3D Printer Filament Shredder

Allyson Texley, Christian Pavlovich, George Davis, Jake Ciasca, Nicholas Petrov, Thomas Lersch, Zackary Tileston

Mentor: Bert Schneider

Sponsor: Matthew Briggs of the Engineering Design Center



The Team

Engineering Design Center



Jake Ciasca



Nicholas Petrov



Allyson Texley



George Davis



Christian Pavlovich



Zackary Tileston



Thomas Lersch

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Project Summary

- University of Arizona makerspaces produce significant waste from 3D printing.
- The EDC alone produces 50 kg and 0.2688m^3 of waste each semester!!
- Traditional shredders are bulky and expensive, or cannot handle the large volume from makerspaces like the EDC.



EDC has a closet full with three 50 gallon bags.

Shredding

Our focus



Recycling

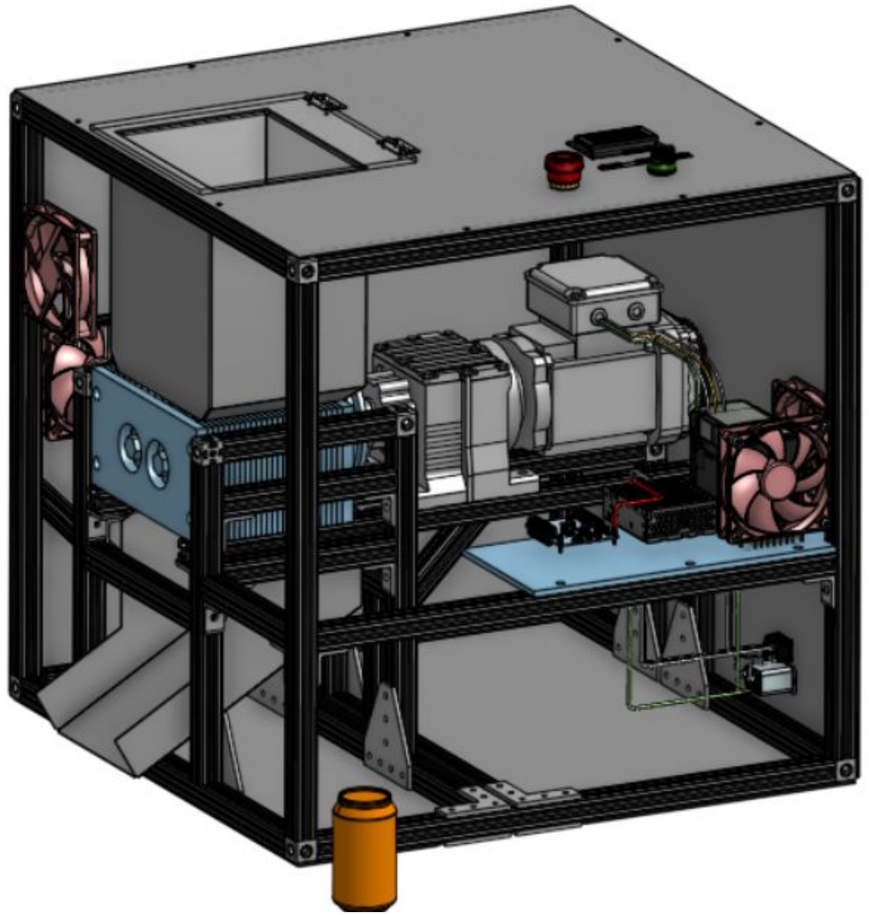
Precious Plastic's Focus



Furniture from Precious Plastic

Project Summary

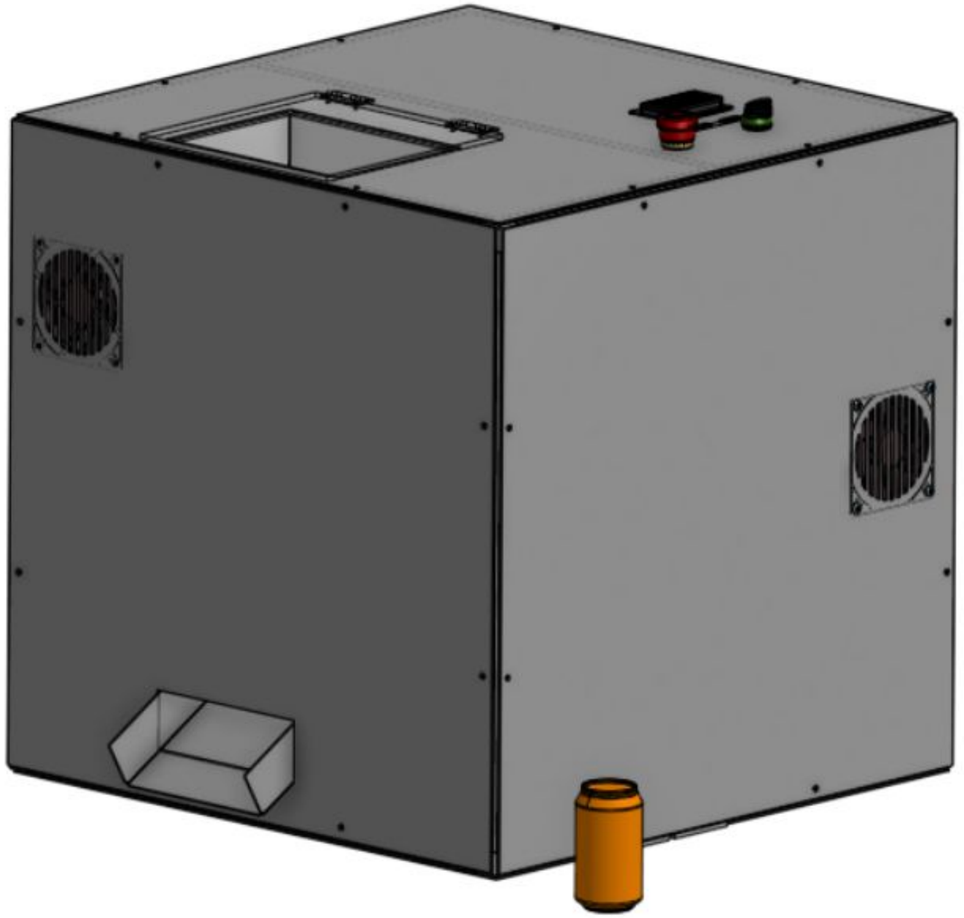
- The Engineering Design Center (EDC) has tasked us with developing a shredder designed to process PLA waste, and to have safety measures to protect users.
- Our product will reduce the size of 3D printed waste for makerspaces across the University of Arizona campus by at least 50%, yielding estimated volume reduction of 0.022m^3 per month.
- The reduction comes from 3D prints of infill 20% and lower. The EDC has a requirement for printing infill being no more than 20%.
- Our product will have the ability to shred automatically and will output the shredded plastic into a recycling bin.
- Our product will be operational by December 2025.

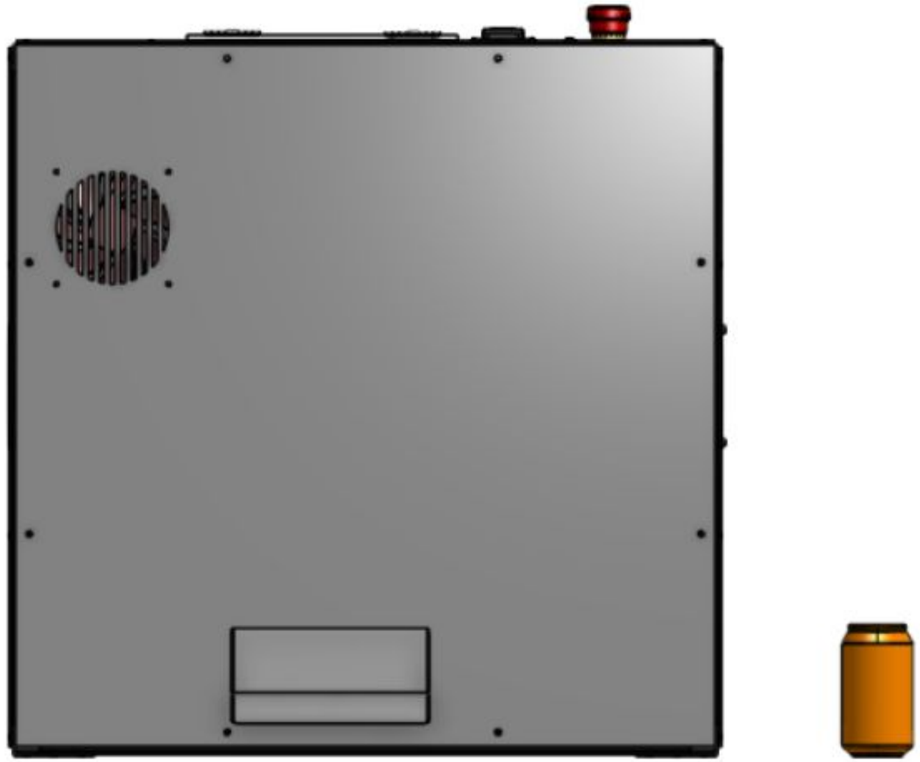


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General Size Comparison

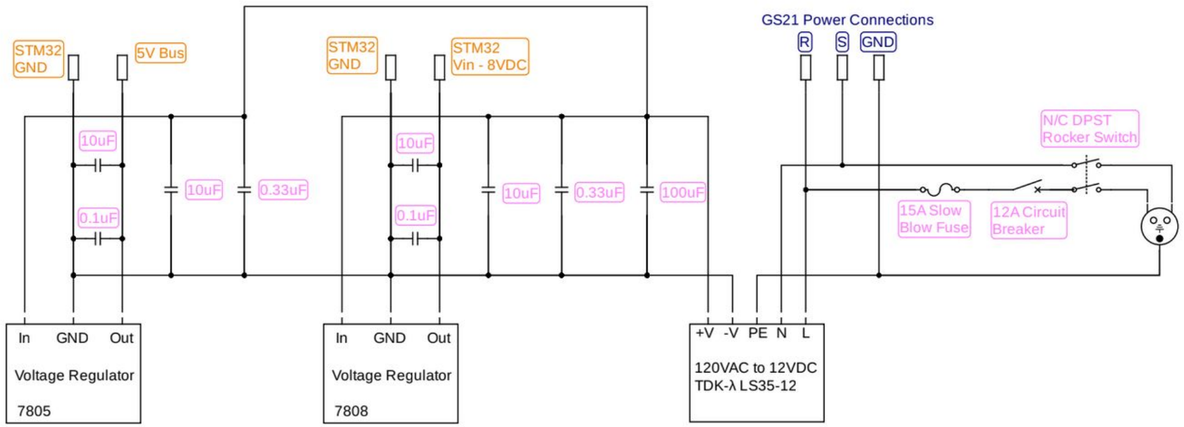




*Orange cylinder represents a standard soda can of about 4.8 inches tall 2.6 inches in diameter

