Automatic Solder Paste Dispenser for Prototype Printed Circuit Boards

Group 4 CDR Presentation 2025

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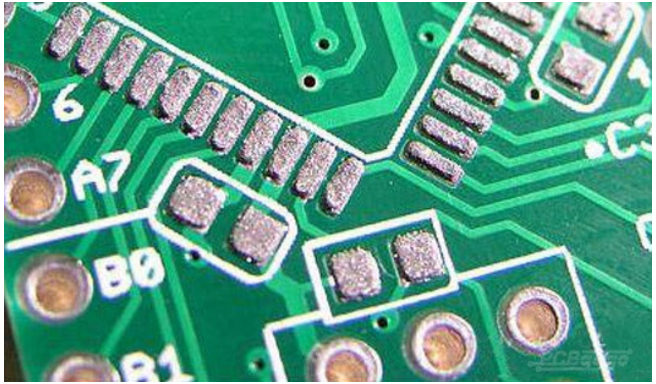
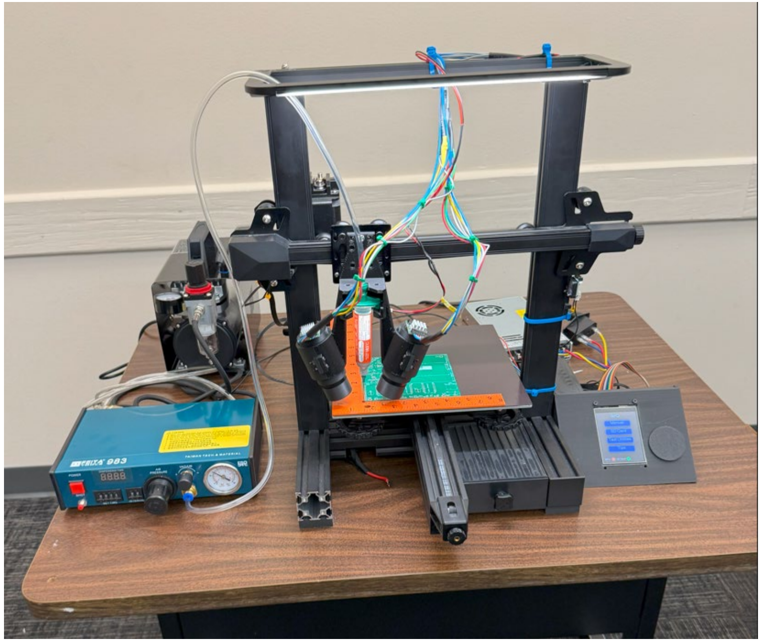
Motivation and Background

- Help automate the PCB fabrication process
- Alternative to hand solder/laying out paste
- Saves time for students
- Uses the shell of an old Ender 3
- Stereolithography for quality control
- Sponsored by Dr. Weeks



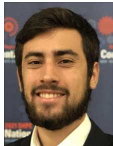


Goals and Objectives

Basic Goals:
- Create a solder paste dispenser utilizing the Creality Ender 3
- Implement a schematic/Gerber file upload system
- Determine user's PCB placement
- Dispense proper amount of solder based on required SMD size
- Achieve SMD package size of 0603(imperial)/1608(metric)
- Design optical inspection system for stereo vision and magnification
- Program Touchscreen display

Advanced Goals:
- Achieve SMD package sizes 0402(imperial)/1005(metric)
- Optimize dispensing time on the max supported PCB size
- Develop image processing software that exports a metric 3D reconstruction of PCB to measure heights.

Stretch Goals:
- Achieve SMD package sizes 0201(imperial)/0603(metric) or less
- Implement a pick-and-place system
- Determine origin point of more uniquely shaped PCBs
- Establish Wi-Fi/Bluetooth modules for schematic upload option and 3D model exports



Goals and Objectives

Objectives to achieve Basic Goals:
- Design custom main PCB, stepper motor driver PCB, power regulator PCB
- Implement schematic file upload system using external USB port and/or SD card reader
- Locate user’s PCB placement using L-bracket and stereoscopy system
- Dispense solder paste at SMD package size 0603(imperial) / 1608(metric) (test)
- Display all information on touchscreen display

Objectives to achieve Advanced Goals:
- Dispense solder paste at SMD package size 0402(imperial) / 1005(metric) (test)
- Test/optimize dispensing time for prototype PCBs within our maximum supported size
- Generate/export 3D reconstruction of dispensed solder dots using OpenCV

Objectives to achieve Stretch Goals:
- Dispense solder paste at SMD package size 0201(imperial) / 0603(metric) or less
- Implement pick and place system utilizing pneumatic pump
- Expand stereoscopy system to determine origin points of differently shaped PCBs
- Implement Wi-Fi module/Bluetooth support for schematic upload

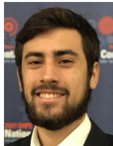


Table of Engineering Specifications

Board Handling	
* àüễ úî ñàỗã 0ể å Ńi̧ü ŷő	8” x 8” / (203.2mm x 203.2mm)
* ễï ễ úî ñàỗã 0ể å Ńi̧ü ŷő	1” x 1” / (25.4mm x 25.4mm)
Board Securing Method	Rubber mat
Touchscreen	
Touchscreen Reactiveness	Registers 95% of light touches
Facilities	
Power Requirements	120VAC
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Table of Engineering Specifications

Print Parameters	
* àüẽ úî - ôẽi õ ôåà Ńi̦ü ŷő	200 mm x 200 mm
Solder Dispensing Resolution	0.2 mm
Minimum Surface Mount Size Supported	0603 (imperial) 1608 (metric)
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Motor Precision (Percent Error)	5% Margin of Error

Table of Engineering Specifications

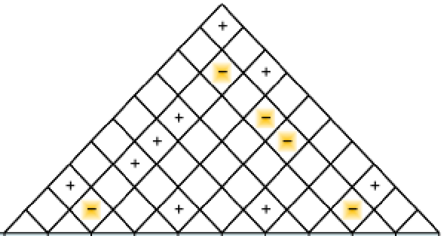
Optical System	
Image Area	5 mm x 5 mm (7.07 mm diagonal length)
Effective Magnification (Optical x Digital)	>18x
Minimum Surface Mount Size for Imaging	0603 (imperial) 1608 (metric)
Stereoscopic Height Resolution	10 µm
Minimum Depth of Field	1 mm
Minimum Resolution	25 µm
Length	<300 mm

House of Quality

Correlations	
Positive	+
Negative	−
No Correlation	

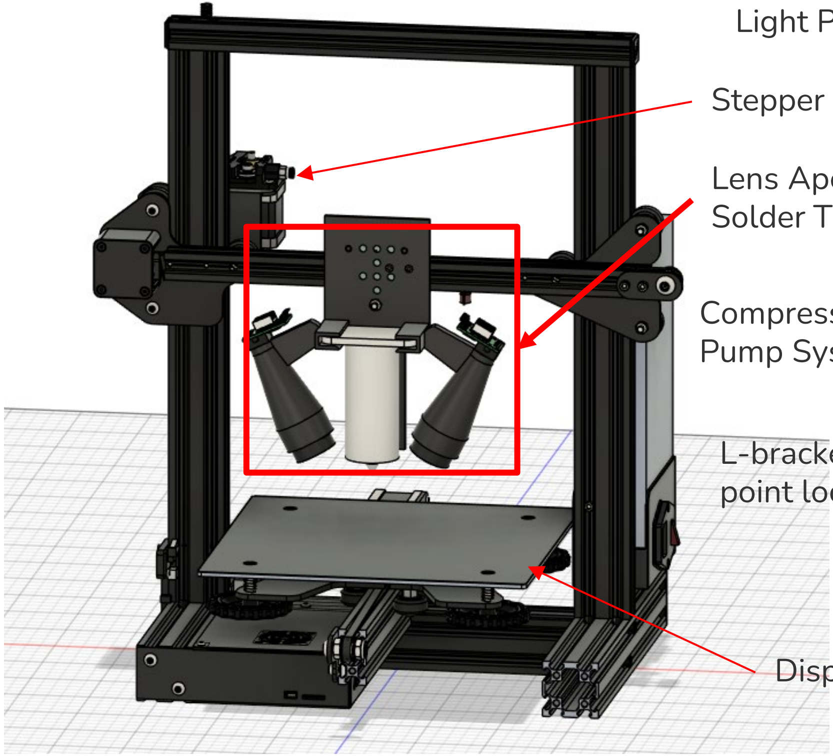
Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼



Direction	Column #	1	2	3	4	5	6	7	8	9	10
	Direction of Improvement	▲	▼	▲	▲	▼	▼	▼	▲	▼	▼
Direction	Customer Requirements (Explicit and Implicit) / Engineering Requirements	Power Consumption	Motor Precision	Motor Power Efficiency	Optical Target Magnification	Stereoscopic Height Resolution	Solder Paste Ball Size	SMD Package Size	Touch Screen Reactiveness	Cost	Minimimum Idle Time
▲	Affordability	○	●		●	●	○	●	●	●	○
▲	Reliability	○	○	●			○	○	○		●
▲	Ease of Use	○		○				○	○		●
▲	Time Efficient		●		○	○	○	●	●	●	○
▲	Safe	●		●						●	
▲	Easy Verification				●	●			●	●	
▲	Low Noise	○	○	●						●	○
	Target	120V @60Hz	0.1mm Precision	80% Power Effeciency	10x Magnification	0.1mmHeight Resolution	0.2mm Ball Size	0603 (Imperial) / 1608 (metric)	Register 95% of light touches	$1,000 for Production Unit	24 Hours

System Overview



Light Panel

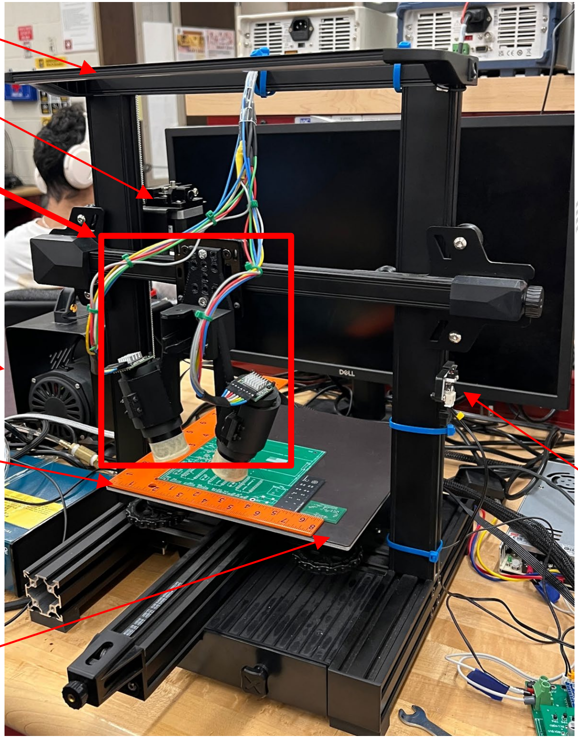
Stepper Motors

Lens Aperture and
Solder Tube Holder

Compressor/Pneumatic
Pump System

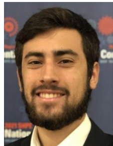
L-bracket for origin
point location

Dispensing Bed



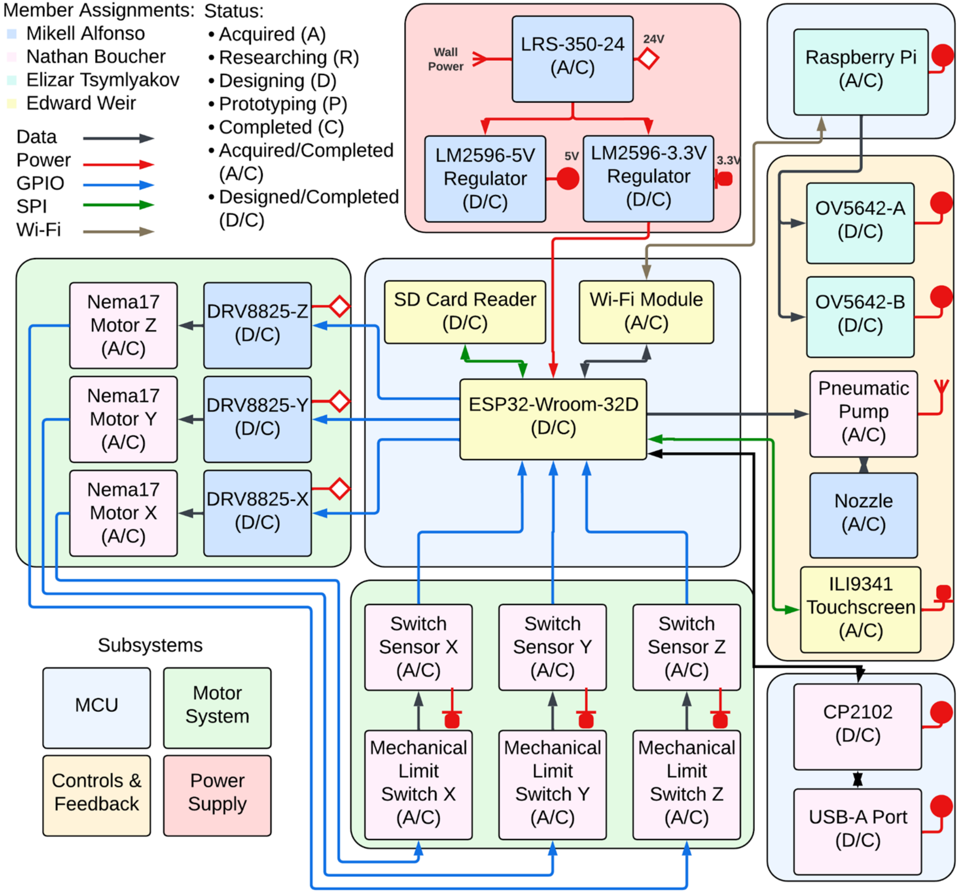
Limit
switch

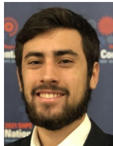
Machine Dimensions: 45cm x 45cm x 50 cm (l x w x h)



