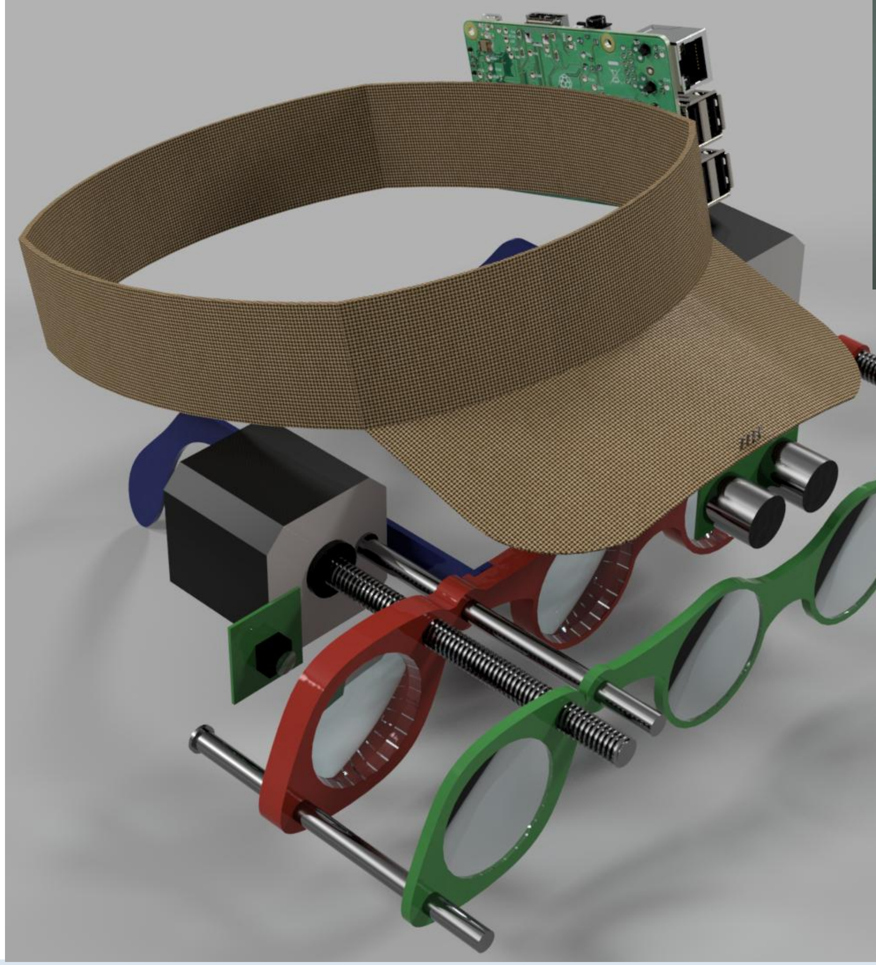
Auto-Focusing and Color Identifying Lenses for Mild Visual Impairments



Critical Design Review

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Meet the Team

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Idea

Utility lenses for visually impaired individuals designed to assist with various visual disabilities.

Key feature include:

- Auto-focusing
- Color identification
- Auditory response

Background and Motivation

- Visual impairments create obstacles performing everyday tasks
  - Nearly 2.2 billion individuals have some form of near or farsightedness.
  - Approximately 0.5% of women and 8.3% of men have color blindness.
- Current assistance apps rely on volunteers
- We want to provide more freedom and improve the quality of life for the visually impaired
- Initial prototype will be limited to focusing and color-based impairments

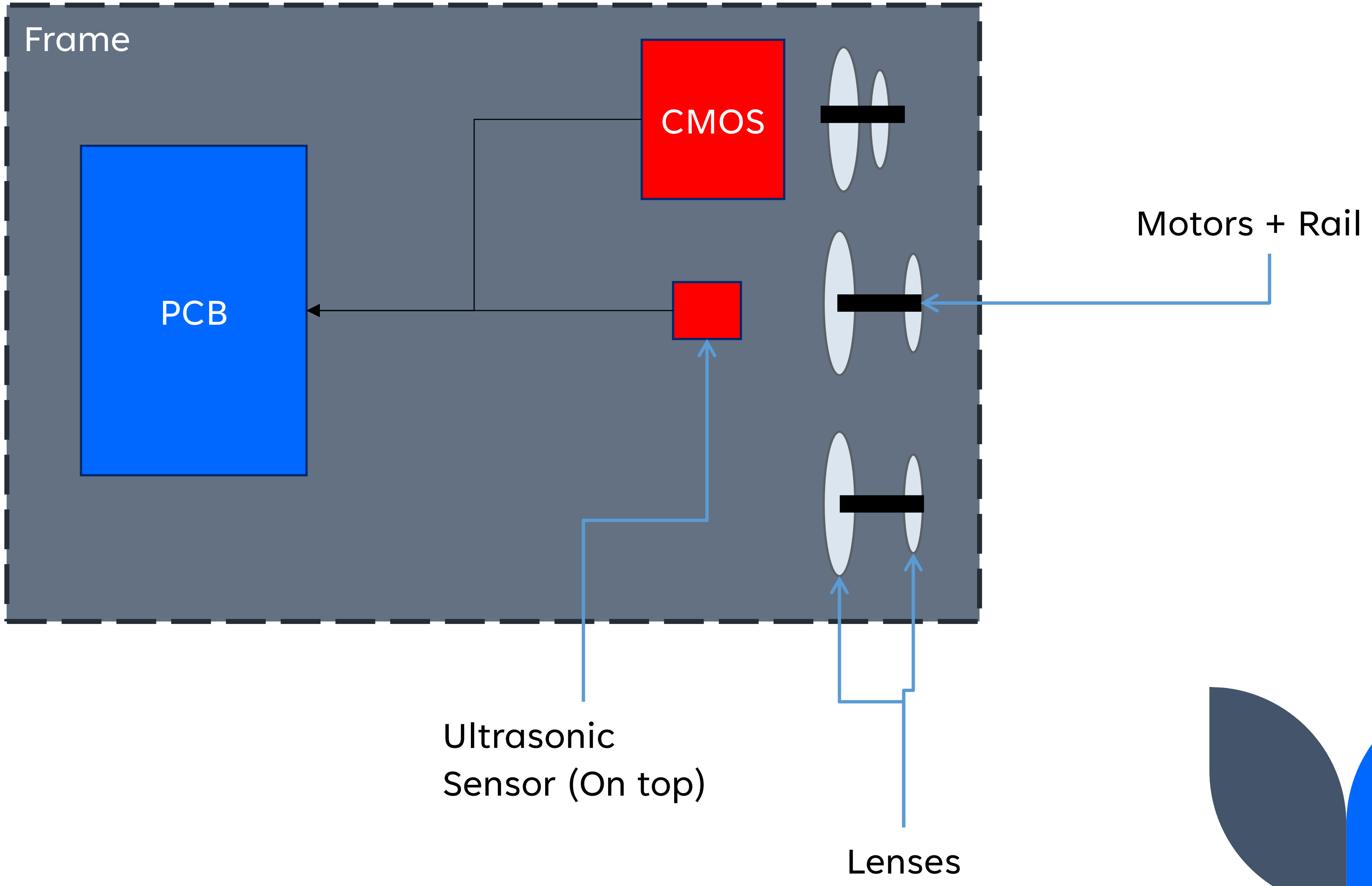
Requirements & Specifications

System Engineering Requirements	
Parameter	Requirements
Time to Focus	≤ 1 minute
Battery Life	≥ 2 continuous hours
Manufacturability	≤ $1000
Bluetooth Range	33 feet
Distance Measured	2cm-200cm
System Boot Time	<5 seconds

