TSUNAMI

Hyperspectral Imager for Chlorophyll Analysis

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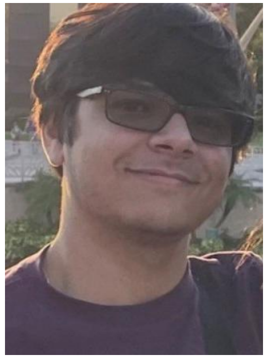
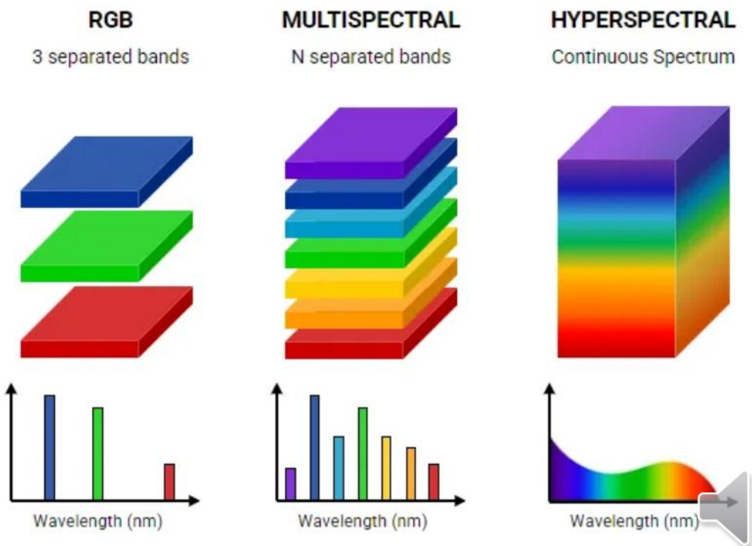


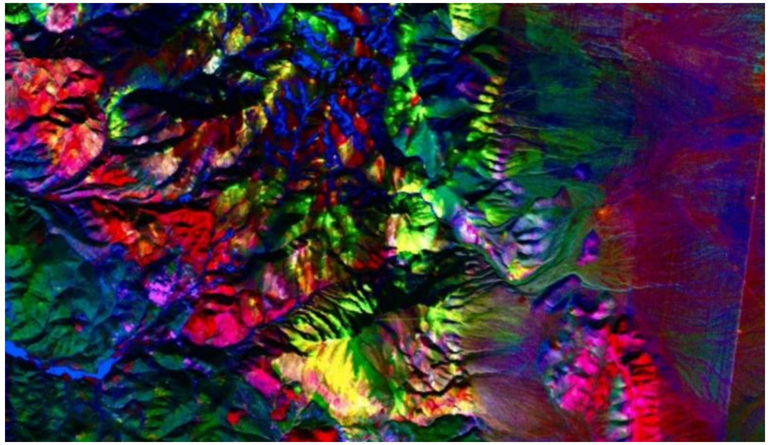
Research and Motivation

- Spectrometers accomplish spectral measurement along a single field angle
- Hyperspectral imaging provides spectrometer-style data on a per-pixel basis through an image
- Commercial and government developments have been developed in depth

Resonon Pika L-F 420-980nm [1]



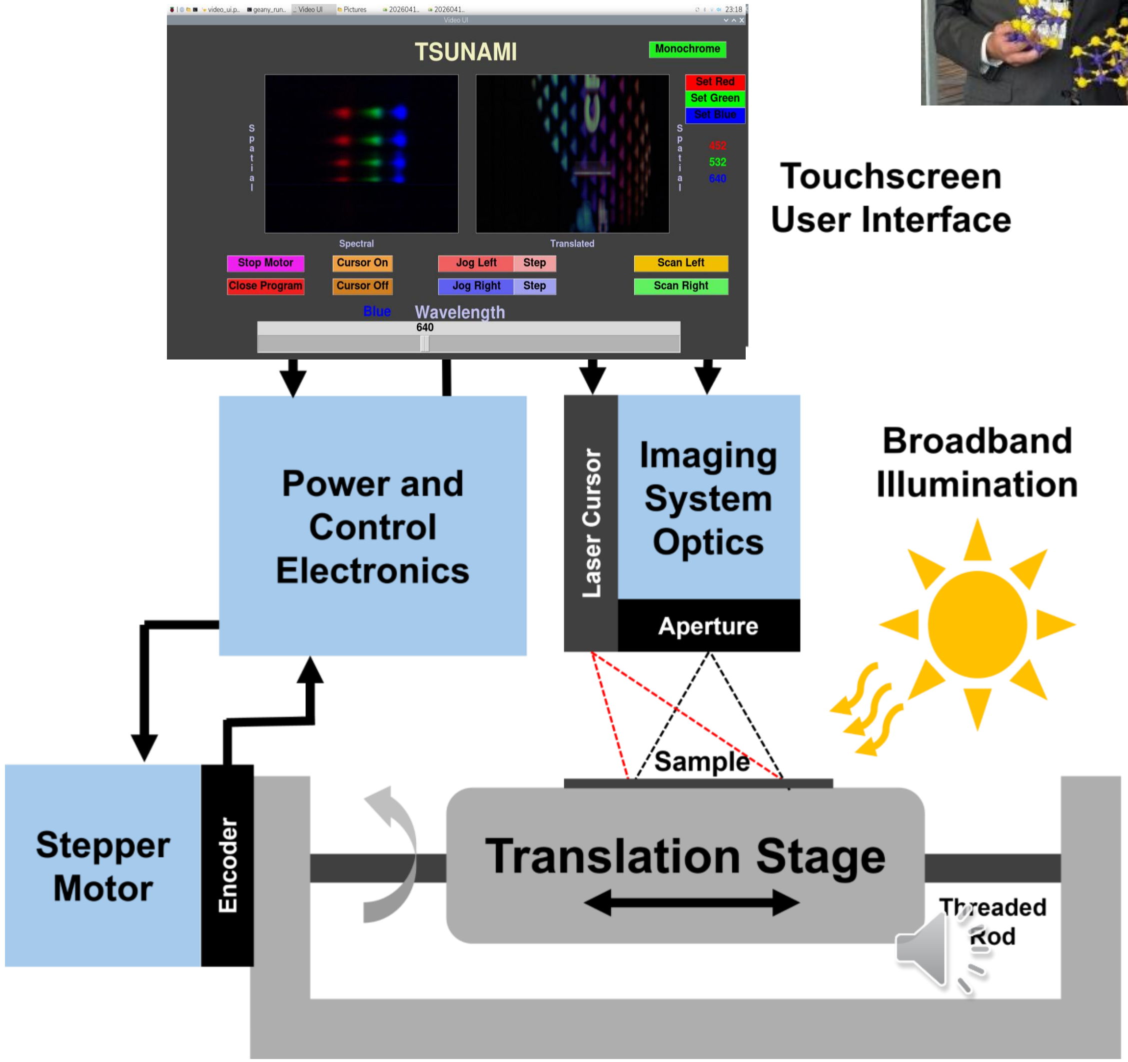
RGB vs Multispectral vs Hyperspectral Imaging (Credit: Nireos)



Land False-Color Image from NASA "Classic" Airborne Visible Near Infrared Spectrometer (AVIRIS-C) [2, 3]

Project Description

- TSUNAMI is a hyperspectral imager for environmental analysis.
- A three-dimensional (space x space x spectra) dataset is collected to analyze reflectivity spectra per pixel, going far beyond a standard RGB camera.
- A motorized stage translates the sample to regain the lost spatial axis
- A laser cursor indicates to the user where the camera is pointed.



Goals & Objectives

Basic Goals	Advanced Goals	Strech Goals
Capture spatial and VNIR spectral (400 nm-850nm) data simultaneously	Implement the user interface as a touchscreen for easy display of the scan results	Design the instrumentation optics to be completely diffraction-limited on the spatial capture axis
Capture and display data locally on an embedded computing platform, with a small touchscreen	Show false-color images as remapping of the RGB display channels	Be able to export finalized hyperspectral data to another device via removable storage media
Create a line-shaped laser “cursor” to match the imager’s linear target to see the scan location before capture	Design the instrumentation optics to limit chromatic aberration along the spatial capture axis	Use multiple different wavelength lasers to indicate the functional state or progress of the scan along the targe as colored information

Basic Objectives	Advanced Objectives	Strech Obj
Implement embedded m otor control of translation stage using a microcontroller’s (MCU) timing and data-transfer peripherals	Utilize a graphics programming library on the embedded computer to design a custom, interactive touch user interface for rendering and control of the instrument	Write custom monitoring code to automatically detect potential power faults as well as reporting these to the computer
Ensure the MCU handles all other tasks besides UI processing and CMOS sensor readout, **being commanded by the UI software over serial interface**	Design the MCU firmware to support open-loop control of the motor’s angular position, using micro-stepping techniques to move accurately.	Support variable brightness and closed-loop MCU control of laser optical output power via the laser diode’s auxiliary photodiode
Design power electronics to supply the computer, control, and MCU systems from a single external DC feed with their needed voltages and currents, reliably	Design the translation motor supply to have digitally programmable voltage and current limiting ability, protecting against back EMF all while interfacing to the MCU	Connect buttons, switched, knobs, and LEDs to extra peripherals on the MCU to create a custom interface, relaying user inputs to the embedded computer

Specifications

Type	Specification	Value
Optical	Operational Wavelength Range	400nm – 850nm
	Spectral Resolution (FWHM)	≤ 10nm
	Entry Focal-Length Range	20cm – ∞cm
	Laser Cursor Profile (FWHM asp. ratio)	≥ 20:1
	Laser Cursor Operational Output Power	0mW – 20mW
	Laser Cursor Pulse Slew (10%-90%)	≤ 10μs (rise/fall)
Electrical	Time Needed for Full Scan/Render	≤ 150s
	System Power Consumption	≤ 60W (peak)
	Imaging Sensor Type	CMOS
Mechanical	Instrument Weight (total)	≤ 10kg
	Instrument Size (tentative, maximum)	≤ 50x50x50cm
	Translation Stage Linear Resolution	≤ 0.2mm
	Translation Stage Speed	≥ 50mm/s

HoQ (House of Quality)

HOUSE OF QUALITY

TSUNAMI

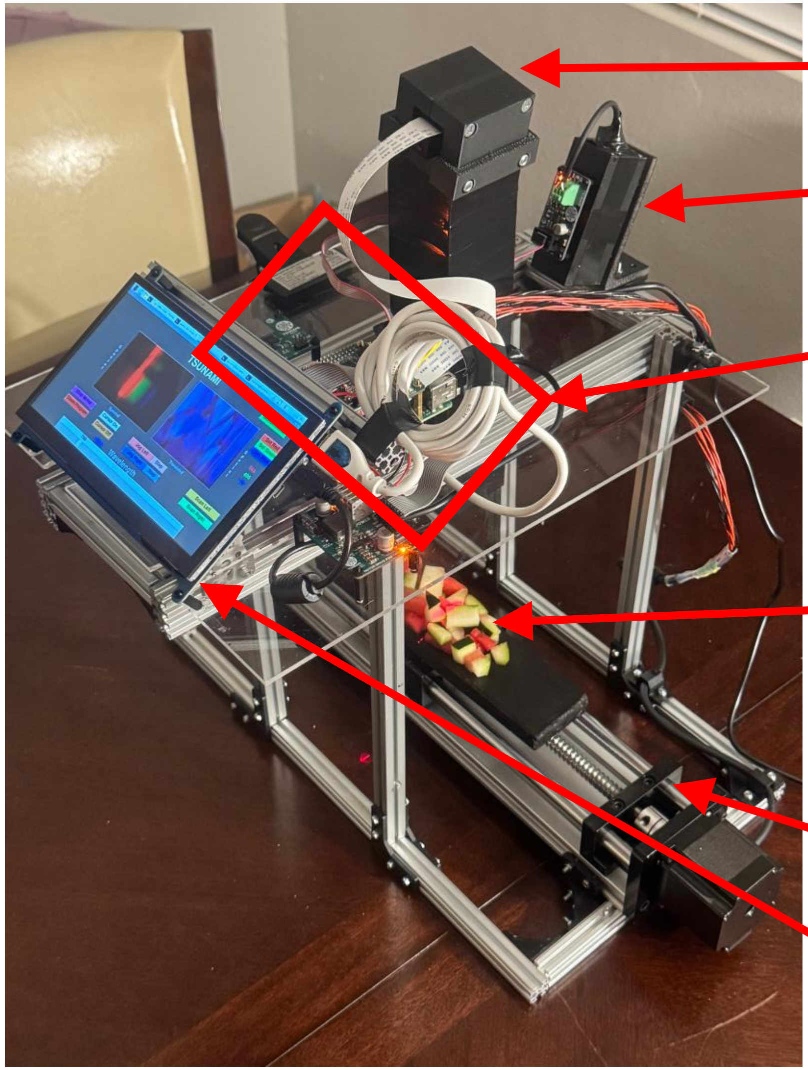
Roof Corr.: + Positive; - Negative; O None

+							
+	O						
+	O	O					
O	O	O	+				
+	O	O	O	O			
+	O	O	+	O	+		
O	+	O	O	+	+	-	

Customer/Marketing Requirements:	Technical Requirements:	Instrument Size	Wavelength Range	Spectral Resolution	Spatial Resolution	Laser Power	Power Draw	Linear Speed	Linear Accuracy
	Goal:	↓	↑	↑	↑	↓	↓	↓	↑
Affordability	↑	Medium	Strong	Strong	Medium	Weak	Weak	Strong	Strong
Transportability (Weight)	↑	Strong	None	None	None	None	Weak	Medium	Weak
Overall Reliability	↑	Weak	Weak	Weak	Weak	Weak	Medium	Strong	Strong
Ease of Use	↑	Medium	Weak	Medium	Medium	Weak	Weak	Medium	Strong
Ease of Maintnance	↑	Medium	Weak	Weak	Weak	Weak	Weak	Medium	Medium
Expandability of Optics	↑	Weak	Weak	Strong	Strong	None	None	None	None
Instrument Longevity	↑	Weak	Weak	Weak	Weak	Weak	Medium	Medium	Medium
Customization	↑	None	None	Weak	Weak	Medium	None	Medium	Medium
System Scan Time	↓	Medium	Weak	Weak	Strong	None	Strong	Strong	Strong
	Target Value:	≤ 50x50x50cm	400nm – 850nm	≤ 10nm (FWHM)	1080 pix	0mW – 50mW	≤ 60W (Peak)	≥ 50mm/s	≤ 0.2mm

Requirement Matrix Correlation Key	
Strong Correlation:	(circle with two dots)
Medium Correlation:	(circle with one dot)
Weak Correlation:	(solid circle)
No Correlation:	O