Hardware Block Diagram

- 24V Source = LRS-350-24
- 5V Regulator = LM2596-5V
- 3.3V Regulator = LM2596-3.3V
- Microcontroller = ESP32-Wroom-32D
- Wi-Fi Module = Built-in Wi-Fi antenna to ESP32
- SD Card Reader = TF-01A microSD Card Reader
- Motor Driver = DRV8825
- Stepper Motor = NEMA17
- Mechanical Limit Switch/Switch Sensor = Creality Endstop Limit Switch
- Website Host Microcontroller = Raspberry Pi
- Camera = OV5642
- Pneumatic Pump = Feita 983
- Nozzle = >Metal Needle Nozzle
- Touchscreen Display = ILI9341
- USB-UART Bridge = CP2102
- USB Port = 1932258-1 USB-A Port





Hardware Selection: MicroController Selection

	ESP32-WROOM-MD	MSP430F6459	RP2530B
Cores	2	1	2
CPU Frequency	80MHz-240MHz	20MHz	150MHz
Wi-Fi Support (Natively)	Yes	No	No
Bluetooth Support (Natively)	Yes	No	No
RAM	448kb ROM, 520 kb of SRAM	512kb non-Volatile, 66kb RAM	520kb of SRAM
Supports External Memory	Yes	No	Yes
GPIO Pins	38	74	48

ESP32 was selected because...

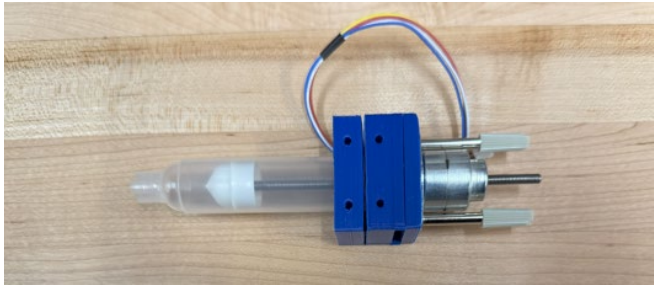
Hardware Selection: Touch Screen

	ST7789	ST7735R	HX8357	ILI9488	ILI9341
Interface	SPI	SPI	SPI	SPI	SPI
Pixel Resolution (pixels x pixels)	240 x 320	128 x 160	320 x 480	320 x 480	240 x 320
Color Depth (bits)	18	18	18	16	16
Screen Size (inches)	2	1.8	3.5	3.5	3.2
microSD Card Reader	Yes	Yes	Yes	No	No
SD Card Reader	No	No	No	Yes	Yes

- ILI9341 chosen for mainly for comm protocol of SPI, decent color depth, and just right size of 3.2 inches

Hardware Selection: Dispensing Methods

	Pneumatic Dispenser:	Stepper Motor Driven Screw Dispenser:
Precision	High	High
Speed	Fast	Moderate
Calibration needed	Minimal	Maximul
Cost	Moderate	Moderate



Hardware Selection: Stepper Motor Drivers

	A4988	DRV8825	TMC2225
MicroStepping Resolution	1/16	1/32	1/256
GPIO Pins Required (Minimum Configuration)	2 (Step +Dir)	2 (Step +Dir)	2 (Step +Dir)
Voltage Input (VMOT)	8V-35V	8.2V-45V	4.75V-36V
Logic Voltage Level (High)	3V-5.5V	2.2V-5.25V	3.3V-5V
Max Current (Per Coil)	2A	2.2A	2A
Price Per Unit (Per IC not the board itself)	$4.25	$5.73	$5.61

Hardware Selection: CMOS Sensor

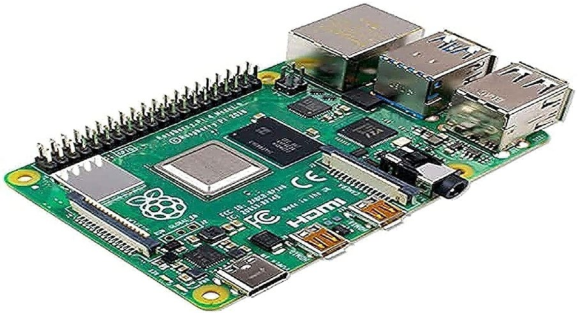
	Arducam OV2640	Arducam IMX 230	Arducam OV5642
Price	$10-$15	$80-$90	$40
Sensor size (pixels)	1600 x 1200 (2 MP)	5472 x 3648 (21 MP)	2592x1944 (5 MP)
Pixel Size	1.75 µm x 1.75 µm	1.12 µm (w) x 1.12 µm (h)	1.4 µm x 1.4 µm
Sensor size (mm)	4.6 mm x 3.4 mm	7.216 mm x 5.497 mm	3.67 mm x 2.73 mm
Diagonal Length	4.5 mm	7.487 mm	4.57 mm
Dynamic Range	50 dB	“High”	68 dB
SNR	40 dB	“High”	36 dB
Power Supply	2.5~3.0V	3.3V DC	5V/390mA
Interface	CSI-2	CSI-2	SPI

Hardware Selection: Lens

	Thorlabs LB1378-ML	Thorlabs TRH-040-A-ML	Thorlabs TRS-040-A-ML
Price	$52.28	$111.38	$117.31
Working Distance	40 mm	68.2 mm	68.2 mm
Focal Length	40 mm	40 mm	40 mm
Diameter	12.7 mm	25.4 mm	25.4 mm
Type	Singlet	Hastings Triplet	Steinheil Triplet

Hardware SubSystem: Raspberry Pi (4)

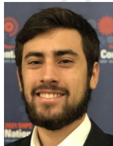
- Hosts the Web Server (including local MongoDB)
- Utilizes the two cameras to take pictures
- Runs the python Code for the stereoscopy system
- UI for users to upload Gerber Files, as well as download their images
- Communicates with the ESP-32 in order to POST Gerber-Files, as well as receive a request to take a picture



Power Distribution Table

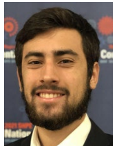
	ESP32	ILI9341	CP2102	OV5642 A	OV5642 B	DRV8825 X	DRV8825 Y	DRV8825 Z	Total
Expected Supply Voltage	3.3V	3.3V	3.3V	5V	5V	24V	24V	24V	24V
Expected Supply Current	<300mA	<50mA	26mA	390mA	390mA	2.5A	2.5A	2.5A	8.656A
Expected Power Consumption	0.99W	0.165 W	0.0858 W	1.95W	1.95W	60W	60W	60W	185.14W

*Raspberry Pi 4 powered externally due to Wi-Fi Connectivity

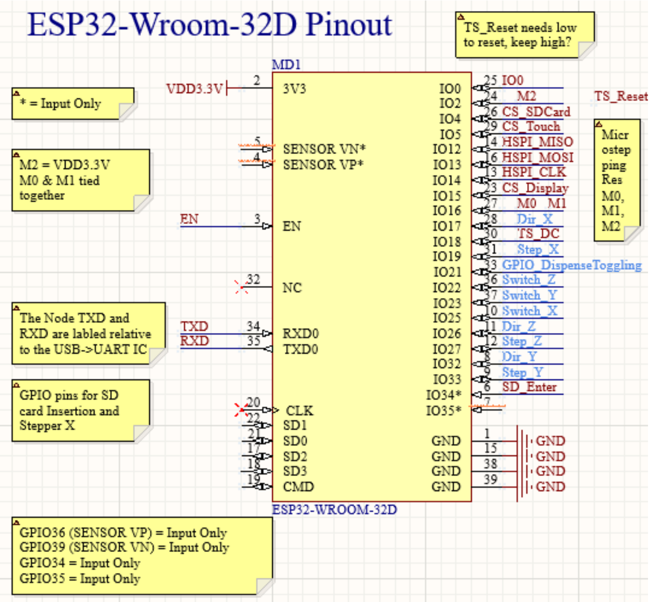


Hardware Selection: Power Supply Unit

	CMS350-24	LRS-350-24	S35024	UHP-350-24	PMT-24V350W1AK	WMA350H-24	233-6892
Manufacturer	Creality	Mean Well	Mean Well	Mean Well	Delta	Cosel	RSPRO
Output	24V, 14.6A	24V, 14.6A	24V, 14.6A	24V, 14.6A	24V, 14.6A	24V, 14.6A	24V, 14.6A
Efficiency	NA	88%	81%	94%	87%	87%	93%
MTBF	NA	328.6K hrs (25℃)	234.3Khrs (25℃)	285Khrs (25℃)	700Khrs (35℃)	NA	>300Khrs (25℃)
Protections	SC, OV, OL, OT	OL, OV, OT	OL, OV	OL, OV, OT	OV, OL, OT, SC	OC, OV	OV, OC, SC
Dimensions (mm)	215x115x30	215x115x30	215x115x50	220x62x31	215x115x50	115x30x215	130x86x35
Cost	$31.67 (Creality)	$38.11 (DigiKey)	Obsolete	$69.31 (MeanWell)	$74.98 (DigiKey)	$75.88 (DigiKey)	$133.84 (eezee)

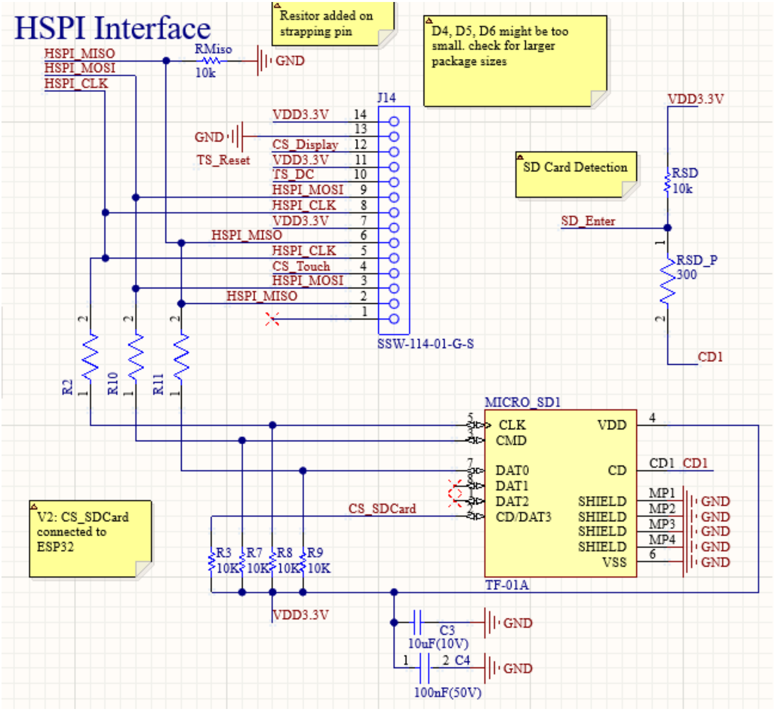


Hardware Design: ESP32-WROOM-32D



- Flashing VIA a CP2102 USB -> UART Circuit
- Main Driver of the SPD
- Built in PCB Antenna for 2.4GHz
- Powered by 3.3V from the Regulator Circuit
- Responsible for Controlling:
    - Stepper Motor Drivers
        - Step + Dir
        - Microstepping Resolution
    - Mechanical Switches
    - TouchScreen
    - MicroSD Card
    - SSR hooked up to the Pneumatic Device
- Interfaces VIA Wi-Fi to the Web Server

Hardware Design: SPI Interface

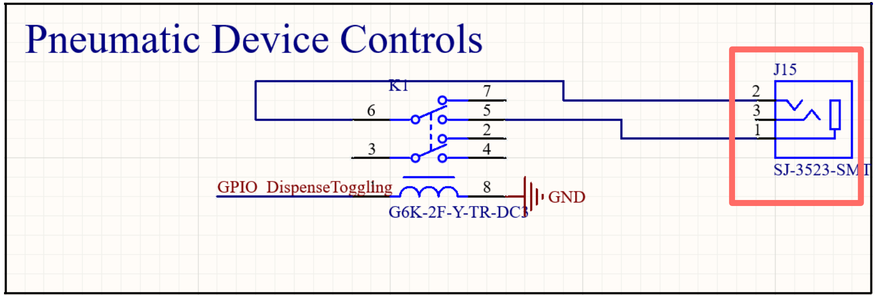


- Three Slaves:
  - MicroSD Card
  - TouchScreen Display
  - TouchScreen Touch
- Header pins to connect to the touch screen
- Pull-up resistors and bypass capacitors for the MicroSD Card
- Utilizing Chip Detect on the SD Card to determine when it is removed, re-initializes the SD card every time it is plugged back in
- 0 Ohm resistors for potential impedance matching

