FAMU-FSU College of Engineering

Virtual Design Review 6

Team 505

Danfoss Stepper Motor Lifecycle Fixture

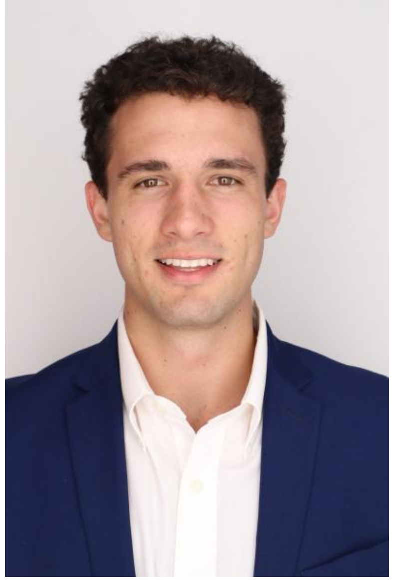
04/03/2025

Team Introductions

Bradford Andrews
Mechatronics Engineer

Albert Auer
Mechanical Design Engineer

Chaney Bushman
Manufacturing and Test Engineer



Joseph Garvie
Systems Engineer

Mason Herbet
CAD Designer

FAMU-FSU College of Engineering

Sponsor and Advisors

FAMU-FSU
College of Engineering

Sponsor
Cole Gray
Senior Mechanical Design Engineer

Academic Advisor
Patrick Hollis, Ph.D.
Associate Professor & Undergraduate Coordinator

Academic Advisor
Shayne McConomy, Ph.D.
Senior Design Professor

Project Description

Albert Auer

The objective of this project is to design and produce a stepper motor lifecycle test fixture for Danfoss Turbocor to improve user-friendliness and reliability over their current testing procedure.

FAMU-FSU College of Engineering

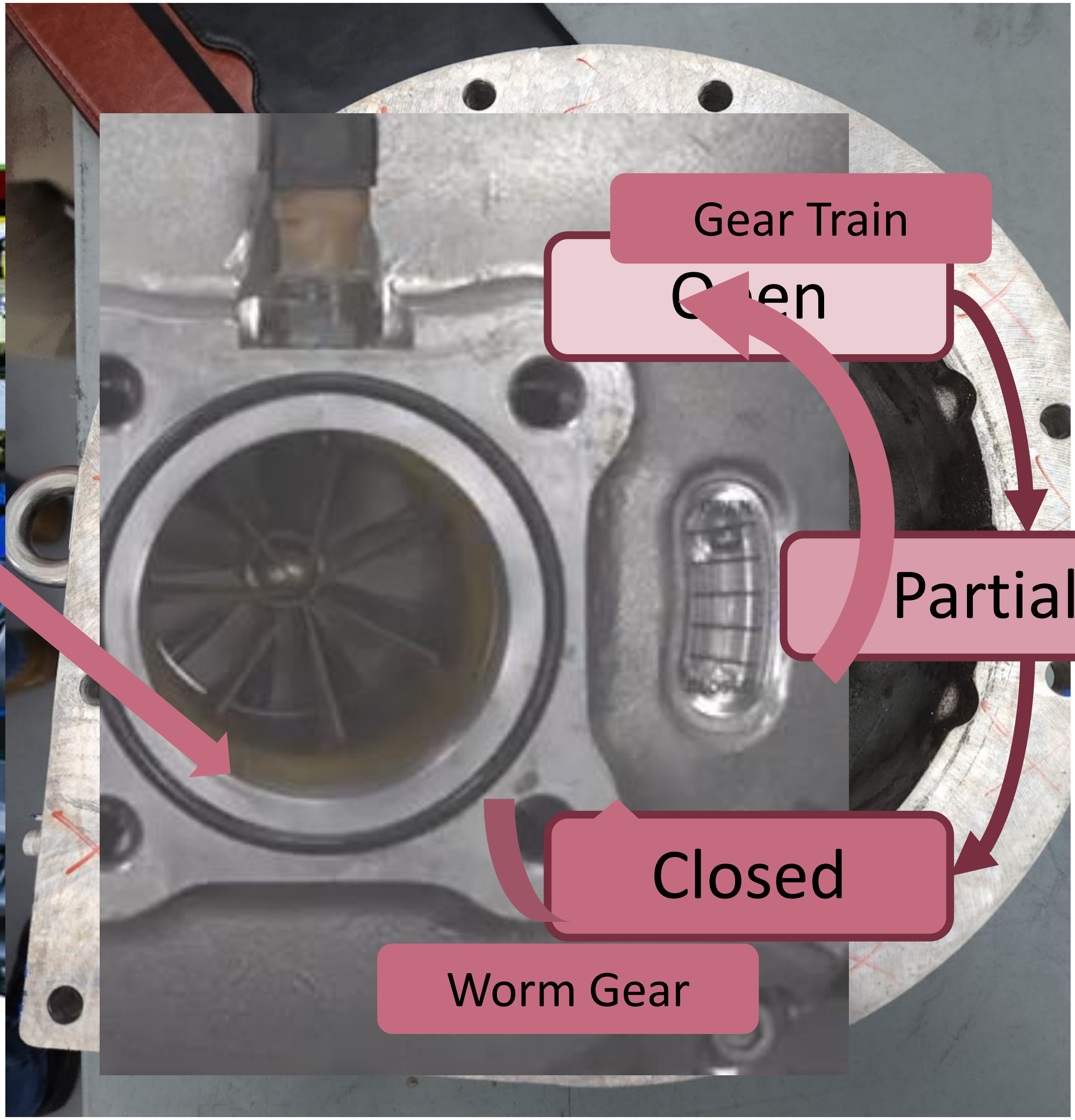
Albert Auer

IGV Assembly

910098 Stepper Motor

Controls the fluid flow at the intake of the compressor

Danfoss Turbocor TG Series



FAMU-FSU College of Engineering

Lifecycle Test

What is it?

- A stepper motor lifecycle test aims to evaluate the expected lifespan and reliability of the motor under typical operating conditions.

Why does Danfoss use it?

- Quality control
- Customer Confidence
- Varied Motor Manufacturers

Proposed Lifecycle = Actual Lifecycle

Albert Auer

Customer Needs

One Direction Test

Runs continuously in one direction (CW CCW)

Alternating Test

Switches direction after a designated cycle time

Orientation

Motor is oriented downwards (similar to assembly)

Targets & Metrics

Adjust Cycle Time (0-300sec)

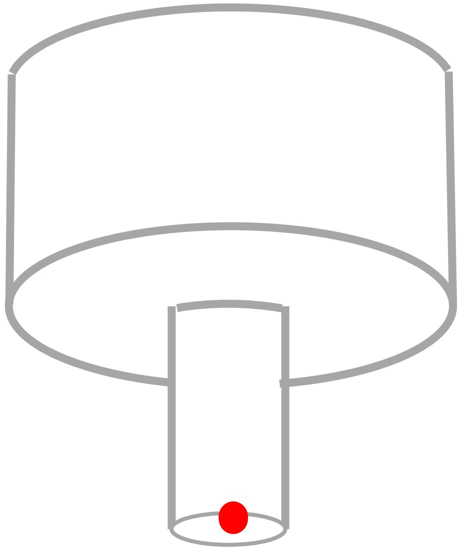
Adjust Speed (0-300pps)

Track Rotations (>98% Acc)

Similarities

- Constant speed (pulses per second)
- Constant resistance torque (N-m)
- Run until failure (motor cannot rotate)
- Track total runtime and total rotations

Alternating Test



FAMU-FSU College of Engineering

Starting Point

Perma-Tork

Uses permanent magnets to apply a constant torsional load to the central shaft

Reasons to Use:

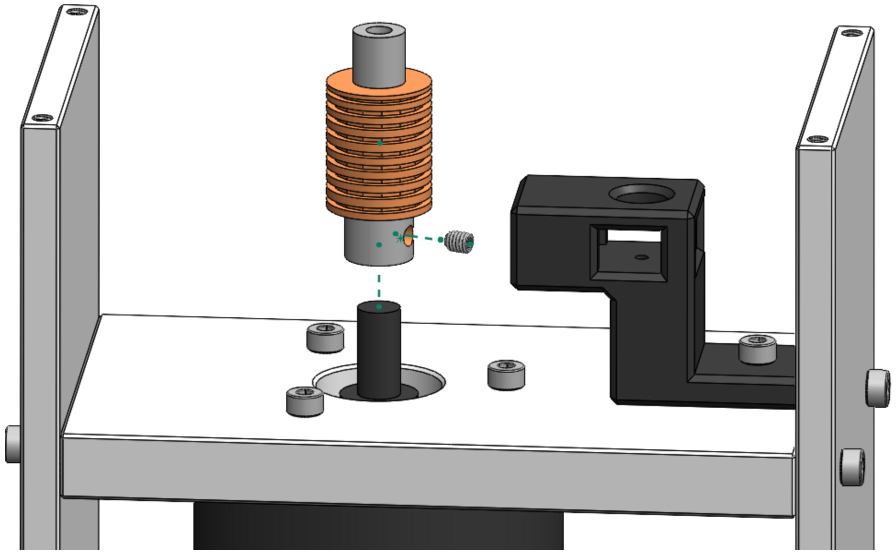
- Eliminates unnecessary friction
- Requires no power supply
- Allows manual torque adjustment

