ELEC 391

ECE, UBC

Spring 2020

'ConcertMaster'

Team 420:

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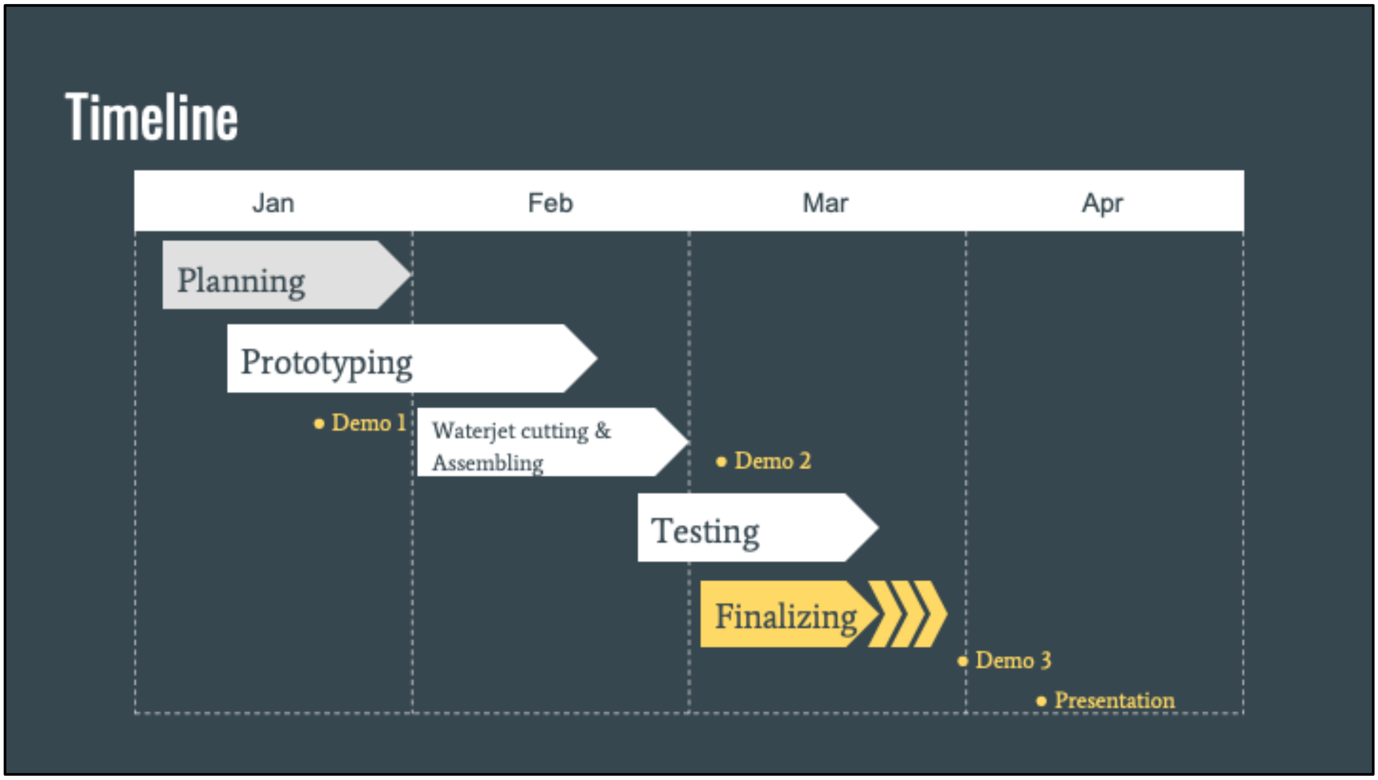
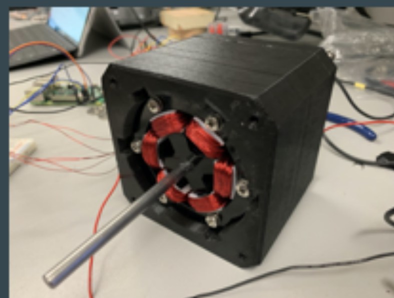

Timeline
Jan
Feb
Mar
Apr
Planning
Prototyping
Demo 1
Waterjet cutting & Assembling
Demo 2
Testing
Finalizing
Demo 3
Presentation

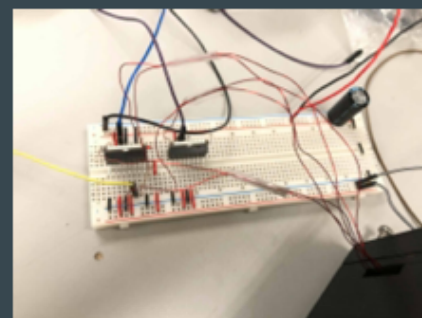
Motors

(Jacky Yu #78202876, Jian Gao #89101919)