Hardware Design: Dispensing System

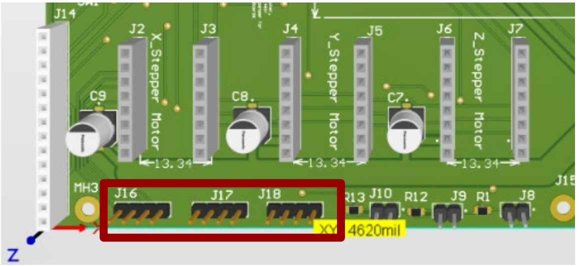
- Feita 983
- Solid-State Relay (SSR) controlled by GPIO pin
- Shorts pins 1 and 2 on the 3.5mm headphone jack to dispense
- Continuously dispenses while 3.5mm jack is shorted

3.5mm
Headphone Jack

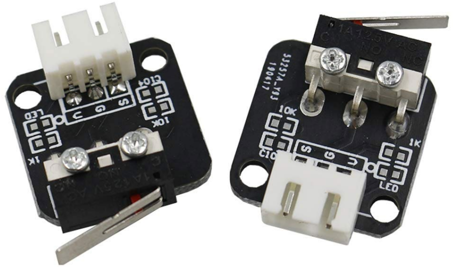


Hardware Design: Stepper Motors

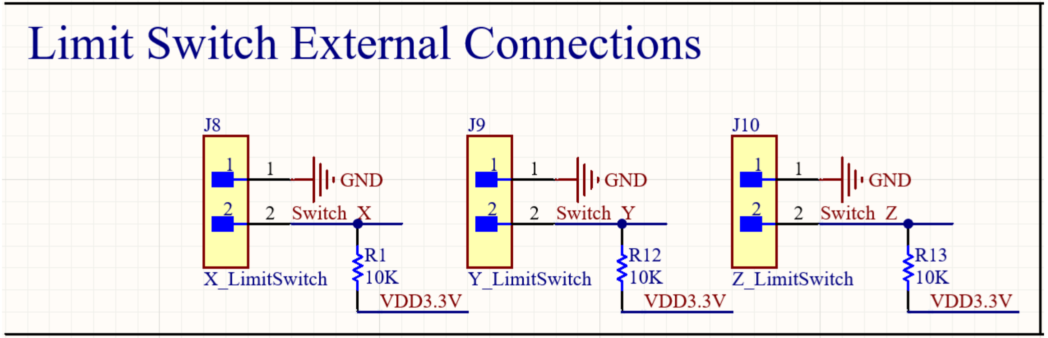
- Three NEMA 17 Motors
  - X-Axis
  - Y-Axis
  - Z-Axis
- Creality 42-34s
- Powered and controlled by the custom DRV8825
- 1.5Amps Per Phase
- 1.8* step resolution
- 2 GPIO pins required per AXIS
- External header-pins to wire the motors.
- Utilizing 1/32nd Microstepping



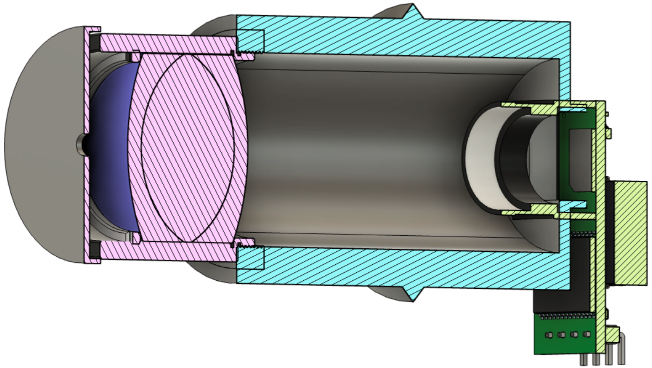
Hardware Design: Mechanical Switches

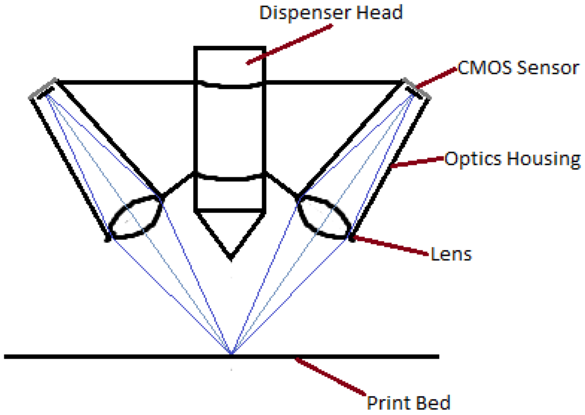


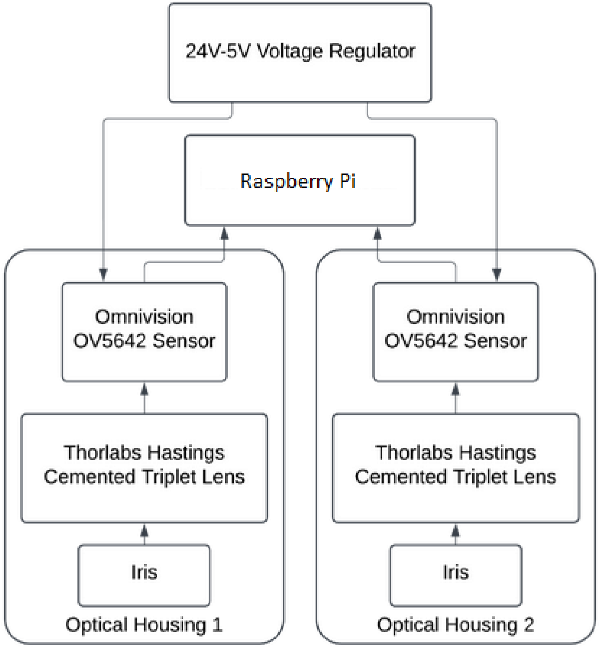
- Creality Mechanical Switches
- Three Axis:
  - X-Axis
  - Y-Axis
  - Z-Axis
- Initial Calibration Required
- Pull-up Resistors
- Logic-Low
- Connected with a set of Header Pins
- 3D printed holder for Z-limit Switch



Hardware Design: Optical Stereo System







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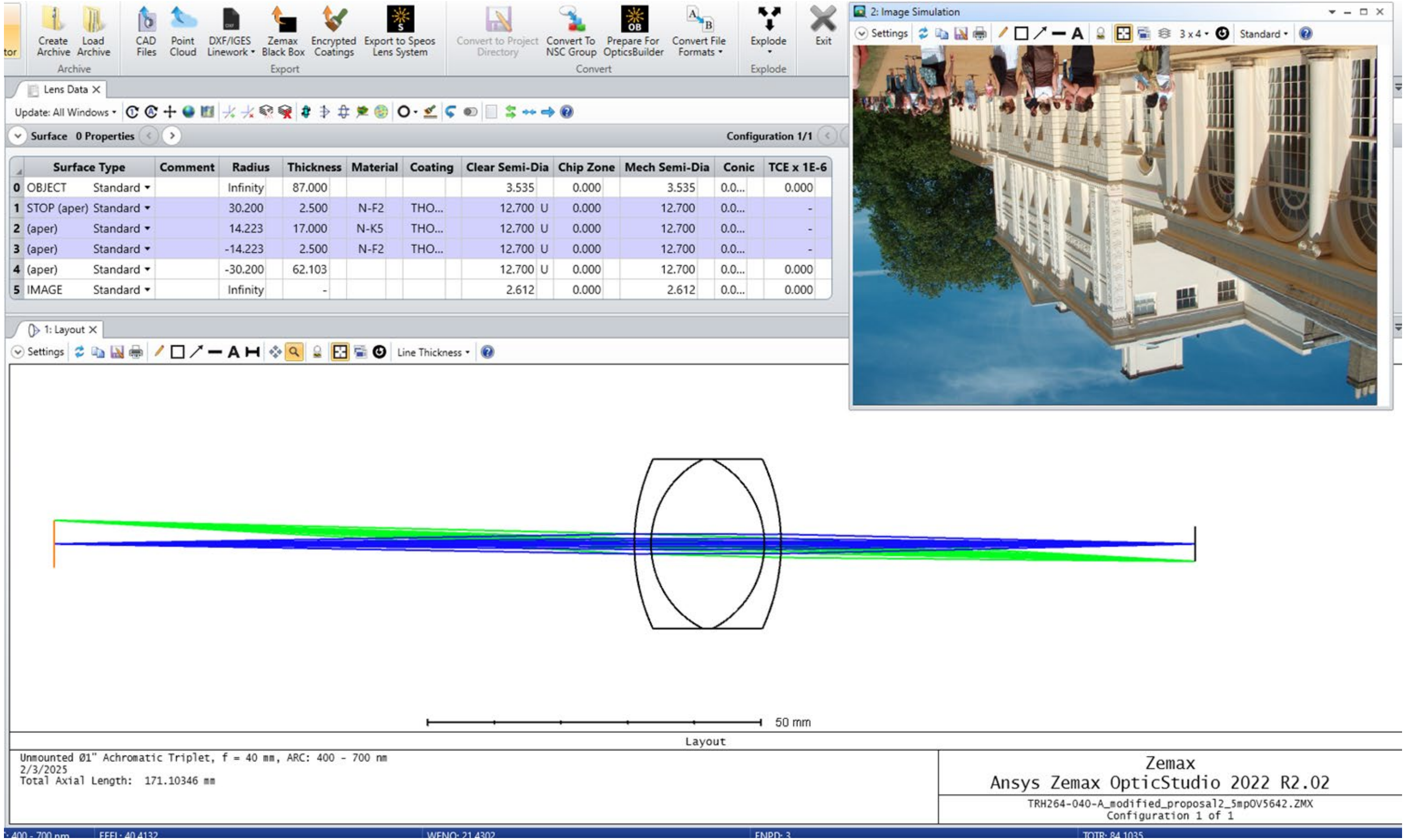


Hardware Design: Optical Stereo System

Optical Magnification

$$M_{optical} = \frac{sensor\ diameter}{image\ diameter} = \frac{4.57\ mm}{7.07\ mm} = 0.646 \qquad M_{optical} = \frac{z\prime}{z} = \frac{62.1\ mm}{87\ mm} = 0.646$$

Total Magnification

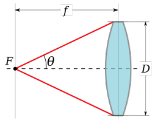
$$M_{Total} = \frac{feature\ length\ in\ image}{feature\ length\ in\ object} = \frac{125\ mm}{5\ mm} = 25$$

System Length

$$62.1\ mm + 87\ mm\ + 22\ mm\ = 171.1\ mm$$

Numerical Aperture

$$NA = \frac{D}{2 \times f} = \frac{3\ mm}{2 \times 40\ mm} = 0.0375$$



Minimum Achievable Resolution

$$Resolution = \frac{0.61 \times\ \lambda}{NA} = \frac{0.61 \times 750 \times 10^{-9}\ m}{0.0375} = 12.2\ \mu m$$

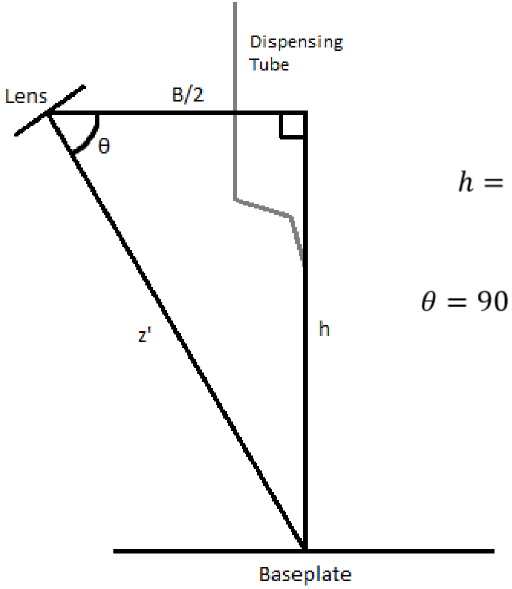
Depth of Field

$$DoF = \frac{2 \times z'^2 \times \frac{f}{D} \times c}{f^2} = \frac{2 \times 87^2 \times \frac{40}{3} \times 0.01}{40^2} = 1.262\ mm$$

Hardware Design: Optical Stereo System

Engineering Requirement	Chosen Specification	Calculated Specification	Comparison
Optical Configuration Length	<300 mm	171.1 mm	Achieved
Numerical Aperture	>0.0183	0.0375	Achieved
Minimum Feature Size	25 µm	12.2 µm	Achieved
Total Magnification	>18x	25x	Achieved
Dynamic Range	>40 dB	63.3 dB	Achieved
Depth of Field	>1.0 mm	1.26 mm	Achieved

