  - 24 V
  - 76% power conversion efficiency
- Weight

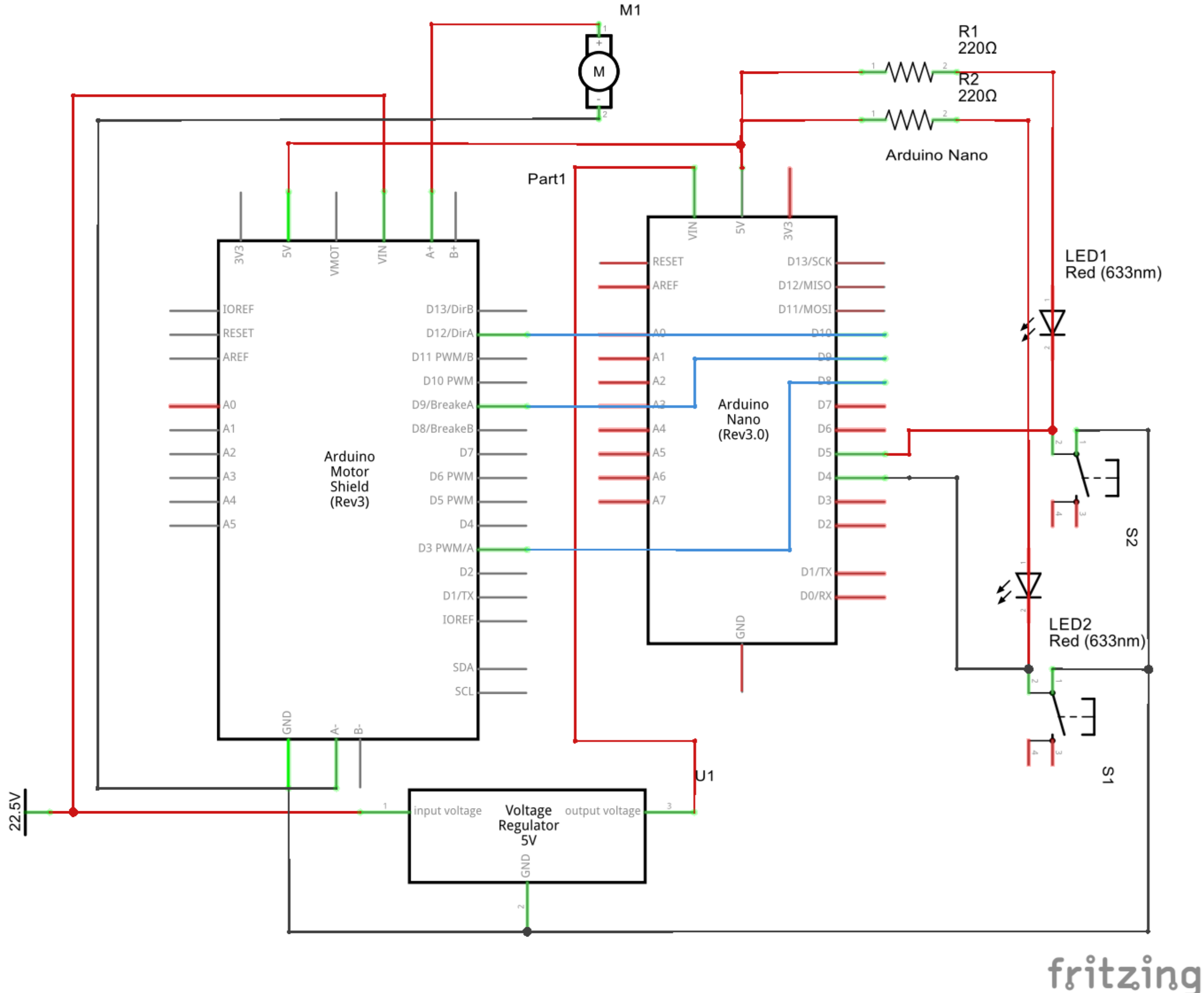

AmpFlow E30-400 24V
Speed (RPM)
Current (Amps)
Power (Watts)
Efficiency (%)
Torque (Nm)
0
750
1500
2250
3000
3750
4500
5250
6000
0
35
70
105
140
175
210
245
280
0
200
400
600
800
1000
1200
1400
1600
0
10
20
30
40
50
60
70
80
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0

