

ECE 342 FINAL PROJECT

Developer Guide

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1 System Overview

Our team developed a SpyderCam style payload positioning system that moves a payload around in an 8.5 by 11-inch area by using three strings that connect a central payload to pylons at the corners of an equilateral triangle. An Arduino AT MEGA2560 is used to control the stepper motors that allow for the payload to change position, the Arduino also is used to measure the sensor values from the RFID and light sensors on the payload. G-Code commands generated by a MATLAB GUI are used to provide the Arduino with instructions on where to move the payload.

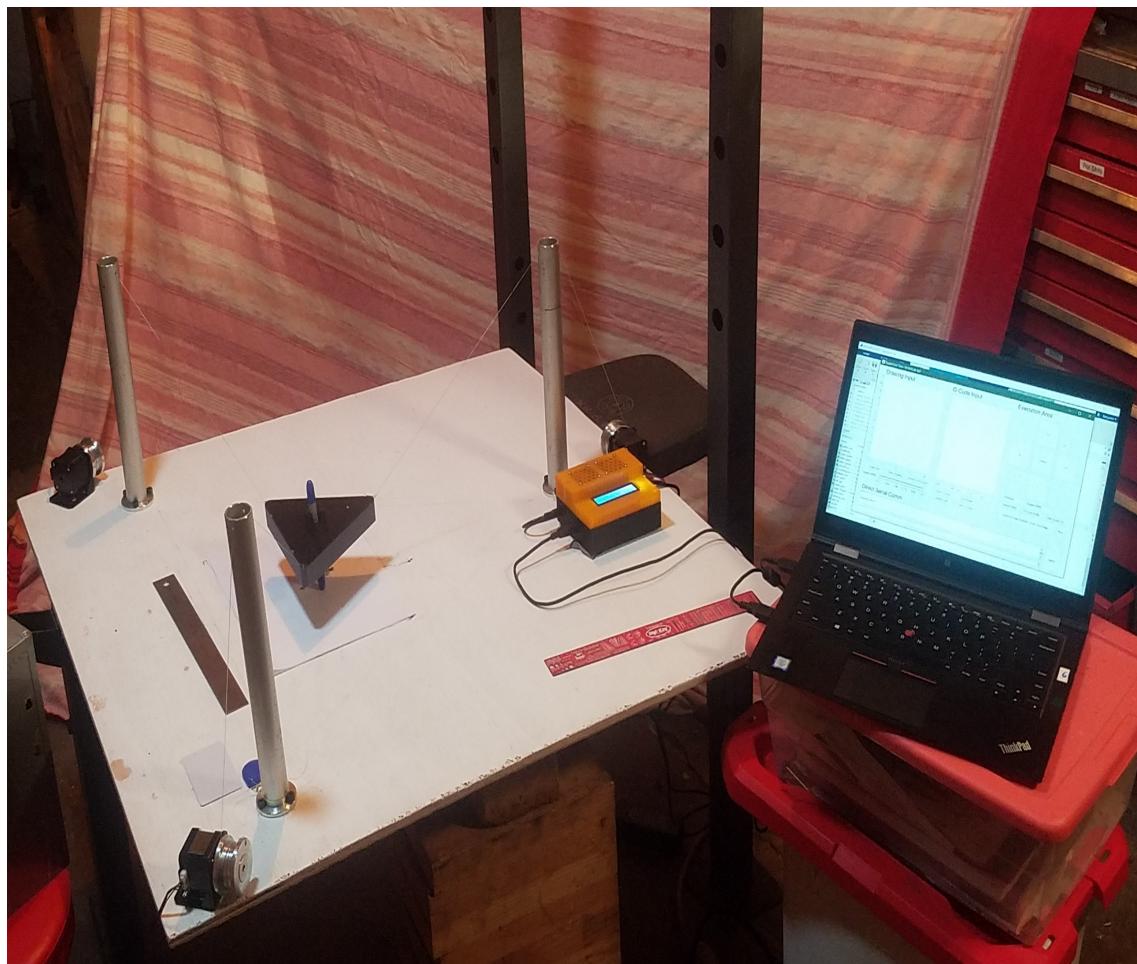


Figure 1: This is an image of what the completed project looks like.

1.1 System Block Diagram

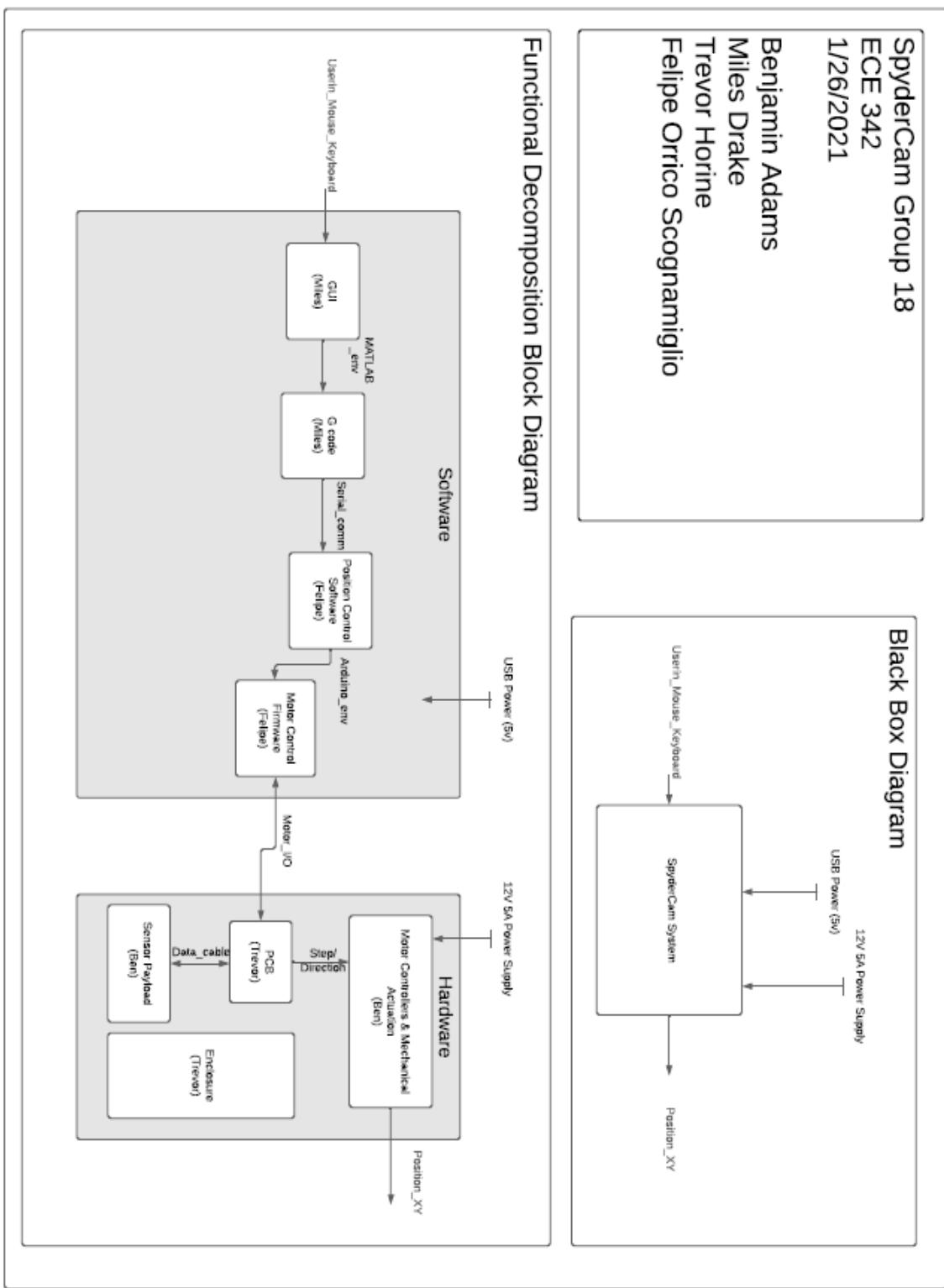


Figure 2: This is the block diagram of the whole system.

2 Electrical Specifications

The Arduino AT MEGA 2560 is powered off the USB that is also used for serial communication with the computer and MATLAB script that provides G-code commands for the system to perform. In addition, the system also has a 12 volt five amp power input that supplies the higher voltage and current that is required to drive three stepper motors used to move the payload around. With the exception of the outputs from the DRV8825 stepper motor drivers to the motors the rest of the system uses five volt logic.

2.1 System Interface Table

Interface Definitions	
Userin_Mouse_Keyboard	PS/2 Keyboard Interface Vcc = 5.0V
MATLAB_env	Internally Defined MATLAB Variables Floating-point precision
Serial_comm	Protocol: UART 115200 baud G-Code Commands
Arduino_env	Internally Defined Arduino Variables See ATMEGA 2560 DS
Motor_I/O	10 Digital Pins Vmin = 0V Vmax = 5V
Step/Direction	Vmin = -0.5 V Vmax = 7.0 V
Data_cable	6 Pin High Speed UART (115200 Baud) Vmin = 0V Vmax = 5V
USB_Power	V = 5 V I = 0.5 A P = 2.5 W
Motor_Power	V = 12.0V I = 1.5 A (nominal) I <= 1.1 A (Actual)
Position_XY	x/y payload position spanning 23.00" equilateral triangle Lateral Deviation $\leq 0.25"$ per 10" travel

Figure 3: This is the interface table for the system.

2.2 Schematics

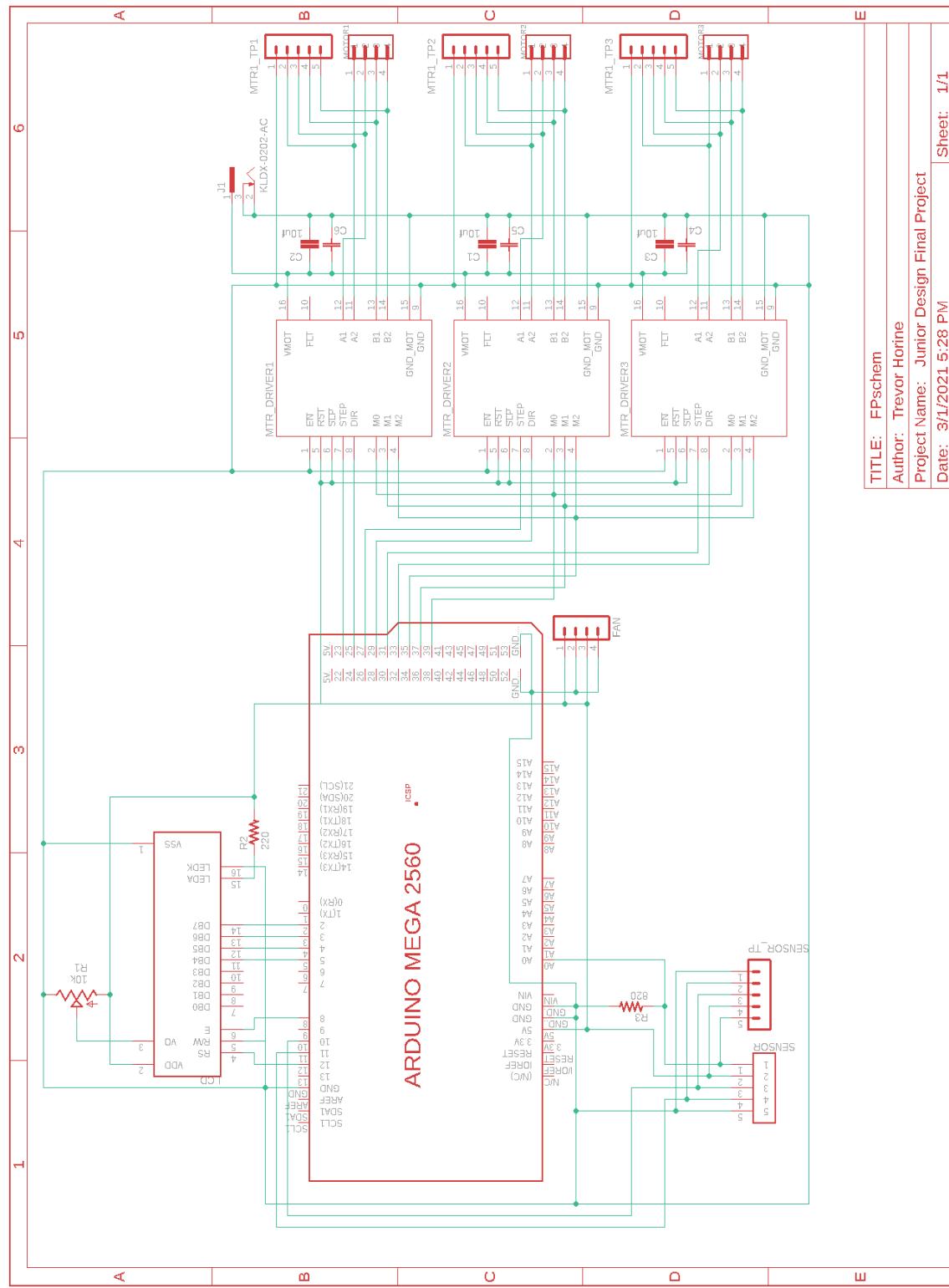


Figure 4: Detailed schematic of the system, motors connect to the connectors marked MOTOR1, MOTOR2, and MOTOR3, the sensor payload connects to the connector labeled SENSOR, and the fans connect to the pins labeled FAN.

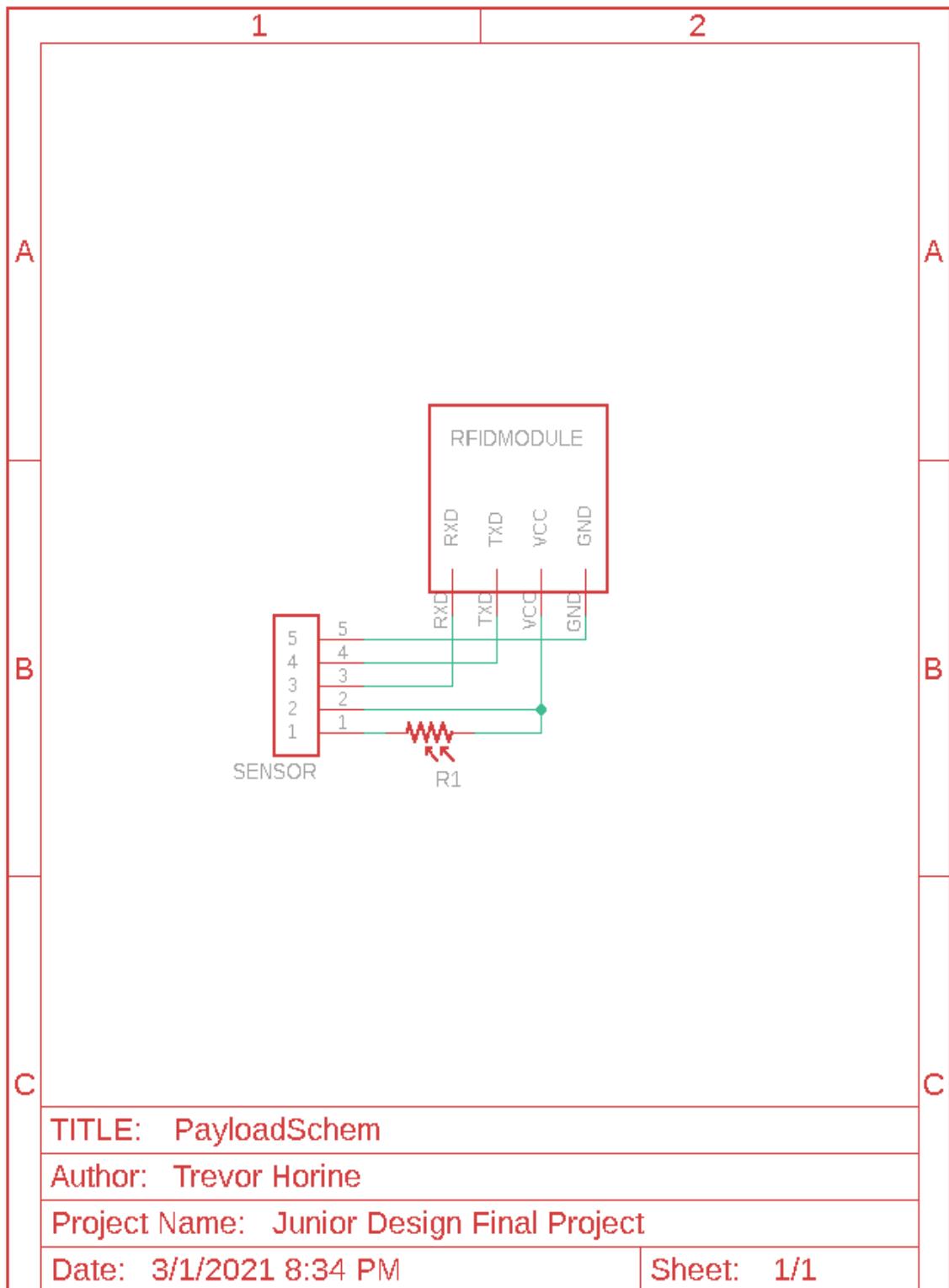


Figure 5: Detailed schematic of the payload that connects to the SENSOR connector in Figure 4.

3 User Guide

3.1 Setup

The following sections describe the initial setup and running of separate components of the Spydercam Project.

3.1.1 Hardware

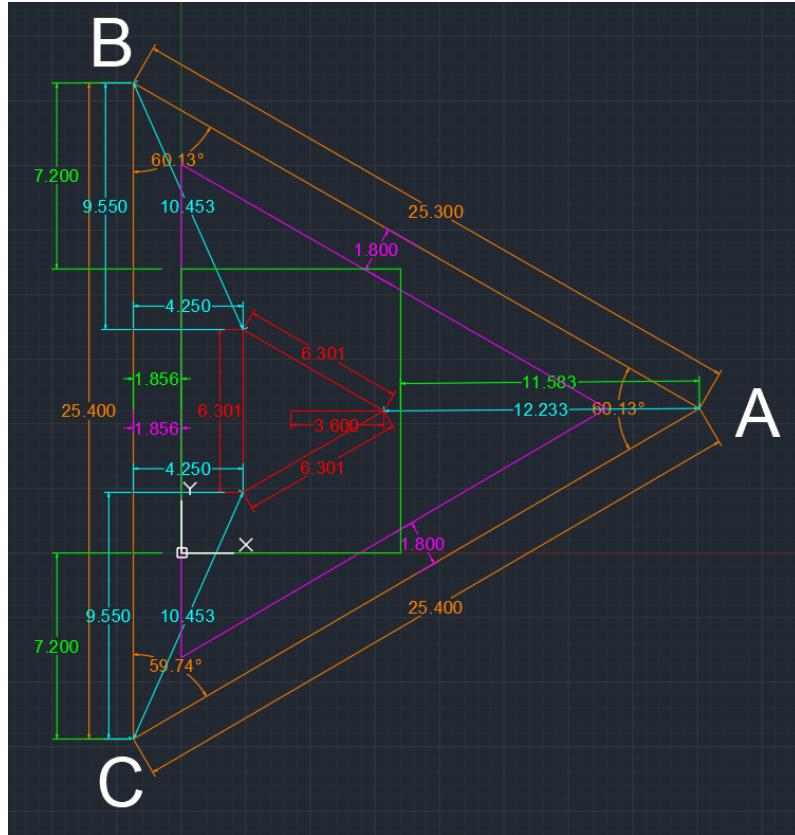


Figure 6: CAD image of relative hardware measurements with a triangular payload

Begin by setting up the pylon mounts and pylons in accordance with Figure 6 (note that different payloads can be compensated by changing software parameters (see section 3.1.2, but the pictured payload does not alter other dimensions)).

Dimensions pictured are from the point where the thread leaves the pylon, so some basic shop math is required. Once positioned, the pylon feet will balance the pylon, allowing for easy positioning before installation. Carefully mark all of the bolt hole positions in the pylon feet, then drill 5/16" holes to allow the insertion of 1/4 – 20" socket-headed cap screw. Install 1/4 – 20 screws, washers, and bolts, and tighten. Carefully position the nema 17 motor mounts outside of the triangle, allowing for a clear trajectory for the thread to travel, and bolt down after making sure that motor cables are long enough to reach the microcontroller box. After wiring up the stepper motors, the microcontroller enclosure can be mounted to the frame. Finally, care should be taken in accurately positioning any paper inside the drawing area. Paper can be easily secured with double-sided tape, and marking the paper registration makes the reloading of paper more efficient.

The final hardware should look like Figure 7.

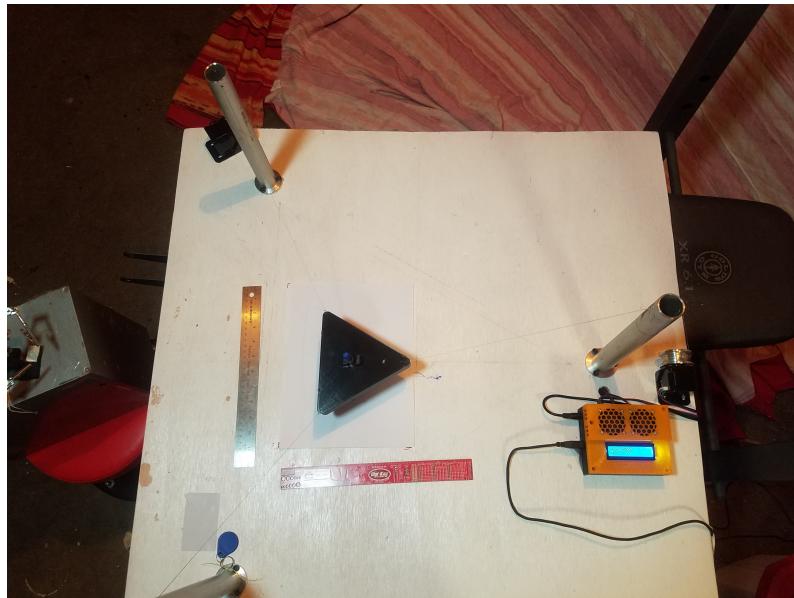


Figure 7: Final Hardware- top view

3.1.2 Software - Arduino

Before installing the Arduino software, be sure that the payload dimensions in lines 56–60 match the payload that you are using. After this is verified, load the provided Arduino code and libraries to the Arduino Mega using the Arduino IDE. After the program has loaded, the LCD display will request you to input some current values so that it knows where the payload is located, more precisely, it requests X, Y and Z (i.e. current payload X and Y location with relation to the C-edge of the paper, and the current height of the payload from paper-level to the top of the payload (where the threads are attached). After all requested values are input, the Arduino side of the setup is complete, and it is ready to receive G-Code inputs to move the payload or perform another task.

3.1.3 Software - MATLAB

To set up the MATLAB GUI for this system, load spyderGUI.m ([8.2](#)) into MATLAB. Replace the value "COM3" on line 38 to the name of the serial port being used on your computer. Plug in the Arduino to the specified serial port using a USB cable and then run the program. If the serial device is not properly connected, MATLAB will throw an error and exit the program. If this is the case, reconnect the Arduino and confirm that the proper serial port is specified. Once the main GUI window opens up, setup is complete and MATLAB is ready to send commands. Before sending any G-Code, the direct serial communication section of the GUI should be used to send the initial location values of the payload, as stated in section [3.1.2](#) above.

3.2 Operation

Operation of the SpyderCam is viable in two different ways. It is possible to control the hardware by inputting commands straight to the Arduino or through the MATLAB GUI.

3.2.1 MATLAB

The MATLAB portion of the system serves as a graphical user interface (GUI). Its purpose is to take instructions from the user, send those instructions to the Arduino, then receive and display sensor and location data from the Arduino. There are four different ways that a user can enter instructions into the MATLAB GUI: By typing a sequence of G-Code, by making a drawing, by pressing incremental movement buttons, or by sending serial commands directly to the Arduino. The layout of the GUI can be seen in Figure 9.

The main focus of this GUI is the drawing input area. After making a line drawing in this area, the user can convert it to G-Code which will be sent to the G-Code text input box. From here, it can be edited using the options listed below the text area, or simply edited directly by typing in the box. Once the sequence of G-Code is ready to be executed, it can be sent to the G-Code buffer (shown in Figure 10), which will send commands to the Arduino one at a time. It sends a command, then waits for a package of location and sensor information to be returned from the Arduino as discussed in section 4.1. The 'G' at the end of the information package lets the buffer know that it's time to send another command. The information received is parsed and plotted in the sensor data window, shown in Figure 11.

In addition to the main program flow described in the previous paragraph, the direct serial communication area can be used to send commands to the Arduino regardless of whether a 'G' has been sent back. This is useful for sending M6 or M2 commands, which need to interrupt a current process. Received serial data from the Arduino will also appear in this section of the GUI.

3.2.2 Arduino

Operating SpyderCam with the Arduino is quite simple. After the setup is complete, all that needs to be done is to send commands through Serial to the Arduino. Those commands are in standard G-Code format and you can find a full list of them in Figure 8.

4 Design Artifacts

4.1 Arduino Code

The Arduino code Block contains two sub-blocks: Motor Control Firmware (MCF) and Control Software (CS). Those two sub-blocks work together to translate G-Code input into correct payload movement. The CS receives the G-Code input from Serial and collects all necessary values from it. It then interprets that information and sends a move request to the MCF. The MCF upon receiving a move request will calculate the target thread lengths and the amount of steps that each motor has to perform in order to achieve the correct displacement. It will then communicate with the stepper library AccelStepper to calculate the necessary speeds for each of the motors so that they reach each of their individual displacements at the same time. The CS is also responsible to reporting back values to MATLAB such as sensor data and current thread lengths and payload position.

G/M-CODE	VAR 1	VAR 2	Var 3	VAR 4	Definition
G0	X	Y	Z	-	Takes Payload to X, Y at max speed
G1	X	Y	Z	F	Takes Payload to X, Y at F speed
G20	-	-	-	-	Mode: Inputs in Inches
G21	-	-	-	-	Mode: Inputs in Millimeters
G90	-	-	-	-	Mode: Absolute Coordinates
G91	-	-	-	-	Mode: Incremental Coordinates
M2	-	-	-	-	End Program
M6	-	-	-	-	Tool Change
C1	-	-	-	-	Send Payload location to Serial
C2	-	-	-	-	Send thread lengths to Serial

Figure 8: Table of available G-Code commands within the Control Software

After any command from Figure 8 is sent to the Arduino and executed, the Control Software will send back information to MATLAB in the following format:

X<x-location>Y<y-location>Z<z-location>A<thread-len-a>B<thread-len-b>C<thread-len-c>L<light-level>R<rfid-data>G

The letter ‘G’ that is sent after the information indicates that the software is ready to receive another command. When a C1 or C2 command is executed, the format is different in the way that the information is sent to MATLAB. It will include a ‘#’ to indicate the end of the transmission cycle of the information requested.

4.2 MATLAB Code

The Drawing Input section of the MATLAB GUI allows the user to control the SpyderCam by entering a line drawing. MATLAB converts this drawing into G-Code by creating commands which move to the start of each line, lower the pen onto the paper, move along the path created by the line, then raise the pen and continue to the next line. The G-Code is all written in standard G-Code notation.

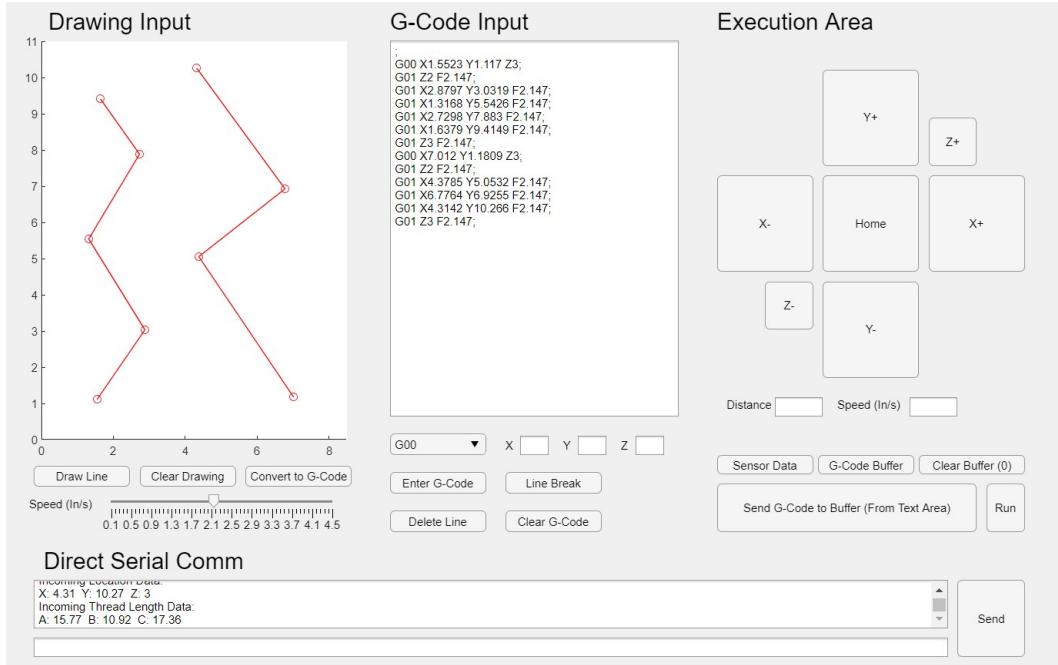


Figure 9: MATLAB GUI. Sections from left to right are: Drawing input area, G-Code text box, Execution area. The direct serial communication area is at the bottom.