Hardware Design: Optical Stereo System



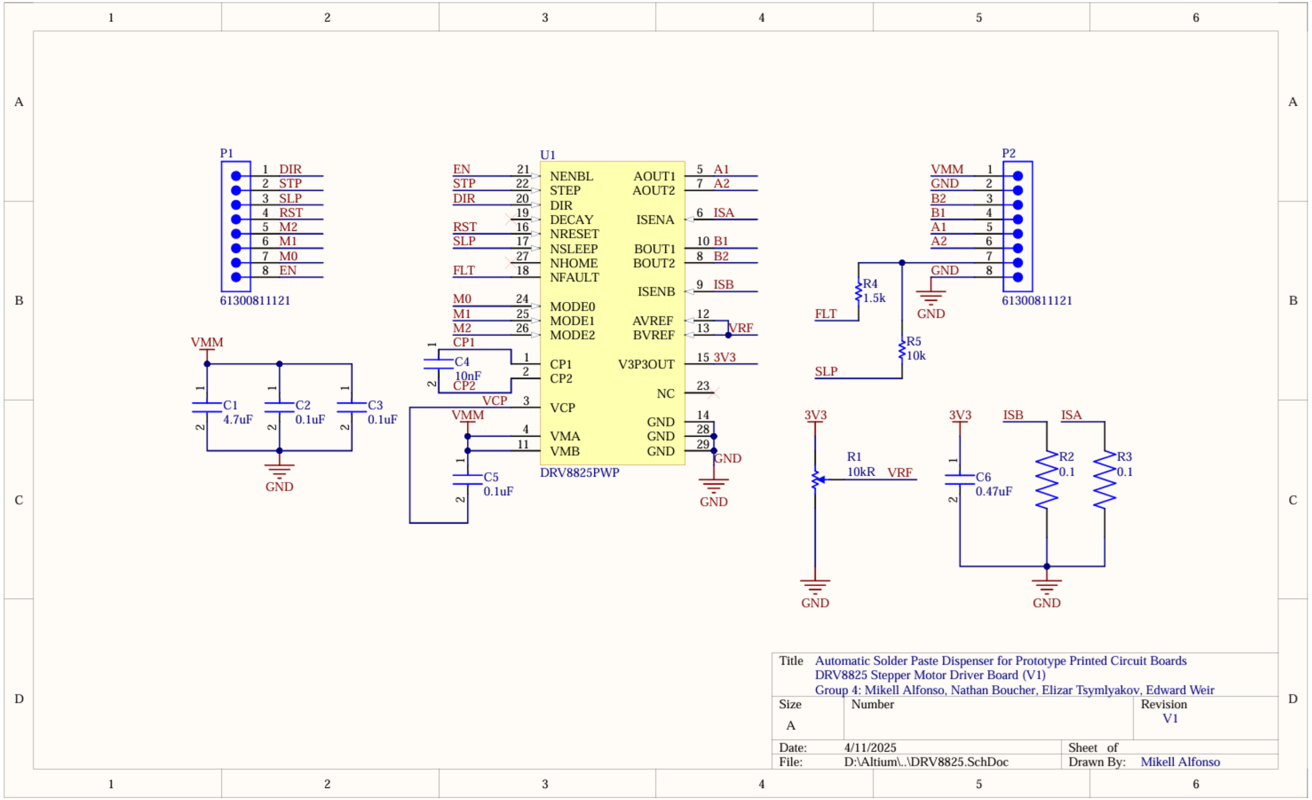
$$h = \sqrt{z'^2 - \frac{B^2}{2}}$$

$$\theta = 90 - \sin^{-1}\frac{B/2}{z'}$$

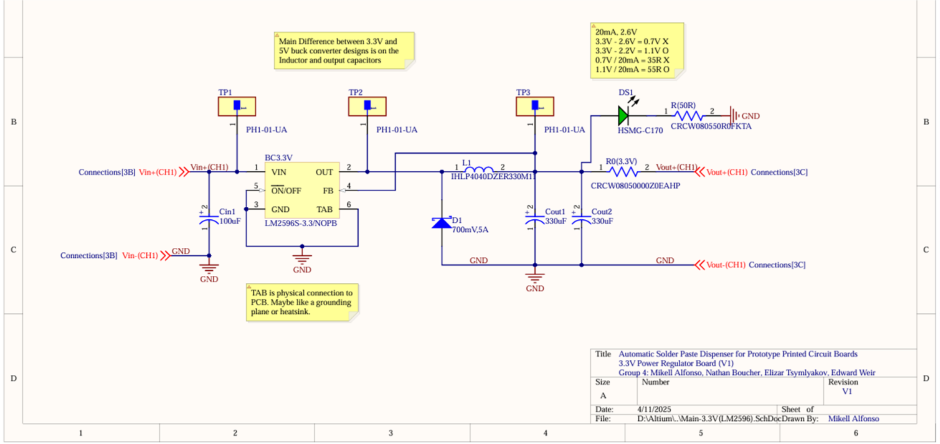
- Increasing baseline (B), increases camera angle. This increases the difficulty of matching pixels for stereo.
- Optimal camera angle (θ) 60°-80° (1)
- Minimum baseline possible depends on the width of the dispensing tube.
- If z' = 87 mm and we want the optimal camera angle, the baseline length must be be 30 - 87 mm.

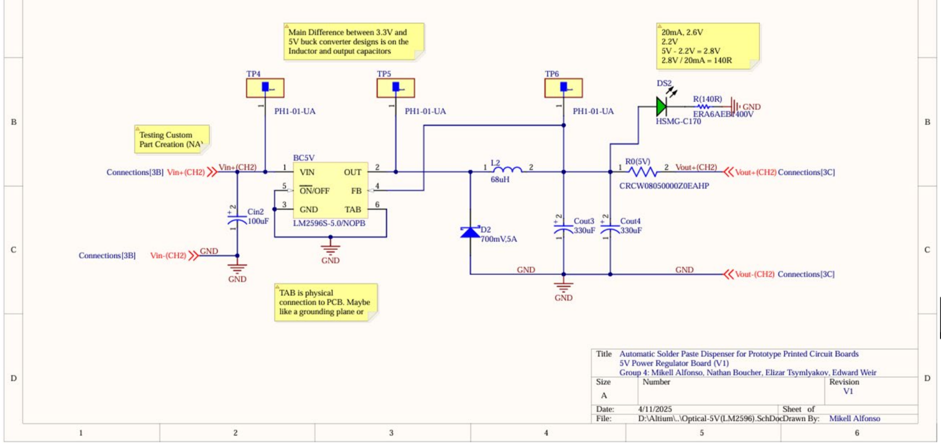
(1) X. Liu, W. Chen, H. Madhusudanan, L. Du and Y. Sun, "Camera Orientation Optimization in Stereo Vision Systems for Low Measurement Error," in IEEE/ASME Transactions on Mechatronics, vol. 26, no. 2, pp. 1178-1182, April 2021, doi: 10.1109/TMECH.2020.3019305.

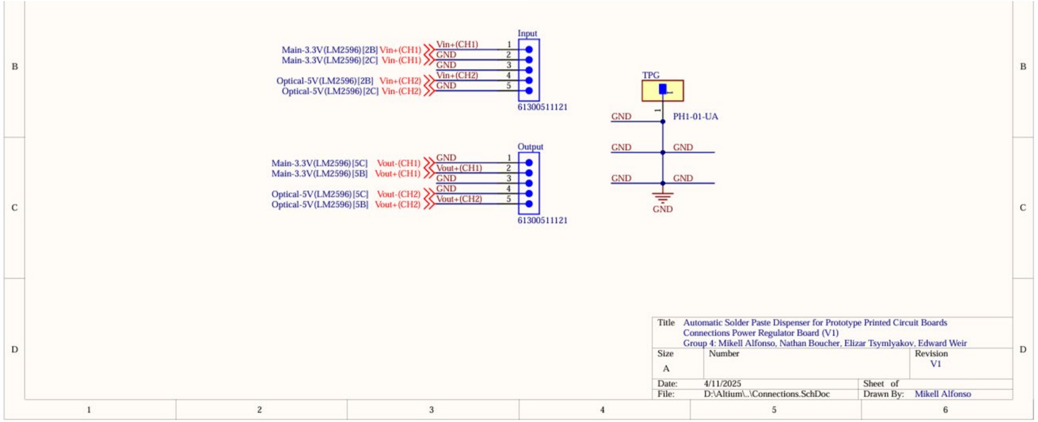
Hardware Design: Motor Driver Schematic

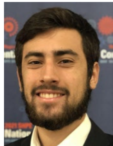


Hardware Design: Power Regulator Schematic

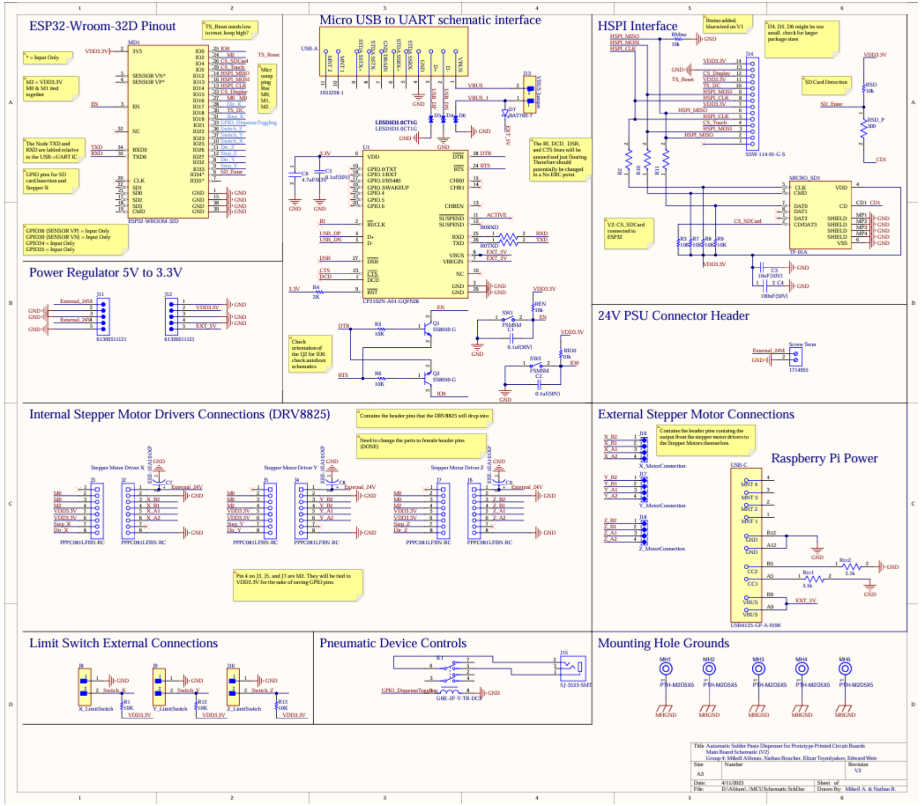


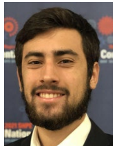






Hardware Design: Main Board Schematic V2

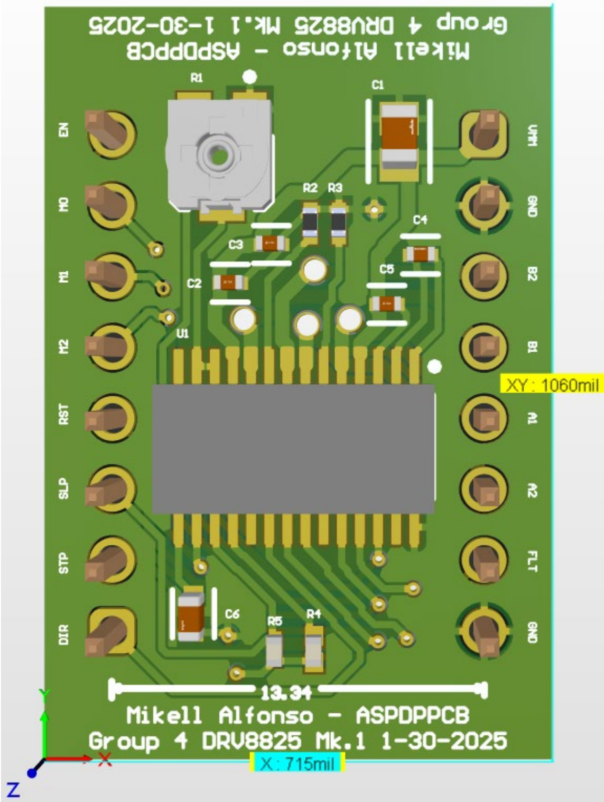


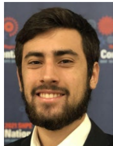


Hardware Design: Motor Driver PCB

- Two Layers (Signals)
- GND Copper Pour (0.468 in² Top Layer and 0.546 in² Bottom Layer)
- Matched pin layout and distance between header pins of DRV8825 modules purchasable online
- Three duplicates of these will be used

#	Name	Material	Type	Weight	Thickness
	Top Overlay		Overlay		
	Top Solder	Solder Resist	Solder Mask		0.4mil
1	Top Layer		Signal	1oz	1.4mil
	Dielectric 1	FR-4	Dielectric		12.6mil
2	Bottom Layer		Signal	1oz	1.4mil
	Bottom Solder	Solder Resist	Solder Mask		0.4mil
	Bottom Overlay		Overlay		



