System Overview

The OPEnS Lab HyperRail is a motion control system developed for agricultural sensing of large areas. It is developed with 3 axis movement, similar to a typical 3D printer movement system, but on a larger scale and expandable to fit the users' needs. This included using consumer components that are readily accessible to order online rather than specialized and custom components. Key requirements for the team were making the system both fast and accurate, using existing OPEnS lab hardware, creating a robust tool changing system, and controlling the system using G-code sent wirelessly via wi-fi.

Electrical Specifications

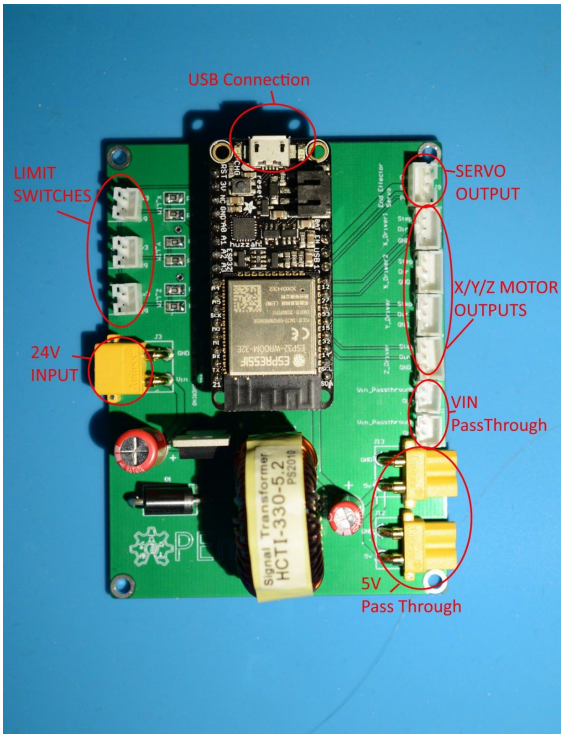
The only inputs to the system are power and limit switches. The limit switches can only use 3.3 volt signals, as the ESP32 cannot tolerate a higher voltage. The limit switches are connected to 3.3 volts on their connectors, so no user changes are necessary in this regard. The power input can be chosen by the user, and can be anywhere from 12 to 30 volts DC. The electrical specifications are summarized below.

Parameter	Value
Minimum Supply Voltage	12 v
Maximum Supply Voltage	30 v
Nominal Supply Current	500 mA
Maximum Supply Current	2 A
Limit Switch Min Voltage Input	3.3 v
Limit Switch Max Voltage Input	3.3 v

Interface Definitions

Interface	Interface Type	Specifics
12-30v_dcpwr	DC power	V_min = 12 v V_max = 30 v I_max = 2 A
5v_dcpwr	DC Power	V_max = 5.25 v V_min = 4.75 v I _max = 3 A
gcode_userin_rf	wireless serial transmission	IEEE 802.11b/g/n protocol 9600 baud Input
gcode_code	Software	gcode interpretation software
X/Y/Z_step_dsig	digital signal	5 v logic level TTL output
X/Y/Z_dir_dsig	digital signal	5 v logic level TTL output
X/Y/Z_limswitch_dsig	digital signal	3.3 v logic level TTL input
Servo_pwm	PWM signal	5 v logic level PWM output, 50 Hz, 1ms - 2ms period

User Guide



1. ## Mounting to HyperRail
   The enclosure is easily mounted to the frame of the Hyper Rail. Using M5 screws and extruded aluminum mounts, the user can place the device where-ever they need. It is suggested that the user puts the device in a location that can reach all connected components with ease, and provides extra length for movement along the system once it is operational.

2. ## Making connections between motors and electronics:
   Motor connections are handled easily with JST connectors and connections to 5V pass through. Two of these connections are used for motors on the X axis of the system. These connectors connect to stepper motor drivers which then drive the motors.

3. ## Making connections between end effector servo and electronics
   The end effector servo is connected to the electronics using a 3 pin JST. This provides 5V, GND, and signal to the servo. This connection is at the top right of the PCB.

4. ## Making connections between limit switches and electronics
   Limit switches can be connected using 2 pin JST connectors to a 3.3V, and signal pins. There are 3 valid inputs to connect limit switches to on the upper left side of the board.

5. ## Assembling Gripper Arm:
   Gripper arm is assembled using 10 M5 x 25mm screws and 10 M5 nuts. 2 M2 screws are used to mount the servo motor to the gripper.