G-Code which is sent to the buffer will appear in the G-Code buffer window. G-Code is sent from the buffer to the Arduino and subsequently removed from the buffer upon receiving a 'G' character through serial. The G-Code buffer window is shown in the figure below.

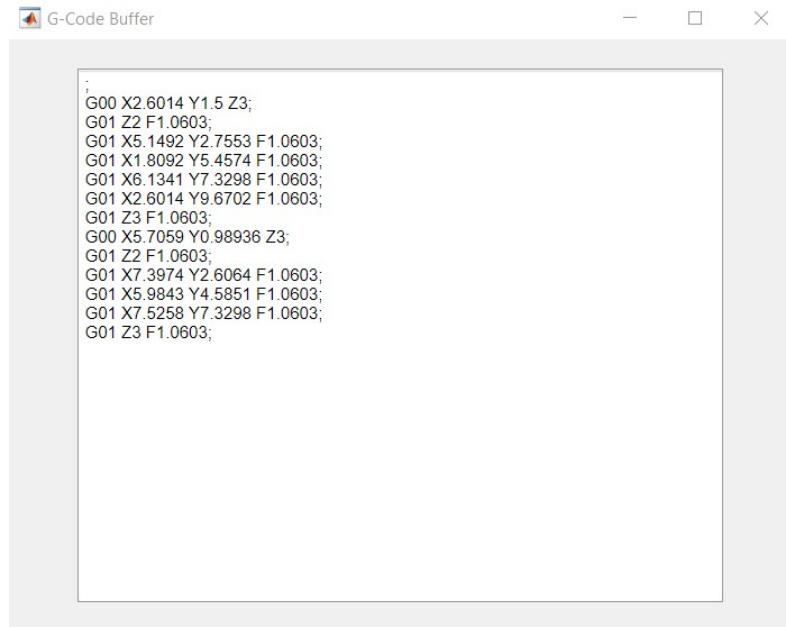


Figure 10: MATLAB GUI G-Code Buffer. This window shows a list of G-Code which is queued to be sent to the Arduino.

When the Arduino reaches its current destination, it sends back a packet of location and sensor information as described in the previous section. The information is then parsed and displayed in the Sensor Data Window, shown in the figure below.

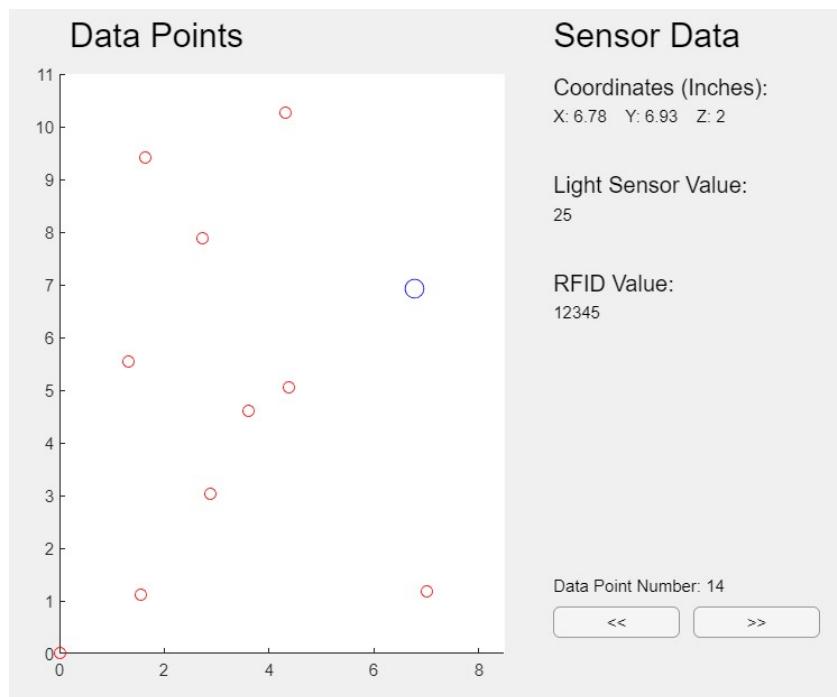


Figure 11: MATLAB GUI sensor data view. Each data point is contains a packet of sensor and location data received from the Arduino

4.3 Mechanical Subsystem

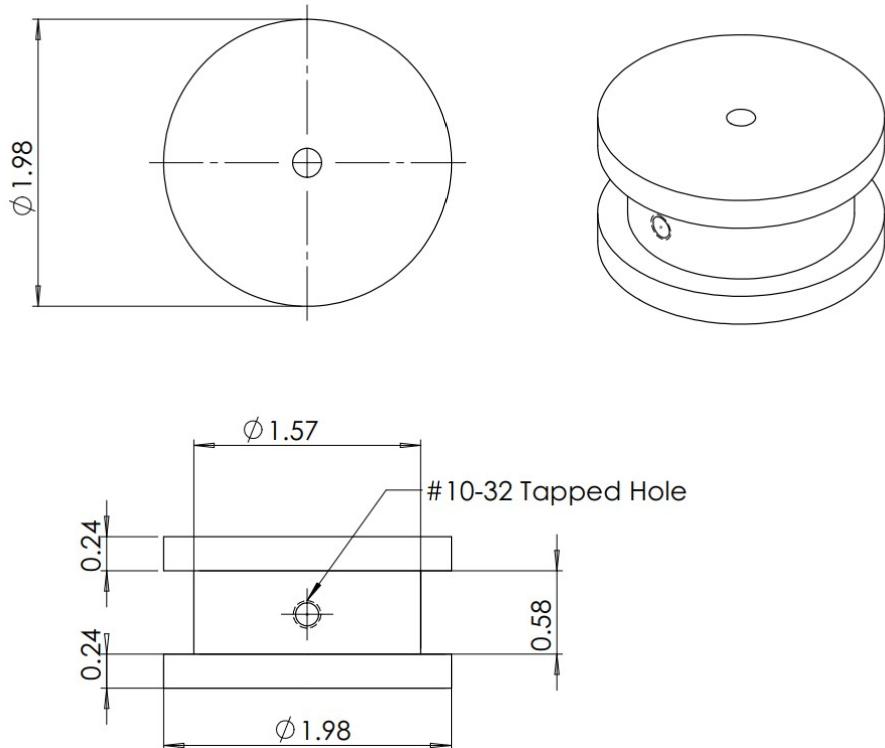


Figure 12: Aluminum motor-mounted spool blueprint

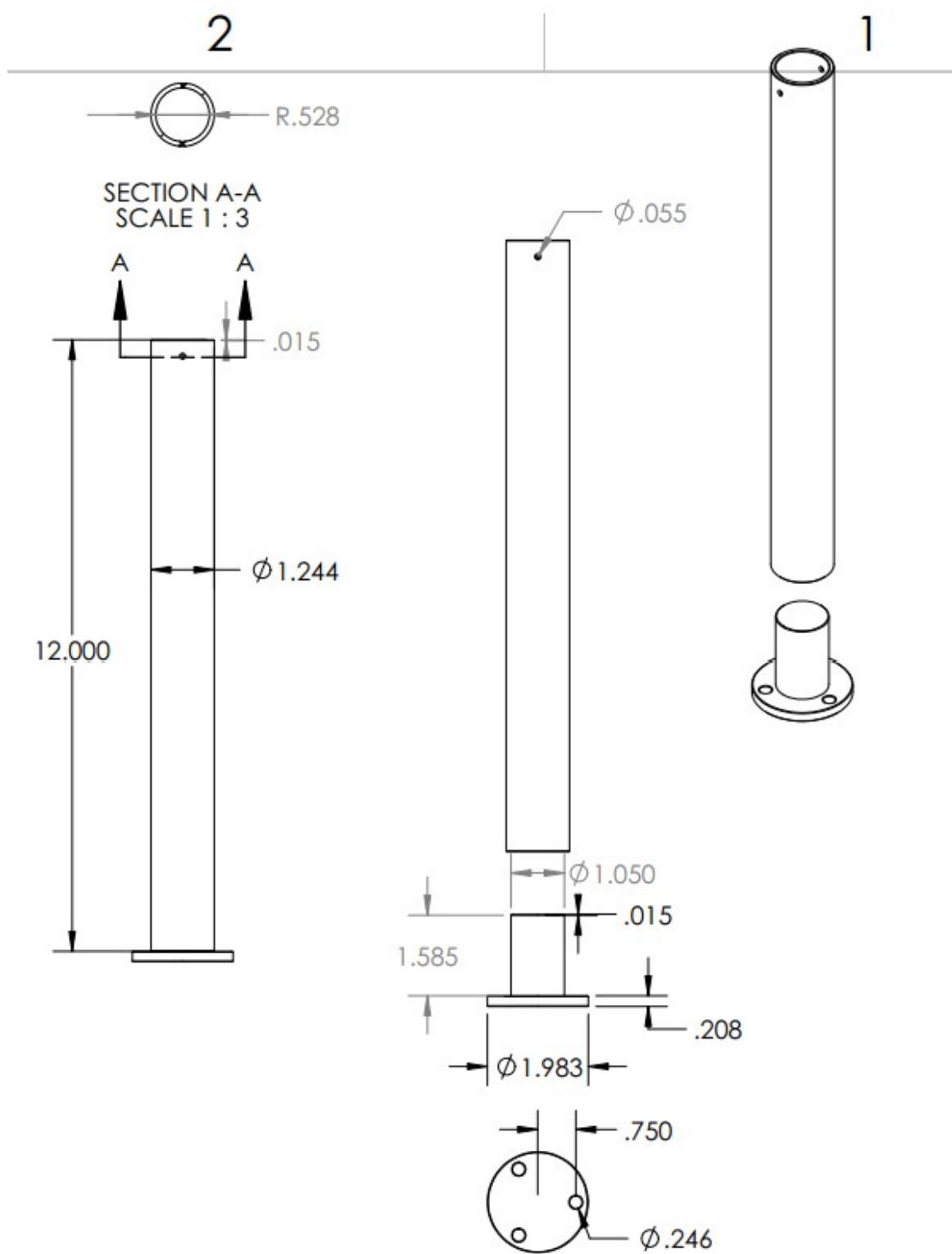


Figure 13: Aluminum pylon assembly blueprint

4.4 Payload

4.4.1 Triangular Payload

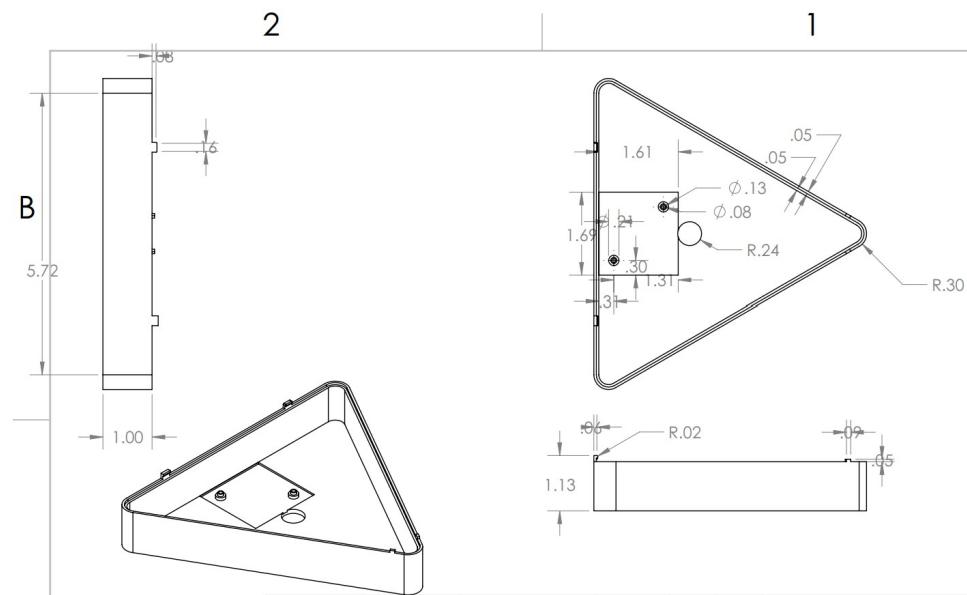


Figure 14: Triangular payload bottom part

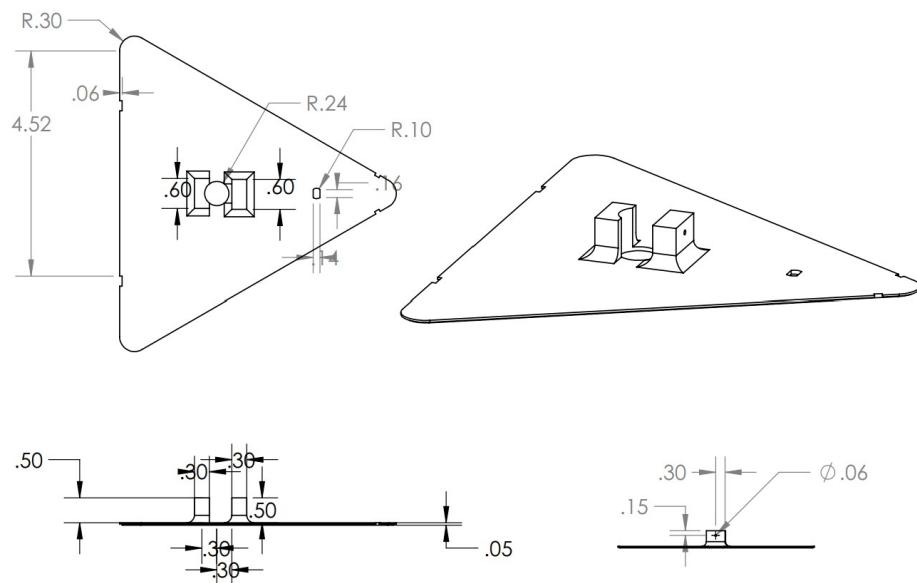


Figure 15: Triangular payload top part

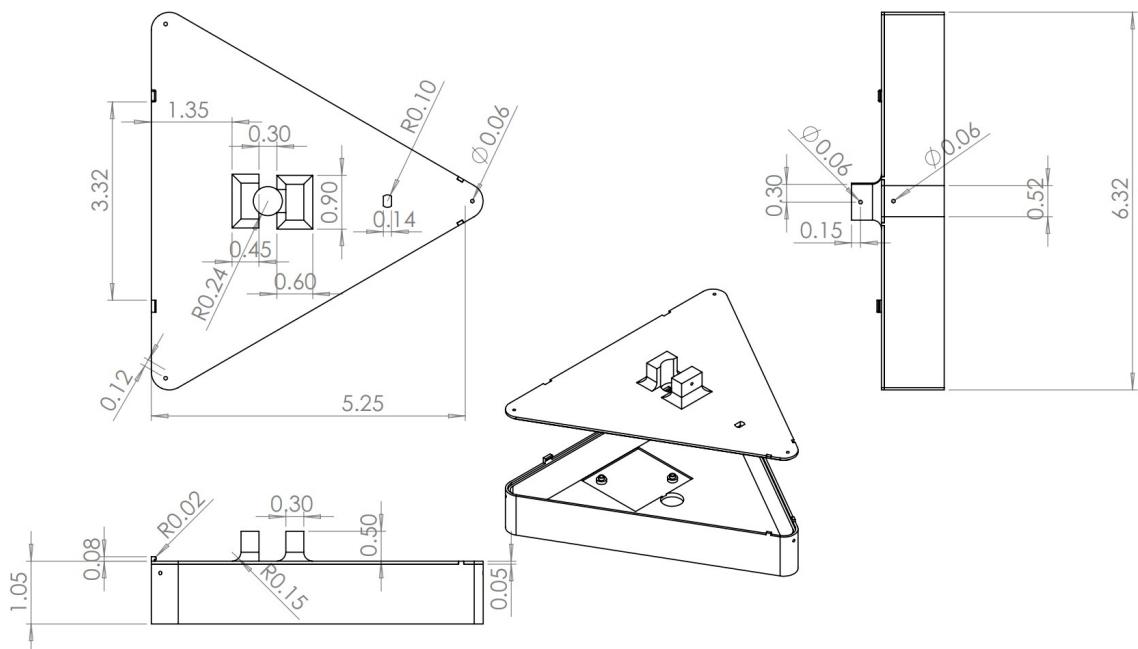


Figure 16: Triangular payload assembly- exploded view

4.4.2 Rectangular Payload

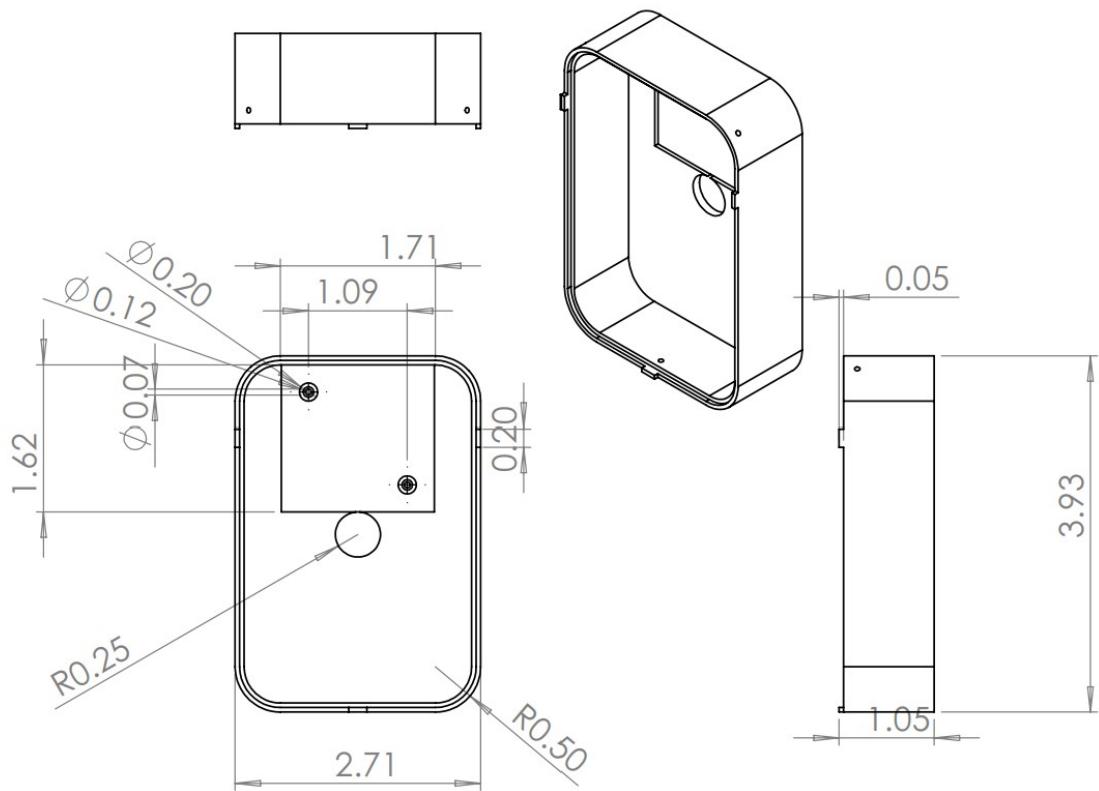


Figure 17: Rectangular payload- bottom part

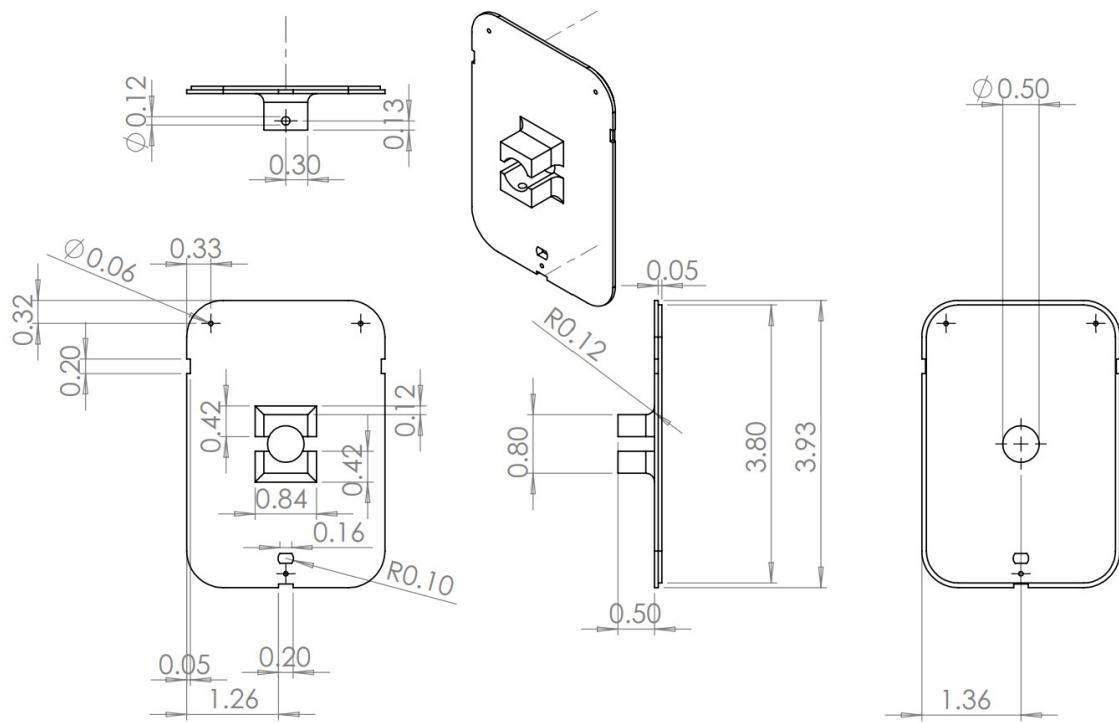


Figure 18: Rectangular payload- top part

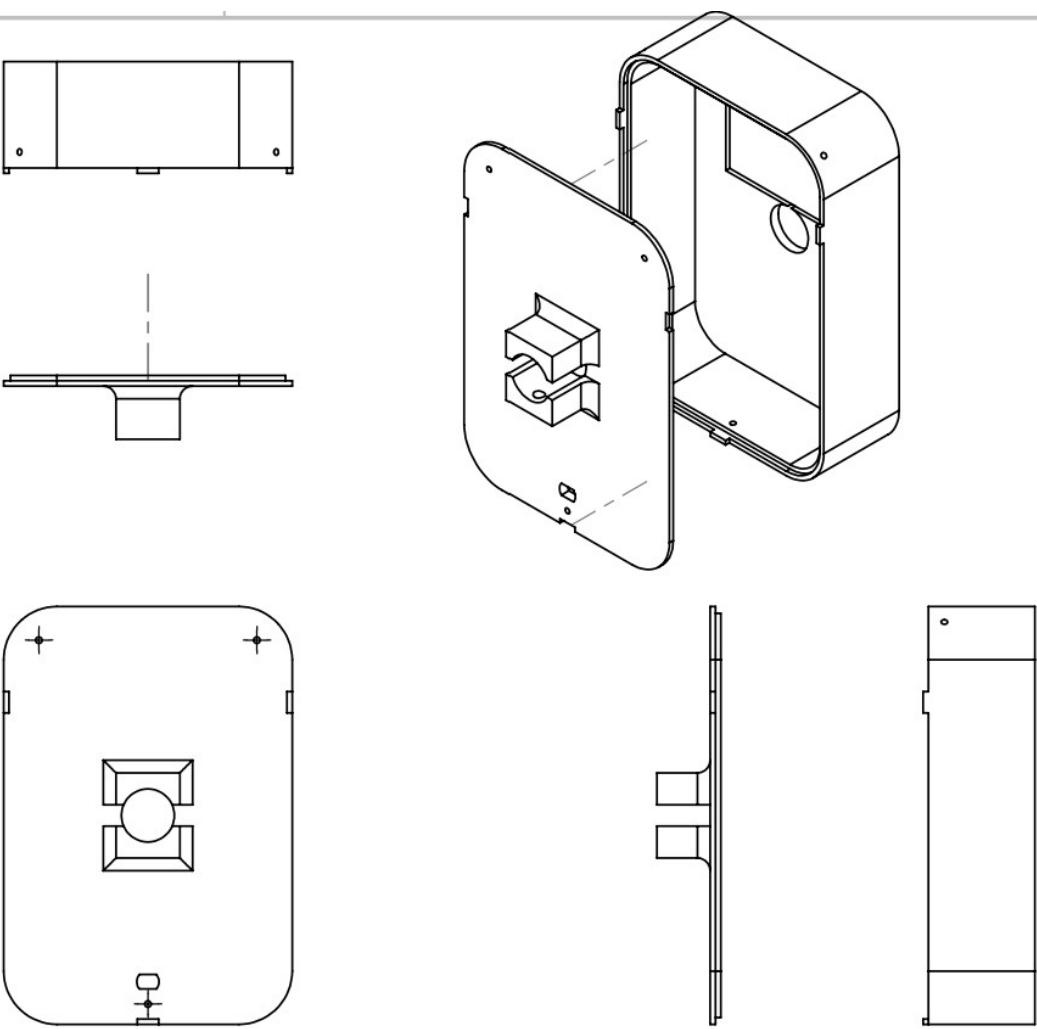


Figure 19: Rectangular payload- exploded assembly view

4.5 PCB Enclosure

The PCB enclosure was modeled using the 3D model of the PCB, such that the board would sit on supports around the mounting holes, and the top would have supports that come down to hold the board in place. four 35 mm long M3 screws hold the enclosure together. The two 40mm by 40mm by 10mm fans also mount to the top of the enclosure to provide air circulation in the top on to the motor drivers and out the side vents. there is a window in the top to make the LCD screen visible and ports in the sides for the Arduino USB, 12 volt motor power, three motor cables and the one sensor cable. Figure 20 shows the 3D model of both halves together with the model of the PCB inside of the enclosure. Mechanical drawings for bottom and top halves of the enclosure can be found in Figures 21 and 23 respectively, followed by the models of each half in Figures 22 and 24 respectively. The final enclosure with the built PCB inside can be found in Figure 25.



Figure 20: This is a rendering of the 3D model of what both pieces would look like together. This model has the model for the PCB inside, and has blue boxes for fans.

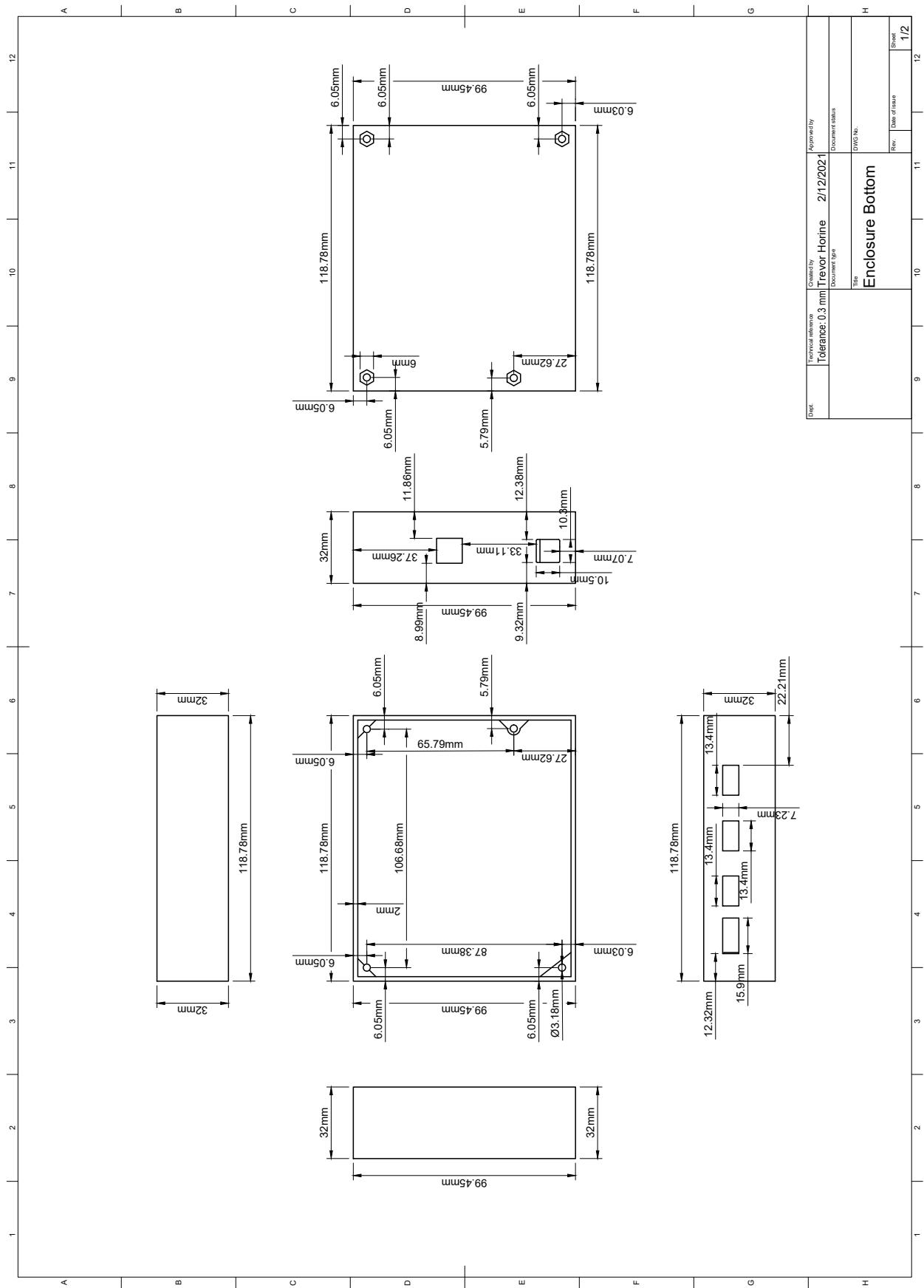


Figure 21: Mechanical drawing of the bottom half of the enclosure designed to hold the PCB.