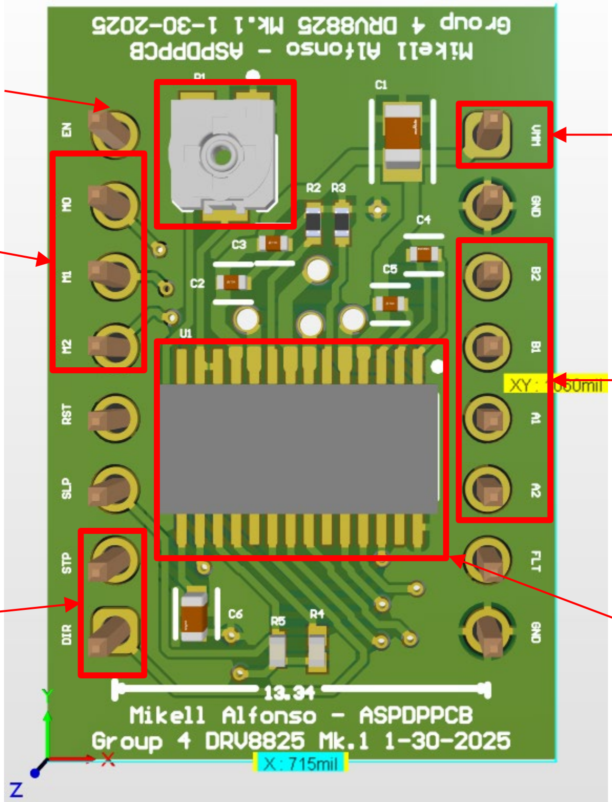


Hardware Design: Motor Driver PCB

Current Limiting Potentiometer

Step Precision Pins

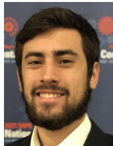
Direction
& Step



Power

Coil Connections

DRV8825 IC



Hardware Design: Power Regulator PCB

- Two Layers (Signals)
- GND Copper Pour (6.296 in² Top Layer and 7.046 in² Bottom Layer)
- LM2596-3.3V and LM2596-5V Fixed Output Versions
- Inductor values from datasheet
- DS1 and DS2 are LEDs
- R0 are zero ohm resistors
- Test Points

#	Name	Material	Type	Weight	Thickness
	Top Overlay		Overlay		
	Top Solder	Solder Resist	Solder Mask		0.4mil
1	Top Layer		Signal	1oz	1.4mil
	Dielectric 1	FR-4	Prepreg		12.6mil
2	Bottom Layer		Signal	1oz	1.4mil
	Bottom Solder	Solder Resist	Solder Mask		0.4mil
	Bottom Overlay		Overlay		

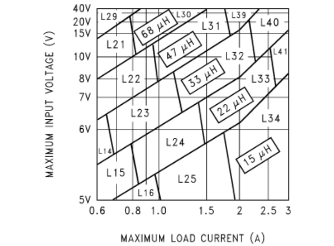


Figure 9-5. LM2596-3.3

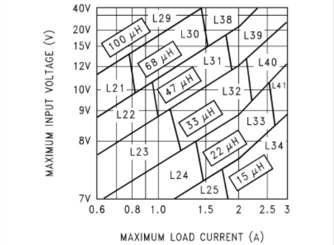
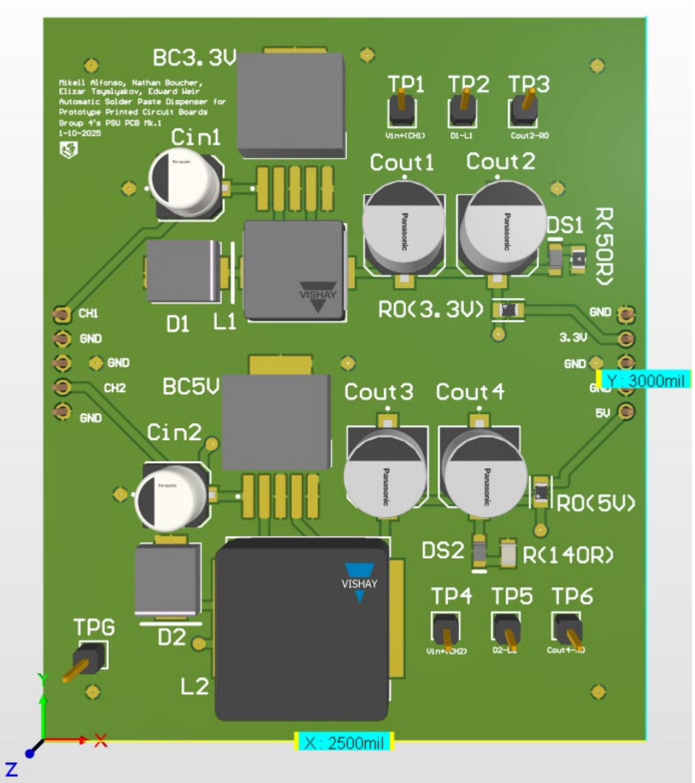
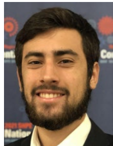


Figure 9-6. LM2596-5.0





Hardware Design: Power Regulator PCB

LM2596-3.3V Regulator

Input Bypass Capacitor

Catch Diode

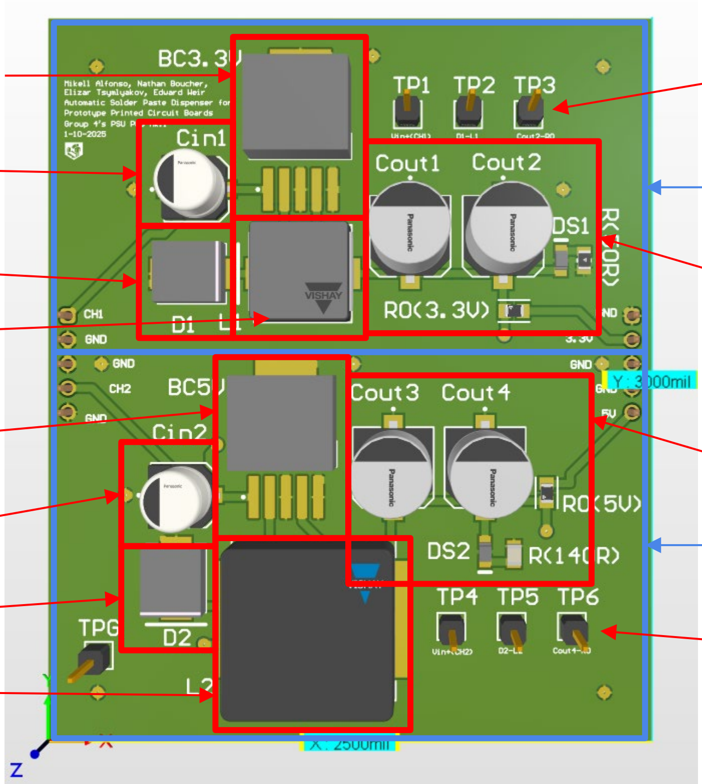
33 uH Inductor

LM2596-5V Regulator

Input Bypass Capacitor

Catch Diode

68 uH Inductor



Test Points

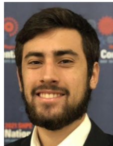
3.3V Regulator Side

Output Capacitors & LED

Output Capacitors & LED

5V Regulator Side

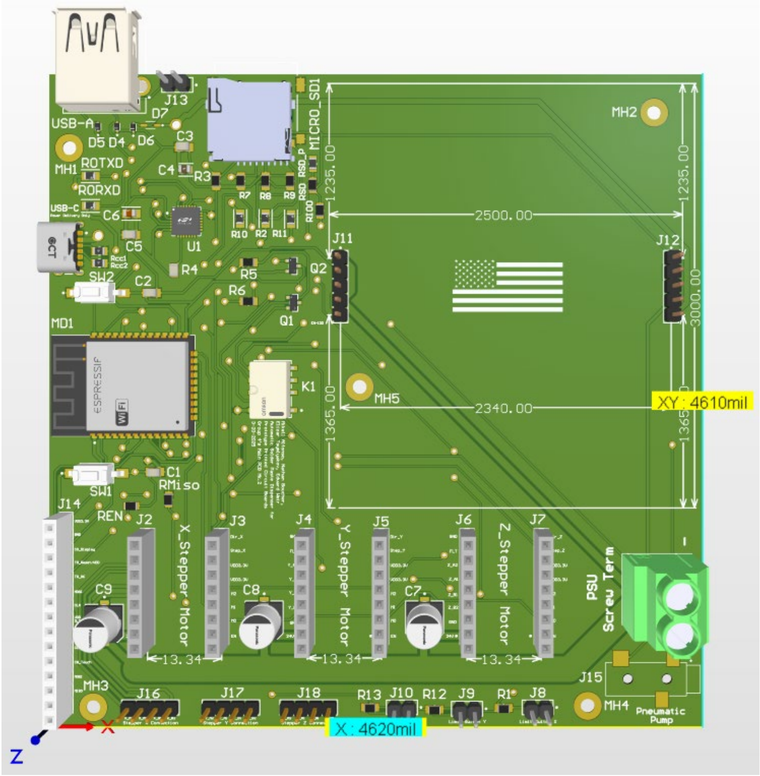
Test Points

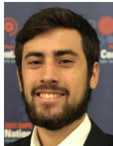


Hardware Design: Main PCB V2

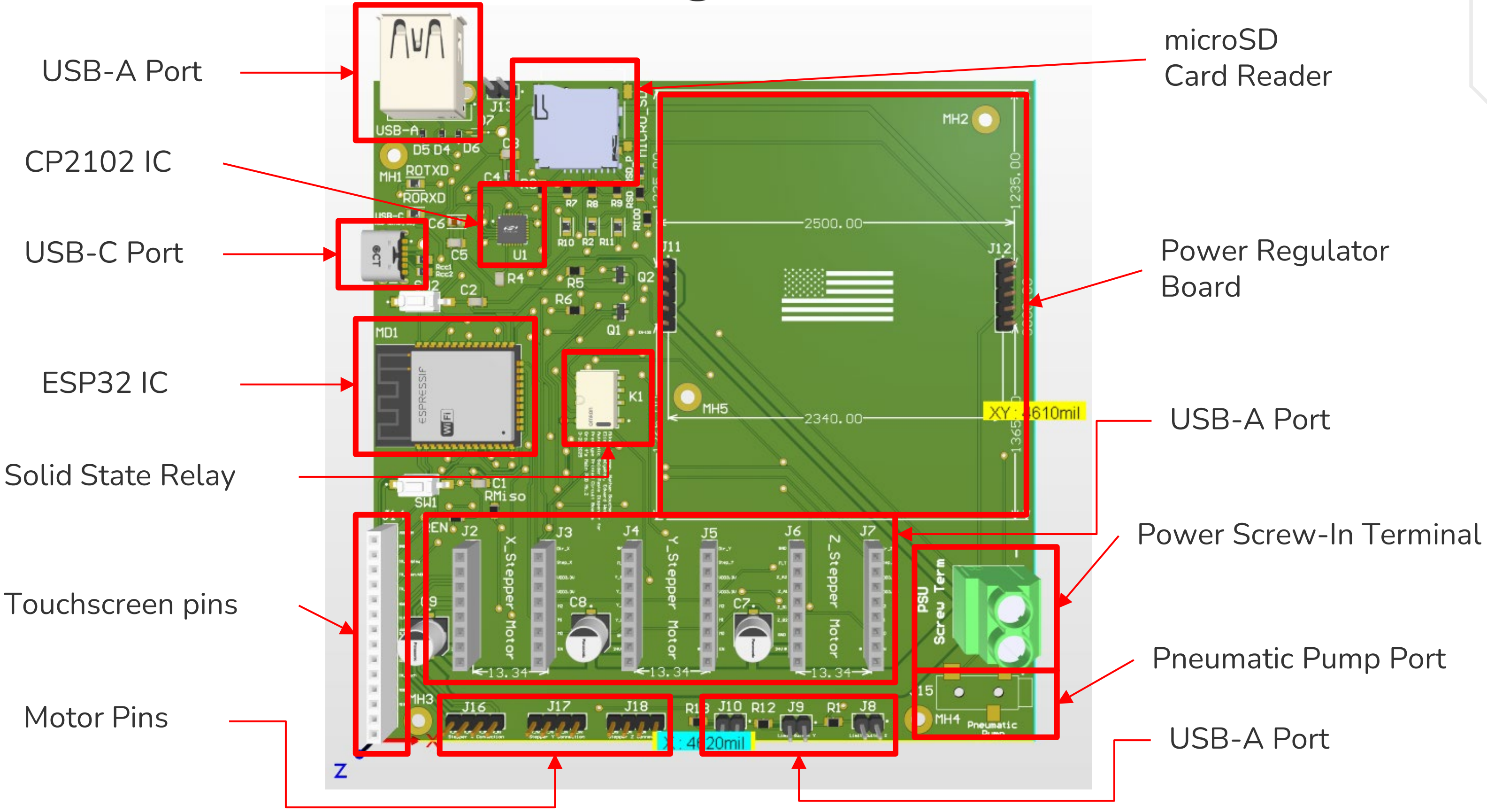
- Two Layers (Signals)
- GND Copper Pour (16.34 in² Top Layer and 18.652 in² Bottom Layer)
- USB-A Port
- microSD Card Reader
- CP2102 USB-to-UART Bridge
- ESP32-Wroom-32D
- Solid State Relay (K1 - Pneumatic Pump)
- ILI9341 Display Female Header Pins (J14)
- DRV8825 Motor Driver Header Pins (J2-J7)
- Stepper Motor Connections (J16-J18)
- Limit Switches (J8-J10)
- Auxiliary Port (J15 - Pneumatic Pump)
- Screw Terminal for power from PSU
- Male Header Pins for Regulator PCB

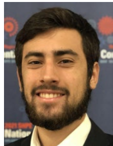
#	Name	Material	Type	Weight	Thickness
	Top Overlay		Overlay		
	Top Solder	Solder Resist	Solder Mask		0.4mil
1	Top Layer		Signal	1oz	1.4mil
	Dielectric 1	FR-4	Dielectric		12.6mil
2	Bottom Layer		Signal	1oz	1.4mil
	Bottom Solder	Solder Resist	Solder Mask		0.4mil
	Bottom Overlay		Overlay		





Hardware Design: Main PCB V2





Hardware Testing: Regulator PCB

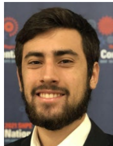
	Input Voltage	Input Current	Input Power	Output Voltage	Output Current	Output Power	ΔPower	Operating Temp	Efficiency
3.3V Regulator	24V	0.1984A	4.7612W	3.2540V	0.9960A	3.2410W	1.5202W	~45.61℃	68.07%
5V Regulator	24V	0.2807A	6.7366W	4.9950V	0.9960A	4.9750W	1.7616W	~52.85℃	73.85%

7.4 Thermal Information

THERMAL METRIC(1)			LM2596		UNIT
			KTW (TO-263)	NDZ (TO-220)	
			5 PINS	5 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance(2) (3)	See(4)	—	50	°C/W
		See(5)	50	—	
		See(6)	30	—	
		See(7)	20	—	

(6) Junction to ambient thermal resistance with the TO-263 package tab soldered to a single sided printed circuit board with 2.5 in^2 of 1-oz copper area.

