Project Showcase Technical/Developer Guide

ECE 342: HyperRail, Winter 2021

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Table of Contents

Development of a custom tool head and control system for OSU's HyperRail with OPEnS. Control system is written in MATLAB and Python, and utilizes an Arduino library for G-CODE parsing. Images are input to MATLAB to generate tool paths based on edge-detection. The resulting path is converted into a G-CODE file that is input to a Python-based GUI program, and an Arduino onboard the HyperRail. The custom tool head for the HyperRail is built of low-cost and 3D printed parts that are light and easily assembled. Head is controlled by a 360deg servo that can be pre-mounted with 4 pens on compliant mechanisms. The tool head features a quick release pin for easy removal.

Electrical Specifications

Table 1.1: Specifications for 24V to 5V Step down power supply

Name	Value	Description
Iout	1.0A	Maximum Output Current
VinMax	24.0V	Maximum Input Voltage
VinMin	24.0V	Minimum Input Voltage
base_pn	LMR14010A	Base Product Number
Source	DC	Input Source Type
Ta	30.0°C	Ambient Temperature

User Guide

This section will outline the instructions for setting up and operating the control system.

Edge Detection:

1. Take a picture of what you want you want the Hyper Rail to travel around
2. Upload picture to computer
3. Run MATLAB script “Edge_Detection.m”
4. Input file path
5. Open gcode.txt in Python G-Code parser for Auto Mode

G-Code Parser:

1. Open the terminal and run “python3 parser.py”(Assuming python3 is installed)

2. The program will then ask if you would like to run your G-Code commands manually or put it in auto mode. The G-Code commands must have the right amount of parameters to work.
    a. When in manual mode you will type the G-Code command to run.
    b. When in auto mode it will read from the file. Type in the file path for the G-Code file to run, the format for the file will be a text file(.txt)
3. Then it will display on the GUI using python Turtle Library

Design Artifact Figures

This section includes the block diagram and interface table designed for this project.

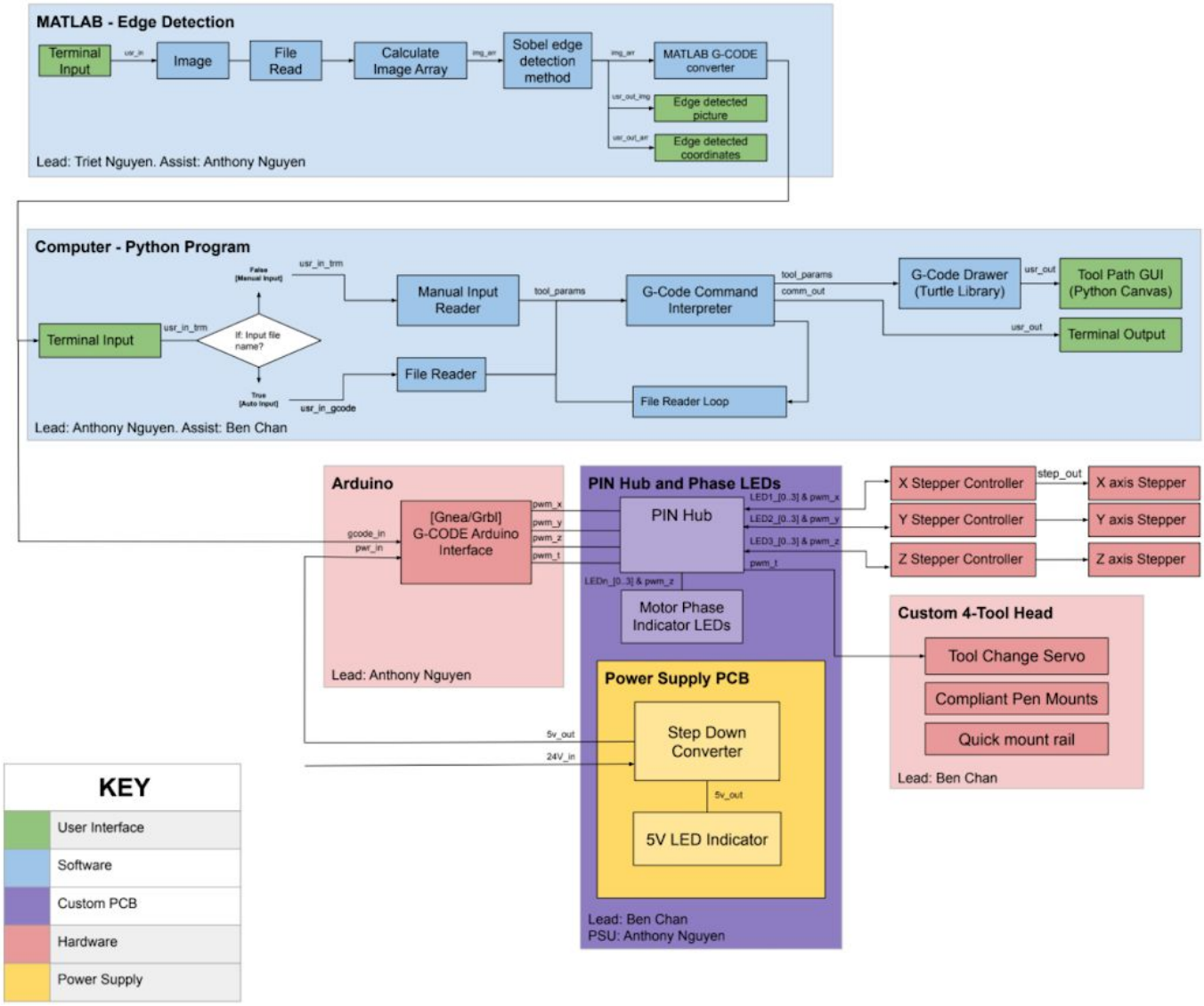


Figure 3.1: Project Block Diagram

Table 3.1: Interface Definition Table

Interface Definition Table			
Name	Type	Value	Description
usr_in_img	User input	Image path	Receive Inputs: ● Image ● File path to an image
usr_in_gcode	User input	G-CODE file path	Receive inputs: ● G-CODE file
usr_in_trm	User input	Terminal input	Receive inputs: ● Terminal inputs ● Manual G-CODE commands
usr_out_img	User output	Image	Display: ● Edge detection image ● 2D array
usr_out_arr	User Output	Array	Output: ● Edge detection values converted to an array
img_arr	Image array	2D array	● 2D array of values
gcode	G-CODE file	G-CODE	G-CODE file containing G-CODE commands. Output form MATLAB, and input to the G-CODE parser/GUI and Arduino.
tool_params	Python object: Tool parameters	Python object containing variables for the following values: • float X • float Y • float Feed rate • str Mode • str Units • int Current tool • int Next tool	• Target x-coordinate • Target y-coordinate • Target feed rate • Set tool movement to absolute or relative • Set units between inches and millimeters • Keep track of the current tool for switching tools • Set next tool
comm_out	Python variables: Tool commands	Float values for X, Y, Z, and T positions.	Instantaneous power state • X-axis motion • Y-axis motion • Z-axis motion • Tool switch rotation
pwr_in	Power input	Voltage (5V)	• Arduino NANO regulated power supply
pin_out	Arduino PIN output		• Arduino output PINs
step_out	Stepper Output	A+, A-, B+, B-	Pulse voltages from motor

			controller to stepper motors
pwm_x	x-axis servo PWM	Integer [0, 255]	• Instantaneous feed rate of x-axis servo. Min 0, Max 255 = 6” per second.
pwm_y	y-axis servo PWM	Integer [0, 255]	• Instantaneous feed rate of y-axis servo. Min 0, Max 255 = 6” per second.
pwm_z	z-axis servo PWM	Integer [0, 255]	• Instantaneous feed rate of z-axis servo. Min 0, Max 255.
LEDn_[0..3]	LED indicators	4 sets of LEDs • LED1_[0..3] • LED2_[0..3] • LED3_[0..3] • LED4_[0..3]	4-LEDs for each motor controller. 16 total. LED indicators are powered by an op-amp and are wired in parallel with A+, A-, B+, B- for each controller. Wired to ground.
24v_in	24V input	Voltage (24V)	Receives 24V input from external source.
5v_out	5V output	Voltage (5V)	Output 5V ● Supplies the Arduino with 5V ● Indicating supply voltage output with an indicator LED.

3D models and part dimensions

This section includes CAD renders and photos of the tool head. Extensive part drawings and dimensions can be found at the end of this document.