Key Objectives

- Motor
- Control Circuit
- Gearbox
- Four-bar Linkage

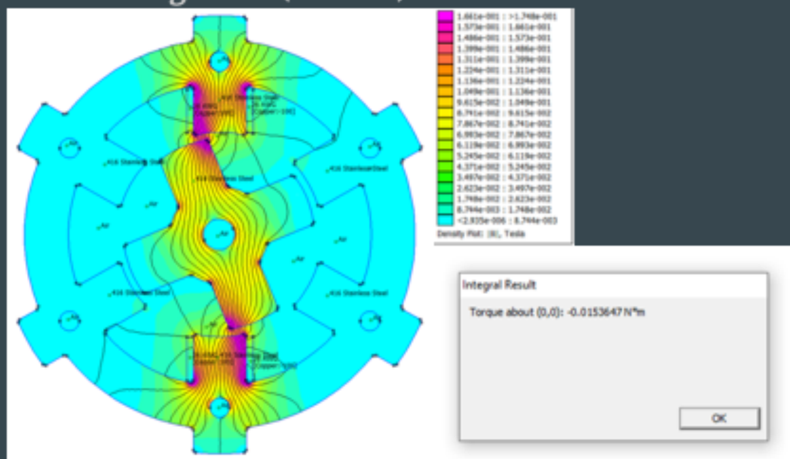




We divide our work into four sectors-- motor, control circuit, gearbox system, and four-bar linkage. Starting with the motor, I would like to introduce our approach to nailing down the specifications of our design. That is to use a simulation software. We will compare the torque from the simulation and the actual motor we built-- it is clear that the simulation model is surprisingly accurate and reliable.

Motor Calculation/Simulation

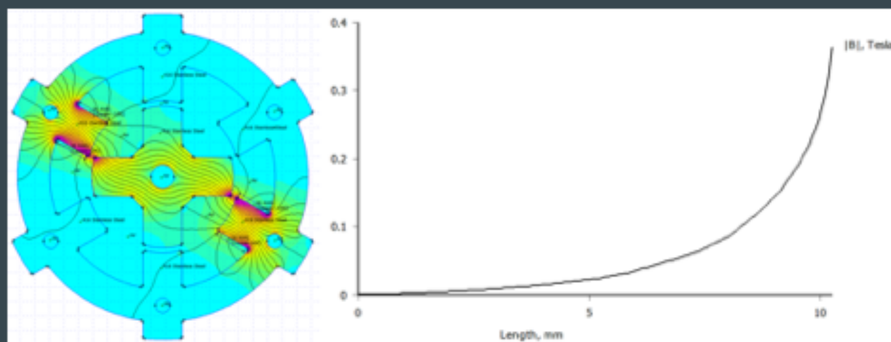
Finite Element Method Magnetics (FEMM):



Due to the complexity of calculating the torque generated by the designed motor, we used a software called Finite Element Method Magnetics (FEMM) to extract the value of torque from the simulation.

FEMM

This approach does not only help us obtain the torque but also offer us an easy access to other physical values of our current model.



Magnetic Flux Density Distribution along One Pole of the Rotor

This approach does not only help us obtain the torque but also offer us an easy access to other physical values of our current model. This is beneficial in terms of iterating our design and verifying the torque deduced by the software.

Altering current and the angle between poles

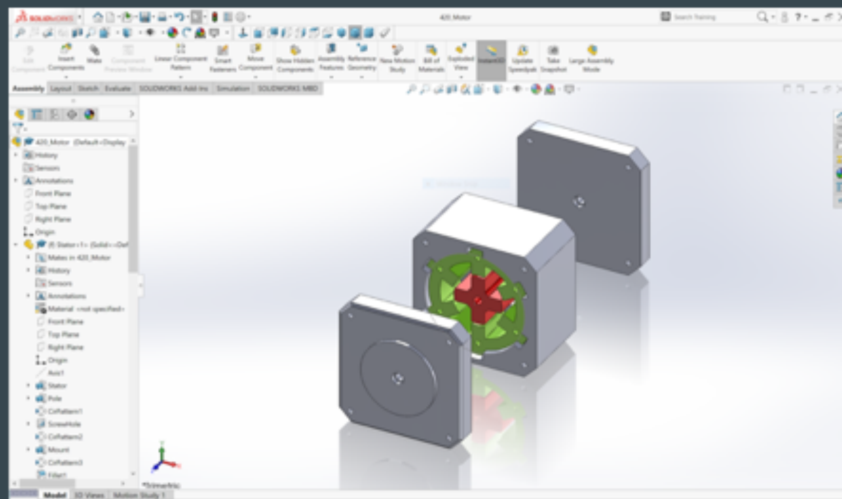
	1.5 A	2.0 A	2.5 A	3.0 A	3.5 A	4.0 A
15 degrees	0.00797	0.0142	0.0223	0.0322	0.0440	0.0576
22.5 degrees	0.00863	0.0154	0.0241	0.0347	0.0474	0.0621
30 degrees	0.00778	0.0138	0.0217	0.0312	0.0426	0.0557

Torque Generated According to FEMM (N*m)

To examine the performance of our model, we obtained the torques under numerous different circumstances. The table above indicates that 22.5 degrees gives us the largest amount of torque among the three.