Block Diagram



[1] Indicates presence of a safety mechanism

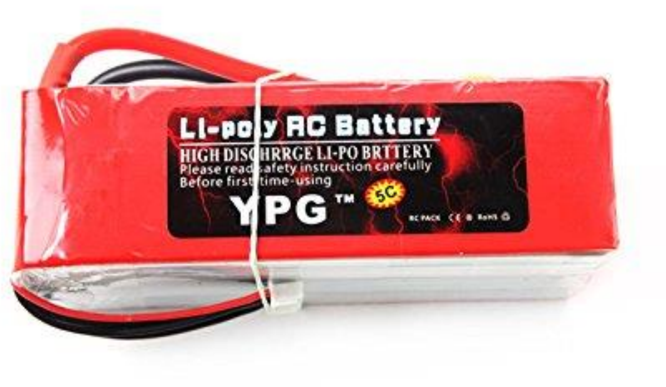
Circuit Schematic



Battery - 5600 mAh LiPo, 24V

- Required current: 47 A
- Estimated lifting time: 1.14 s
- Approximately 376.26 lift cycles

Weight: 1.72lb

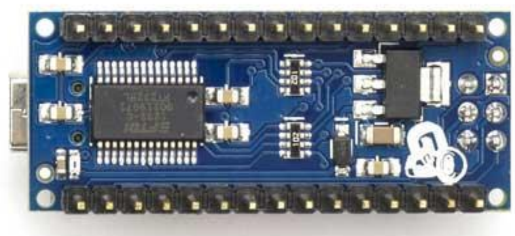


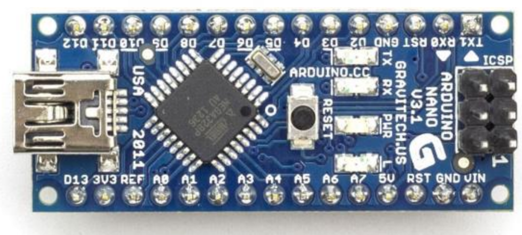
Motor Driver - SyRen 50

- 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
- Regenerative braking capability

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).





Arduino Code

Pulse Width Modulation (PWM):A technique for getting analog results with digital means.

```
int ledPin = 9;      // LED connected to digital pin 9

int analogPin = 3;   // potentiometer connected to analog pin 3

int val = 0;         // variable to store the read value

void setup()

{

           pinMode(ledPin, OUTPUT);   // sets the pin as output

}

void loop()

{

           val = analogRead(analogPin);   // read the input pin

           analogWrite(ledPin, val / 4);  // analogRead values go from 0 to 1023, analogWrite
values from 0 to 255

}
```

Input A	Input B	Motor State
High	Low	Turns clockwise
Low	High	Turns anti-clockwise
High	High	Braking occurs
Low	Low	Braking occurs

Budget Analysis

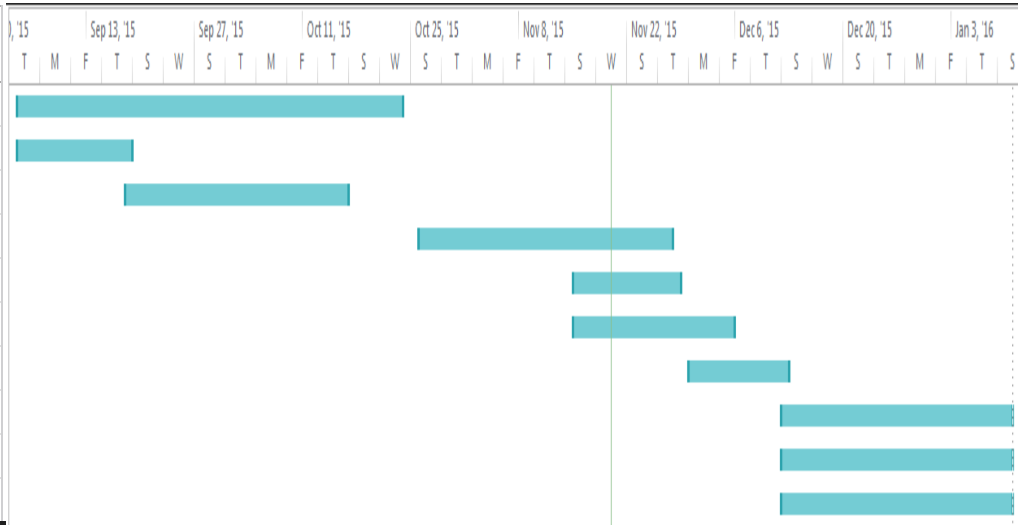
Budget for the project is $1,400.