FAMU-FSU College of Engineering

Starting Point

Albert Auer

Helical Coupler



Uses two set screws to fasten the Stepper motor shaft and the Perma-tork shaft

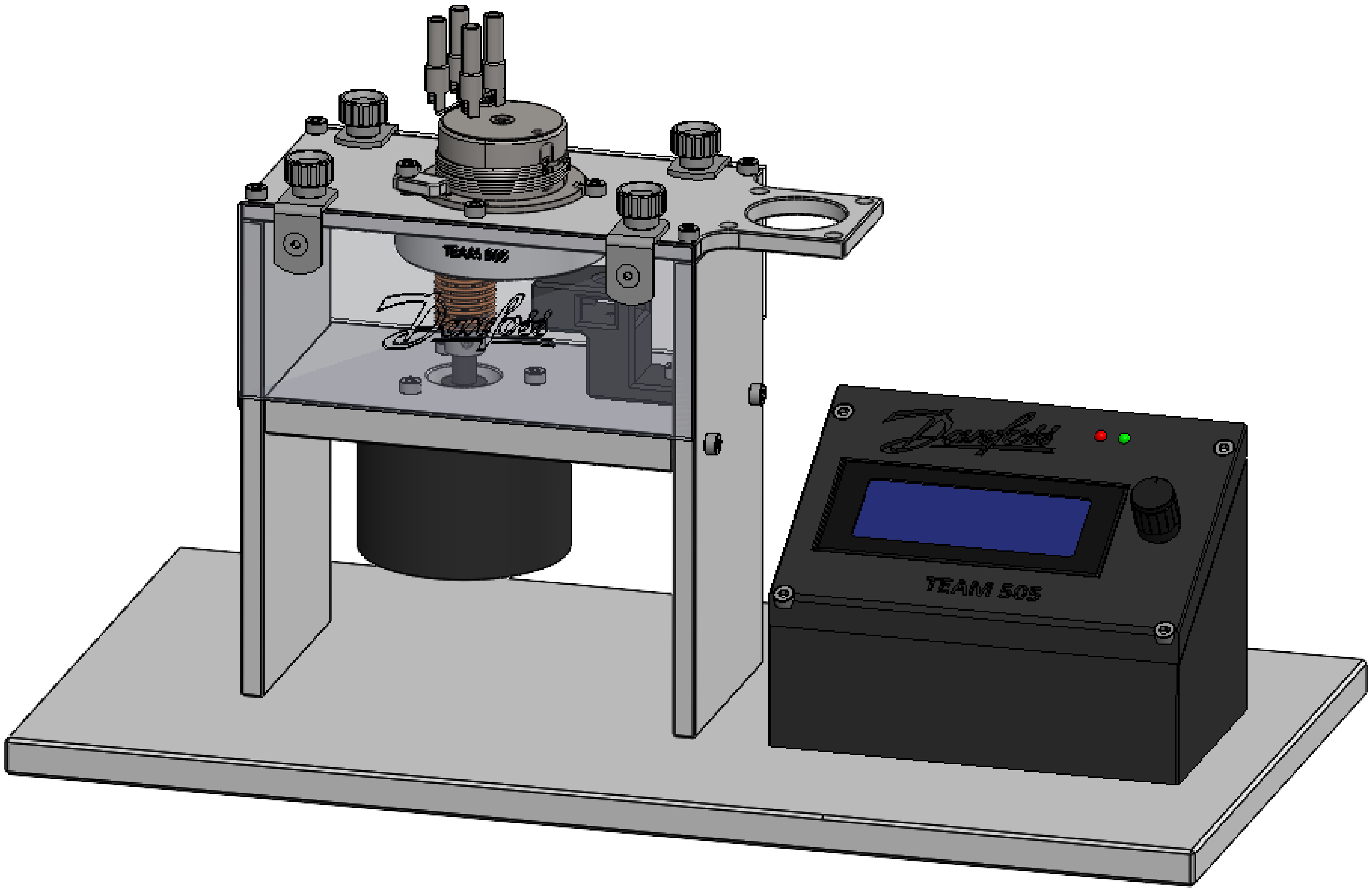
Reasons to Use:

- Accommodates for axial misalignment
- Securely couples the Perma-tork and stepper motor
- Proper power transmission