Motor Design

- Stator, Rotor
- Motor Case
- Shaft (¼ ”), Encoder, Ball Bearings (¼ ” x ⅜ ” x ⅛ ”)



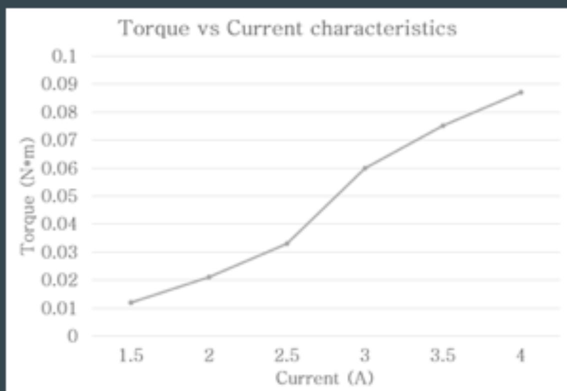
The motor design consists of a case to hold the stator, rotor, shaft and encoder circuit, with wires coming out the sides. This results in a clean looking motor that houses everything. Two ball bearings hold the shaft in place while minimizing friction. The rotor and the encoder wheel are glued to the shaft.

Other Parameters of Our Motor

Nominal Current Per Phase	3.5 A
Number of Winding Per Phase	100 Turns
Phase Resistance	2.63 Ohms
Wire Thickness	26 Ga
Holding Torque	0.08 N*m
Step Angle	30 Degrees
Mass (w/ case)	1.30 Kg

The table above shows the characteristics of the motor. The step angle is 30 degrees, but we can achieve 15 degrees steps by half stepping the motor.

In practice, when our motor stalls

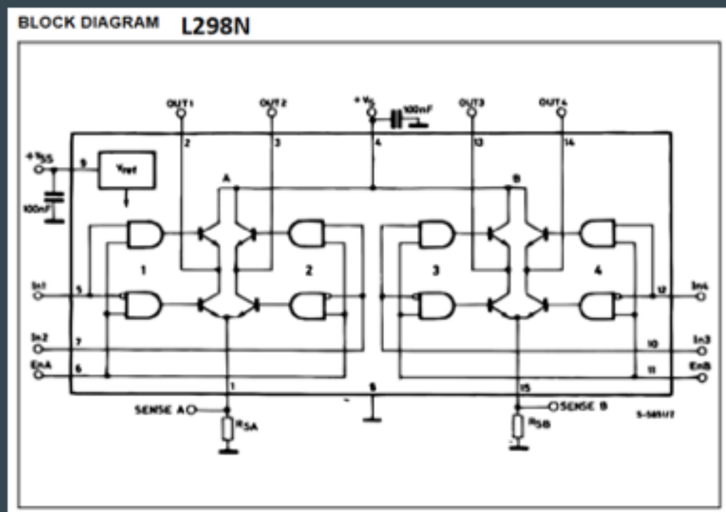


Note that:

1. 4A is the rated current of motor driver L298N
2. Torque in the graph refers to the maximum torque we could get out of the motor through our measurement.
3. When current exceeds 2.5 A, the heat in coil seems to accumulate faster than it dissipates.

This graph shows the maximum measured torque vs the applied current when the motor is not spinning. The maximum torque is observed at a torque angle of 22.5 degrees. As you can see, the torque matches up well with the simulated model. The error may have resulted from the fact that we did not incorporate the steel shaft and the friction into the simulation.

Control Circuit



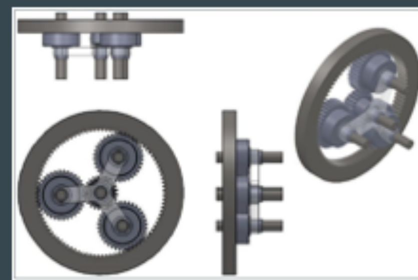
The control circuit consists of 2 l298n motor drivers and a voltage regulator to provide the reference voltage. This driver can provide up to 4A of current. Diodes will be added for protection.

Gearbox

- Input Torque: 0.08 N*m
- Desired Maximum Output Torque: 2 N*m
- Planetary Gear Ratio: 25 (Two-stage system: 5*5)

For Each Stage:

Z_{sun}	Z_{planet}	Z_{ring}
24	36	96



One Stage w/ Gear Ratio of 5

This is the current gearbox design for our motors. One problem we have right now is that 3D-printed gears have significant friction. Meanwhile, the gear ratio is meant to be lowered later since we will be building a motor with a bigger torque.

Four-bar Linkage

Material: medium density fiber boards (MDF):

- Smooth surface
- Light
- Less noise when pressing the keys
- Easier to manufacture

MDF Board

We decided to cut out the four-bar structure out of a medium density fiber board (MDF) due to several reasons as listed. The dimensions of four-bar linkage have not be finalized yet since when tend to play more than one octave on the keyboard if possible. However, that comes after we boost up the torque of our motor by a decent amount.

Possible Improvements for Demo 3

- Improve the torque (to at least 0.2 N*m)
- Reduce required gear ratio (by improving torque)
- Craft gears with optimal material to reduce the friction