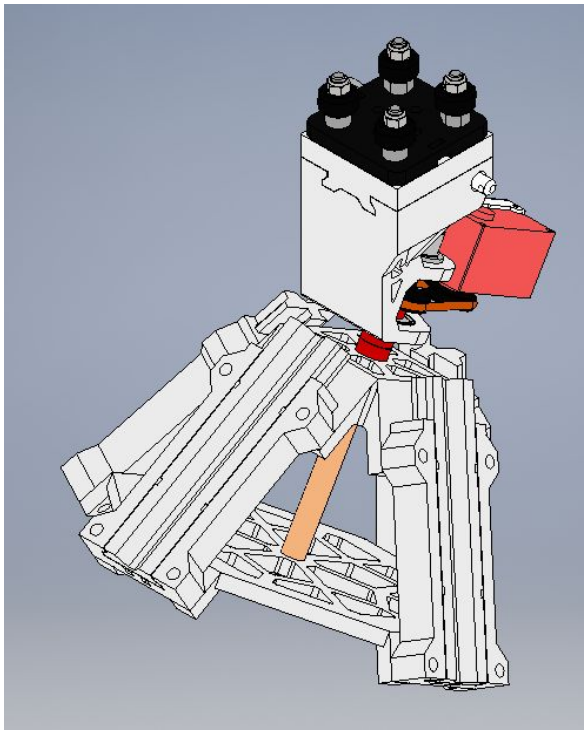


Figure 4.1: Iso view of tool head assembly

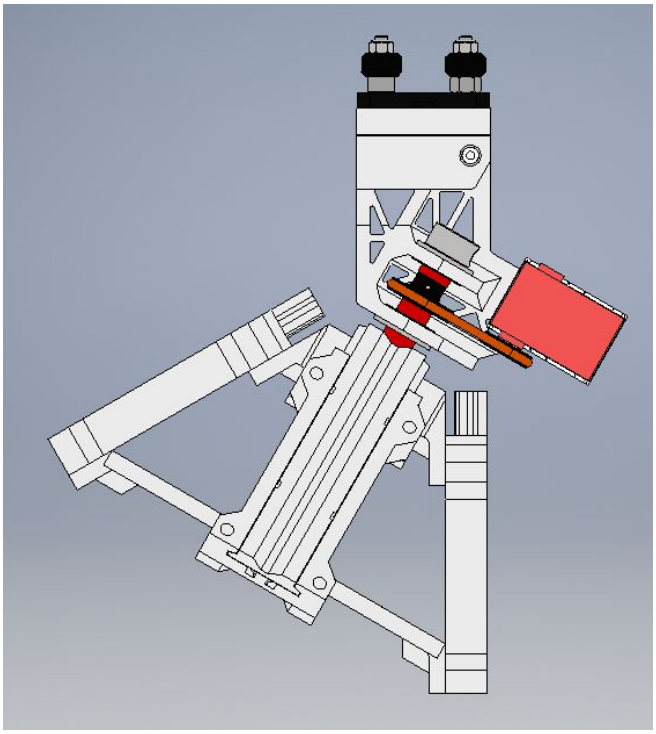


Figure 4.2: Side view of tool head assembly

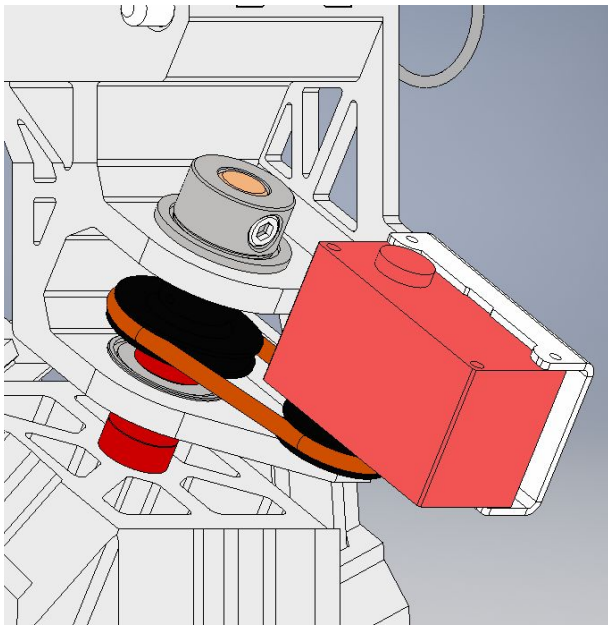


Figure 4.3: Servo mount and pulley system

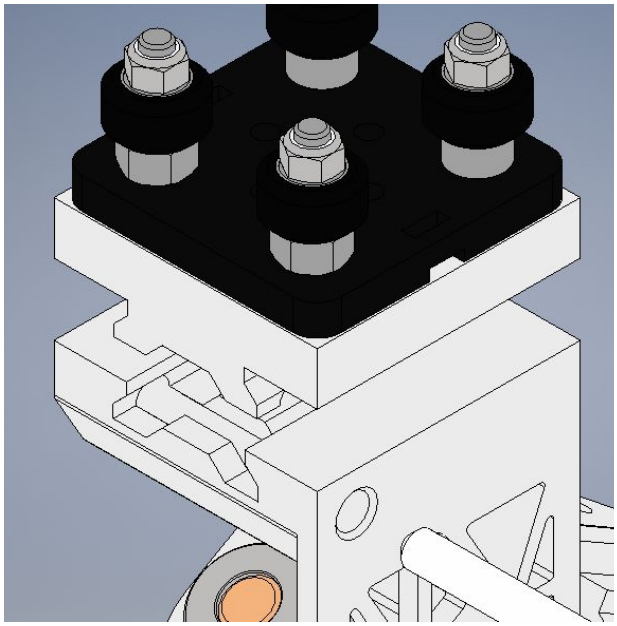


Figure 4.4: Quick swap/mount rail system

PCB Schematics and Information

This section will include the PCB schematic and board layouts, as well as the major dimensions of the PCB for mounting. This section will also include the enclosure design/renders, as well as the major dimensions of the enclosure.

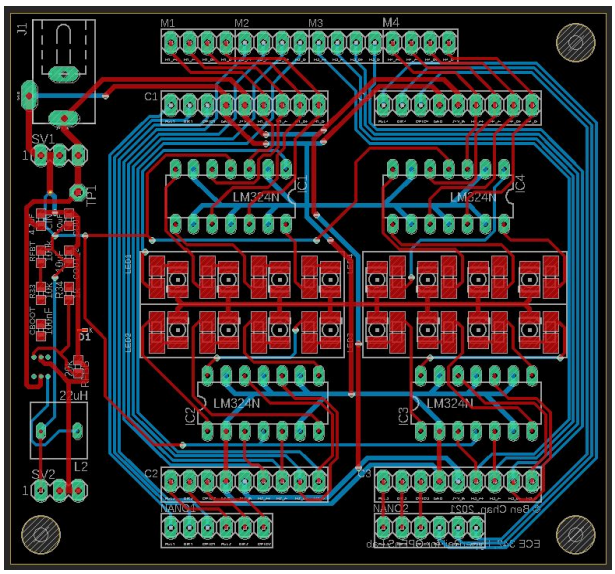


Figure 5.1: PCB all layers

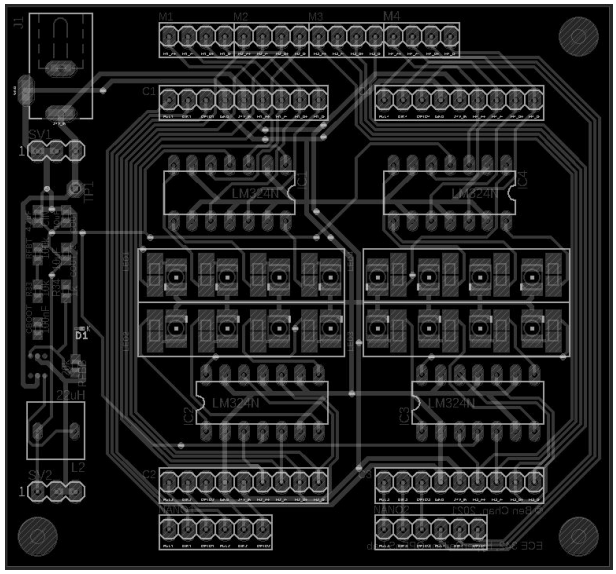


Figure 5.2: PCB component layout

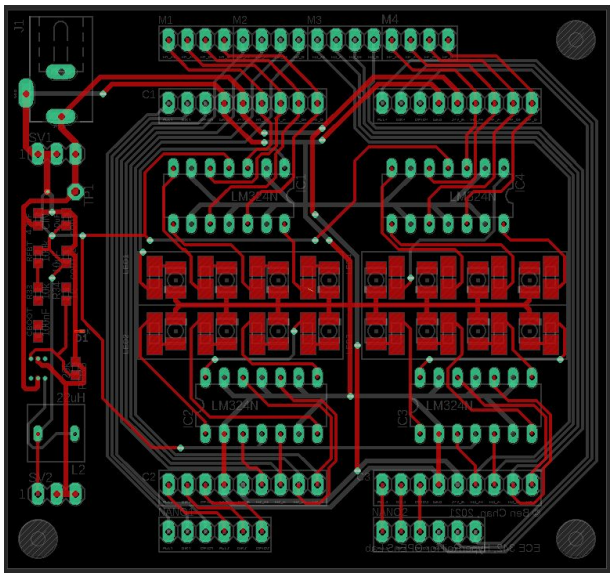


Figure 5.3: PCB top layer pads and traces

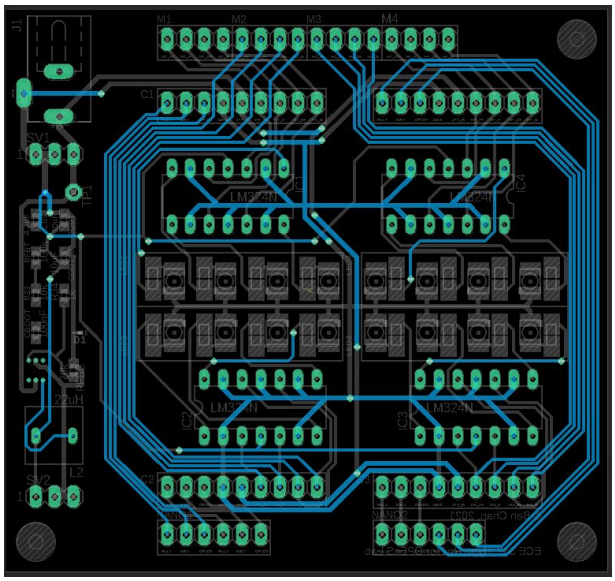


Figure 5.4: PCB bottom layer pads and traces

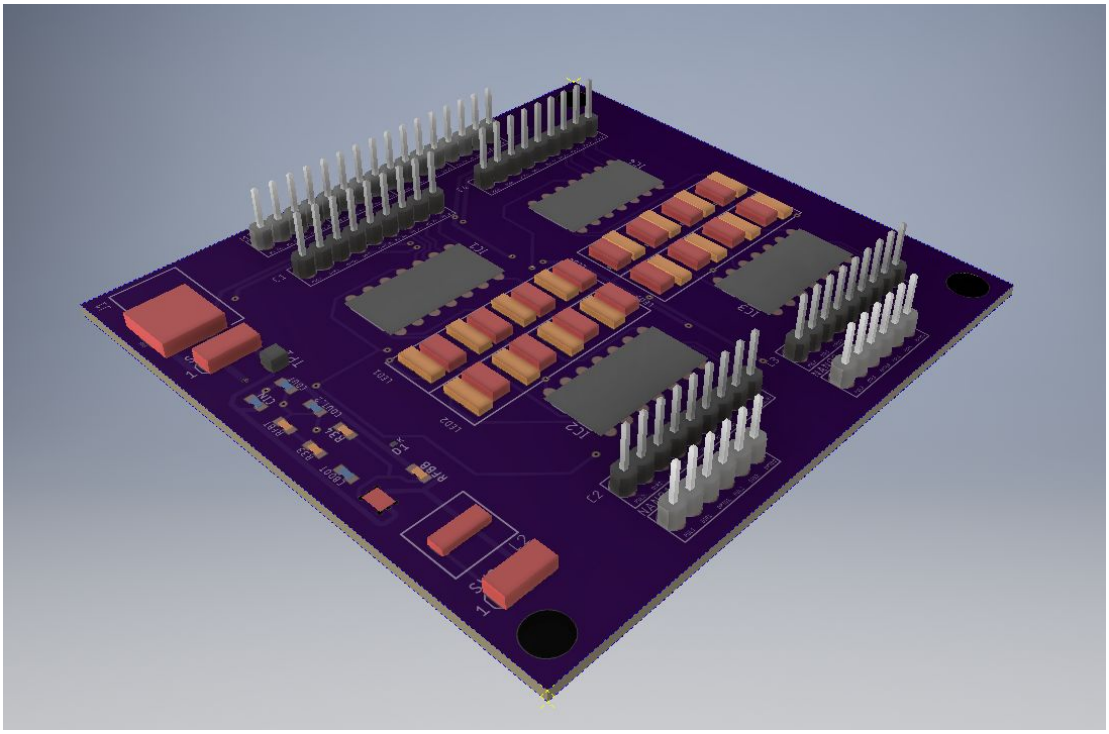


Figure 5.5: PCB Layout Render in Inventor Professional

Note that in Figure 5,5 and in the dimensions shown in Figure 5.6, components are represented by the default Autodesk Eagle component blocks. Package sizes for most components are accurate for blocking. Exceptions to this include the 4-channel op amps and the 24V jack.