(7) Junction to ambient thermal resistance with the TO-263 package tab soldered to a double sided printed circuit board with 3 in^2 of 1-oz copper area on the LM2596S side of the board, and approximately 16 in^2 of copper on the other side of the PCB.

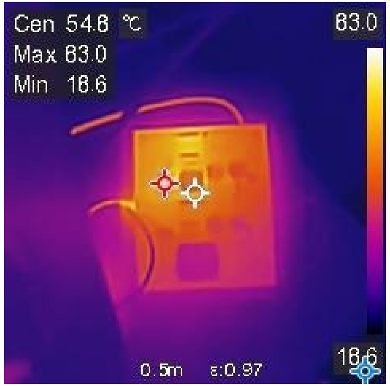


Hardware Testing: Regulator PCB

3.3V Regulator

Electronic Load: CC 2.5A

3.3V Regulator @ 69.8°C.
To: -40°C ≤ Tj ≤ 150°C.

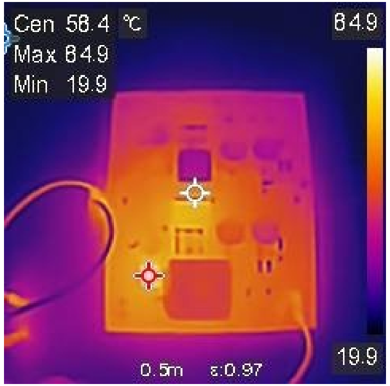


3.3V Diode @ 83.0°C.
To: -55°C ≤ Tj ≤ 150°C

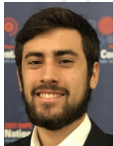
5V Regulator

Electronic Load: CC 2.5A

5V Regulator @ 71.0°C.
To: -40°C ≤ Tj ≤ 150°C.



5V Diode @ 84.9°C.
To: -55°C ≤ Tj ≤ 150°C



PCB Problems with Solutions

Motor PCB

Problems:
- High Frequency Noise
- Jittery movement
- IC Frying

Solutions:
- Impedance matching & trace lengths for V2
- Calibration
- Replace IC

Regulator PCB

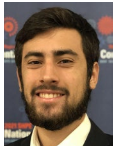
Problems:
- LED Burning (shorted with DMM)
- Hot temperatures past 2.5A

Solutions:
- Replace LED
- 2.5A surpasses power consumption

Main PCB V1

Problems:
- Driver pins connected to input only pins on ESP32 (blue wire)
- Impedance matching resistors missing (blue wire)

Solutions:
- Blue wired for V1, Retraced for V2
- Blue wired for V1, added resistors for V2
- Introduced SD card sensing
- Introduced USB-C for power delivery



COMM PROTOCOL

SPI

- ESP32 to Touch Screen
    - Display
    - Touch
- ESP32 to SD Card Reader
- Cameras to Raspberry Pi

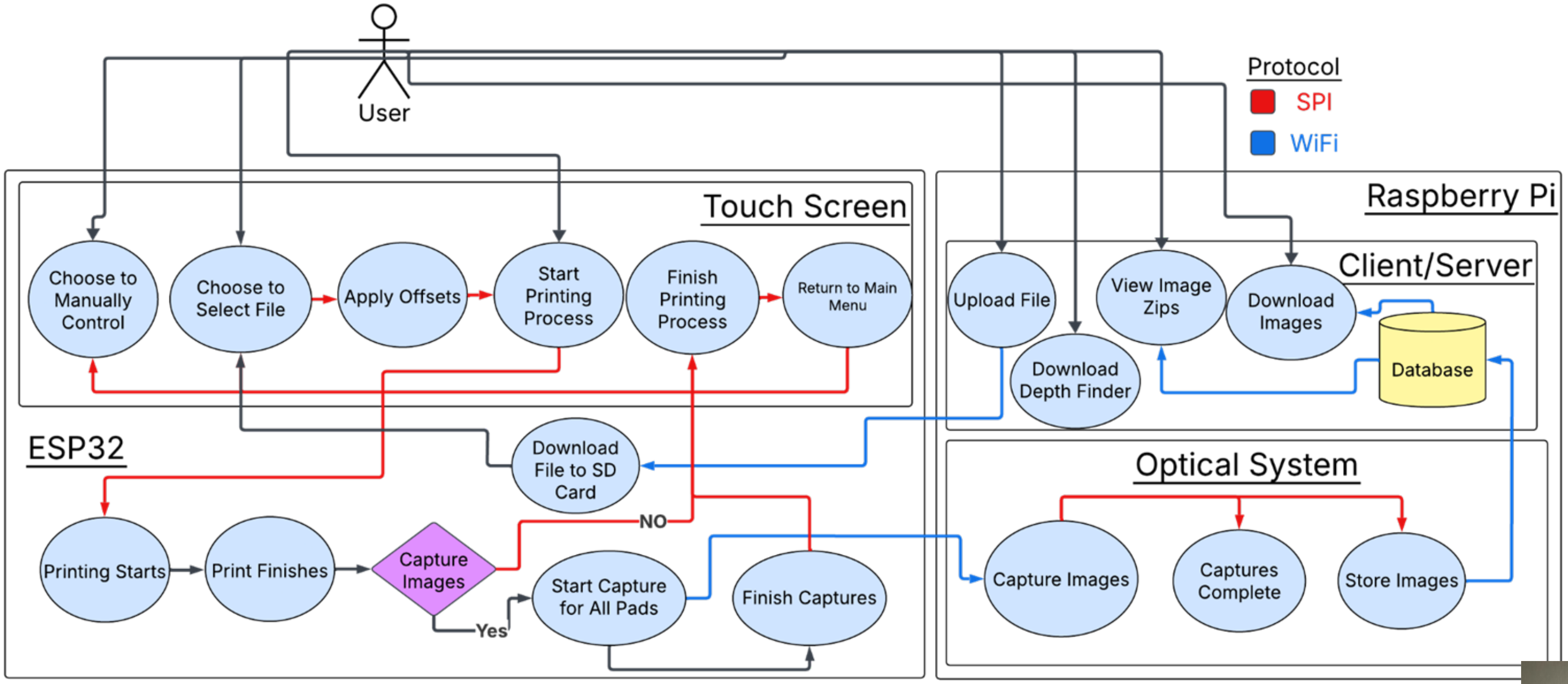
Why: With many peripherals connected to the ESP32, SPI was chosen to reduce the amount of pins needed as the Touch Screen display and touch, and SD Card Reader share the same SPI lines with separate Chip Selects

WiFi

- Raspberry Pi to ESP32
- Raspberry Pi to Website

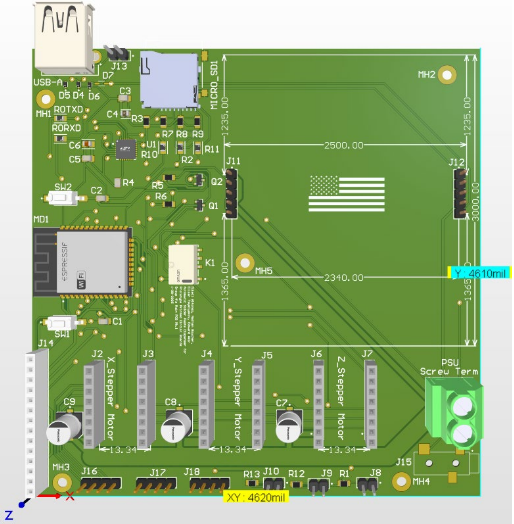
Why: The Raspberry Pi and ESP32 share this Protocol and the Website can be easily accessed after connecting to the Raspberry Pi's Access Point

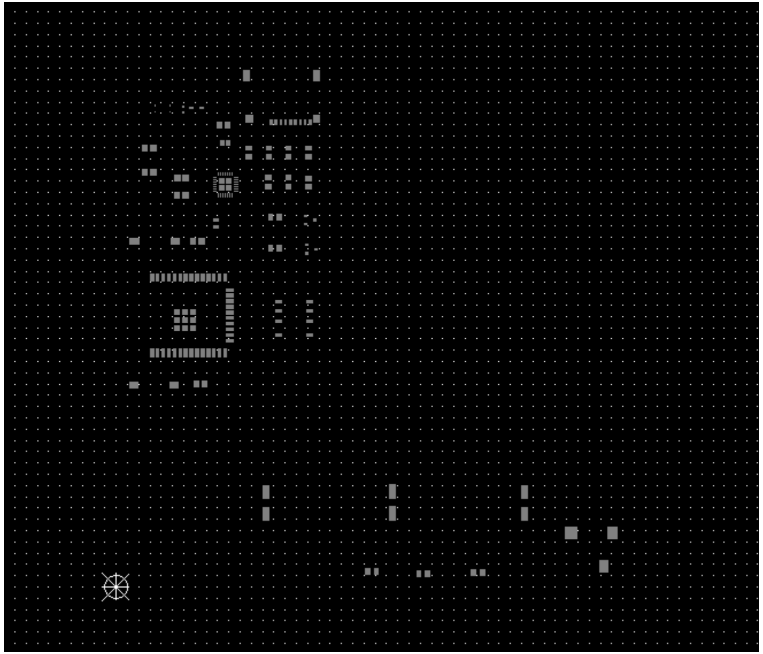
User Diagram



Software Design: Parsing Gerber Files

Objective: Automatically Parser Gerber Files to locate Surface Mount Pads on a X and Y Plane.





```
std::regex flashRegex(R"(X(-?\d+)Y(-?\d+)D03\*)");
std::regex scaleRegex("%MO(IN|MM)*%");
std::regex formatRegex(R"(%FS(L|T)(A|I)X(\d)(\d)Y(\d)(\d)\*%)");
std::regex edgeRegex(R"(X(-?\d+)Y(-?\d+)D0[12]\*)");
std::regex apertureDefinitionRegex(R"(%ADD(\d+)([A-Z]),([\d.]+)(?:X([\d.]+))?\*%)");
std::regex singleMoveRegex(R"((X|Y)(-?\d+)D02\*)");
std::regex apertureSelection(R"(D(\d+)\*)");
```

Software Design: Parsing Gerber Files

Features:

- Stores files Format Specification and Unit Selected
- Store Aperture Definitions (Pad Sizes)
- Locates each SMD Pad and stores it with it's Aperture Definition
- Custom sort of the pads utilizing a snake like track on the PCB
- Offset can be applied prior to printing in order to move origin to the bottom left of the PCB.
- Tested with:
  - Altium
  - Eagle
  - KiCad

GerberUtils

```
«entity»
GerberFile

-m_filePath: std::string
+m_pads: std::vector<SolderPad>
+m_apertures: std::vector<apertureDefinition>
+log: std::vector<std::string> log
+m_Scale: Scale
+m_format: CoordinateFormat
+xFormatFactor: double
+yFormatFactor: double

+GerberFile(const std::string& filePath): void
+applyCoordinateOffset(double xOffset, double yOffset): void
+addCoordinate(std::smatch match): void
+setScale(std::smatch match): void
+setCoordinateFormat(std::smatch match): void
+getNumberOfPads(): int
+padsToString(): std::string
+aperturesToString(): std::string
```

Solder Pad

```
«struct»
SolderPad

+x: double
+y: double
+apertureDefinition: padSize

+operator<(SolderPad other): bool //Custom comparison
```