Final Implementation



Imager

Laser Cursor Assembly

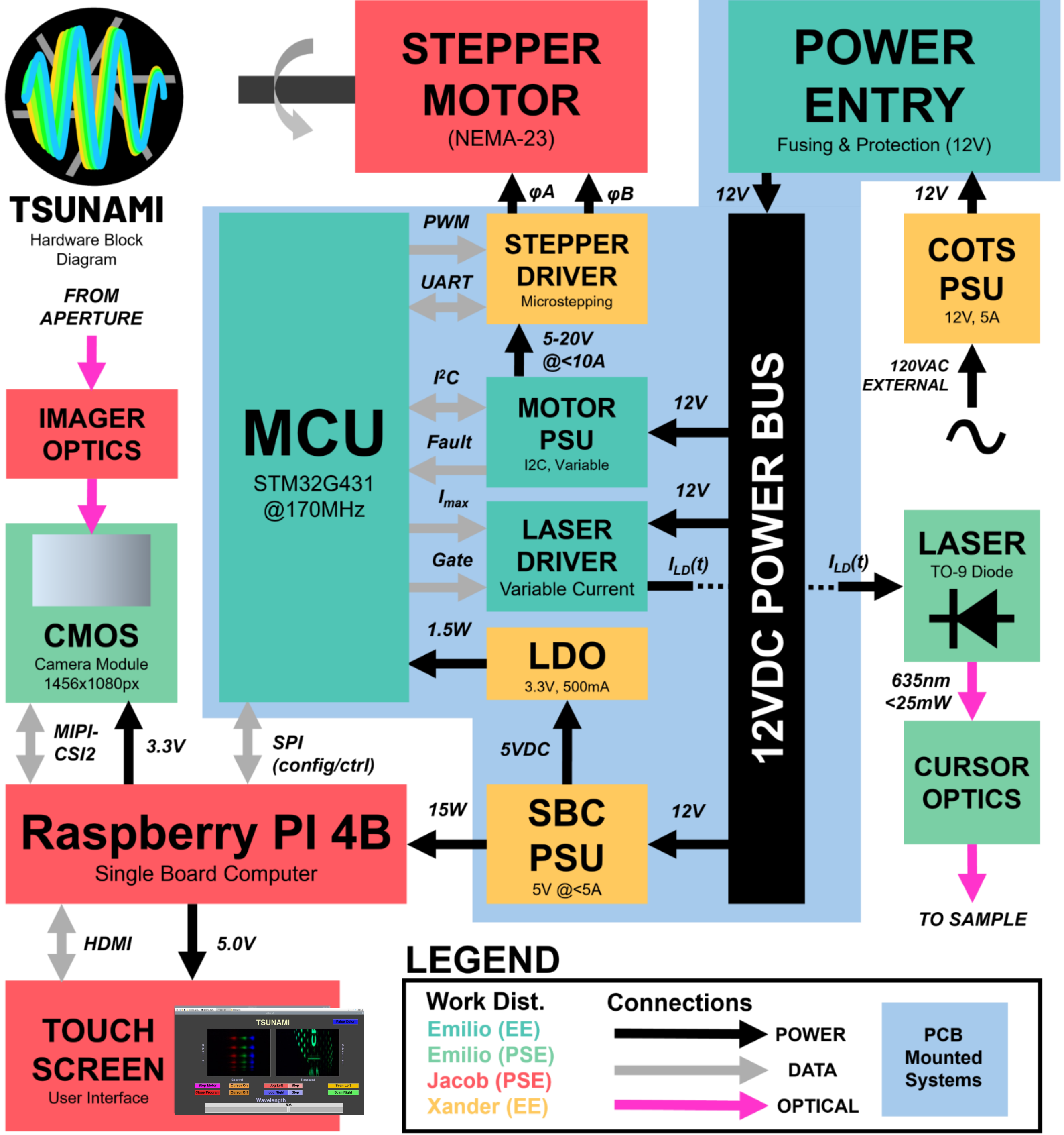
Electronics Area

Target w/ cursor line

CNC Rail

Touchscreen w/ GUI

Hardware Block Diagram



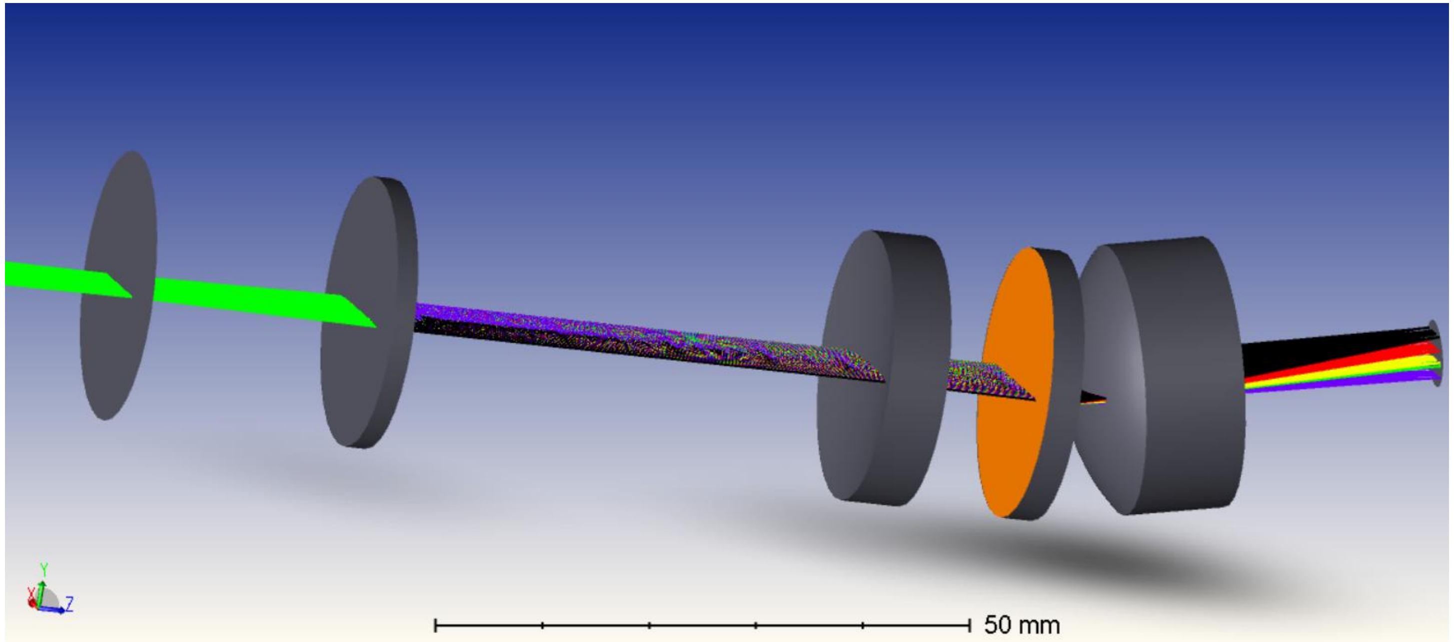
Imager Calculation and Parts Selection

- Achromaticity most relevant for final lens

- Focal length of final lens and grating period are pinned by

$$\theta = \frac{\Delta\lambda}{a} = \frac{h_{det}}{f}$$

- A broader grating (larger *a*) allows for a longer focal length and therefore less aberration. Using a wavelength range of 600 nm and a detector height of 6 mm, a grating period of 300 lines/mm (3.33 um per line) gives a focal length of 33.3 mm, close to a f = 30 mm achromat offered by ThorLabs



Imager Parts Selection

300 Grooves/mm Visible Transmission Gratings

Universal (3 Items)	
Item	
GT13-03	Visible Transmission Grating, 300 Grooves/mm, 17.5° Groove Angle, 12.7 m
GT25-03	Visible Transmission Grating, 300 Grooves/mm, 17.5° Groove Angle, 25 mm x 25 mm
GT50-03	Visible Transmission Grating, 300 Grooves/mm, 17.5° Groove Angle, 50 mm x 50 mm

600 Grooves/mm Visible Transmission Gratings

830 Grooves/mm Visible Transmission Gratings

1200 Grooves/mm Visible Transmission Gratings

Ø1" Unmounted Achromatic Doublets, AR Coated: 400 - 1100 nm

Table G2.1 Specifications

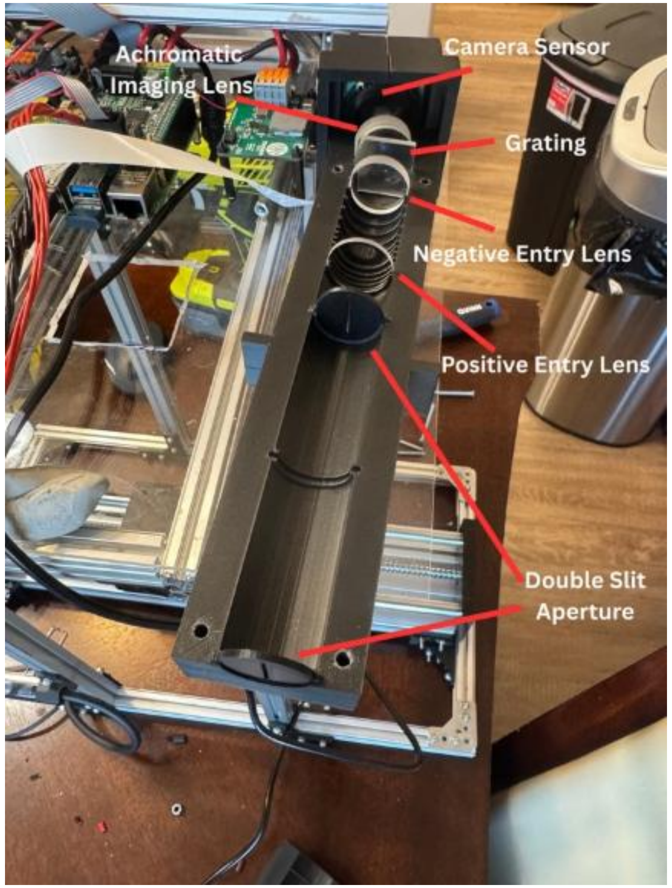
Item #	Diameter (mm)	f^a (mm)	f_b^a (mm)	Graphs[b]	R_1^a (mm)	R_2^a (mm)	R_3^a (mm)	t_{c1} (mm)	t_{c2} (mm)	t_e^c (mm)	Materials[d]
AC254-030-AB	25.4	30.0	21.22	ⓘ	20.0	-17.4	-93.1	12.0	3.0	9.5	S-BAH11 / S-TIH6
AC254-050-AB	25.4	50.0	43.39	ⓘ	34.9	-28.8	-137.5	9.0	3.5	9.5	N-BAF10 / N-SF6
AC254-075-AB	25.4	75.0	68.72	ⓘ	52.0	-43.4	-217.4	8.0	4.0	10.0	N-BAF10 / N-SF6
AC254-100-AB	25.4	100.0	95.03	ⓘ	92.4	-48.2	-152.8	8.0	4.0	10.5	N-LAK22 / N-SF10
AC254-150-AB	25.4	150.0	143.68	ⓘ	87.9	-105.6	Plano	6.0	3.0	8.0	N-LAK22 / N-SF10
AC254-200-AB	25.4	200.0	194.15	ⓘ	117.1	-142.1	Plano	5.0	3.0	7.3	N-LAK22 / N-SF10

LA1134	1"	59.8	+16.7	30.9	4.7
LA1608	1"	74.8	+13.3	38.6	4.1
LA1509	1"	99.7	+10.0	51.5	3.6
LA1986	1"	124.6	+8.0	64.4	3.3
LA1433	1"	149.5	+6.7	77.3	3.1

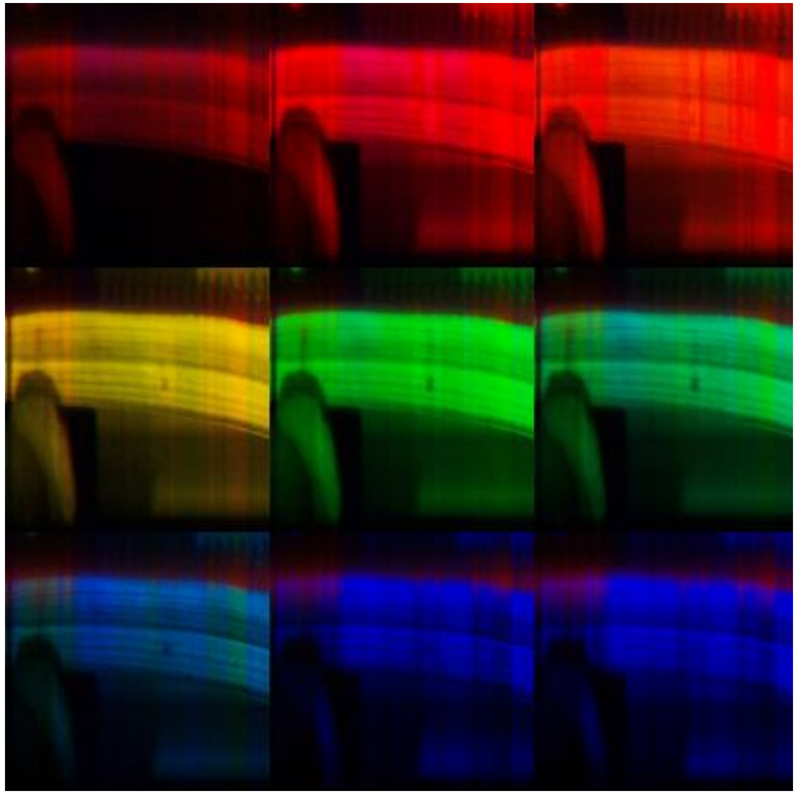
Ø1" (25.4 mm) N-BK7 Plano-Concave Lenses

Item #	Diameter	Focal Length	Diopter[a]	Radius of Curvature	Center Thickness	Edge Thickness[a]	Back Focal Length
LC1715	1"	-49.8 mm	-20.1	-25.7 mm	3.5 mm	6.9 mm	-52.1 mm
LC1582	1"	-74.7 mm	-13.4	-38.6 mm	3.5 mm	5.6 mm	-77.0 mm
LC1120	1"	-99.6 mm	-10.0	-51.5 mm	4.0 mm	5.6 mm	-102.2 mm