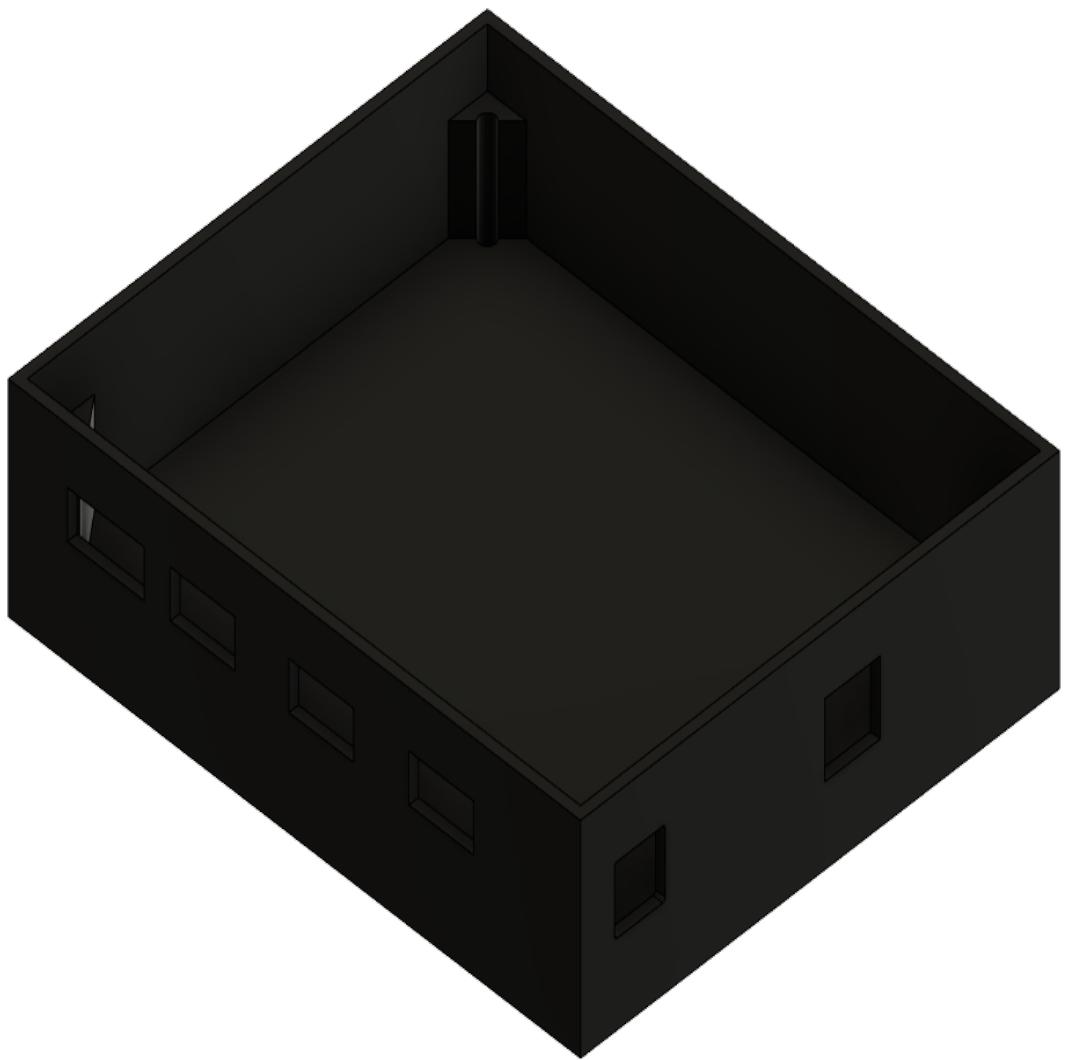


Figure 22: This is a rendering of the 3D model of the bottom half of the enclosure.

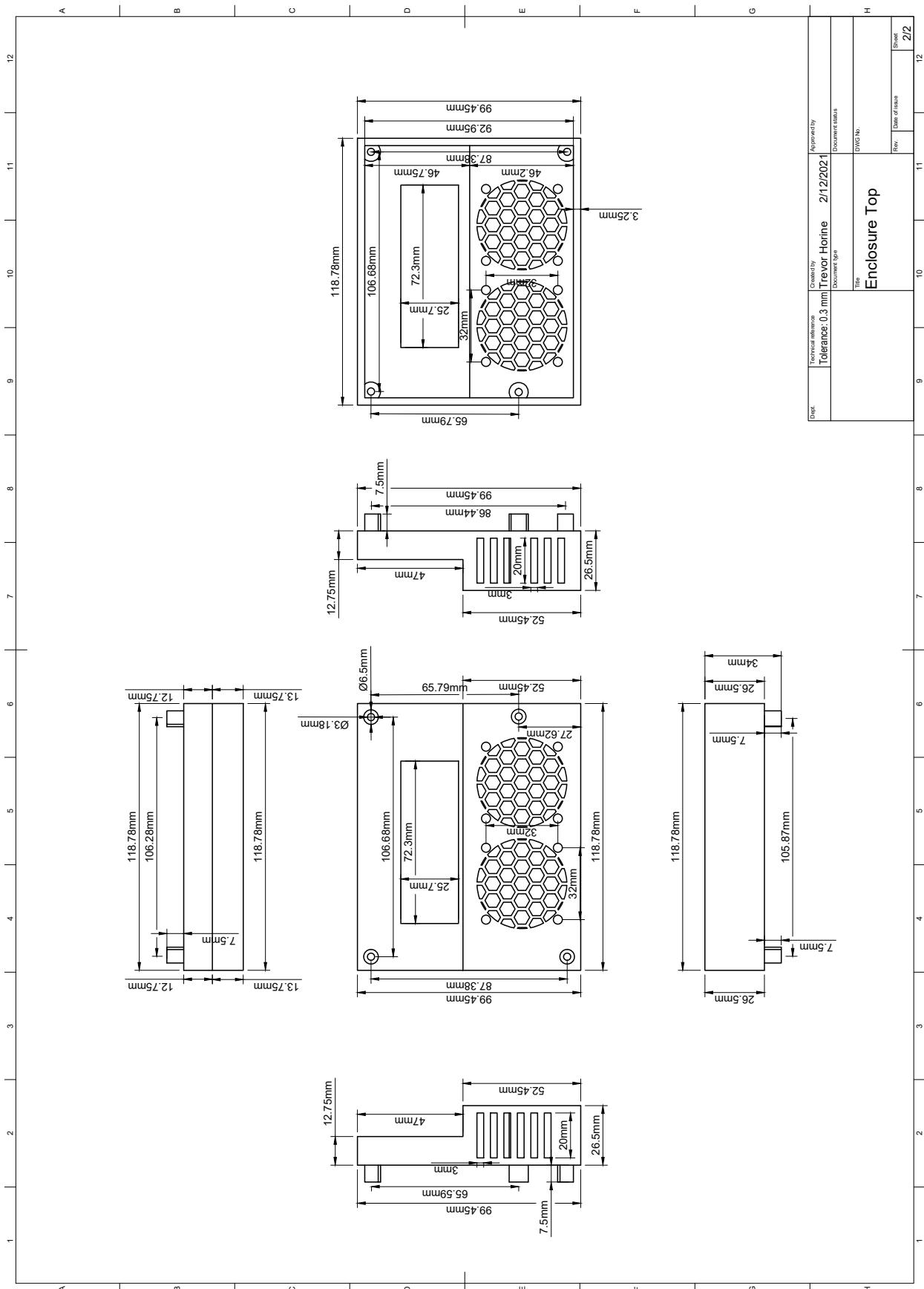


Figure 23: Mechanical drawing of the top half of the enclosure designed to hold the PCB.

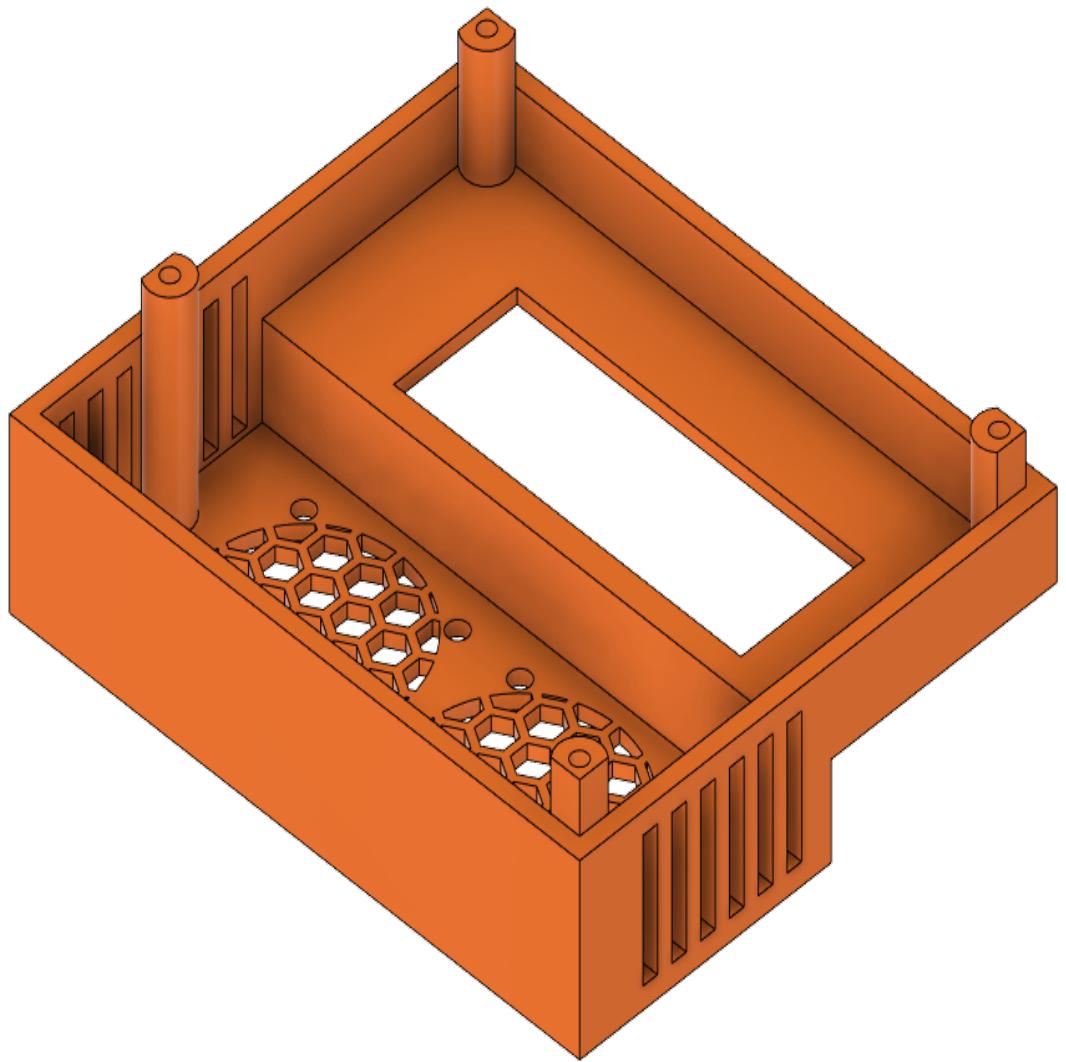


Figure 24: This is a rendering of the 3D model of the top half of the enclosure.



Figure 25: This is an image of the final enclosure with the built PCB inside.

5 PCB Information

5.1 PCB Block Diagram

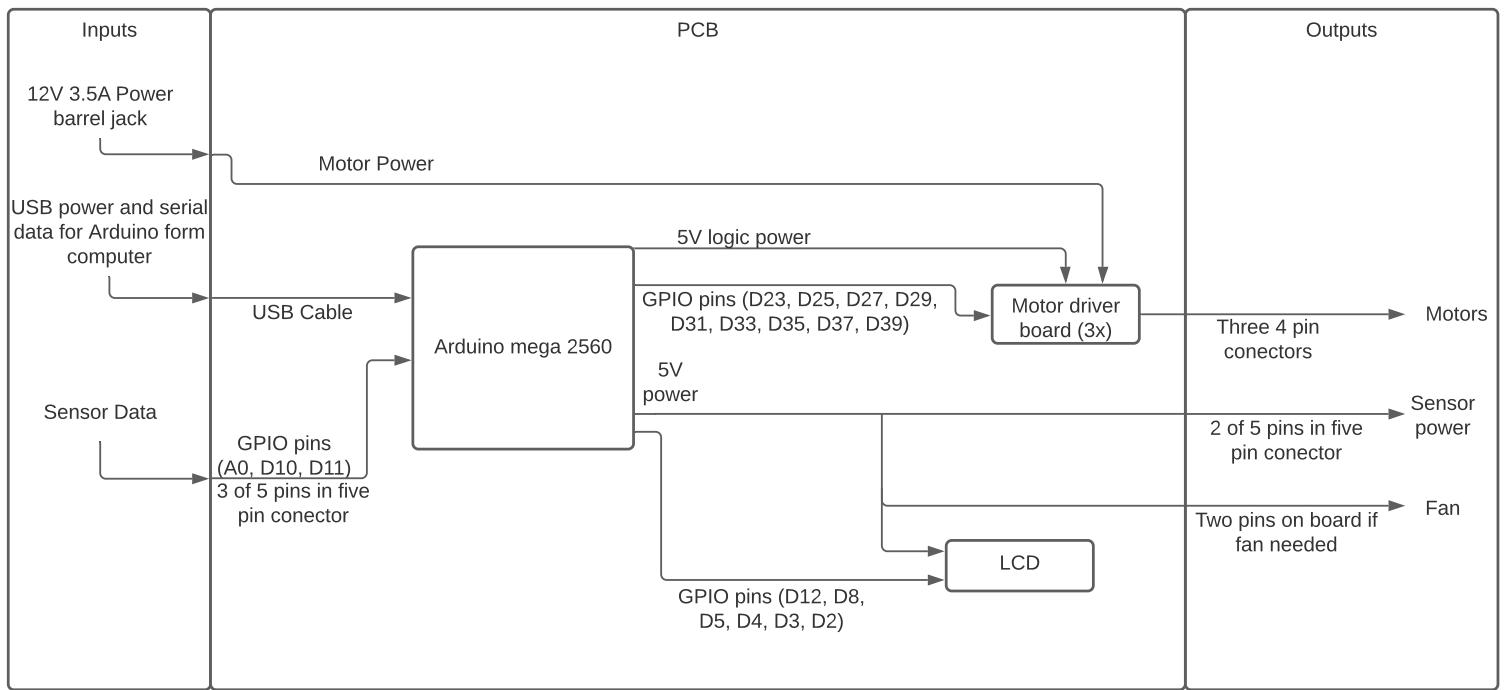


Figure 26: Block Diagram of the PCB with inputs in the inputs box on the left, outputs in the output box on the right and the blocks that make up the PCB in the middle section labeled PCB.

5.2 PCB Schematics

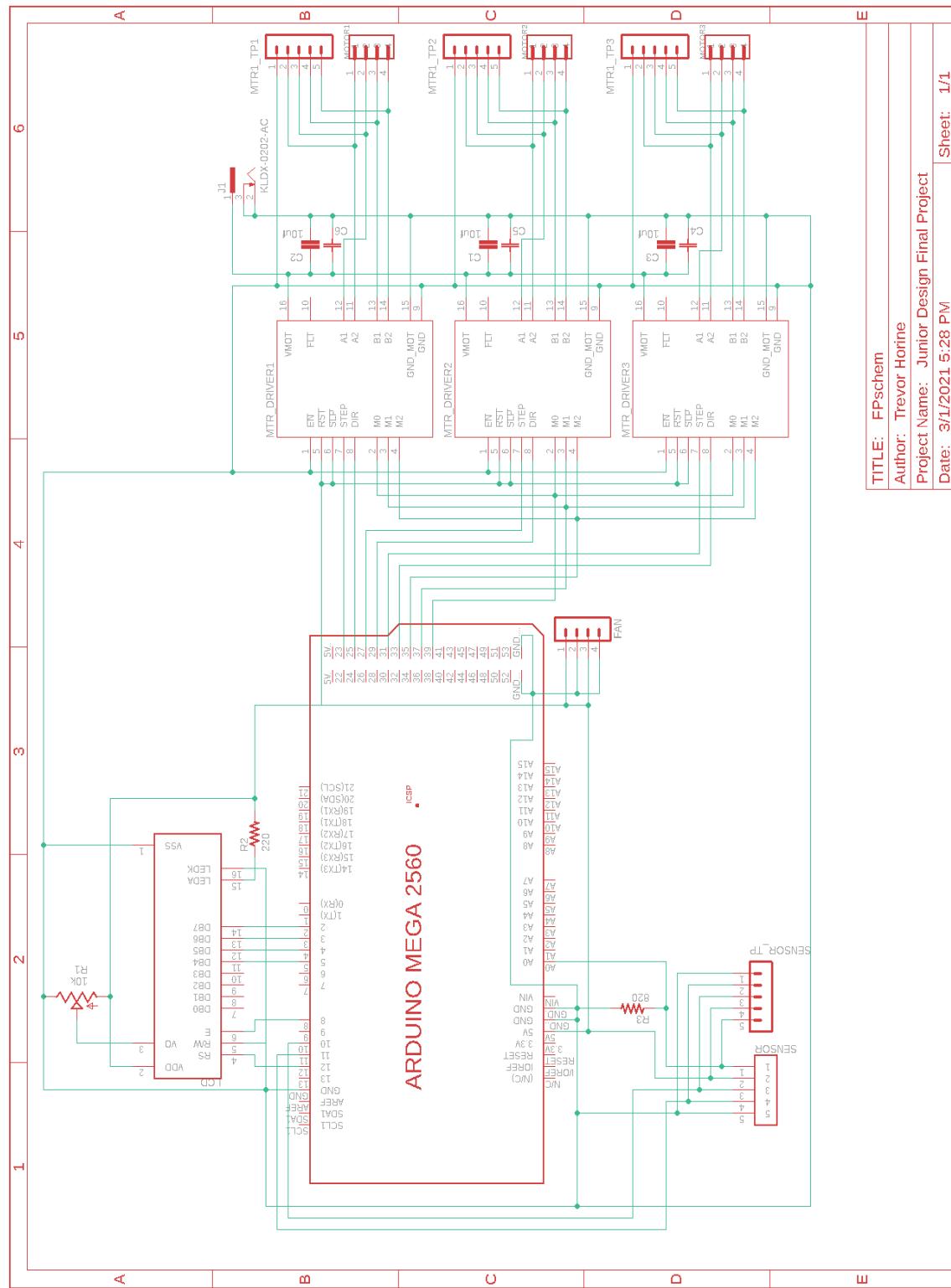


Figure 27: Detailed schematic control board, used for design layout of the PCB, which is designed as a breakout for an Arduino MEGA 2560 R3.

5.3 PCB Interface Table

Interface table	
Interface	Properties
Inputs	
USB	Supplies 5V power to Arduino. Also used a serial communication between computer and Arduino
12V Power	12V, 3.5 A power supplied to board via a barrel jack for the motor drivers.
Sensor Inputs	Three of the five pins in the 5 pin sensor conector. The light sensor goes to GPIO pin A0, and RFID goes to GPIO pins D10 and D11.
Outputs	
Motors	Three 4 pin connectors that connect the motors to the PCB. Each of these connectors is attached to a different motor controller
Fan Power	These are a few pins on the board that are connected to 5V and GND so a fan could be added to help with cooling if needed.
Sensor Power	The remaining two pins in the 5 pin sensor connector to carry 5V and ground to the sensors on the payload.
LCD	16 pin 2x16LCD attached to GPIO pins D12, D8, D5, D4, D3, D2, 5V and GND. This will be used for debugging. (displaying coordinates, or sensor values.)

Figure 28: list of input and outputs, as well as some of their properties or what they will be used for.

5.4 Eagle Layout and Board Dimensions

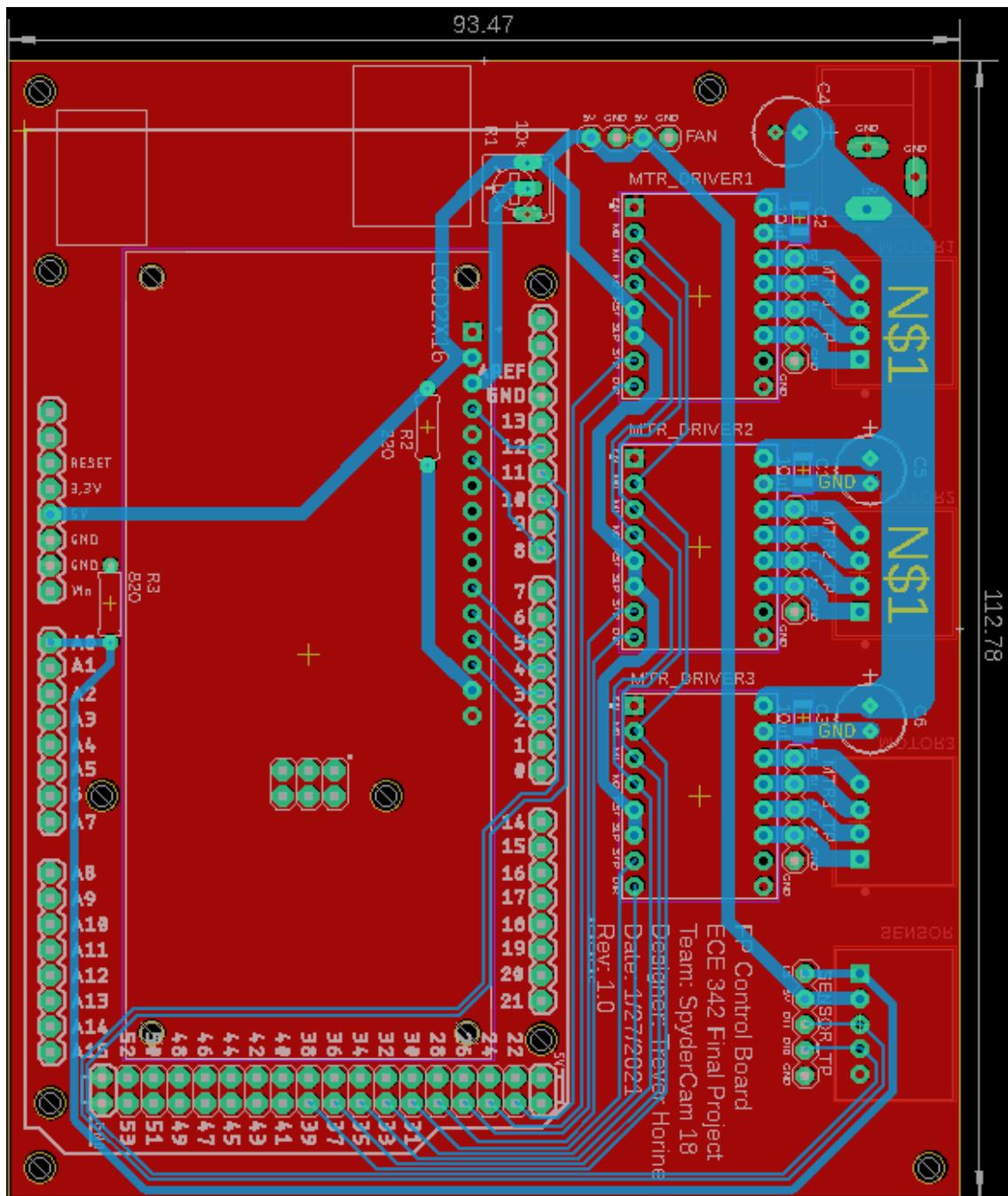


Figure 29: Layout of the PCB board built from the schematic in Figure 27, red is the bottom layer and a ground plane, blue is the top layer with traces for signals.

5.5 PCB Mechanical Drawing

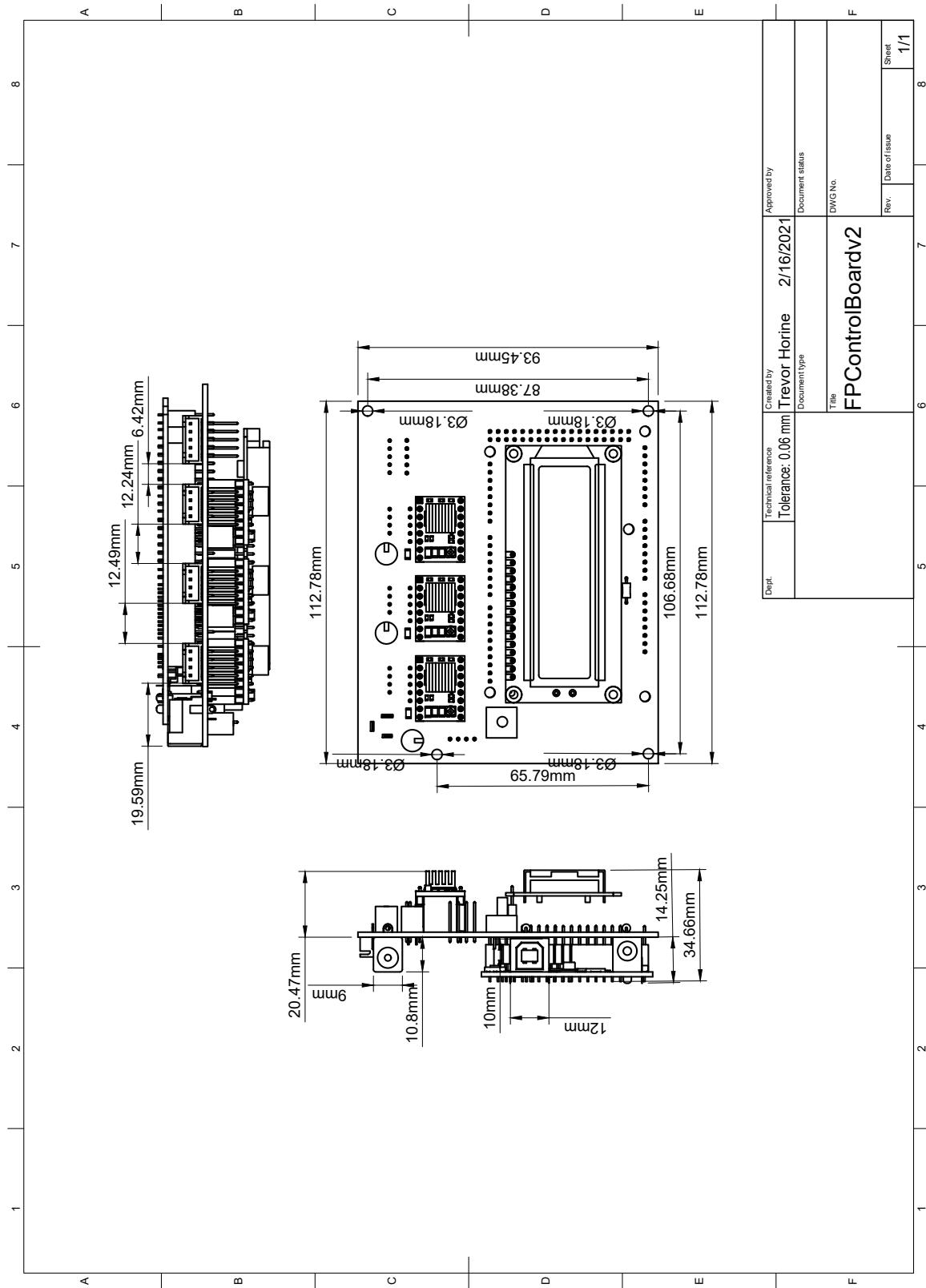


Figure 30: Mechanical drawing of PCB, with dimensions and locations of mounting holes

5.6 Board Profile

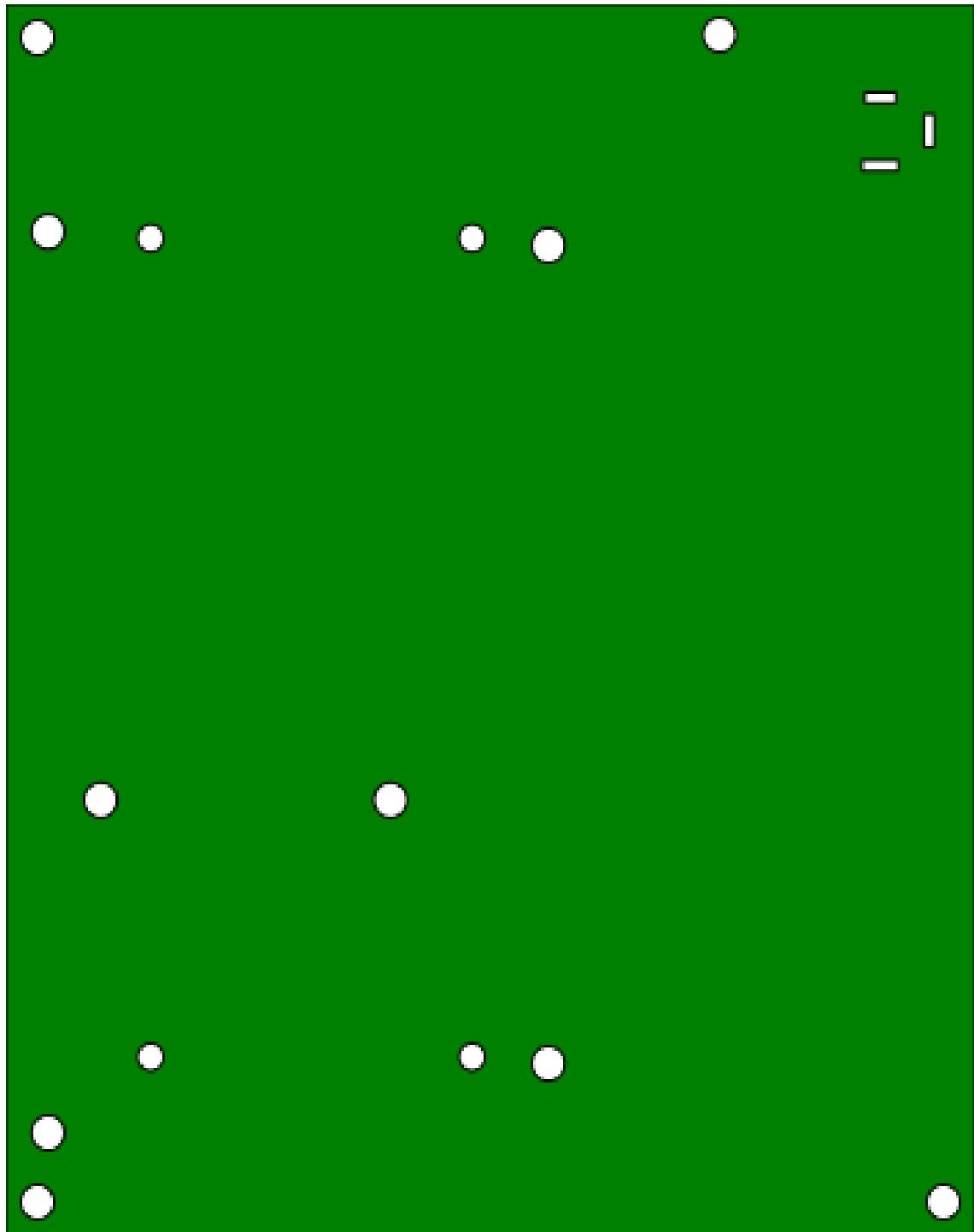


Figure 31: This is a rendering of the board profile. This image was generated from the Gerber files.