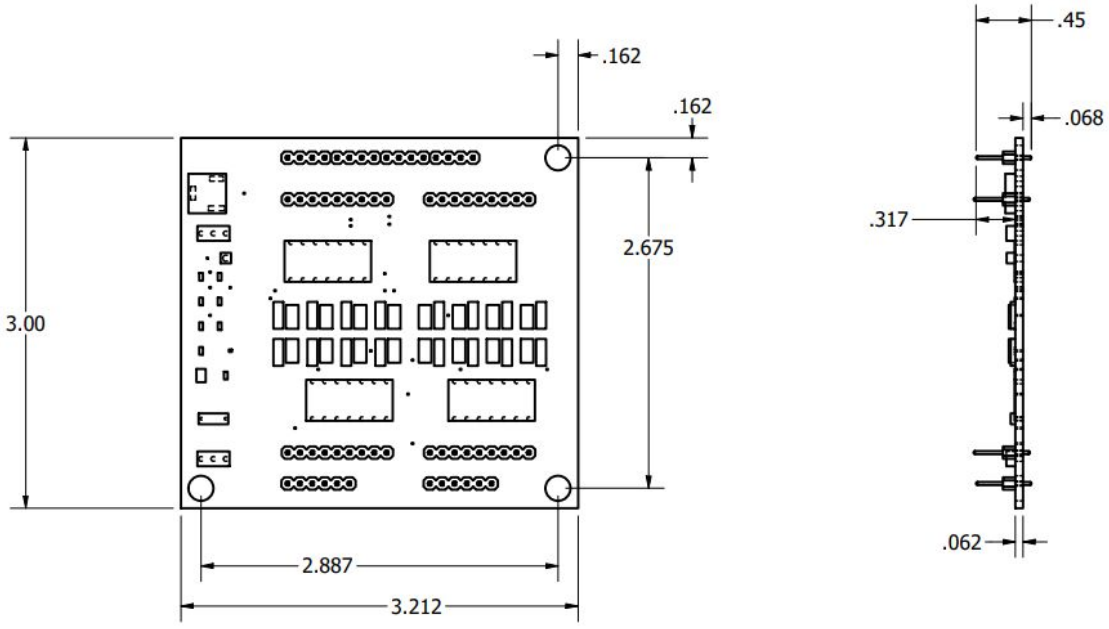


Figure 5.6: PCB Major dimensions

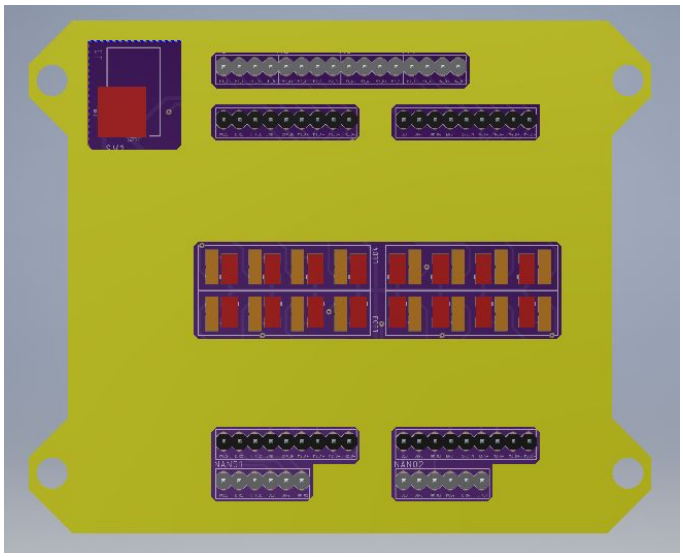


Figure 5.7: Enclosure top view

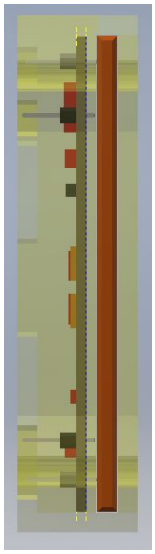


Figure 5.8: X-ray enclosure side view

The enclosure was designed to be easily assembled. The PCB is inserted via an opening in the bottom of the enclosure. Three hardstops in the corners of the enclosure hold the board in place once the back panel (see orange panel in Figure 5.8) has been installed. All pieces are locked in place once the 10-24 screws have been inserted into the four corners.

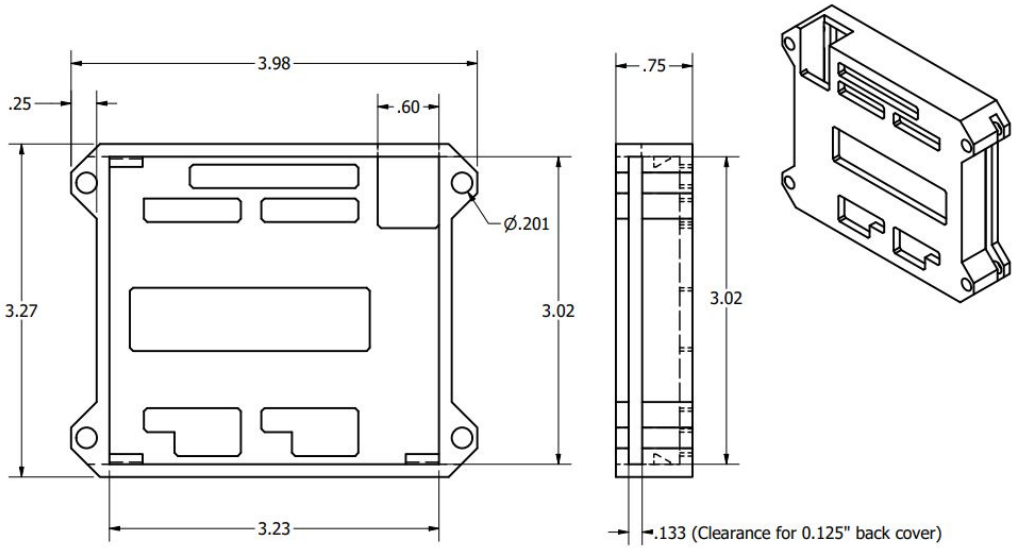


Figure 5.9: Enclosure major dimensions

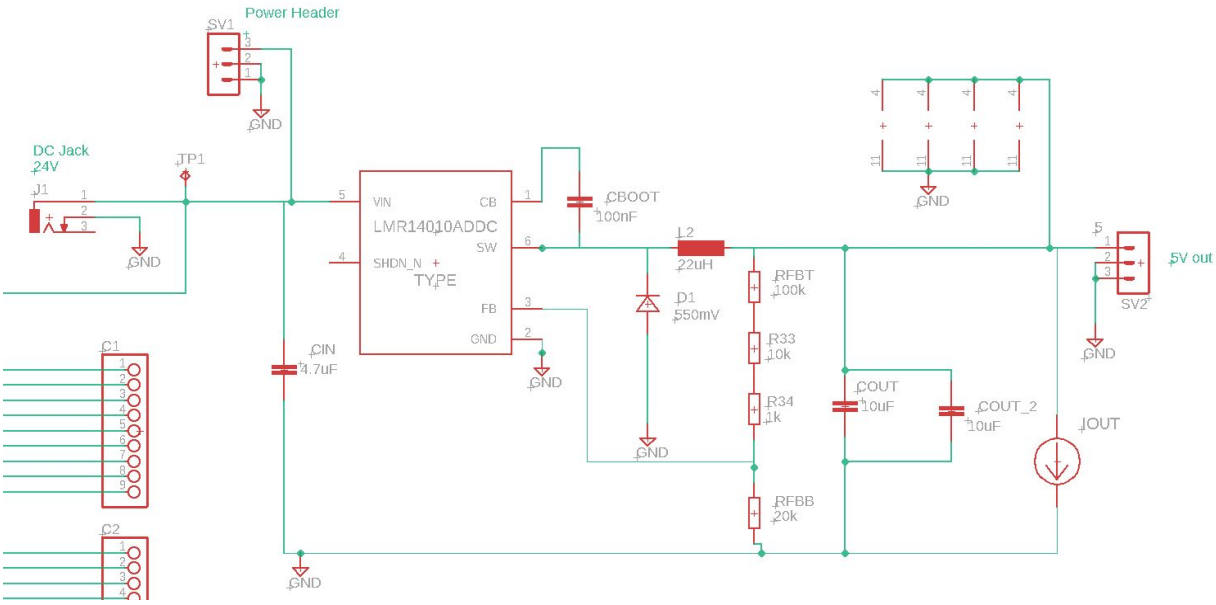


Figure 5.10: 24V to 5V Step Down Power Supply Schematic

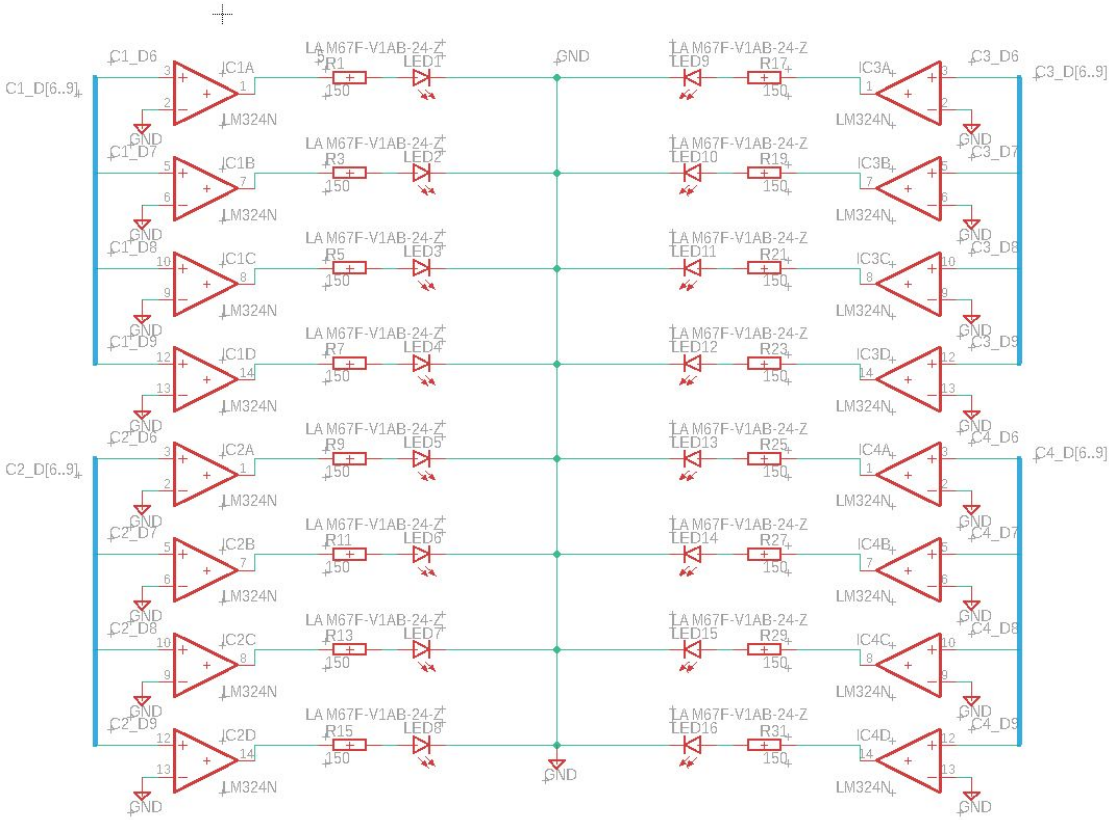


Figure 5.11: Indicator LEDs in op-amp.

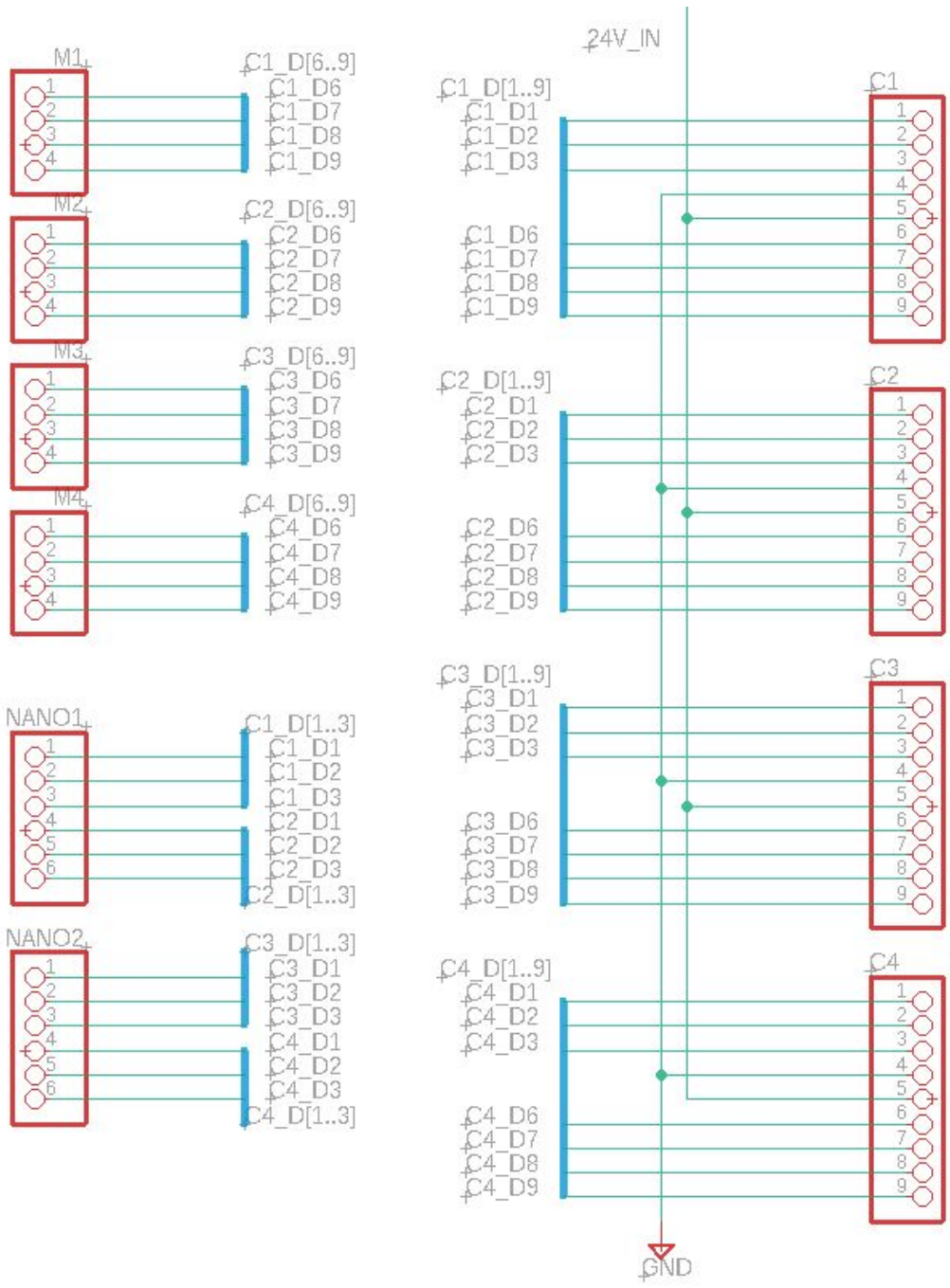


Figure 5.12: PIN layouts and busses for NANO, motor controller and motor I/O

Bill of Materials (BOM)