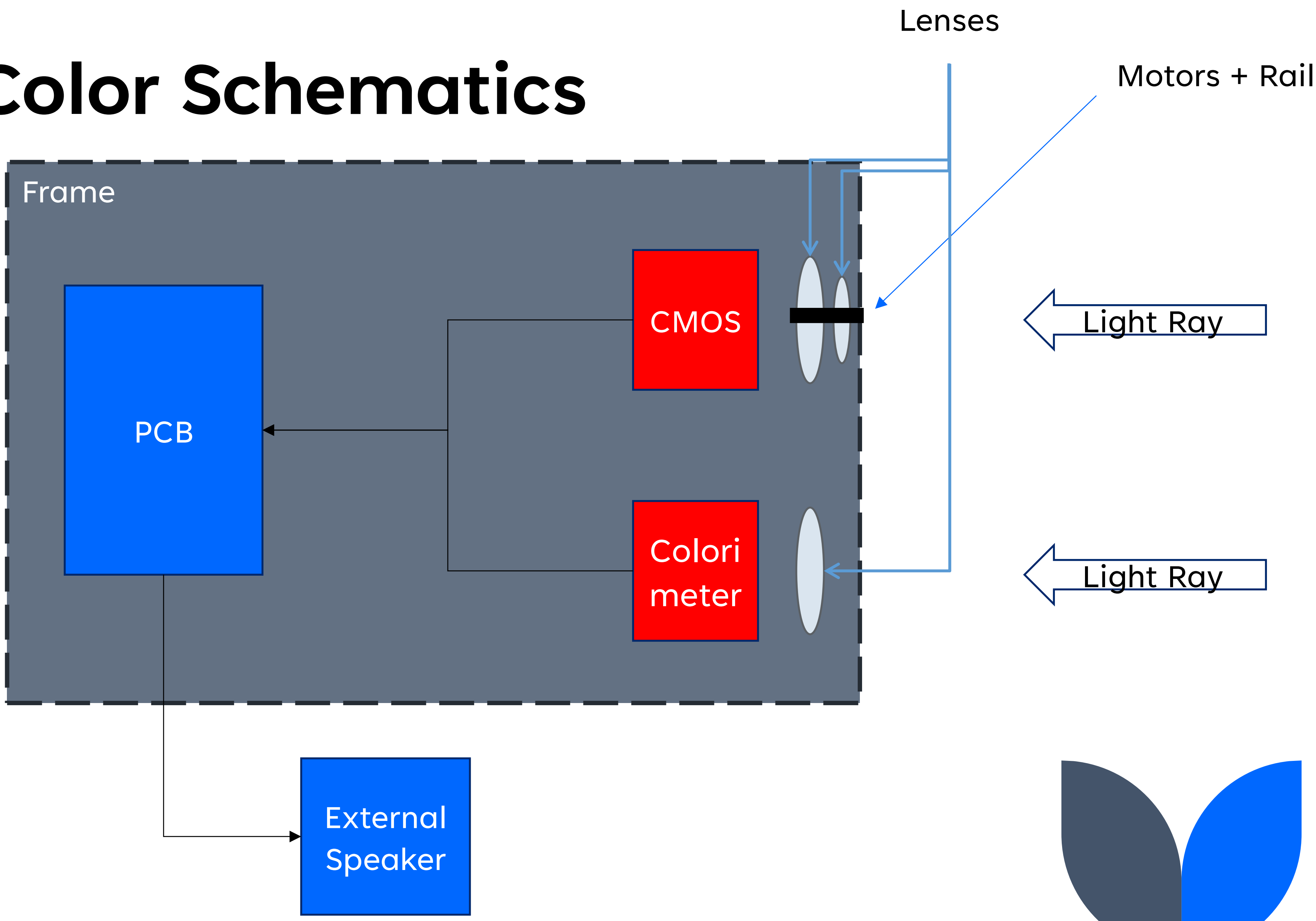
Optical System Engineering Requirements	
Parameter	Requirements
Color Accuracy	≥ 80%
Focusing Power	Variable from -1.5 D to +2.5 D
Color Identification	≥ 3 colors
Sensor Resolution	≥ 5 MP
Simultaneous Colors Identifiable	≥ 1 color

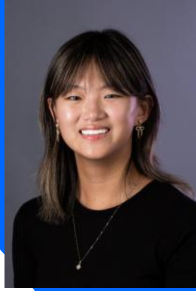
Component Specifications	
Parameter	Specification
Linear Railing Length	≤ 200 mm
Linear Railing Step Size	≤ 2 mm
Motor Maximum Power	≤ 6W
Camera Field of View	≥ 60°

Auto-Focusing Schematics



Color Schematics





Goals

Basic

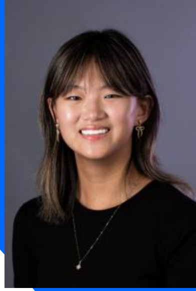
- Automated adjustment of optical power between -0.5 D and +1 D.
- Identify when focus has been acquired above threshold value
- Successfully identify red, green, and blue
- Have a functioning speaker response system

Advanced

- Improve autofocusing system to provide between -1.5 D and +2.5 D of optical power in under one minute
- Improve color identification accuracy above 80%

Stretch

- Miniaturization of system
- Additional identifiable colors
- Text-to-speech feature
- Object identification



Objectives

Basic

- Utilize Time of Flight sensor to acquire initial distance then adjust distance between lenses with motors and rails
- Create program for edge detection of images with CMOS sensor
- Design color identification system in conjunction with a lens system for accurate identification of red, blue, and green.
- Integrate audio system with MCU and program the audio responses

Advanced

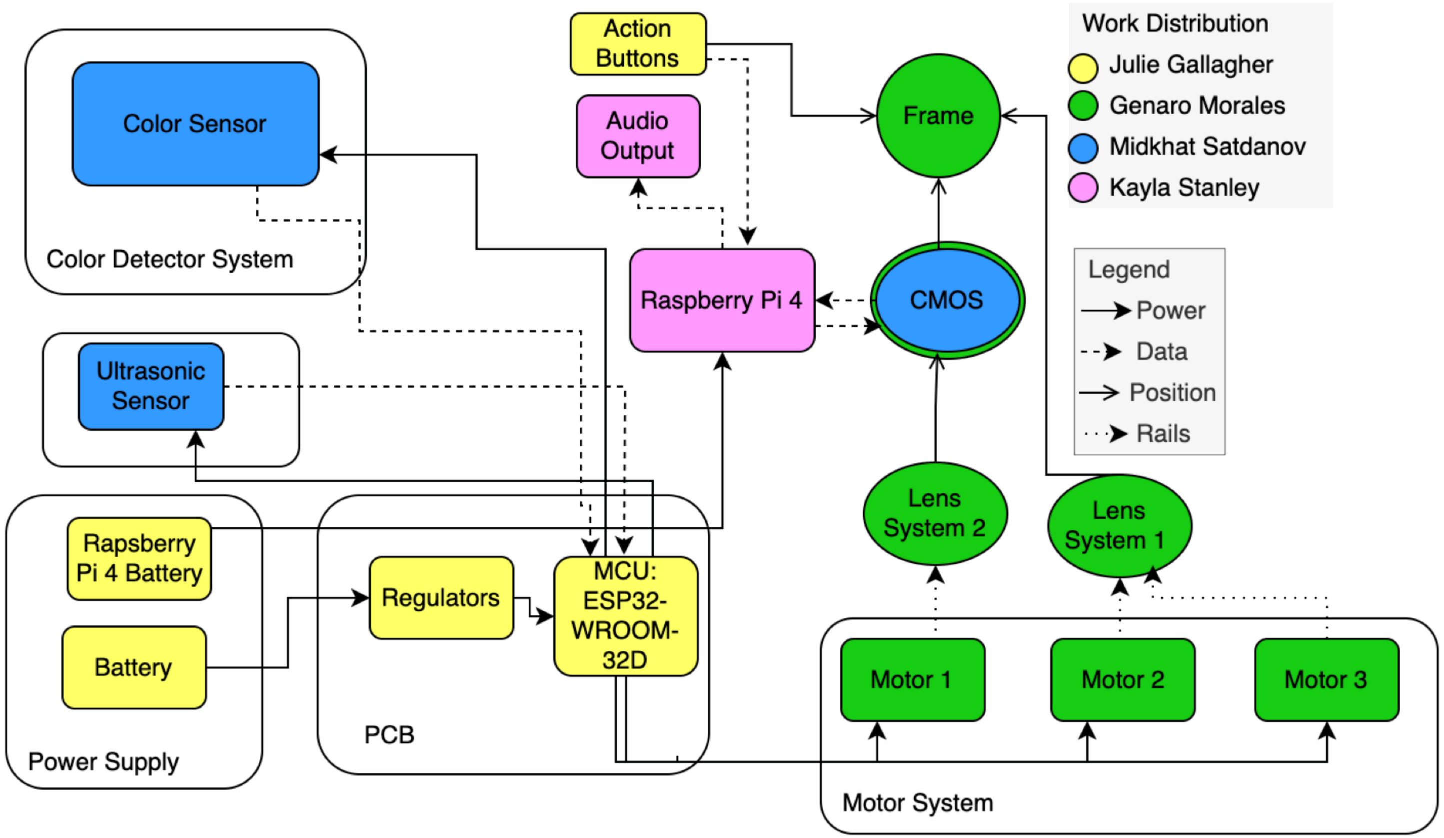
- Improved lens design for minimized aberrations, larger depth of field, and a higher range of variable optical power
- Program color identification utilizing the CMOS sensor and a color library for improved accuracy

Stretch

- Conduct research on affordable smaller components
- Improve color library to accurately detect more unique colors
- Program sensor to detect text and map it to text library
- Use computer vision for object detection