5.7 Top Silkscreen

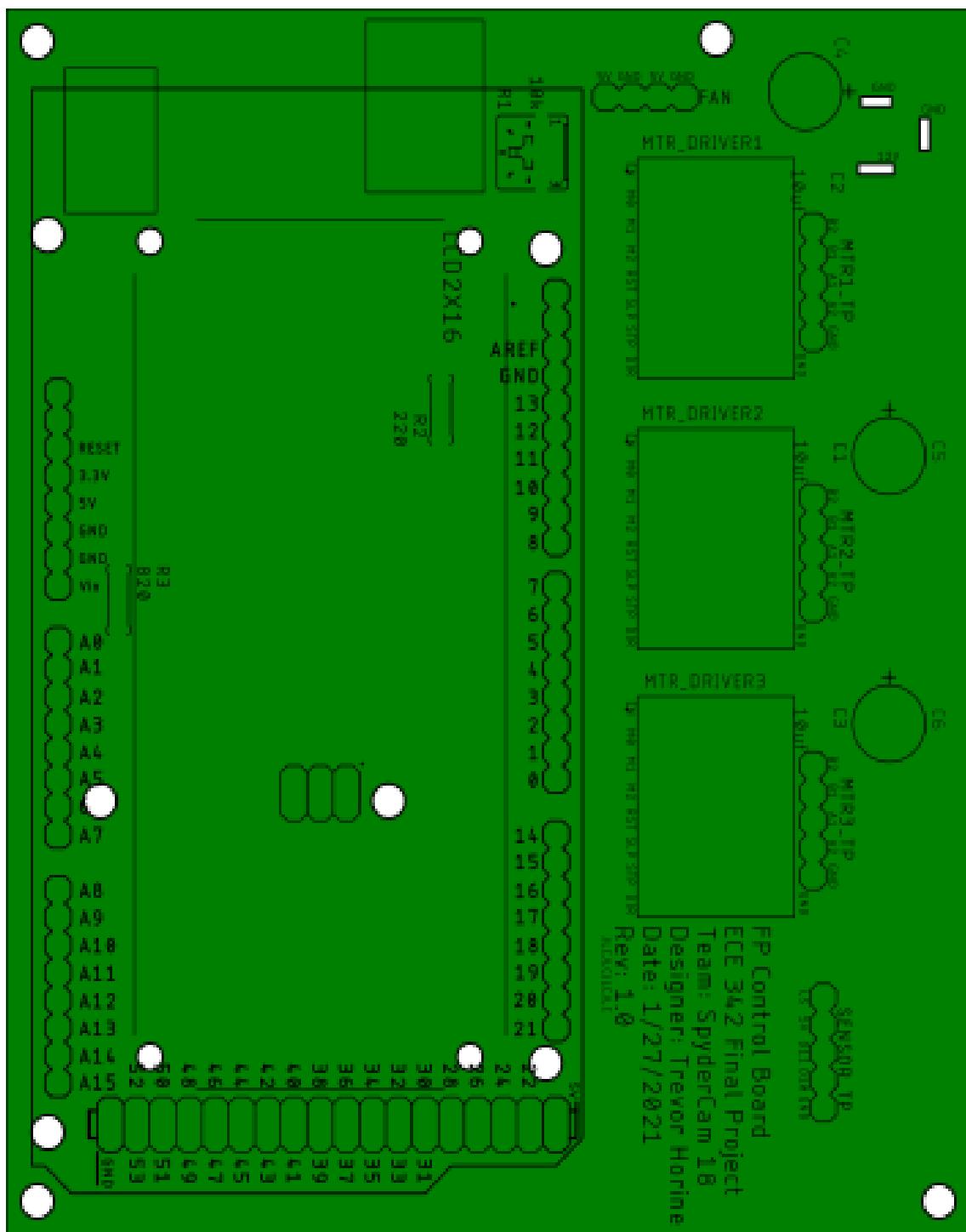


Figure 32: This is a rendering of the top silkscreen layer on top of the board profile. This image was generated from the Gerber files.

5.8 Top Copper

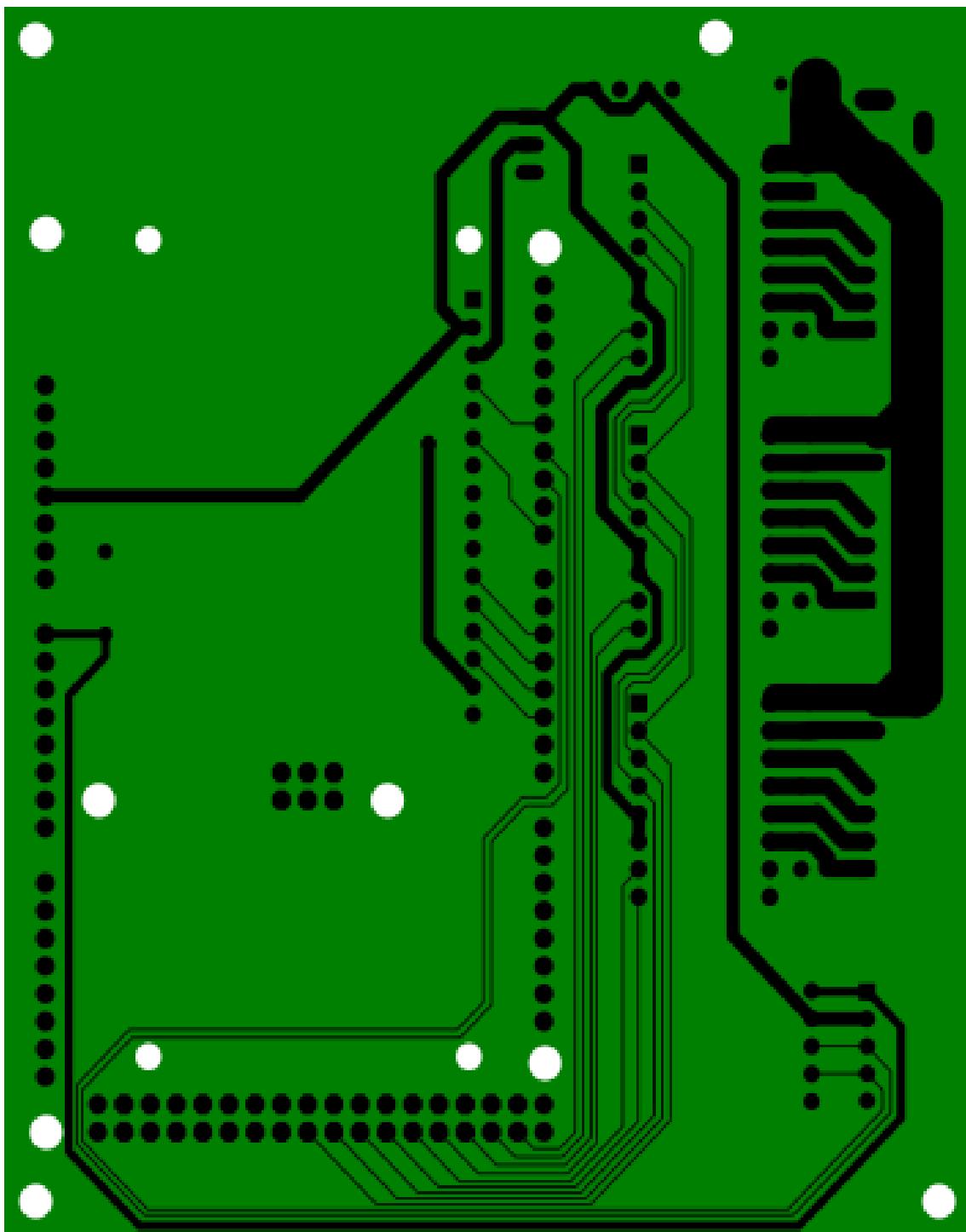


Figure 33: This is a rendering of the top copper layer on top of the board profile. This image was generated from the Gerber files.

5.9 Top Soldermask

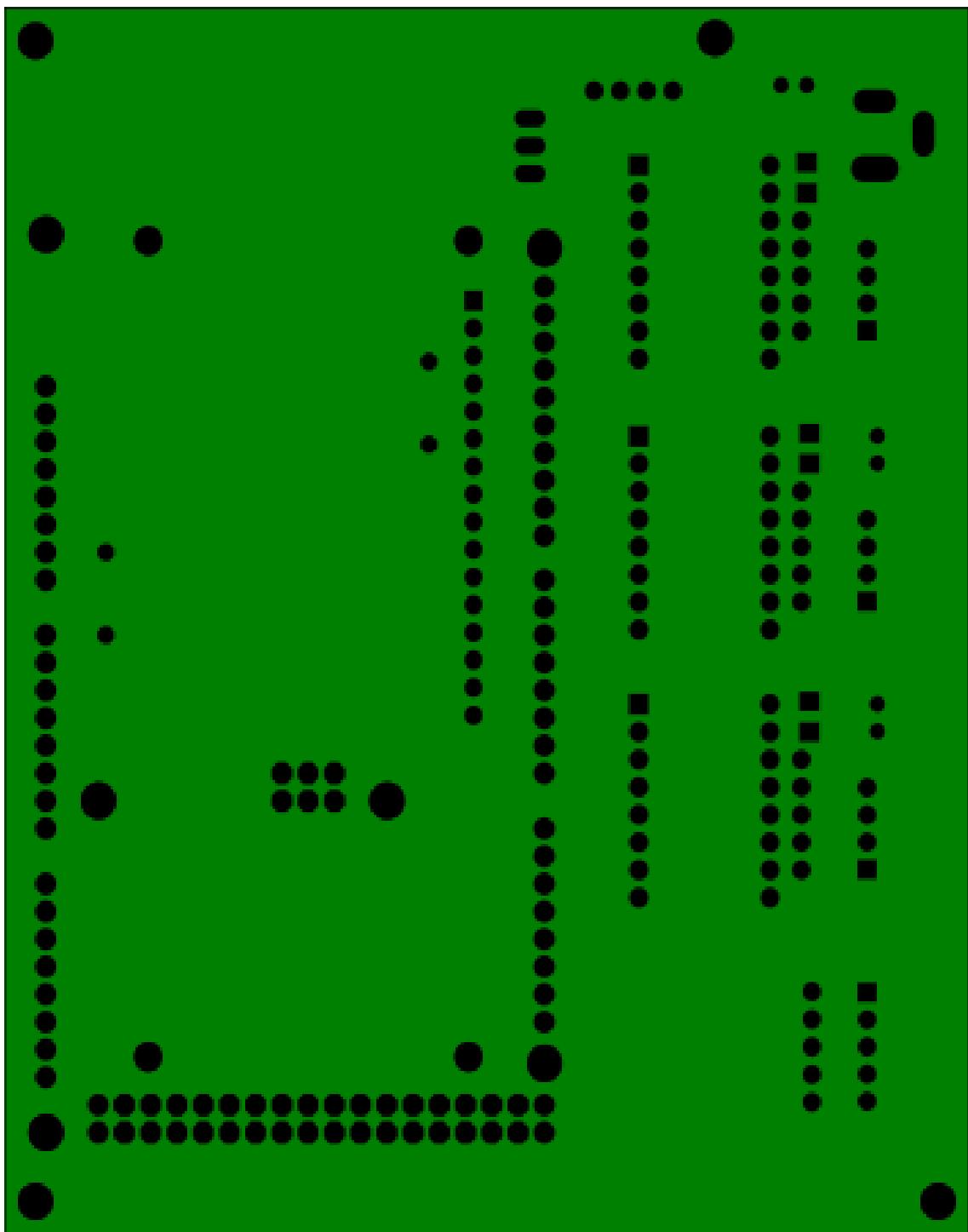


Figure 34: This is a rendering of the top soldermask layer on top of the board profile. This image was generated from the Gerber files.

5.10 Top Soldermask And Silkscreen

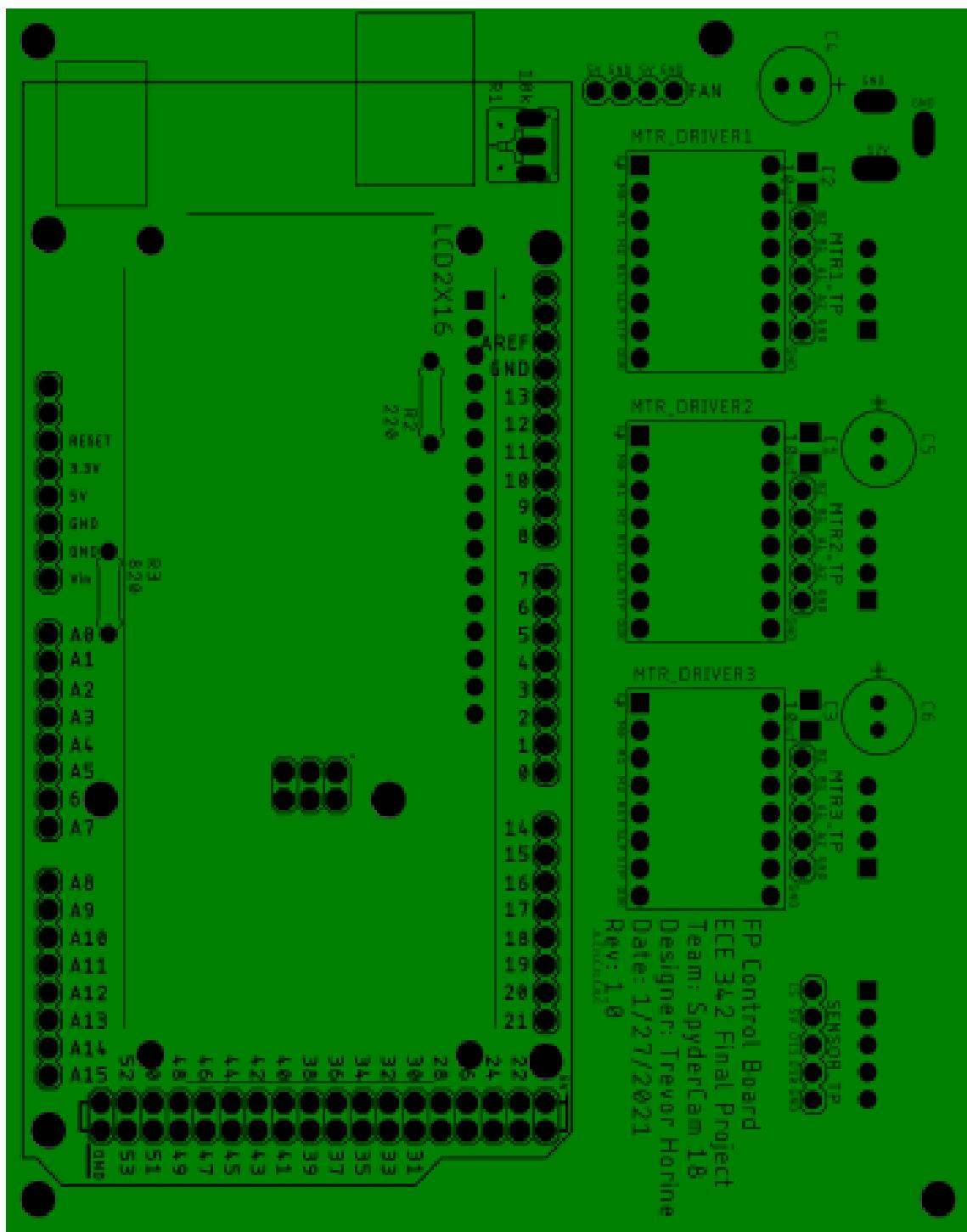


Figure 35: This is a rendering of the top soldermask layer and the top silkscreen layer on top of the board profile. This image was generated from the Gerber files.

5.11 Bottom Silkscreen

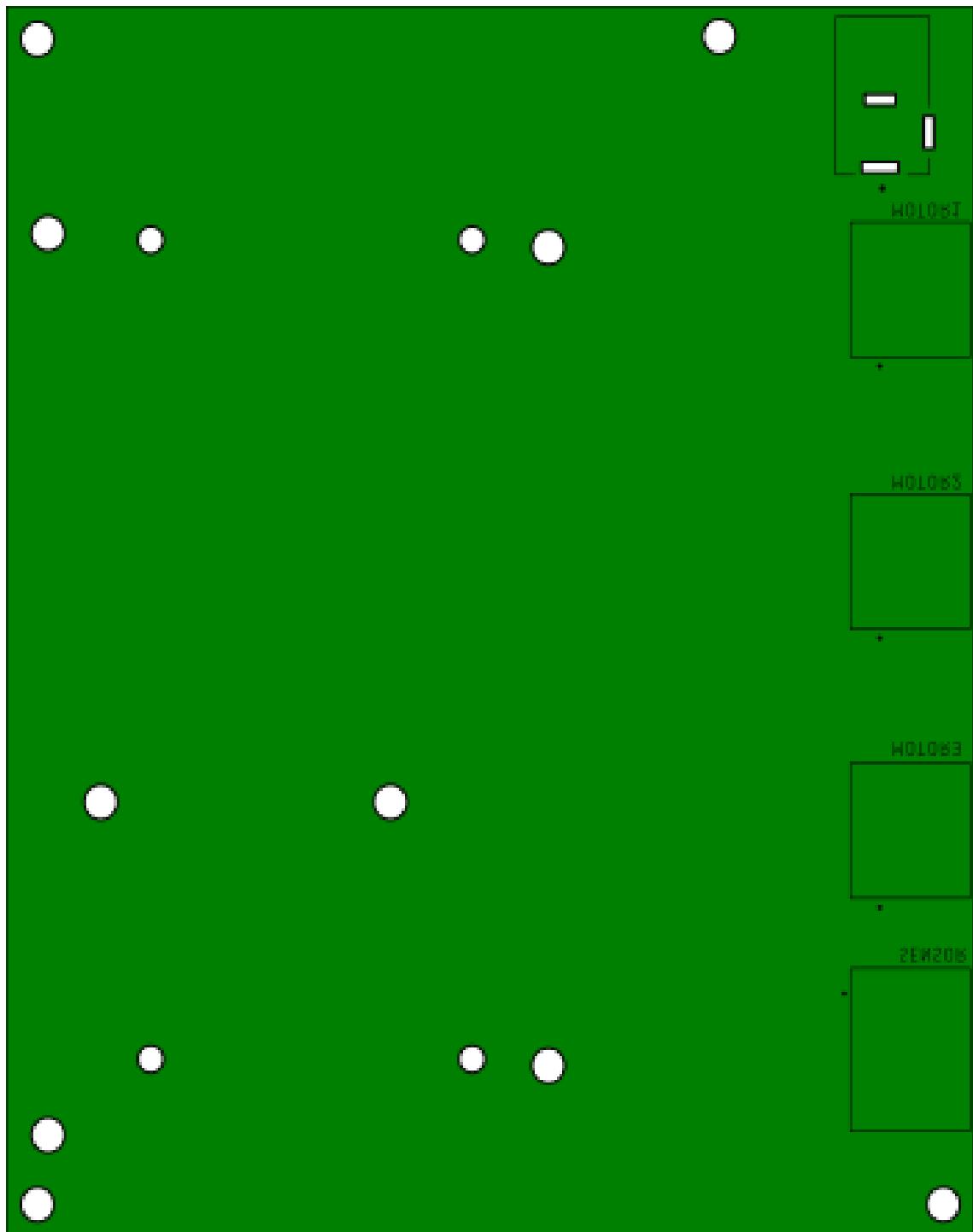


Figure 36: This is a rendering of the bottom silkscreen layer on top of the board profile. This image was generated from the Gerber files.

5.12 Bottom Copper

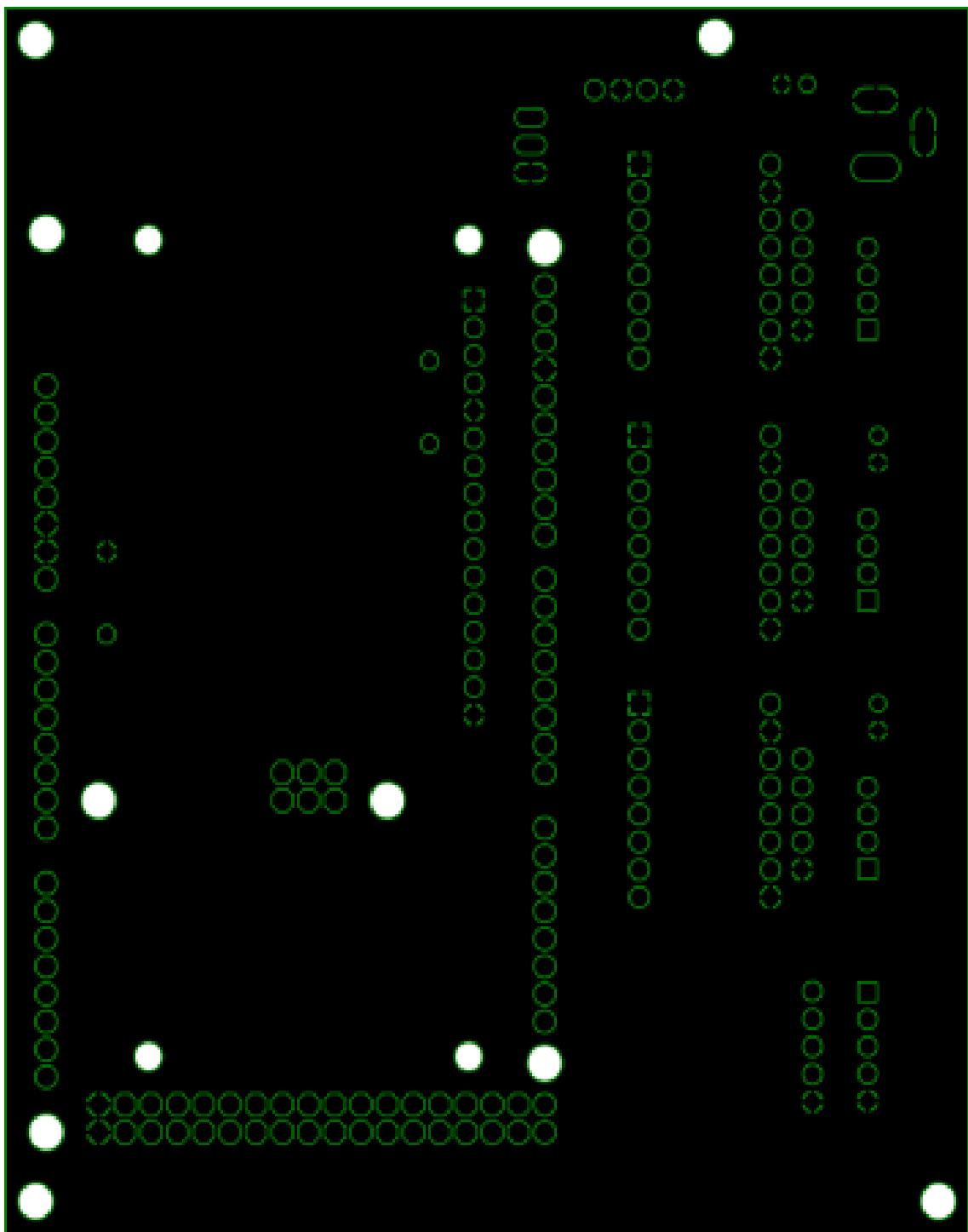


Figure 37: This is a rendering of the bottom copper layer on top of the board profile. This image was generated from the Gerber files.

5.13 Bottom Soldermask

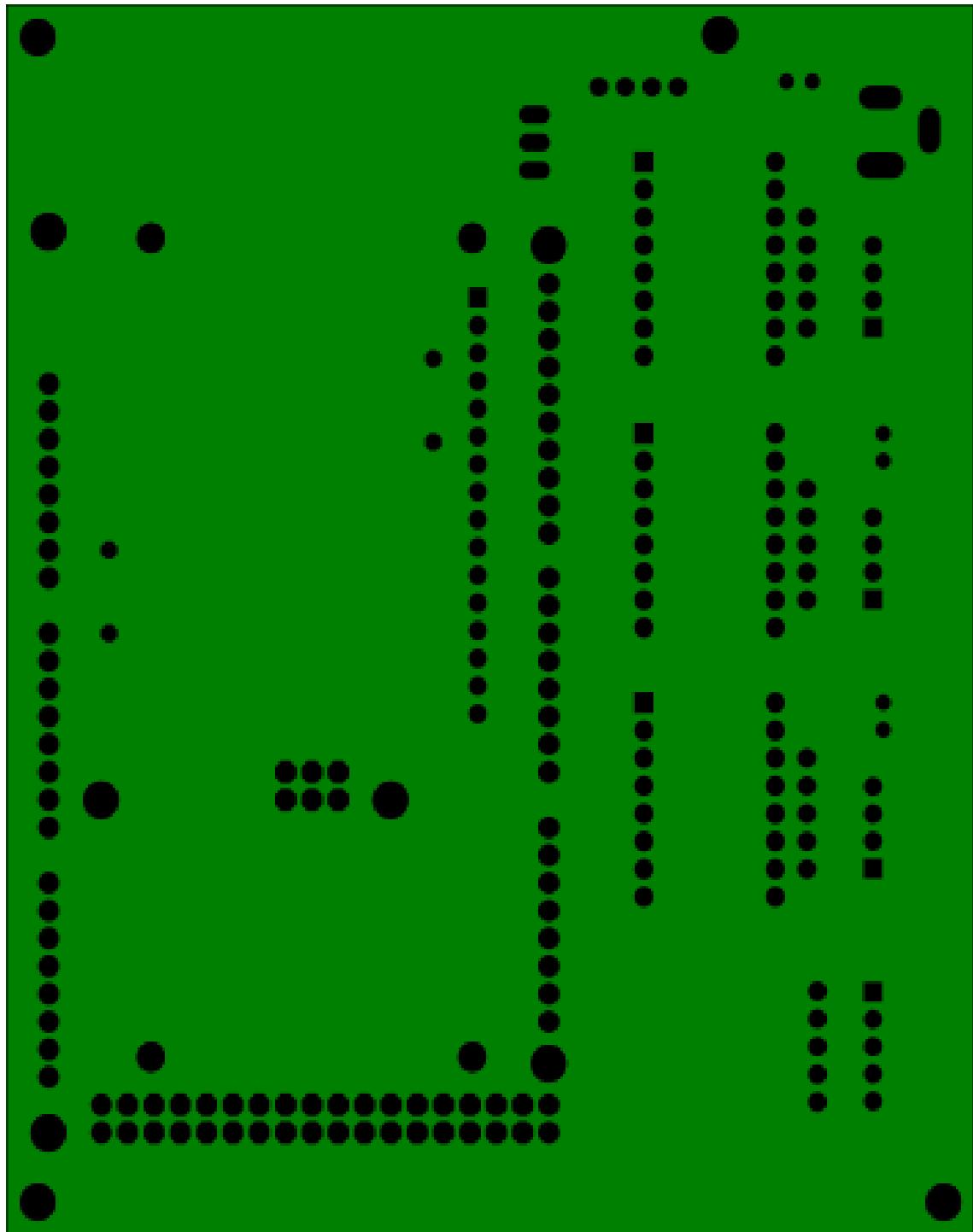


Figure 38: This is a rendering of the bottom soldermask layer on top of the board profile. This image was generated from the Gerber files.