FAMU-FSU College of Engineering

The H-Frame Concept

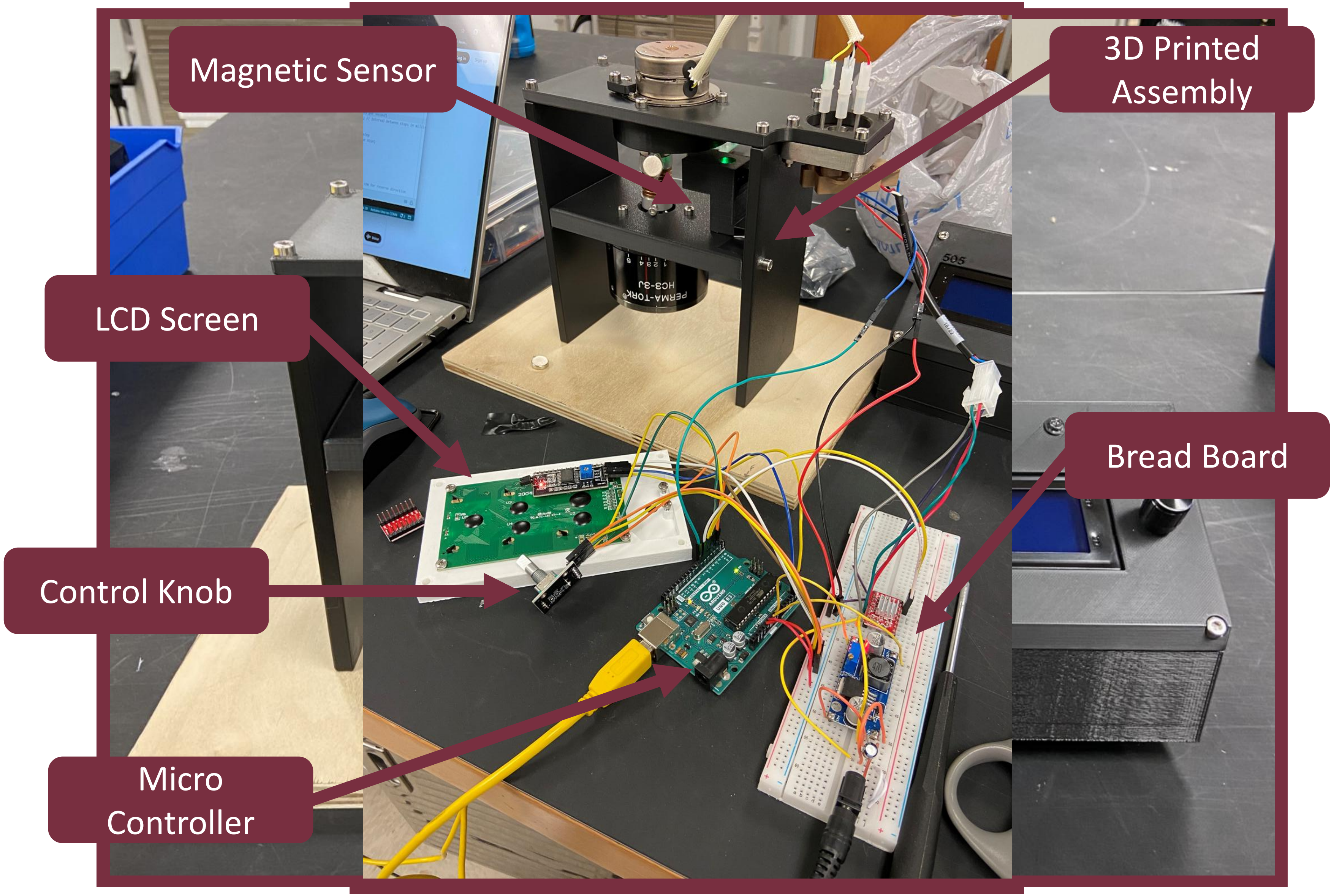
Chaney
Bushman



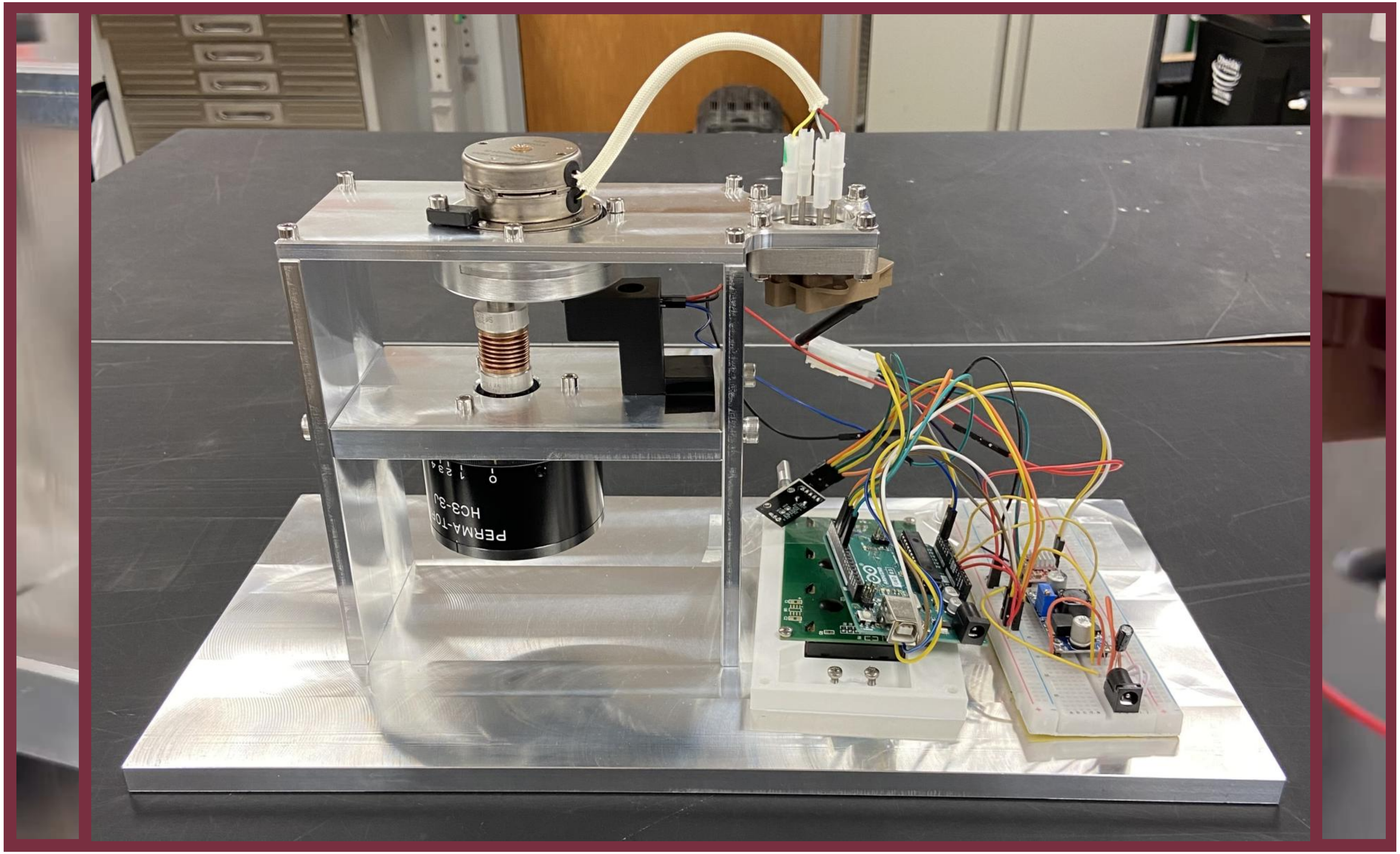
FAMU-FSU
College of
Engineering

Prototype Stage 1

Chaney
Bushman



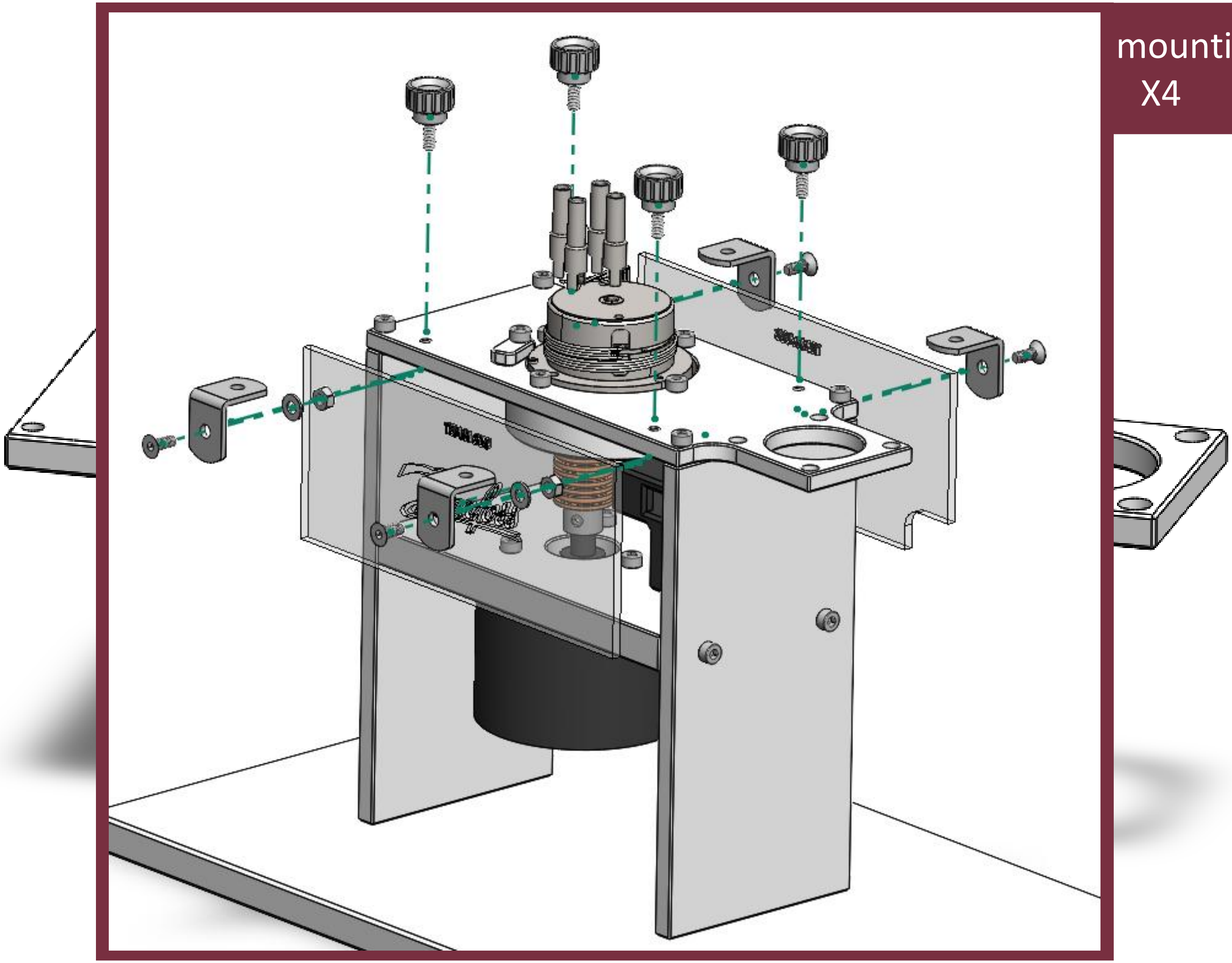
Prototype Stage 2



FAMU-FSU College of Engineering

Prototype Stage 2

Chaney
Bushman

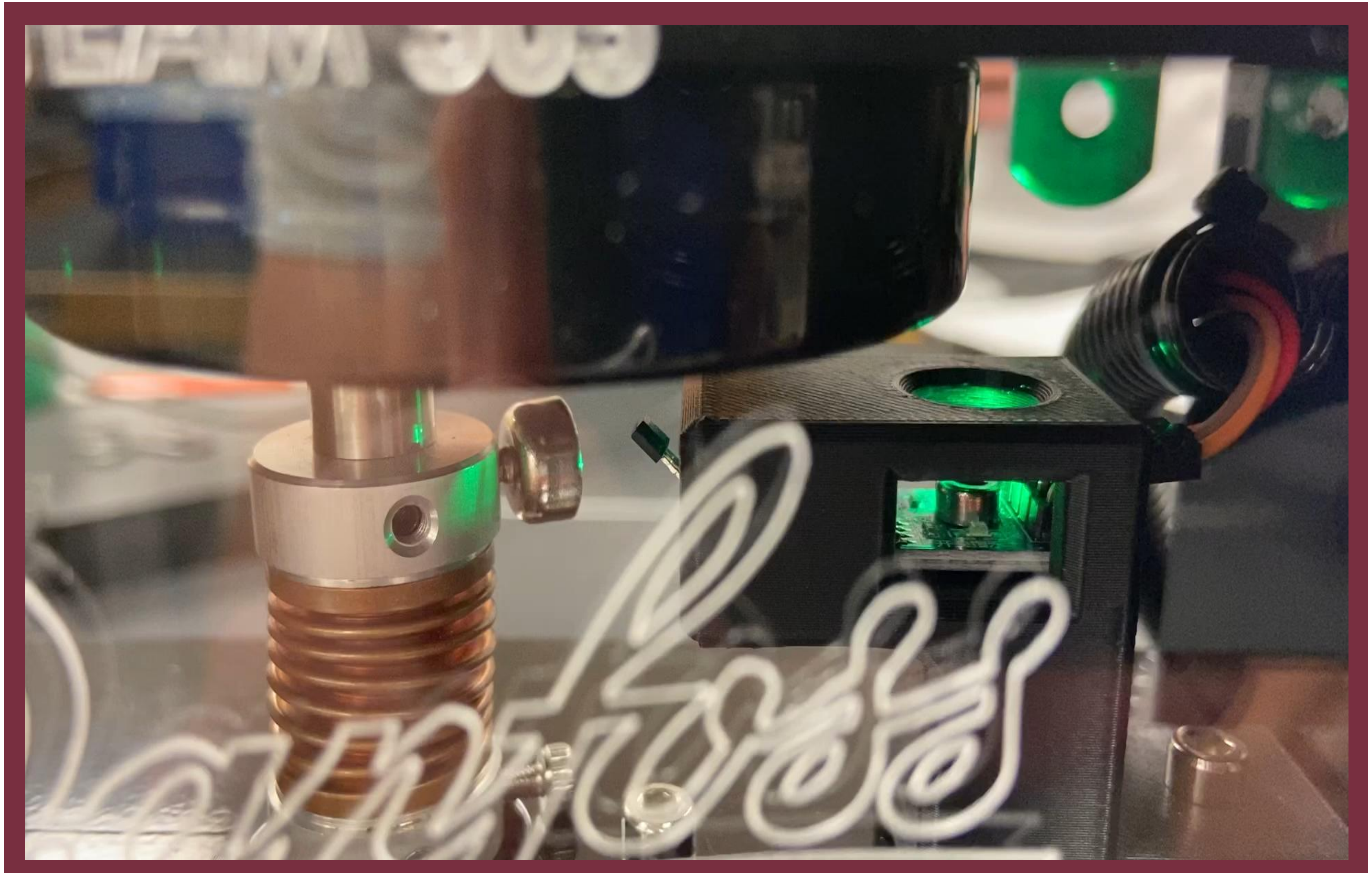


mounting holes
X4

FAMU-FSU
College of
Engineering

Final Stage

Chaney
Bushman

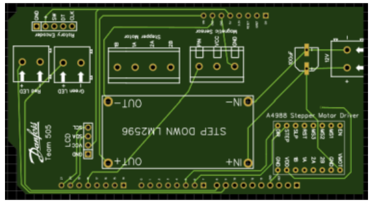


FAMU-FSU
College of
Engineering

Mason Herbet

Main Electronics

Arduino Mega



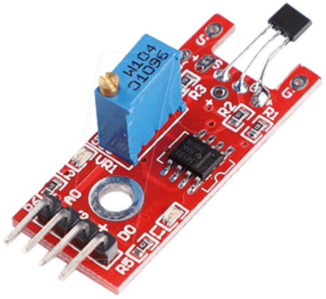
Custom PCB

Integrated Microcontroller

4x20 LCD

Rotary Encoder

Human-Machine Interface (HMI)