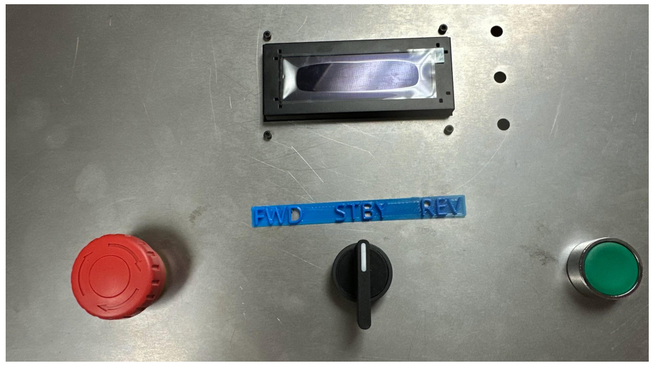
Power Subsystem

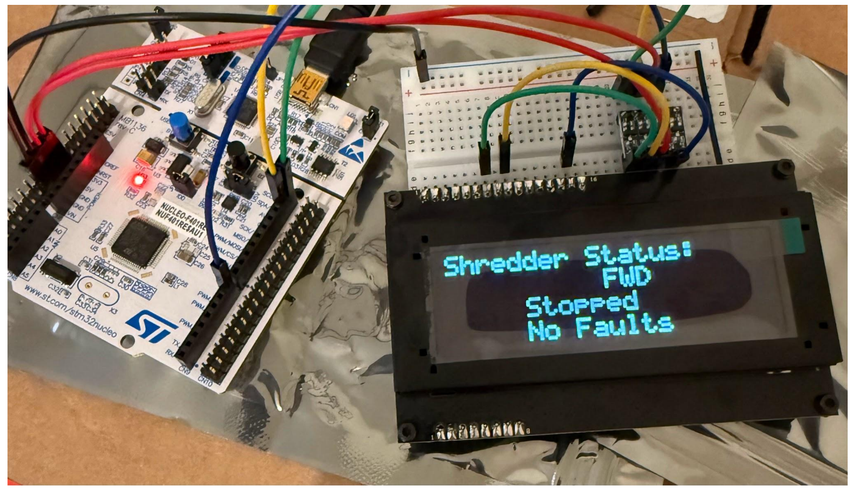
- 120VAC input with 12A circuit breaker and 15A fuse in-line.
- 120VAC to 12VDC power supply.
  - Directly supports cooling fans.
- 8VDC voltage regulator for microcontroller power in.
- 5VDC voltage regulator for user-interface status display power.



User-interface Subsystem

- Simple user-interface:
  - Green "run" button
  - 3-position selector switch for direction:
    - Right - Forward
    - Middle - Stop
    - Left - Reverse
  - Red emergency stop button
  - Large Status Display:
    - Shows current direction
  - Fault reset button on back of shredder





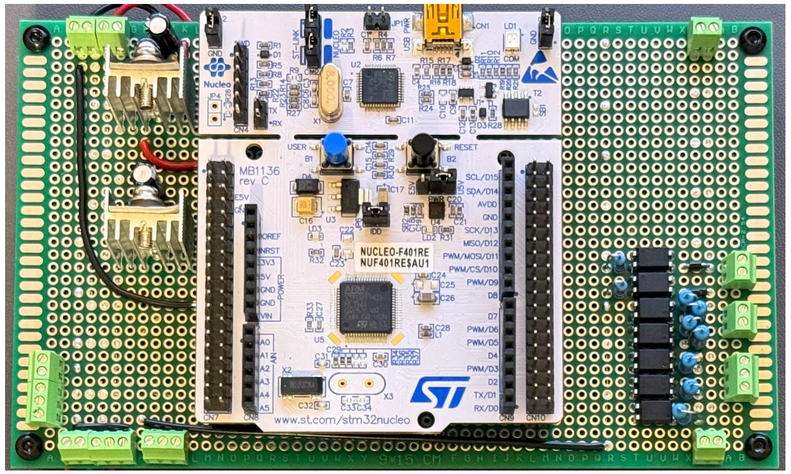
Motor Drive Subsystem

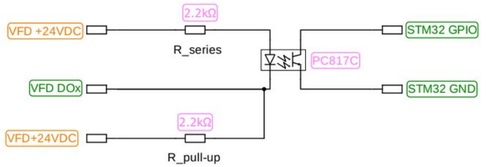
- Variable Frequency Drive (VFD): GS21-10P5
  - 1-phase 120VAC to 3-phase 230VAC.
  - Digital inputs and outputs for controlling motor and monitoring.
- VFD enables direction and speed control, and 3-phase motor compatibility.
- Safe Torque Off (STO): Emergency stop wired directly to VFD. When pressed, motor coasts to stop.
  - Compliant with:
    - ISO 13849-1: 2015 Category 3 PL d
    - IEC 61508 SIL2
    - EN 62061 SIL CL 2
    - EN 60204-1 Category 0



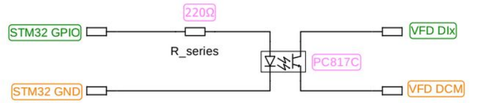
Controller Subsystem

- Microcontroller: STM32 F401RE Nucleo
  - 3.3V logic, 15 external interrupts, power efficient, wide temperature tolerance, common in industrial embedded systems.
- Takes in UI inputs and VFD state information.
- Outputs information to UI display and commands to VFD
- Optocouplers electrically isolate and protect the microcontroller from VFD.

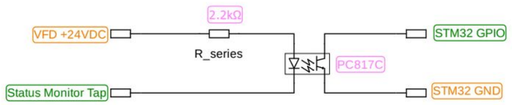




VFD Digital Output to STM32
for Direction and Run commands



VFD Digital Input from STM32
for Overtorque and STO states

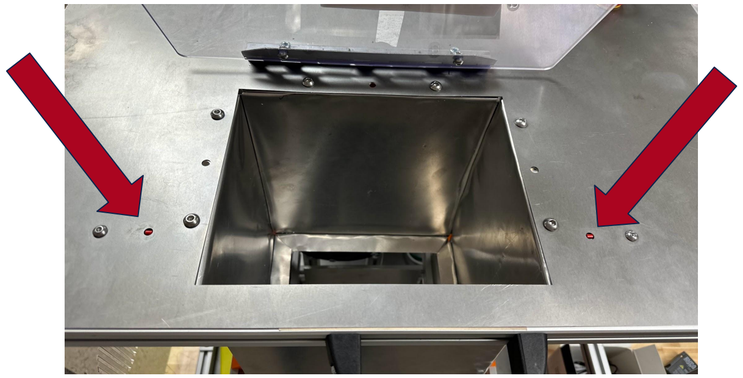


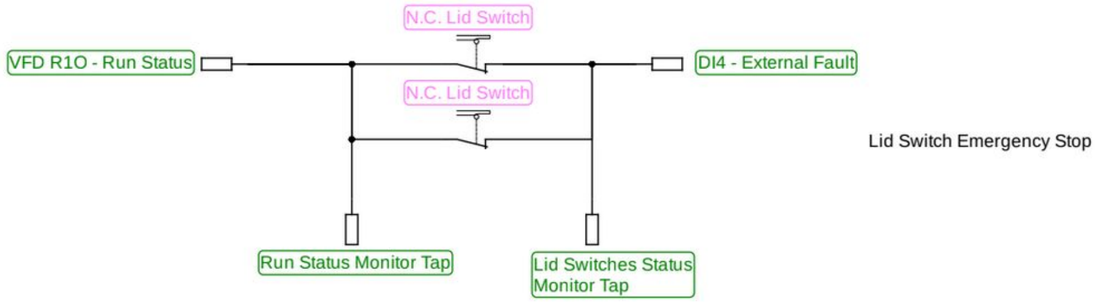
VFD State Monitor to STM32
for Run Status, Lid Status, Reset Button

Safety Subsystem

- Emergency Stop Button:
  - Decouples power from motor. Requires Estop to be reset, and the fault reset button to be pressed to clear.
- Lid Interlocks:
  - When motor is turning, opening the lid will initiate an emergency stop. Requires fault reset button to be pressed to clear.
- Overtorque:
  - Motor can draw up to 115% of rated full load amps for 60 seconds. If more than 115% or longer than 60 seconds, then motor is automatically stopped. Requires fault reset button to be pressed to clear.

