Experiments in Low Speed Brushless Motor Control

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1 General Description

Brushless motors have revolutionized robotics, providing high efficiency and high power density to consistently push the edges of what is possible. However for low speed applications, the control and sensing circuitry required to run them becomes prohibitively expensive, ranging from several hundred to several thousand dollars, effectively making them prohibitive for all but the best funded research projects. A lower cost alternative to this technology would be directly beneficial to other research projects, both at Olin and beyond, as well as to industrial robotics and robotics prototyping.

We are creating a robotic actuator with a custom positional feedback motor controller and gearbox with the intent of providing low-speed, high-torque, and high-precision control. We hope that the creation of a functional and robust prototype would aid in dramatically decreasing the cost, and therefore increasing the feasibility, of a large range of robotics projects that would otherwise be prohibitively expensive. We believe that creating such a system would encourage and empower engineers to create better products and more quickly proceed to better prototypes, leaving more time to focus on design principles and research rather than on sourcing reasonable materials and funding.

2 Current Work

We have already completed the initial design and ideation stages of the project, and have both a working 3D printed gearbox prototype and a preliminary positional sensor and motor feedback board.

2.1 Motor sensors

In order to effectively control the motor, we need to know its exact position at all times. This is accomplished by using an array of linear hall effect sensors. In conjunction with a small inexpensive magnet attached to the rotating axes of our motors, we can measure the orientation of the rotating magnetic field with extreme precision and speed. Unlike other encoder applications, the sensors we're prototyping should be able to provide absolute rotational positioning, allowing us to implement better, more reliable, and more resilient control software.

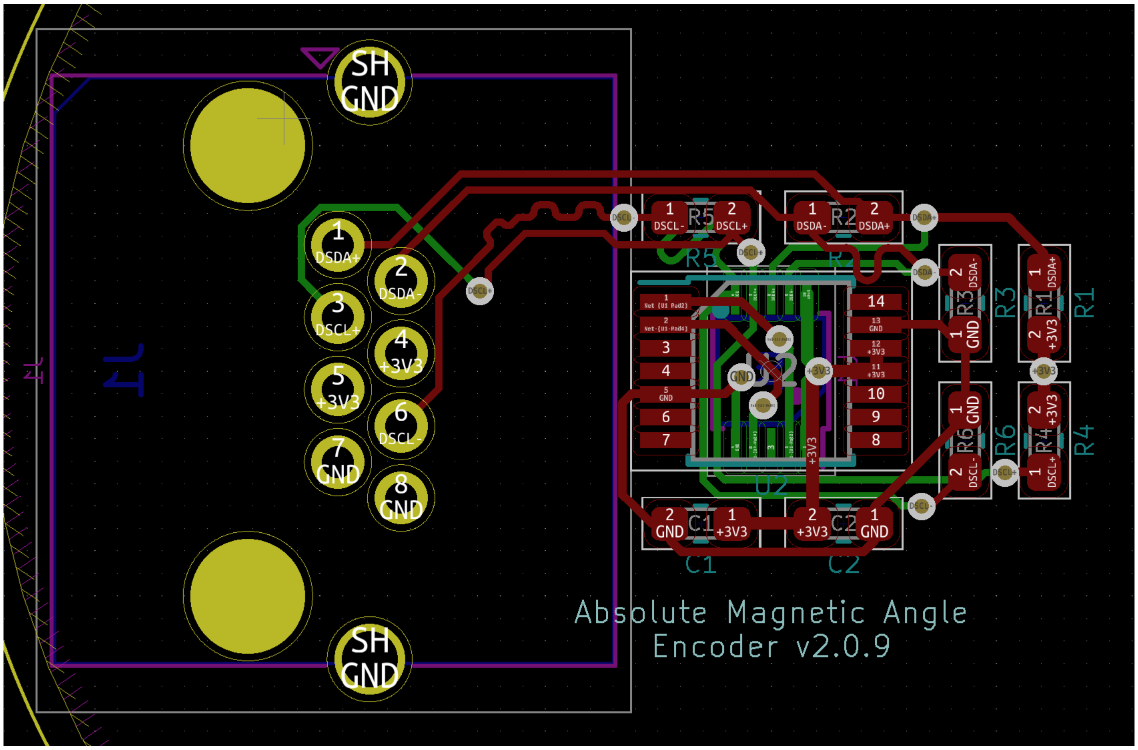

Figure 1: A prototype circuit and magnetic angle encoder. Taking advantage of low-voltage differential signaling in combination with dynamic peripheral buses (I^2C) and twisted-pair cables (Cat5e), we believe we can create more environmentally- and noise-resilient sensors.

2.2 Cycloidal drive

In order to get high gear reductions with low backlash in a relatively small space, we designed a cycloidal reduction mechanism to transmit torque from the motor to the joint. The input shaft has eccentric lobes which drive the cycloidal disks in a circular path. As the disks revolve around the center axis, they engage with the ring gear, causing them to rotate at 1/10th the speed of the input shaft. The output shaft is driven by steel dowel pins that pass though intersecting holes in the cycloidal disks.