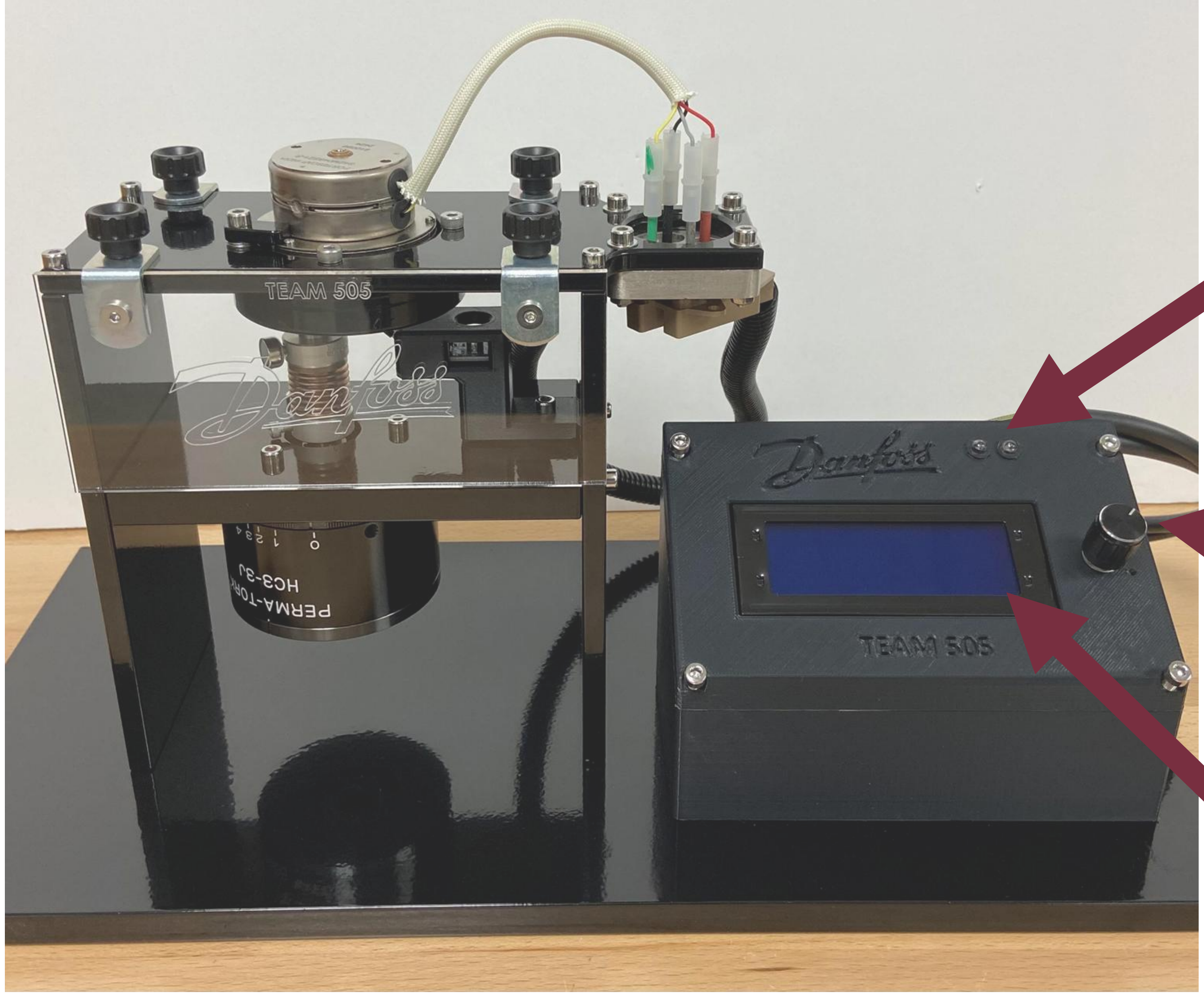


Magnetic Sensor

Main Test Sensor

FAMU-FSU College of Engineering

HMI Features



Green/Red LEDs

Show when test is running/stopped

Rotary Encoder

Navigate testing menu, adjust test variables, and start/stop test

LCD Screen

Display test parameters, current test variables, and test results

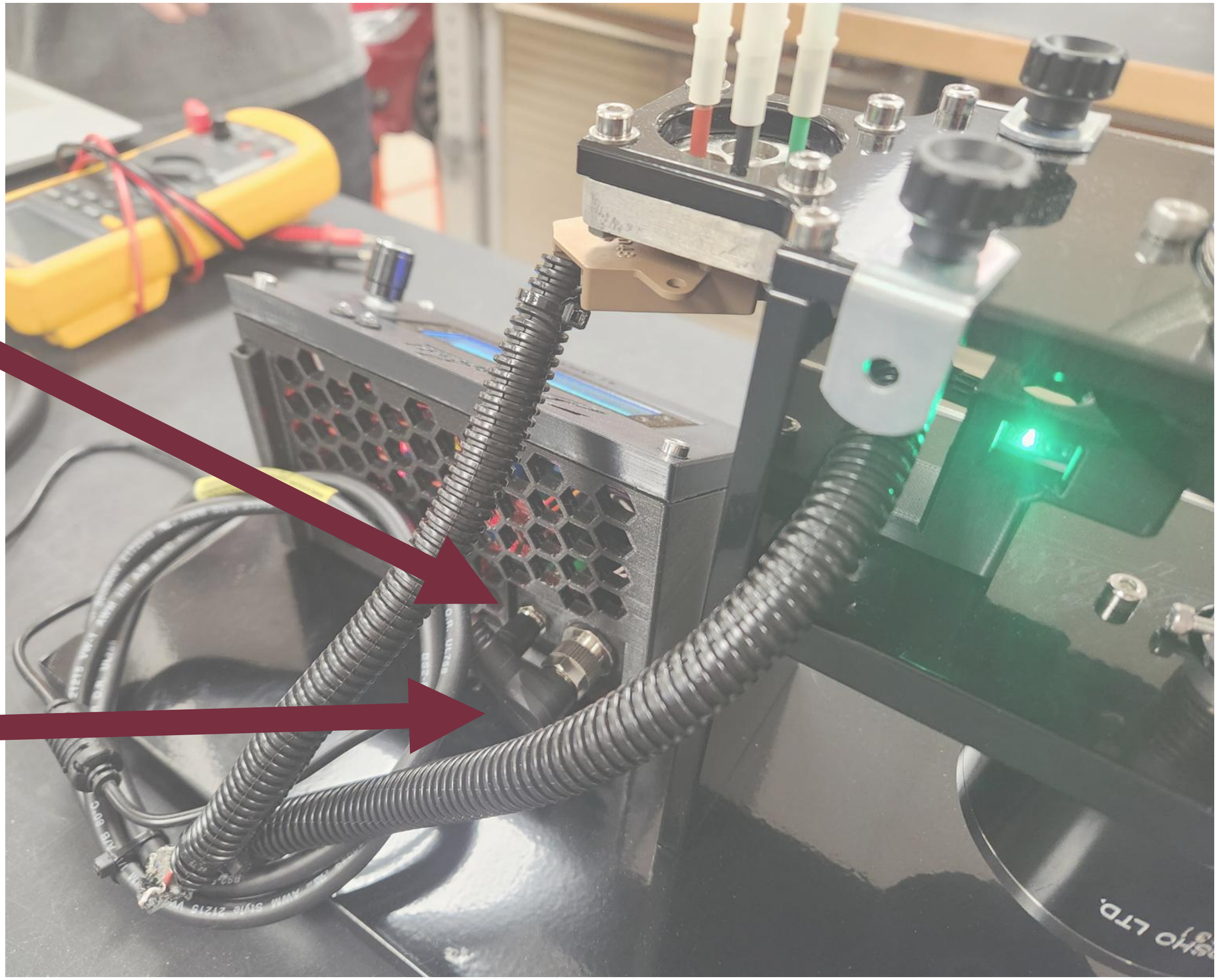
External Wiring

Power Jack

12V AC/DC Power Converter plugs into a panel-mounted port on HMI

Molex Connector

8-pin, Circular Molex connector combines magnetic sensor and motor wires to a panel-mounted port on the HMI