Part	Price	Time
Arduino Uno Nano	$8.88	Here
DC Voltage Step-down Regulator	$8.36	Here
Two Wire DC Voltmeter	$10.99	Here
	$109.00	Not Ordered. - 7 to 10 days
Driver Board	$110	Not Ordered. - 7 to 10 days
Aluminum	$110	Not Ordered
24V Battery	$87	Not Ordered - 8 to 12 weeks
Push Buttons	$4	Not Ordered
High Current Wire	$10	Not Ordered
Wire	$0	Not Ordered
Solder, Glue, Aluminum Tape	$0	Not Ordered
Worm Gearset	$80	Not Ordered
Bushings	$30	Not Ordered
Other Gears		Not Ordered
Axle Bearing		Not Ordered
Heat Sink	$20	Not Ordered
Total Current Cost:	$588.13	
Money Leftover	$811.87	

The original motor we chosen was $859.25, but the price of this one is significantly cheaper. We save a lot of money from the new motor.

Gantt Chart

Task Name	Duration	Start	Finish
Designing	36 days	Fri 9/4/15	Fri 10/23/15
Brainstorming	11 days	Fri 9/4/15	Fri 9/18/15
Actuation Method	21 days	Fri 9/18/15	Fri 10/16/15
Frame Design	25 days	Mon 10/26/15	Fri 11/27/15
Finalize Design	12 days	Sun 11/15/15	Sat 11/28/15
Order Parts	17 days	Sun 11/15/15	Sat 12/5/15
Construct Subsystems	11 days	Mon 11/30/15	Sat 12/12/15
Build Prototype	22 days	Sat 12/12/15	Sun 1/10/16
Program Microcontrol	22 days	Sat 12/12/15	Sun 1/10/16
Test Prototype	22 days	Sat 12/12/15	Sun 1/10/16



Safety Analysis

- Potential Problems
  - Fire hazards
    - Motor Overloading
    - Battery Overloading
    - Driver Overloading
  - User Hazards
    - Movement too fast/slow
    - Movement of arm outside of designated parameters

Safety Analysis (Cont.)

- Solutions
  - Fire hazards
    - All tests performed in fire-resistant environment, with fire extinguishers present
  - User Hazards
    - Meticulous testing of setup under multiple test conditions to simulate different use cases
    - Multiple failsafes on multiple levels to ensure immediate shutdown upon abnormal operating conditions
  - 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

Future Plans

Order parts before the Fall semester ends

- Finish mechanical design
- Construct the subsystems
- Design a back chassis to support the battery
- Build a prototype
- Program the microcontroller
- Begin testing subsystems

Conclusion

- The motor, gearing system, and driver have all been selected and will be finalized soon.
- Our calculations predict at least a 20 pound lifting capacity with a decent battery lifetime using the selected motors, drivers, and gear sets.
- Our calculations for the necessary parts put us within budget for this project, as far as the prototype is concerned.

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, 'Amazon.com: Gartt ®5200mAH 45C 22.2V 6S Lipo Li-Po Lipoly Battery for RC Helicopter & Airplane: Toys & Games', 2015. [Online]. Available: http://www.amazon.com/dp/B00GNNWZU6/ref=asc_df_B00GNNWZU63941758?smid=A2VS8HDVIIQ0HN&tag=shopz0d-20&ascsubtag=shopzilla_mp_1422-20%3B14475745291454861986510060302008005&linkCode=df0&creative=395105&creativeASIN=B00GNNWZU6. [Accessed: 15- Nov- 2015].

[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].