Hardware Design

Hardware Block Diagram



CAD Model Visual Representation

- Initial design for the prototype involved the use of a visor.
  - Comfortable while maintaining optical alignment.
  - Moving forward, a flat-brimmed ball cap will be implemented.
- Components are evenly distributed around the hat to maintain comfortability
  - Certain components, such as the motors are being replaced with much lighter options
- The main lens system is aligned with the user’s eyes
- The ultrasonic sensor and color detection system are attached to the brim of the hat

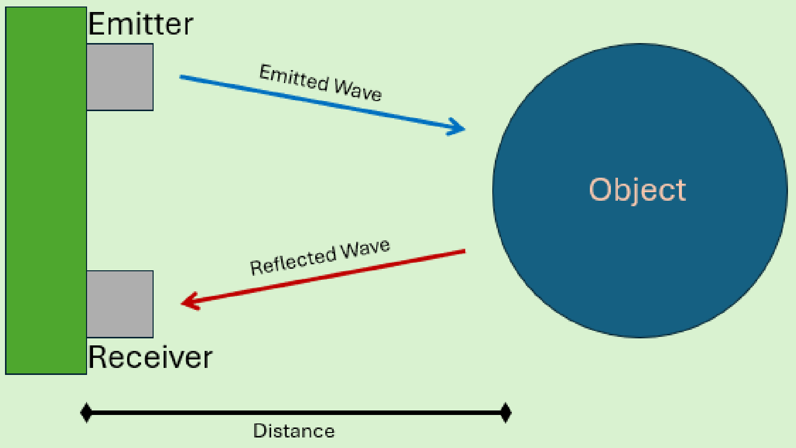
Comparison and Selection

Hardware

Time of Flight (ToF) Comparison

- A starting distance will be necessary for the auto-focus feature to function properly.
- The auto-focusing assists individuals with presbyopia*

*Age-related far-sightedness



Time of Flight Sensor Selection

Sensors	Sensor Type	Measurement Range (cm)	Operating Voltage (V)	Operating Current (mA)	Cost
TeraRanger Evo Mini	Laser Diode	3 - 330	4.75 - 5.25	50	$43
TFmini Plus	Laser Diode	10 - 1200	4.5 - 5.5	110	$51
TF Mini LiDAR	Laser Diode	10 - 1200	4.5 - 6	120	$40
Sharp GP2Y0A21YK0F	Light-Emitting Diode	10 - 80	4.5 - 5.5	30	$10.43
Grove VL53L0X	Light-Emitting Diode	3 - 100	3.3 or 5	19	$7.25
Grove Ultrasonic Distance Sensor	Ultrasonic	3 - 350	3.3 or 5	8	$3.95
HC-SR04	Ultrasonic	2 - 450	5	< 5	$0

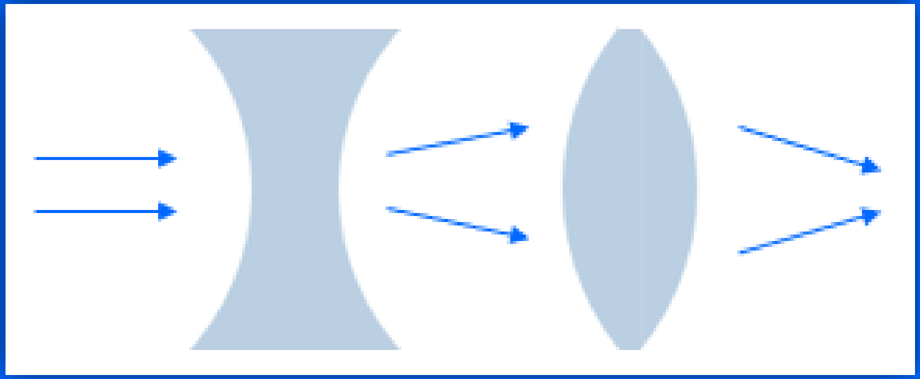
- The HC-SR04 was selected for its reasonable measurement range that would be helpful for individuals with various levels of presbyopia. The cost-effective aspect of already having one available for use was the ultimate deciding factor.
- It should be noted that focus can still be acquired at distances beyond the maximum range of the sensor as the starting point would simply be set to the maximum range and the focus will shift further away until focus is acquired

Lens Comparison

- Our auto-focusing lens system will have a variable optical power that ranges from -1.5 D to 2.5 D to successfully shift the focal length.

Lensmaker's Equation

- A variable effective focal length can be accomplished by using at least two lenses.
- By imagining the system as a single thick lens, we can estimate the distance required to achieve the desired optical power.



<u>Lensmaker's Equation</u>

$$P = P_1 + P_2 - \frac{d}{n} P_1 P_2$$

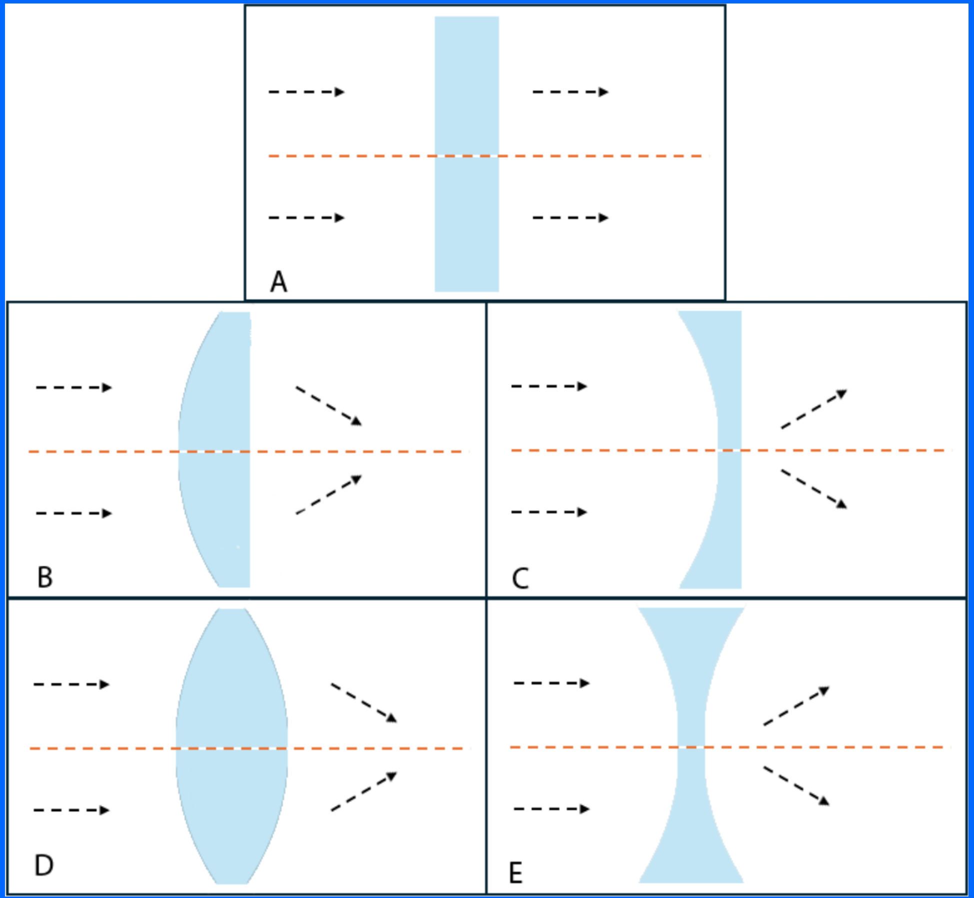
$$d = \frac{n(P_1 + P_2 - P)}{P_1 P_2}$$

<u>Power and Focus Relationship</u>

$$P = \frac{1}{f}$$

Lens Shape

- Traditional Spherical Lenses
  - No vergence
    - Planar Lenses (A)
  - Converging
    - Plano-Convex (B)
    - Biconvex (D)
  - Diverging
    - Plano-Concave (C)
    - Biconcave (E)
- Nontraditional Lenses
  - Cylindrical Lenses
  - Fresnel Lenses
  - Flexible Lenses



Traditional Spherical Lens Shapes

Lens Selection

- United Scientific Lenses
  - Great Variety
  - Cost Uncertainty
- Eisco Lenses
  - Some Variety
  - Low Cost
- Edmund Optics Lenses
  - Amazing Variety
  - Much higher costs