5.14 Bottom Soldermask and Silkscreen

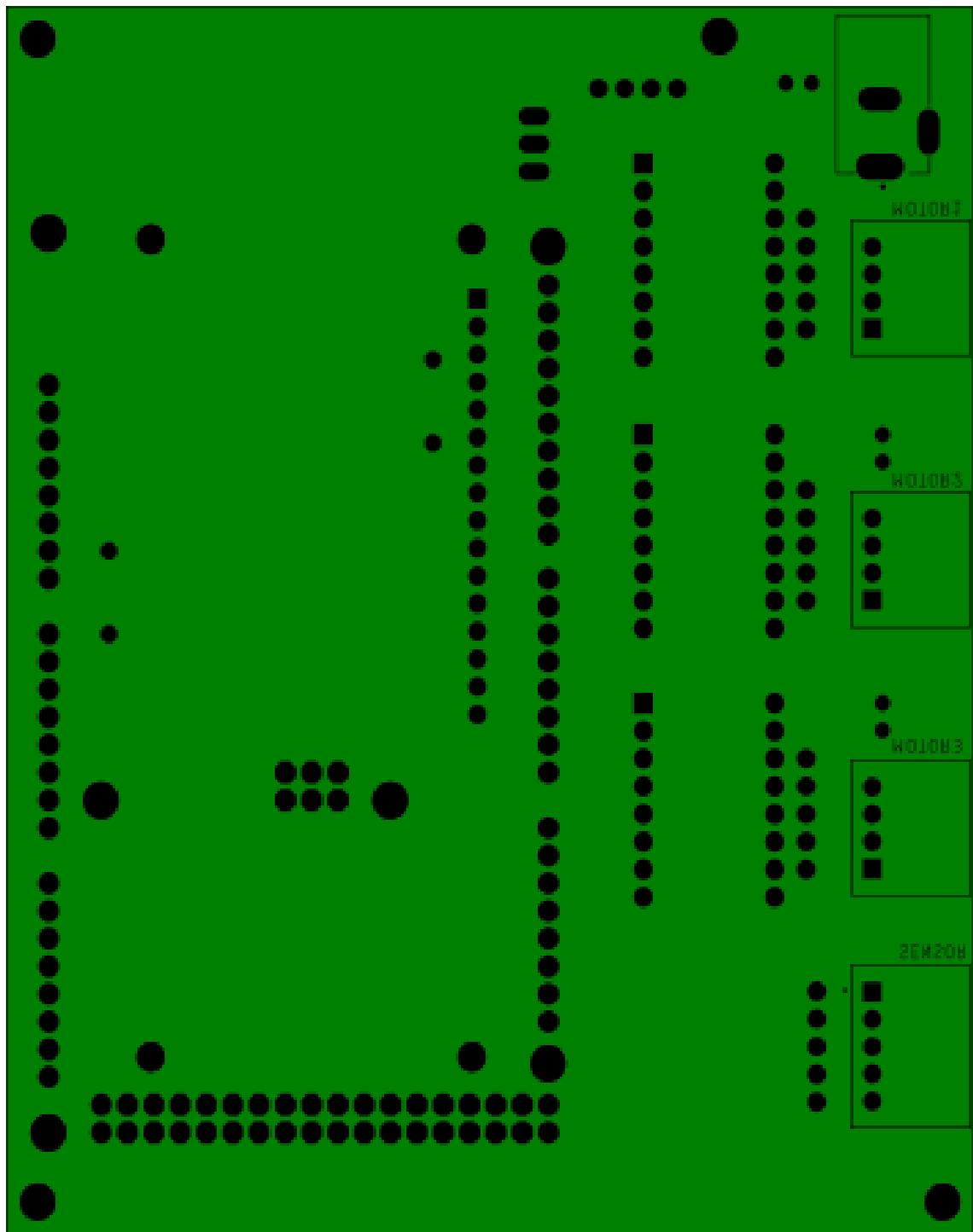


Figure 39: This is a rendering of the bottom soldermask and silkscreen layers on top of the board profile. This image was generated from the Gerber files.

5.15 Top Gerbers

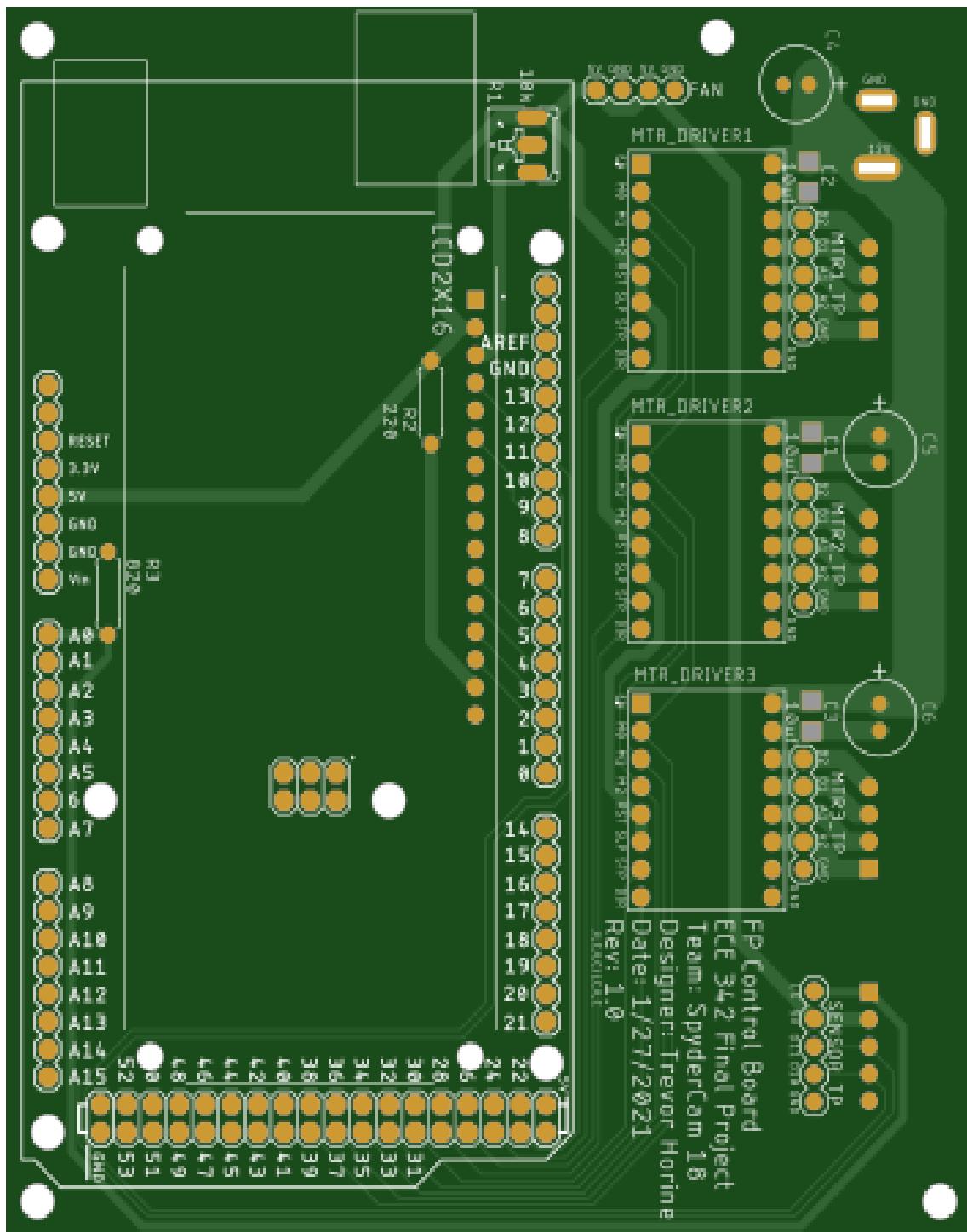


Figure 40: This is a rendering of the top layer Gerber files placed on top of each other. The white is the text and lines are the silkscreen, the gold is the soldermask, light green is the copper traces, and gray is the solderpaste. All of this is on top of the profile of the board or the darker green area, the black holes are holes in the board.

5.16 Bottom Gerbers

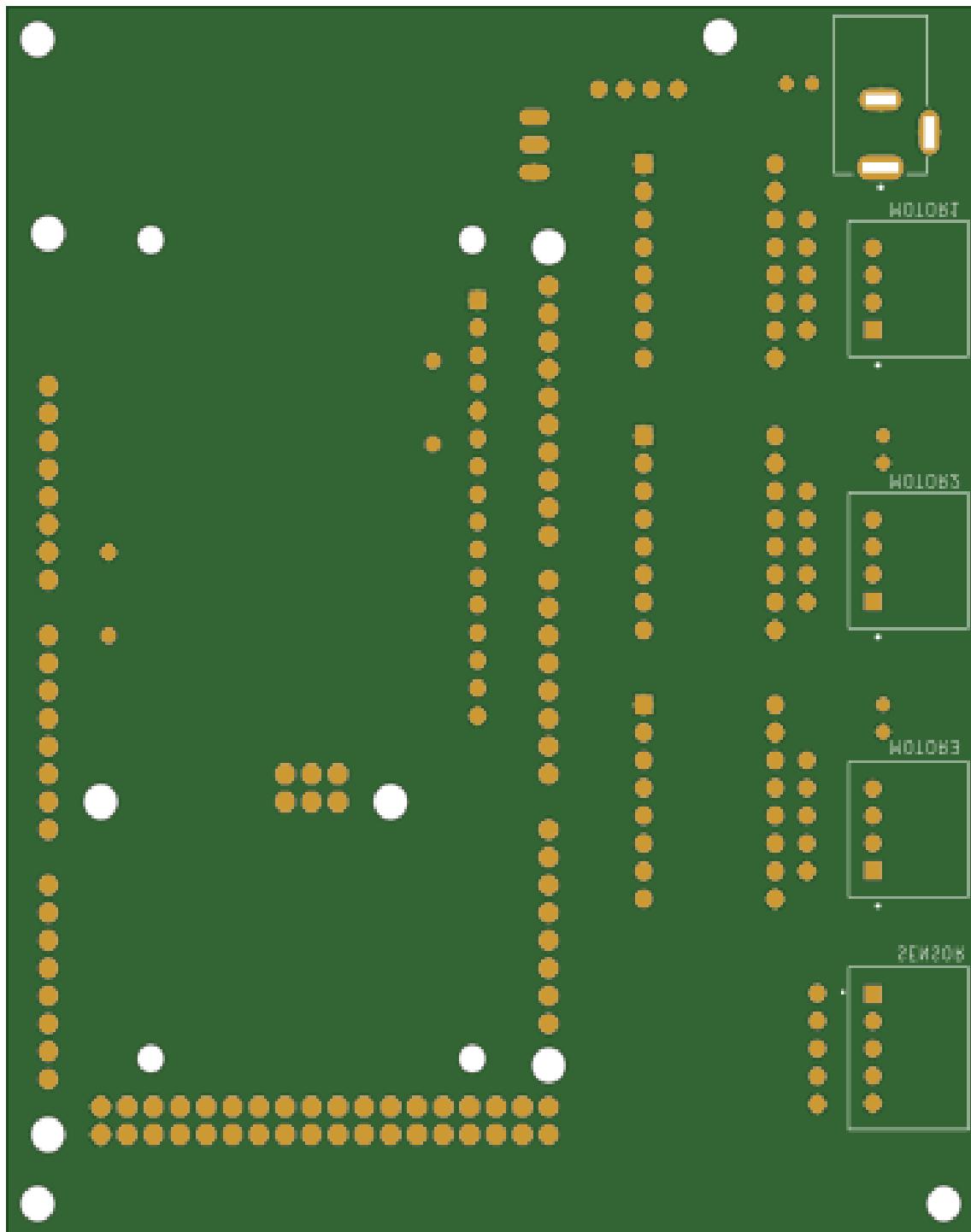


Figure 41: This is a rendering of the bottom layer Gerber files placed on top of each other. This layer has no white silkscreen, the gold is the soldermask, light green is the copper traces, and there is no gray solderpaste on this layer. All of this is placed on the profile of the board or the darker green area, the black holes are holes in the board. It may be hard to tell but the is only a little dark green around the soldermask and the edges of the board and holes because the bottom of this board is a copper ground plane.

5.17 3D Model

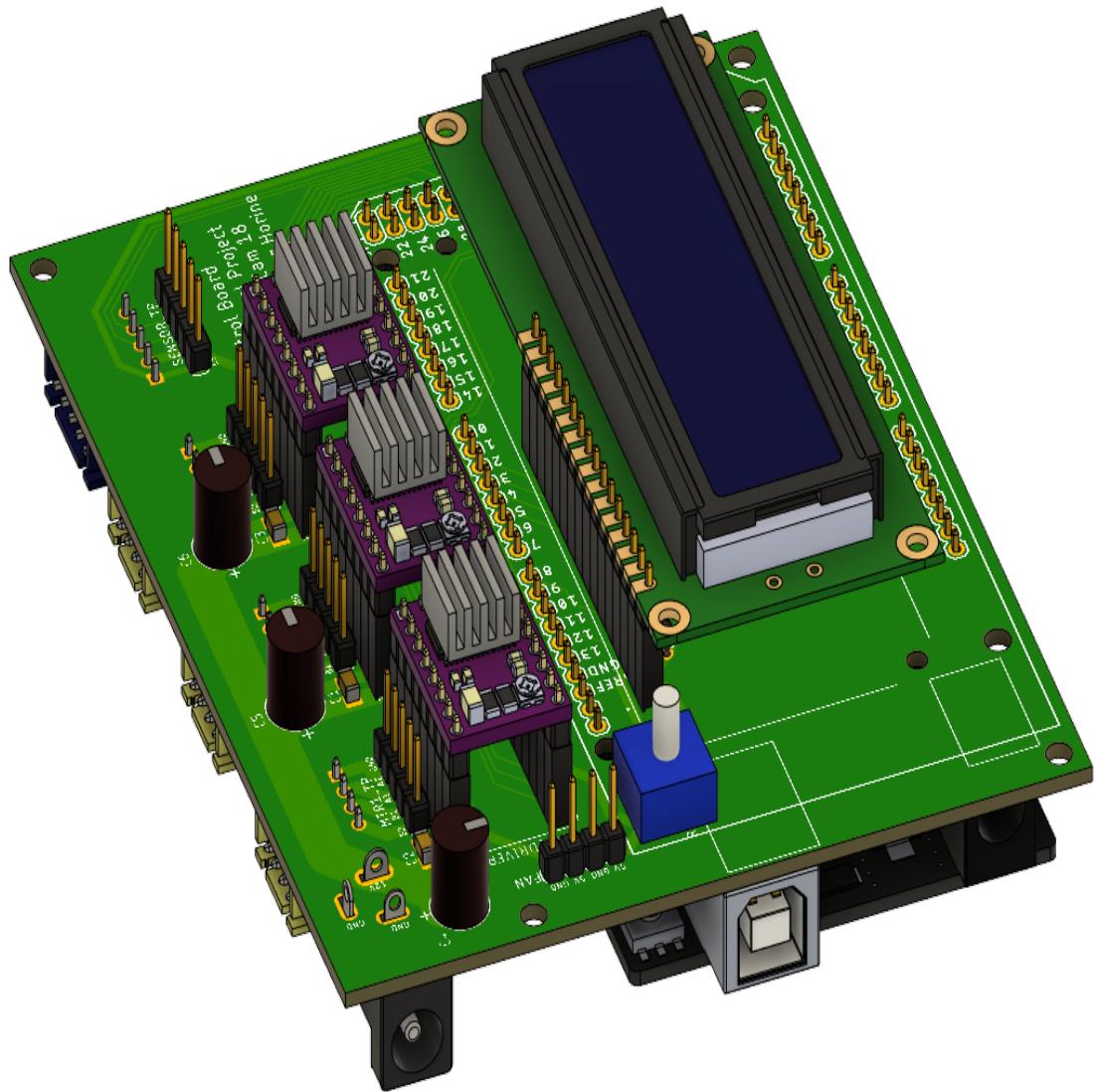


Figure 42: This is a rendering of the 3D model produced from the board designed with components added to give an idea of what the board will look like assembled. It will also be used to design the enclosure.

5.18 Assembled Board

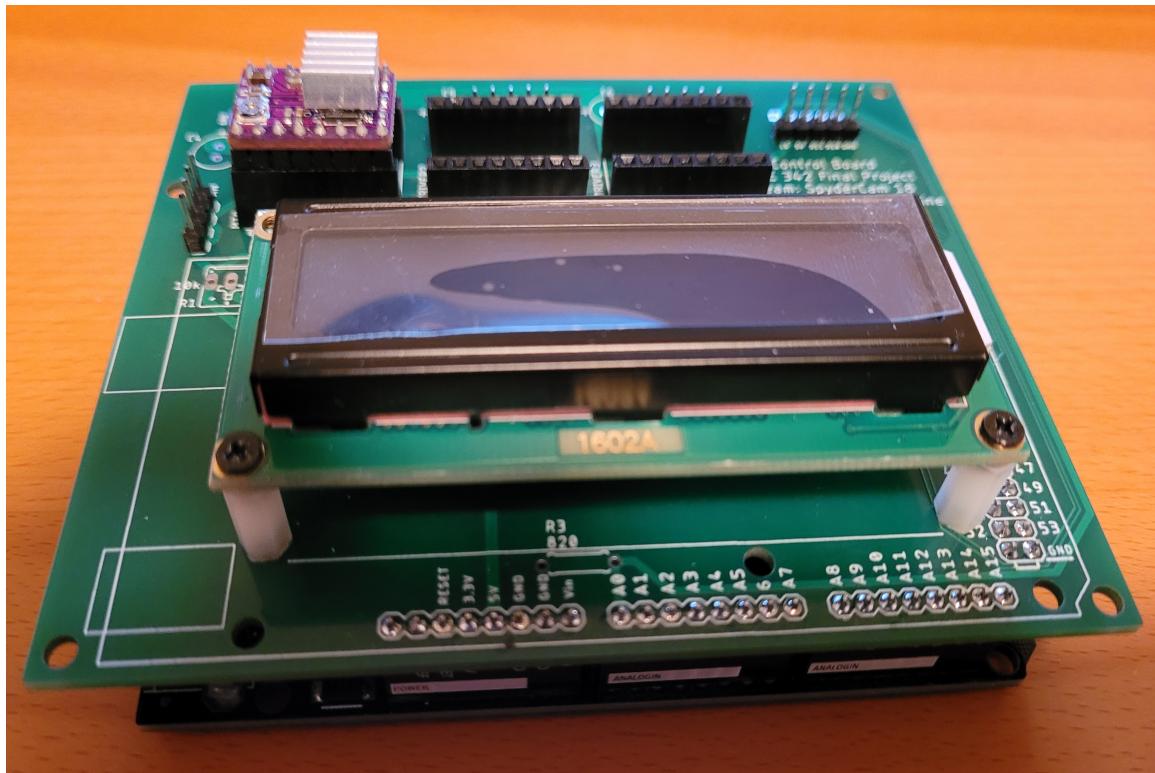


Figure 43: This is the board with some of the components added to it.

6 Parts Information and Bill of Material

Part	Value and units	Quanitity	Price	Notes
PCBs				
Stepper drivers		5	9.99	Datasheet was found for a board that appears to be same as there was not a datasheet on the amazon page. DRV8825 Chip data sheet
Pin Headers		150	0	Will use pin headers from previous classes 64 female, 86 male
Barrel Jack		1	0.53	Used to conect wall wart to board
LCD		1	3.25	Used for debug and display
S5B-XH(LF)(SN)	Conector	1	0.31	Conector to attach light sensor and RFID 5 pin right angle conector
S4B-XH-A(LF)(SN)	Conector	3	0.81	Conectors to attach motors to board each one is a 4 pin right angle conector
Arduino Mega 2560	Arduino	1	16.99	Arduino, this is the brain
POTENTIOMETER	10k	1	2.9	Used for contrast on LCD
Resistor	220	1	0	Resistor for LCD
Resistor	10K	1	0	Resistor for voltage divider with photocell to measure light level
Capacitor	100μ	3	0.69	Used on the 12 volt power source before the motor drivers to help with current draw
Capacitor	10μ	3	0.66	Used on the 12 volt power source before the motor drivers to help with current draw. These may not be needed but pads were added so they could be added later if needed.
Fan	Fan	2	6	40mmx40mmx10mm fan should it be needed to keep motor drivers from heating up to much.
Boards		5	10	Minimum order quantitay is 5 baords.
PCB Enclosure		1	5	3D printed enclosusre for the PCB
M3, 35mm screws		4	2.48	Screws used to hold PCB in place and the enclosure colsed.
PAYOUT				
Photocell		1	0.89	photocell to be used in voltage divider for measuering light level
RFID breakout		1	10	
Female Cable Connector Housing		1	0.12	
Ribbon Cable	3 ft, 6 wire 24awg	1	5.05	
#2 screw- RFID board mount		2	0.14	Used to mount board to payout
#6-32 1/2" set screw		1	0.19	Used to secure writing utensil
Payload Enclosure- Top		1	5.44	3D printed enclosure for the payload sensors and writing impliment through Corvallis3d.
Payload Enclosure- Bottom		1	14.98	3D printed enclosure for the payload sensors and writing impliment through Corvallis3d.
Mechanical				
Stepper motors		3	24.99	Datasheet info on the amazon page
Stepper Motor Brackets		5	13.99	
2" Aluminum Round Stock	1 ft		0	Used scrap aluminum
Aluminum Tube Stock 1/8" wall, 1" nominal (ID)	3.375 ft		0	Used scrap aluminum
15/32" Plywood sheet	3.5' x 3.5'		0	Used scrap wood
1/4"-20 x 1.25" Socket Head Cap Screw		9	1.71	Pylon attachment hardware
1/4" Washer		9	0.63	Pylon attachment hardware
1/4"-20 Nut		9	0.81	Pylon attachment hardware
Fishing line			0	Monofilament 9lb test fishing line was used as a strong light weight string to conect the payload to the motors.
			Total Cost	
			138.55	

Figure 44: This is the bill of materials for the system. The bill of materials also lists component's values, name on board, quantities and costs.

7 Time Report

7.1 Time sheet

Name	Date	Time spent (Hours rounded to nearest .5)	What did you work on
All	1/8/2021		4 Team Meeting
All	1/10/2021		4 Team Meeting
All	1/11/2021		4 Meet with mentor an debrief
All	1/13/2021		2 Recitation work time
Trevor	1/13/2021		1 CAD Drawings
All	1/14/2021		8 Team Meeting
Ben	1/14/2021		2 Hardware Research and order
Miles	1/12/2021		3 MATLAB Code
Trevor	1/15/2021		4 Schematics, Sensor payload, and PCB
Trevor	1/16/2021		6 Schematics, Sensor payload, and PCB
Trevor	1/17/2021		5 Schematics and PCB
Ben	1/17/2021		6 Mechanical Component Design & Fabrication
Ben	1/20/2021		2 Mechanical Component Design & Fabrication
All	1/24/2021		12 Team meeting and block checkoff prep
Miles	1/26/2021		8 MATLAB GUI
Ben	1/26/2021		3 Mechanical assembly testing
Trevor	1/26/2021		5 PCB finishing touches and ordering
Trevor	2/5/2021		3 Putting the PCBs together
Ben	2/6/2021		6 Payload Design
Trevor	2/1-9/2021		18 Enclosure design
Ben	2/8/2021		3 Payload Redesign for 3d printing
Trevor	2/11-2/13		3 Enclosure mechanical drawings
Ben	2/13/2021		4 Payload implementation and testing
Trevor	2/15/2021		1 Enclosure
Miles	2/15/2021		4 MATLAB Arduino Serial Comm
Miles	2/17/2021		4 MATLAB Arduino Serial Comm
Ben	2/18/2021		2 Hardware integration testing
Felipe	1/17/2021		12 Arduino Control Software Design/Implementation
Felipe	2/7/2021		8 Arduino Motor Control Firmware Design/Implementation
Felipe	2/14/2021		9 Testing Arduino Software
All	2/20/2021		12 Putting together the final hardware and troubleshooting
Miles	2/20/2021		3 Finishing serial interface and reading Arduino code
Ben	2/21/2021		3 Testing Hardware/software integration
Trevor	2/26/2021		2 CAD Drawings
All	2/27/2021		4 Debug and testing
Ben	2/28/2021		6 MATLAB testing, arduino testing, redesigning payload for backup
Miles	2/28/2021		2 MATLAB debugging
All	2/28/2021		8 System debugging and testing
Trevor	3/1/2021		3 Documentation
Ben	3/1/2021		1 Documentation
Trevor	3/3/2021		2 Documentation
		Total Manhours	
	Percentage per Person	202	
Trevor	33.42	67.5	
Ben	25.99	52.5	
Miles	19.06	38.5	
Felipe	21.53	43.5	

Figure 45: This is the time sheet used to track hours on this project.

7.2 Percentage By Person

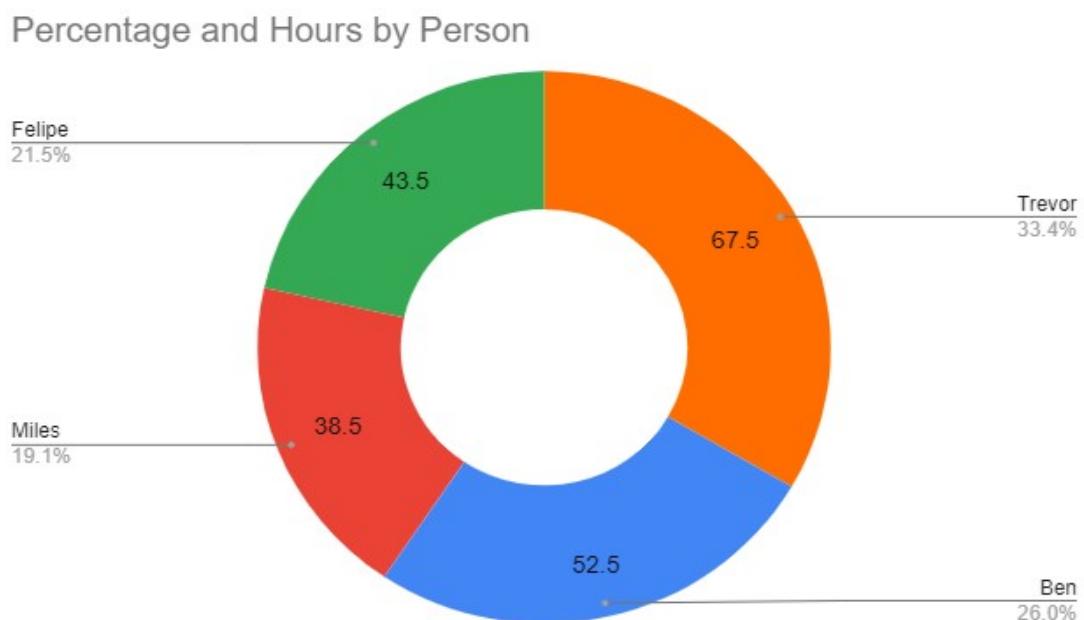


Figure 46: This graph plots the hours spent on the project by person.