FAMU-FSU College of Engineering

PCB Design

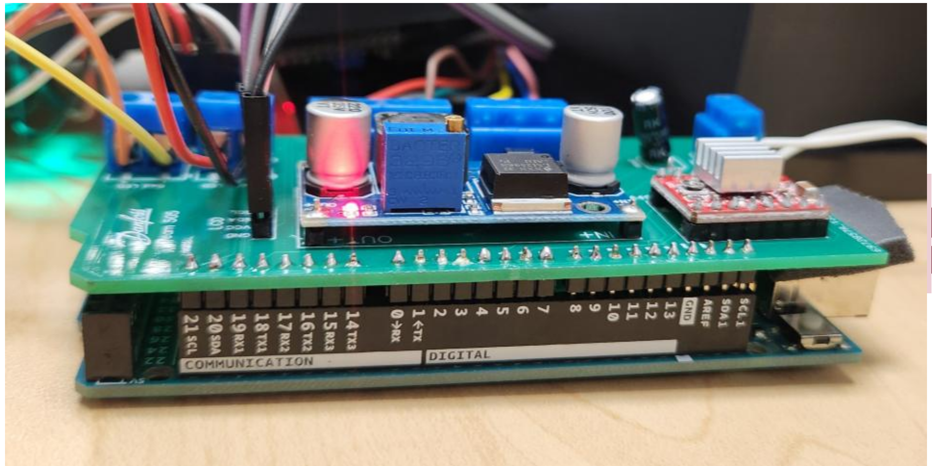
Mason Herbet

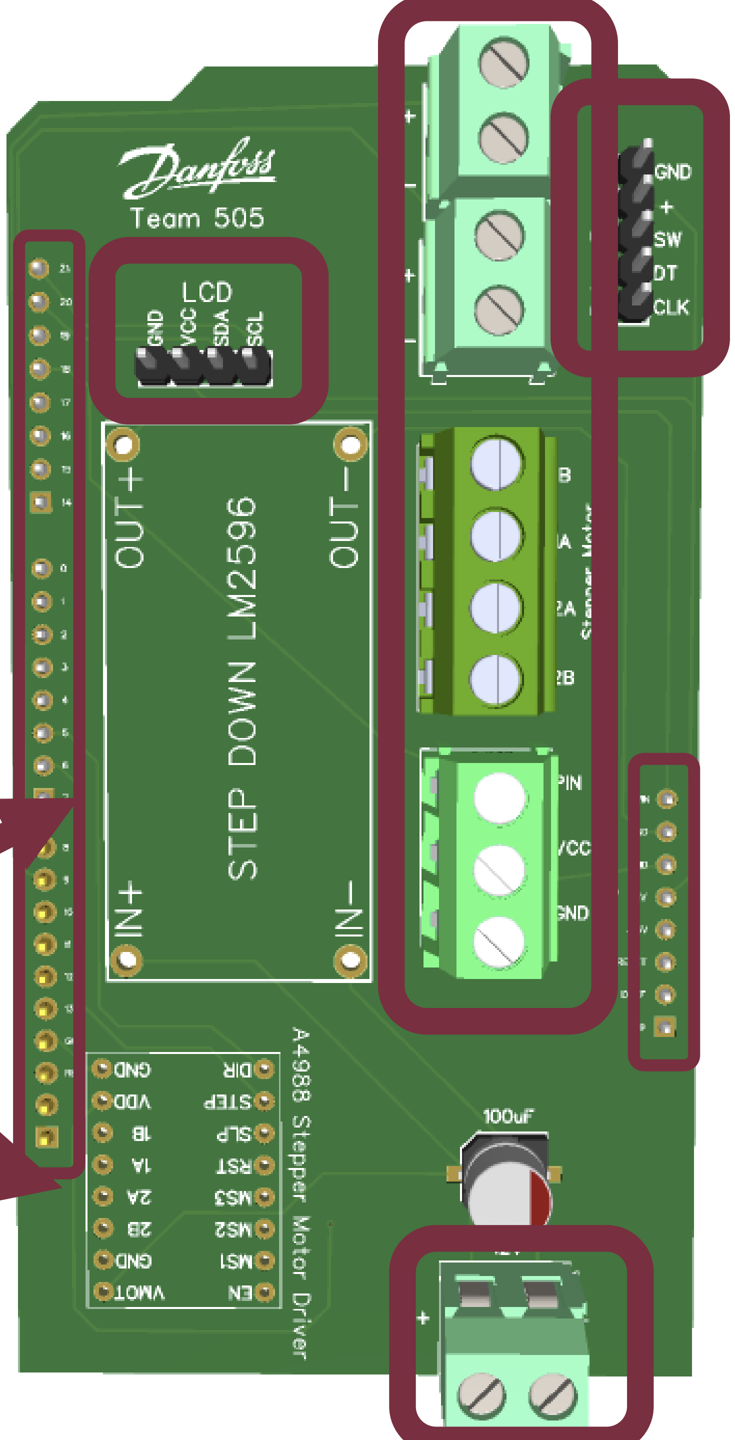
Screw-in Terminals

Include wires from power source, Molex connector, and LEDs

Header Pins

Header Pins connect LCD and Rotary Encoder to PCB and PCB to Arduino

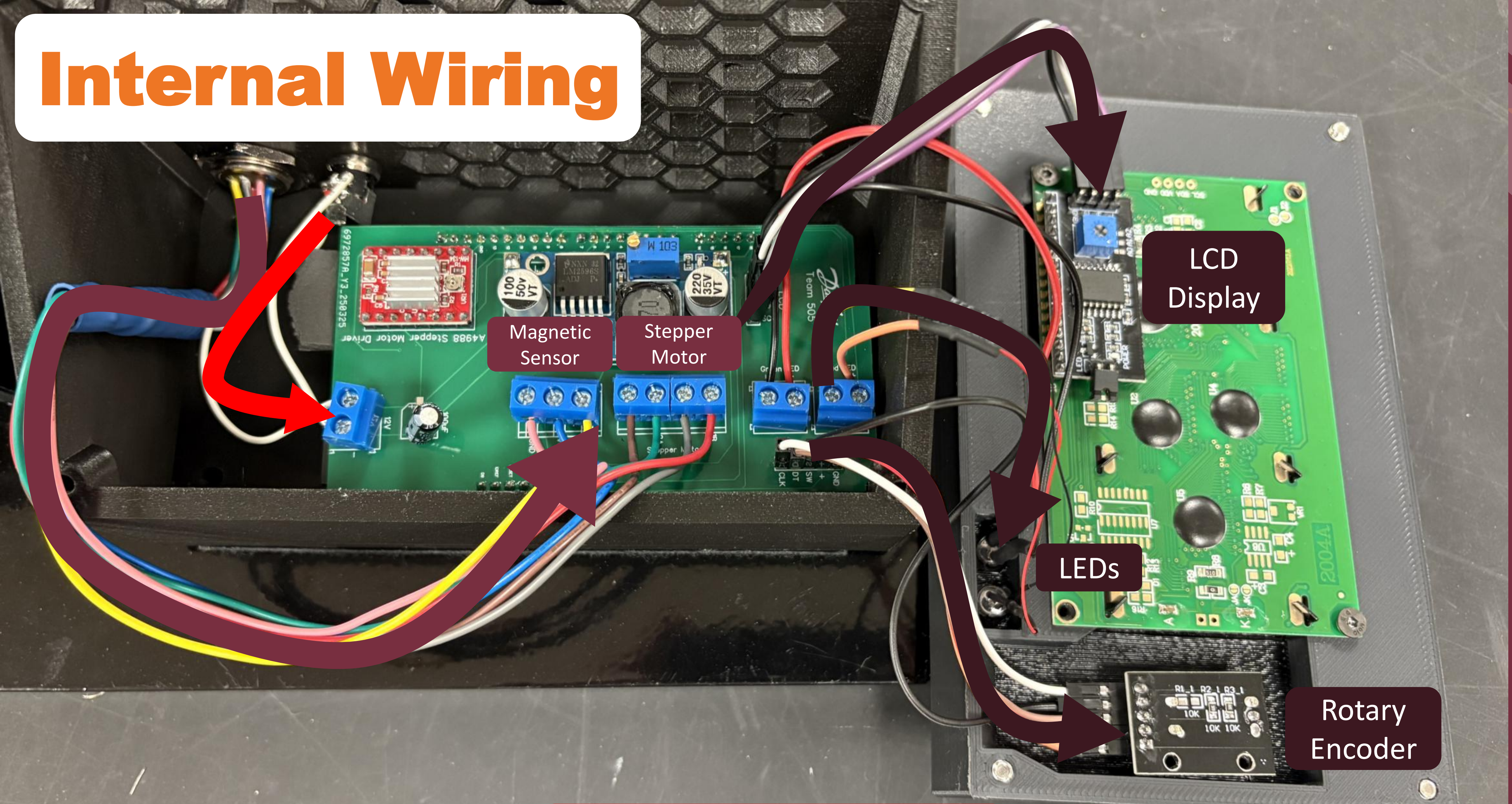




FAMU-FSU College of Engineering

Mason Herbet

Internal Wiring



Molex Wiring

Power Input

HMI Parts

FAMU-FSU College of Engineering

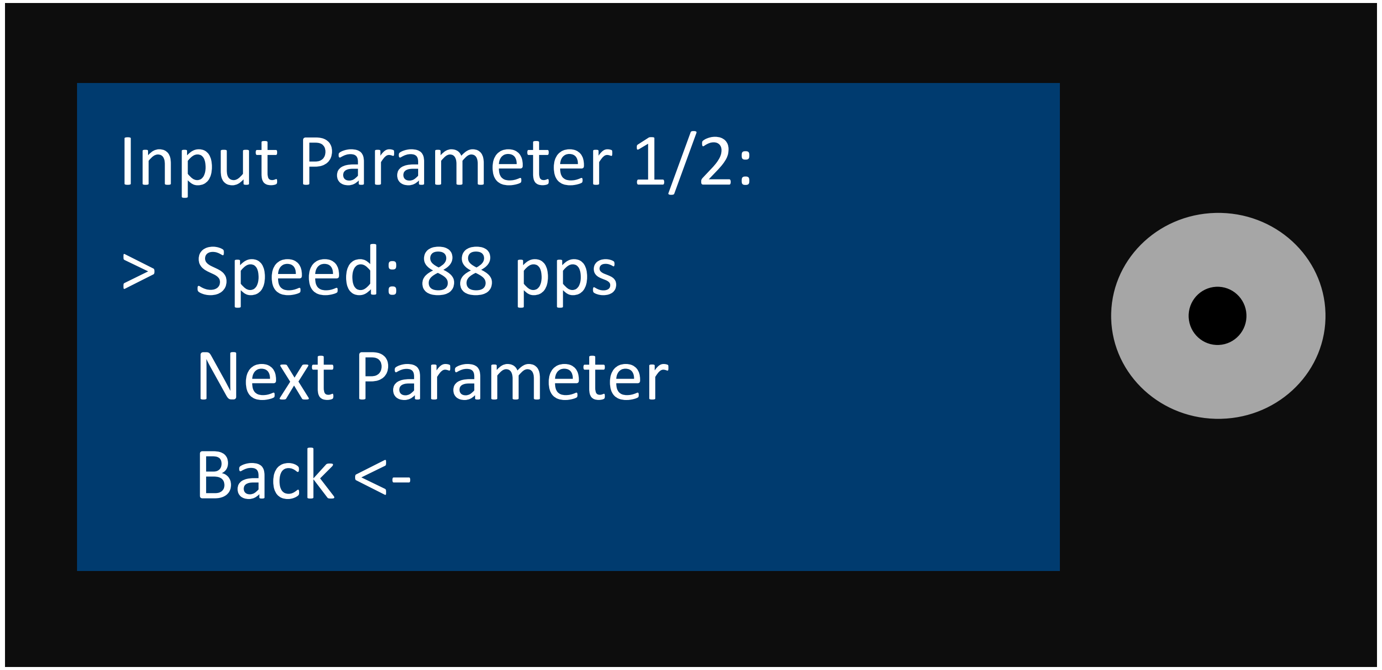
Bradford
Andrews

Pre-Test Menu

FAMU-FSU
College of
Engineering

Bradford
Andrews

Pre-Test Menu

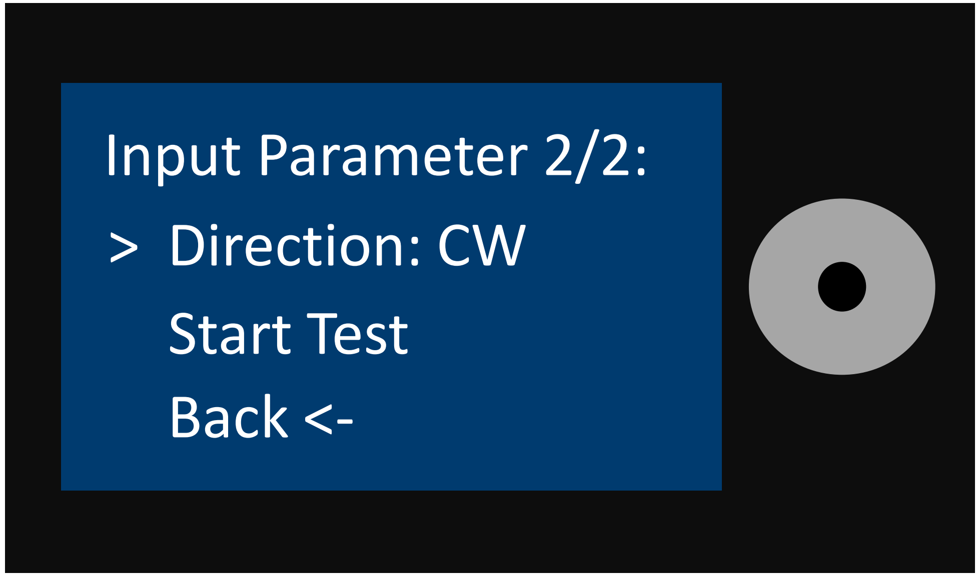


FAMU-FSU
College of
Engineering

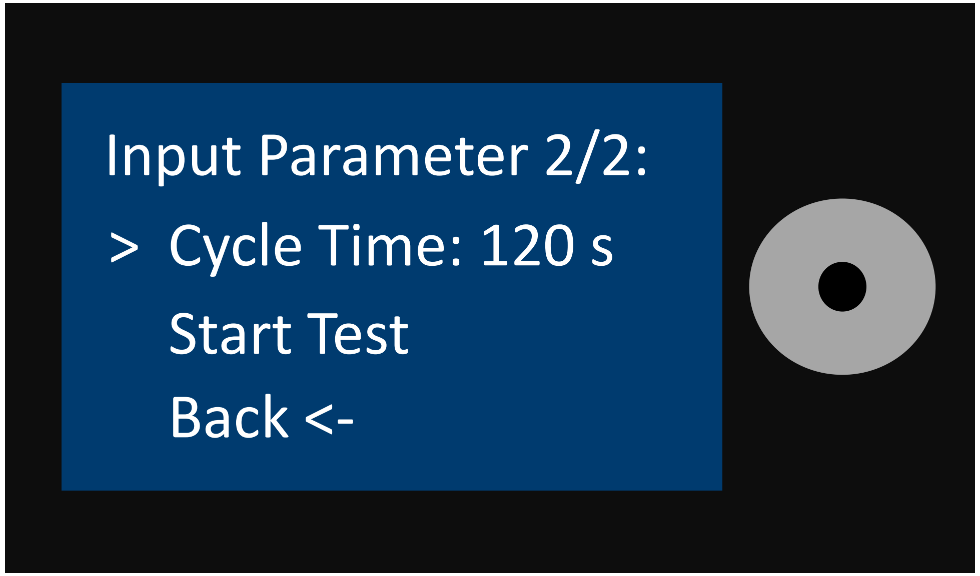
Bradford
Andrews

Pre-Test Menu

One Direction Test



Alternating Direction Test



FAMU-FSU
College of
Engineering

Bradford
Andrews

Test Program

Arduino Internal Clock

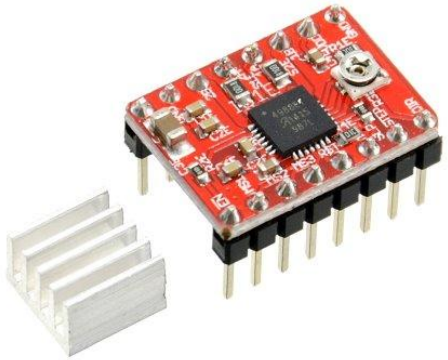
Difference-Based Timers

Current Time – Last Event Time >= Event Time Interval

FAMU-FSU College of Engineering