Brand	Lens Shape	Diameter (mm)	Focal Lengths Available (mm)	Cost (USD)
United Scientific	Biconcave (negative)	38	50, 100, 150, 200, 300, 350, 400, 450, 500	Unknown
		50	50, 100, 150, 200, 250, 300, 350, 400, 450, 500	Unknown
		75	200, 300, 350, 400, 450, 500	Unknown
	Biconvex (positive)	38	50, 100, 150, 200, 250, 300, 350, 400, 450, 500	Unknown
		50	50, 100, 150, 200, 250, 300, 350, 400, 450, 500	Unknown
		75	150, 200, 300, 350, 400, 450, 500	Unknown
Eisco	Biconcave (negative)	38	50, 100, 150, 200, 250, 300	\$10 - \$14
		50	50, 100, 150, 200, 250	\$11 - \$20
		75	100, 150, 200, 250, 300, 500, 1000	\$12 - \$18
	Plano-Convex (positive)	25	50, 71	\$9 - \$10
		50	100, 150, 200	\$10 - \$13
	Biconvex (positive)	38	50, 100, 150, 200, 250, 300	\$8 - \$16
		50	50, 100, 150, 200, 250, 300	\$9 - \$18
		75	100, 150, 200, 250, 300, 500, 1000	\$11 - \$15
Edmund Optics	Plano-Concave (negative)	6	6, 9, 12, 15, 18	\$30
		9	9, 12, 18, 27	\$30
		12	12, 15, 18, 24, 48	\$30
		20	30, 40, 50, 100	\$31
		25	25, 35, 50, 100	\$32
		50	100, 125	\$48
	Biconcave (negative)	6	6, 9, 12	\$28
		9	9, 12, 18	\$29
		12	12, 18, 24	\$31
		20	20	\$31
		25	25, 50, 100	\$33
	Plano-Convex (positive)	6	6, 7.5, 9, 10, 12, 15, 18, 20, 21, 24, 25, 30, 36, 48, 60, 72	\$26 - \$27
		9	9, 10, 12, 13.5, 15, 18, 20, 22, 25, 27, 36, 45, 54, 72, 90	\$27 - \$28
		12	12, 15, 18, 20, 24, 25, 30, 36, 42, 48, 50, 54, 60, 72, 84	\$29 - \$30
		20	20, 24, 30, 35, 40, 50, 60, 70, 80, 100, 150	\$29 - \$31
		25	25, 30, 35, 40, 50, 60, 75, 85, 100, 125, 150, 175, 200, 250, 300, 400, 500, 750	\$29 - \$31
		50	50, 75, 100, 125, 150, 175, 200, 250, 500	\$43 - \$48
	Biconvex (positive)	6	6, 9, 12, 18, 24, 30, 36	\$29
		9	9, 13.5, 18, 27, 36, 45	\$30
		12	12, 18, 24, 30, 36, 48, 72	\$30
		20	20, 25, 30, 40, 50, 60, 80	\$32
		25	25, 30, 35, 40, 50, 75, 100, 125, 150, 175, 200	\$32
		50	50, 100, 150, 200, 250	\$48

Motor Comparison

To accomplish our design goals, we took in consideration factors such as: weight, torque, price and programmability.

Comparison Table

Parameters	NEMA 17	NEMA 8	MG90S	MG996R
Type	Stepper Motor	Stepper Motor	Servo Motor	Servo Motor
RPM	200-600	200-600	470	60
Weight	280-400g	80-150g	13.4g	55g
Size	42x42x34mm	20x20x25-40mm	22.8x12.2x31mm	40.7x19.7x42.9mm
Torque	0.28-0.5 Nm	0.03-0.035Nm	0.22Nm	1.0Nm
Price	$15-$30	$10-$25	$4-$8	$7-$15
Driver	Yes	Yes	N/A	N/A

*We picked this motor as it met our required weight of less than 50g, it is compact and is also in the lower price range.

Power Supply Comparison

To accomplish our design goals, we took in consideration factors such as: Power capabilities, safety and voltage stability.

Power Distribution Table

Components	Voltage (v)	Current (A)	Power (W)
3X MG90S servo motor	5	0.8 each	3.6 (1.2A x 3)
HC-SR04	5	0.015	0.075
TCS3200	3.3	0.002	0.0066
ESP32-WROOM-32D	3.3	0.240	0.792
TOTAL			4.3 W

- 5V Power: 3.6W (motors) + 0.075W (HC-SR04)= 3.675W
- 3.3V Power: 0.0066W (TCS3200) + 0.792W (ESP32)= 0.7986W

Comparison Table

Parameters	NiCd	NiMH	Li-ion	LiPo
Voltage	1.2V per cell	1.2V per cell	3.6-3.7 V	3.7 V
Life cycle	Moderate (500-1,000)	Moderate (300-500)	Long (5000-2,000)	Moderate (300-500)
Memory Effect	Yes	Minimal	None	None
Environmental Impact	Toxic Materials	Less Toxic	More eco-friendly	Requires disposal
Applications	Power tools, RC toys	Consumer electronics	Smartphones, EVs	Drones, portable devices
Cost	Generally lower	Moderate	Moderate to high	Moderate to high
Charging Time (depending on capacity)	1-2 hours	1-4 hours	1-3 hours	1-3 hours
Durability	High (can withstand many cycles)	Moderate (wears over time)	Moderate to high	Moderate (depends on handling)

*Picked a Li-Ion as it had good durability, long life cycle and met our power requirements.

Battery Selection

Parameters	12V/6Ah Rechargeable Li-ion battery pack	12V/6.5Ah Rechargeable Li-ion battery pack	12V/9Ah Rechargeable Li-ion battery pack
Brand	Talentcell	Raphtor	Talentcell
Voltage	12V	12V	12V
Current	6Ah	6.5Ah	9Ah
Price	$32.99	$34.99	$47.99
Weight	380g	362g	500g

*We picked this battery because it meet our power needs and was the less expensive option.

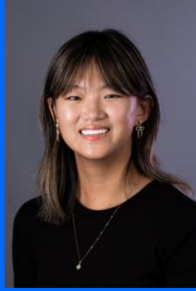
Regulators

Parameters	LD1117	MCP1700	AMS1117	MIC293000
Vin	4.5 – 15V	2.3 – 6V	4.5 – 15V	Up to 26V
Vout	1.25-13.8V Adjustable	Fixed Value. Typically: 3.3V	Fixed and Adjustable. Max: 5V	Fixed and Adjustable
Max Output Current	800mA	250mA	1A	3A
Type	LDO (Low-dropout)	LDO	LDO	LDO
Thermal Protection	Yes	No	Yes	Yes
Noise	Moderate	Low	Moderate	Moderate

*We picked the AMS1117 to regulate power to 3.3V as it provided enough current to power our peripherals.

Parameters	LM5161	LMR33630	LM2596
Vin	4.5V- 100V	5V-36V	4.5V-40V
Vout	Adjustable 1.225V-15V	3.3V or 5V	Adjustable: 1.25V-15V
Output Current	1A	3A	3A
Efficiency	<95%	<90%	<90%
Type	Wide Input Buck Regulator	DC-DC Converter	Step-down Regulator
Manufacturer	Texas Instrument	Texas Instrument	Texas Instrument
Price	$5-$10	$5	<$5

*We picked the LM2596 for meeting our current requirements and simple design.



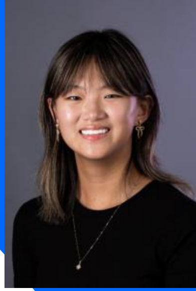
Logic Devices Comparison

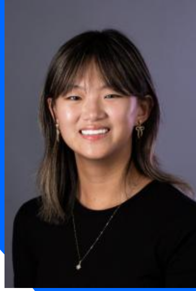
To achieve our goal specifications, we needed a logic device that was budget friendly and looked specifically at hitting our requirements in processing power, camera interface, number of I/O ports, memory size, and power consumption.

MCU vs. FPGA

Criteria Factors	MCU	FPGA
More budget friendly option	✓	
Lower power consumption	✓	
Higher real-time performance		✓
Uses high-level programming languages	✓	
Suitable for simple control tasks	✓	✓
Suitable for complex tasks		✓
Fast development time	✓	
Suitable for parallel processing		✓
Flexible and/or custom hardware design		✓
Real-time performance		✓
Peripheral add-on capabilities	✓	

*Selected based on ability to be programmed with high-level programming languages.