6. Creating WebUI

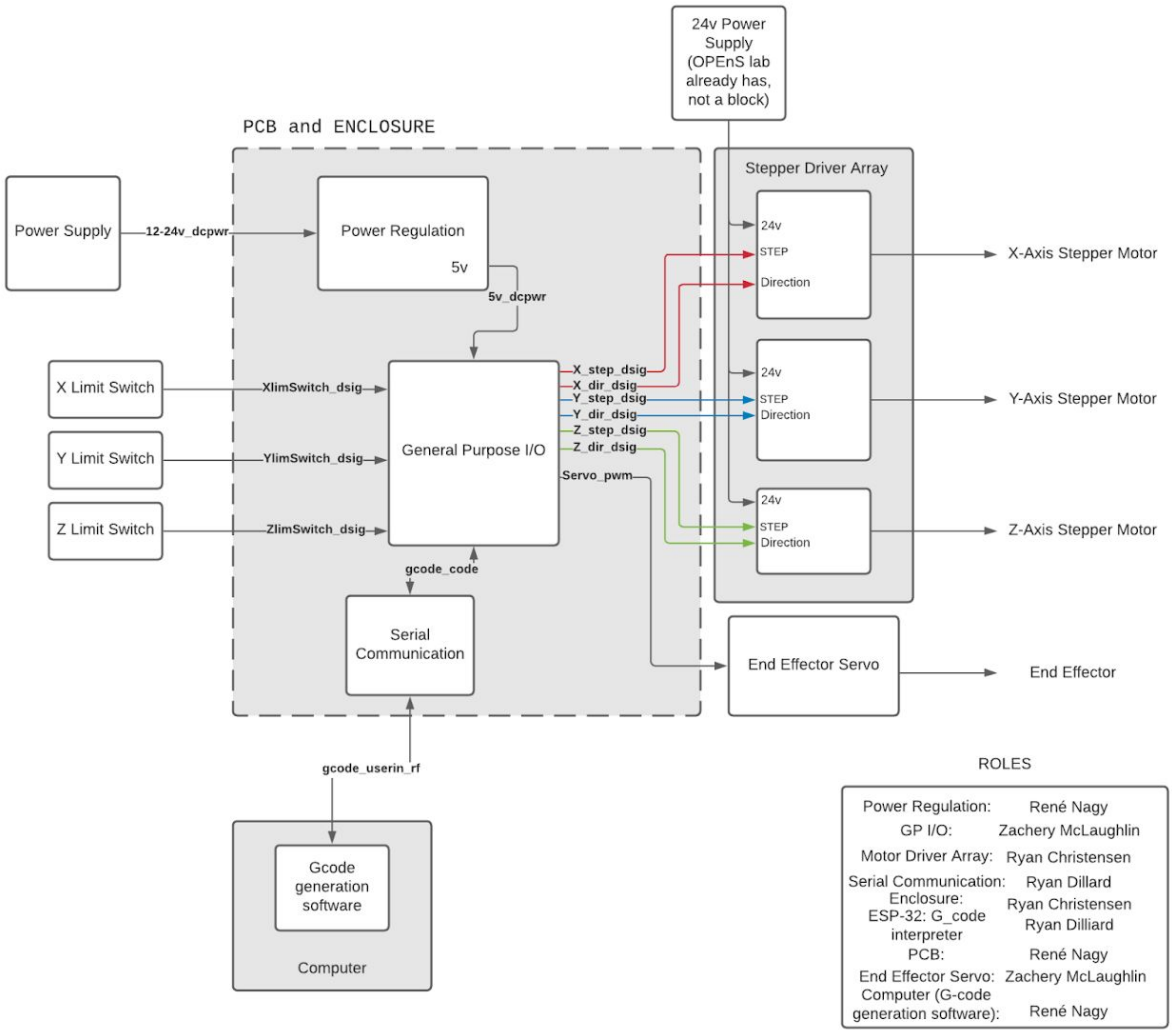
   On startup the ESP32 creates an access point named GRBL-ESP. This can be accessed by entering the password 12345678. Once connected to the ESP32 the user can open up the web page by entering the address `192.168.0.1` into a browser. From here the user can upload the WebUI data found in `Grbl_Esp32/src/data/index.html.gz` to the ESP32. With this file loaded, refresh the browser and the WebUI will be available.

7. Loading G-Code

   From the control panel of the WebUI the user can home the system, and perform jogging. To perform individual G-code commands the user can send commands using the Command panel to see the system status, and write and send commands. The SD card panel is where G-code files could be uploaded if there was an SD card attached to the system.

Design Artifacts

Block Diagram and Interface Definitions



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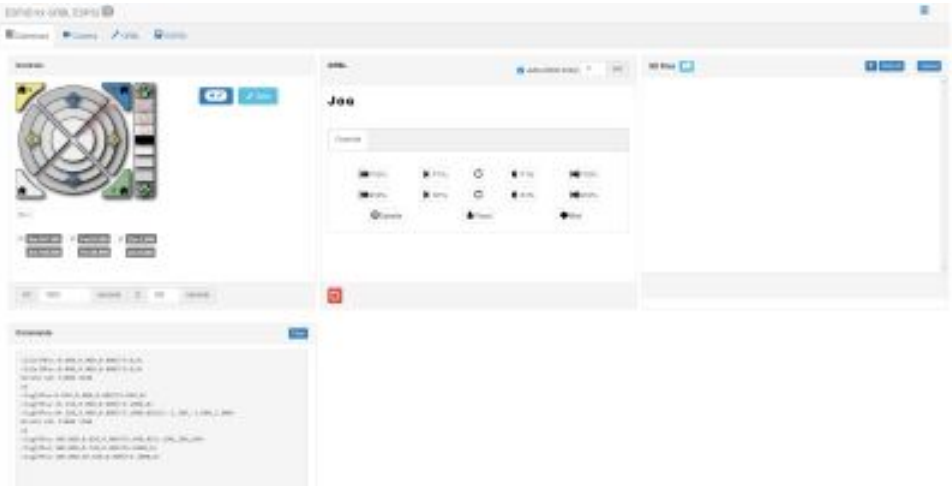
Web Interface