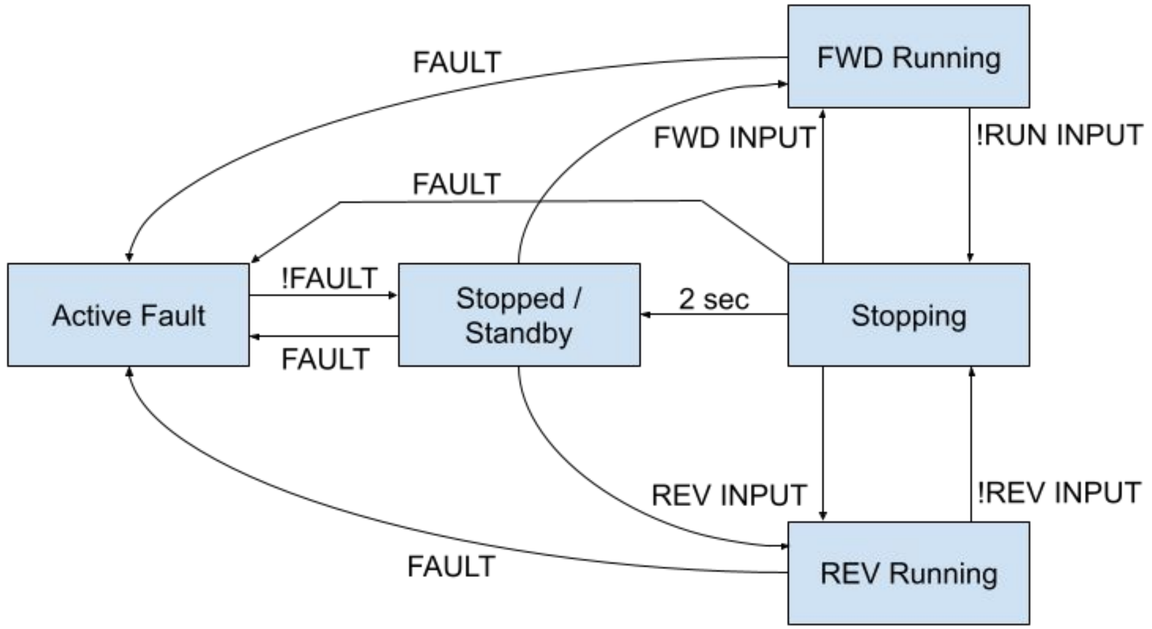






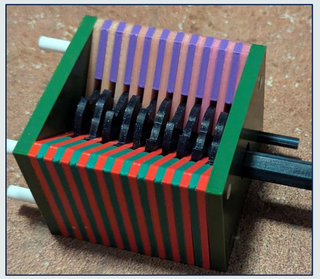
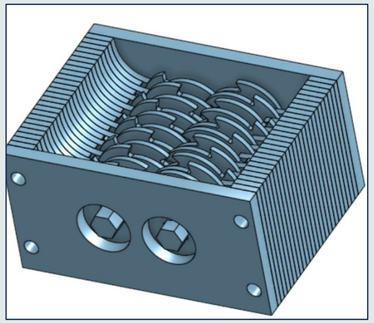
Software

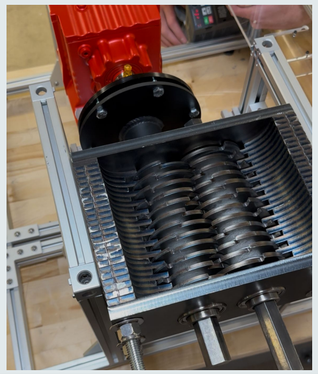
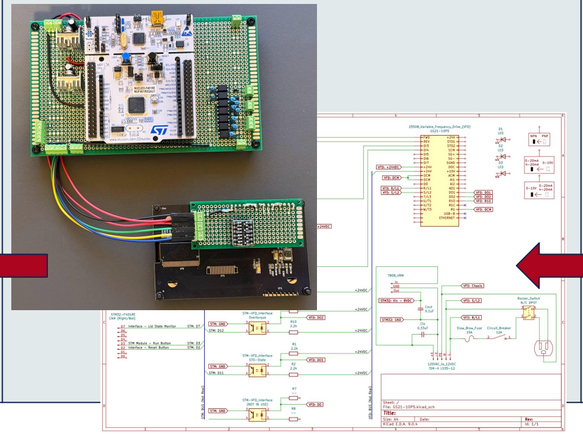
- Implemented using a finite state machine.
- Transitions triggered using external interrupts on STM32 digital inputs.
- STM32 set to low power mode after state change, and waits for next interrupt.
- Code implemented using Arduino library as to be tolerant of different boards and architectures.



Path to Results

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3D Printed Model	Wood Model	Single ⟶ Double Blade	Double Blade CAD Model
		- Double blades pull material in - Wider for more material	

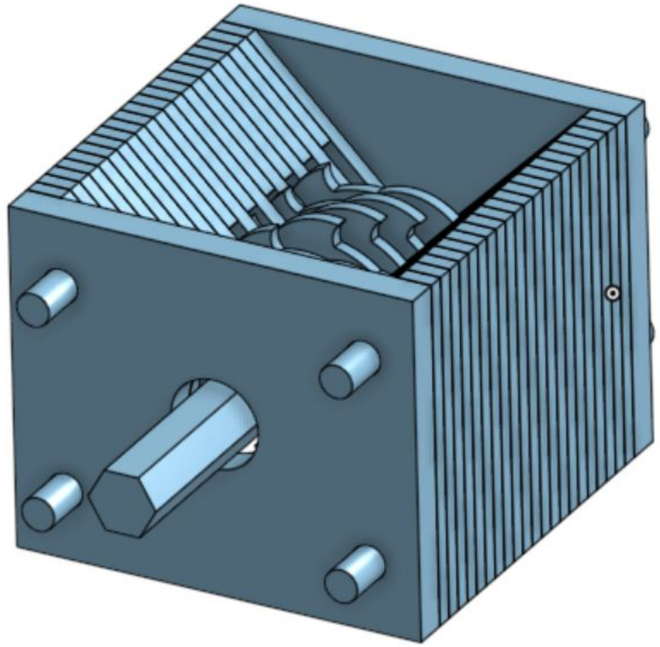
Verified Results	Assembly of Entire System	Electrical Sub-Assembly	Shredder Sub-Assembly
Example: sound testing normal operating sound level of (73.2dB for 45 minutes)			

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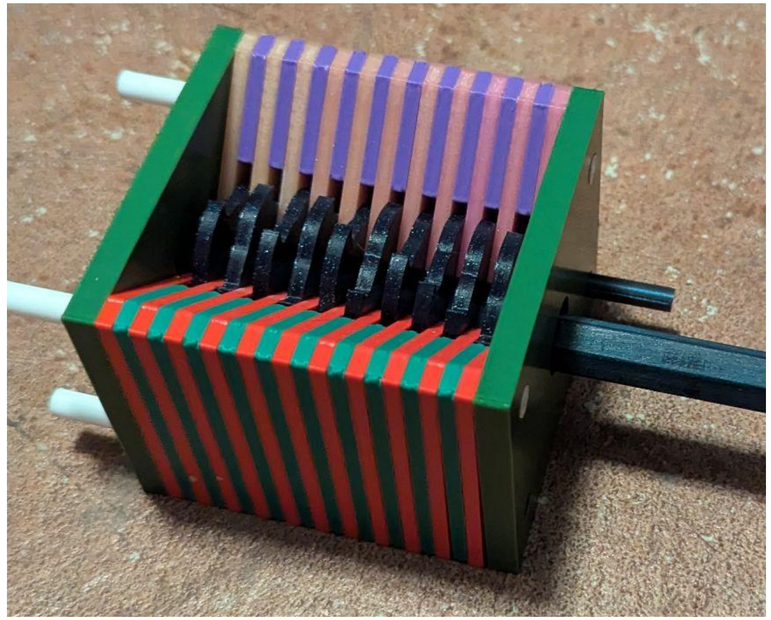
Single-Bladed Design