Imager Design

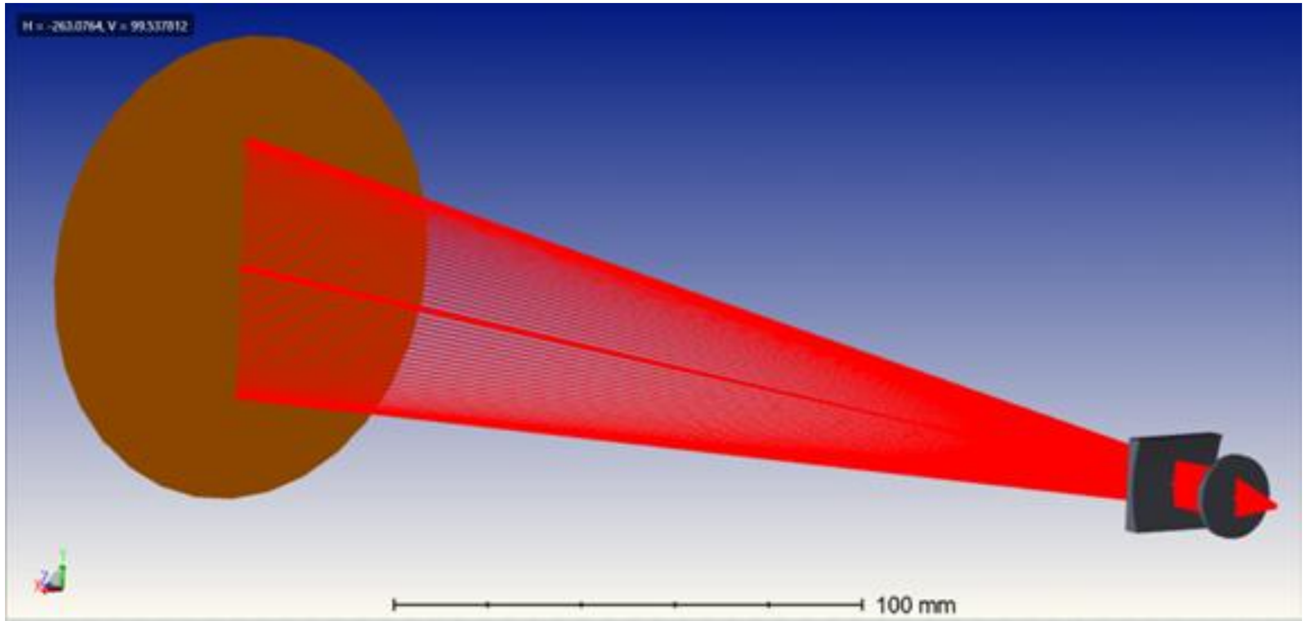


Optics Train



Example Output

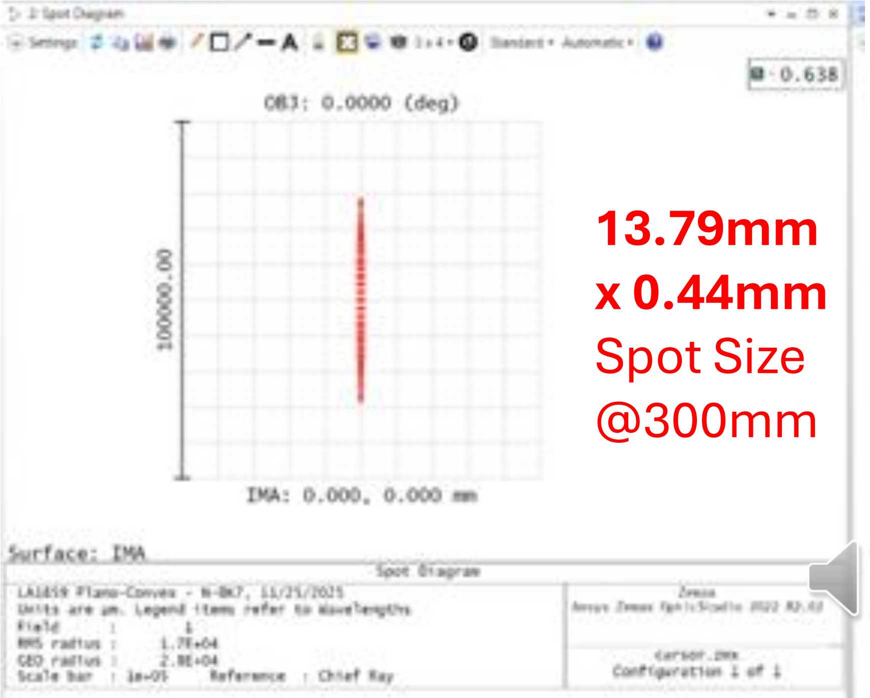
Laser Cursor Optical Design



Update: All Windows · Surface 7 Properties · Configuration 1/1

	Surface Type		Comment	Radius	Thickness		Material	Coating	Clear Semi-Dia		Chip Zone	Mech Semi-Dia		Conic	TCE x 1E-6
0	OBJECT (ap	Standard		Infinity	0.000				0.000		-	-		0.0...	0.000
1		Standard		Infinity	1.000				0.000		0.000	0.000		0.0...	0.000
2	(aper)	Standard		Infinity	14.500	V			5.000	U	-	-		0.0...	0.000
3	STOP (aper)	Standard	LA1859	Infinity	7.080		N-BK7		9.000	U	0.000	9.000		0.0...	-
4	(aper)	Standard		-10.300	15.000				9.000	U	0.000	9.000		0.0...	0.000
5	(aper)	Toroidal	LK1662L1	-25.840	2.000		N-BK7		10.000	U	-	-		0.0...	-
6	(aper)	Toroidal		Infinity	330.000				10.000	U	-	-		0.0...	0.000
7	IMAGE	Standard		Infinity	-				50.000	U	0.000	50.000	U	0.0...	0.000

- Needs at least 20:1 shaped spot at target distance
- Must operate at 635nm
- Must compensate for elliptical laser diode beam



13.79mm x 0.44mm
Spot Size
@300mm

Laser Cursor Parts Selection

- Optical design concerned a single PCV lens for slow-axis collimation. 20mm was chosen for best beam NA to match diode
- Focal lengths were selected independently
- A Galilean beam expander is created but set to diverge at 6° instead of collimation. This matches the imager FOV.
- BK-7 Glass is selected, no particular throughput requirement beyond the spot being of enough power to see
- 300-750nm basic coating is selected to prevent stray reflections from showing up off-axis
- Design was limited to two elements to allocate more funds to the critical imager design

Ø18.0 mm N-BK7 Plano-Convex Lenses (AR Coating: 350 - 700 nm)

Item #[a]	Diameter (mm)	Focal Length (mm)	Diopter[b]	Radius of Curvature (mm)	Center Thickness (mm)	Edge Thickness (mm)	Back Focal Length (mm)	Reference Drawing
LA1859-A	18.0	19.9	+50.0	10.3	7.1	1.8	15.3	ⓘ
LA1270-A	18.0	24.9	+40.0	12.9	5.5	1.8	21.3	
LA1085-A	18.0	29.9	+33.3	15.5	4.7	1.8	26.8	
LA1119-A	18.0	49.8	+20.0	25.8	3.4	1.8	47.6	

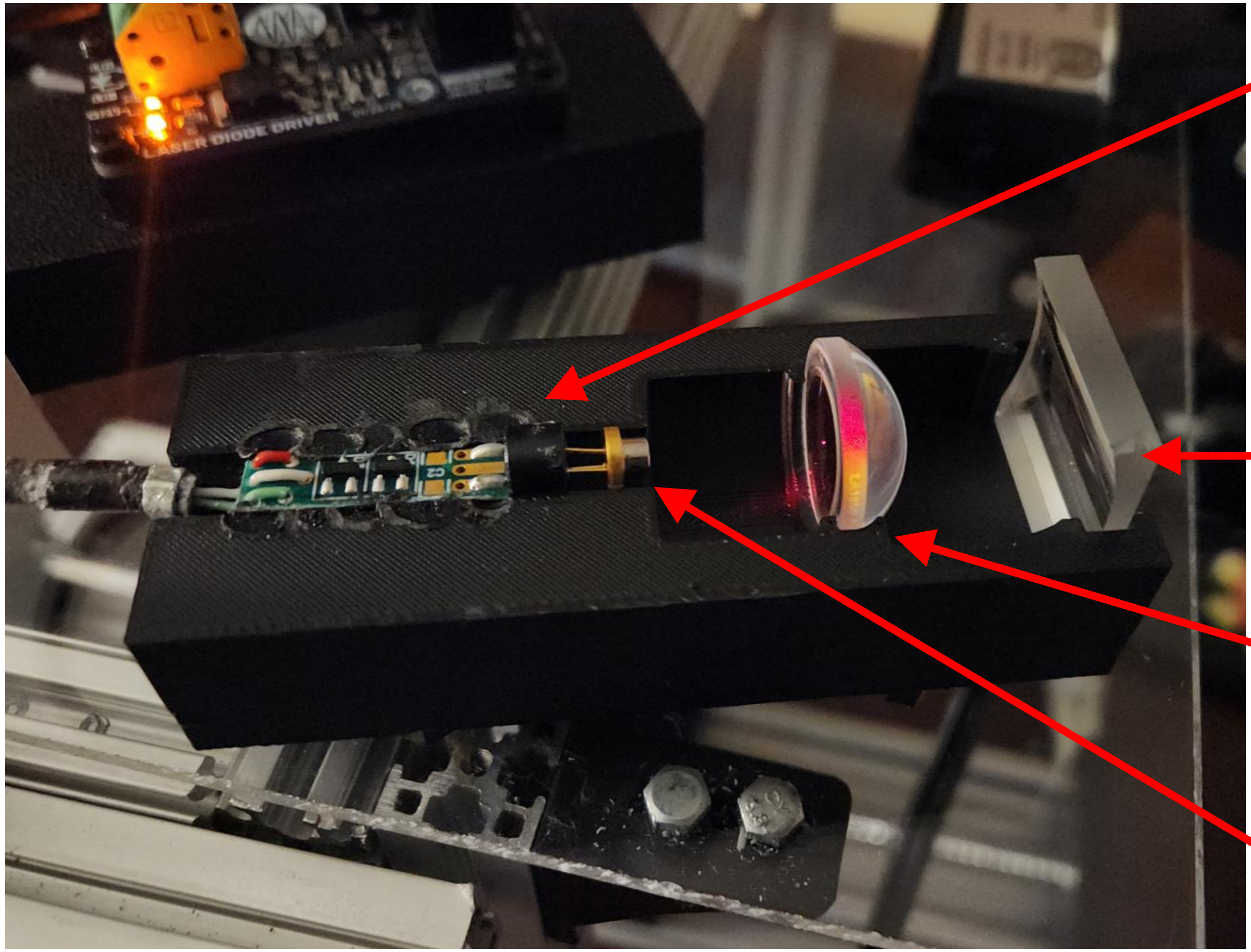
a. Suggested Fixed Lens Mount: LMR18(/M) Fixed Lens Mount
b. Reciprocal of the Focal Length in Meters

Plano-Concave Cylindrical Lenses, N-BK7, AR Coating: 350-700 nm (f=-29.99 to -79.99 mm)

Item #[a]	Focal Length	Length	Height	Radius	Center Thickness	Edge Thickness	Back Focal Length	Reference Drawing
LK1982L1-A	-29.99 mm	22.0 mm	20.0 mm	-15.5 mm	2.0 mm	5.3 mm	-31.3 mm	ⓘ
LK1982L2-A		40.0 mm						
LK1283L1-A	-40.00 mm	12.0 mm	10.0 mm	-20.7 mm	2.0 mm	2.5 mm	-41.3 mm	
LK1662L1-A	-50.00 mm	22.0 mm	20.0 mm	-25.8 mm	2.0 mm	3.8 mm	-51.3 mm	
LK1336L1-A	-50.00 mm	32.0 mm	30.0 mm	-25.8 mm	2.0 mm	6.5 mm	-51.3 mm	
LK1792L1-A	-50.99 mm	53.0 mm	50.8 mm	-26.4 mm	2.0 mm	19.9 mm	-52.3 mm	
LK1913L1-A	-69.99 mm	32.0 mm	30.0 mm	-36.2 mm	2.0 mm	5.2 mm	-71.3 mm	
LK1431L1-A	-75.00 mm	53.0 mm	50.8 mm	-38.8 mm	2.0 mm	11.1 mm	-76.3 mm	
LK1526L1-A	-79.99 mm	22.0 mm	20.0 mm	-41.3 mm	3.0 mm	4.1 mm	-82.0 mm	

a. If our catalog offerings do not fit your needs, please click here to learn more about how we can help with a custom solution.

Laser Cursor Construction



ESD Protecting Electrical Mount

-50mm PCC lens

+20mm PCV lens

24mW 635nm LD

SBC Comparison/Selection

SBC Options	Raspberry Pi Model 4B	Raspberry Pi Model 5	Pine64 RockPro64 4GB
CPU Cores	4xARM Cortex A72 @1.8GHz	4xARM Cortex A76 @2.4GHz	2xARM Cortex A72 @1.4GHz, 4xARM Cortex A53 @1.8GHz
Power Consumption	15W	15W	36W
RAM Size	4GB (selected)	4GB (selected)	4GB, LPDDR4
Networking	Gigabit Ethernet + WiFi/BLE	Gigabit Ethernet + WiFi/BLE	Gigabit Ethernet
External I/O Connections	4K Digital Video, 2xUSB 2.0, 2xUSB 3.0, MIPI-SCI, 2x20 GPIO header	4K Digital Video, 2xUSB 2.0, 2xUSB 3.0, MIPI-SCI, 2x20 GPIO header	4K Digital Video, 2xUSB 2.0, 1xUSB 3.0, MIPI-SCI, 2x20 GPIO header
Manufacturer Support	Long-term device support, 2034	Long-term device support, 2036	Long-term device support, 2027
3rd Party Software	Significant	Moderate	Limited.
Price	$55.00/1 unit	$66.00/1 unit	$80.00/1 unit

Raspberry Pi 4b:

- 1ST Party CMOS Image Sensor Offerings
- Market Confidence due to it being out longer than Raspberry Pi 5
- 3rd Party Software

MCU Comparison/Selection

MCU Options	Espressif ESP32-S3	STMicroelectronics STM32G431RBT6	Texas Instruments MSP430FR6989IPN
CPU Core	Xtensa LX7 x2	ARM Cortex M4 x1	RISC (16bit!) x1
Max Clock	240MHz	170MHz	16MHz
ADC Specs	2xSAR, 12bit	2xSAR, 12bit	1xSAR, 12bit
DAC Specs	N/A	4x, 12bit, 1MSPs	N/A
Timers	4x54bit	10x16bit, 1x32bit	5x16bit, 7CCR/each
Digital Comms	2xI^{2}C, 4xSPI, 3xUART	3xI^{2}C, 4xSPI, 4xUART	1xI^{2}C/SPI, 1xSPI/UART
Development Complexity	Significant	Moderate	Low
DMA Channels	5 TX, 5 RX	6 TX/RX x2, 12 total	3 TX/RX
Price	$1.85/1 unit	$5.60/1 unit	$11.20/1 unit

STM32G431:

- Simpler architecture with more control over less peripherals
- Professional and Academic Experience with the G4 framework
- On-Board ADC suite and DAC are integrated within MCU AHB/APB buses with dedicated DMAs