Future versions will have less eccentric input shafts which will allow for higher reduction density, larger output shaft pins, and smoother operation. We plan on CNC milling the majority of the components from aluminum and using the bearings listed in our itemized budget to minimize internal friction.

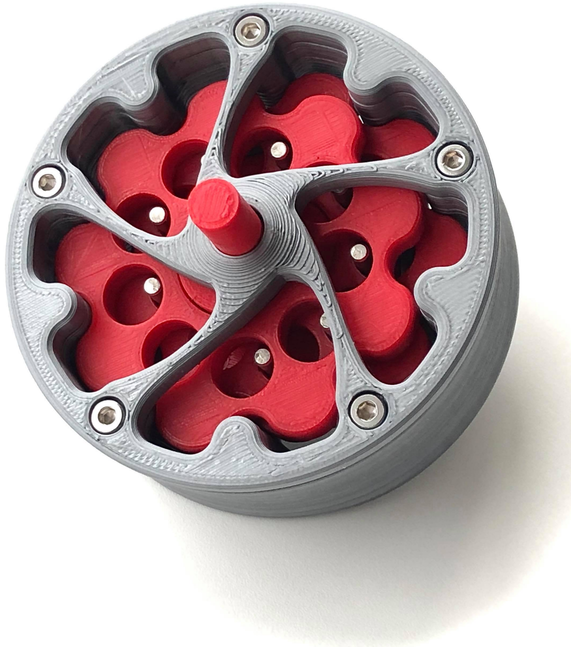

Figure 2: Our working 3D printed cycloidal drive prototype

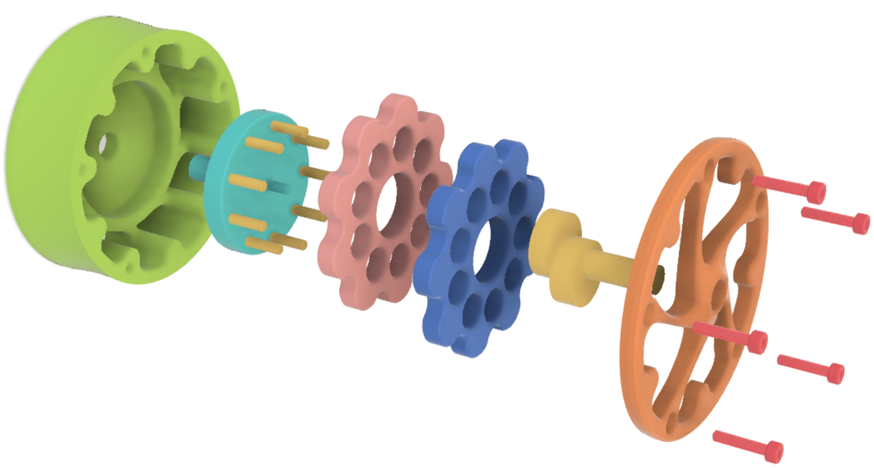

Figure 3: An exploded view of our cycloidal mechanism. It uses two gears on an eccentric shaft to achieve a 10:1 reduction ratio in just one stage.

3 Budget and resource requirements

In order to continue this project, we need to purchase stock, motors, and circuit boards to create a next-generation prototype which will incorporate all of our current design work and allow us to evaluate the system using real materials. We have already done all we can without additional funding using Olin's 3D printers, the ECE stockroom, and our own motors, batteries, and controllers. With additional funding, we can take full advantage of the Olin machine shop and electrical prototyping areas to build a working model and eventually a final product that can be used by others for experimentation and implementation.

Item	Quantity	Price Per	Total	Supplier
10mm Ball Bearing (x10)	1	$ 8.49	$ 8.49	Amazon
20mm Ball Bearing (x10)	1	$ 13.51	$ 13.51	Amazon
Printed Circuit Boards (x3)	3	$ 10.00/in^2	$\approx$ $ 120.00	Oshpark
Teensy 4	1	$ 19.95	$ 19.95	PJRC
LD-POWER MT Brushless Motor	2	$ 45.00	$ 90.00	RC-Wing
3.5 in square aluminum, 12 in length	1	$ 111.61	$ 111.61	OnlineMetals
Cat5e Connectors (x100)	1	$ 24.99	$ 24.99	Amazon
Cat5e Cable	1	$ 6.84	$ 6.84	Amazon
			$ 395.39	

4 Space Requirements

There are almost no space requirements for this project as most of the work is CAD or electrical design. The stock and materials we purchase can easily fit in a bin outside the shop and be stored there during the semester.

5 Project Timeline

- Jan 22 — Work begun
- Jan 26 — Initial encoder board completed
- Feb 03 — Prototype gearbox created
- Feb 10 — Submit SAG funding application
- Feb 21 — Revise gearbox for higher reduction
- Mar 13 — Integrate motor controller and angle sensor
- Mar 27 — Machine final gearbox
- Apr 17 — Complete system-wide test
- Apr 24 — Tweak and optimize for performance
- May 01 — Begin work on user interface
- May 11 — Olin Expo