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CAD Model



3D Printed Model



Wood Model

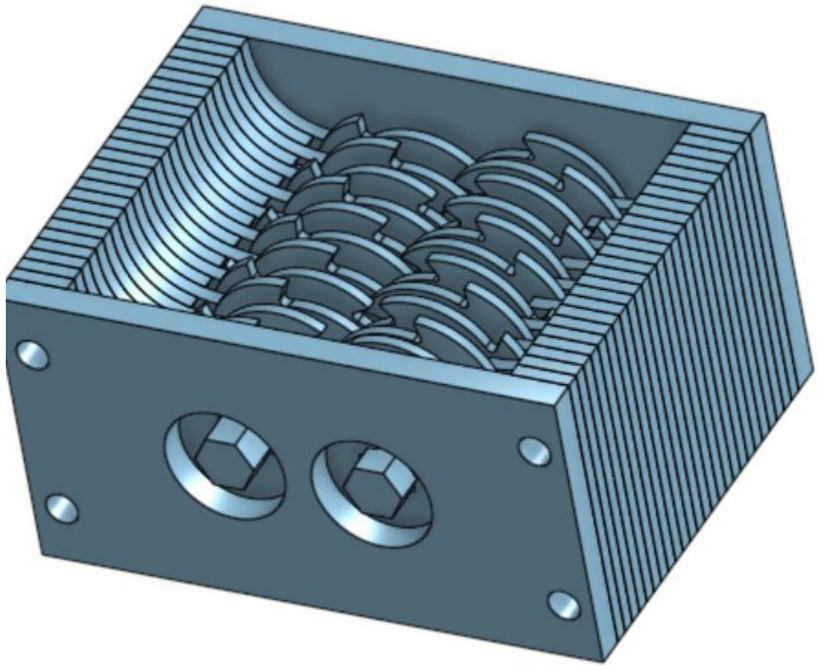


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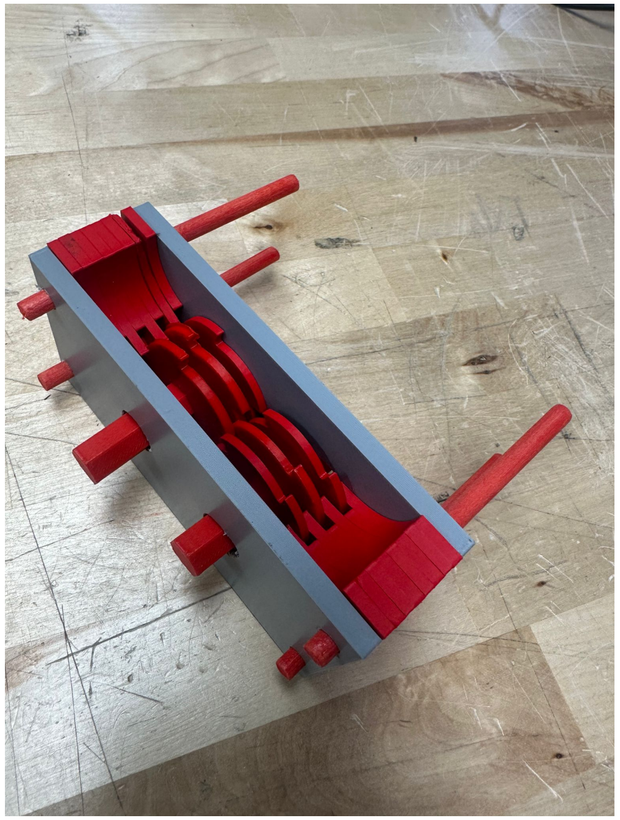
Double-Bladed Design

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CAD Model



3D Printed Model



Metal Model



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System Verification: Video



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System Verification Chart

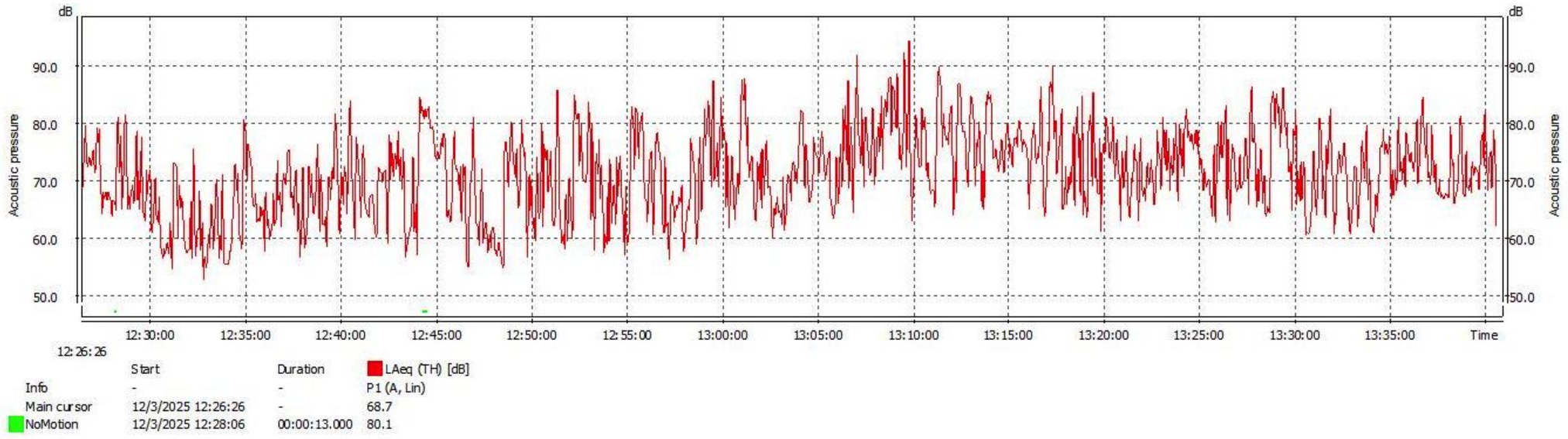
System Requirement Verification				
Requirement	**Method**	**Limit/ Reference**	**Measured/ Ref Value**	**Pass/Fail**
1. Interface Requirements				
a. Power: Total current draw from the wall outlet shall be no more than 12 Amps	I	12 A	<2 A (idle) <12 (Full load)	Pass
b. User Interface (UI) & Interaction: Operator shall be given an interface to control the shredder and shall not have direct access to the VFD.	D	Control over motor state (run/stop; forward/reverse). VFD is accessible upon removal of enclosure panel.	Shredder state controlled by UI with status indication	Pass
c. Maintenance: Blades, comb plates, and jams are serviceable	D	The shredder is accessible through the enclosure panel for maintenance, and manual de-jamming.	None	Pass
2. Environmental Requirements				
a. Sound Level: The noise level shall not exceed 85dB during operation.	T,I	< 85dB (OSHA 1910.9.5C)	75.3	Pass

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System Verification: Sound Test Results

System Requirement Verification				
Requirement	**Method**	**Limit/ Reference**	**Measured/ Ref Value**	**Pass/Fail**
2. Environmental Requirements				
a. Sound Level: The noise level shall not exceed 85dB during operation.	T,I	< 85dB (OSHA 1910.9.5C)	75.3 over 8 hours	Pass



System Verification Chart

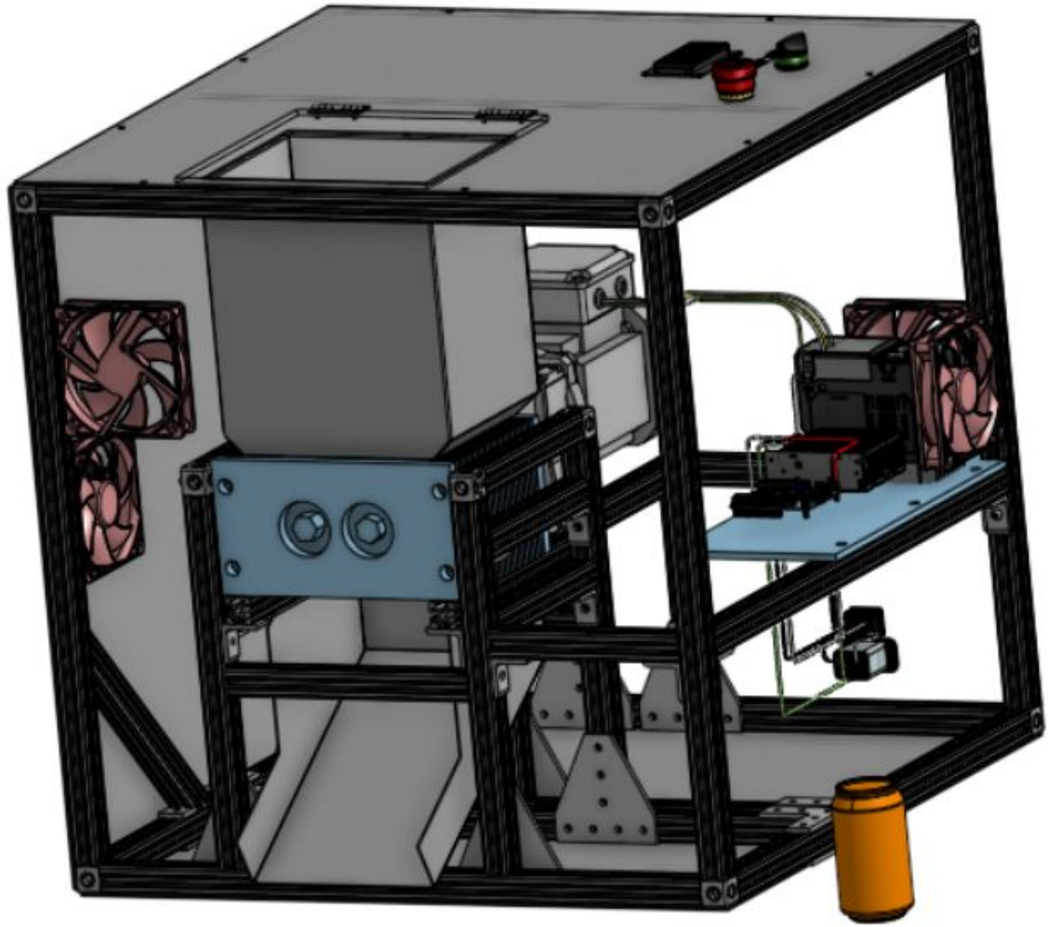
Requirement	Method	Limit/ Reference	Measured/ Ref Value	Pass/Fail
3. Customer Constraints				
a. Foot Print Size: The filament shredder footprint shall be inspected so that it is approximately 26 x 2inches squared.	I	26 x 26 in	26 x 26 in	Pass
b. Weight: The filament shredder shall be demonstrated to be moveable by 1-2 people safely.	I	<150 Lbs	145 Lbs	Pass
c. Shredder Input Capacity: The input to the shredder could take multiple prints at a time and shall be verified by inspection of the dimensions.	I	Does the shredder hold a collection of filament pieces fitting within 6”x6”x6”?	Input accepts 9”x7”x9”	Pass
4. Performance Requirements				
a. Shred Size: The shredder shall reduce the size of plastic waste by 50%	D,I	Reduced by at least 50%	~75%	Pass
b. Autonomy: The shredder will have the ability to shred filament without operator contact or supervision.	D	Does the shredder operate without user contact?	STM32 controls shredder	Pass
c. Shred 6"x6"x6": The shredder shall be able to accept plastic waste that is up to 6 x 6 x 6 inches.	T,I	Parts fitting within 6”x6”x6”	Input accepts 9”x7”x9”	Pass
d. Shred Infill <= 20%: The shredder shall be able to shred plastic waste with infills up to 20% plastic.	T,I	<=20%	Can shredd 100% infill	Pass
e. 3 wall max width: The shredder shall be able to shred plastic waste with up to a 3 wall construction.	T,I	3 walls	Can shred 5+ walls	Pass