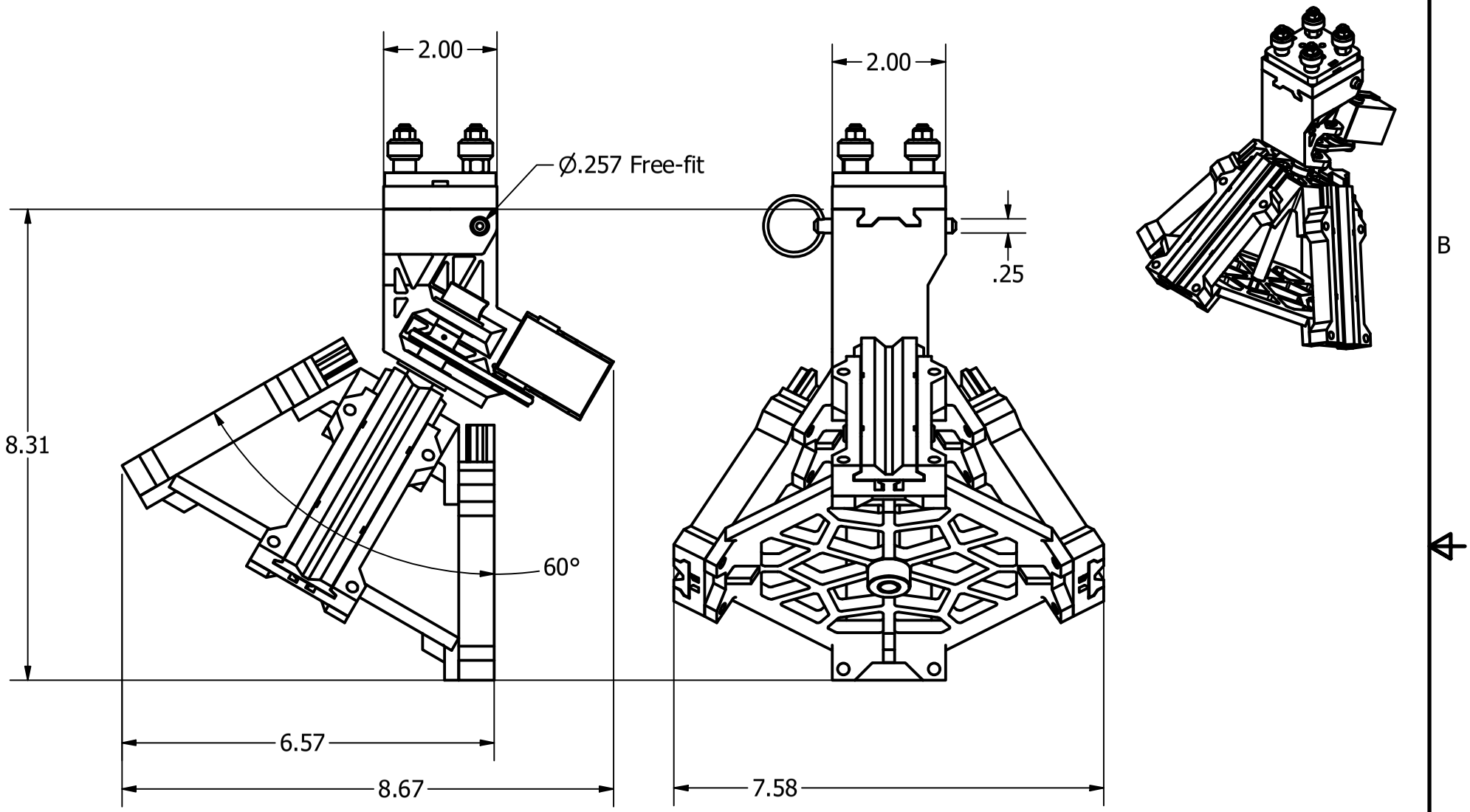
Oregon State University	Bill of Materials (BOM) for HyperRail with OPEnS Control System and Custom Tool Head						
Mechanical Parts							
Assembly	Source/Manufacturer	Description	Price/unit	Units	Price Total	Mfr. Part #	Part number
HyperRail	Arrow	Stepper Motor - 68 oz.in (400 steps/rev)		3			ROB-10846
HyperRail	Amazon	Motor Mounting Bracket		2			
HyperRail	StepperOnline	Nema 23 Motors		4			23HS22-2804S-PG4
HyperRail	StepperOnline	Digital Stepper Drive		4			DM332T
HyperRail	StepperOnline	Power Supply		2			S-201-24
HyperRail	adafruit	bump switches		4			818
HyperRail	McMaster	Male-Female Threaded Hex Standoff (M6, 20mm long)		8			98952A437
HyperRail	Grainger	Nylon Spacer M3, 5mm long (10pk)		1			3ZMR8
HyperRail	Grainger	Shoulder Screw - 1/4 Diameter, 1.5" length, #10-24		1			4XY22
HyperRail	Misumi	Rollers for Aluminum Extrusion - 5, HFROLLM		8			HFROLLM5
HyperRail	McMaster	Flanged Sleeve Bearing		2			6338K568
HyperRail	McMaster	Hex bolt (pack of 25)		1			91292A142
HyperRail	McMaster	Threaded Hex standoff		10			95947A562
HyperRail	McMaster	15mm Hex Drive Screw (pack of 50)		1			92095A128
HyperRail	OpensBuild	Mini V Gantry Kit Cart		1			1185-Set
HyperRail	Amazon	Cable Wire Carrier - 15*15B semi enclosed		4			lm201904221110
HyperRail	OpensBuild	Solid V Wheel Kit		8			480
HyperRail	OpenBuild PartStore	Timing Pulley		1			200
HyperRail	OpenBuild PartStore	Timing Belt		8			470-By-the-Foot
Tool Head	3D Print	Custom 3D printed tool head frame					
Tool Head	Amazon	3/8" OD wood dowel		1	$7.99		
Tool Head	Amazon	Hiwonder LX-15D High Torque Full Metal Gear Servo	$18.99	1	$18.99	LX-15D	
Tool Head	Amazon	10-24 nylon hex nuts		Set	$6.69		
Tool Head	Amazon	#10-24 x 1-1/4" button head socket cap screws		Set	$9.99		
Tool Head	Amazon	3/8" Bore axle shaft collars w/ Set screw		2	$12.99		

Tool Head	Amazon	Hiwonder Servo Bracket compatible with LX-15D Bus Servo	$9.99	1	$9.99		
Tool Head	Amazon	24ft x 3mm Polyurethane Transmission Round Belt (orange)	$8.79	1	$8.79		
Tool Head	Onyx Green	Assorted Rubber bands (100% Natural Rubber)	$2.75	Set	$2.75		
Electronics/ Sensor Package							
Assembly	Source/Manufacturer	Description	Price/unit	Units	Price Total	Mfr. Part #	Part #
HyperRail	Adafruit	Adafruit Feather M0 with RFM95 LoRa Radio - 900MHz - RadioFruit		2			3178
HyperRail	Adafruit	uFL SMT Antenna Connector		2			1661
HyperRail	Adafruit	900Mhz Antenna Kit - For LoPy, LoRa, etc		2			3340
HyperRail	CO2Meter	K30 10,000ppm CO2 Sensor		1			SE-0018
HyperRail	Digikey	Adafruit TSL2591 High Dynamic Range Digital Light Sensor		1			1980
HyperRail	Adafruit	PowerBoost 1000 Charger - Rechargeable 5V Lipo USB Boost @ 1A - 1000C		1			2465
HyperRail	Adafruit	Short Feather Male Headers - 12-pin and 16-pin Male Header Set		1			3002
HyperRail	Digikey	Header Kit for Feather - 12-pin and 16-pin Female Header Set		1			2886
HyperRail	Adafruit	Stacking Headers for Feather - 12-pin and 16-pin female headers		1			2830
HyperRail	Adafruit	Adafruit Ethernet FeatherWing		1			3201
HyperRail	PCBWAY	PCB for the eGH Sensor Pacakge		5			
HyperRail	Mouser	Short Feather Male Headers - 12-pin and 16-pin Male Header Set		2			3002
HyperRail	Mouser	Header Kit for Feather - 12-pin and 16-pin Female Header Set		1			2886
HyperRail	Amazon	A container to store all the sensors		1			B07RNM73P3
HyperRail	Mouser	M0 Board for Sensor controller		1			2772
HyperRail	Mouser	TSL2591 Light Sensor		1			1980
HyperRail	Mouser	SHT31-D Humidity & Temp Sensor		1			2857
HyperRail	Mouser	Adalogger FeatherWing - RTC + SD		1			2922
HyperRail	C02Meter	C02 Sensor		1			SE-0018
HyperRail	Mouser	M0 LoRa		2			3178
HyperRail	Mouser	LoRa Antenna		2			485-3340
HyperRail	Mouser	u.Fl connector		2			485-1661
HyperRail	Mouser	TSL2591 Light Sensor		1			1980
HyperRail	Mouser	SHT31-D Humidity & Temp Sensor		1			2857