The Web Interface makes use of software provided by the GRBL ESP32 software. The ESP32 creates an access point hosting a web server. The WebUI is uploaded to the ESP32 resulting in an easily accessible interface. This interface gives the user the ability to send any Gcode command to the ESP32 through a serial command line. It includes two different interfaces in addition that allow commands to occur through button press. In addition to this user friendly interface there are other pages that allow the user to adjust settings related to the web server, and connections.



Gripper

The Gripper used within the design was created to allow the HyperRail to be able to equip several tools for use such as a marker, pencil, pen, RFID scanner, and a light sensor as per OPEnS lab requirements. The gripper can open to 30mm at its maximum and close to 6mm at its minimum. The system is operated by an arm that pushes in and pulls out to open and close the claws. Advantages of this system is that it is simple and easily disassembled/assembled; moreover, the gripper uses minimal outside parts such as just ten screws/nuts and one hobby servo motor for full functionality making the system overall cheaper to produce. Another advantage is that the system can be easily made from metal components instead of 3D print filament because of the simplicity of the components involved.

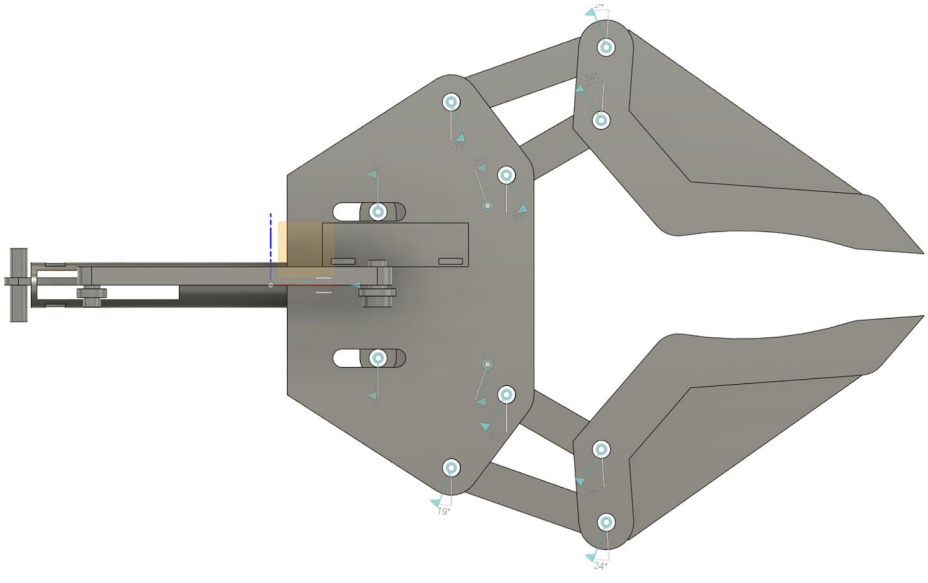


Figure 2.1 -

The Image above shows the customer how the gripper can open to an acceptable distance for the system to be able to hold desired tools. Using just six overall joints in the main assembly, the gripper maintains simplicity and ease of use for anyone to operate.

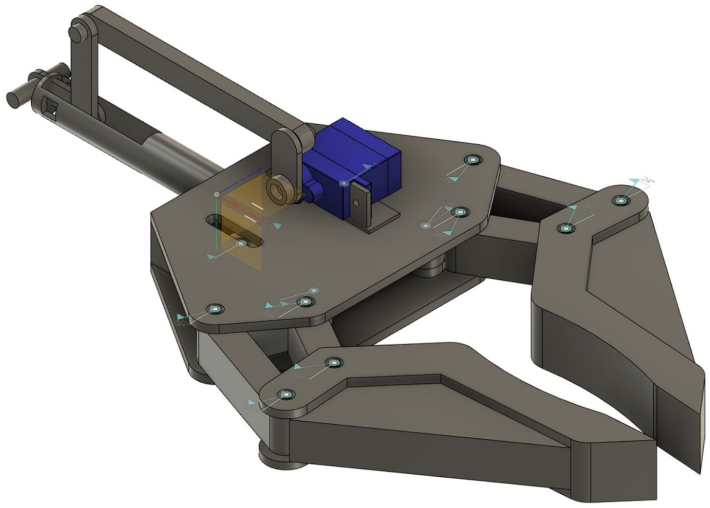


Figure 2.2 -

An angled profile image shows the opened gripper and accentuates the rotational-to-linear mechanism that will take the rotational movement of the RC motor to linear push/pull movement for the gripper.