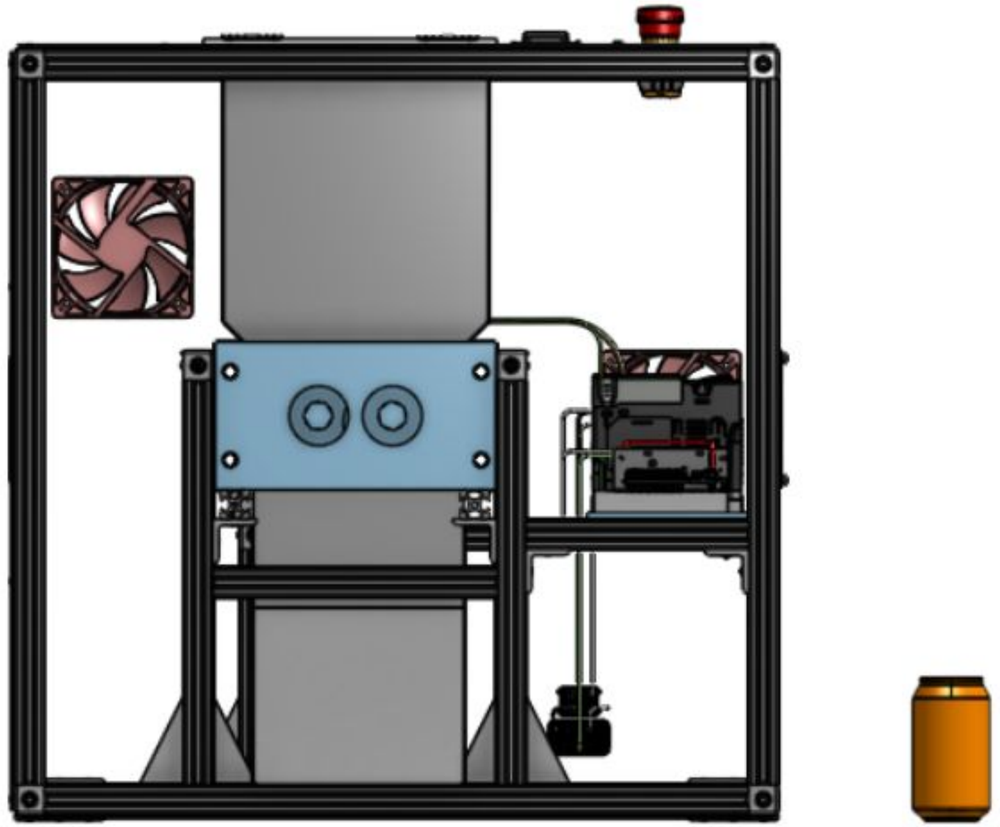
System Verification Chart

Requirement	Method	Limit/ Reference	Measured/ Ref Value	Pass/Fail
5. Safety Requirements				
a. Emergency Shutoff: The emergency-stop button shall be demonstrated. The auto-shutoff for when the lid is opened shall be tested and demonstrated. The overcurrent shutoff shall be shown via analysis.	T,D,I	Does the E-stop cut power to the motor during operation when compressed? Do the lid switches also cut power to the motor when the lid is opened during operation?	E-stop cuts power to the motor Lid auto-shutoff cuts power to the motor	Pass
b. Current Sensing: The shredder shall have a sensor detecting current spikes indicating that foreign material is stuck in the shredding blades and combs. (Not part of MVP)	A,I	Does the sensor accurately measure the current?	VFD internally measures current. STM32 stops the motor at 115% max amps with a hard stop by VFD at 120%	Pass
c. Enclosed Shredder: The shredder shall be enclosed in a box that separates the shredder blades from the user and verified by inspection.	I	Are the main parts of the shredder system easily accessible by the user?	No	Pass

Model Views

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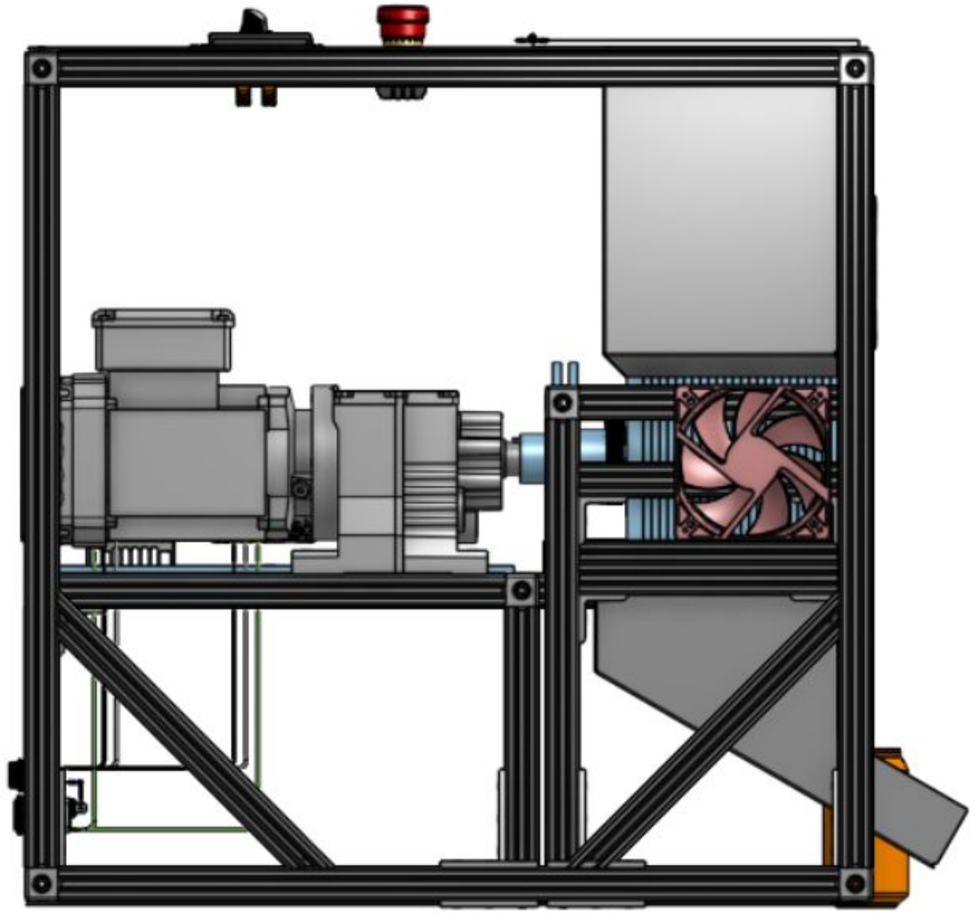