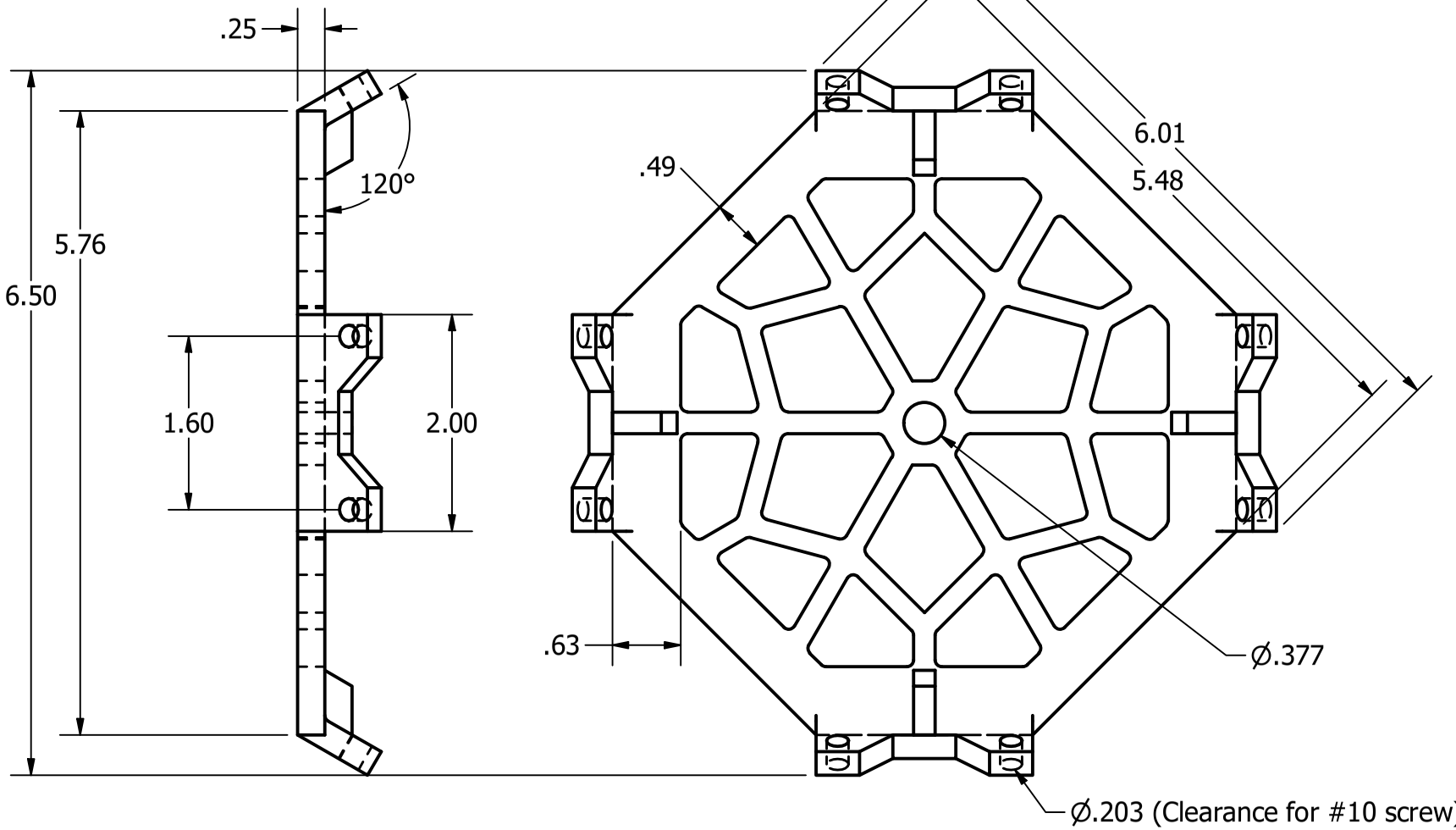
Pin Hub PCB	Amazon	Housing Adapter Cable Connectors		Set	$17.99		
PIN Hub PCB	Amazon	EDGELEC Jumper Wires (MtM, MtF, FtF) Ribbon Cables		Set	$5.89		
PIN Hub PCB	Yageo	150 Ohms ±1% 0.1W, 1/10W Chip Resistor 0603 (1608 Metric) Thin Film	$0.06	16	$0.90	RT0603FRE07150RL	YAG5941CT-ND
PIN Hub PCB	Osram	LED Lighting Color Mini TOPLED Amber 618nm (612nm ~ 624nm) 2-SMD, J-Lead	$0.28	16	$4.43	LA M67F-V1AB-24-Z	475-3396-1-ND
PIN Hub PCB	Oupiin	PIN HEADER, SINGLE ROW, 40 PIN,	$0.17	2	$0.34	2011H-1X40HB	2553-2011H-1X40HB-ND
24v to 5v PS	TDK Corporation	CAP CER 4.7UF 35V X5R 0603	$0.46	1	$0.46	C1608X5R1V475K080AC	445-9064-1-ND
24v to 5v PS	AVX Corporation	CAP CER SMD	$0.14	1	$0.14	06035L104K4T4A	478-06035L104K4T4ACT-ND
24v to 5v PS	Taiyo Yuden	CAP CER 10UF 25V X5R 0603	$0.44	2	$0.88	TMK107BBJ106MA-T	587-6023-1-ND
24v to 5v PS	Yageo	RES SMD 100K OHM 1% 1/10W 0603	$0.10	1	$0.10	RC0603FR-07100KL	311-100KHRCT-ND
24v to 5v PS	Yageo	RES SMD 1K OHM 5% 1/10W 0603	$0.10	1	$0.10	RC0603JR-071KL	311-1.0KGRCT-ND
24v to 5v PS	Yageo	RES SMD 10K OHM 5% 1/10W 0603	$0.10	1	$0.10	RC0603JR-0710KL	311-10KGRCT-ND
24v to 5v PS	Yageo	RES SMD 20K OHM 1% 1/10W 0603	$0.10	1	$0.10	RC0603FR-0720KL	311-20.0KHRCT-ND
24v to 5v PS	Würth Elektronik	FIXED IND 22UH 3A 50 MOHM SMD	$2.12	1	$2.12	7450000000	732-2992-1-ND
24v to 5v PS	Switchcraft Inc.	CONN POWER JACK SOLDER EYELET	$6.55	1	$6.55	ST10U	SC2073-ND
24v to 5v PS	Texas Instruments	IC REG BUCK ADJ 1A TSOT23-6	$1.40	1	$1.40	LMR14010ADDCR	296-49761-1-ND
24v to 5v PS	Oupiin	PIN HEADER, SINGLE ROW, 40 PIN,	$0.17	1	$0.17	2011H-1X40HB	2553-2011H-1X40HB-ND

Part Drawings and Documentation

The following section includes all of the drawings for the 3D models designed for this project. This includes all custom parts for the tool head, as well as PCB enclosure.

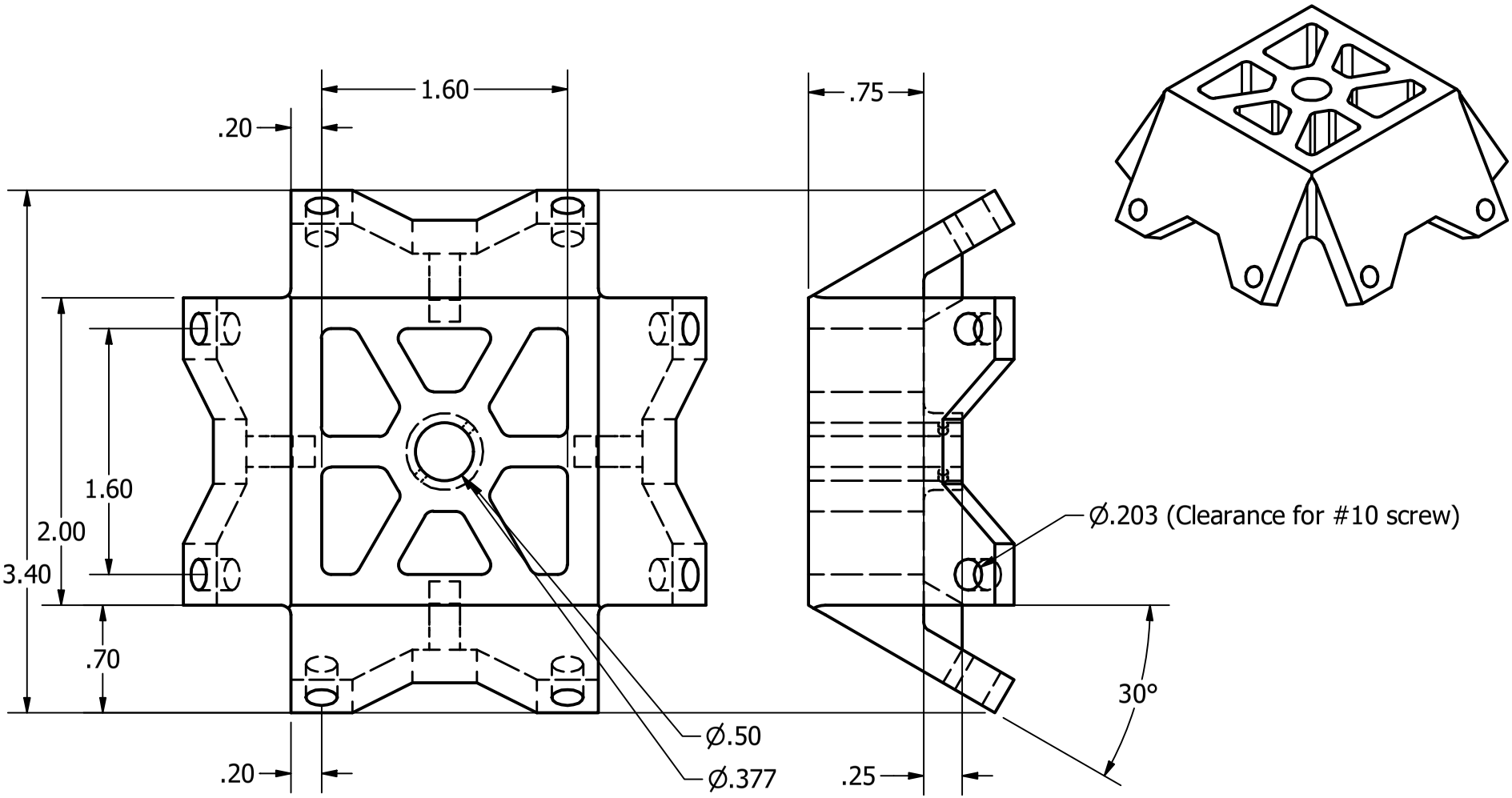


DRAWN Ben Chan	2/23/2021	Tool_Head_Assem Count: 1
CHECKED		TITLE Assembly - Major dimensions
QA		
MFG		
APPROVED		
		SIZE A | DWG NO Assem_Drawings | REV
		SCALE 0.4 | SHEET 1 OF 10



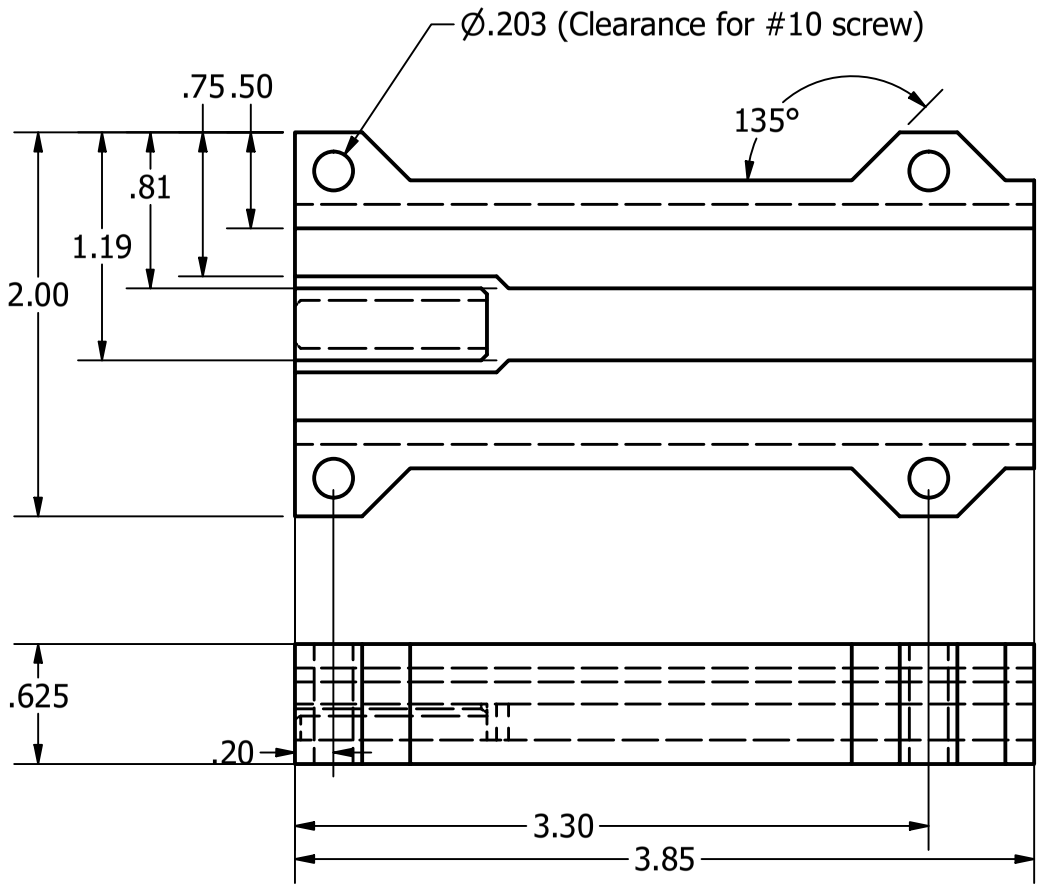
Note: Part is rotationally symmetric

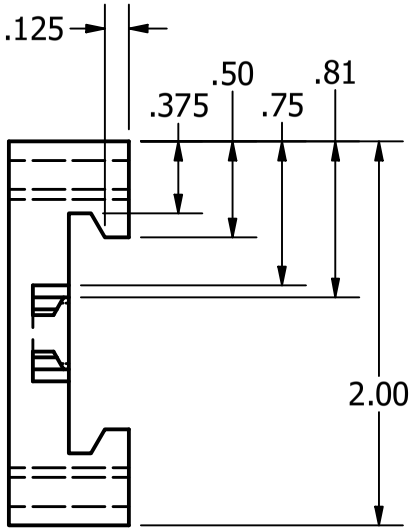
DRAWN Ben Chan	2/23/2021	4-Tool_Lower Count: 1
CHECKED		TITLE Lower tool mounting plate
QA		
MFG		
APPROVED		
		SIZE A | DWG NO Assem_Drawings | REV
		SCALE 2/3 | SHEET 2 OF 10