7.3 What We Worked On

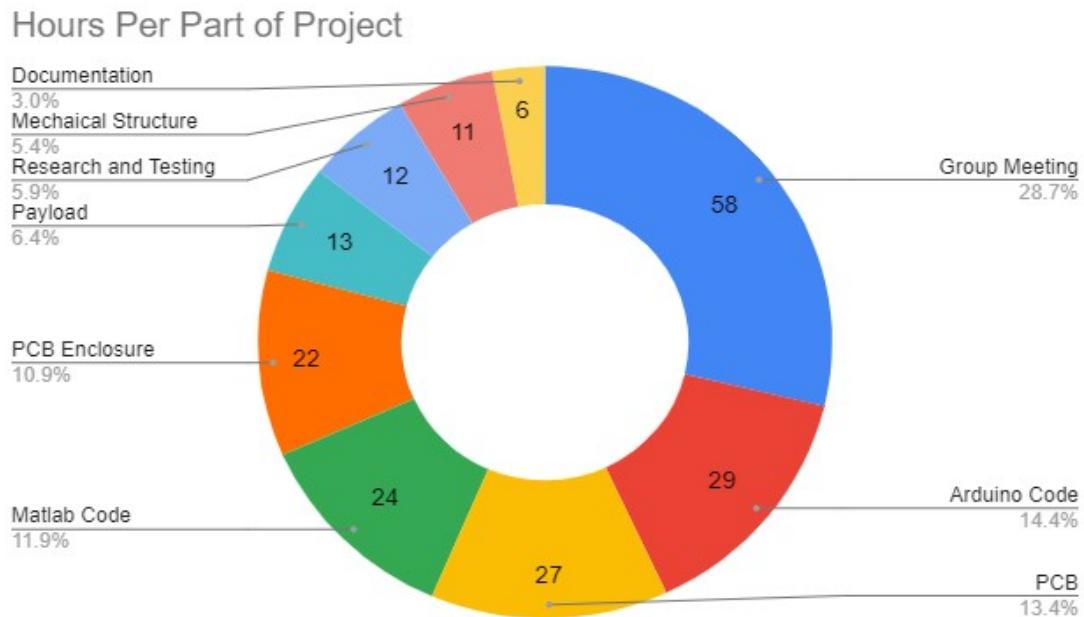


Figure 47: This graph plots the hours spent on each part of the project.

8 Appendix

8.1 Arduino Code

```
1  /*
2   * Arduino Control Software Block & Motor Control Firmware
3   * Author: Felipe Orrico Scognamiglio
4   * For: Oregon State University - Junior Design - Final Project
5   * Spydercam18
6   * Date: 03/01/2021
7   * Version: BETA 1.25 - FINAL
8   */
9  /*
10  Known Problems:
11  - After M2 command, Incremental Coordinate mode will not work
12  properly
13  and C1 will not be able to report correct coordinates
14  - Inputting M2 and M6 right after the other has undefined
15  behaviour
16  - Current X, Y, Z positions are not available after receiving
17  M2/M6, only
18  after another G0 or G1 is executed. This happens because it is
19  hard to extrapolate
20  the current position only based on current thread lengths.
21  Instead, the program will
22  update after another G0 or G1 command.
23 */
24
25 ////////////////LCD SETUP/////////////
26 #include <LiquidCrystal.h>
27 const int rs = 12, en = 8, d4 = 5, d5 = 4, d6 = 3, d7 = 2;
28 LiquidCrystal lcd(rs, en, d4, d5, d6, d7);
29 ////////////////LCD SETUP/////////////
30
31 ////////////////Sensor SETUP/////////////
32 #include <SoftwareSerial.h>
33 #include "PN532_SWHSU.h"
34 #include "PN532.h"
35
36 SoftwareSerial SWSerial( 10, 11 ); // RX, TX
37 PN532_SWHSU pn532swhsu( SWSerial );
38 PN532 nfc( pn532swhsu );
39
40 const int sensor = A0;
41
42 ////////////////Sensor SETUP/////////////
43
44 ////////////////CONSTANTS/////////////
45
46 //ALL PHYSICAL VALUES ARE REPORTED IN INCHES
47 const double A_PAPER_DISTANCE = 11.583;
```

```

49 const double B_PAPER_DISTANCE = 7.2;
50 const double C_PAPER_DISTANCE = 7.2;
51
52 const double HEIGHT_PYLON_A = 11.8;
53 const double HEIGHT_PYLON_B = 11.8;
54 const double HEIGHT_PYLON_C = 11.8;
55
56 const double PAYLOAD_CENTER_THREAD_DISTANCE_A_x = 3.6;
57 const double PAYLOAD_CENTER_THREAD_DISTANCE_C_x = 1.85;
58 const double PAYLOAD_CENTER_THREAD_DISTANCE_C_y = 3.15;
59 const double PAYLOAD_CENTER_THREAD_DISTANCE_B_x = 1.85;
60 const double PAYLOAD_CENTER_THREAD_DISTANCE_B_y = 3.15;
61
62 const double PAPER_HEIGHT = 11.00;
63 const double PAPER_WIDTH = 8.50;
64
65 const double PAPER_DISTANCE_LOW_EDGE = 1.856;
66
67 const double HOME_X = 0;
68 const double HOME_Y = 0;
69 const double HOME_Z = 6;
70
71 const double INCHES_PER_STEP = 0.024662;
72 const double MAX_STEPS_PER_SEC = 182;
73
74 ////////////////////////////////////////////////////////////////////CONSTANTS/////////////////////////////////////////////////////////////////
75
76 ////////////////////////////////////////////////////////////////////VARIABLES/////////////////////////////////////////////////////////////////
77
78 double CURRENT_PAYLOAD_HEIGHT = 0;
79 double CURRENT_THREAD_LEN_A = 0;
80 double CURRENT_THREAD_LEN_B = 0;
81 double CURRENT_THREAD_LEN_C = 0;
82 double CURRENT_X = 0;
83 double CURRENT_Y = 0;
84
85 //values that are updated when there is movement
86 int OPCODE = -1;
87 double X_ADDRESS_TARGET = -1;
88 double Y_ADDRESS_TARGET = -1;
89 double Z_ADDRESS_TARGET = -1;
90 int F_PERCENT_SPEED = 100;
91
92 ////////////////////////////////////////////////////////////////////M6/////////////////////////////////////////////////////////////////
93 double M6_SAVE_LEN_A = 0;
94 double M6_SAVE_LEN_B = 0;
95 double M6_SAVE_LEN_C = 0;
96 double M6_SAVE_X = -1;
97 double M6_SAVE_Y = -1;
98 double M6_SAVE_Z = -1;
99 double M6_SAVE_Speed = 0;
100 bool M6_EN = false;
101
102 ////////////////////////////////////////////////////////////////////VARIABLES/////////////////////////////////////////////////////////////////
103
104 ////////////////////////////////////////////////////////////////////FLAGS/////////////////////////////////////////////////////////////////
105
106 bool UNIT_MODE = true; //true = inches, false = mm;

```

```

107 bool ABSOLUTE_COORDINATES = true; //true = absolute, false =
108     incremental
109 bool ON_MOVE = false;
110 bool M2_EN = false;
111 ////////////////////////////////////////////////////////////////////FLAGS/////////////////////////////////////////////////////////////////
112
113 ////////////////////////////////////////////////////////////////////STEPPER/////////////////////////////////////////////////////////////////
114
115 #include "AccelStepper.h"
116 #include "MultiStepper.h"
117
118 //change pins here to reflect correct pins
119 #define dirPinA 25
120 #define stepPinA 23
121 #define dirPinB 29
122 #define stepPinB 27
123 #define dirPinC 33
124 #define stepPinC 31
125
126 #define motorInterfaceType 1
127
128 AccelStepper stepperA;// = AccelStepper(motorInterfaceType,
129     stepPinA, dirPinA);
130 AccelStepper stepperB;// = AccelStepper(motorInterfaceType,
131     stepPinB, dirPinB);
132 AccelStepper stepperC;// = AccelStepper(motorInterfaceType,
133     stepPinC, dirPinC);
134
135 MultiStepper steppers = MultiStepper();
136 ////////////////////////////////////////////////////////////////////STEPPER/////////////////////////////////////////////////////////////////
137
138 ////////////////////////////////////////////////////////////////////G-CODE LIB SETUP/////////////////////////////////////////////////////////////////
139
140 #include "gcode.h"
141 #include "Arduino_Firmware_ALPHA.h"
142 #define NumberOfCommands 10
143 //you can add more commands here if needed and create a
144     function under G-Code to execute.
145 struct commandcallback commands[NumberOfCommands] = {{"G0",G0_cmd}
146     ,{"G1",G1_cmd},{"G20",G20_cmd},{"G21",G21_cmd},{"G90",G90_cmd}
147     ,{"G91",G91_cmd},{"M2",M2_cmd},{"M6",M6_cmd},{"C1",C1_cmd},{"C2
148     ",C2_cmd}};
149 gcode Commands(NumberOfCommands,commands);
150 ////////////////////////////////////////////////////////////////////G-CODE LIB SETUP/////////////////////////////////////////////////////////////////
151
152 ////////////////////////////////////////////////////////////////////G-Code/////////////////////////////////////////////////////////////////
153
154 void G0_cmd(){
155
156     if (ON_MOVE || M6_EN) {
157         //Serial.println("ON_MOVE");
158         return;
159     }
160
161     double x_coord = CURRENT_X;
162     double y_coord = CURRENT_Y;

```

```

157     double z_coord = CURRENT_PAYLOAD_HEIGHT;
158
159     if (Commands.availableValue('X')){
160         x_coord = Commands.GetValue('X');
161     }
162     if (Commands.availableValue('Y')){
163         y_coord = Commands.GetValue('Y');
164     }
165     if (Commands.availableValue('Z')){
166         z_coord = Commands.GetValue('Z');
167     }
168
169     int f_speed = 100; //maximum speed
170
171     if (!UNIT_MODE){ //translate mm to in
172         x_coord = mm_to_in(x_coord);
173         y_coord = mm_to_in(y_coord);
174         z_coord = mm_to_in(z_coord);
175     }
176
177     if (!ABSOLUTE_COORDINATES){ //incremental mode
178         x_coord += CURRENT_X;
179         y_coord += CURRENT_Y;
180         z_coord += CURRENT_PAYLOAD_HEIGHT;
181     }
182
183     //checking for boundaries
184     if (x_coord > 8.5)
185         x_coord = 8.5;
186     if (y_coord > 11)
187         x_coord = 11;
188     if (z_coord > 11)
189         z_coord = 11;
190
191     //update global values
192     Y_ADDRESS_TARGET = y_coord;
193     X_ADDRESS_TARGET = x_coord;
194     Z_ADDRESS_TARGET = z_coord;
195     F_PERCENT_SPEED = f_speed;
196
197     update_lcd(0);
198
199     go(x_coord,y_coord,z_coord,f_speed);
200 }
201
202 void G1_cmd(){
203
204     if (ON_MOVE || M6_EN) return;
205
206     double x_coord = CURRENT_X;
207     double y_coord = CURRENT_Y;
208     double z_coord = CURRENT_PAYLOAD_HEIGHT;
209     double f_speed_in = 4.5;
210     int f_speed = 100; //maximum speed
211
212     if (Commands.availableValue('X')){
213         x_coord = Commands.GetValue('X');
214     }

```

```

215     if (Commands.availableValue('Y')){
216         y_coord = Commands.GetValue('Y');
217     }
218     if (Commands.availableValue('Z')){
219         z_coord = Commands.GetValue('Z');
220     }
221     if (Commands.availableValue('F')){
222         f_speed_in = Commands.GetValue('F');
223     }
224
225     if (!UNIT_MODE){ //translate mm to in
226         x_coord = mm_to_in(x_coord);
227         y_coord = mm_to_in(y_coord);
228         z_coord = mm_to_in(z_coord);
229         f_speed_in = mm_to_in(f_speed_in);
230     }
231
232     if (!ABSOLUTE_COORDINATES){//incremental mode
233         x_coord += CURRENT_X;
234         y_coord += CURRENT_Y;
235         z_coord += CURRENT_PAYLOAD_HEIGHT;
236     }
237
238     //checking for boundaries
239     if (x_coord > 8.5)
240         x_coord = 8.5;
241     if (y_coord > 11)
242         x_coord = 11;
243     if (z_coord > 11)
244         z_coord = 11;
245
246     f_speed_in = (f_speed_in/4.5)*100;
247
248     if (f_speed_in > 100)
249         f_speed = 100;
250     else if (f_speed_in <= 1)
251         f_speed = 1;
252     else
253         f_speed = int(f_speed_in);
254
255     //update global values
256     Y_ADDRESS_TARGET = y_coord;
257     X_ADDRESS_TARGET = x_coord;
258     Z_ADDRESS_TARGET = z_coord;
259     F_PERCENT_SPEED = f_speed;
260
261     update_lcd(1);
262
263     go(x_coord, y_coord, z_coord, f_speed);
264 }
265
266 void G20_cmd(){
267
268     if (ON_MOVE || M6_EN) return;
269
270     UNIT_MODE = true;
271     update_lcd(20);
272 }
```

```

273
274 void G21_cmd(){
275
276     if (ON_MOVE || M6_EN) return;
277
278     UNIT_MODE = false;
279     update_lcd(21);
280 }
281
282 void G90_cmd(){
283
284     if (ON_MOVE || M6_EN) return;
285
286     ABSOLUTE_COORDINATES = true;
287     update_lcd(90);
288 }
289
290 void G91_cmd(){
291
292     if (ON_MOVE || M6_EN) return;
293
294     ABSOLUTE_COORDINATES = false;
295     update_lcd(91);
296 }
297
298 void M2_cmd(){
299     update_lcd(2);
300     if (ON_MOVE){
301         stepperA.stop();
302         stepperB.stop();
303         stepperC.stop();
304
305         ON_MOVE = false;
306         ABSOLUTE_COORDINATES = true;
307         M2_EN = true;
308         M6_EN = false;
309     }
310 }
311
312 void M6_cmd(){
313     update_lcd(6);
314     if (!M6_EN){ //m6 first time
315         //stop
316
317         //if (ON_MOVE){
318         stepperA.stop();
319         stepperB.stop();
320         stepperC.stop();
321
322         ON_MOVE = false;
323         ABSOLUTE_COORDINATES = true;
324         M6_EN = true;
325
326         double actual_a = stepperA.currentPosition() * INCHES_PER_STEP;
327         double actual_b = -(stepperB.currentPosition() *
328             INCHES_PER_STEP);
329         double actual_c = stepperC.currentPosition() * INCHES_PER_STEP;

```

```

330     CURRENT_THREAD_LEN_A += actual_a;
331     CURRENT_THREAD_LEN_B += actual_b;
332     CURRENT_THREAD_LEN_C += actual_c;
333
334     M6_SAVE_LEN_A = CURRENT_THREAD_LEN_A;
335     M6_SAVE_LEN_B = CURRENT_THREAD_LEN_B;
336     M6_SAVE_LEN_C = CURRENT_THREAD_LEN_C;
337     M6_SAVE_X = X_ADDRESS_TARGET;
338     M6_SAVE_Y = Y_ADDRESS_TARGET;
339     M6_SAVE_Z = Z_ADDRESS_TARGET;
340
341     if (M6_SAVE_X == -1 || M6_SAVE_Y == -1 || M6_SAVE_Z == -1){
342         M6_SAVE_X = CURRENT_X;
343         M6_SAVE_Y = CURRENT_Y;
344         M6_SAVE_Z = CURRENT_PAYLOAD_HEIGHT;
345     }
346     if (M6_SAVE_X == 0 && M6_SAVE_Y == 0 && M6_SAVE_Z == 0){
347         M6_SAVE_X = CURRENT_X;
348         M6_SAVE_Y = CURRENT_Y;
349         M6_SAVE_Z = CURRENT_PAYLOAD_HEIGHT;
350     }
351     M6_SAVE_Speed = F_PERCENT_SPEED;
352
353     go_block(HOME_X, HOME_Y, HOME_Z, 100);
354 }
355 else {
356
357     go_len_block(M6_SAVE_LEN_A, M6_SAVE_LEN_B, M6_SAVE_LEN_C, 100);
358
359     M6_EN = false;
360
361 //go(M6_SAVE_X, M6_SAVE_Y, M6_SAVE_Z, M6_SAVE_Speed);
362
363 /*M6_SAVE_LEN_A = 0;
364 M6_SAVE_LEN_B = 0;
365 M6_SAVE_LEN_C = 0;
366 M6_SAVE_X = -1;
367 M6_SAVE_Y = -1;
368 M6_SAVE_Z = -1;
369 M6_SAVE_Speed = 0; */
370 }
371 }
372
373 void C1_cmd(){ //Write value of X,Y,Z to the Serial Connection
374
375 //if (ON_MOVE || M6_EN) return;
376
377 Serial.write("X");
378 Serial.print(CURRENT_X);
379 Serial.write("Y");
380 Serial.print(CURRENT_Y);
381 Serial.write("Z");
382 Serial.print(CURRENT_PAYLOAD_HEIGHT);
383 Serial.write("#");
384 update_lcd(57);
385 delay(500);
386 }

```

```

388 void C2_cmd() { //Write thread lengths to Serial
389   //if (ON_MOVE || M6_EN) return;
390
391   Serial.write("A");
392   Serial.print(CURRENT_THREAD_LEN_A);
393   Serial.write("B");
394   Serial.print(CURRENT_THREAD_LEN_B);
395   Serial.write("C");
396   Serial.print(CURRENT_THREAD_LEN_C);
397   Serial.write("#");
398   update_lcd(58);
399   delay(500);
400 }
401
402 ///////////////////////////////////////////////////////////////////G-Code/////////////////////////////////////////////////////////////////
403
404
405 ///////////////////////////////////////////////////////////////////THREAD CALCULATIONS/////////////////////////////////////////////////////////////////
406 double calculate_thread_height_var(double z){
407   return HEIGHT_PYLON_A - z;
408 }
409
410 double calculate_thread_length_A_h(double x, double y, double z) {
411   double height_created_triangle = A_PAPER_DISTANCE + 8.5 - x -
412     PAYLOAD_CENTER_THREAD_DISTANCE_A_x;
413   double side_created_triangle;
414   if ((y - 5.5) < 0)
415     side_created_triangle = 5.5 - y;
416   else
417     side_created_triangle = y - 5.5;
418
419   double trace_length = sqrt(pow(height_created_triangle, 2) + pow(
420     side_created_triangle, 2));
421
422   double thread_length = sqrt(pow(trace_length,2) + pow(
423     calculate_thread_height_var(z),2));
424
425   return thread_length;
426 }
427
428 double calculate_thread_length_B_h(double x, double y, double z) {
429   double height_created_triangle = PAPER_HEIGHT + B_PAPER_DISTANCE
430   - y - PAYLOAD_CENTER_THREAD_DISTANCE_B_y;
431   double side_created_triangle = PAPER_DISTANCE_LOW_EDGE + x -
432     PAYLOAD_CENTER_THREAD_DISTANCE_B_x;
433
434   double trace_length = sqrt(pow(height_created_triangle,2) + pow(
435     side_created_triangle,2));
436
437   //double trace_length = PAPER_DISTANCE_1 - y -
438   //PAYLOAD_CENTER_THREAD_DISTANCE_B_y;
439
440   double thread_length = sqrt(pow(trace_length,2) + pow(
441     calculate_thread_height_var(z),2));
442
443   return thread_length;
444 }

```

```

438 double calculate_thread_length_C_h(double x, double y, double z) {
439     double height_created_triangle = C_PAPER_DISTANCE + y -
        PAYLOAD_CENTER_THREAD_DISTANCE_B_y;
440     double side_created_triangle = PAPER_DISTANCE_LOW_EDGE + x -
        PAYLOAD_CENTER_THREAD_DISTANCE_C_x;
441
442     double trace_length = sqrt(pow(height_created_triangle,2) + pow(
        side_created_triangle,2));
443
444     double thread_length = sqrt(pow(trace_length,2) + pow(
        calculate_thread_height_var(z),2));
445
446     return thread_length;
447 }
448
449 ////////////////////////////////////////////////////////////////////THREAD CALCULATIONS/////////////////////////////////////////////////////////////////
450
451 ////////////////////////////////////////////////////////////////////UNIT CONVERSION/////////////////////////////////////////////////////////////////
452 double mm_to_in(double mm){
453     return (mm/(25.4));
454 }
455
456 double in_to_mm(double in){
457     return (in *(25.4));
458 }
459 ////////////////////////////////////////////////////////////////////UNIT CONVERSION/////////////////////////////////////////////////////////////////
460
461 void update_lcd(int opcode){
462     lcd.clear();
463     if (opcode == 0 || opcode == 1){ //G0 or G1 (displays as integer
        for size)
464         lcd.setCursor(0, 0); //1st line 1st char
465         lcd.print("OPCODE: G");
466         lcd.print(opcode);
467         lcd.print(" F:");
468         lcd.print(F_PERCENT_SPEED);
469         lcd.setCursor(0, 1); //2nd Line 1st char
470         double x = X_ADDRESS_TARGET;
471         double y = Y_ADDRESS_TARGET;
472         if (!UNIT_MODE){ //translate mm to in
473             x = in_to_mm(X_ADDRESS_TARGET);
474             y = in_to_mm(Y_ADDRESS_TARGET);
475         }
476         lcd.print("X: ");
477         lcd.print(x);
478         lcd.setCursor(8, 1); //2nd Line 9th char
479         lcd.print("Y: ");
480         lcd.print(y);
481     }
482     else if (opcode == 20){
483         lcd.setCursor(0, 0); //1st line 1st char
484         lcd.print("OPCODE: G");
485         lcd.print(opcode);
486         lcd.setCursor(0, 1); //2nd Line 1st char
487         lcd.print("Input Mode > IN");
488     }
489     else if (opcode == 21){
490         lcd.setCursor(0, 0); //1st line 1st char

```



```

547 ////////////////CALCULATIONS FOR MOVEMENT
548 /////////////////
549 int calculate_number_steps(double current_ , double new_){
550     int num_steps = int((new_ - current_)/INCHES_PER_STEP);
551     return num_steps;
552 }
553
554 int go_block(double x, double y, double z, int f_speed) {
555     X_ADDRESS_TARGET = x;
556     Y_ADDRESS_TARGET = y;
557     Z_ADDRESS_TARGET = z;
558     F_PERCENT_SPEED = f_speed;
559
560     //calculate new necessary thread lengths
561     double new_len_a = calculate_thread_length_A_h(x,y,z);
562     double new_len_b = calculate_thread_length_B_h(x,y,z);
563     double new_len_c = calculate_thread_length_C_h(x,y,z);
564
565     //calculate number of steps and direction of movement to move
566     //from current pos to new pos.
567     int steps_A = calculate_number_steps(CURRENT_THREAD_LEN_A ,
568                                         new_len_a);
569     int steps_B = calculate_number_steps(CURRENT_THREAD_LEN_B ,
570                                         new_len_b);
571     int steps_C = calculate_number_steps(CURRENT_THREAD_LEN_C ,
572                                         new_len_c);
573
574     //Setting important info in stepper classes
575     stepperA.setCurrentPosition(0);
576     stepperB.setCurrentPosition(0);
577     stepperC.setCurrentPosition(0);
578     int max_speed = int((MAX_STEPS_PER_SEC/100)*f_speed);
579     stepperA.setMaxSpeed(max_speed);
580     stepperB.setMaxSpeed(max_speed);
581     stepperC.setMaxSpeed(max_speed);
582     //move the payload to location
583     long steps [] = {steps_A , -steps_B , steps_C};
584
585     lcd.clear();
586     lcd.print("Moving to >>>");
587     lcd.setCursor(0, 1);
588     lcd.print(x);
589     lcd.print(" ");
590     lcd.print(y);
591     lcd.print(" ");
592     lcd.print(z);
593
594     steppers.moveTo(steps);
595
596     //move_to(steps_A , steps_B , steps_C);
597
598     //blocks until steppers finish moving
599     while(steppers.run()){
600
601     }
602
603     //find actual displacement

```

```

600    double actual_a = stepperA.currentPosition() * INCHES_PER_STEP;
601    double actual_b = -(stepperB.currentPosition() * INCHES_PER_STEP);
602    ;
603    double actual_c = stepperC.currentPosition() * INCHES_PER_STEP;
604
605    //after done, update current values
606    CURRENT_X = x;
607    CURRENT_Y = y;
608    CURRENT_PAYLOAD_HEIGHT = z;
609    CURRENT_THREAD_LEN_A += actual_a;
610    CURRENT_THREAD_LEN_B += actual_b;
611    CURRENT_THREAD_LEN_C += actual_c;
612
613    return 0;
614}
615int go_len_block(double a, double b, double c, int f_speed) {
616
617    //calculate number of steps and direction of movement to move
618    //from current pos to new pos.
619    int steps_A = calculate_number_steps(CURRENT_THREAD_LEN_A, a);
620    int steps_B = calculate_number_steps(CURRENT_THREAD_LEN_B, b);
621    int steps_C = calculate_number_steps(CURRENT_THREAD_LEN_C, c);
622
623    //Setting important info in stepper classes
624    stepperA.setCurrentPosition(0);
625    stepperB.setCurrentPosition(0);
626    stepperC.setCurrentPosition(0);
627    int max_speed = int((MAX_STEPS_PER_SEC/100)*f_speed);
628    stepperA.setMaxSpeed(max_speed);
629    stepperB.setMaxSpeed(max_speed);
630    stepperC.setMaxSpeed(max_speed);
631    //move the payload to location
632    long steps[] = {steps_A, -steps_B, steps_C};
633
634    steppers.moveTo(steps);
635
636    //blocks until steppers finish moving
637    while(steppers.run()){
638    }
639
640    //find actual displacement
641    double actual_a = stepperA.currentPosition() * INCHES_PER_STEP;
642    double actual_b = -(stepperB.currentPosition() * INCHES_PER_STEP);
643    ;
644    double actual_c = stepperC.currentPosition() * INCHES_PER_STEP;
645
646    //after done, update current values
647    CURRENT_THREAD_LEN_A += actual_a;
648    CURRENT_THREAD_LEN_B += actual_b;
649    CURRENT_THREAD_LEN_C += actual_c;
650
651    X_ADDRESS_TARGET = 0;
652    Y_ADDRESS_TARGET = 0;
653    Z_ADDRESS_TARGET = 0;
654
655    return 0;

```

```

655 }
656
657
658 int go(double x, double y, double z, int f_speed) {
659     X_ADDRESS_TARGET = x;
660     Y_ADDRESS_TARGET = y;
661     Z_ADDRESS_TARGET = z;
662     F_PERCENT_SPEED = f_speed;
663
664     //calculate new necessary thread lengths
665     double new_len_a = calculate_thread_length_A_h(x,y,z);
666     double new_len_b = calculate_thread_length_B_h(x,y,z);
667     double new_len_c = calculate_thread_length_C_h(x,y,z);
668
669     /*Serial.println("");
670     Serial.print("New Length A: ");
671     Serial.println(new_len_a);
672     Serial.print("New Length B: ");
673     Serial.println(new_len_b);
674     Serial.print("New Length C: ");
675     Serial.println(new_len_c);
676
677     Serial.println("");
678     Serial.print("CurrentLength A: ");
679     Serial.println(CURRENT_THREAD_LEN_A);
680     Serial.print("CurrentLength B: ");
681     Serial.println(CURRENT_THREAD_LEN_B);
682     Serial.print("CurrentLength C: ");
683     Serial.println(CURRENT_THREAD_LEN_C);*/
684
685     //calculate number of steps and direction of movement to move
686     //from current pos to new pos.
687     int steps_A = calculate_number_steps(CURRENT_THREAD_LEN_A ,
688                                         new_len_a);
689     int steps_B = calculate_number_steps(CURRENT_THREAD_LEN_B ,
690                                         new_len_b);
691     int steps_C = calculate_number_steps(CURRENT_THREAD_LEN_C ,
692                                         new_len_c);
693
694
695     //Setting important info in stepper classes
696     stepperA.setCurrentPosition(0);
697     stepperB.setCurrentPosition(0);
698     stepperC.setCurrentPosition(0);
699     int max_speed = int((MAX_STEPS_PER_SEC/100)*f_speed);
700     stepperA.setMaxSpeed(max_speed);
701     stepperB.setMaxSpeed(max_speed);
702     stepperC.setMaxSpeed(max_speed);
703     //stepperA.setAcceleration(max_speed/5);
704     //stepperB.setAcceleration(max_speed/5);
705     //stepperC.setAcceleration(max_speed/5);
706     //move the payload to location
707     long steps[] = {steps_A, -steps_B, steps_C};
708
709     lcd.clear();
710     lcd.print("Moving to: F");
711     lcd.setCursor(0, 1);
712     lcd.print(x);