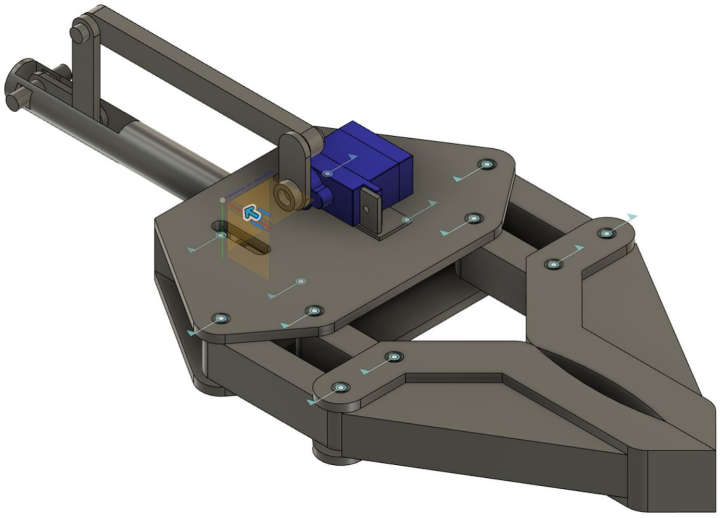


Figure 2.3 -

Initial rest state of the gripper. This state aids the user in seeing the overall simplicity of the whole mechanism. Kept within a compact package, the gripper can be used in a variety of scenarios as long as it has a motor to power it.

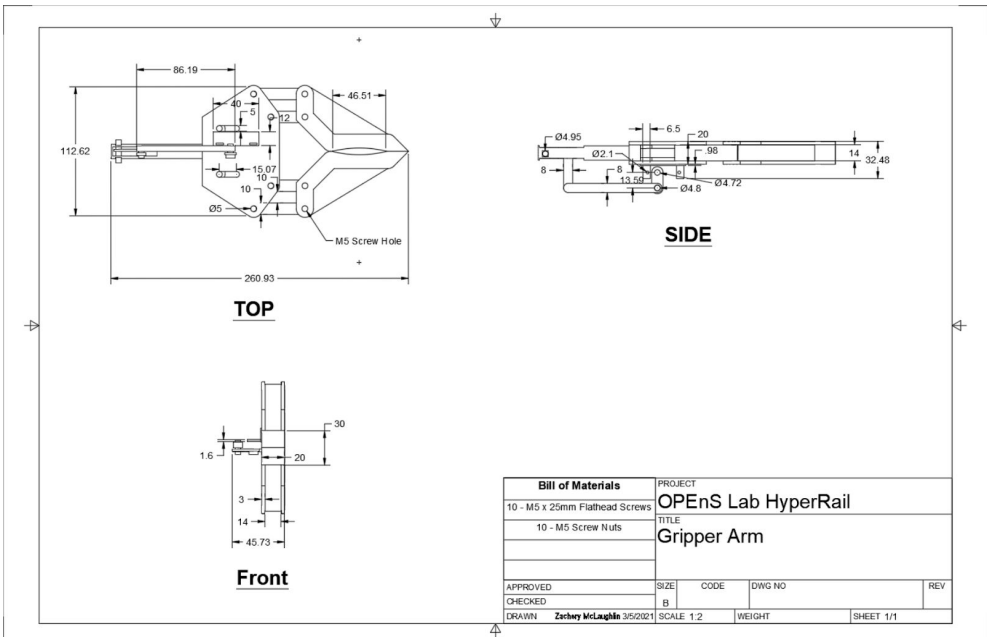


Figure 2.4 -

Datasheet for the gripper arm assembly. These drawings are provided to give precise measurements for the user to study and examine in order to fully understand the dimensions of the overall system.