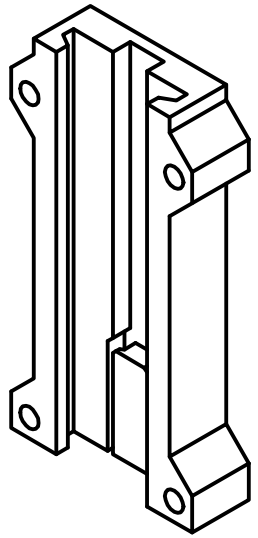


Note: Part is rotationally symmetric, except for lightening patterns

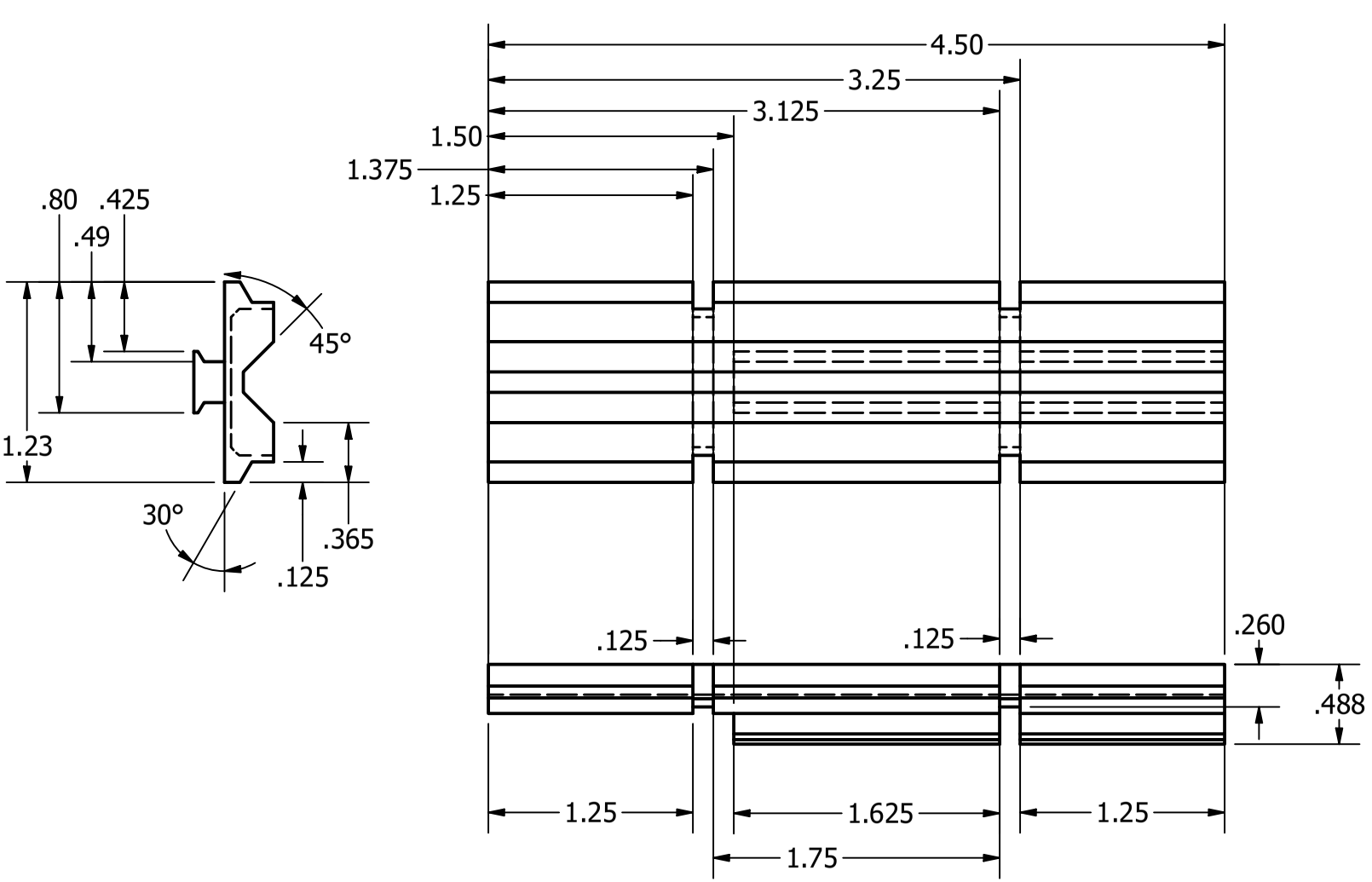
DRAWN Ben Chan	2/23/2021	4-Tool_Upper Count: 1
CHECKED		TITLE Upper tool mounting part
QA		
MFG		
APPROVED		
SIZE A		DWG NO Assem_Drawings / REV
SCALE 1 : 1		SHEET 3 OF 10

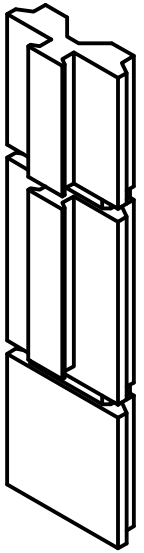




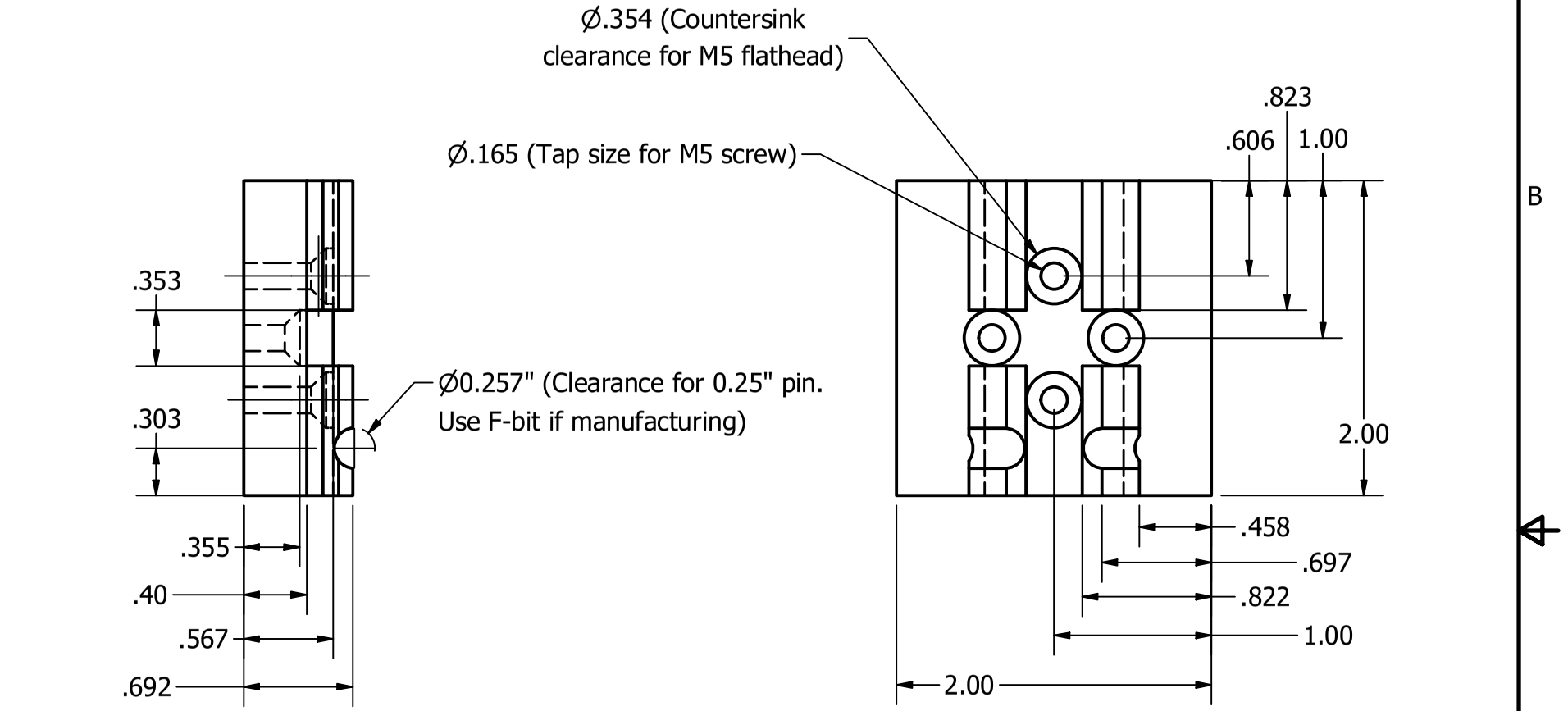


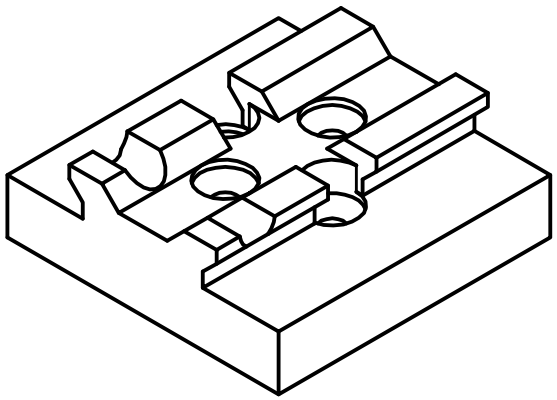
DRAWN Ben Chan	2/23/2021	Holder_Mount Count: 4
CHECKED		TITLE Compliant pen mount base
QA		
MFG		
APPROVED		
		SIZE A | DWG NO Assem_Drawings | REV
		SCALE 1 : 1 | SHEET 4 OF 10





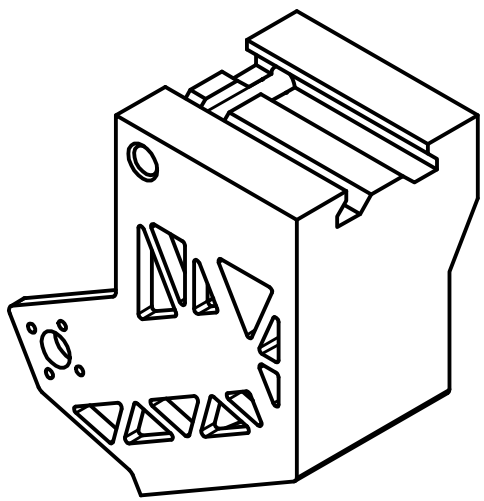
DRAWN Ben Chan	2/23/2021	Holder_Slide Count: 4
CHECKED		TITLE Compliant pen mount slide
QA		
MFG		
APPROVED		
SIZE A		DWG NO Assem_Drawings — REV
SCALE 1 : 1		SHEET 5 OF 10