Bradford Andrews

Actuate Motor



A4988 Stepper Motor Driver
- Step
- Direction

Step

Last Step

Step Interval (µs)

Derived from User Input: Speed (pps)

Direction

One Direction Test

Alternating Test

- Constant (User Input: CW/CCW)

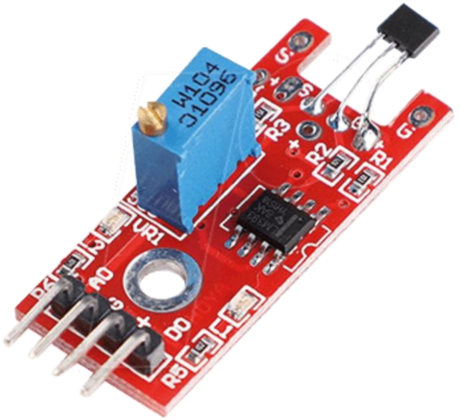
Last Direction Change

Half Cycle Time (ms)

FAMU-FSU College of Engineering

Bradford
Andrews

Detect Rotation/Failure



3144E Magnetic Sensor

- Senses magnet attached to coupler
- Connected to interrupt pin

Rotation

Interrupt Triggered → Rotation Counted

Failure

Last Rotation Time

Rotation Detected (Interrupt)

2*ERT
One Dir.

3*ERT
Alt. Dir.

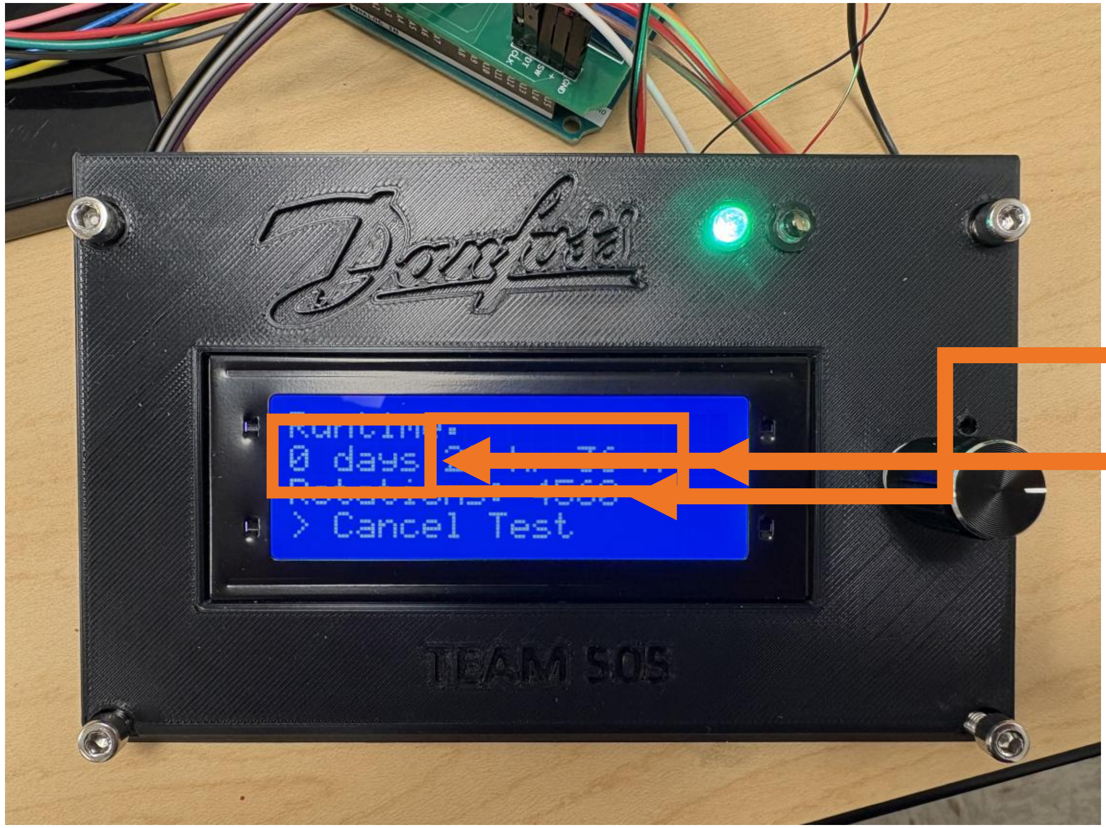
Expected Rotation Time (ERT)
- Derived from user input speed (pps)

Failure Detected!

FAMU-FSU College of Engineering

Bradford Andrews

Display Results



Direction Test

Day Count

- Updates Rotation Count

0 hr. Elapsed Day (ms) 24 hr.

Alternating Direction Test

Runtime Refresh

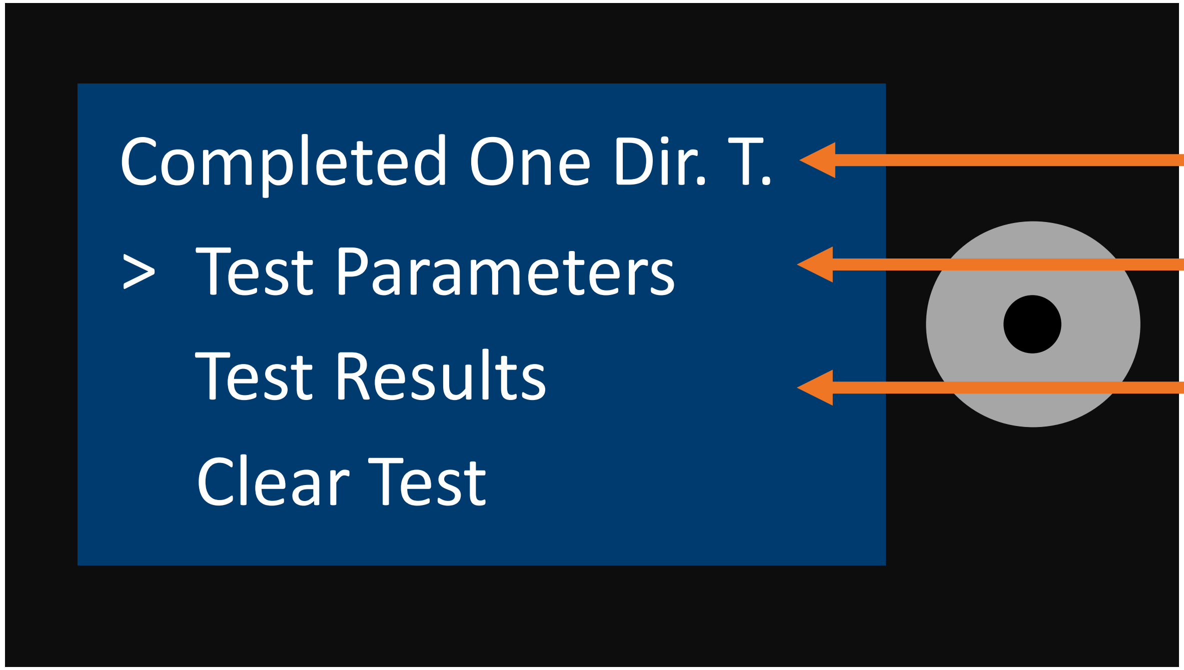
- Updates Cycle Count

0 min. 1 min.