Motor Driver Comparison/Selection

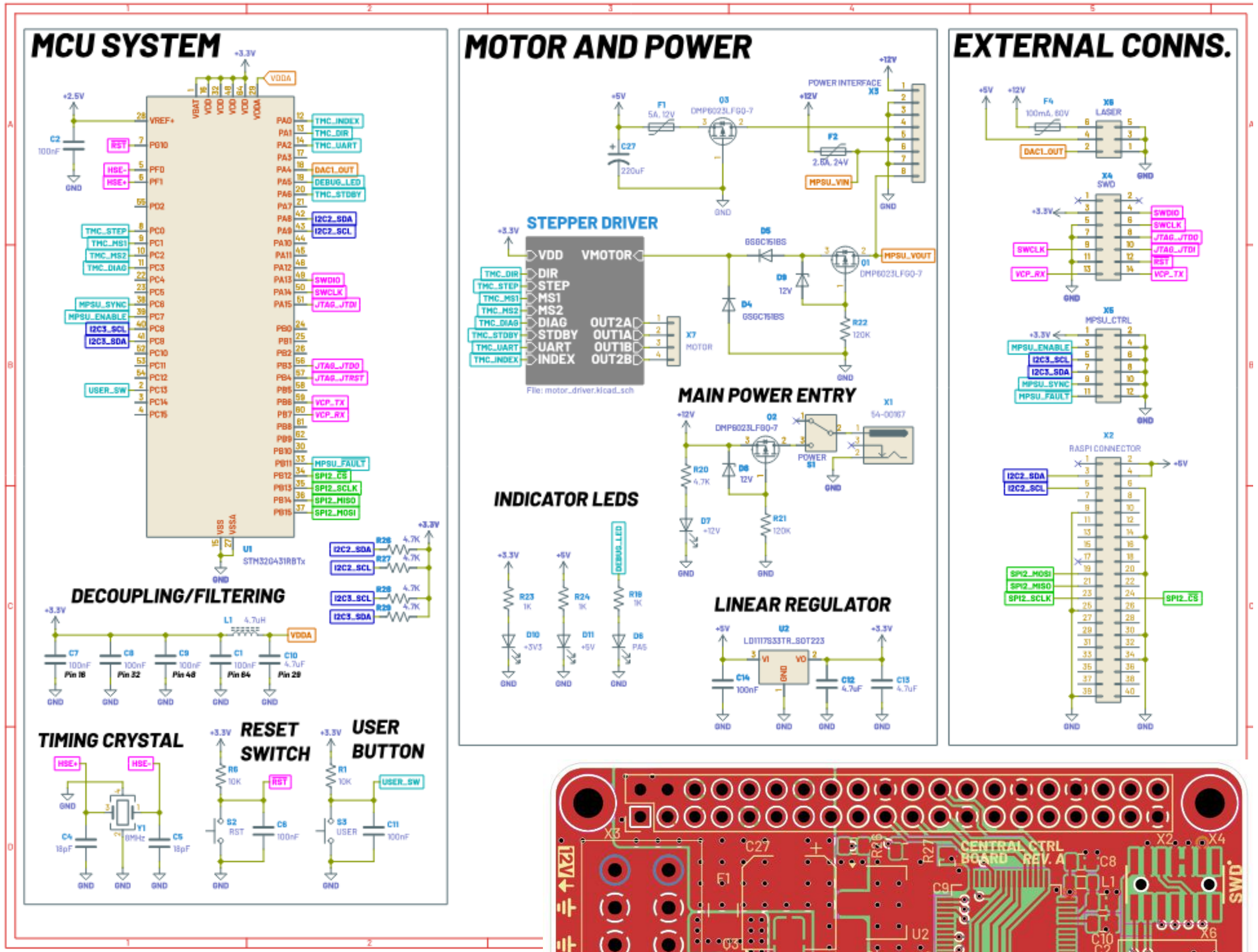
Feature	TB6600	DRV8825	G203V	TMC2209
Max Current	4 A	2.2 A	7 A	2.8 A
Voltage Range	9 V – 42 V	8.2 V – 45 V	18 V – 80 V	4.75 V – 28 V
Power Efficiency	Moderate	High	Very High	High
Microsteps	1/32	1/32	1/10	1/256
Control Interface	Step/DIR	Step/DIR	Step/DIR	Step/DIR and UART
Cost	$10.89	$12.95	$155	$8.95

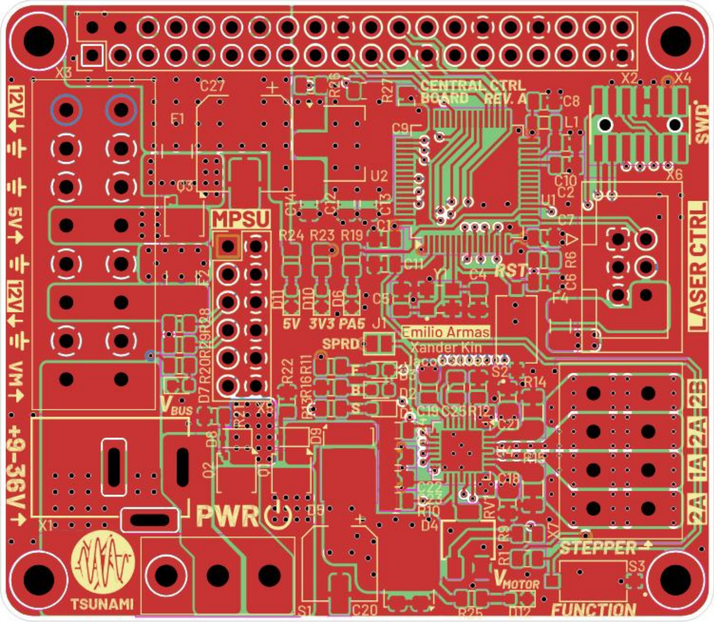
TMC2209:

- Chip handled testing of earlier prototype motors (Nema 17)
- Balance of Specs gives good range for chosen motor (Nema 23)
- Range of 1/256 Stepping

Master Control PCB

- Hosts system microcontroller (STM32G431)
- MCU has integrated DAC to digitally synthesize laser cursor control signal
- 9-36V input power bus (12V nominal)
- Extensive protection circuitry
- Power distribution
- TMC2209 Stepper Driver





Master Control PCB

Raspberry Pi Header

STM32G431

Debug Header

Power Distribution

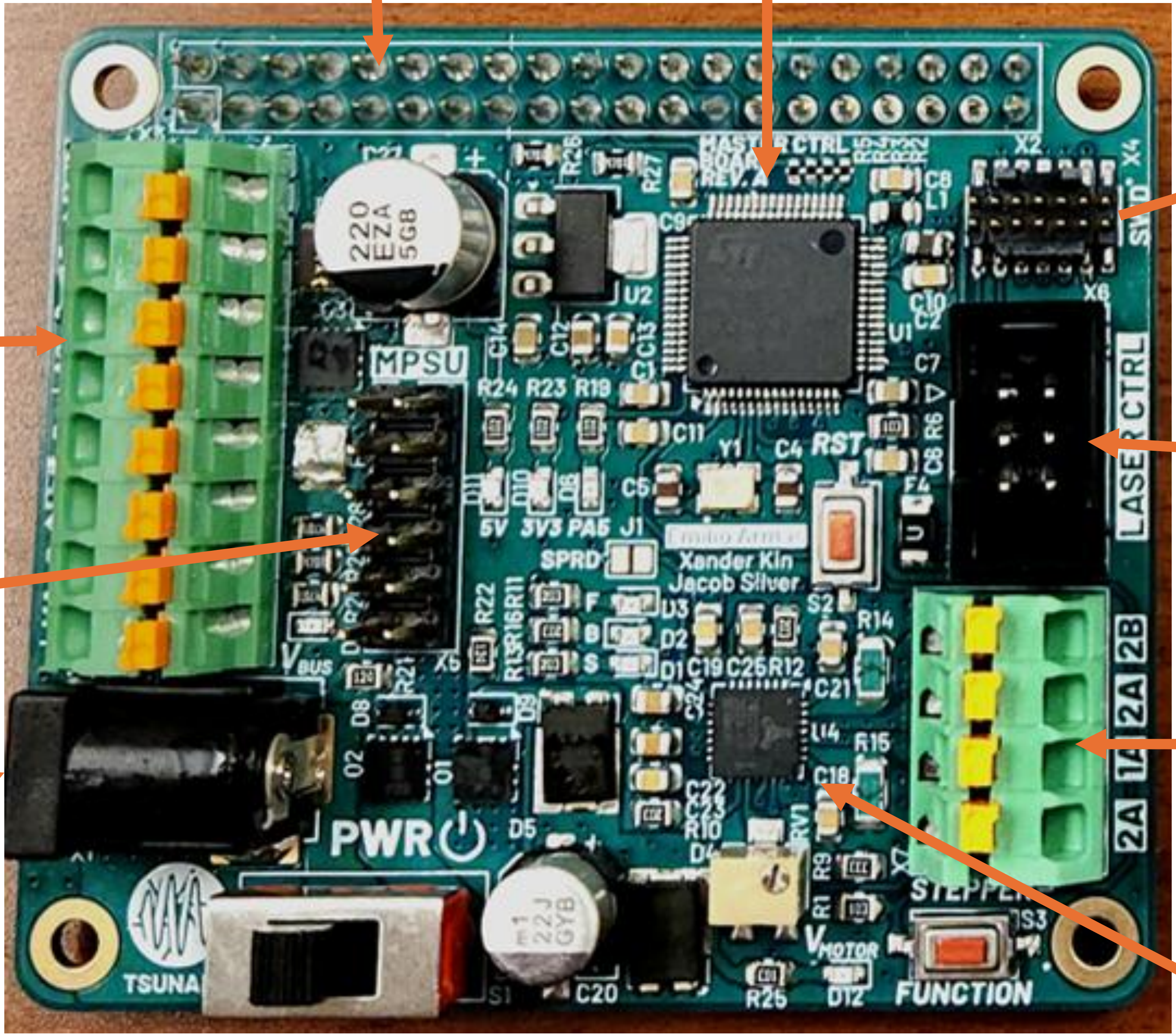
Laser Driver Connection

Motor Driver Control

Stepper Motor Output

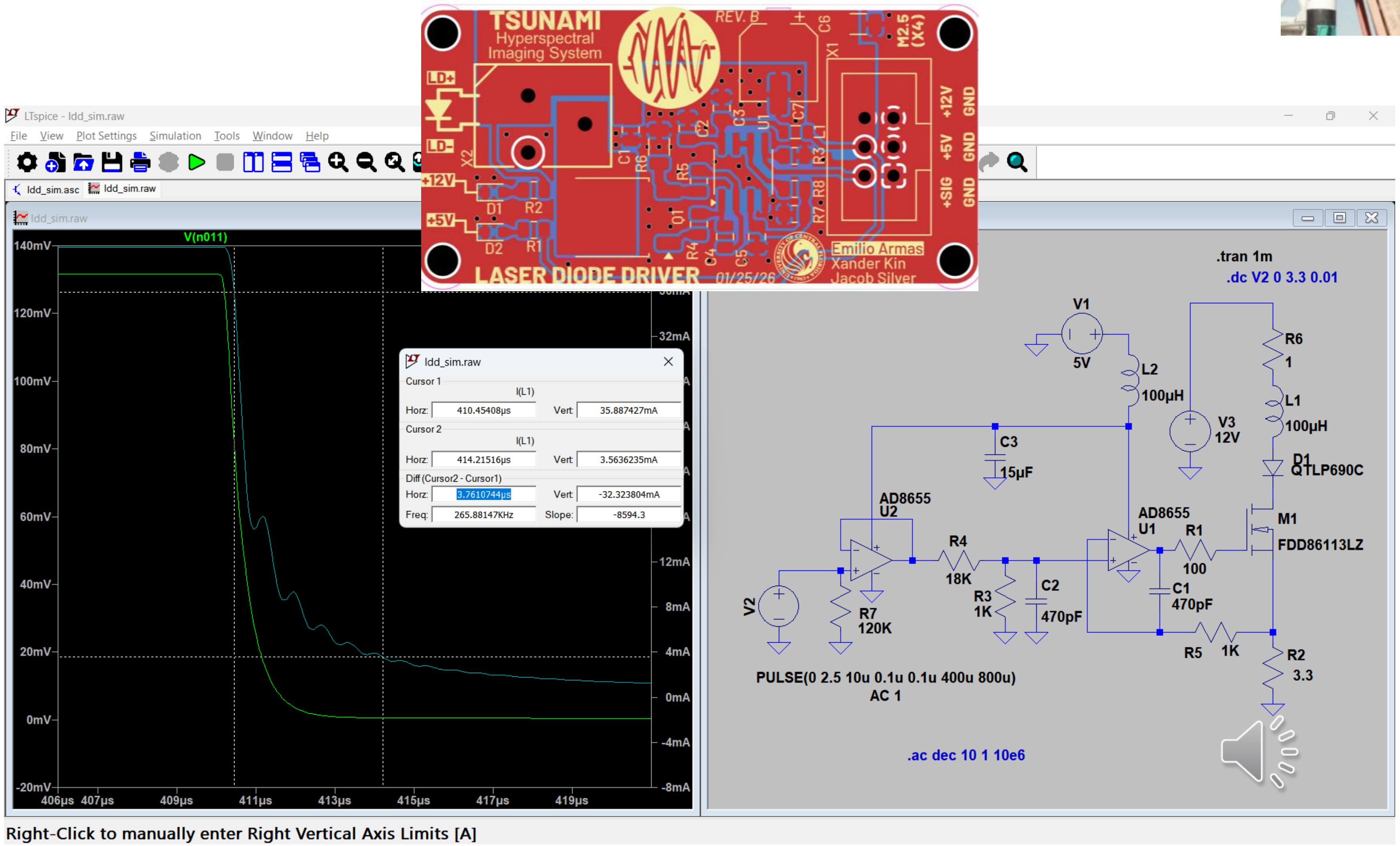
DC Power Jack

TMC2209



High-Speed Laser Diode Driver

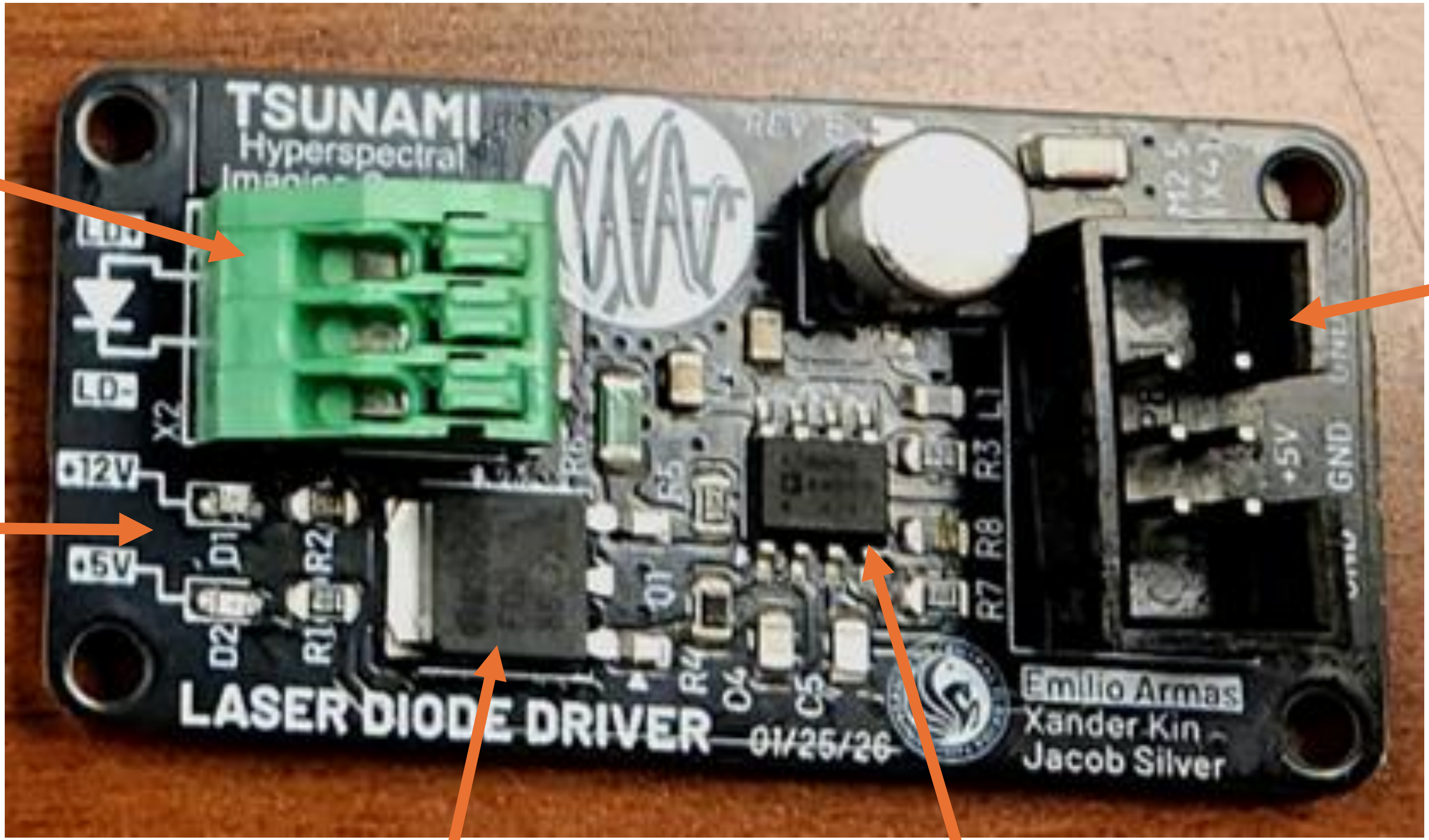
- Converts 0-2.5V DAC control voltage to 0-40mA laser diode current
- 10µs rise/fall time requirement
- 9-36V laser diode supply voltage
- Low-side linear FET for current control
- Designed to be stable even with extreme lead inductance



High-Speed Laser Diode Driver, Cont.