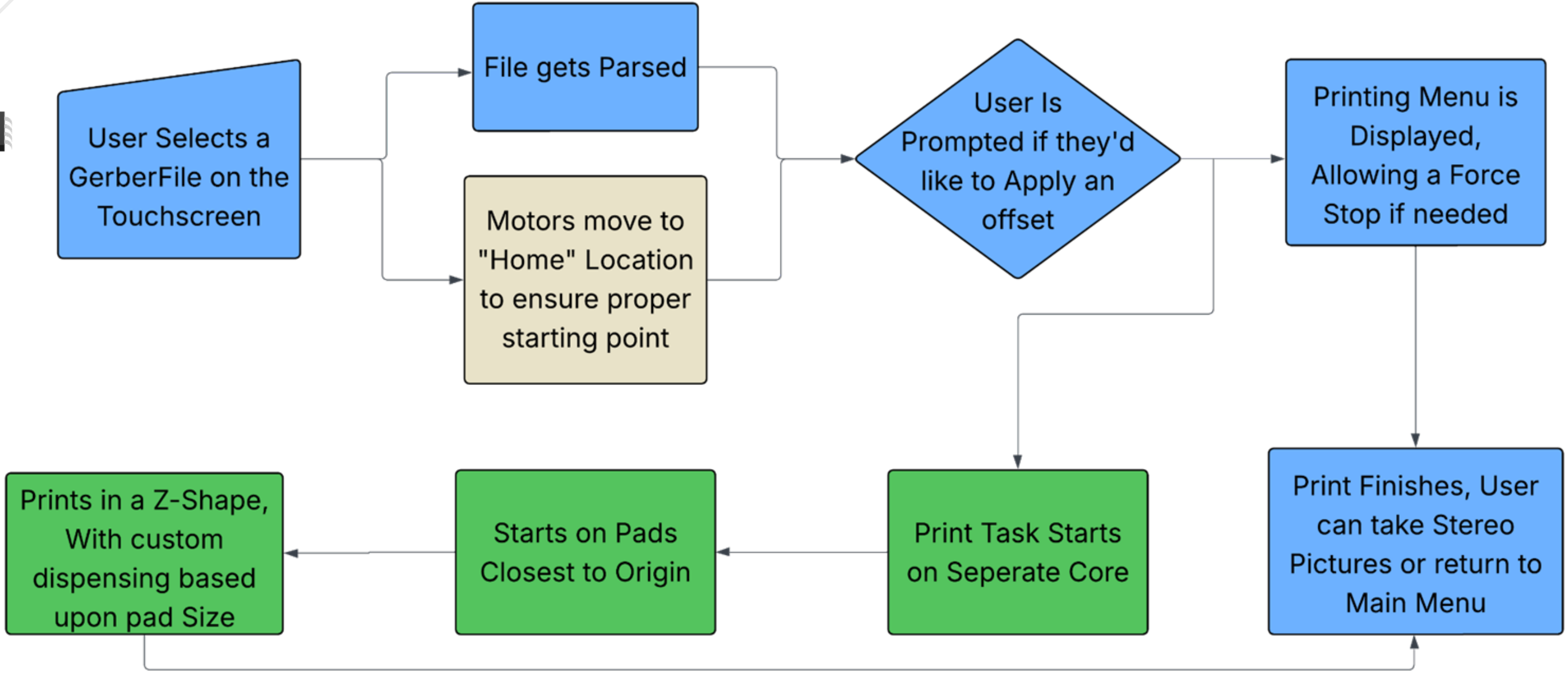
Aperture Definition

```
«entity»
apertureDefinition

+apertureNumber: int
+mType = apertureType
+xSize: double
+ySize: double
+circleDiameter: double

+apertureDefinition(): void
```

Software Design: Executing a Print

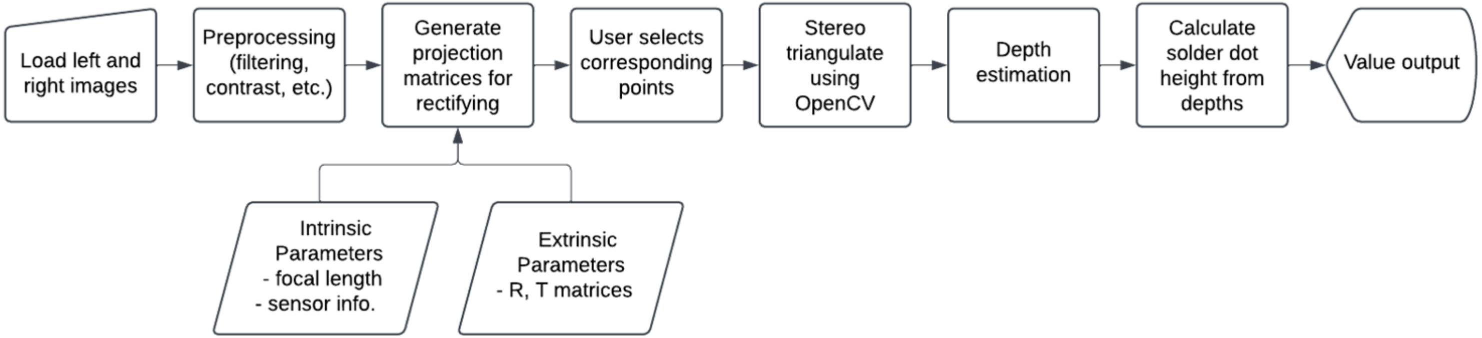


Note: Each Color represents a separate Task Scheduled

Software Comparison: Vision Libraries

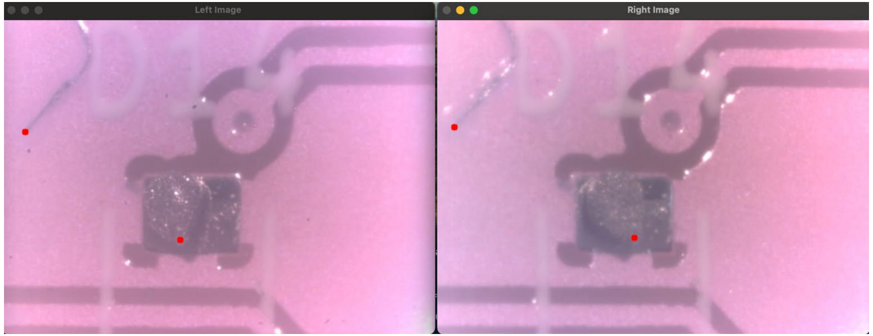
	OpenCV	SimpleCV	TensorFlow
Price	Free and open-source	Free and open-source	Free and open-source
Primary Purpose	Computer vision and image processing	Simplified interface for computer vision tasks	Machine learning and deep learning
Ease of Use	Moderate, involves coding knowledge	High, easy to use and beginner friendly	Moderate to difficult, requires knowledge of machine learning
Programming Languages	C++, Python, Java, JavaScript	Python	Python, C++, JavaScript, Swift, Java
Image processing capabilities	Extensive	Basic	Limited (mostly for data preprocessing)
Stereo vision capabilities	Stereo vision and depth maps	Basic	Limited
Video processing	Real-time video and image processing	Basic video support	Limited, other libraries necessary for integration

Software Design: Depth Estimation Flowchart



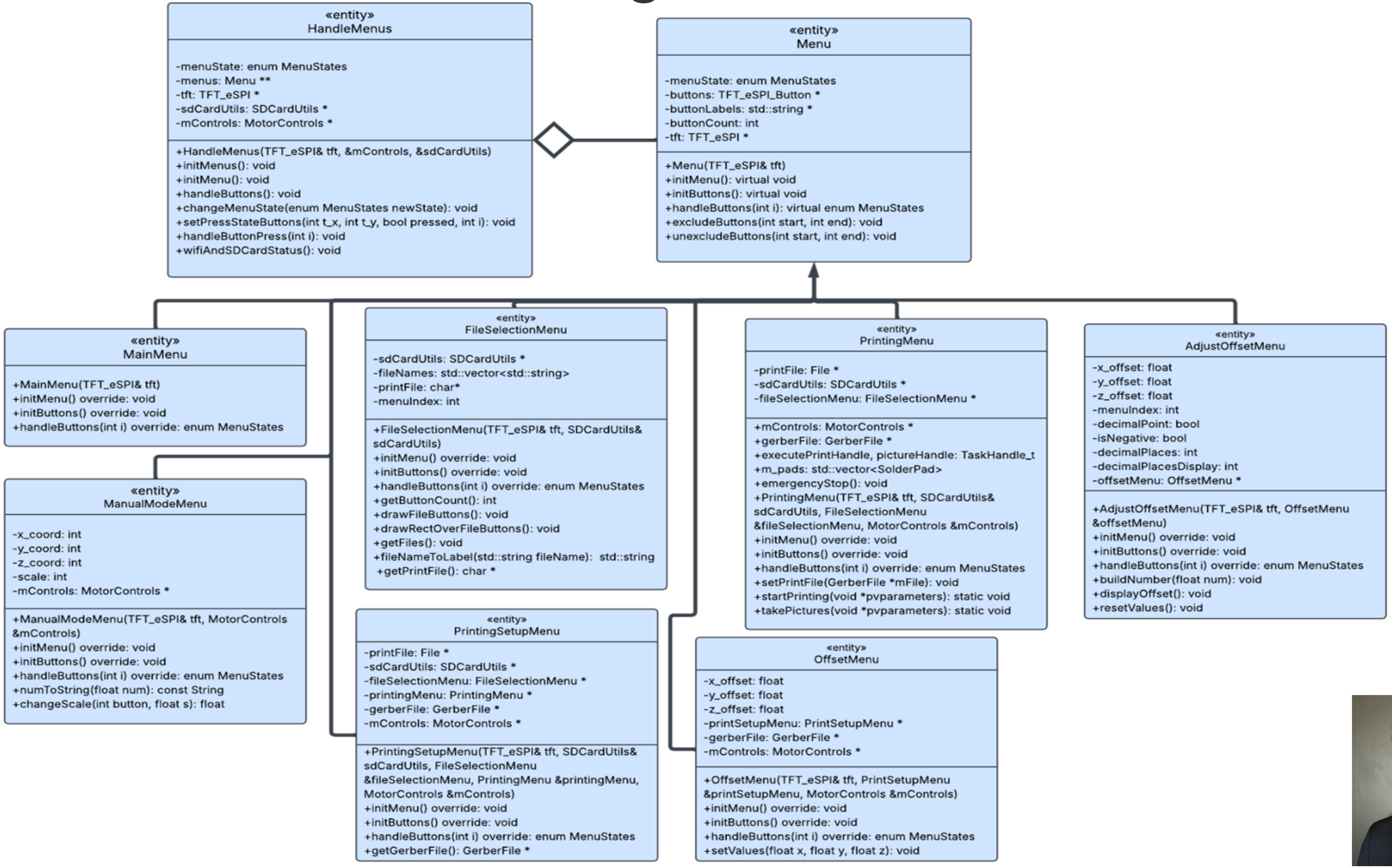
Software Design: Stereo Height Measurement

- Due to difficulties in reliably identifying corresponding pixels between the left and right images, producing a high-quality 3D reconstruction of the object area is not possible.
- Specular reflections in combination with low texture areas in the images further sabotage any efforts towards algorithmic pixel correspondence.
- For this reason, the stereo software has been reduced to a manual pixel correspondence which has to be done by the user.
- Solder dot heights have been successfully measured using manual pixel correspondence and stereo triangulation.



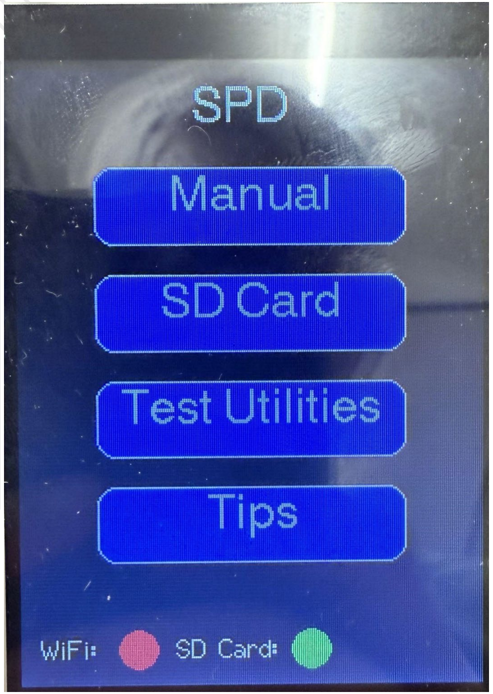

```
============== RESTART: /Users/elizartsy/Documents/ManualStereo.py =============
Select two pairs of corresponding points in both images (in the same order).
For example, first point for the solder tip and second point for the flat PCB.
Press 'c' to calculate height
Press 'q' to quit
Solder dot height: 0.54 mm
```

Software Design: Touch Screen

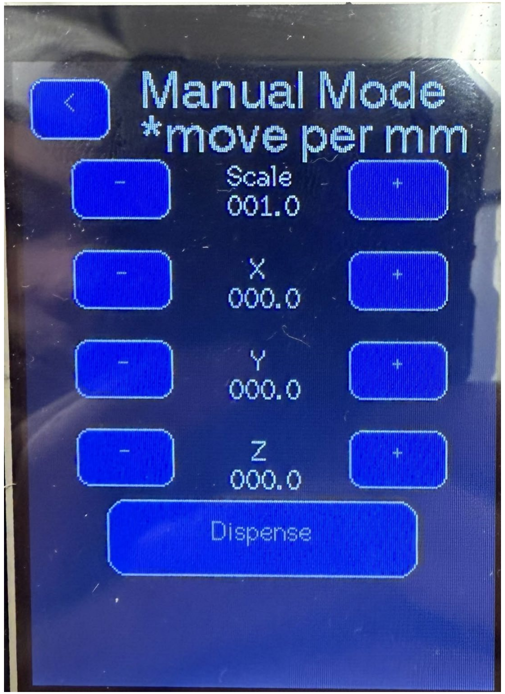


Software Design: Touch Screen Menus

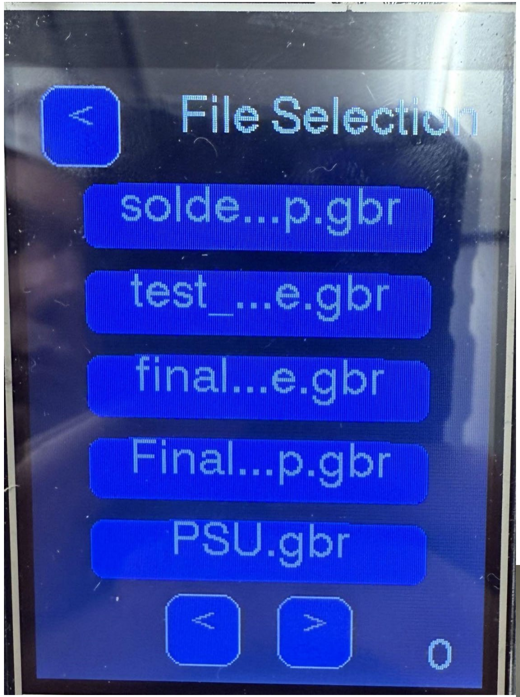
Main Menu



Manual Mode Menu



File Selection Menu



Software Design: Motor and Dispense Controls

«entity»
MotorDispenseControl

-maxSpeed: int -maxAcceleration: int -dispenseDelay: int
-xPadding: float -yPadding: float
-dispenseThickness: float
-sortSpacing: float
-m_Pads: std::vector<SolderPad>
-mServer: ServerHandler *
-fileName: String