Comparison of MCUs for CMOS sensor

Features	Raspberry Pi 4	ESP32-S3	Seeeduino Lotus	Raspberry Pi 5	Raspberry Pi Pico
Processor	Quad-core Cortex-A72 64-bit SoC, up to 1.5GHz and VideoCore VI	Dual-core Xtensa LX7, up to 240 MHz	ATmega328P, 8-bit AVR running at 16 MHz	Quad-core Cortex-A76 64-bit SoC, up to 2.4 GHz and VideoCore VII	Dual-core Arm Cortex-M0+ processor, up to 133 MHz
Memory	Option of 2GB, 4GB, 8GB LPDDR4-3200 SDRAM	512KB SRAM, 384KB ROM, 16MB of flash	32KB flash, 2KB SRAM, 1KB EEPROM	4GB and 8GB LPDDR4X	264kB on-chip SRAM, 2 MB flash, external memory support
Connectivity	2 USB 3.0 ports, 2 USB 2.0 ports, 1 micro-HDMI ports, 2.5mm audio jack and HDMI audio	USB 1.1 with OTG, SPI/I2C/I2S/UART/CAN interface support, camera interface support	Micro USBs, support UART, I2C, and SPI	2 USB 3.0 ports, 2 USB 2.0 ports, 1 micro-HDMI ports, 2.5mm audio jack and HDMI audio	USB 1.1 micro-USB, 26 multi-function GPIO pins, 3 analog inputs, support I2C, SPI, and UART

*Selected based on processing power requirements

Comparison of our Main MCU

Features	ESP32-WROOM-32D	ESP32-WROOM-32E	STM32
Processor	Dual-core Xtensa LX6 (240 MHz)	Dual-core Xtensa LX6 (240MHz)	ARM Cortex-M (M0/M3/M4)
Memory	520KB SRAM, 4MB flash	520KB SRAM, 4-16MB flash	64KB to 512KB SRAM, Flash 128KB to 2MB
Wireless	Wi-Fi, Bluetooth	Wi-Fi, Bluetooth	External Wi-Fi module needed
GPIO Pins	34	34	37 to 100+
Power Consumption	240mA (Wi-Fi active)	240mA (Wi-Fi active)	60mA
Operating Voltage	2.7V-3.6V	2.7V-3.6V	1.8V-3.6V
Cost	$4-$6	$4.50-$7	$2-$15
Complexity	Moderate	Moderate	High

*We picked the **ESP32-WROOM-32D** as it offers good performance, cost, and ease of use.

Camera Sensor Comparison

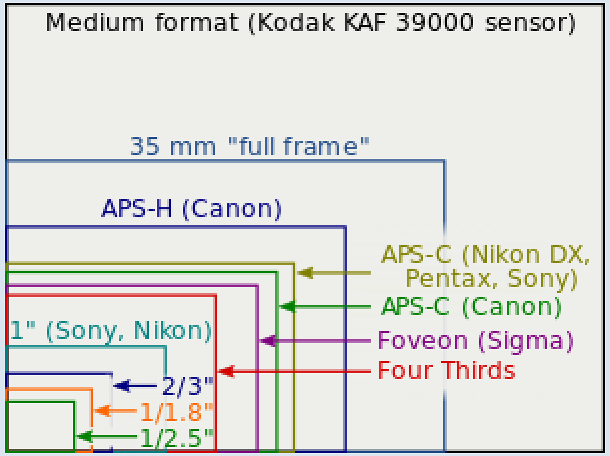
- One half of the color detection system requires processing live feed from a video camera
- Determines the focusing power required for the primary lens system

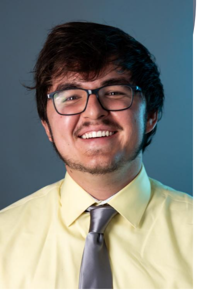
CMOS vs CCD

- CMOS
  - Smaller power consumption
  - Faster processing
  - Greater miniaturization
  - Lower signal-to-noise (SNR) ratio
- CCD
  - More expensive
  - Higher image quality

Camera Considerations

- Resolution
- Image format
    - The crop factor determines how large our image will be
- FOV
    - As similar to the FOV of the human eye is desirable
- Focal Length





Camera Sensor Selection

- Despite its lower resolution, we have moved forward with the Camera Module v2
    - Lowest price
    - No autofocus
    - Similar FOV to human eye

	Camera Module v2	Camera Module 3 Wide	HQ Camera	GS Camera	BETAFPV C02
Net Price	$25	$35	$75	$75	Free (Already owned)
Size	25 x 24 x 9 mm	25 x 24 x 12.4 mm	38 x 38 x 18.4 mm	38 x 38 x 19.8 mm	13 x 11 x 8 mm
Weight	3g	4g	30.4g	34g	1.4g
Still Resolution	8 MP	11.9 MP	12.3 MP	3 MP	1200 TVL
Video Modes	1080p47, 1640 × 1232p41 and 640 × 480p206	2304 × 1296p56, 2304 × 1296p30 HDR, 1536 × 864p120	2028 × 1080p50, 2028 × 1520p40 and 1332 × 990p120	1456 × 1088p60	N/A
Sensor	Sony IMX219	Sony IMX708	Sony IMX477	Sony IMX296	N/A
Sensor Image Area	4.6 mm diagonal	7.4 mm diagonal	7.9 mm diagonal	6.3 mm diagonal	2 mm diagonal
Pixel Size	1.12 µm × 1.12 µm	1.4 µm × 1.4 µm	1.55 µm × 1.55 µm	3.45 µm × 3.45 µm	N/A
Image Format	1/4”	1/2.43”	1/2.3”	1/2.9”	1/4”
FOV	62.2°	102°	71°	56°	160°
Focal Length	3.04 mm	2.75 mm	7.53 mm	7.53 mm	2.1 mm

Colorimeter Comparison

- A secondary color detection system to verify the results of the CMOS

TCS3200

- Less compact
- Higher accuracy

TCS34725FN

- Shorter range
- Smaller light collection area

Audio Delivery Method Comparison

- Determining whether we desire Bluetooth or auxiliary connections
- Examining the merits of both

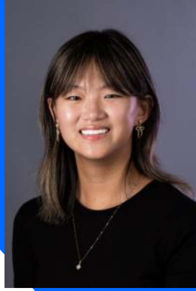
Bluetooth vs Auxiliary

	Bluetooth	Auxiliary
Connection Type	Wireless	Wired
Sound Quality	< 990 kbit/s	< 1,411 kbit/s
Range	< 33 ft	Length of Wire

- Bluetooth was chosen as it would reduce the wiring surrounding the headset

Comparison and Selection

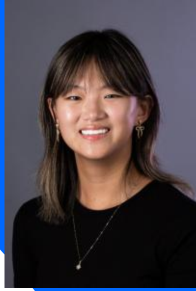
Software



Programming Language Comparison

Features	Python	C++	Java	C	Assembly Language
Abstraction Level	High	Medium	High	Low	Very Low
Performance	Moderate, interpreted slower for real-time applications	High, compiled, allows direct memory management	Moderate, JVM-based, slower than C/C++ for embedded uses	High, compiled, very efficient for embedded systems	Very high, directly mapped to hardware instructions
Ease of Use	Very easy	Moderate	Moderate	Moderate	Difficult
Memory Management	Automatic garbage collection	Manual Control	Automatic garbage collection	Manual Control	Direct control
Real-Time Capabilities	Low, lacks real-time processing	High, supports real-time and deterministic applications	Low, not ideal due to JVM overhead	High	Very High
Hardware Access	Limited	Good	Limited	Very Good	Excellent
Error Handling	High-level exceptions and try-except blocks	Strong exception handling, low -level debugging issues are complex	High-level exception handling	Limited to basic error codes	Minimal, no built-in error handling

*Selected based on ease of development and comfortability level with OpenCV.