Laser wire connector block

Power Indicator LEDs



Power and Signal Input

N-Channel MOSFET

Closed-loop current controller (AD8656)

Power Management

Component	Power Consumption	Operating Voltage
Raspberry Pi 4b	~3 W (idle) ~10 W (Moderate Load) ~20 W (Heavy Load)	5.00 V – 5.25 V
Motor Driver	10 W – 58 W (when on)	5 V – 29 V
Microcontroller	330 mW	1.8 V -3.6 V (3.3 V nominal)

This is the overall power requirement for the entire system.

- Note: Our control board will be supplied our 12V bus to power all our systems and distribute power throughout the regulators, powering our components.

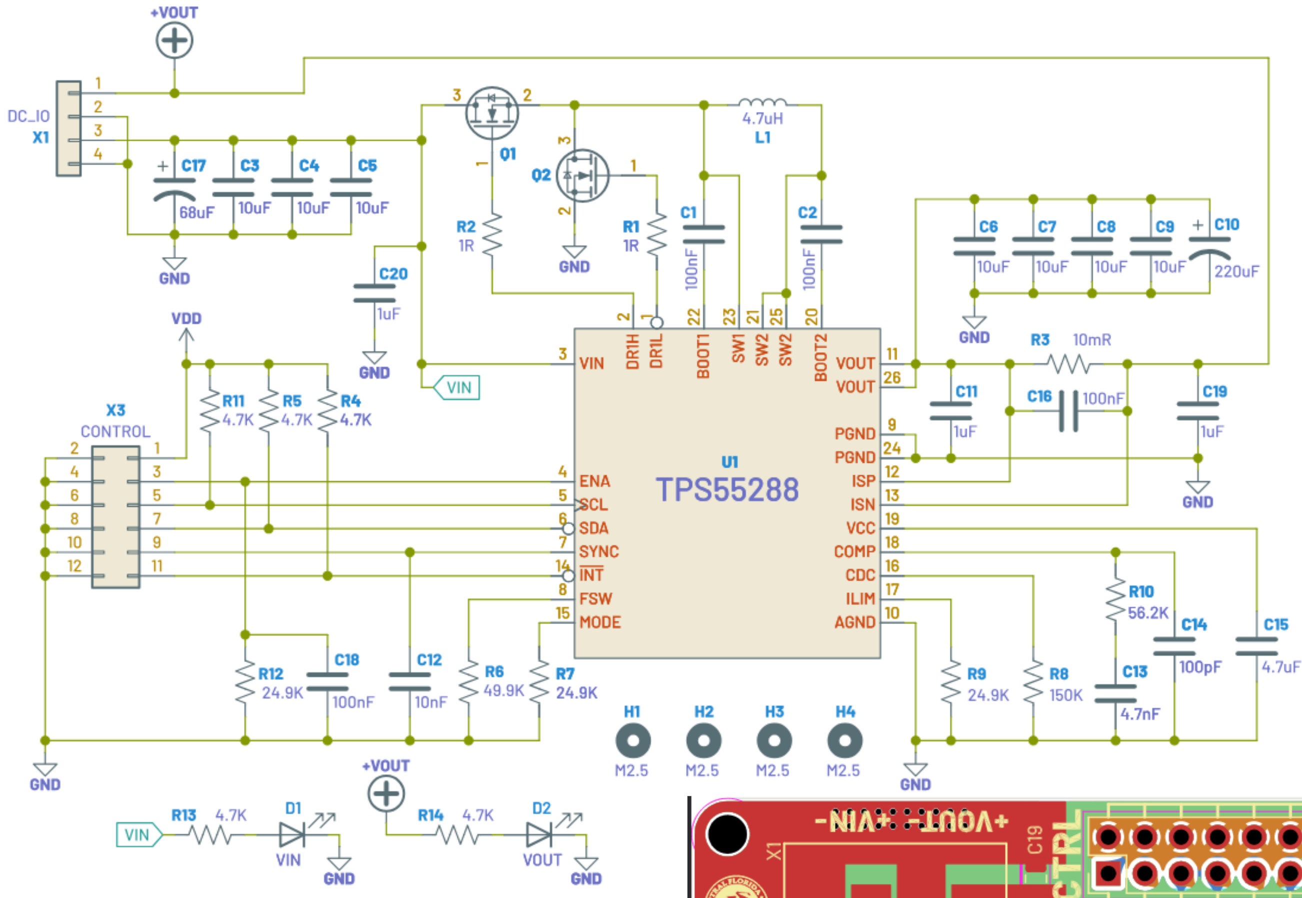
Energy Source Comparison/Selection

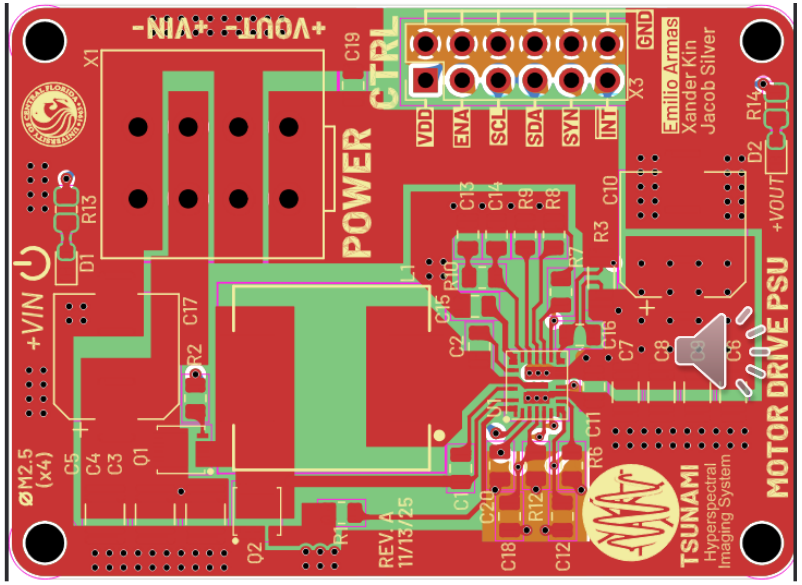
Model	Output Voltage	Output Current	Power Rating	Plug Size (mm)	Cost
HQ-60W-12V	12V	5A	60W	5.5x2.5	$14.15
TOBWOLF DC AC Wall Outlet	12V	5A	60W	5.5x2.5	$9.99
Arybroourd AC Adapter Power Supply	12V	8A	96W	5.5x2.5	$18.23
ALITOVE Power Supply	12V	10A	120W	5.5x2.5	$20.00
Facmogu Power Supply	12V	10A	120W	5.5x2.5 5.5x2.1	$19.99

Facmogu Power Supply:
- Price
- High Current Throughput
- Stability and Reliability

Stepper Motor Driver PSU

- Accepts 9-36V bus input
- Regulates from 5-20V up to 3A
- Buck/boost topology
- Output voltage/current and system status digitally controllable via I2C interconnect to MCU
- Variable voltage to control motor step energy/speed
- TPS55288 based





Stepper Motor Driver PSU

External FETs for buck/boost operation

TPS55288

Power In/
Power Out

Motor Driver Control

SBC PSU Comparison/Selection

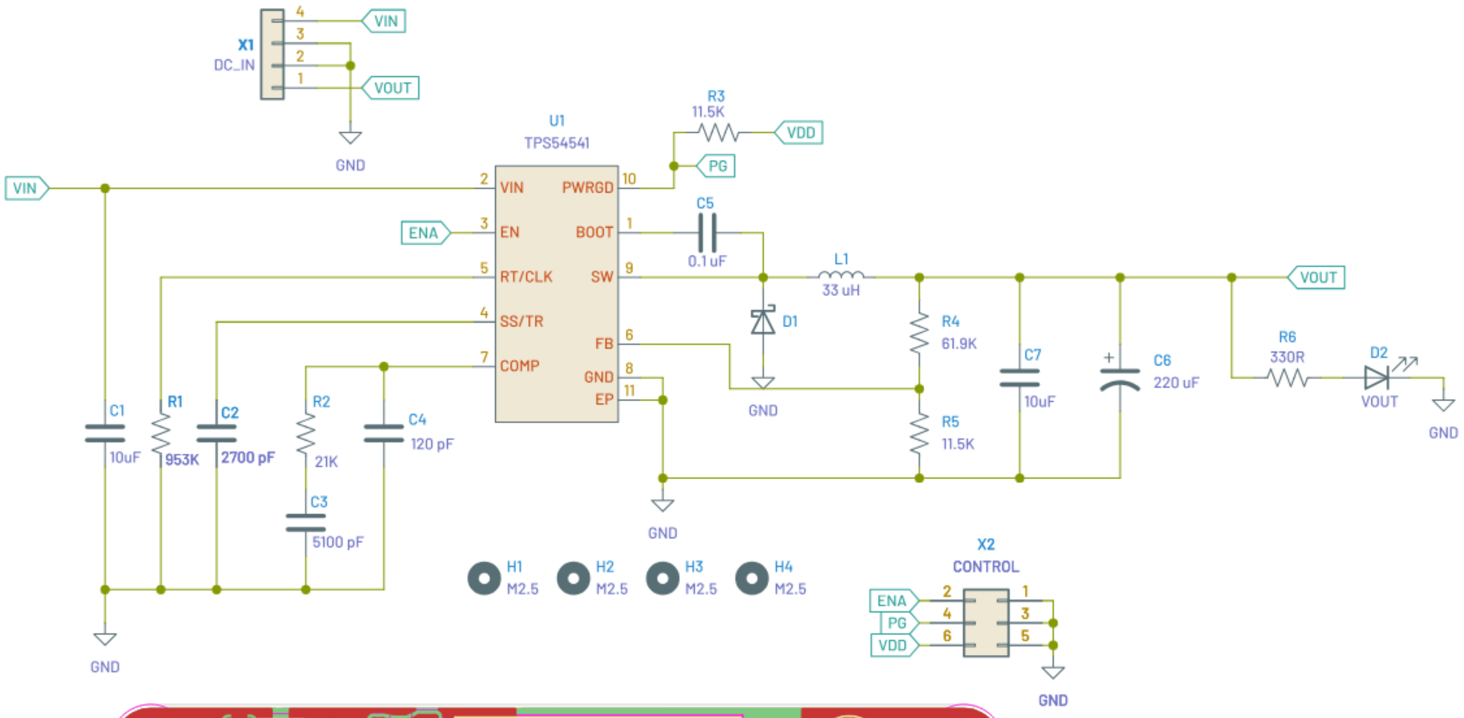
Buck IC Options	MAX20406AFOB	TPS54541	LMR51450SDRRR
Input Voltage	3V – 36V	4.5V – 42V	4V – 36V
Out. Voltage	0.8V – 10V	0.8V – 41V	0.8V – 28V
Current Limit	6A (continuous)	5A (continuous)	5A (continuous)
Operational Efficiency	~93% (12V to 5V @3A load)	91% (12V to 5V @3A load)	~94% (12V to 5V @3A load)
Thermal Res. ($R_{\theta JA}$)	38.4°C/W	35.1°C/W	47.4°C/W
Switching Frequency	400kHz – 3.0MHz	100kHz – 2.5MHz	200kHz – 1.1MHz
Package	17-PowerWFQFN	10-WSON (4x4mm)	12-WSON (3x3mm)
Protection Features?	Overtemperature, Short-Circuit	Overvoltage, Undervoltage	Overtemperature, Short-Circuit, Undervoltage
Price	$4.36/1 unit	$5.14/1 unit	$2.03/1 unit

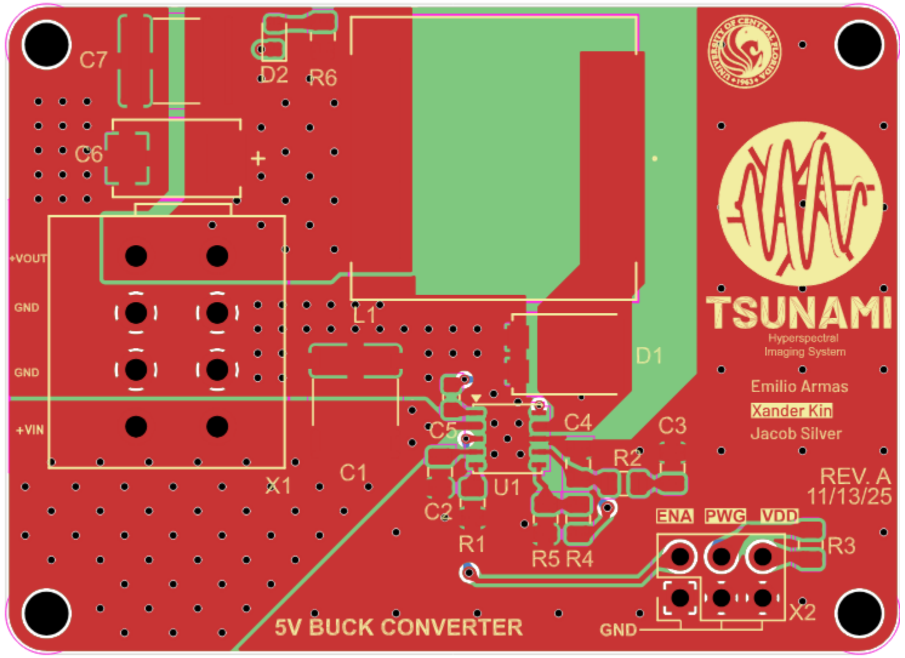
TPS54541:

- Regulates 9V-36V input voltage
- Delivers maximum current of 3A
- Best Thermal resistance

SBC PSU

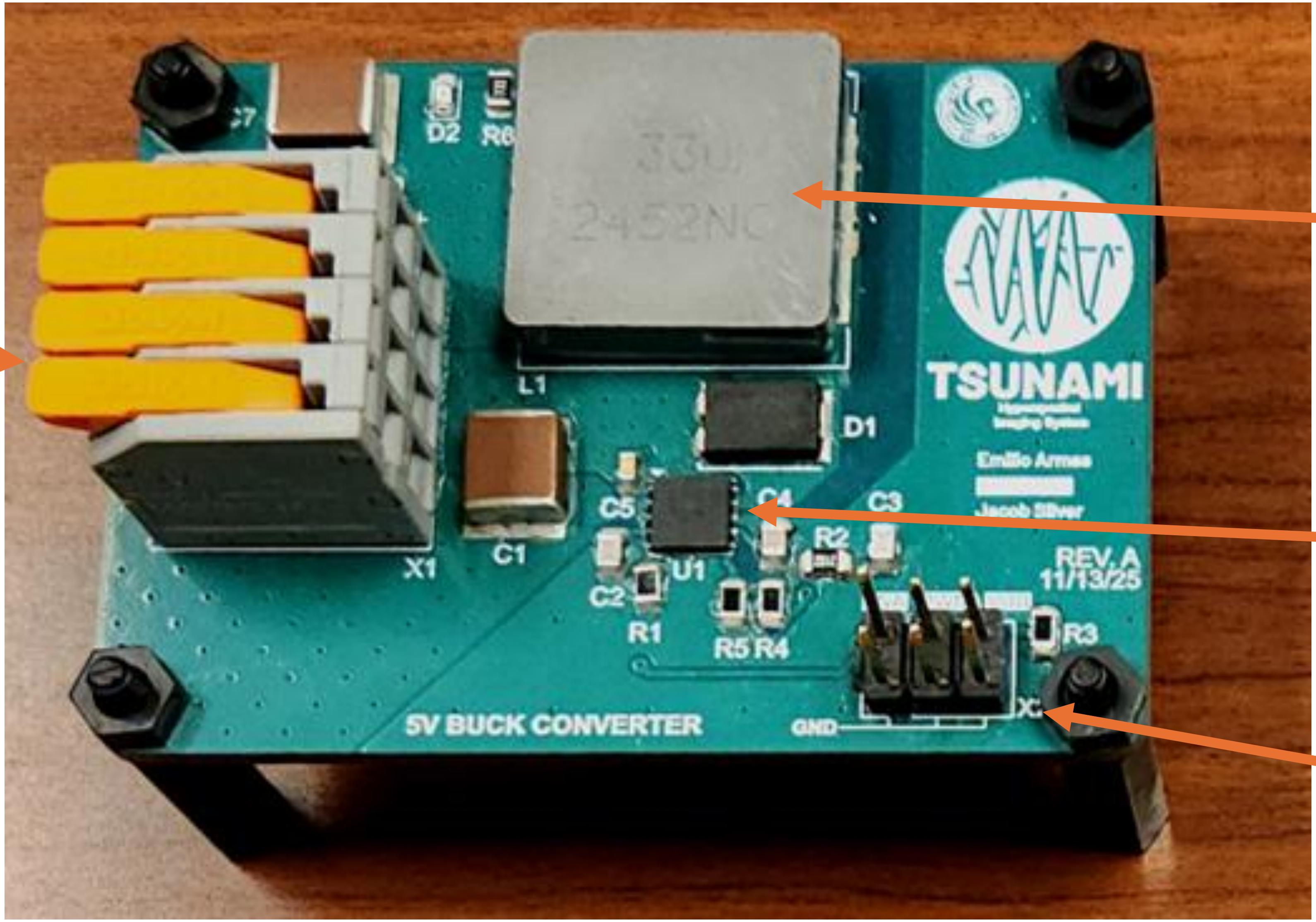
- Accepts 9-36V bus input
- Regulates up to 5A at 5.1V output continuously
- 5.1V to account for cable/connector loss
- Designed to supply a Raspberry Pi model 4B with continuous draw of roughly 3A
- TPS54541 based





SBC PSU

Power In/
Power Out



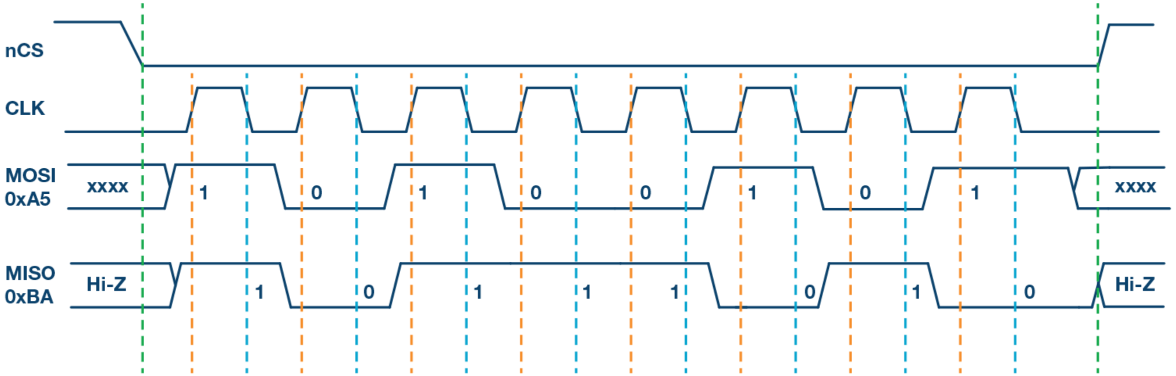
High Current
Power
Inductor

TPS54541

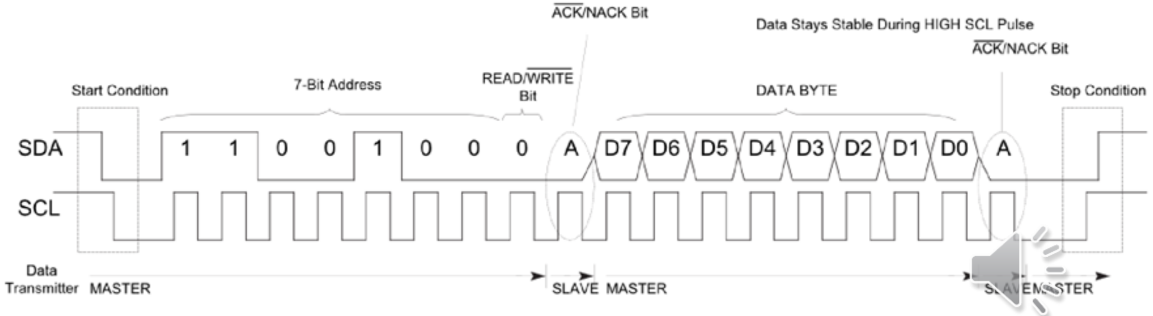
Control Header

Communication Protocols

- Between the SBC and MCU, a master->slave (respectively) SPI link exists
- SPI was chosen as it has a very simple data-frame and is easily accessible via the PI kernel and the MCU peripheral in slave mode
- Our SPI transactions consist of nine bytes:
  - Byte 0: 8bit command
  - Byte 1-8: assignable as two 32bit, four 16bit, or eight 8bit integers.
- I2C was used for the motor PSU as it was the only interface provided by the IC manufacturers



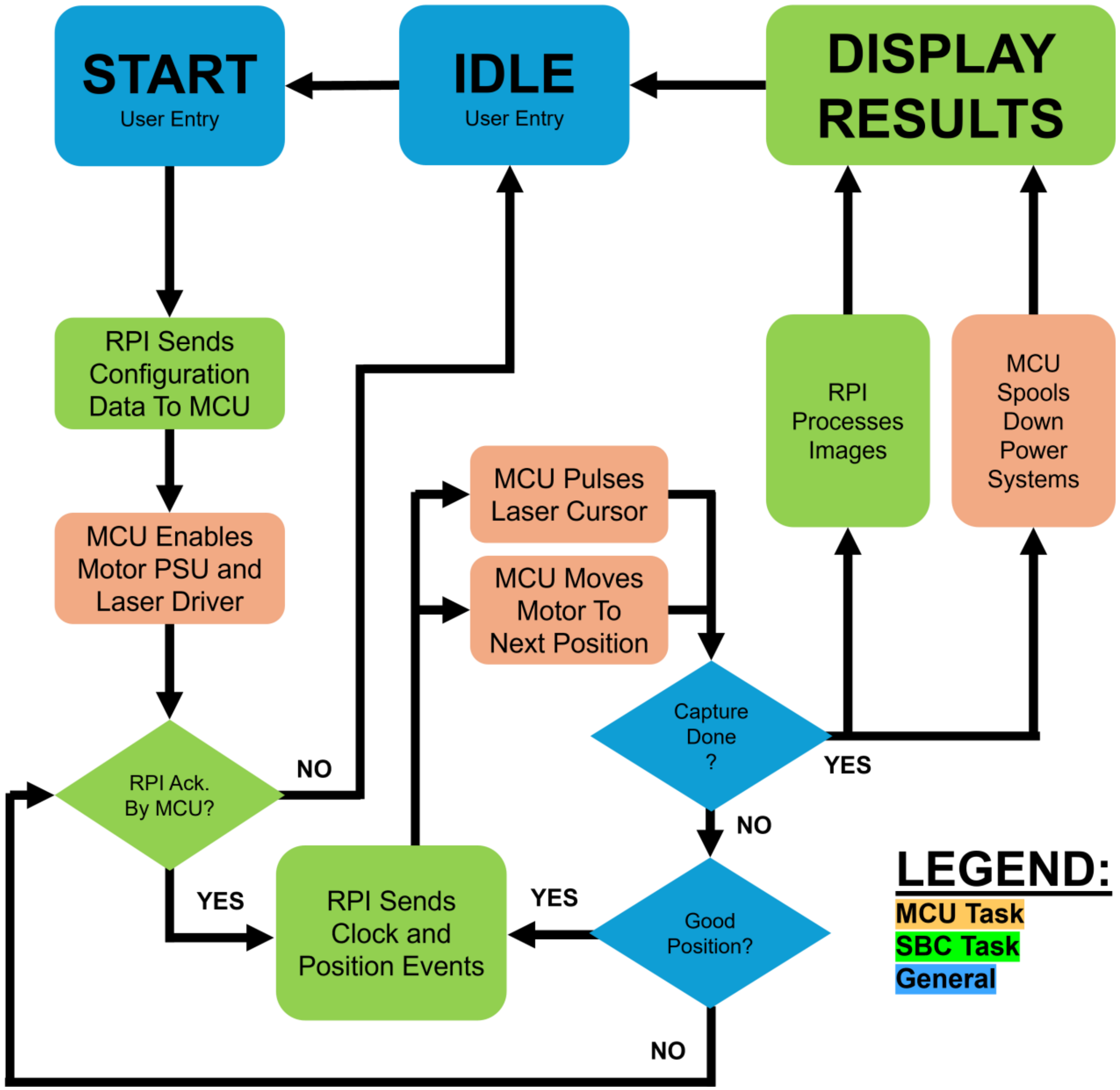
SPI Waveform, Credit: Piyu Dhaker of Analog Devices



I2C Waveform, Credit: Sal Afzal

Inter-Controller Software Design

- Camera image processing, frame capture, and GUI hosting best done on SBC
- MCU to work to fill all other roles, specifically close-to-hardware tasks
- MCU to interface with Raspberry Pi via digital serial communication and direct GPIO for timing signals
- WiringPi library used to control kernel drivers of GPIO and I2C on the SBC

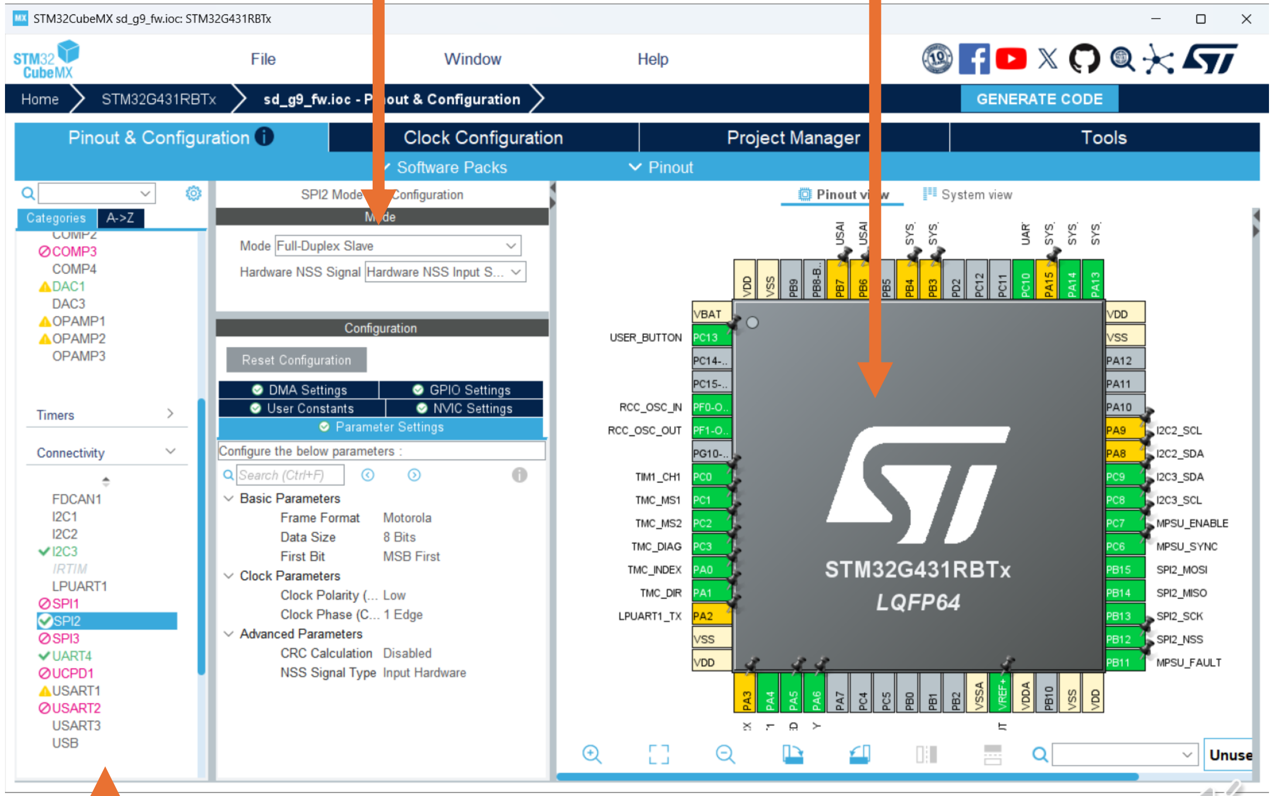


Inter-Controller Software Design (Cont'd)