```

```

709 lcd.print(" ");
710 lcd.print(y);
711 lcd.print(" ");
712 lcd.print(z);
713
714 steppers.moveTo(steps);
715
716 //move_to(steps_A, steps_B, steps_C);
717
718 ON_MOVE = true;
719
720 //blocks until steppers finish moving
721 while(steppers.run() && ON_MOVE){
722     Commands.available();
723 }
724
725 //find actual displacement
726 double actual_a = stepperA.currentPosition() * INCHES_PER_STEP;
727 double actual_b = -(stepperB.currentPosition() * INCHES_PER_STEP)
728 ;
729 double actual_c = stepperC.currentPosition() * INCHES_PER_STEP;
730
731 /*Serial.println("");
732 Serial.print("DELTA A:");
733 Serial.println(actual_a);
734 Serial.print("DELTA B:");
735 Serial.println(actual_b);
736 Serial.print("DELTA C:");
737 Serial.println(actual_c);
738
739 Serial.println("\nFinal Stepper Pos:");
740 Serial.print("Stepper A: ");
741 Serial.println(stepperA.currentPosition());
742 Serial.print("Stepper B: ");
743 Serial.println(-stepperB.currentPosition());
744 Serial.print("Stepper C: ");
745 Serial.println(stepperC.currentPosition());*/
746
747 ON_MOVE = false;
748
749 //after done, update current values
750 if (!M2_EN && !M6_EN){
751     CURRENT_X = x;
752     CURRENT_Y = y;
753     CURRENT_PAYLOAD_HEIGHT = z;
754 }
755 if (!M6_EN){
756     CURRENT_THREAD_LEN_A += actual_a;
757     CURRENT_THREAD_LEN_B += actual_b;
758     CURRENT_THREAD_LEN_C += actual_c;
759 }
760 M2_EN = false;
761
762 X_ADDRESS_TARGET = 0;
763 Y_ADDRESS_TARGET = 0;
764 Z_ADDRESS_TARGET = 0;
765
766 /*Serial.println("");
```

```

766 Serial.print("Final Length A: ");
767 Serial.println(CURRENT_THREAD_LEN_A);
768 Serial.print("Final Length B: ");
769 Serial.println(CURRENT_THREAD_LEN_B);
770 Serial.print("Final Length C: ");
771 Serial.println(CURRENT_THREAD_LEN_C);*/
772
773     return 0;
774 }
775 ////////////////////////////////////////////////////////////////////CALCULATIONS FOR MOVEMENT
776 ///////////////////////////////////////////////////////////////////
777 void init_values(){ //expects in not mm
778     lcd.clear();
779     lcd.print("Location:");
780     lcd.setCursor(0, 1);
781     lcd.print("Z, X, Y");
782     while(Serial.available() <= 0){
783     }
784     double h = Serial.parseFloat();
785     double x = Serial.parseFloat();
786     double y = Serial.parseFloat();
787
788     CURRENT_PAYLOAD_HEIGHT = h;
789
790     double La = calculate_thread_length_A_h(x,y,h);
791     double Lb = calculate_thread_length_B_h(x,y,h);
792     double Lc = calculate_thread_length_C_h(x,y,h);
793
794     CURRENT_THREAD_LEN_A = La;
795     CURRENT_THREAD_LEN_B = Lb;
796     CURRENT_THREAD_LEN_C = Lc;
797     CURRENT_X = x;
798     CURRENT_Y = y;
799
800     lcd.clear();
801     lcd.print("Z: ");
802     lcd.print(CURRENT_PAYLOAD_HEIGHT);
803     lcd.setCursor(0, 1); //2nd Line 1st char
804     lcd.print("X: ");
805     lcd.print(CURRENT_X);
806     lcd.setCursor(8, 1); //2nd Line 9th char
807     lcd.print("Y: ");
808     lcd.print(CURRENT_Y);
809
810 }
811
812 void ready_command_lcd(){
813     lcd.clear();
814     lcd.setCursor(0, 0); //2nd Line 1st char
815     lcd.print("      <READY>      ");
816     lcd.setCursor(0, 1); //2nd Line 1st char
817     lcd.print("      Listening      ");
818 }
819
820
821 void send_sensor(){
822 }
```

```

823
824     sensorVal = analogRead(sensor);
825     lightLevel = (sensorVal/1023)*10;
826     Serial.write("L");
827     Serial.print(lightLevel);
828
829     boolean success = false;
830     uint8_t uid[] = { 0, 0, 0, 0, 0, 0, 0, 0 }; // Buffer to store the
831     // returned UID
832     uint8_t uidLength; // Length of the UID (4
833     // or 7 bytes depending on ISO14443A card type)
834     success = nfc.readPassiveTargetID(PN532_MIFARE_ISO14443A, &uid
835     [0], &uidLength);
836     long test = 0;
837     if (success){
838         for (uint8_t i=0; i < uidLength; i++)
839         {
840             //Serial.print(" 0x");Serial.print(uid[i], HEX);
841             test = test + uid[i];
842             if(i<3){
843                 test = test * 256;
844             }
845         }
846         Serial.write("R");
847         Serial.write(test);
848     } else {
849         Serial.write("R0");
850     }
851
852     void task_done(){
853         X_ADDRESS_TARGET = 0;
854         Y_ADDRESS_TARGET = 0;
855         Z_ADDRESS_TARGET = 0;
856         F_PERCENT_SPEED = 100;
857         OPCODE = 1000; //change OPCODE to 1000 when task is done
858         //delay(2000);
859         ready_command_lcd();
860
861         Serial.write("X");
862         Serial.print(CURRENT_X);
863         Serial.write("Y");
864         Serial.print(CURRENT_Y);
865         Serial.write("Z");
866         Serial.print(CURRENT_PAYLOAD_HEIGHT);
867         Serial.write("A");
868         Serial.print(CURRENT_THREAD_LEN_A);
869         Serial.write("B");
870         Serial.print(CURRENT_THREAD_LEN_B);
871         Serial.write("C");
872         Serial.print(CURRENT_THREAD_LEN_C);
873
874         send_sensor();
875
876         delay(1000);
877
878         Serial.write("G"); //let matlab know when it is good to send
879         //another command.

```

```

877 }
878 }
879
880 void set_pins(){
881     //LCD
882     pinMode(2, OUTPUT);
883     pinMode(3, OUTPUT);
884     pinMode(4, OUTPUT);
885     pinMode(5, OUTPUT);
886     pinMode(8, OUTPUT);
887
888     //STEPPERS
889     pinMode(25, OUTPUT);
890     pinMode(23, OUTPUT);
891     pinMode(29, OUTPUT);
892     pinMode(27, OUTPUT);
893     pinMode(33, OUTPUT);
894     pinMode(31, OUTPUT);
895
896     pinMode(35, OUTPUT);
897     pinMode(37, OUTPUT);
898     pinMode(39, OUTPUT);
899 }
900 }
901
902 void setup() {
903     Commands.begin();
904     lcd.begin(16, 2);
905     lcd.print("      <FP>      ");
906     lcd.setCursor(2, 1);
907     lcd.print("Spydercam 18");
908     delay(2000);
909     lcd.clear();
910     lcd.print("      BETA      ");
911     lcd.setCursor(0, 1);
912     lcd.print("Arduino Firmware");
913     delay(2000);
914     init_values();
915     delay(2000);
916     set_pins();
917     stepperA = AccelStepper(motorInterfaceType, stepPinA, dirPinA);
918     stepperB = AccelStepper(motorInterfaceType, stepPinB, dirPinB);
919     stepperC = AccelStepper(motorInterfaceType, stepPinC, dirPinC);
920
921     digitalWrite(35, LOW);
922     digitalWrite(37, LOW);
923     digitalWrite(39, LOW);
924
925     steppers.addStepper(stepperA);
926     steppers.addStepper(stepperB);
927     steppers.addStepper(stepperC);
928
929
930     //sensor setup
931     nfc.begin();
932     lcd.clear();
933     lcd.print("  Enabling NFC  ");
934     lcd.setCursor(0, 1);

```

```
935 lcd.print(" In Progress... ");
936 uint32_t versiondata = nfc.getFirmwareVersion();
937 if (!versiondata) {
938     lcd.clear();
939     lcd.print("      ERROR      ");
940     lcd.setCursor(0, 1);
941     lcd.print("    NFC Failed    ");
942     while (1); // Halt
943 }
944 delay(1000);
945 nfc.SAMConfig();
946 ready_command_lcd();
947
948 //Serial.write("G");
949 }
950
951 void loop() {
952     if (Commands.available()) {
953         task_done();
954     }
955 }
```

8.2 MATLAB Code

```
1 % ===== %
2 % === MATLAB GUI FOR SPYDERCAM TEAM 18 === %
3 % ===== %
4
5 % === Main Program === %
6 clear;
7
8 % --- Variables --- %
9 global drawing_input; %Cell array holding sets of user drawn lines
10 drawing_input = cell(1);
11
12 global num_sets; %Number of user entered sets of lines. (Sets are
13     connected lines
13 num_sets = 0;
14
15 global home; %Home Location for Payload
16 home = [0 0 3];
17
18 global draw_height; %Height (Z Pos) for Drawing with Pen attachment
19 draw_height = 3.6;
20
21 global non_draw_height; %Height (Z Pos) for NOT Drawing with pen
22 non_draw_height = 4.6;
23
24 global gcode_buffer; %Buffer for holding G-Code to be sent to
25     Arduino
25 gcode_buffer = [];
26
27 global sensor_data; %Incoming sensor data from the Arduino is
28     stored here
28 sensor_data = zeros(0,5);
29
30 global serial_on; %Turn on or off incoming serial (1 = on, 0 =
31     off)
31 serial_on = 1;
32
33 global prgm_end; %Set to 0 if the current Gcode sequence is over
34 prgm_end = 1;
35
36 % --- Serial --- %
37 global s; %Serial port. Open it up. Throw an error and quit if it
38     wont open
38 try s = serialport("COM3",9600);
39 catch
40     disp("Serial device not connected. Reconnect and restart");
41     return;
42 end
43 configureCallback(s,"byte",1,@readSerialData) %Callback function
44     for serial. Executes if there is 1 byte available
44
45 % --- GUI Figure --- %
46 global gui; %GUI uifigure and overarching labels
47 gui = uifigure(1,'Position',[250, 70, 1100, 700], 'Name', 'SpyderCam
48     Team 18 MATLAB GUI');
48
49 % Main area labels
```

```

50 drw_lbl = uilabel(gui,'Text','Drawing Input','Position',[45 660
    200 40],'FontSize',24);
51 gcode_lbl = uilabel(gui,'Text','G-Code Input','Position',[400 660
    200 40],'FontSize',24);
52 ea_lbl = uilabel(gui,'Text','Execution Area','Position',[740 660
    200 40],'FontSize',24);
53
54 % Child figures
55 global sensorViewFig; %Figure that shows sensor data
56 global bufferfig;    %Figure that shows Gcode buffer
57
58 % --- User Drawing Input Area --- %
59 draw_area = uiaxes(gui,'Position',[20, 227, 340, 440],'
    ButtonDownFcn',@axesCallback); %Create Axes
60 draw_area.XLim = [0 8.5]; %Set axes limits
61 draw_area.YLim = [0 11];
62 draw_area.PickableParts = 'all'; %Make axes clickable
63 draw_area.HitTest = 'off'; %Make axes not clickable
64 draw_area.NextPlot = 'replacechildren'; %Each plot replaces the
    last, but axes settings stay the same
65
66 % Buttons for adding a new line set or clearing the drawing
67 draw_line = uibutton(gui,'state','Text','Draw Line','Position',[30,
    197, 100, 22], 'ValueChangedFcn',{@drawBtnCallback,draw_area});
    %State button: pushed in is drawing mode, pushed out = finished
    drawing line set
68 clear_drawing = uibutton(gui,'push','Text','Clear Drawing','
    Position',[140, 197, 100, 22], 'ButtonPushedFcn',{
    @clearBtnCallback,draw_area}); %Push button: clears everything
    in drawing window
69 slbl = uilabel(gui,'Text','Speed (IPM)','Position',[25, 167, 70,
    25]); %Label for Speed Slider
70 speed = uislider(gui,'Position',[110, 180, 230, 3],'Limits',[0.1
    4.5]); %Speed Slider
71 convert_to_gcode = uibutton(gui,'push','Text','Convert to G-Code ->
    ','Position',[250, 197, 110, 22]); %Convert to G-Code Button
72
73
74 % --- GCODE Input Area --- %
75 gcode_area = uitextarea(gui,'Position',[400, 270, 300, 390]); %Text
    box for inputting GCODE
76 gcode_area.Value = sprintf(""); %Initialize gcode text input area
77 gcode_dropdown = uidropdown(gui,'Items',{ 'G00', 'G01', 'G04', 'G20',
    'G21', 'G28', 'G90', 'G91', 'M00', 'M02', 'M06', 'M30', 'M72'},'Position',
    ,[400,230,100,22], 'ValueChangedFcn', @GdownCallback); %Dropdown
    for choosing G-code
78 arg_boxes(); %Set up boxes for inputting arguments
79 disp_args('G00','000'); %Initialize argument boxes with the ones
    for G00
80 global currentgcode; %Current G-Code being formulated with dropdown
    and argument input boxes
81 enter_gcode = uibutton(gui,'push','Text','Enter G-Code','Position'
    ,[400, 190, 100, 22], 'ButtonPushedFcn',{@enterCallback,
    gcode_area}); %Send current G-Code into the G-Code text area
82 line_break = uibutton(gui,'push','Text','Line Break','Position'
    ,[520, 190, 100, 22], 'ButtonPushedFcn',{@linebreakCallback,
    gcode_area}); %Add a line break ();
83 delete_line = uibutton(gui,'push','Text','Delete Line','Position'

```

```

        ,[400, 150, 100, 22], 'ButtonPushedFcn', {@deleteLineCallback,
    gcode_area}); %Delete 1 line from the G-Code text area
84 clear_gcode = uibutton(gui,'push','Text','Clear G-Code','Position'
    ,[520, 150, 100, 22], 'ButtonPushedFcn', {@clearGcodeCallback,
    gcode_area}); %Clear all G-Code from text area
85
86 convert_to_gcode.ButtonPushedFcn = {@convertCallback, gcode_area,
    speed}; %Set callback for convert_to_gcode button. Down here so
    it can reference speed
87
88
89 % --- Execution Area ---
90 incr_distance = uieditfield(gui,'Position',[800, 270, 50, 20]); %
    Incremental movement distance
91 incr_dlbl = uilabel(gui,'Text','Distance','Position',[750, 270, 60,
    25]); %label for ^
92 incr_speed = uieditfield(gui,'Position',[940, 270, 50, 20]); %
    Incremental movement speed
93 incr_slbl = uilabel(gui,'Text','Speed (IPM)','Position',[865, 270,
    70, 25]); %Label for ^
94
95 % X, Y, and Z incremental movement buttons
96 yplus_btn = uibutton(gui,'push','Text','Y+','Position',[850, 530,
    100, 100], 'ButtonPushedFcn', {@directionBtnCallback,"Y+",
    incr_distance,incr_speed});
97 xminus_btn = uibutton(gui,'push','Text','X-','Position',[740, 420,
    100, 100], 'ButtonPushedFcn', {@directionBtnCallback,"X-",
    incr_distance,incr_speed});
98 xplus_btn = uibutton(gui,'push','Text','X+','Position',[960, 420,
    100, 100], 'ButtonPushedFcn', {@directionBtnCallback,"X+",
    incr_distance,incr_speed});
99 yminus_btn = uibutton(gui,'push','Text','Y-','Position',[850, 310,
    100, 100], 'ButtonPushedFcn', {@directionBtnCallback,"Y-",
    incr_distance,incr_speed});
100 zplus_btn = uibutton(gui,'push','Text','Z+','Position',[960, 530,
    50, 50], 'ButtonPushedFcn', {@directionBtnCallback,"Z+",
    incr_distance,incr_speed});
101 zminus_btn = uibutton(gui,'push','Text','Z-','Position',[790, 360,
    50, 50], 'ButtonPushedFcn', {@directionBtnCallback,"Z-",
    incr_distance,incr_speed});
102 home_btn = uibutton(gui,'push','Text','Home','Position',[850, 420,
    100, 100], 'ButtonPushedFcn', {@directionBtnCallback,"home",
    incr_distance,incr_speed}); %Button for sending the payload to
    the home locations
103
104 % Buffer and sensor data control buttons
105 send_btn = uibutton(gui,'push','Text','Send G-Code to Buffer (From
    Text Area)','Position',[740, 150, 270, 50], 'ButtonPushedFcn', {
    @send2bufferCallback,gcode_area}); %Sends G-Code from text area
    to buffer
106 run_btn = uibutton(gui,'state','Text','Run','Position',[1020, 150,
    40, 50], 'ValueChangedFcn', @runCallback, 'Tag','RUN'); %Start the
    gcode sequence
107 sensor_data_btn = uibutton(gui,'push','Text','Sensor Data','
    Position',[740, 210, 100, 20], 'ButtonPushedFcn',
    @sensorViewCallback); %Show the sensor data window
108 buffer_btn = uibutton(gui,'push','Text','G-Code Buffer','Position'
    ,[845, 210, 100, 20], 'ButtonPushedFcn', @bufferCallback); %

```

```

    Displays the contents of the buffer in a new window
109 clear_buffer_btn = uibutton(gui,'push','Text','Clear Buffer (0)',,
    'Position',[950, 210, 110, 20],'Tag','C','ButtonPushedFcn',
    @bufferClearCallback); %Clears the contents of the buffer (if
    they haven't been sent to the Arduino)

110
111 % Direct Serial Area
112 ds_lbl = uilabel(gui,'Text','Direct Serial Comm','Position',[40,
    100, 300, 40], 'FontSize',24); % Label for direct serial area
113 ser_get = uitextarea(gui,'Position',[30 50 950, 50], 'Tag','SER',
    'ValueChangedFcn',@serGetCallback); % Box for receiving serial
114 dir_ser = uitextarea(gui,'Position',[30 20 950, 20]); % Box for
    sending serial
115 dir_send = uibutton(gui,'push','Text','Send','Position',[990 20 70,
    80], 'ButtonPushedFcn',{@dirSendCallback,dir_ser,ser_get}); %
    Button that sends serial

116
117 % === UTILITY FUNCTIONS === %
118 function plot_input(obj,new_point)
119     % This is the plotting function. It takes in the axes object
    and a new
120     % point. It adds the point to drawing input, then plots all of
    drawing
121     % input. Inputing [-1 -1] clears the plot

122
123     global drawing_input;
124     global num_sets;

125
126     if new_point ~= [-1 -1] %Only plot if the new point is not [-1
    -1];
127         drawing_input{num_sets+1} = [drawing_input{num_sets+1};
    new_point]; %Add new point to drawing input

128
129         inplot = cell(num_sets+1); %Input plot
130         obj.NextPlot = 'add'; % Change plot settings so that plots
    get added to existing plots
131         for i = 1:1:num_sets+1 % Draw each cell (1 cell = 1 line
    set) of drawing input. Make them not clickable.
132             inplot{i} = plot(obj,drawing_input{i}(:,1),
    drawing_input{i}(:,2),'r-o');
133             inplot{i}.HitTest = 'off';
134         end
135         obj.NextPlot = 'replacechildren'; %Change plot back to
    replaceable
136         else %If new_point is [-1 -1]
137             plot(obj,-1,-1); %Just plot 1 garbage point off the axes
138         end
139     end

140
141 function disp_args(code,prevcode)
142     % This is the display arguments function. This function turns
    on or off
143     % the visibility of each argument editfield depending on which
    G-Code
144     % has been chosen in the dropdown menu. code and prevcode refer
    to the
145     % new and old values of the dropdown, respectively.
146
```

```

147 global gui;
148 global currentgcode;
149 children = get(gui, 'Children');
150
151 % If dropdown changed from G00
152 if sum(prevcode == 'G00') == 3
    %Find the editfields/labels with the G00 tag and make them
invisible.
    for i = 1:1:length(children)
        if ~isempty(children(i).Tag) && (children(i).Tag == "G00")
            children(i).Visible = 'off';
            %Find the editfield and set its value to empty
            if length(children(i).Type) == 11
                children(i).Value = '';
            end
        end
    end
    %Find the editfields/labels with the G01 or G00 tag and make
them
    %invisible. (G00 and G01 both have XYZ, G01 just also has F)
    elseif sum(prevcode == 'G01') == 3
        for i = 1:1:length(children)
            if ~isempty(children(i).Tag) && ((children(i).Tag == "G00") || (children(i).Tag == "G01"))
                children(i).Visible = 'off';
                %Find the editfield and set its value to empty
                if length(children(i).Type) == 11
                    children(i).Value = '';
                end
            end
        end
        %Find the editfields/labels with the G04 tag and make them
invisible
        elseif sum(prevcode == 'G04') == 3
            for i = 1:1:length(children)
                if ~isempty(children(i).Tag) && (children(i).Tag == "G04")
                    children(i).Visible = 'off';
                    %Find the editfield and set its value to empty
                    if length(children(i).Type) == 11
                        children(i).Value = '';
                    end
                end
            end
        end
    else
        end
    %If the new code is G00, turn editfields/labels tagged G00
visible
    if sum(code == 'G00') == 3
        for i = 1:1:length(children)
            if ~isempty(children(i).Tag) && (children(i).Tag == "G00")
                children(i).Visible = 'on';
            end
        end
    end

```

```

197     %Set the current G-Code to be filled with arguments
198     currentgcode = ["G00" " " " " "];
199     %If the new code is G01, turn editfields/labels tagged G00 or
200     %G01 visible
201     elseif sum(code == 'G01') == 3
202         for i = 1:1:length(children)
203             if ~isempty(children(i).Tag) && ((children(i).Tag == "G00") || (children(i).Tag == "G01"))
204                 children(i).Visible = 'on';
205             end
206         end
207         %Set the current G-Code to be filled with arguments
208         currentgcode = ["G01" " " " " " "];
209         %If the new code is G04, turn editfields/labels tagged G04
210         %visible
211         elseif sum(code == 'G04') == 3
212             for i = 1:1:length(children)
213                 if ~isempty(children(i).Tag) && (children(i).Tag == "G04")
214                     children(i).Visible = 'on';
215                 end
216             end
217             %Set the current G-Code to be filled with arguments
218             currentgcode = ["G04" " "];
219         else
220             %Set the current G-Code (no arguments)
221             currentgcode = [convertCharsToStrings(code)];
222         end
223     end
224
225     function arg_boxes()
226         % This function sets up the editfields and labels for argument
227         % input on
228         % the G-Code Input. It puts all of the items in position, then
229         % makes
230         % them all invisible
231
232         global gui;
233
234         % XYZ labels/editfields
235         xl = uilabel(gui,'Text','X','Position',[520 230 10 20],'Tag',"G00");
236         xe = uieditfield(gui,'Position',[535 230 30 20],'Tag',"G00",'ValueChangedFcn',{@fieldChange,'X','0'});
237         yl = uilabel(gui,'Text','Y','Position',[580 230 10 20],'Tag',"G00");
238         ye = uieditfield(gui,'Position',[595 230 30 20],'Tag',"G00",'ValueChangedFcn',{@fieldChange,'Y','0'});
239         zl = uilabel(gui,'Text','Z','Position',[640 230 10 20],'Tag',"G00");
240         ze = uieditfield(gui,'Position',[655 230 30 20],'Tag',"G00",'ValueChangedFcn',{@fieldChange,'Z','0'});
241
242         % F label/editfield
243         fl = uilabel(gui,'Text','F','Position',[640 190 10 20],'Tag',"G01");
244         fe = uieditfield(gui,'Position',[655 190 30 20],'Tag',"G01",'ValueChangedFcn',{@fieldChange,'F','0'});

```

```

241
242 % PX dropdown/editfield
243 pxdd = uidropdown(gui,'Items',{’P’, ’X’},’Position’,[520 230 40
244 20],’Tag’,”G04”);
245 pxe = uieditfield(gui,’Position’,[565 230 30 20],’Tag’,”G04”,’
ValueChangedFcn’,{@fieldChange,’P’,pxdd});
246 pxdd.ValueChangedFcn = {@pxChange,pxe};

247 % Turn all of the elements created in this function invisible
248 xl.Visible = ’off’;
249 xe.Visible = ’off’;
250 yl.Visible = ’off’;
251 ye.Visible = ’off’;
252 zl.Visible = ’off’;
253 ze.Visible = ’off’;
254 fl.Visible = ’off’;
255 fe.Visible = ’off’;
256 pxdd.Visible = ’off’;
257 pxe.Visible = ’off’;

258
259 end
260
261 function [gcode] = drawing2gcode(speed)
262 % This function turns data from the user inputted drawing and
turns it
263 % into G-Code. It takes in a constant speed for the whole
operation. It
264 % orders the drawing lines by proximity and then turns that
path into
265 % G-Code
266
267 %Setup
268 F = speed;
269 global home;
270 global drawing_input;
271 sets = length(drawing_input);
272 if length(drawing_input{sets}) < 1
273     sets = sets-1;
274 end
275 indexes = [];

276
277 %Find the line set that starts closest to the origin
278 lowest_dist = 100;
279 for i = 1:1:sets
280     temp = sqrt(sum((home(1:2) - drawing_input{i}(1,:)).^2));
281     if temp < lowest_dist
282         lowest_dist = temp;
283         indexes(1) = i;
284     end
285 end

286
287 %Add line set that starts closest to the origin to a new
ordered array
288 new_order{1} = drawing_input{indexes(1)};

289
290 % Order the rest of the line sets, next closest starting
point after
291 % current set endpoint.

```

```

292     while length(new_order) < sets
293         lowest_dist = 100;
294         for i = 1:1:set
295             if ~ismember(i, indexes)
296                 temp = sqrt(sum((new_order{end}(end,:) -
297 drawing_input{i}(1,:)).^2));
298                 if temp < lowest_dist
299                     lowest_dist = temp;
300                     indexes(length(indexes)+1) = i;
301                     new_order{length(new_order)+1} = drawing_input{
302 i};
303                 end
304             end
305         end
306         %Initialize gcode
307         gcode = {};
308         gcode{1} = sprintf(';');
309
310         % Turn each set into a set of G-Code Commands
311         for i = 1:1:set
312             %Go to location of first point and lower down into pen
313             height
314             gcode{length(gcode)+1} = ['G00' ' X' num2str(new_order{i}
315 (1,1)) ' Y' num2str(new_order{i}(1,2)) ' Z3;'];
316             gcode{length(gcode)+1} = ['G01' ' Z2' ' F' num2str(F) ';' ];
317             %Stay in pen height and go through the points in the set (
318             draw the
319             %line)
320             for j = 2:1:length(new_order{i})
321                 gcode{length(gcode)+1} = ['G01' ' X' num2str(new_order{
322 i}(j,1)) ' Y' num2str(new_order{i}(j,2)) ' F' num2str(F) ';' ];
323             end
324             %Lift up out of pen height
325             gcode{length(gcode)+1} = ['G01' ' Z3' ' F' num2str(F) ';' ];
326         end
327
328
329 % === GUI ELEMENT CALLBACK FUNCTIONS === %
330 function axesCallback(obj,~)
331     % This is the callback function for clicking on the Drawing
332     Axes.
333     % It gets the mouse click location and sends it to the plotting
334     % function.
335
336     mouse_loc = obj.CurrentPoint;
337     plot_input(obj, mouse_loc(1,1:2));
338
339 function drawBtnCallback(obj,~,obj2)
340     % This is the callback function for clicking the "Draw Line"
341     Button.
342     % It turns on the ability to draw on the axes.

```

```

342
343     global drawing_input;
344     global num_sets;
345
346     if obj.Value == 1                                % If button is pressed
347         obj2.HitTest = 'on';                         % Turn axis clicking on
348         obj.Text = 'End Line';
349     else                                              % If button is not pressed
350         (un-pressed? pulled?)                      % Turn axis clicking
351             obj2.HitTest = 'off';                     % Turn axis clicking
352             off
353             obj.Text = 'Draw Line';
354             if ~isempty(drawing_input{num_sets+1}) % If something has
355                 been drawn in this set
356                 num_sets = num_sets + 1;           % Add 1 to num_sets
357                 drawing_input{num_sets+1} = [];      % Add another
358                 cell to user input
359             end
360         end
361     end
362
363 function clearBtnCallback(~,~,obj2)
364     % This is the callback function for the "Clear Drawing" button.
365     % It just resets the user input/number of sets then plots an
366     empty
367     % graph.
368
369     global drawing_input;
370     global num_sets;
371
372     num_sets = 0;
373     drawing_input = cell(1);
374
375     plot_input(obj2,[-1 -1]);
376
377 end
378
379 function GdownCallback(obj,event)
380     %This is the callback function for the G-Code dropdown menu. It
381     grabs
382     %the current and previous values, then sends them to the
383     disp_args
384     %function
385
386     val = obj.Value;
387     prevVal = event.PreviousValue;
388     disp_args(val,prevVal);
389
390 end
391
392 function enterCallback(~,~,text_area)
393     %This is the callback function for the send gcode button. It
394     adds the
395     %G-Code formed by the dropdown and argument inputs to the text
396     area.
397
398     global currentgcode;
399     index = length(text_area.Value)+1;

```

```

391     text_area.Value{index} = sprintf('');
392     for i = 1:1:length(currentgcode)
393         charcode = convertStringsToChars(currentgcode(i));
394         if ~isempty(charcode)
395             text_area.Value{index} = [text_area.Value{index}
396             sprintf(charcode) sprintf(' ')];
397         end
398     text_area.Value{index} = text_area.Value{index}(1:end-1);
399     text_area.Value{index} = [text_area.Value{index} sprintf(';')];
400
401 end
402
403 function fieldChange(obj,~,lbl,obj2)
404 %This is the callback function for when the argument fields are
405 %updated. This function runs every time those are changed
406 %values.
407
408 global currentgcode;
409
410 %Depending on the argument label, add argument to current g
411 %code
412 if lbl == 'X'
413     currentgcode(2) = convertCharsToStrings([lbl obj.Value]);
414 elseif lbl == 'Y'
415     currentgcode(3) = convertCharsToStrings([lbl obj.Value]);
416 elseif lbl == 'Z'
417     currentgcode(4) = convertCharsToStrings([lbl obj.Value]);
418 elseif lbl == 'F'
419     currentgcode(5) = convertCharsToStrings([lbl obj.Value]);
420 elseif lbl == 'P'
421     currentgcode(2) = convertCharsToStrings([obj2.Value obj.
422 Value]);
423 else
424 end
425
426 end
427
428 function convertCallback(~,~,text_area,speed)
429 % This is the callback function for the convert to G-Code
430 % button. It
431 % calls the drawing2gcode function on the drawing_input, then
432 % puts the
433 % results in the text area.
434
435 global drawing_input;
436 if length(drawing_input{1}) > 0
437     gcode = drawing2gcode(speed.Value);
438     text_area.Value = gcode;
439 end
440
441 end
442
443 function linebreakCallback(~,~,text_area)
444 %This is the callback function for the line break button. It
445 just
446 %prints a ';' on the next line.