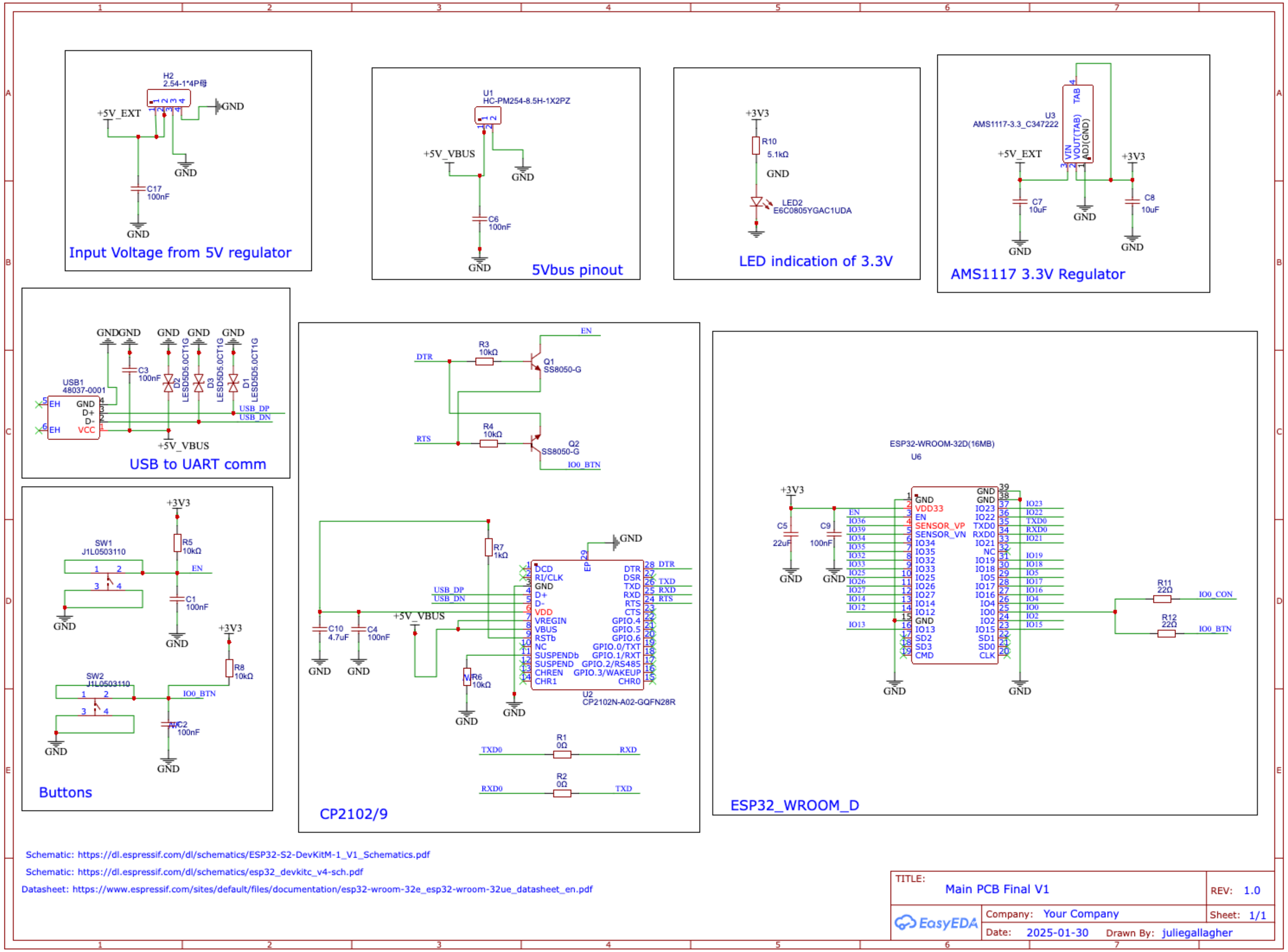
Integrated Development Environment

Features	Visual Studio Code	Thonny IDE	JetBrains PyCharm/ CLion	Jupyter Notebook	MATLAB
Primary Use	General code editor with large language support	Beginner Python IDE	Python or C/ C++ development	Data science, interactive computing	Numerical computing, simulation, and algorithm development
Supported Languages	Most languages (Python, C/ C++, Java, etc.)	Python	Python or C/ C++	Python and others via extensions	MATLAB
Ease-of-use	Medium – requires setup for extensions	High – intuitive user interface made for beginners	Medium – some advanced features that have high learning curve	High – data analysis Medium – general programming	Medium – needs familiarity with MATLAB syntax
Hardware support	Yes, with extensions	Limited, only Python libraries	PyCharm: limited, CLion: Strong support	Limited	Strong hardware toolboxes
Debugging Tools	Advanced debugging	Basic Python debugging	Advanced debugging	Limited	Integrated debugger and simulation tools
Visualization	Moderate	Minimal	Moderate	Excellent	Excellent
Cost	Free	Free	Paid	Free	Paid

*Selected for its ability to add on multiple programming extensions.

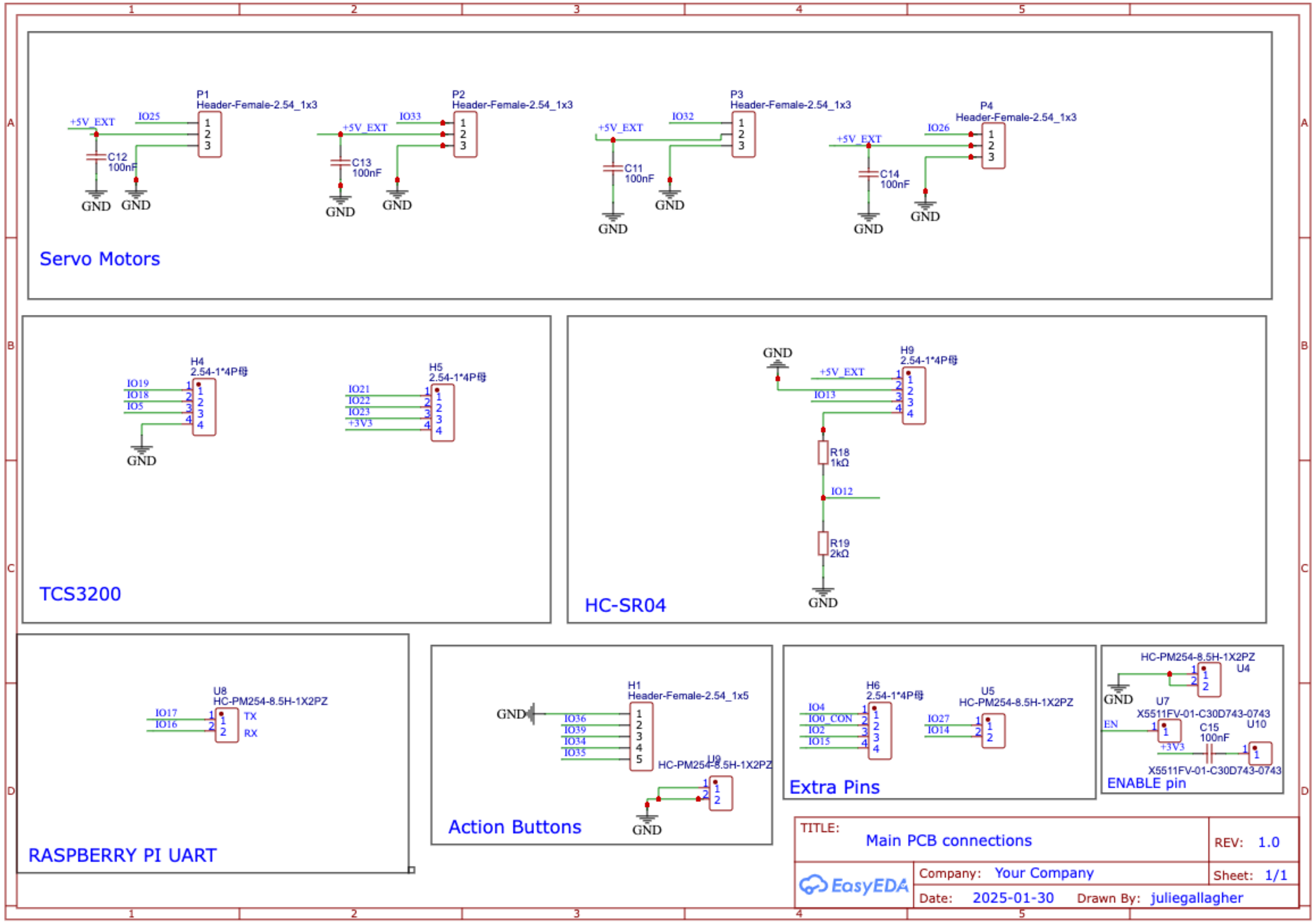
PCB Design

Schematic (1/2)



- **Main PCB (½):**
  - MCU: ESP32-WROOM-32D
  - CP2102 chip
  - USB A connection
  - Two push down button
  - AMS1117 3.3V Linear Regulator
  - Connection for 5V regulator