- MCU firmware written for an STM32G431, hosting a 32-bit ARM Cortex-M4 @ 170MHz
- MCU peripheral instantiation, pin-planning, and some operational drivers handled by STMicro's Hardware Abstraction Layer (HAL) libraries.
- Significant ease of development with GUI editors for timing, system configuration, and interactive debugger

Peripheral Configuration

Interactive Pin-Planner



Peripheral Navigator

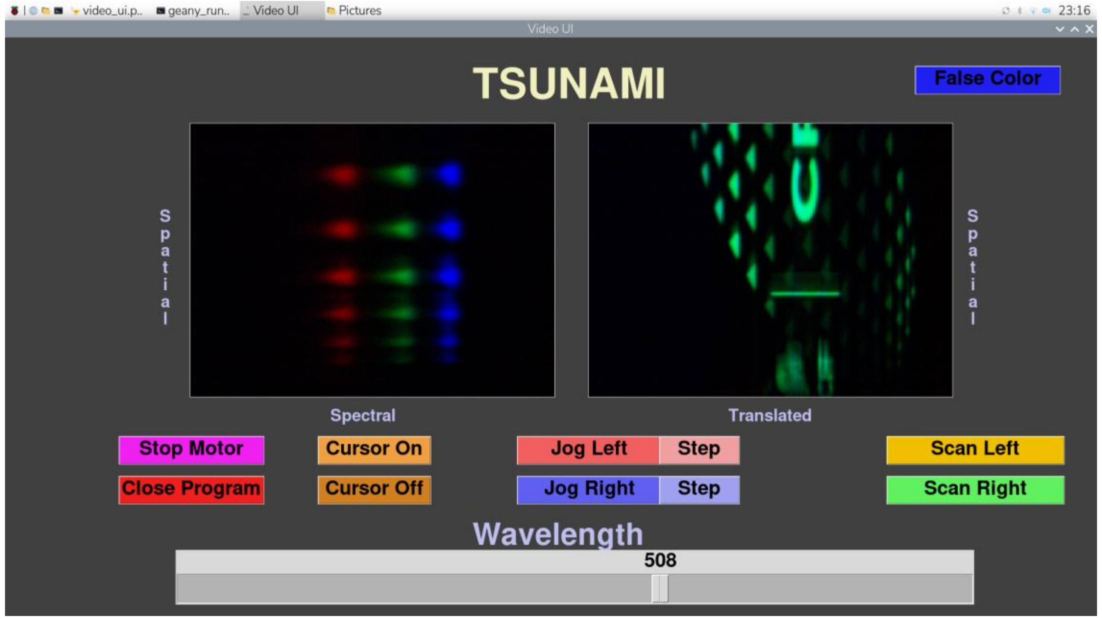
STM32 *CubeMX GUI*

Imaging Software Design

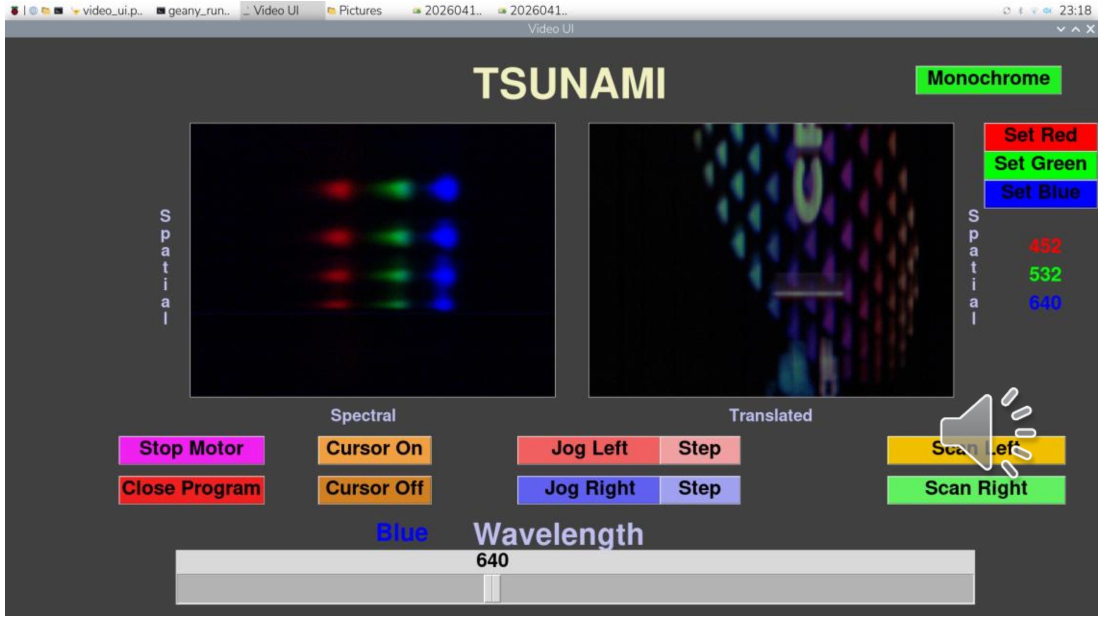
Target image on phone screen

- UI displays the live camera feed, monochrome images, and false color images

UI with live feed on left and monochrome on right



UI showing false color (with blue and red swapped) on right



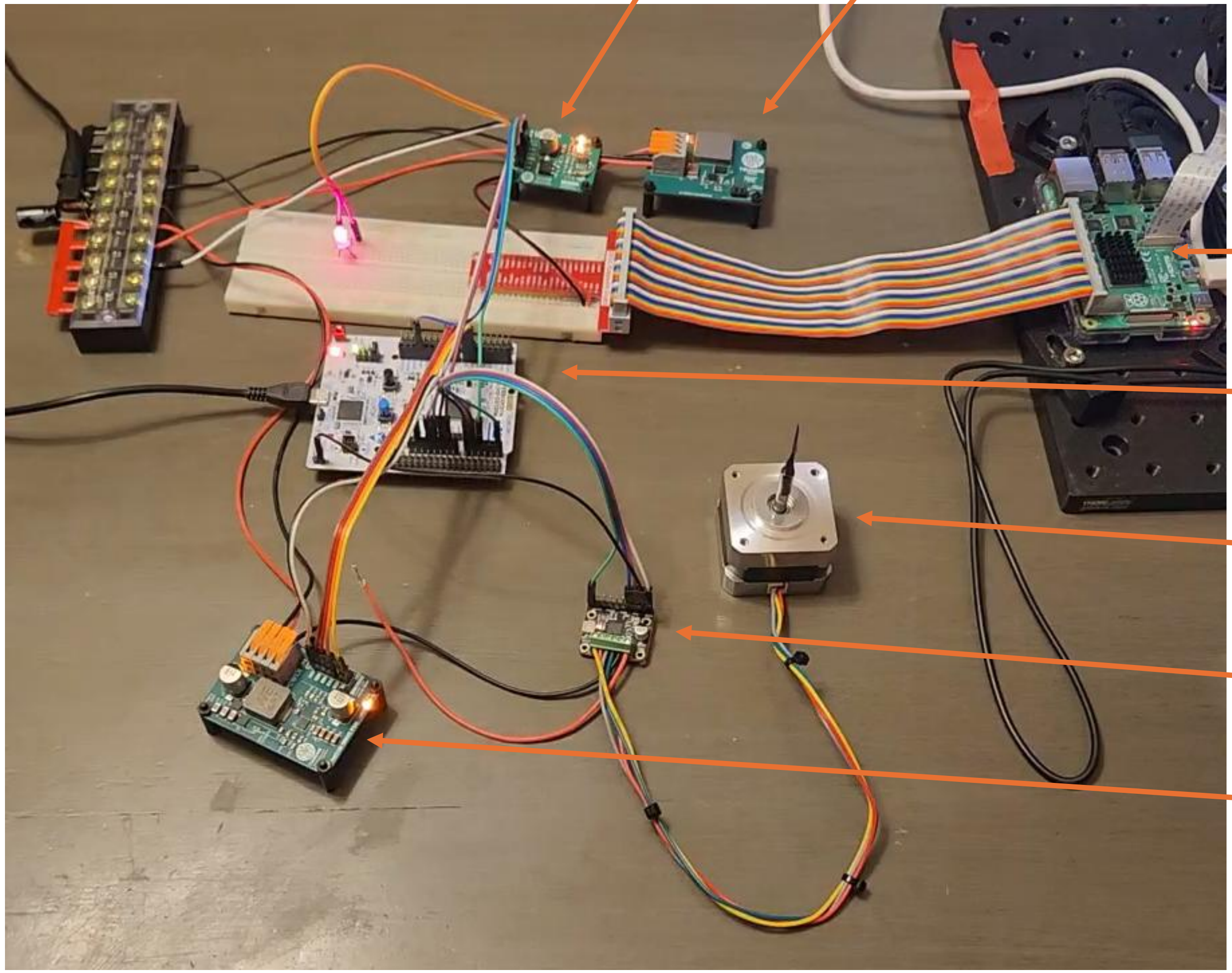
Prototyping (Optics)

First prototype in a flexible TPU housing as to not scratch the optics in case of errant tolerancing

Last prototype before final with earlier iteration in the background. Prototypes were held structurally by tape whereas our current is bolted together

Prototyping (Electronics)

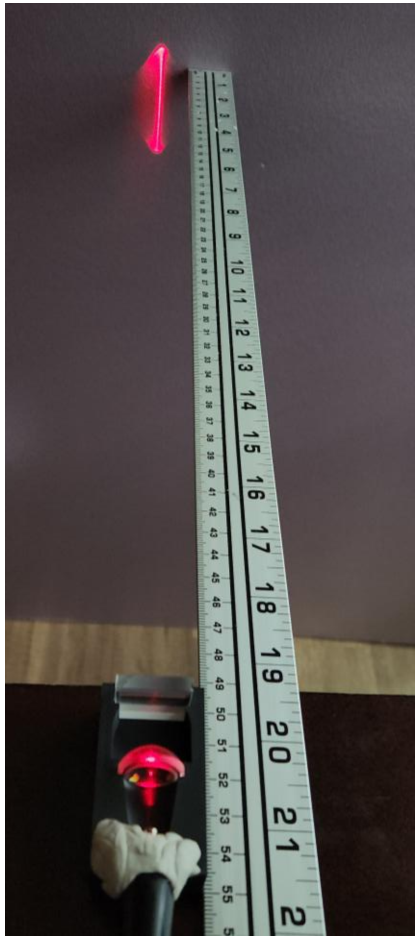
- MCU firmware was started on the G431 Nucleo-64 development board
- TMC2209 was tested using the Adafruit evaluation kit on a NEMA-17 motor
- Laser cursor rev. A PCB worked but needed improvement in control loop
- SBC PSU worked flawlessly, no revision needed
- Motor PSU worked flawlessly, no revision needed



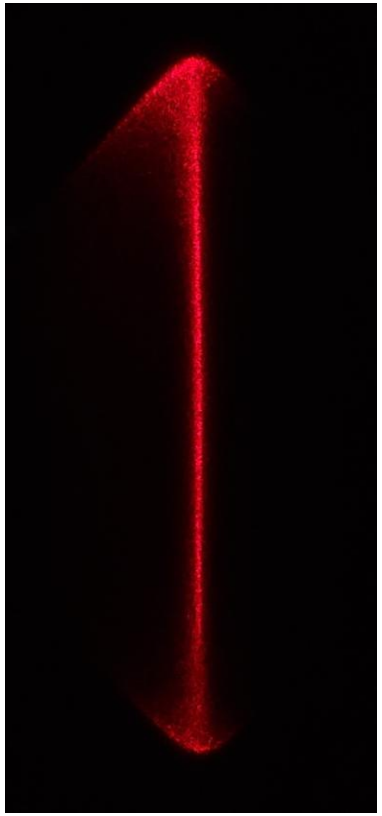
Optical Testing: Cursor Profile

Profile taken at edge (broadest)

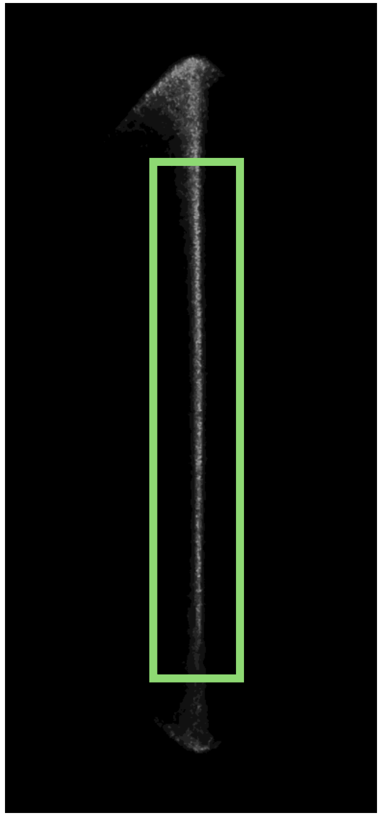
Cross-FWHM



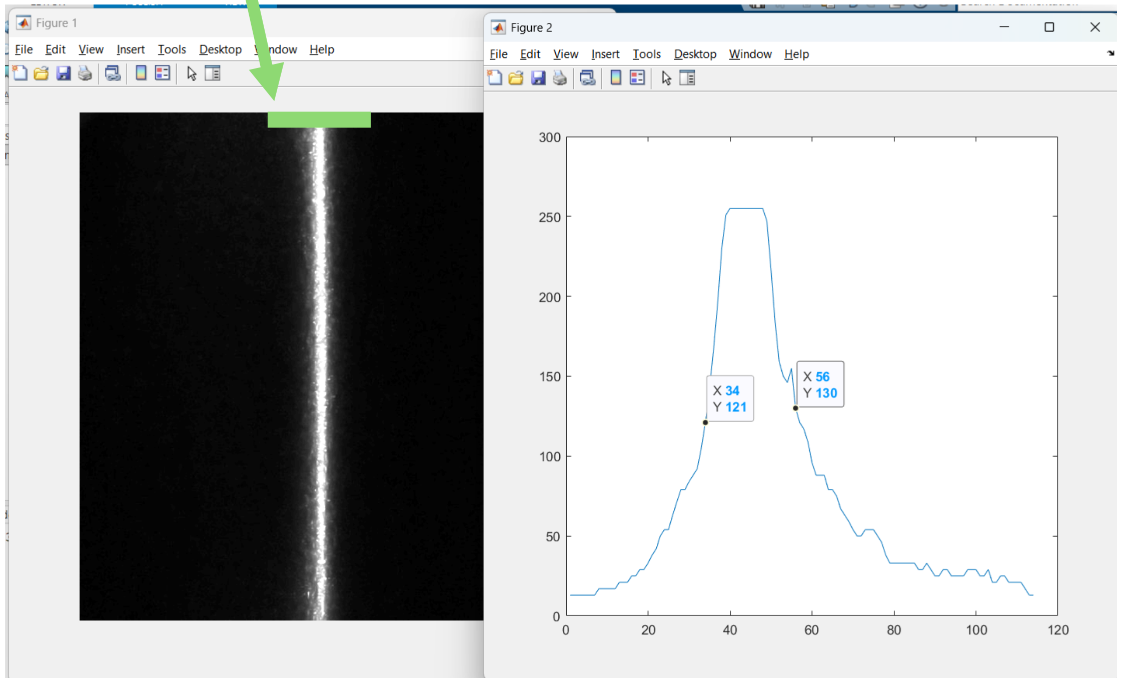
50cm test range



Captured Spot



Color & Contrast Adjusted



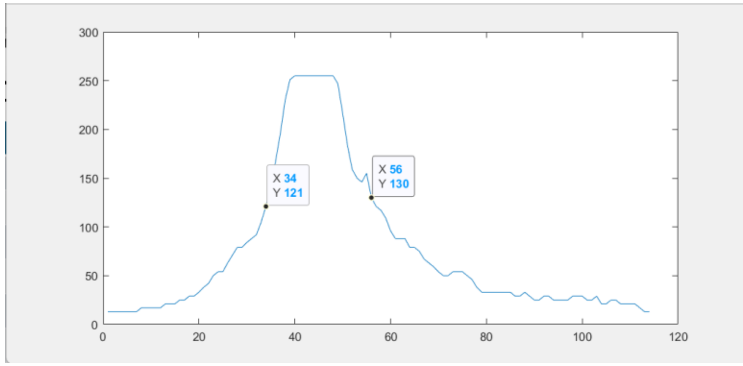
Cropped (Emulating Stop)