```

```

442
443     index = length(text_area.Value)+1;
444     text_area.Value{index} = sprintf(';');
445
446 end
447
448 function deleteLineCallback(~,~,text_area)
449     %This is the callback function for the delete line button. It
450     %just
451     %deletes the last line in the G-Code text box
452
453     temp = {};
454     if length(text_area.Value) > 1
455         for i = 1:1:(length(text_area.Value)-1)
456             temp{i} = text_area.Value{i};
457         end
458         text_area.Value = temp;
459     end
460 end
461
462 function pxChange(obj,~,ef)
463     % This is the callback for the P and X dropdown on the G04
464     % argument
465     % inputs. It updates the currentgcode value and also deletes
466     % the
467     % editfield value if the drop down changes value
468
469     global gui;
470     global currentgcode;
471     children = get(gui,'Children');
472
473     for i = 1:1:length(children)
474         if length(children(i).Type) == 11
475             children(i).Value = '';
476         end
477     end
478     currentgcode(2) = convertCharsToStrings([obj.Value ef.Value]);
479 end
480
481 function clearGcodeCallback(~,~,text_area)
482     % This is the callback function for the clear gcode button. It
483     % just
484     % sets the text_area to be equal ','
485
486     text_area.Value = sprintf(';');
487 end
488
489 function send2bufferCallback(~,~,text_area)
490     % This function is the callback for the send to buffer button.
491     % It adds
492     % the lines from the text area to the buffer, then deletes the
493     % text
494     % area.
495
496     global gcode_buffer;

```

```

494 for i = 1:1:length(text_area.Value)
495     gcode_buffer = [{text_area.Value{i}}; gcode_buffer];
496 end
497 text_area.Value = {''};
498 update_clear_btn();
499 update_bufferfig();
500
501 end
502
503 function directionBtnCallback(~,~,dir,dist,speed)
504 % This is the callback function for the directional buttons. It
505 % takes a
506 % direction, distance, and speed, and then ti moves at that
507 % speed for
508 % that dist in that direction.
509
510 global gcode_buffer;
511
512 %If user didn't set distance or speed, give them some default
513 % values
514 if isempty(dist.Value)
515     dist.Value = '1';
516 end
517 if isempty(speed.Value)
518     speed.Value = '100';
519 end
520
521 % If direction = Y+,Y-,X+,X-,Z+,Z-
522 %     add 'G91' to buffer (Set incremental movement)
523 %     add 'G01' to buffer with distance and speed (Move in the
524 % specified
525 %         direction
526 %         add 'G90' to buffer (Set absolute movement)
527 if dir == "Y+"
528     gcode_buffer = [{'G91';'}; gcode_buffer ];
529     gcode_buffer = {[['G01 Y' dist.Value ' F' speed.Value ' ;
530     ]}; gcode_buffer ];
531     gcode_buffer = [{'G90';'}; gcode_buffer ];
532 elseif dir == "X-"
533     gcode_buffer = [{'G91';'}; gcode_buffer ];
534     gcode_buffer = {[['G01 X-' dist.Value ' F' speed.Value ' ;
535     ]}; gcode_buffer ];
536     gcode_buffer = [{'G90';'}; gcode_buffer ];
537 elseif dir == "X+"
538     gcode_buffer = [{'G91';'}; gcode_buffer ];
539     gcode_buffer = {[['G01 X' dist.Value ' F' speed.Value ' ;
540     ]}; gcode_buffer ];
541     gcode_buffer = [{'G90';'}; gcode_buffer ];
542 elseif dir == "Y-"
543     gcode_buffer = [{'G91';'}; gcode_buffer ];
544     gcode_buffer = {[['G01 Y-' dist.Value ' F' speed.Value ' ;
545     ]}; gcode_buffer ];
546     gcode_buffer = [{'G90';'}; gcode_buffer ];
547 elseif dir == "Z+"
548     gcode_buffer = [{'G91';'}; gcode_buffer ];
549     gcode_buffer = {[['G01 Z' dist.Value ' F' speed.Value ' ;
550     ]}; gcode_buffer ];
551     gcode_buffer = [{'G90';'}; gcode_buffer ];

```

```

543 elseif dir == "Z-"
544     gcode_buffer = {[{'G91;'}]; gcode_buffer ];
545     gcode_buffer = {[{'G01 Z-' dist.Value ' F' speed.Value , ,
546 ;'}]; gcode_buffer ];
547     gcode_buffer = {[{'G90;'}]; gcode_buffer ];
548 elseif dir == "home"
549     gcode_buffer = {[{'G28;'}]; gcode_buffer ];
550 else
551 end
552
553 %Update the clear button because values have been added to the
554 %buffer
555 update_clear_btn();
556 update_bufferfig();
557
558 end
559
560 function bufferCallback(~,~)
561 %This is the view gcode buffer button callback. It shows a
562 %figure which
563 %contains a text area which contains the contents of the G-Code
564 %Buffer
565 global bufferfig;
566 global gcode_buffer;
567 bufferfig = uitextarea('Position',[50 20 460, 380]);
568 bufferfig.Parent.Name = 'G-Code Buffer';
569
570 bufferfig.Value = flip(gcode_buffer);
571
572 end
573
574 function bufferClearCallback(~,~)
575 %This function is the buffer clear button callback. It clears
576 %the
577 %buffer and updates the number on itself.
578
579 global gcode_buffer;
580 gcode_buffer = [];
581 update_clear_btn();
582 update_bufferfig();
583
584 end
585
586 function sensorViewCallback(~,~)
587 %This is the callback function for the button that opens the
588 %sensor
589 %data view window. It opens the sensor data view window.
590
591 global sensorViewFig;
592
593 %Make the figure and the headings
594 sensorViewFig = uifigure('Position',[200 100 600 500], 'Tag', ,
595 'svf');
596 axes_label = uilabel(sensorViewFig, 'Text', 'Data Points', ,
597 'Position',[45 460 200 40], 'FontSize', 24);
598 info_label = uilabel(sensorViewFig, 'Text', 'Sensor Data', ,
599 'Position',[390 460 200 40], 'FontSize', 24);

```

```

592 %Label and values for coordinates (data from Arduino)
593 coord_label = uilabel(sensorViewFig,'Text', 'Coordinates (
594 Inches):', 'Position',[390 430 200 25], 'FontSize',16);
595 coord_val = uilabel(sensorViewFig,'Text', ' ', 'Position',[390
410 200 25], 'Tag','COORD');

596 %Label and value for light sensor (data from Arduino)
597 lsv_label = uilabel(sensorViewFig,'Text', 'Light Sensor Value:',
598 , 'Position',[390 360 200 25], 'FontSize',16);
599 lsv_val = uilabel(sensorViewFig,'Text', ' ', 'Position',[390
340 200 25], 'Tag','LSV');

600 %Label and value for RFID (data from Arduino)
601 RFID_label = uilabel(sensorViewFig,'Text', 'RFID Value:', ,
602 Position',[390 290 200 25], 'FontSize',16);
603 RFID_val = uilabel(sensorViewFig,'Text', ' ', 'Position',[390
270 200 25], 'Tag','RFID');

604 %Axes that will show data points
605 dataAxes = uiaxes(sensorViewFig,'Position', [20, 20, 340,
440], 'ButtonDownFcn',@dataAxesCallback); %Create Axes
606 dataAxes.XLim = [0 8.5]; %Set axes limits
607 dataAxes.YLim = [0 11];
608 dataAxes.PickableParts = 'all'; %Make axes clickable
609 dataAxes.HitTest = 'on'; %Make axes clickable
610 dataAxes.NextPlot = 'replacechildren';

611 %Scroll buttons and data point number. Scrolling increases/
612 %decreases
613 %data point number.
614 scroll_left = uibutton(sensorViewFig,'push','Text','<<', ,
615 Position',[390, 50, 90, 22], 'ButtonPushedFcn',{ ,
616 @leftScrollCallback,dataAxes});
617 scroll_right = uibutton(sensorViewFig,'push','Text','>>', ,
618 Position',[490, 50, 90, 22], 'ButtonPushedFcn',{ ,
619 @rightScrollCallback,dataAxes});
620 dpn_val = uilabel(sensorViewFig,'Text', 'Data Point Number: ', ,
621 Position',[390 75 200 25], 'Tag','DPN');

622 %Plot the sensor data on the axes
623 update_sensor_data(dataAxes);

624 end

625 function runCallback(obj,~)
626 %This is the callback function for the run button. It starts
running
627 %whatever Gcode sequence is currently in the buffer by sending
a start
628 %signal to the Arduino. The Arduino responds with some initial
location
629 %and sensor data, then MATLAB knows that it can send the first
gcode
630 %command

631 global gcode_buffer;
632 global s;

```

```

633     global serial_on;
634     global prgm_end;
635
636     %Program end set to 0 means the program is starting.
637     prgm_end = 0;
638     serial_on = 1;
639
640     %If theres stuff in the buffer and run has been turned on, send
641     %the
642     %start signal
643     if length(gcode_buffer) > 0 && obj.Value == 1
644         %serial_on = 0;
645         t = timer('TimerFcn',@timer_trash,'StopFcn',{@send_gcode,s
646 },'StartDelay',0.05);
647         start(t);
648     %Otherwise, turn the button back off
649     else
650         obj.Value = 0;
651     end
652
653     %If the button has been unpressed, press it again
654     if obj.Value == 0
655         obj.Value = 1;
656     end
657
658     %If there's nothing in the buffer, the program can be ended by
659     %unpressing manually
660     if length(gcode_buffer) == 0 && obj.Value == 1
661         obj.Value = 0;
662     end
663
664 function leftScrollCallback(~,~,dataAxes)
665     %This is the callback function for the left scroll button in
666     %the sensor
667     %view window. This decreases the datapoint number so that you
668     %can look
669     %at the next data point on the list
670
671     global sensor_data;
672     sds = size(sensor_data);
673
674     %Find the data point colored blue
675     last = findobj(dataAxes.Children,'Color',[0 0 1]);
676     if size(last) > 0
677         %get the data point number from the tags
678         id = last.Tag;
679         newid = str2num(id)-1; %decrease data point number (go to
680         %next point)
681         %If the data point number is 0, go to the highest one
682         if newid == 0
683             newid = sds(1);
684         end
685         %Update the sensor view with the new selected data point
686         update_sensor_view(num2str(newid),dataAxes);
687     else
688         %If none had been selected previously, just select the

```

```

        first one
686     update_sensor_view('1',dataAxes);
687 end
688
689 function rightScrollCallback(~,~,dataAxes)
690 %This is the callback function for the right scroll button in
691 %the sensor
692 %view window. This increases the datapoint number so that you
693 %can look
694 %at the next data point on the list
695
696 global sensor_data;
697 sds = size(sensor_data);
698
699 %Find the data point colored blue
700 last = findobj(dataAxes.Children,'Color',[0 0 1]);
701 if size(last) > 0
702     %Grab the data point number and increase it by one
703     id = last.Tag;
704     newid = str2num(id)+1;
705     %If the new data point number is too large, go back to the
706     %first
707     %one
708     if newid == sds(1)+1
709         newid = 1;
710     end
711     %Update the sensor view with the new selected data point
712     update_sensor_view(num2str(newid),dataAxes);
713 else
714     %If no point had been selected previously, just select
715     %number 1
716     update_sensor_view('1',dataAxes);
717 end
718
719 function dataPointCallback(self,~,dataAxes)
720 %This is the callback function for clicking on a data point. It
721 %simply
722 %grabs the tag from itself and then passes it on to the
723 %update_sensor_view function so that it can select this new
724 %point.
725
726 id = self.Tag;
727
728 update_sensor_view(id,dataAxes);
729
730 end
731
732 function dirSendCallback(~,~,dir_ser,ser_get)
733 % Callback function for the send button in the direct serial
734 % comm
735 % section.
736
737 global s;
738
739 % For every item in the serial send bar, send it on serial and
740 % delete

```

```

735 % the line from the text area.
736 for idx = 1:1:length(dir_ser.Value)
737     disp(dir_ser.Value{idx});
738     ser_get.Value{end+1} = ',';
739     ser_get.Value{end+1} = sprintf('Outgoing Serial');
740     ser_get.Value{end+1} = sprintf(dir_ser.Value{idx});
741     scroll(ser_get, 'bottom');

742 % Only send if its not an empty line.
743 if ~isempty(dir_ser.Value{idx})
744     writeline(s,dir_ser.Value{idx});
745     dir_ser.Value{idx} = ',';
746 end
747
748 end
749
750
751 function serGetCallback(self,~)
752     %Scroll the serial monitor to the bottom
753
754     scroll(self,'bottom');
755 end
756
757 function dataAxesCallback(~,~)
758     %This callback function does nothing
759 end
760 % ===== %
761
762
763 % === UPDATE FUNCTIONS === %
764 function update_clear_btn()
765     % This function updates the display on the buffer clear button
766     % that
767     % tells you how many lines are in the buffer
768
769     global gui;
770     global gcode_buffer;
771     children = get(gui,'Children');
772     % Find the button by Tag and then set the number in the text to
773     % include
774     % new size of gcode_buffer
775     for i = 1:1:length(children)
776         if children(i).Tag == 'C'
777             children(i).Text = ['Clear Buffer (' int2str(length(
778             gcode_buffer)) ')'];
779         end
780     end
781
782     if length(gcode_buffer) == 0
783         run_btn = findobj(gui.Children,'Tag','RUN');
784         run_btn.Value = 0;
785     end
786
787
788 function update_bufferfig()
789     %This function updates the contents of the text box in the
790     %external
791     %figure which shows the GCode buffer.

```

```

789
790     global bufferfig;
791     global gcode_buffer;
792
793     %If the gcode buffer has stuff in it and the figure exists, set
794     %the new
795     %value of the text box
796     if length(gcode_buffer) > 0 && sum(size(findobj('Value',
797     bufferfig))) > 0
798         bufferfig.Value = flip(gcode_buffer);
799     end
800
801 end
802
803 function update_sensor_data(dataAxes)
804     %This function updates the plot in the sensor view window. It
805     %plots all
806     %of the newest sensor data on the axes.
807
808     global sensor_data;
809
810     %Set the axes to replace old plots with new ones, then plot a
811     %garbage
812     %point
813     dataAxes.NextPlot = 'replacechildren';
814     plot(dataAxes,-1,-1,'ro');
815
816     %Set axes to ADD all new plots
817     dataAxes.NextPlot = 'add';
818
819     sd = size(sensor_data);
820
821     %Plot all of the points
822     for i = 1:1:sd(1)
823         plot(dataAxes,sensor_data(i,1),sensor_data(i,2),'ro','Tag',
824             num2str(i),'ButtonDownFcn',{@dataPointCallback,dataAxes});
825     end
826
827 end
828
829 function update_sensor_view(id,dataAxes)
830     %This function updates the sensor view window given a newly
831     %selected
832     %data point. The data point with data point number 'id' is
833     %turned blue
834     %and its data is shown on the right hand side of the window.
835
836     global sensorViewFig;
837     global sensor_data;
838
839     %Find the point that's colored blue
840     last = findobj(dataAxes.Children,'Color',[0 0 1]);
841
842     %If there was a blue point, turn it back to red
843     if size(last) > 0
844         last.Color = [1 0 0];
845         last.MarkerSize = 6;
846     end

```

```

840
841 %Get the point with data point number id and turn it blue
842 curr = findobj(dataAxes.Children,'Tag',id);
843 curr.Color = [0 0 1];
844 curr.MarkerSize = 10;
845
846 nid = str2num(id);
847
848 %Grab all of the data display labels
849 coord_lbl = findobj(sensorViewFig.Children,'Tag','COORD');
850 lsv_lbl = findobj(sensorViewFig.Children,'Tag','LSV');
851 rfid_lbl = findobj(sensorViewFig.Children,'Tag','RFID');
852 dpn_lbl = findobj(sensorViewFig.Children,'Tag','DPN');
853
854 %get all of the values to display from the sensor data (depends
855 %on id)
856 x = num2str(sensor_data(nid,1));
857 y = num2str(sensor_data(nid,2));
858 z = num2str(sensor_data(nid,3));
859 lsv = num2str(sensor_data(nid,7));
860 rfid = num2str(sensor_data(nid,8));
861
862 %Change the text of the labels to match the data gathered from
863 %sensor_data
864 coord_lbl.Text = ['X: ' x ' Y: ' y ' Z: ' z];
865 lsv_lbl.Text = lsv;
866 rfid_lbl.Text = rfid;
867 dpn_lbl.Text = ['Data Point Number: ' id];
868
869 end
870 % ===== %
871
872 % === SERIAL FUNCTIONS === %
873 function readSerialData(src,~)
874 %This is the callback function for the serial device. This is
875 %called
876 %when there are bytes available.
877
878 global sensor_data;
879 global gui;
880 global sensorViewFig;
881 global serial_on;
882 values = zeros(1,8);
883
884 %If there are bytes available and serial is enabled, grab all
885 %of the
886 %new data.
887 serial_on = 1;
888 if src.NumBytesAvailable > 0 && serial_on == 1
889     values = getSerial(src);
890     sensor_data = [sensor_data; values];
891
892     %If the sensor view window is open, update the axes.
893     if size(findobj(sensorViewFig,'Type','figure')) > 0
894         dataAxes = findobj(sensorViewFig.Children,'Type','axes',
895 );
896             if size(dataAxes) > 0

```

```

894         update_sensor_data(dataAxes);
895     end
896   end
897 end
898
899 function [values] = getSerial(src)
900 %This function actually accesses the serial data and parses it
901 %into the
902 %sensor data matrix
903
904 global gcode_buffer;
905 global gui;
906
907 character = ' ';
908 data = '';
909 current = '';
910 j = -1;
911 lastj = -1;
912 values = zeros(1,8);
913
914 %Keep getting data until it hits a G (end of code) or a # (end
915 %of transmission);
916 while character ~= 'G' && character ~= '#'
917     character = read(src,1,"char");
918     data = [data character];
919 end
920
921 %Parse data and place into sensor_data depending on the letter
922 %preceding it.
923 for i = 1:length(data)
924     if data(i) == 'X' %X location
925         j = 1;
926     elseif data(i) == 'Y' %Y location
927         j = 2;
928     elseif data(i) == 'Z' %Z location
929         j = 3;
930     elseif data(i) == 'A' %X location
931         j = 4;
932     elseif data(i) == 'B' %Y location
933         j = 5;
934     elseif data(i) == 'C' %Z location
935         j = 6;
936     elseif data(i) == 'L' %Light sensor value
937         j = 7;
938     elseif data(i) == 'R' %RFID value
939         j = 8;
940     elseif data(i) == 'G' %Send another Gcode command
941         j = -1;
942         %For some reason, the serial write command cannot be
943         %used
944         %within the serial read callback, so short timers have
945         %to be
946         %used.
947         if ~isempty(gcode_buffer)
948             t = timer('TimerFcn',@timer_trash,'StopFcn',{
949 @send_gcode,src}, 'StartDelay',0.1);

```

```

947         start(t);
948     end
949 elseif data(i) == '#'
950     while character ~= 'G'
951         character = read(src,1,"char");
952     end
953     character = read(src,1,"char");
954     j=-1;
955 end
956
957 %If theres a new letter, put all of the previous numbers
958 %into the
959 %sensor values
960 if j ~= lastj && lastj ~= -1
961     values(1:lastj) = str2double(current(2:end));
962     current = ',';
963 end
964
965 %If j is unchanged (same letter), keep adding the
966 %information
967 if j ~= -1
968     current = [current data(i)];
969 end
970
971 lastj = j;
972 end
973
974 ser_get = findobj(gui,'Tag','SER');
975
976 if sum(values(1:3)) ~= 0
977     disp("Incoming Location Data:");
978     disp(values(1:3));
979     ser_get.Value{end+1} = sprintf('Incoming Location Data:');
980     ser_get.Value{end+1} = sprintf(['X: ' num2str(values(1)) ,
981                                     'Y: ' num2str(values(2)) , 'Z: ' num2str(values(3))]);
982     scroll(ser_get,'bottom');
983 end
984
985 if sum(values(4:6)) ~= 0
986     disp("Incoming Thread Length Data:");
987     disp(values(4:6));
988     ser_get.Value{end+1} = sprintf('Incoming Thread Length Data:');
989     ser_get.Value{end+1} = sprintf(['A: ' num2str(values(4)) ,
990                                     'B: ' num2str(values(5)) , 'C: ' num2str(values(6))]);
991     scroll(ser_get,'bottom');
992 end
993
994 function send_gcode(~,~,src)
995 %This function sends 1 line of gcode through serial to the
996 %Arduino.
997 %Because of the nature of the serial read callback, this
998 %function has
999 %to be set up as a callback function for a timer.
1000
1001 global gcode_buffer;

```

```

998 global serial_on;
999 global gui;
1000 global prgm_end;
1001
1002 % Grab the serial monitor
1003 ser_get = findobj(gui,'Tag','SER');
1004
1005 serial_on = 0;
1006
1007 %If the gcode buffer has stuff in it and theres nothing more to
1008 %read,
1009 %send the stuff.
1010 if length(gcode_buffer) > 0 && src.NumBytesAvailable == 0
1011     %get rid of all of the empty lines or line breaks
1012     while (sum(gcode_buffer{end} == ';') == 1 && length(
1013         gcode_buffer{end}) == 1) || length(gcode_buffer{end}) == 0
1014         gcode_buffer(end) = [];
1015     end
1016     writeline(src,gcode_buffer{end});
1017     disp("Outgoing GCode:");
1018     disp(gcode_buffer{end});
1019     % Print gcode to serial monitor
1020     ser_get.Value{end+1} = ',';
1021     ser_get.Value{end+1} = sprintf('Outgoing Gcode');
1022     ser_get.Value{end+1} = sprintf(gcode_buffer{end});
1023     scroll(ser_get,'bottom');
1024     gcode_buffer(end) = [];
1025     update_clear_btn();
1026 end
1027
1028 %Only turn the serial back on if the program is not ended
1029 if prgm_end == 0
1030     serial_on = 1;
1031 end
1032
1033 update_bufferfig();
1034
1035
1036 % === PROGRAM FLOW FUNCTIONS === %
1037 function timer_trash(~,~)
1038     %Timers have to have a function to be executed when they start.
1039     %Nothing
1040     %needed to happen at the start of the timers in this program,
1041     %so this
1042     %function is empty.
1043 end
1044
1045 function end_program(~,~)
1046     %This function is run when the current gcode sequence has run
1047     %its
1048     %course. It deactivates serial, deactivates the run button, and
1049     %sets
1050     %the program end flag to true.
1051
1052     global gui;
1053     global serial_on;

```

```
1050 global prgm_end;
1051
1052 run_btn = findobj(gui.Children,'Tag','RUN');
1053 run_btn.Value = 0;
1054 serial_on = 0;
1055 prgm_end = 1;
1056
1057 end
```

8.3 Calculating Thread Lengths in Arduino

Current and target thread lengths are calculated using Pythagorean's theorem within the Arduino. First we must find the length of the projection of the thread connected to the payload. With that length, it is possible to calculate the necessary thread length by using the height of the triangle that is created between the thread, projection and the pylon.

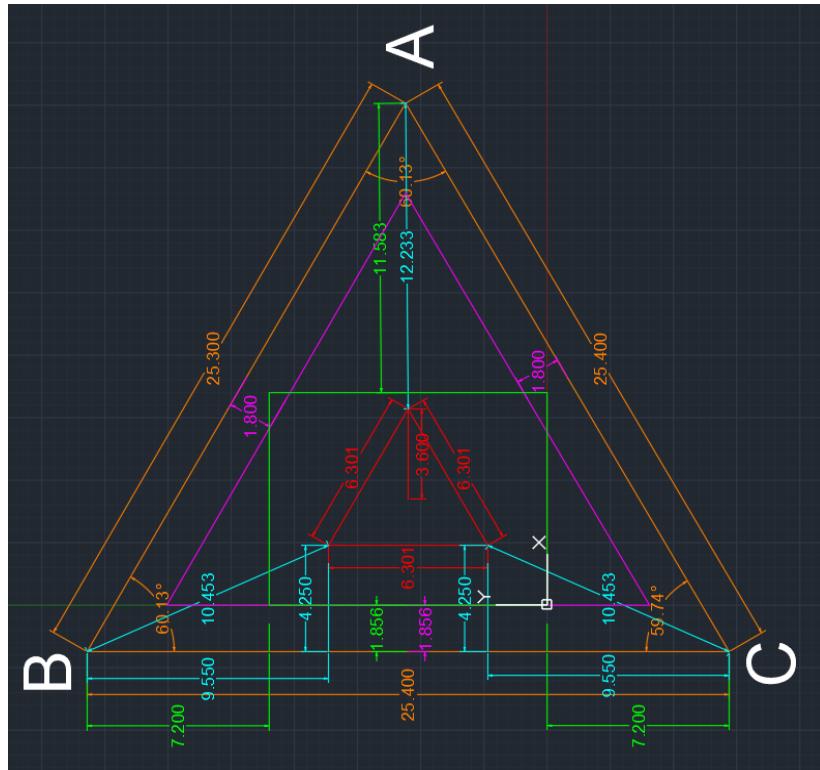


Figure 48: Calculating projection of thread length based on known values.

After the projections in light blue in Figure 48 are calculated, the actual thread length can be calculated by using the Pythagorean's theorem with the difference in height from the top of the pylon to the payload and the projection length. This is very evident when you look at Figure 49.

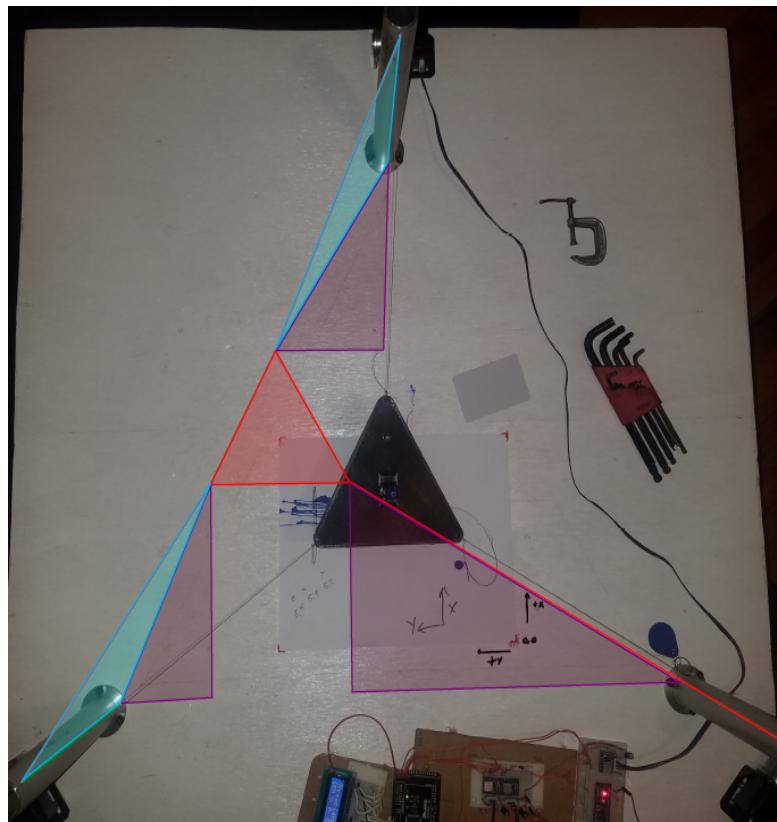


Figure 49: Calculating thread length based on projection of thread and height of the blue triangle.