FAMU-FSU College of Engineering

Bradford Andrews

Post-Test Menu



Identifies:
- Completed/Canceled Test
- One Dir. / Alt. Dir

Accesses:
- Speed
- Direction / Cycle Time

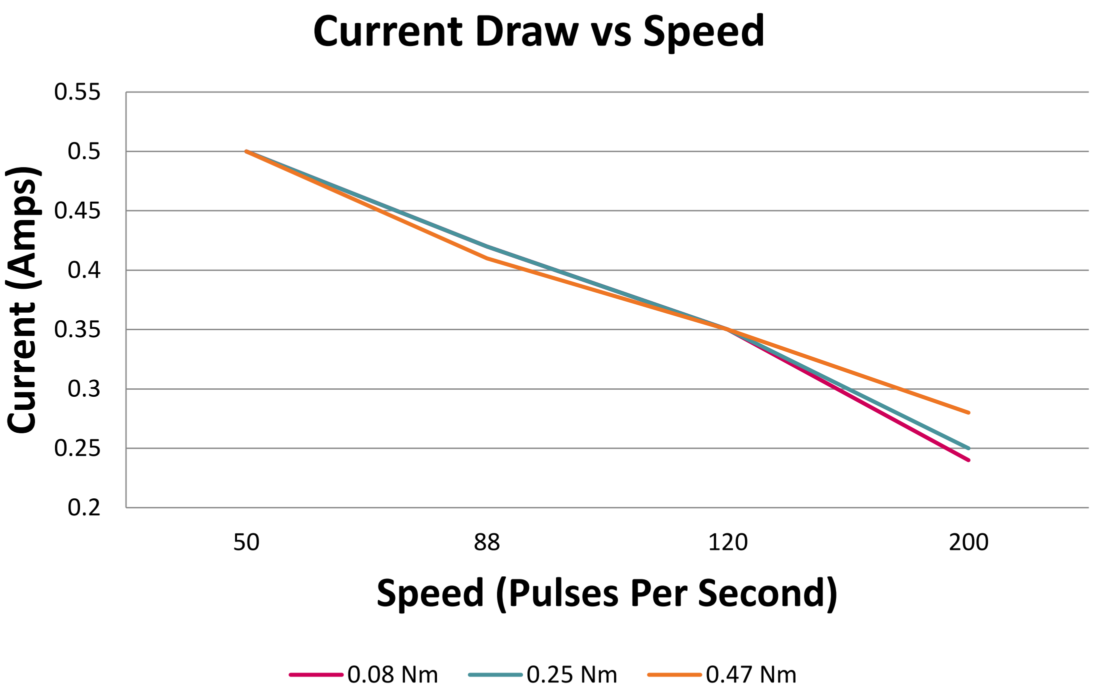
Accesses:
- Runtime
- Rotations

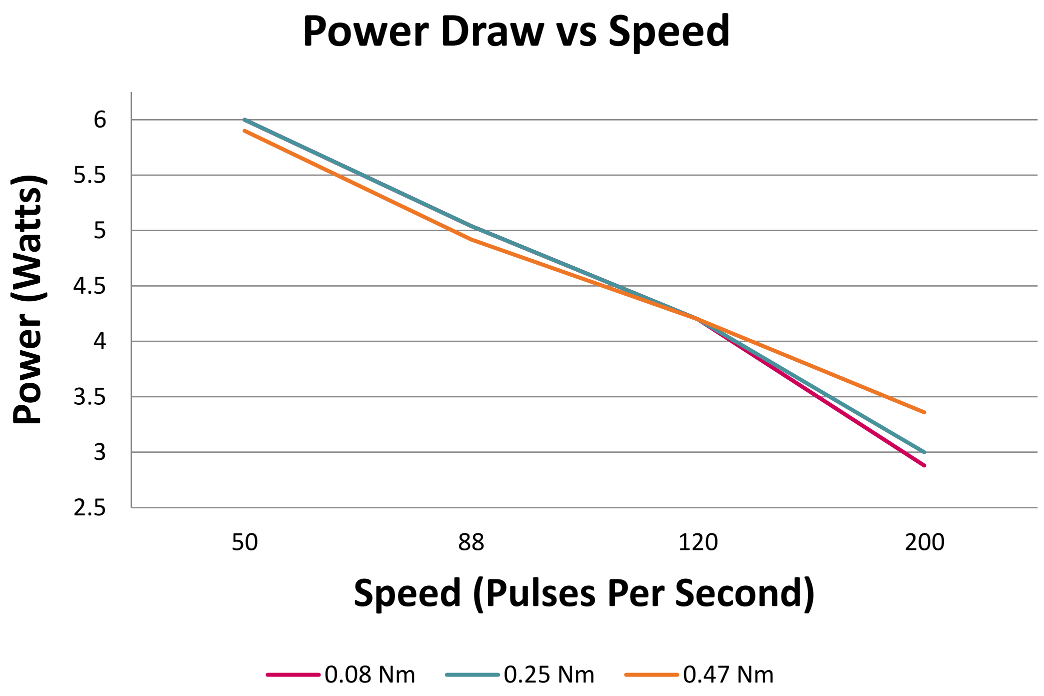
FAMU-FSU College of Engineering

Joseph Garvie

Testing and Validation

Power & Current Draw





Current and Power consumption decrease with increasing motor speed

FAMU-FSU College of Engineering

Testing and Validation

Fixture Specs

Joseph Garvie

State	Current (A)	Power (W)	Notes
Operating (88 PPS)	0.42	5.04	Test Running
Idle (Motor Off)	0.13	1.56	Standby State

Table 1: Fixture Power Consumption

Characteristics	Metric (SI)	US Customary
Weight	5.44 kg	12 lb
Volume	20970 cm^3 (0.02 m^3)	1280 in^3 (0.74 ft^3)

Table 2: General Characteristics

FAMU-FSU College of Engineering

Joseph Garvie

Testing and Validation

Rotation Tracking Error

	Time 1 20 hr 39 min 0 sec	Time2 20 hr 55 min 35 sec	Time3 22 hr 01 min 48 sec
Rotations Tracked by sensor	4574	4633	4876
Expected number of rotations	4543	4604	4847
Rotation Tracking Error	0.68 %	0.63 %	0.61 %

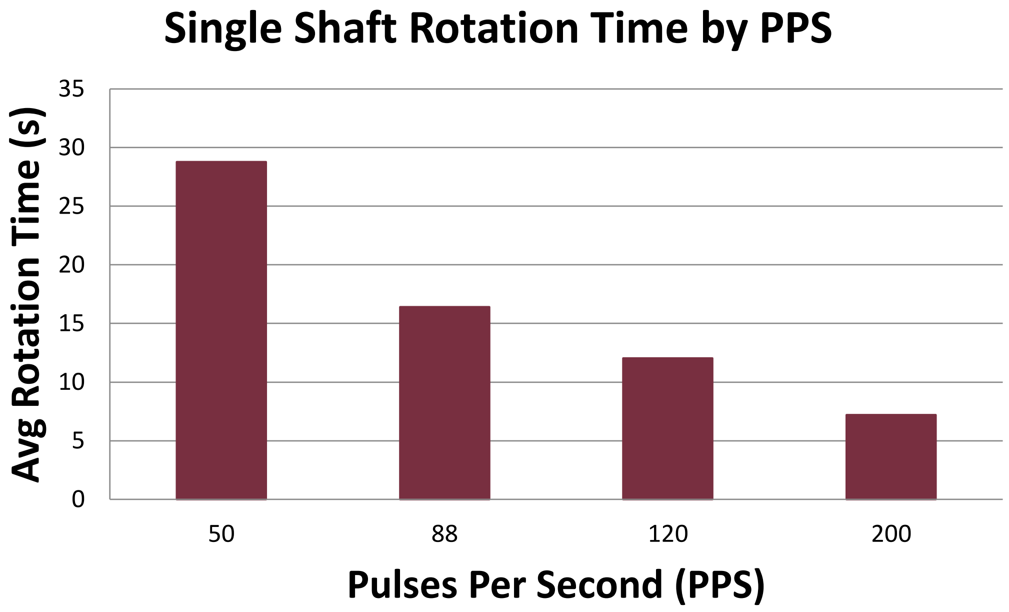
> 99% rotation tracking accuracy

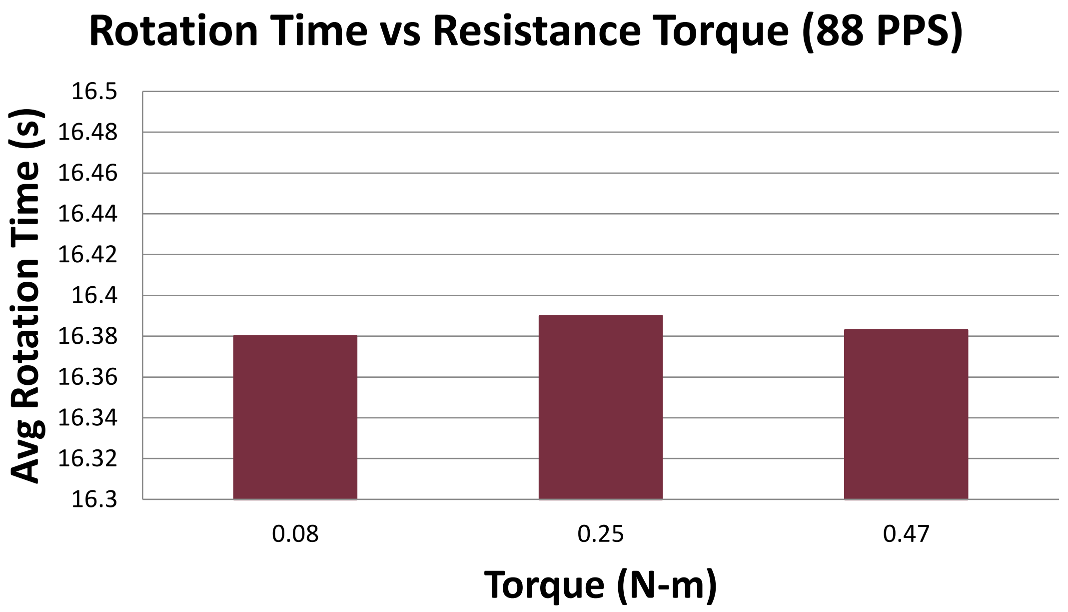
Rotations tracked slightly larger than what we expect