Enclosure

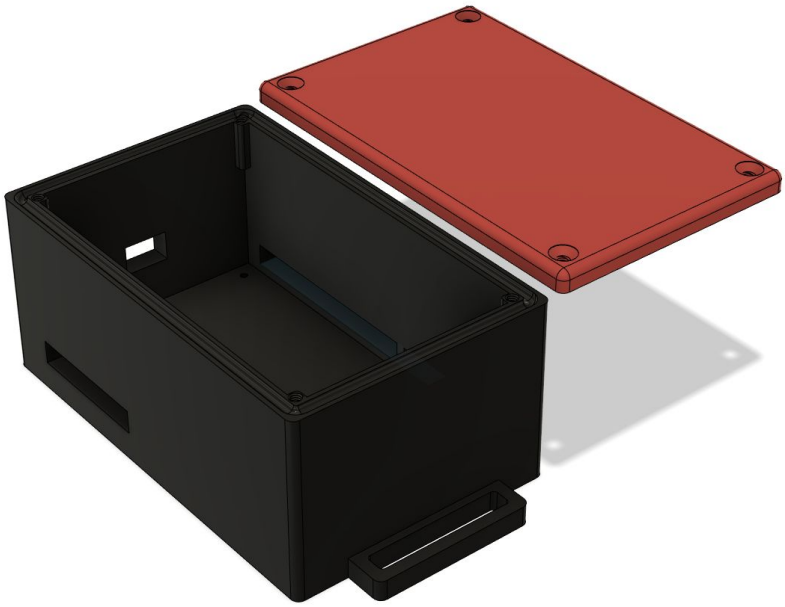
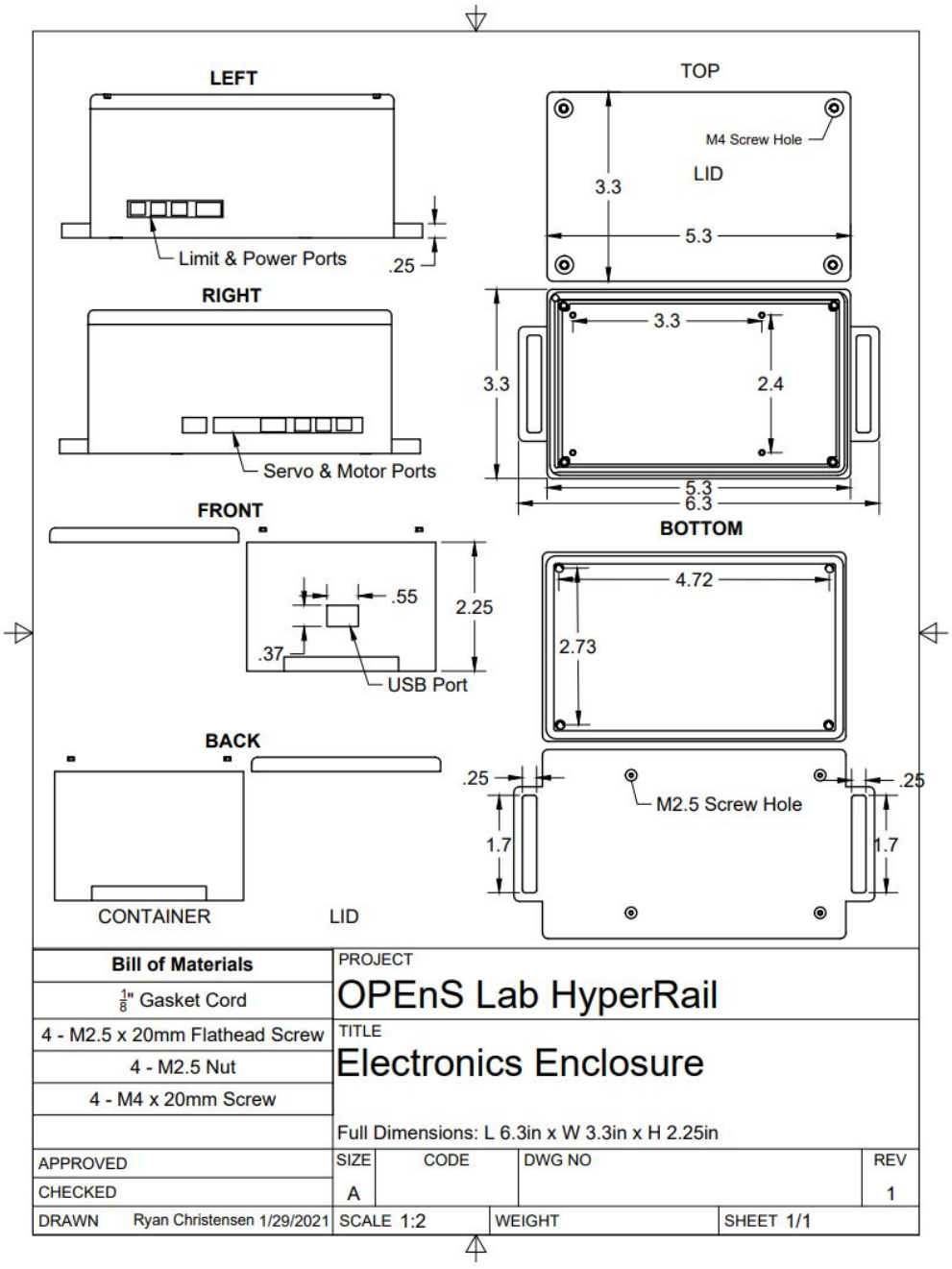