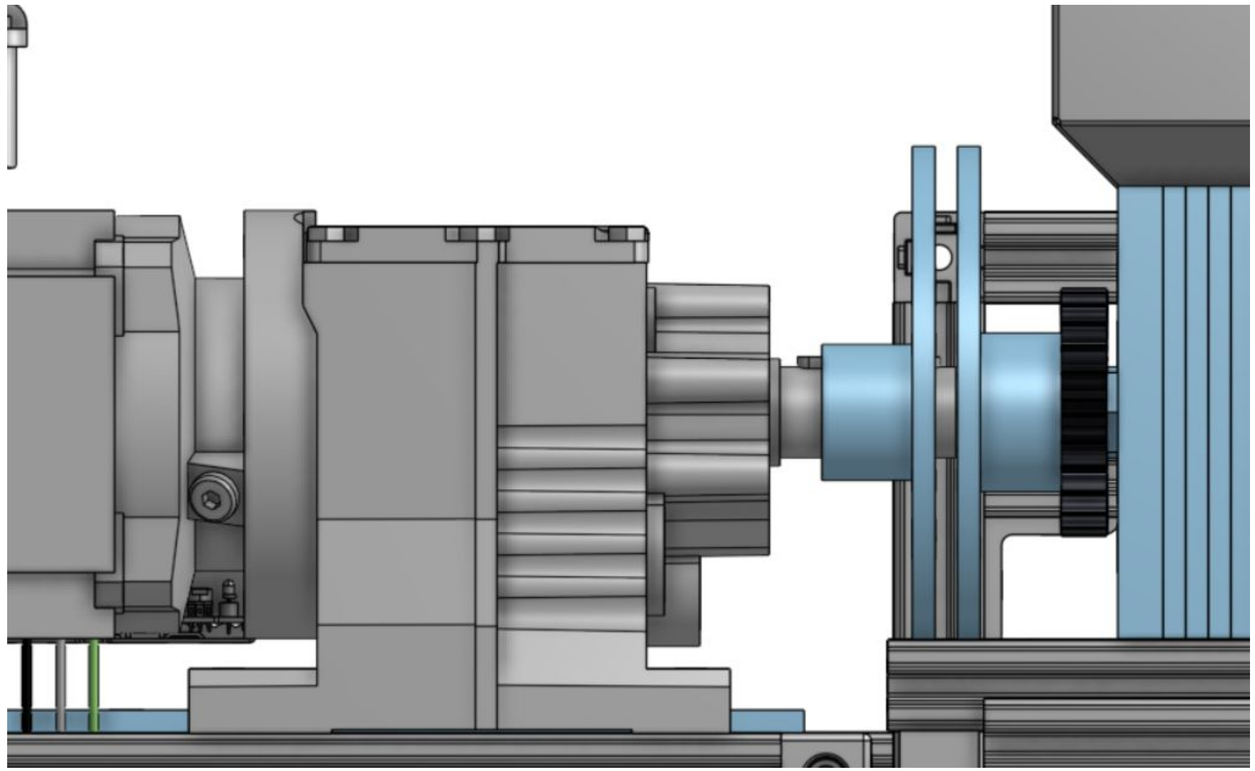


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Additional Model Views

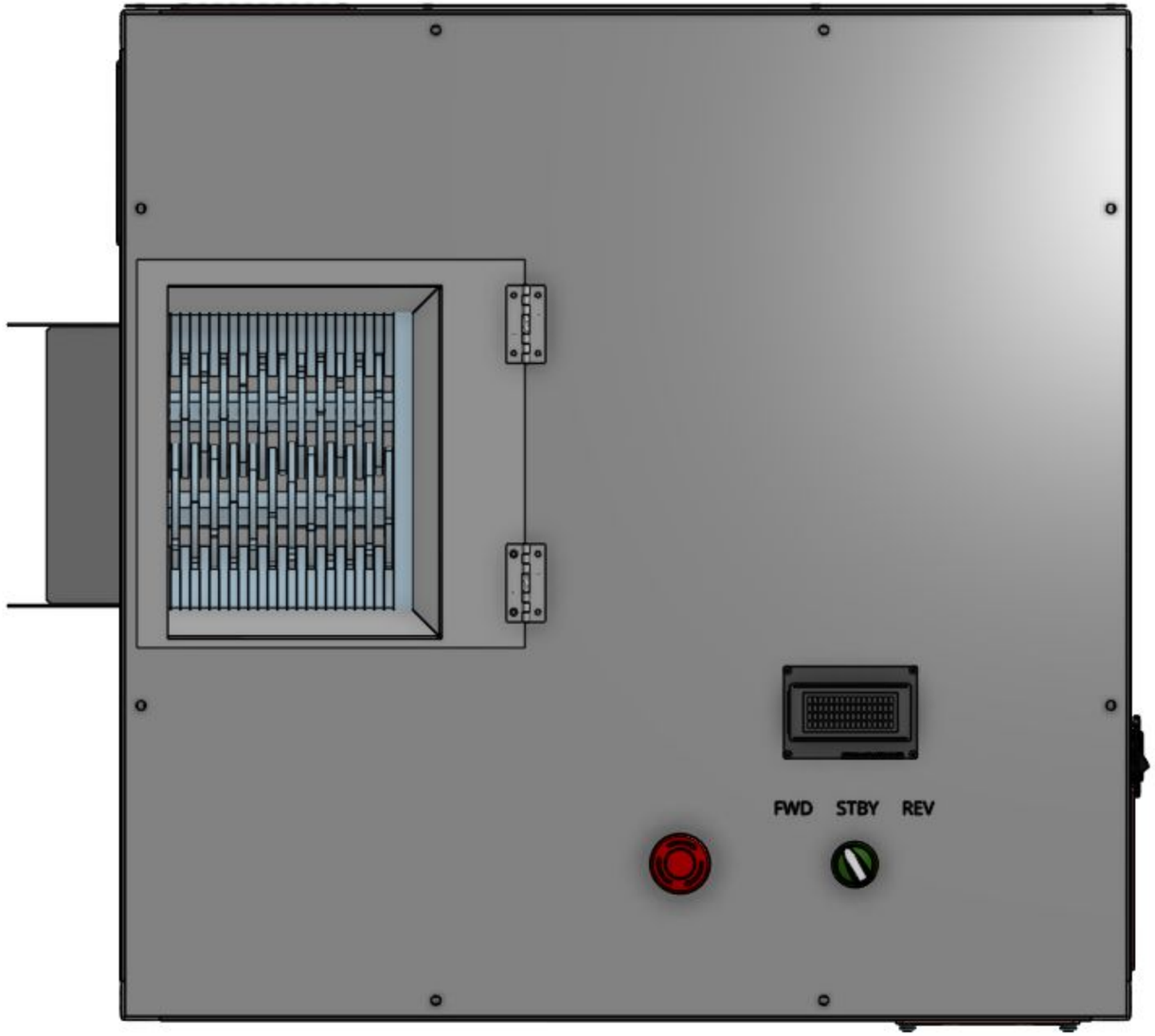
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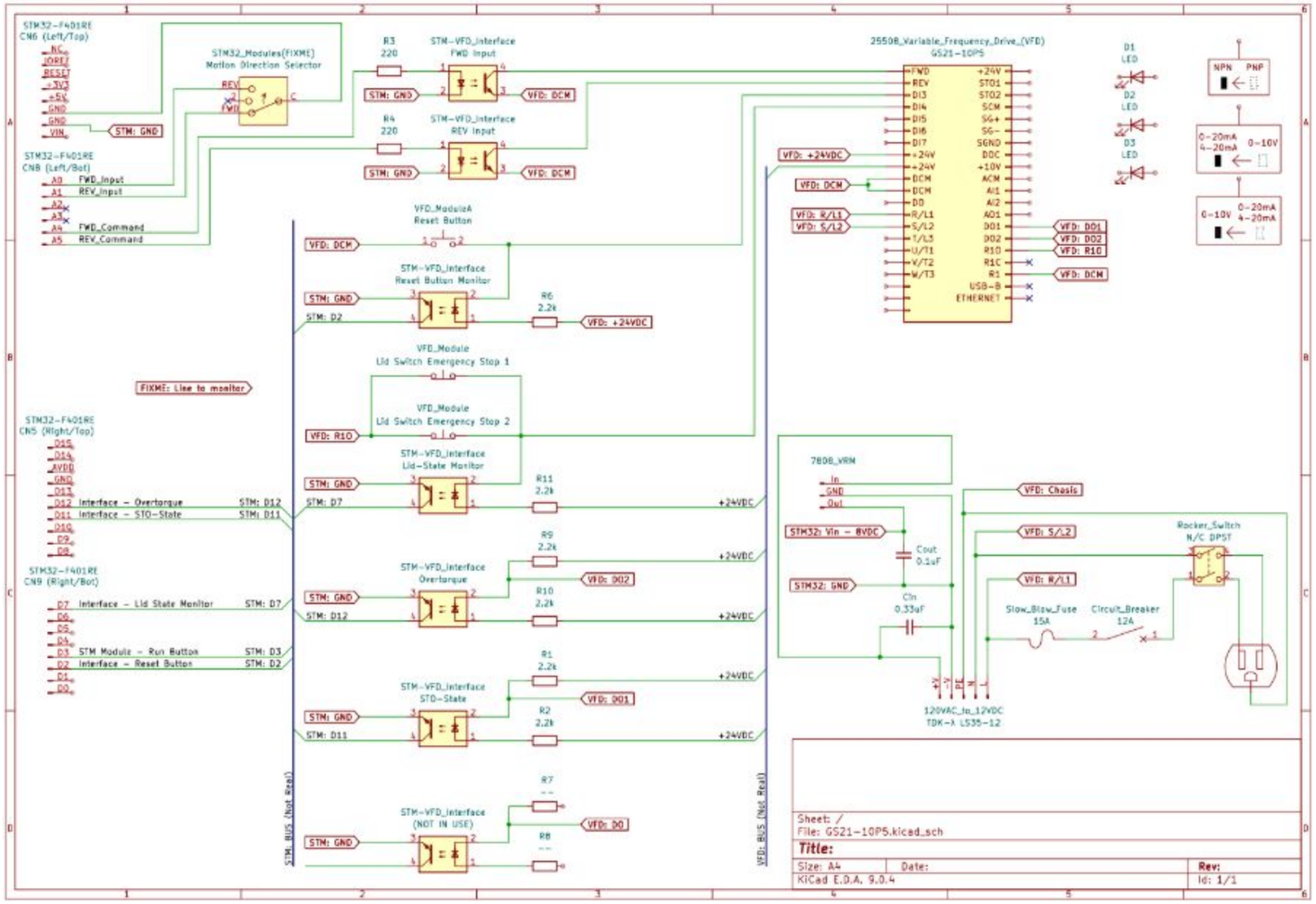