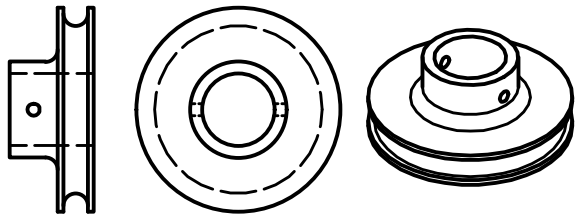


DRAWN Ben Chan	2/23/2021	Gantry_Mount_Rail Count: 1
CHECKED		TITLE
QA		Gantry mount. Bolted in place. Uses a quick release pin to mount remainder of tool head.
MFG		
APPROVED		

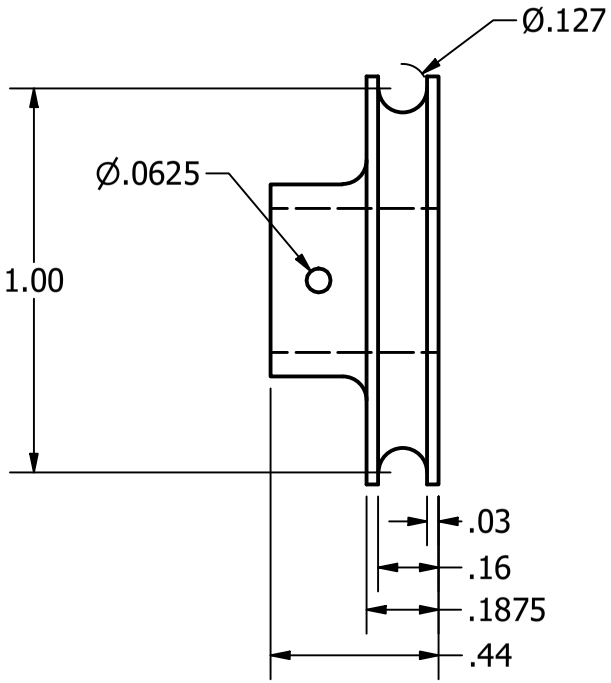
SIZE		DWG NO	REV
A		Assem_Drawings	
SCALE 1 : 1		SHEET 6 OF 10	

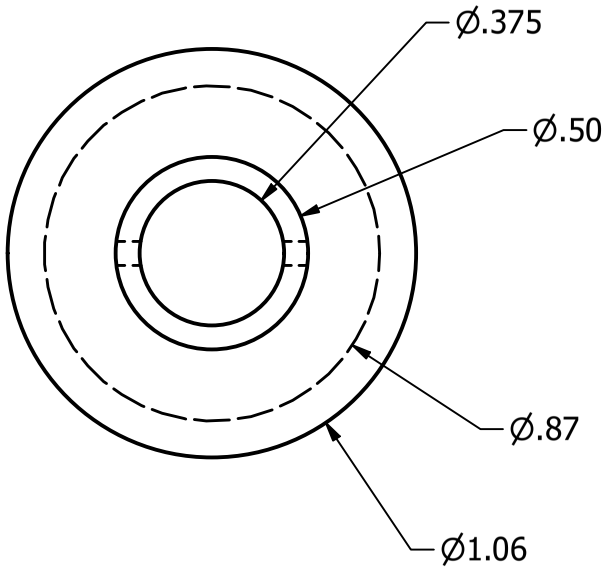


DRAWN Ben Chan	2/23/2021	Gantry_Mount Count: 1
CHECKED		TITLE Gantry mount block. Slides in place and locks with the Gantry Rail. Houses servo.
QA		
MFG		
APPROVED		
		SIZE A | DWG NO Assem_Drawings | REV
		SCALE 1 : 1 | SHEET 7 OF 10

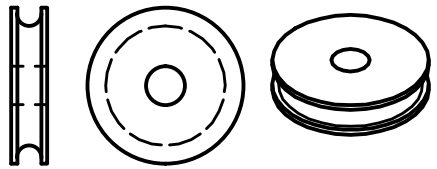


1:1 Scale

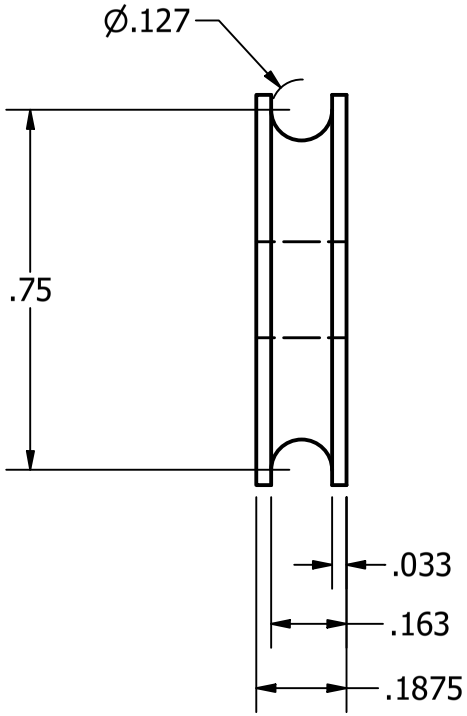


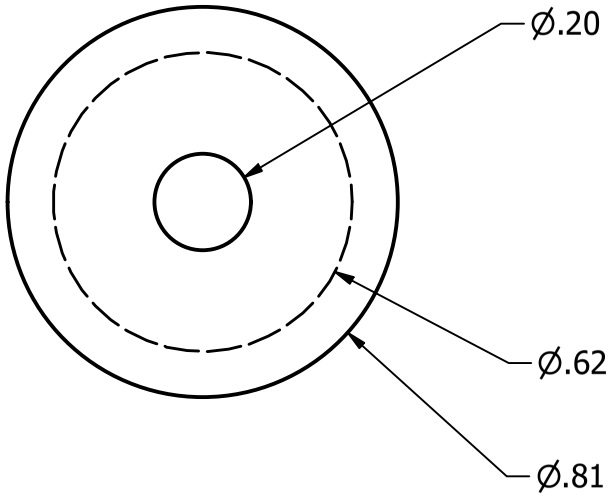


DRAWN Ben Chan	2/23/2021	1.0OD_Pulley Count: 1
CHECKED		TITLE Pulley with 1" OD for 3mm PU belt
QA		
MFG		
APPROVED		
		SIZE A | DWG NO Assem_Drawings | REV
		SCALE 2 | SHEET 8 OF 10

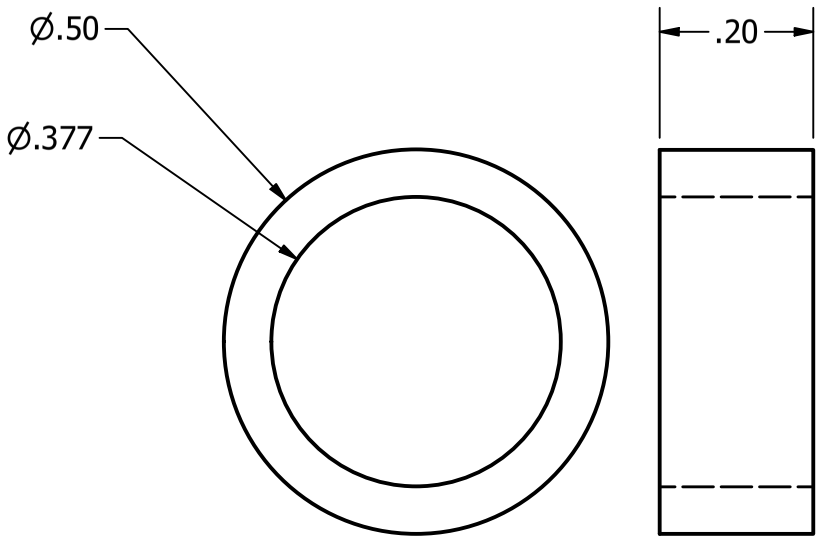


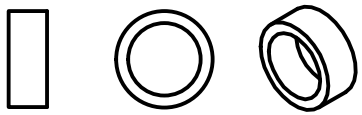
1:1 Scale



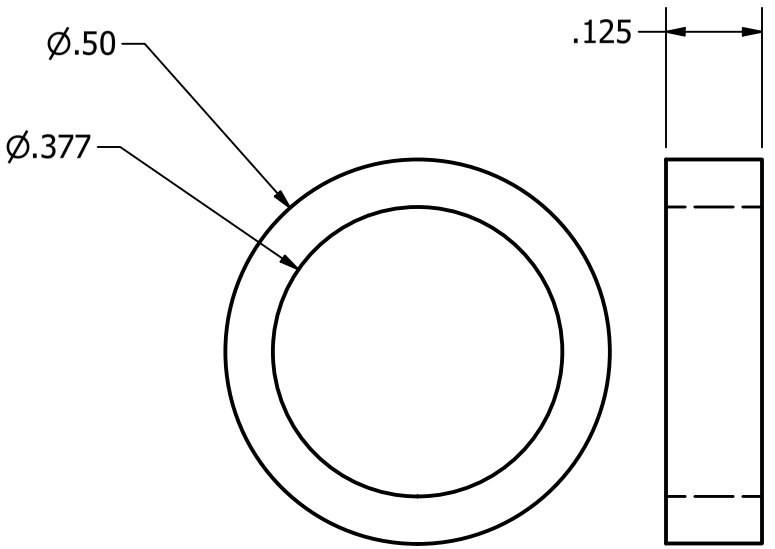


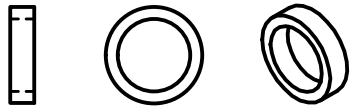
DRAWN Ben Chan	2/23/2021	1.0OD_Pulley Count: 1
CHECKED		TITLE Pulley with 0.75" OD for 3mm PU belt
QA		
MFG		
APPROVED		
		SIZE A | DWG NO Assem_Drawings | REV
		SCALE 2.5 | SHEET 9 OF 10