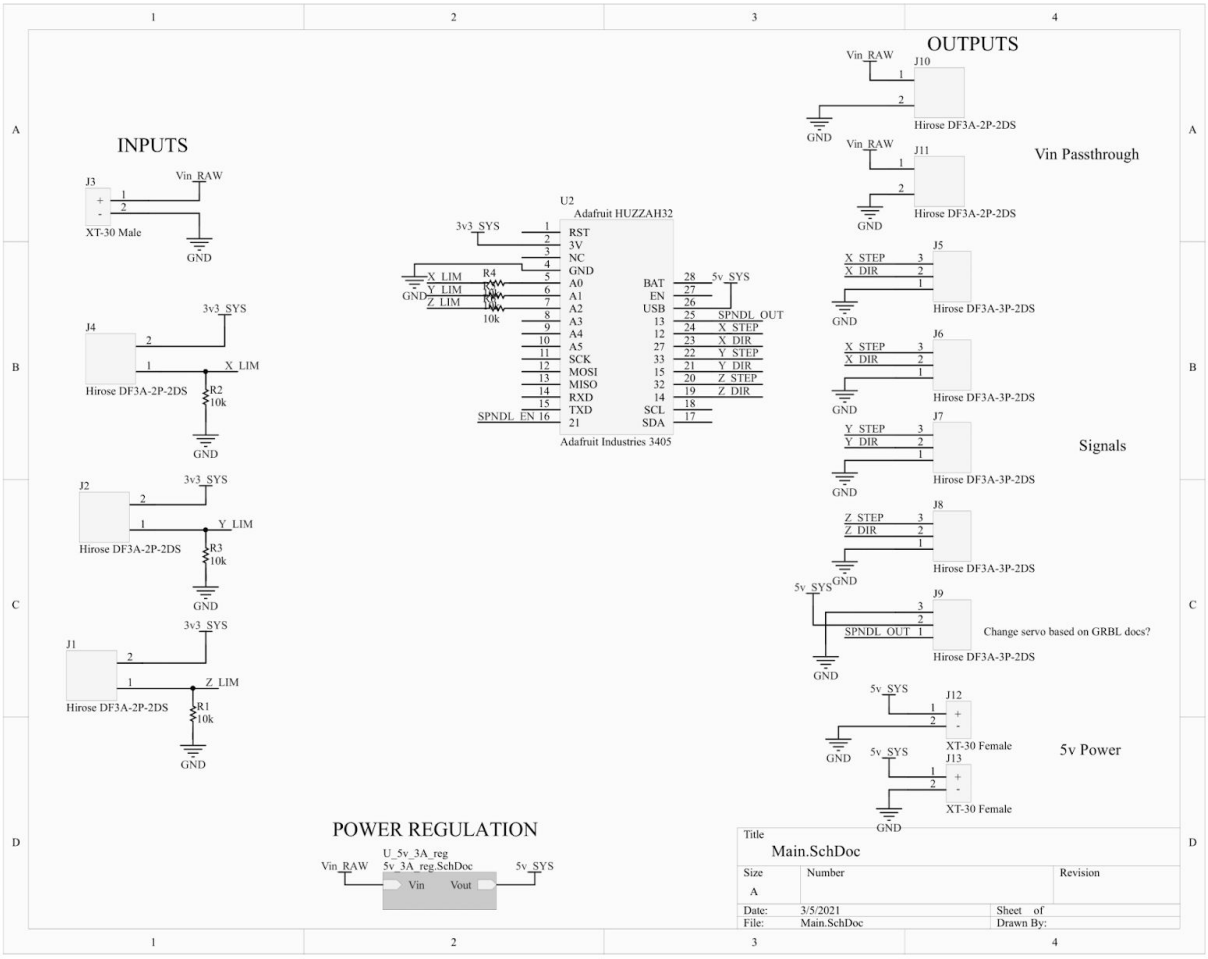
Figure 3.1 Enclosure 3D Model

The enclosure used within the design is smaller than the one previously being used by OPEnS Lab. The goals for the enclosure is for it to have an IP rating of 6x. It is designed as a simple box with a removable lid allowing access to the electronics inside for service, or replacement. On three of the four sides there are openings for 24v power, limit switches input, motor connectors for dual X, single Y, and single Z axis control. Servo port for control over a user designed end effector, and 5V power passthrough. This design has the advantage of being smaller than the previous version used on the old system, and it's smaller size allows it to easily mount directly to the frame of the HyperRail itself.