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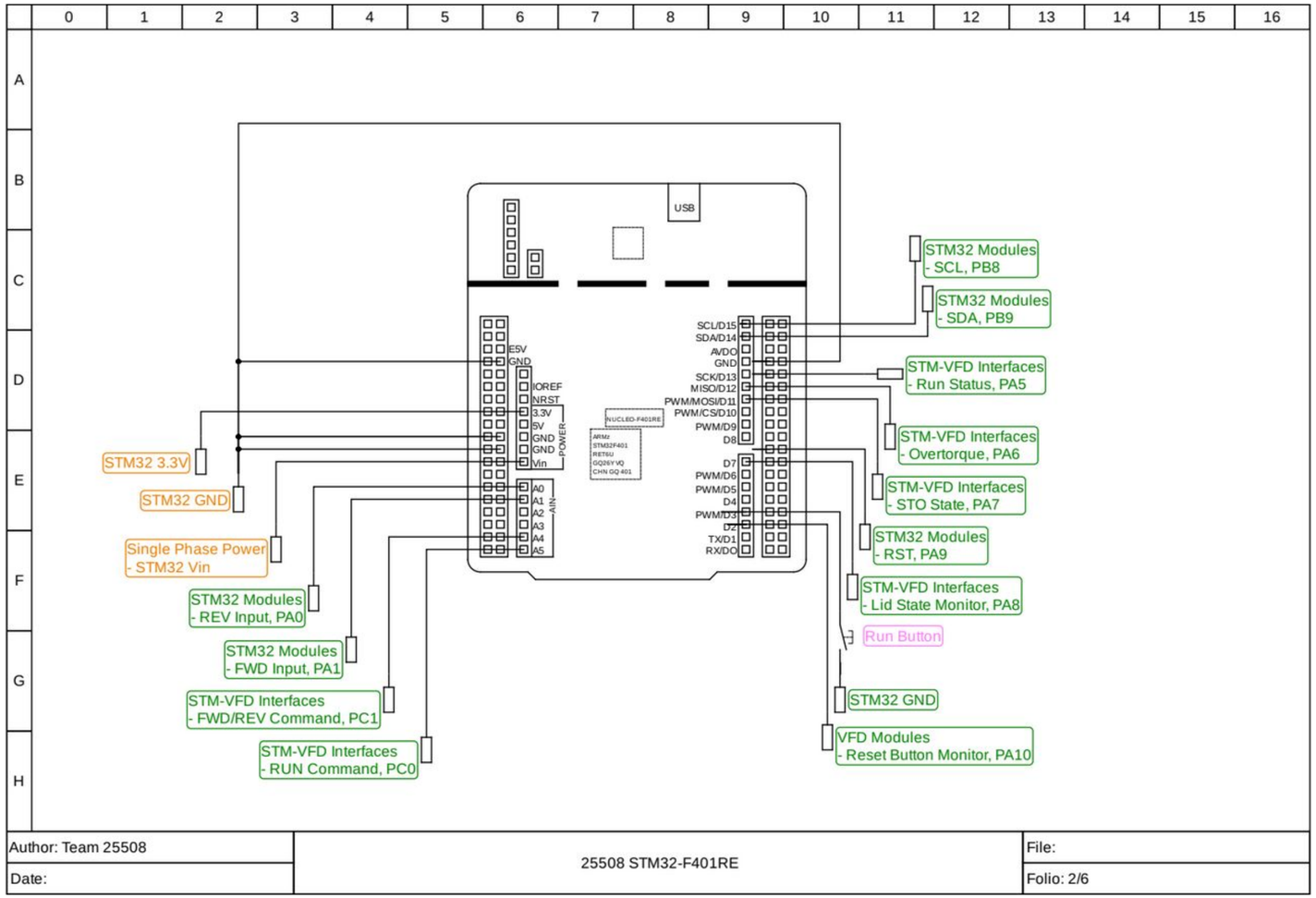
Additional Model Views