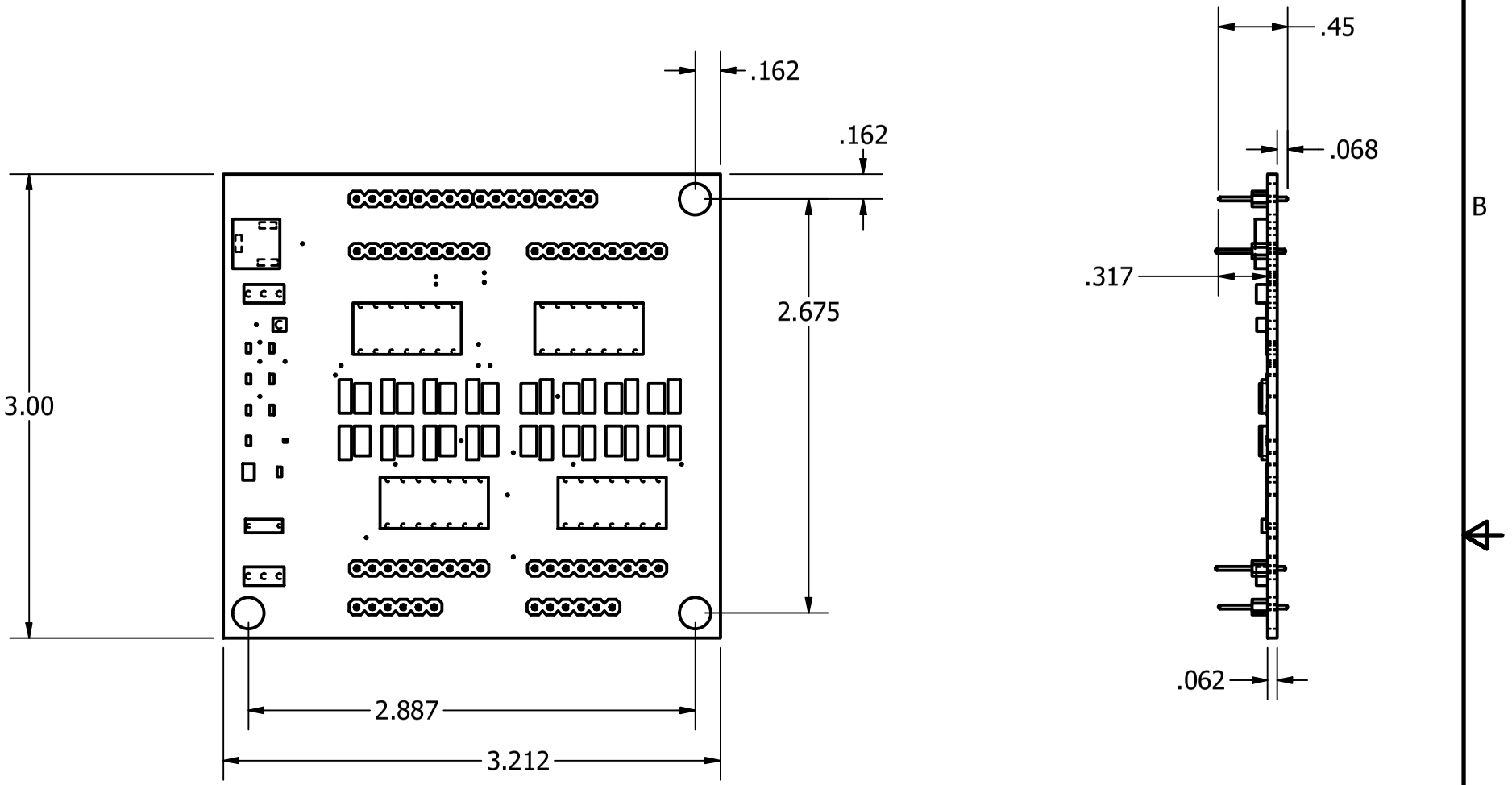
1:1 Scale





1:1 Scale

DRAWN Ben Chan	2/23/2021	0.375ID_0.125_Spacer Count: 1	0.375ID_0.2_Spacer Count: 3
CHECKED		Total part count: 4	
QA		TITLE	
MFG		0.375 ID spacers at 0.2 and 0.125 width	
APPROVED			
		SIZE A	DWG NO Assem_Drawings
		SCALE 4	SHEET 10 OF 10

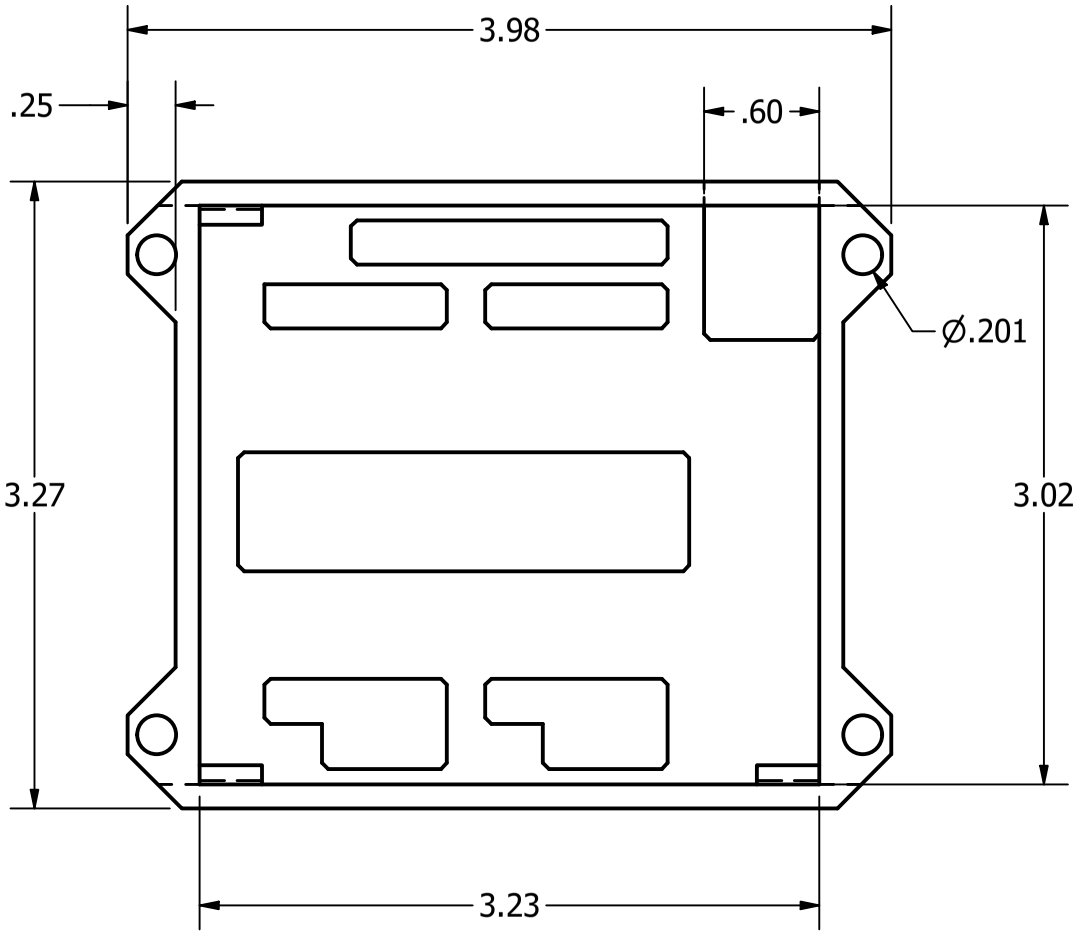


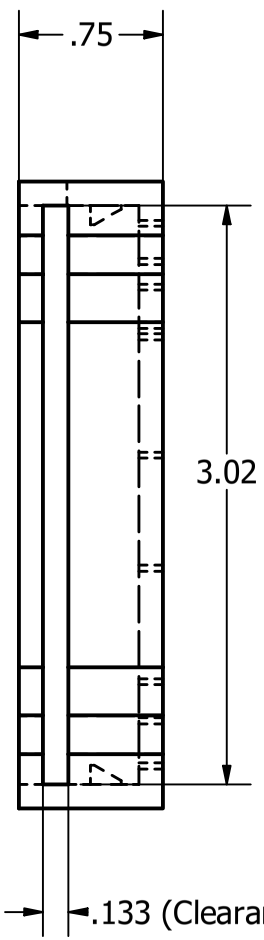
DRAWN Ben Chan	3/3/2021	
CHECKED		
QA		
MFG		
APPROVED		

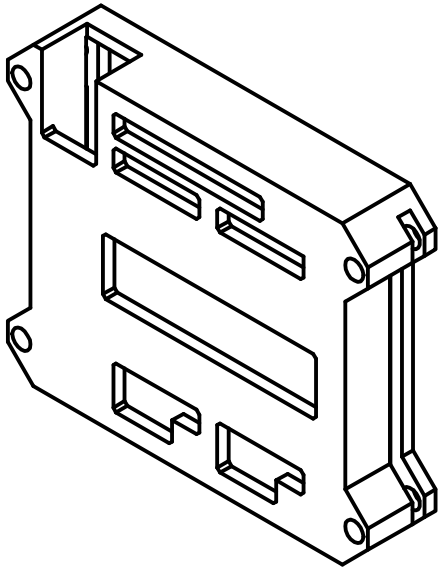
TITLE
LED Indicators and 24V to 5V Step Down PCB Dimensions

SIZE		DWG NO	REV
A		HyperRail_Board_vLED	

SCALE		
1 : 1		SHEET 1 OF 3



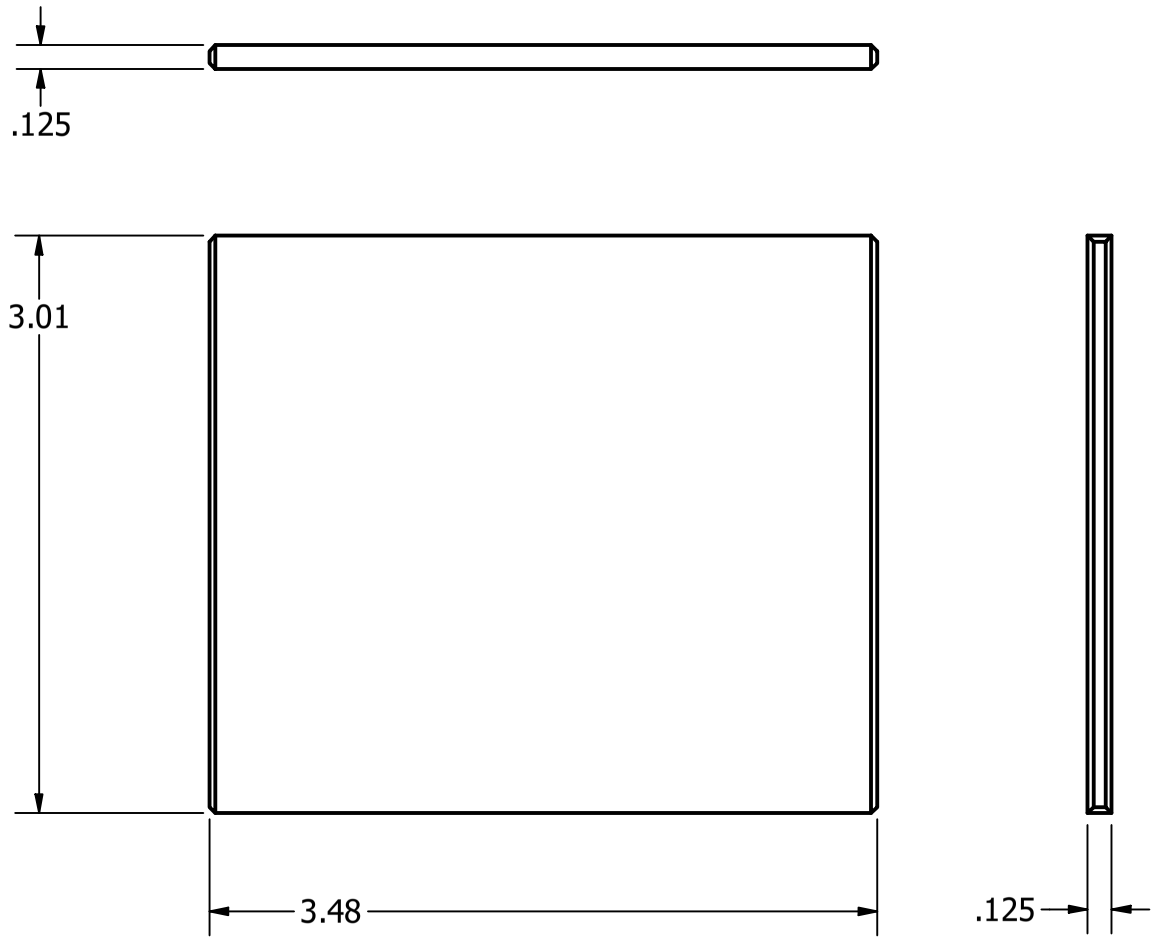




DRAWN Ben Chan	3/3/2021	
CHECKED		
QA		
MFG		
APPROVED		

TITLE
LED Indicators and 24V to 5V Step Down PCB Enclosure Dimensions

SIZE		DWG NO	REV
A		HyperRail_Board_vLED	
SCALE 1 : 1		SHEET 2 OF 3	



DRAWN Ben Chan	3/3/2021	
CHECKED		
QA		
MFG		
APPROVED		

TITLE
LED Indicators and 24V to 5V Step Down
PCB Enclosure Back Cover Dimensions

SIZE		DWG NO	REV
A		HyperRail_Board_vLED	
SCALE 1 : 1		SHEET 3 OF 3	