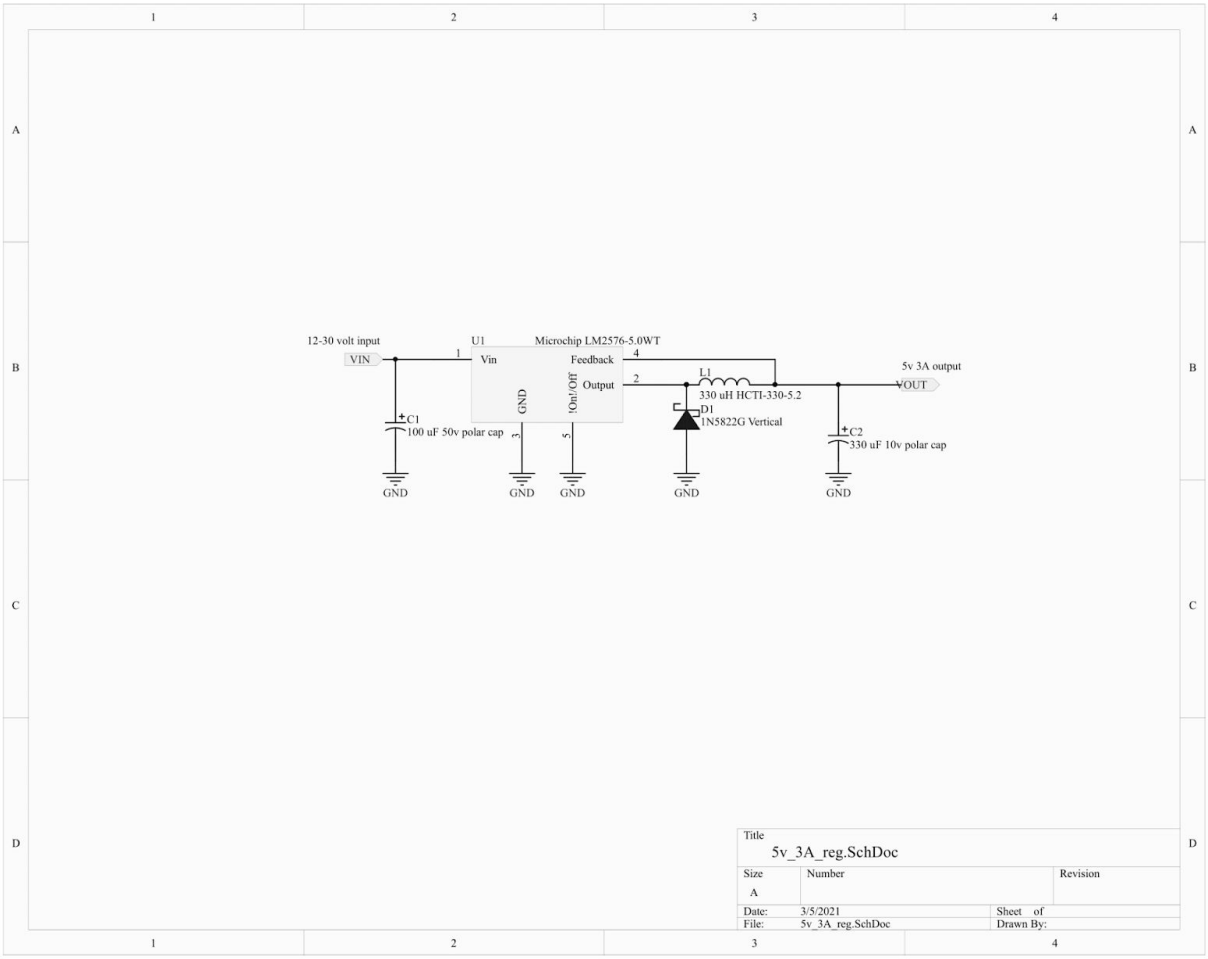


PCB

The PCB is a simple 2.6 by 3.5 inch breakout board for the Adafruit Huzzah32 board. It contains a 5 volt switching regulator that can take in a 12-30 volt input, and can output up to 3 amps of current at 5 volts. Inputs and outputs for the board are broken out to connectors on the left side of the board for inputs, and the right side of the board for outputs. The inputs include power (12-30 volts), and 3 limit switch inputs. Outputs include two 5 volt outputs, two voltage input pass throughs, a PWM control signal to control the gripper, and four step and direction signals for inputs to the stepper motor drivers.