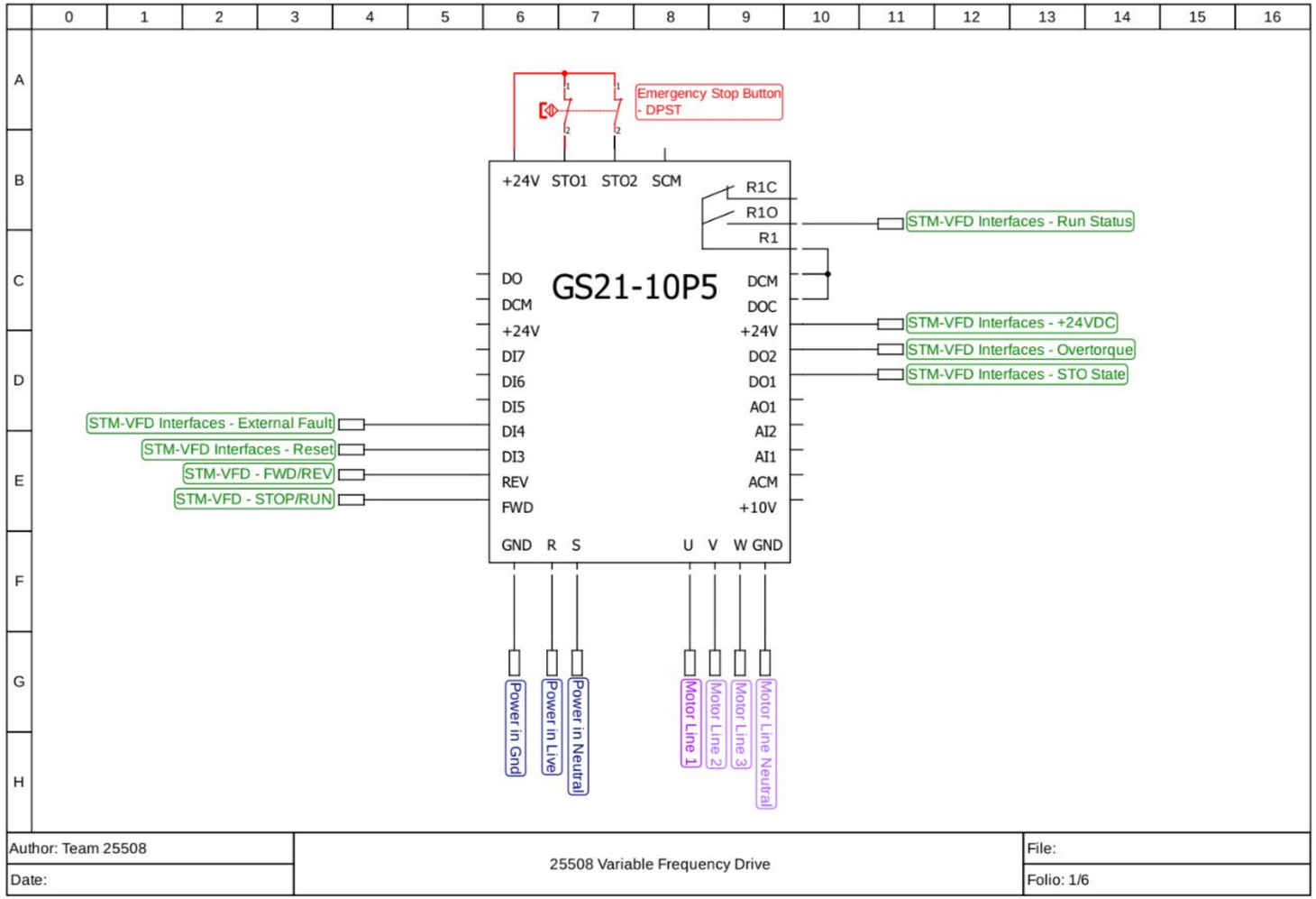
Full Circuit Schematic



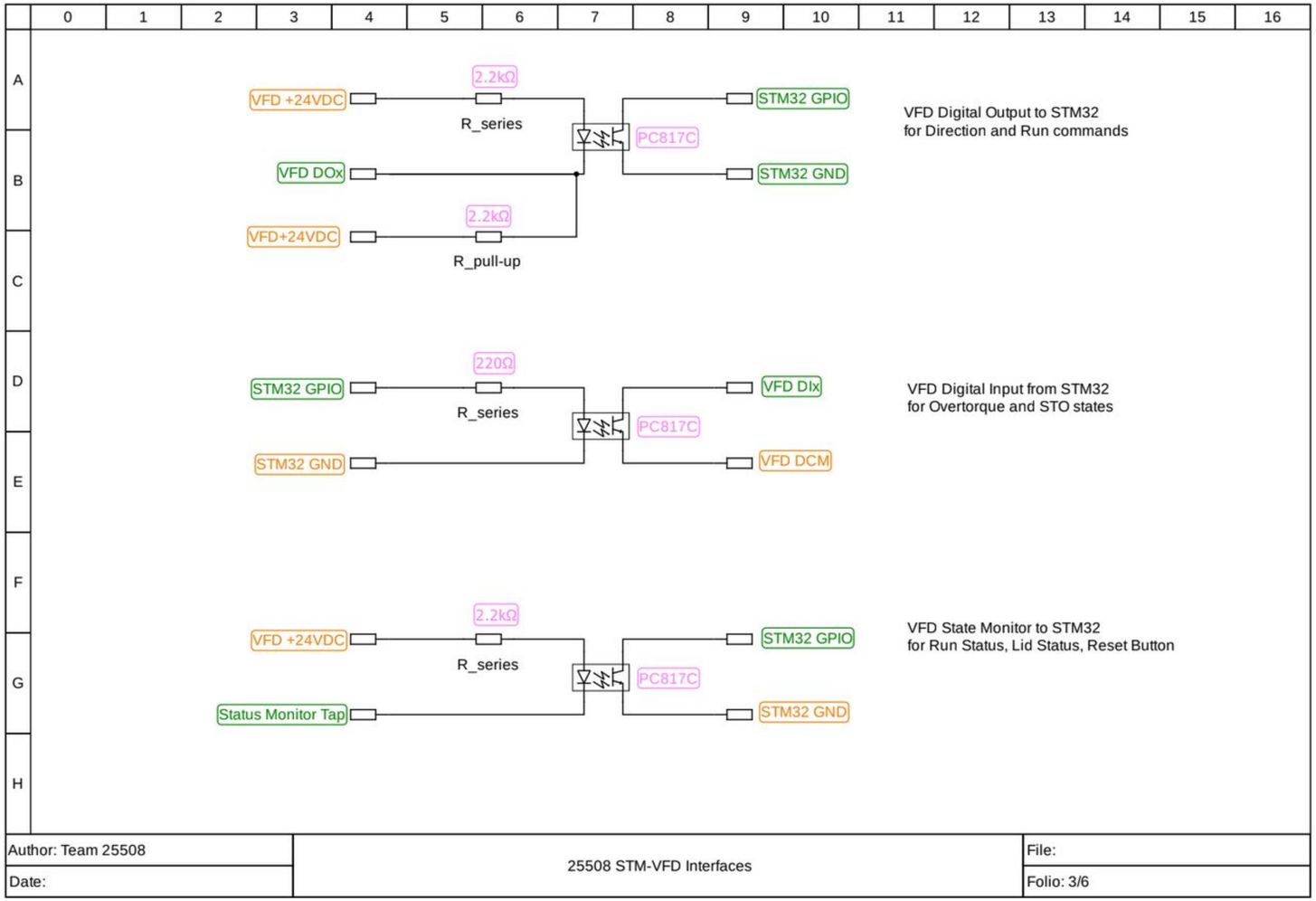
Microcontroller Schematic



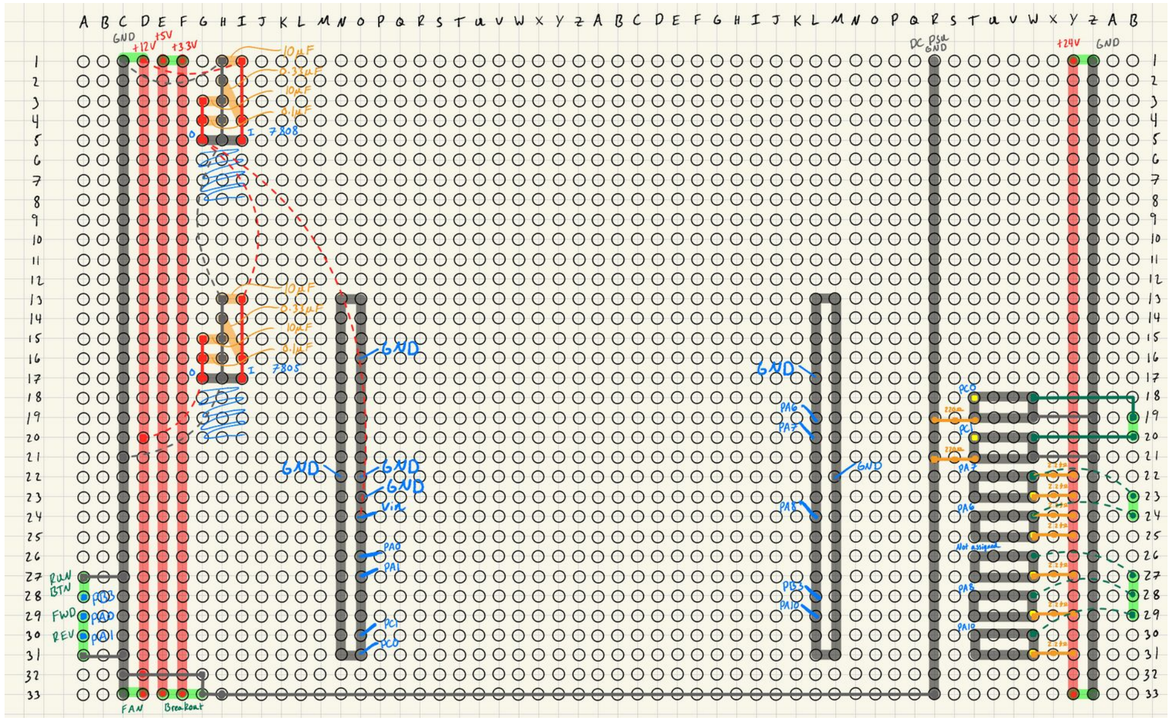
VFD Schematic

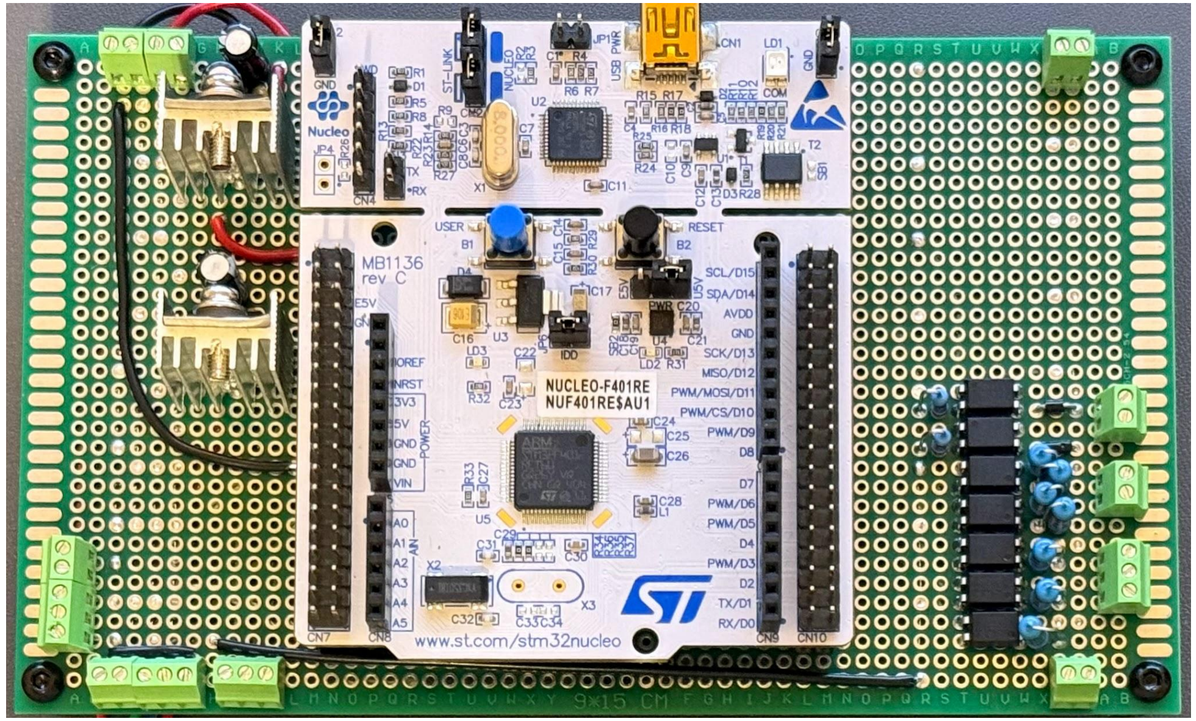


Interface Schematic



Perforated Solder Board Layout





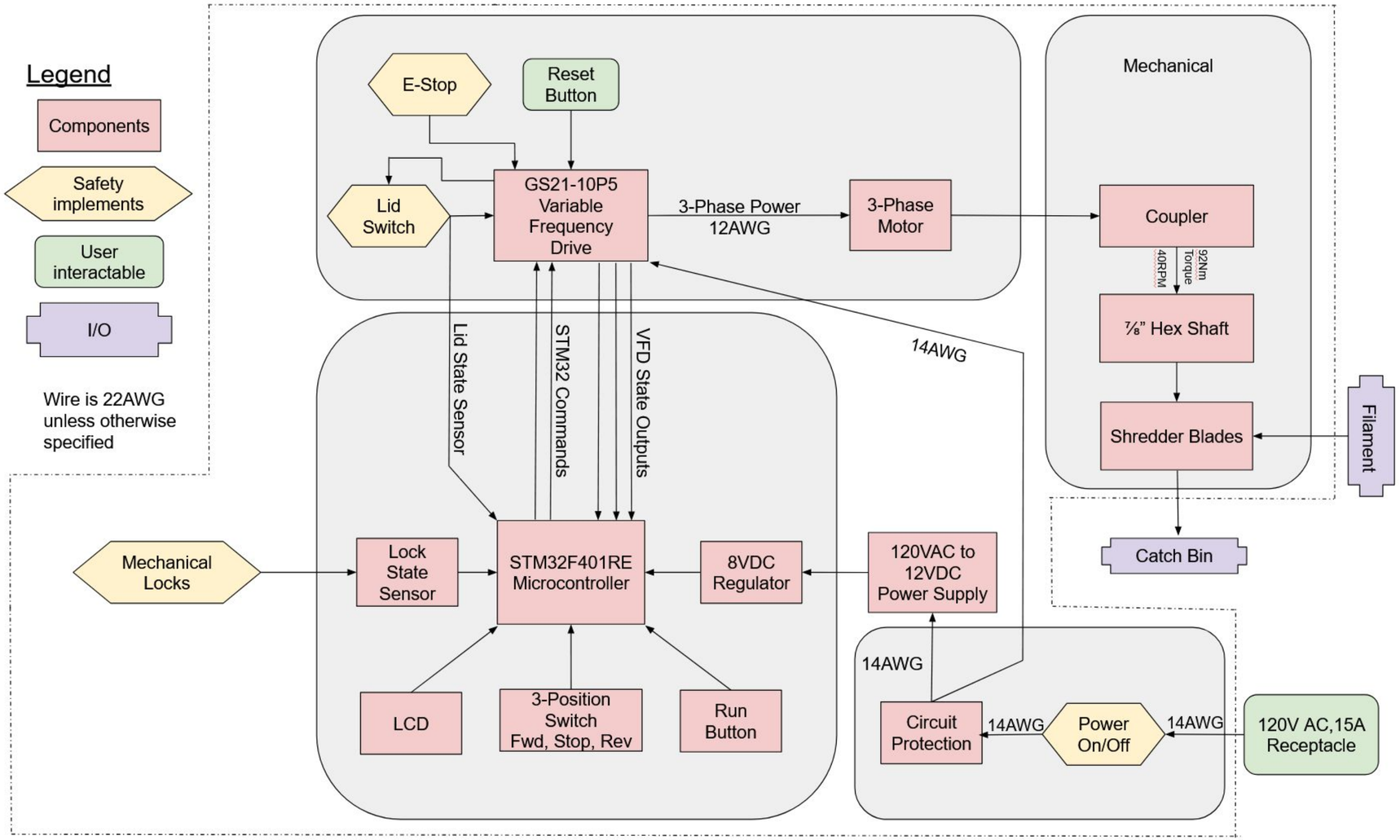
The Team

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System Block Diagram



Project 25508 - 3D Printer Filament Shredder

Thomas Lersch, Nick Petrov, Christian Pavlovich, Allyson Texley, Jake Ciasca, Zack Tileston, George Davis

E-Stop Verification

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Workshop Days



Engineering Design Center

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Project Video