FAMU-FSU College of Engineering

Testing and Validation

Rotation Times (Validation)





Single shaft rotation time decreases with increasing PPS ✓

Single shaft rotation time constant across increasing resistance torques ✓

~3.7 rpm at 88 PPS across all resistance torques

Joseph Garvie

FAMU-FSU College of Engineering

Joseph Garvie

Testing and Validation

Fixture Run Cost Breakdown

Assumptions:

1. Tallahassee Electricity Energy Rate (Commercial)* = 0.10883 $\frac{\$}{kWh}$
2. Stepper Motor Lifespan (Approx.): 9 months (270 Days)

Energy Consumption:

$$\frac{6\ W\ x\ 24\ hrs}{1000\,\frac{W}{kW}} = 0.144\ \frac{kWh}{Day}$$

Daily Cost:

$$0.144\ \frac{kWh}{Day}\ x\ 0.11\ \frac{\$}{kWh} = 0.02\ \frac{\$}{Day} = 2\ \frac{¢}{Day}$$

Total Lifecycle Cost:

$$60\ \frac{¢}{Month}\ x\ 9\ Months = 540\,\frac{¢}{Motor} = \$5.40$$

Conclusion:

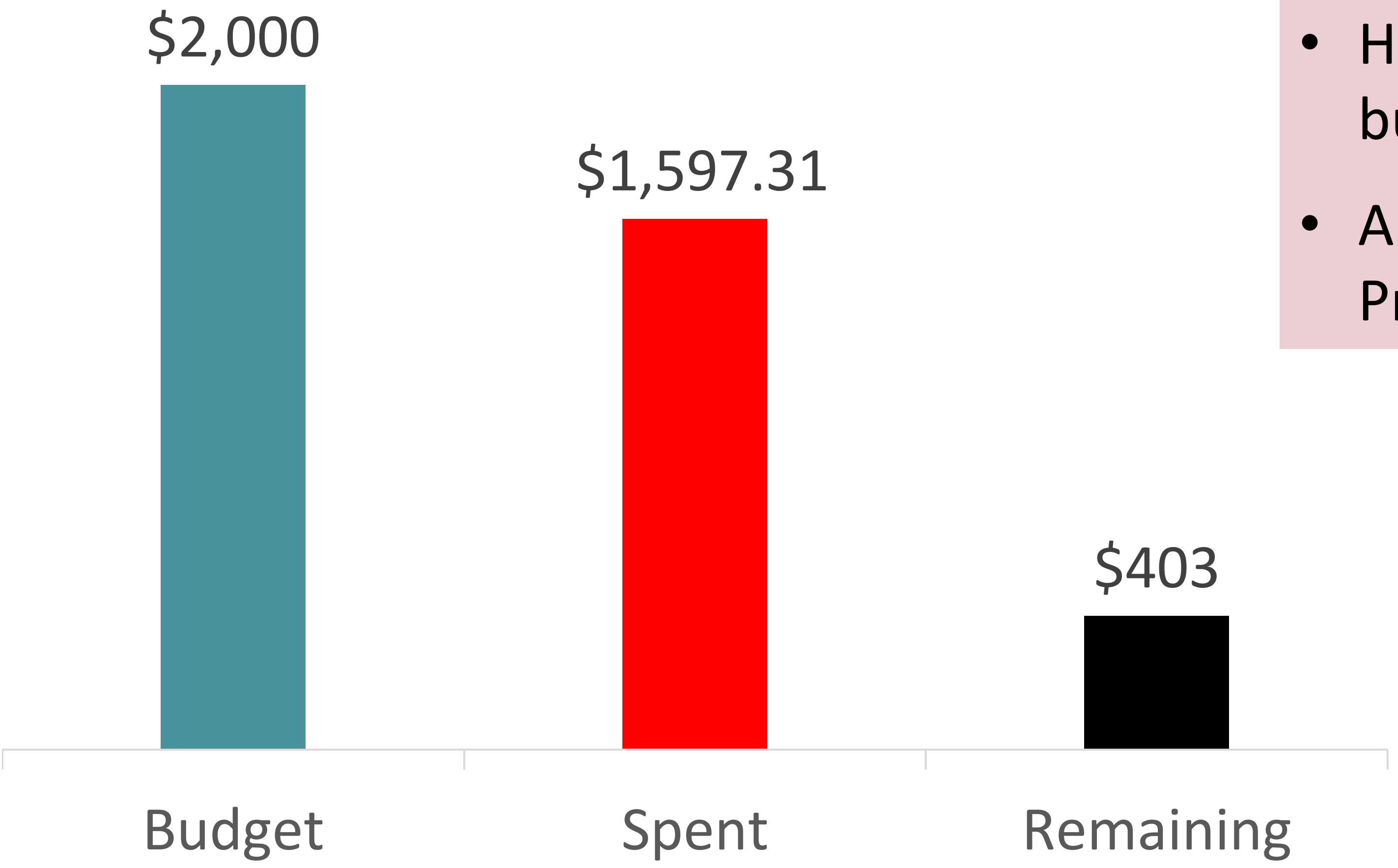
It costs $5.40 to run a full lifecycle test on one stepper motor at maximum power.

https://www.talgov.com/you/you-account-plans-index

FAMU-FSU College of Engineering

Joseph Garvie

Updated Budget



Expected Future Costs

- Hardware and Sensors for building more fixtures
- APC Backup UPS with Surge Protection

FAMU-FSU College of Engineering

Future Work

Joseph Garvie

Trim Extraneous Wires

Apply magnetic shielding material

Order and replicate fixture components

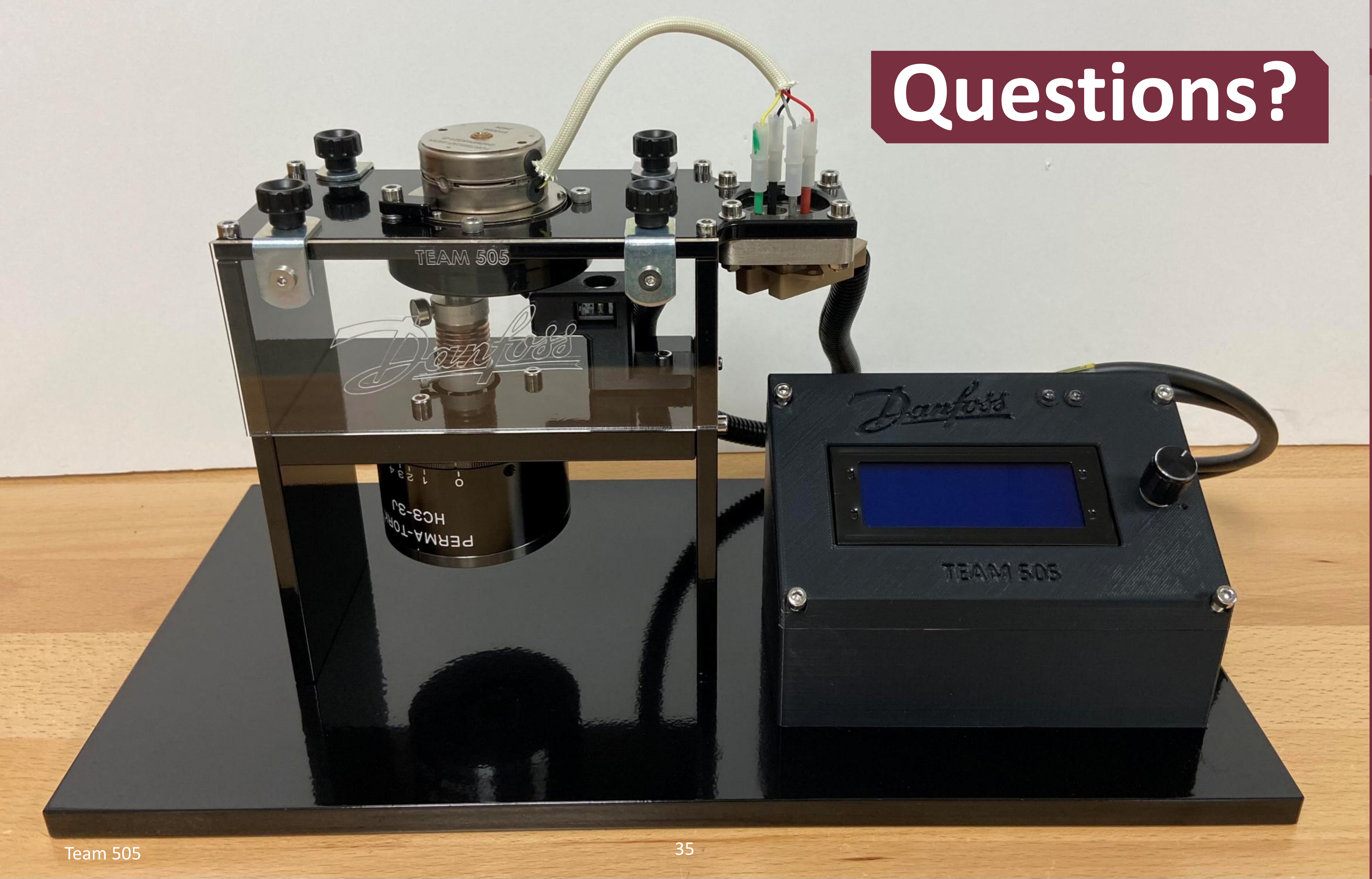
Attach handles for ergonomics

Finalize build and operation documents

FAMU-FSU College of Engineering

Joseph Garvie

Questions?



FAMU-FSU College of Engineering