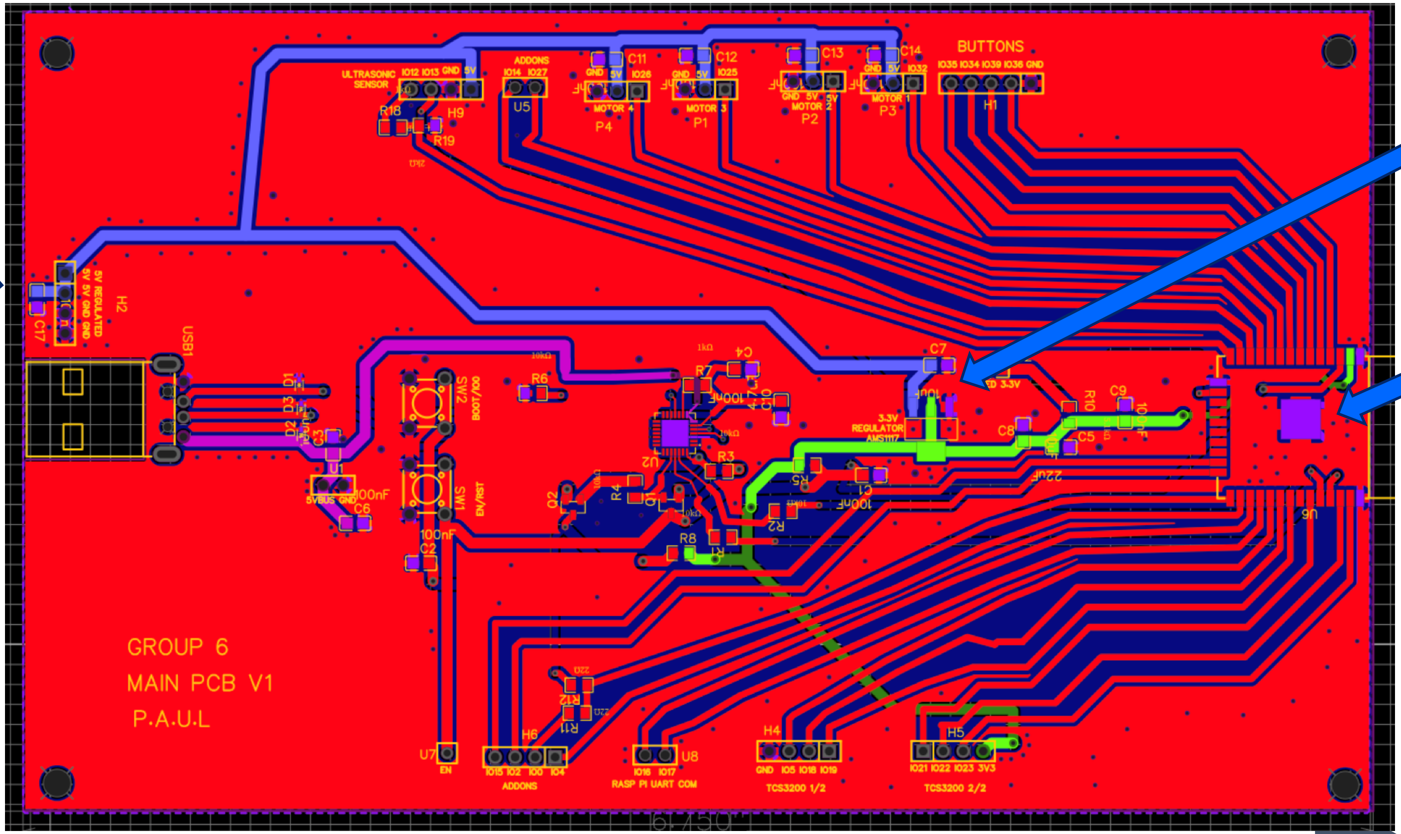
Schematic (2/2)



- **Main PCB (2/2)**
  - Connection Pins for:
    - TCS3200
    - HC-SR04
    - Raspberry Pi UART
    - 3 MG90S servo Motors
    - Action Buttons

PCB Layout

- Main PCB: ESP32, AMS1117 (3.3V regulator)