+StepsPerMMX: float +StepsPerMMY: float +StepsPerMMZ: float
+zHeight: float +distanceToHomeX: float +distanceToHomeY: float
+motorXLocation: float +motorYLocation: float +motorZLocation: float
+pictureHeight: float
+motorX: AccelStepper +motorY: AccelStepper +motorZ: AccelStepper
+multiStepper: MultiStepper
+MotorControls()
+printSshape(): void
+executePrint(std::vector<SolderPad> pads): void
+dispensePaste(): void
+setDispenseDelay(int delay): void
+moveToOrigin(motorSelection m): void
+moveToHome(): void
+moveDistanceInMM(motorSelection m, float distance): void
+moveToLocation(float xLocation, float yLocation): void
+moveZUp(): void
+moveZDown(): void
+printPad(): void
+SortPads(std::vector<SolderPad> pads): void
+takePictures(): void
+setServer(ServerHandler &mServer): void
+setFileName(String fileName): void
+setMPads(std::vector<SolderPad> pads): void

Software Design: Website/Client & Servers

File Upload

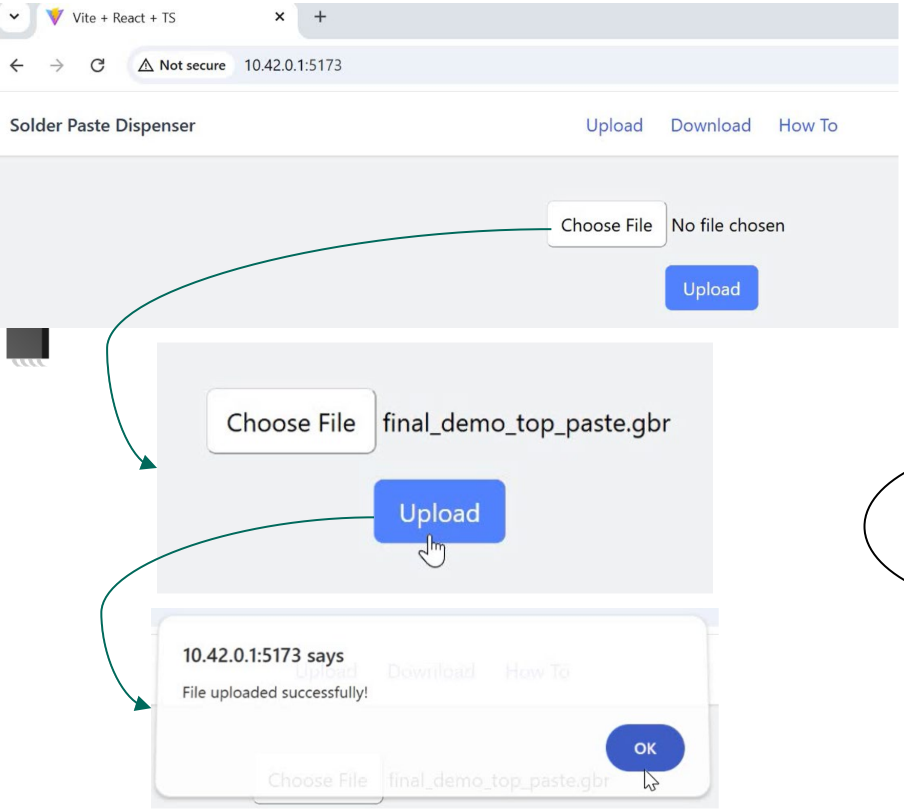
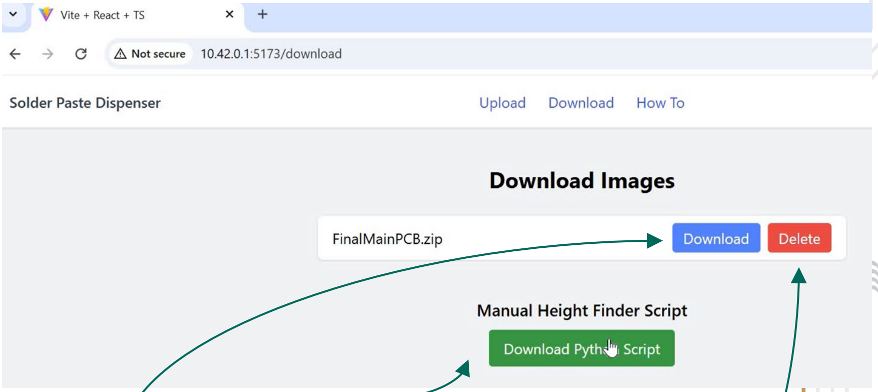


Image Download



Download Zip of Images

Delete Zip of Images

Download Height Finder Script

Software Problems with Solutions

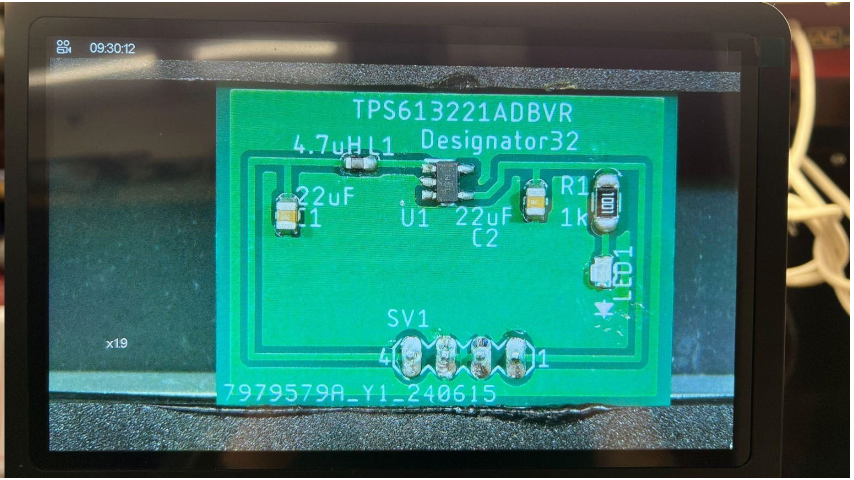
Touchscreen

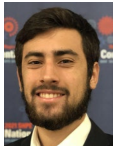
- **Problem:** Buttons from other menus would trigger instead of the current menu displayed
- **Solution:** Create Menu abstract class to base all menus from and create a menu handler which uses the shared functions in the abstract class to handle all button presses

Raspberry Pi 4

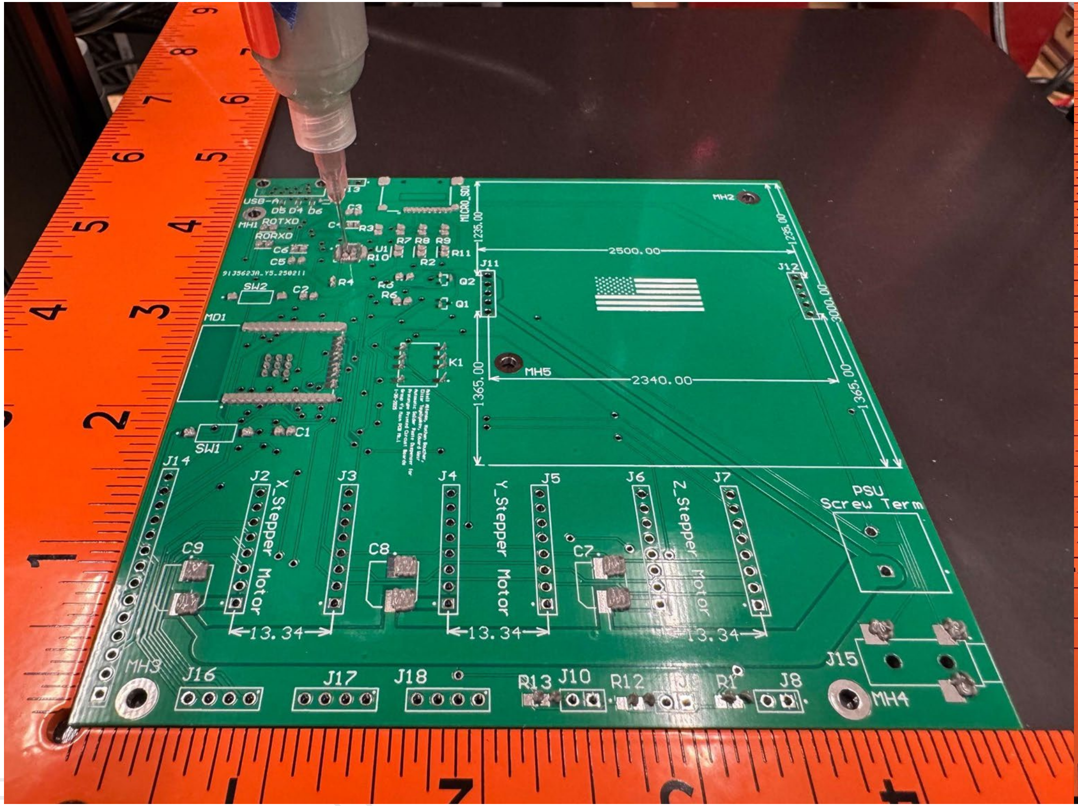
- **Problem:** Raspberry Pi 4 CPU ISA is not compatible with current MongoDb releases
- **Solution:** Find unofficial MongoDb binaries that support the Raspberry Pi 4 CPU ISA

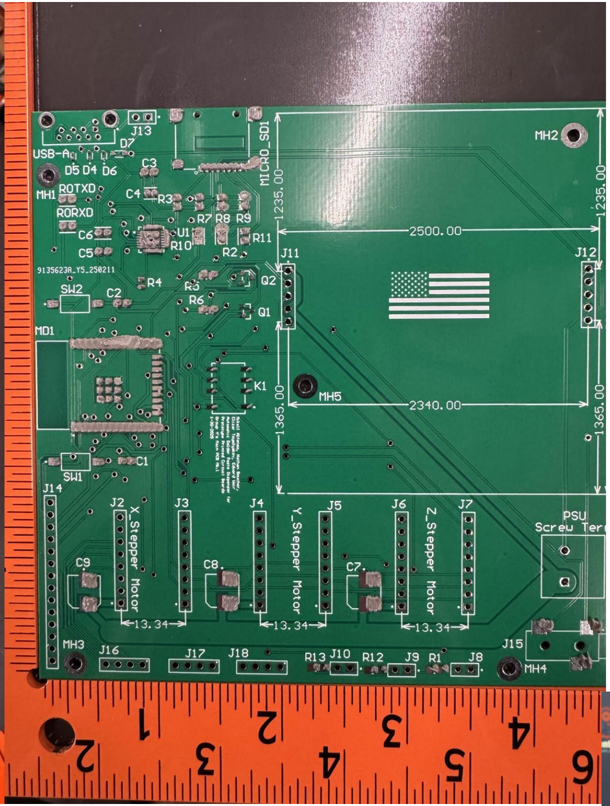
Progress Pictures





Progress Pictures





Budget and Financing

Component	Quantity	Cost per Component	Cost Sum
ESP 32 MCU	1	$8	$8
Touch Screen	1	$25	$25
Stepper Motors	3	$20	$60
Power Supply	1	$25	$25
PS Regulator	1	$12	$12
Cameras	2	$40	$80
Optics	2	$111	$222
Raspberry Pi	1	$110	$110
DRV8825 PCB	3	$15	$45
PSU PCB	1	$40	$40
Main PCB	1	$55	$55

Total Cost
$682

Progress and Plan

Work Distributions

Name	Tasks for Project
Nathan Boucher	Code to take XYZ coordinates and translate to stepper motors movement and dispensing, Code to convert Gerber Files, Part of Code for SD Card Utilities, assisted PCB Design
Mikell Alfonso	PCB design and assembly. PCB design for Main Board, Stepper Motors Driver Boards, and Power Regulator Board. Administrative Content and Video-Editing.
Elizar Tsymlyakov	Optical System Design and Image Processing Software for Stereoscopy and 3D reconstruction
Edward Weir	Code for Display GUI, Website frontend and backend, Part of Code for SD Card Utilities, Server for Microcontroller, Server for Optical Software Connection

Thanks!