Schematic 1: Main Schematic



Schematic 2: 5v Regulator Schematic

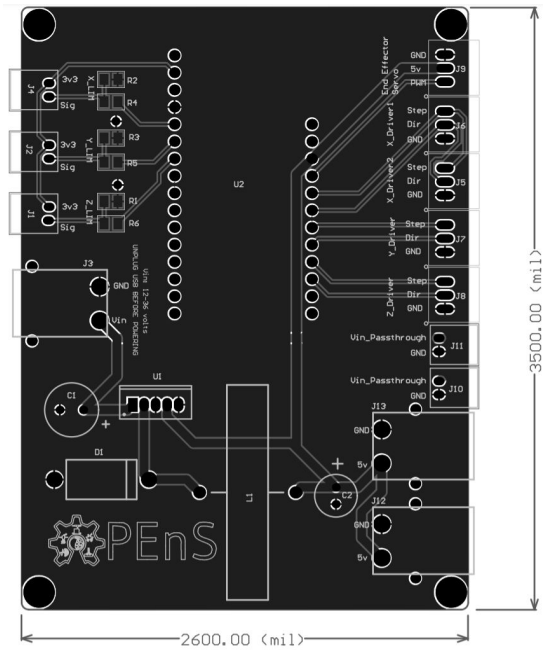


Image 1.1 PCB Footprint and Layout

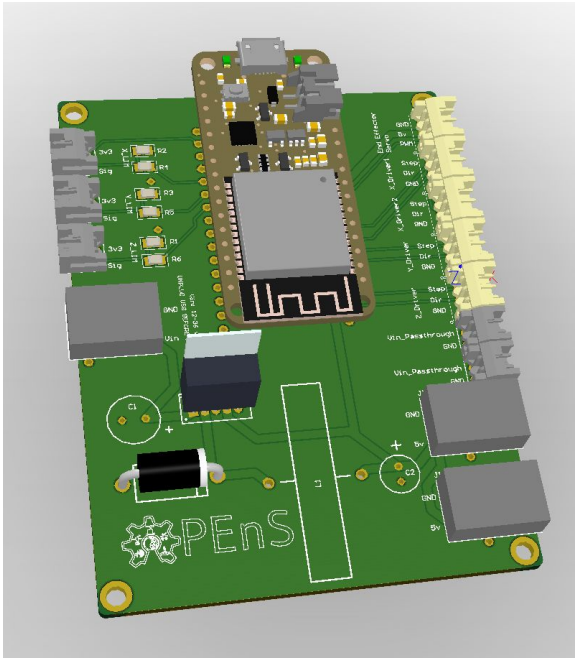


Image 1.2 3D Model of the assembled PCB

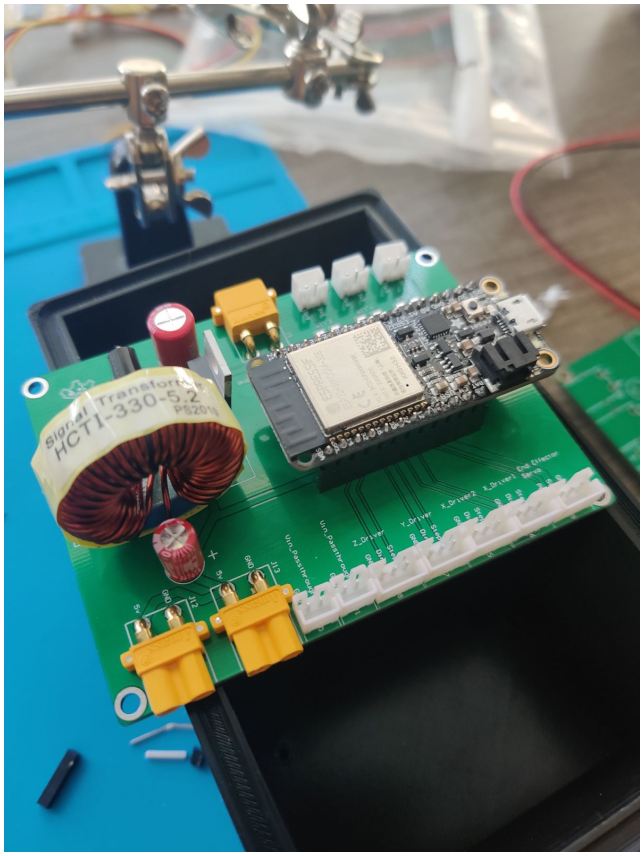


Image 1.3 Assembled PCB

Part Information

Cat	Item Name	Part Designator (if applicable)	Part Value	Vendor	Vender No	Price	BOM Quantity	BOM Total
IC	5v 3A switching reg	U1		Digikey	576-1518-5-ND	2.01	1	2.01
Inductor	330 uF radial inductor	L1	330 uH	Digikey	595-1734-ND	2.54	1	2.54
Diode	40V 3A schottky diode	D1		Digikey	497-11370-1-ND	0.4	1	0.4
Cap	100 uF 50v electrolytic	C1	100 uF	Digikey	732-8666-1-ND	0.26	1	0.26
Cap	330 uF 10v electrolytic	C2	330 uF	Digikey	732-8912-1-ND	0.14	1	0.14
Conn	XT-30 (M/F)	J3, J12, J13		Amazon	N/A	9.99	1	9.99
Conn	2 pin Hirose connector M	J1, J2, J4, J10, J11		Digikey	H3893-ND	0.16	5	0.8
Conn	2 pin Hirose connector F	J1, J2, J4, J10, J11		Digikey	H2083-ND	0.1	5	0.5
Conn	3 pin Hirose connector M	J5 - J9		Digikey	H3894-ND	0.2	5	1
Conn	3 pin Hirose connector F	J5 - J9		Digikey	H2084-ND	0.12	5	0.6
Res	0805 10k resistor	R1-R6	10k	Digikey	RMCF0805JT10K0CT-ND	0.0078	6	0.0468
Screw	M2.5 16mm Screw (x100)	91420A024		McMaster		4.66	4	4.66
Screw	M4 16mm Screw (x100)	91420A226		McMaster		3.60	4	3.60
Screw	M5 25 mm Screw	801098		Home Depot		.6	10	6.00
Nut	M5 Nut	9120324		Home Depot		0.18	25	4.48
Nut	M2.5 Nut (x100)	90592A006		McMaster		1.18	8	1.18
Breakout Board	Adafruit HUZZAH32 - ESP32			Digikey	1528-2514-ND	20.95	1	20.95