MATLAB Cross-Profilec

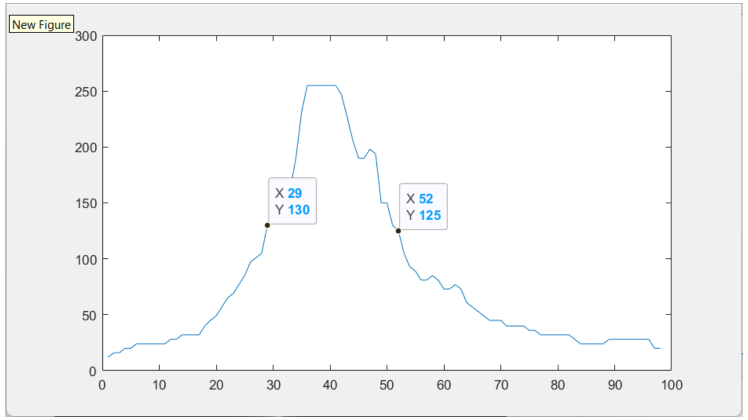
Optical Testing: Cursor Profile

Image #	Crop Height (px)	FWHM at Edge (px)	Spot Size Ratio
1	654	22	**29.7:1**
2	646	23	**28.1:1**
3	656	25	**26.2:1**
4	622	23	**27.0:1**
5	617	23	**26.8:1**
6	527	21	**25.1:1**
7	542	23	**23.6:1**
8	582	21	**27.7:1**
9	612	27	**22.7:1**
10	600	26	**23.1:1**

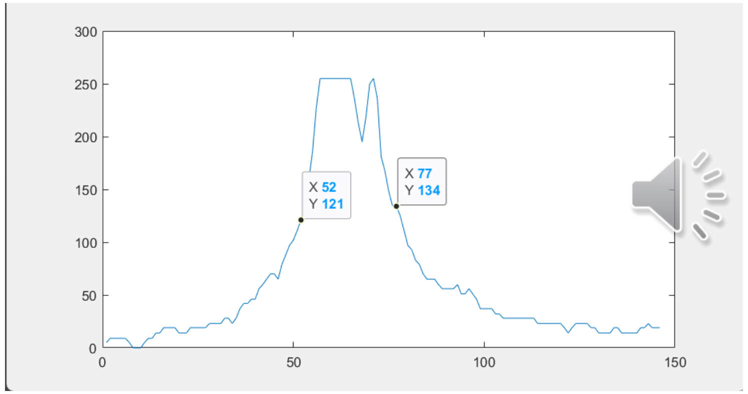
Profile (image #1)



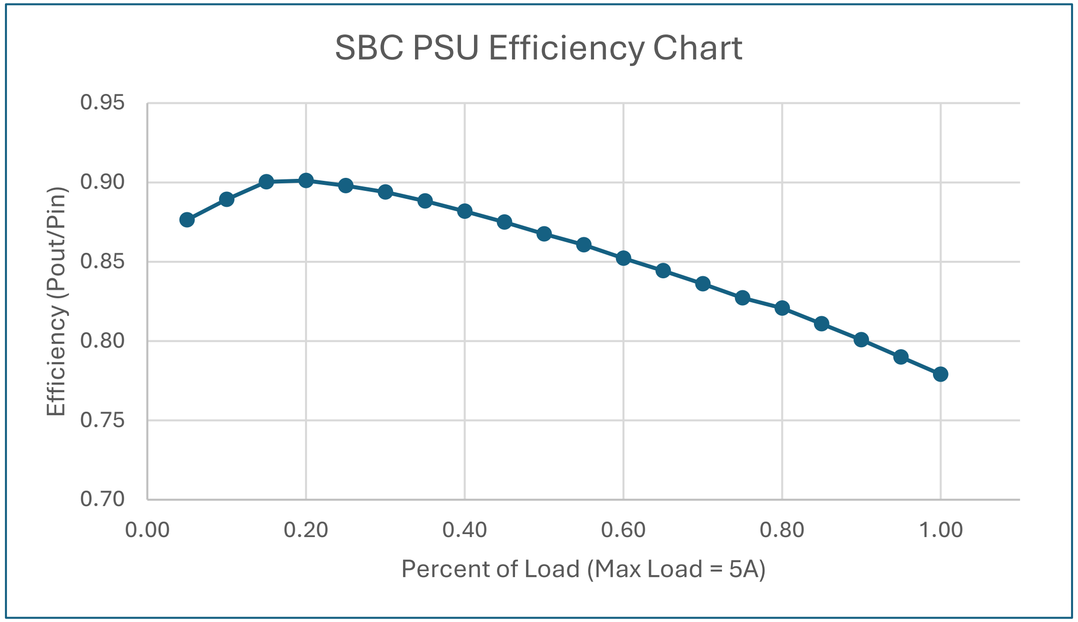
Profile (image #2)

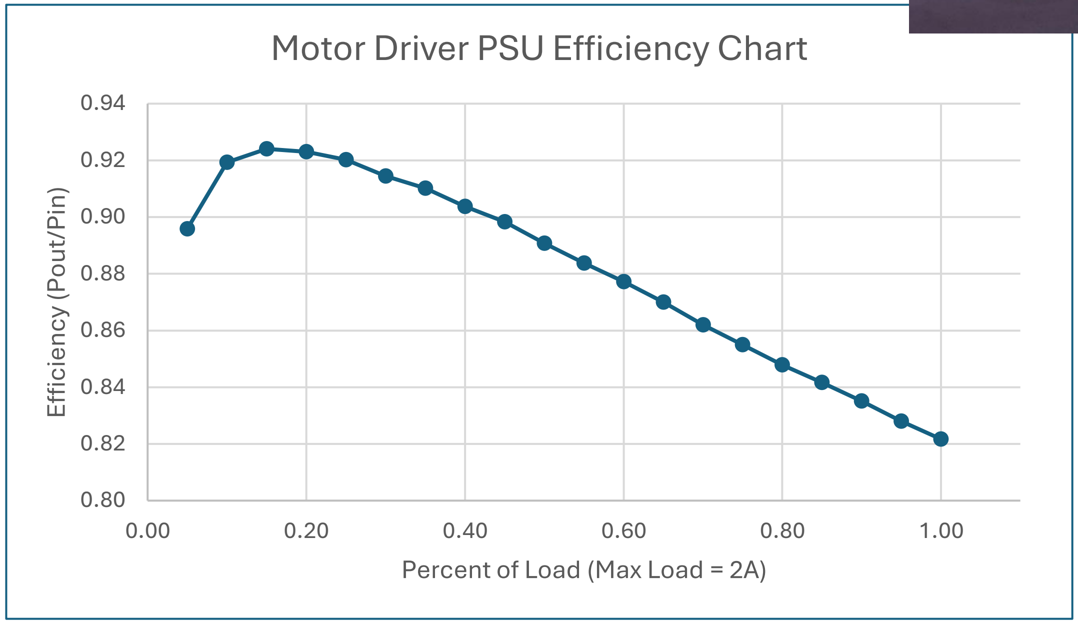


Profile (image #3)



Power Supply Efficiency Tests





Test Setup

SBC PSU	Motor Driver PSU
Input Voltage: 12V Output Current Load: 0A-5A 3 Data Points Per Current Step	Input Voltage: 12V Output Current Load: 0A-2A 3 Data Points Per Current Step
We input 12V into our PSU, then load it with 0-5A, noting our output voltage and input voltage while plotting our efficiency.	We input 12V into our PSU, then load it with 0-2A, noting our output voltage and input voltage while plotting our efficiency. Also, the only bus power that outputs more than 12V at 16V.

Test Results

SBC PSU	Motor Driver PSU
• Account for cable loss in testing. • Programmable Power-Supply and eLoad • Stepping of Current = 0.25 A • Efficiency of Continuous Current (60% of max load or 3A): 85%	• Account for cable loss in testing. • Programmable Power-Supply and eLoad • Stepping of Current = 0.1 A • Efficiency Best: 92% Efficiency Worst: 82%

Major Challenges/Solutions

- Challenge: There is a great excess of ambient light in the near-infrared that bled through the seams of the imager
  - Solution: The imager is wrapped in electrical tape to block the light.
- Challenge: A single slit aperture has a rather large FOV along its short axis unless placed very far from entry.
  - Solution: We used two slits spaced apart to greatly reduce the FOV
- Challenge: Tkinter can run looped processes in parallel, but the limited compute of the Raspberry Pi can cause the UI to crash if too many concurrent processes take place.
  - Solution: Global booleans are used to prevent unused image processing from looping in the background.
- Challenge: The laser diode in the laser cursor heats up rapidly, diminishing optical power
  - Solution: Redesign for closed-loop control over optical output power (use photodiode)

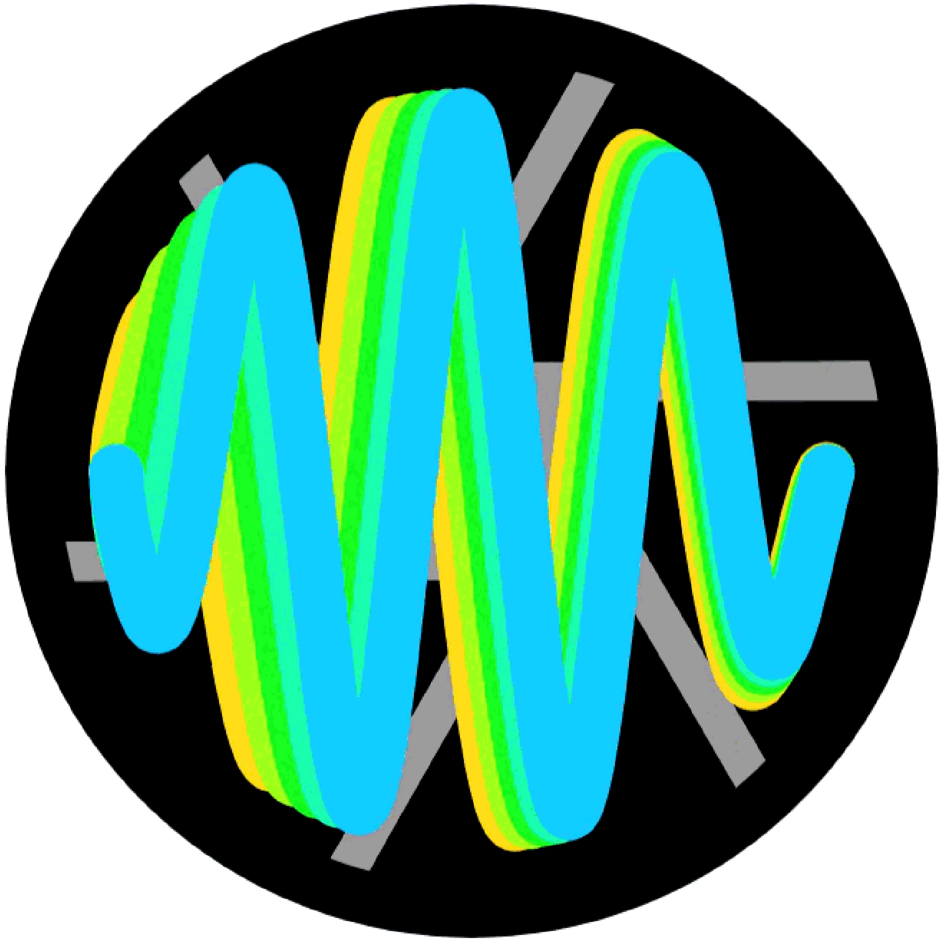
Distribution of Work

Electrical Engineering	Responsibilities
Emilio Armas	Project Lead
	MCU Integration and Implementation
	Motor Controller Power Supply Design
	Laser Diode Driver Circuit/Optoelectronics
	Power Bus and Power Entry Circuitry
	Final PCB design and assembly
Xander Kin	MCU 3.3V LDO Implementation
	Stepper Driver Implementation
	SBC Power Supply Design
	Subcircuit pre-validation PCB design
Photonics Science and Engineering	Responsibilities
Jacob Silver	SBC Image Processing Software
	Imaging System Optical Design
	Motor Mechanical Implementation
Emilio Armas	Laser Cursor Optical and Optoelectronic Design

Budget

Component	Subsystem	Quantity	Unit Cost	Total
PLA Filament, 1kg	Mechincal Structures	3	$22.76	$68.28
Stepper Motor	Mechanical Structures	1	$14.00	$14.00
Transmissive Grating	Hyperspectral Camera	1	$17.76	$17.76
Achromatic Lens Doublet	Hyperspectral Camera	2	$135.09	$270.18
Positive/Negative Focal Le	Hyperspectral Camera	2	$120.00	$240.00
650 nm 7mW Laser Diode	Cursor	1	$20.17	$20.17
MCU	Electronics	1	$4.87	$4.87
CMOS Camera	Hyperspectral Camera	1	$25.00	$25.00
Miscellaneous	All	1	$100.00	$100.00
			Total	$760.26

Conclusion



Thank you for listening! :) :) :)

We're excited to hear your questions and comments on Tuesday.

Bibliography

- [1] “Pika L-F (420-980nm).” *Resonon Pika L-F Hyperspectral Imaging Camera*, Resonon Inc., 2025, resonon.com/Pika-L-F.
- [2] Thompson, D. R., J. W. Boardman, M. L. Eastwood, R. O. Green (2017), A large airborne survey of Earth’s visible-infrared spectral dimensionality. Optics Express 25, 9186-9195 (2017).
- [3] Thorpe, A.K., Roberts, D.A., Bradley, E.S., Funk, C.C., Dennison, P.E., Leifer I. (2013). High resolution mapping of methane emissions from marine and terrestrial sources using a Cluster-Tuned Matched Filter technique and imaging spectrometry. Remote Sensing of Environment, 134, 305-318.