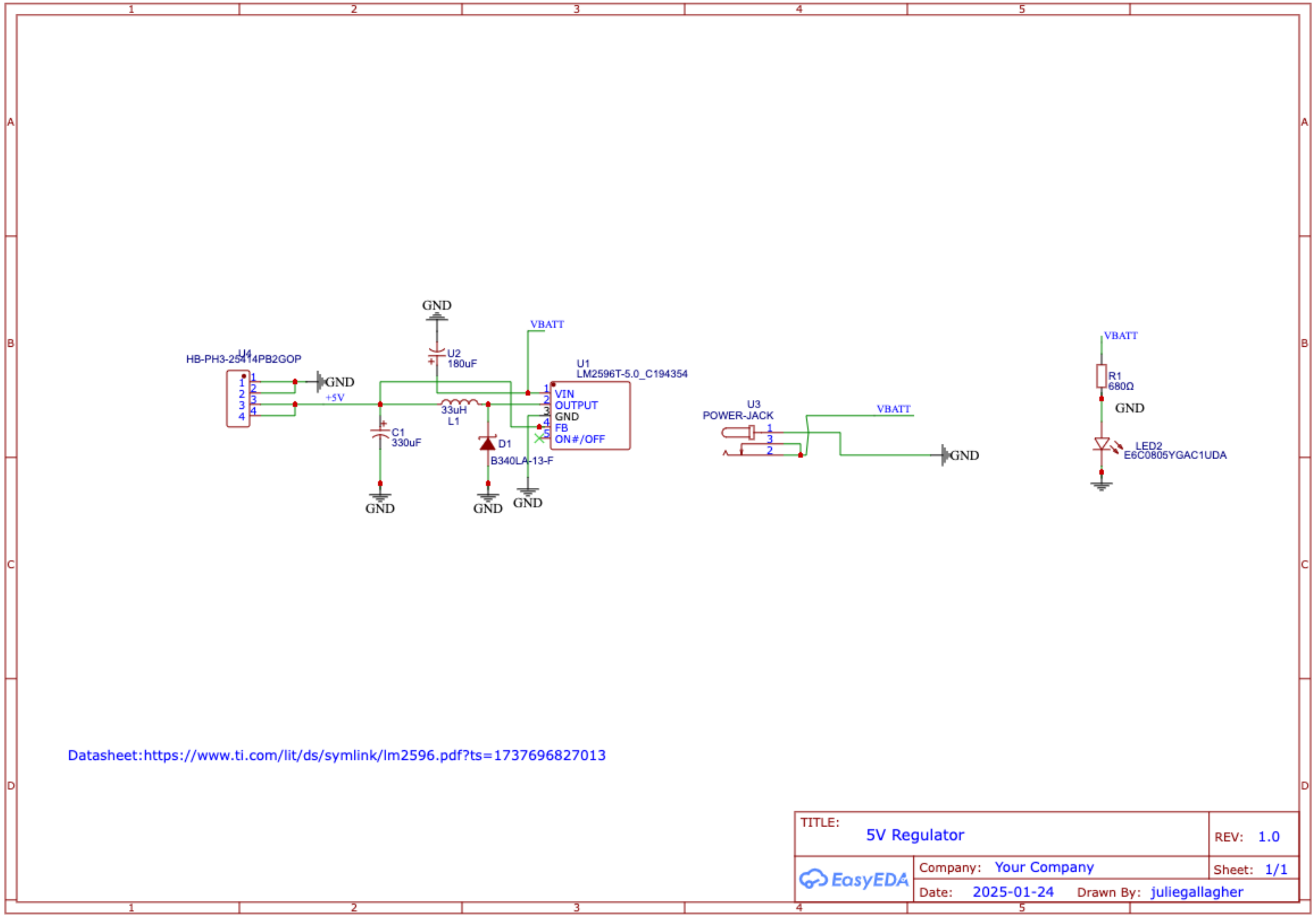


5V regulator Connection Pins

3V Regulator

ESP32 Module

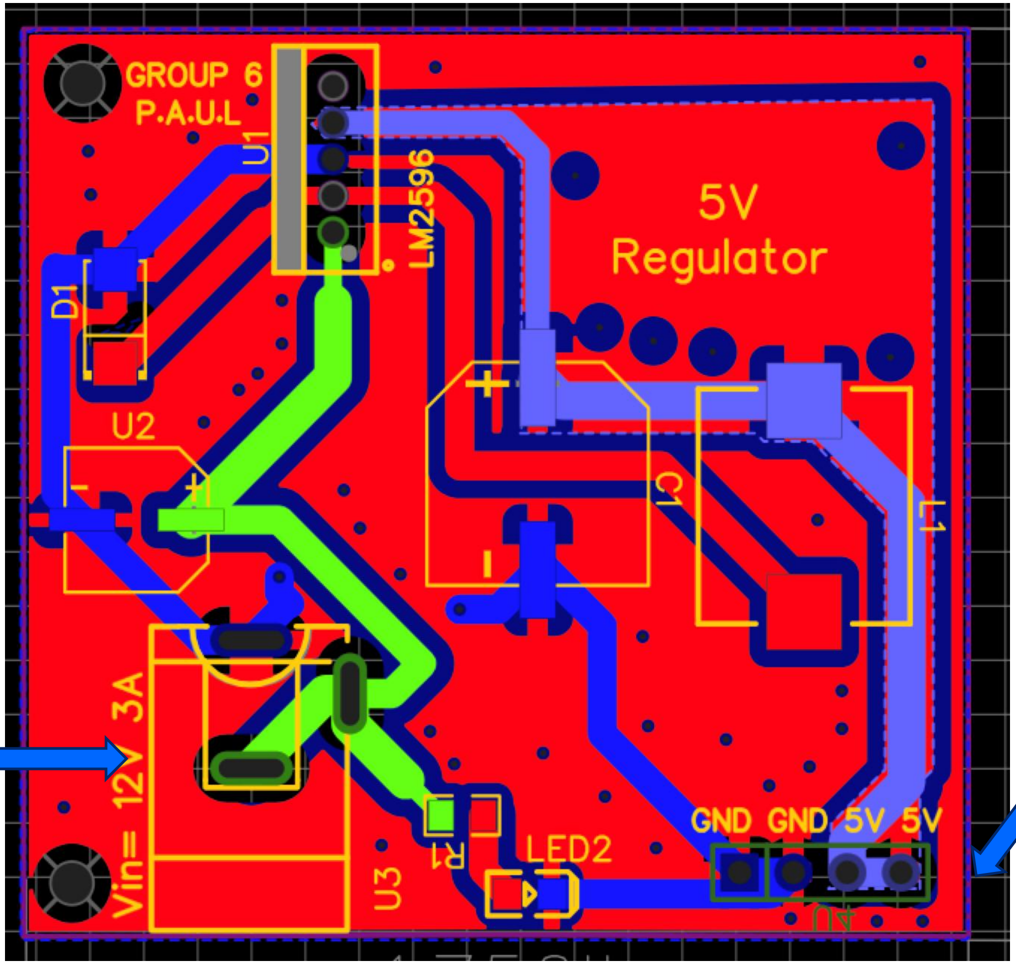
Schematic



- **5V Regulator**
  - **LM2596** step down Regulator
  - Jack connection (Battery input)

PCB Layout

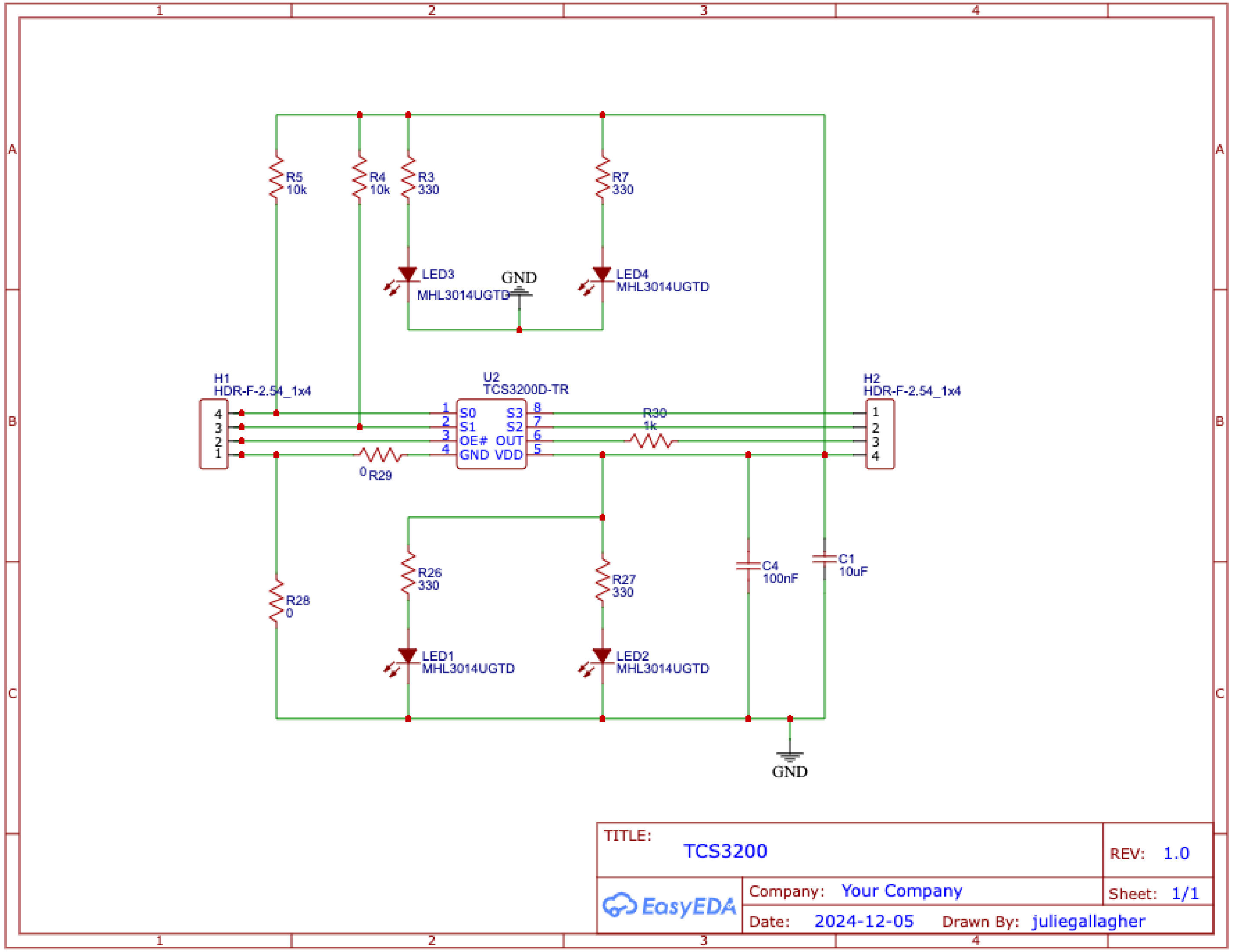
- 5V Regulator- LM2596



Jack Connection for input voltage

Output Voltage 4-PIN header

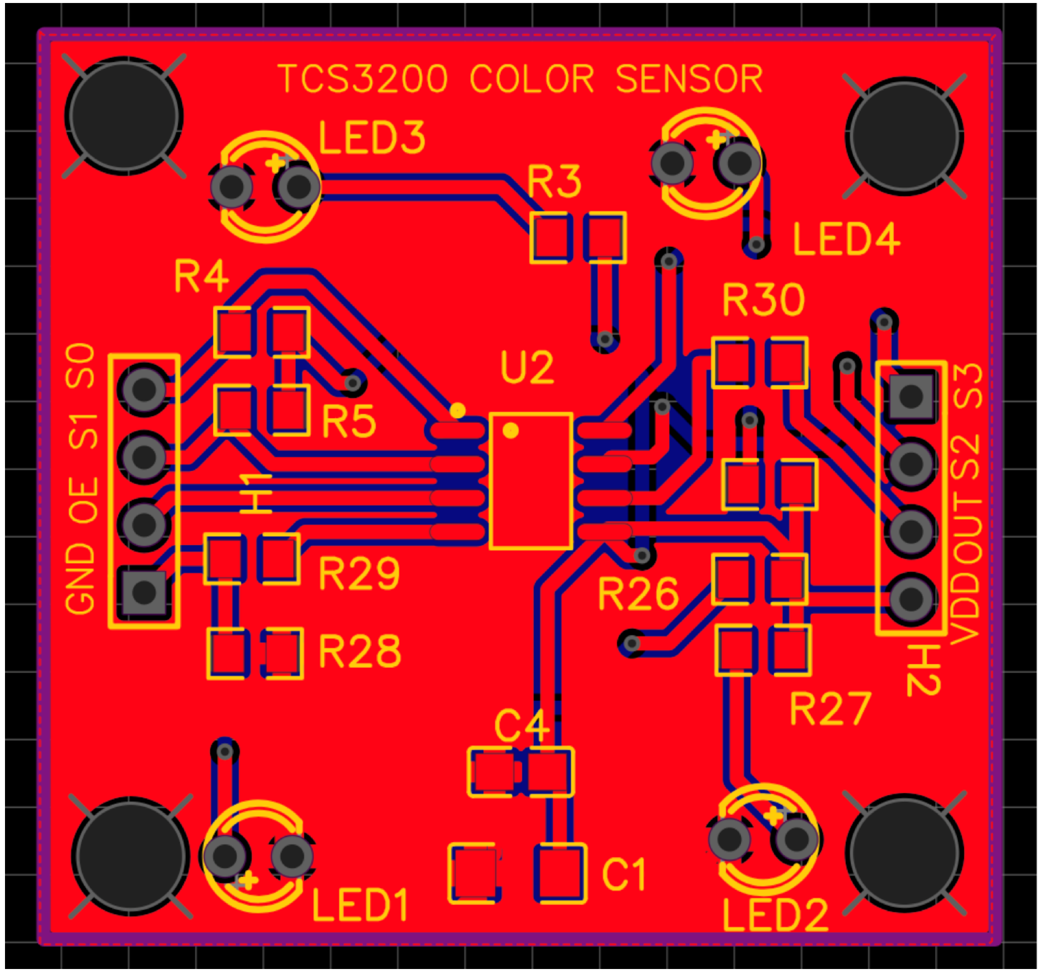
Schematic



- **TCS3200**- Color Detector PCB
- Two 4-pin connection to the ESP32

PCB Layout

- Color Detector Board: TCS3200

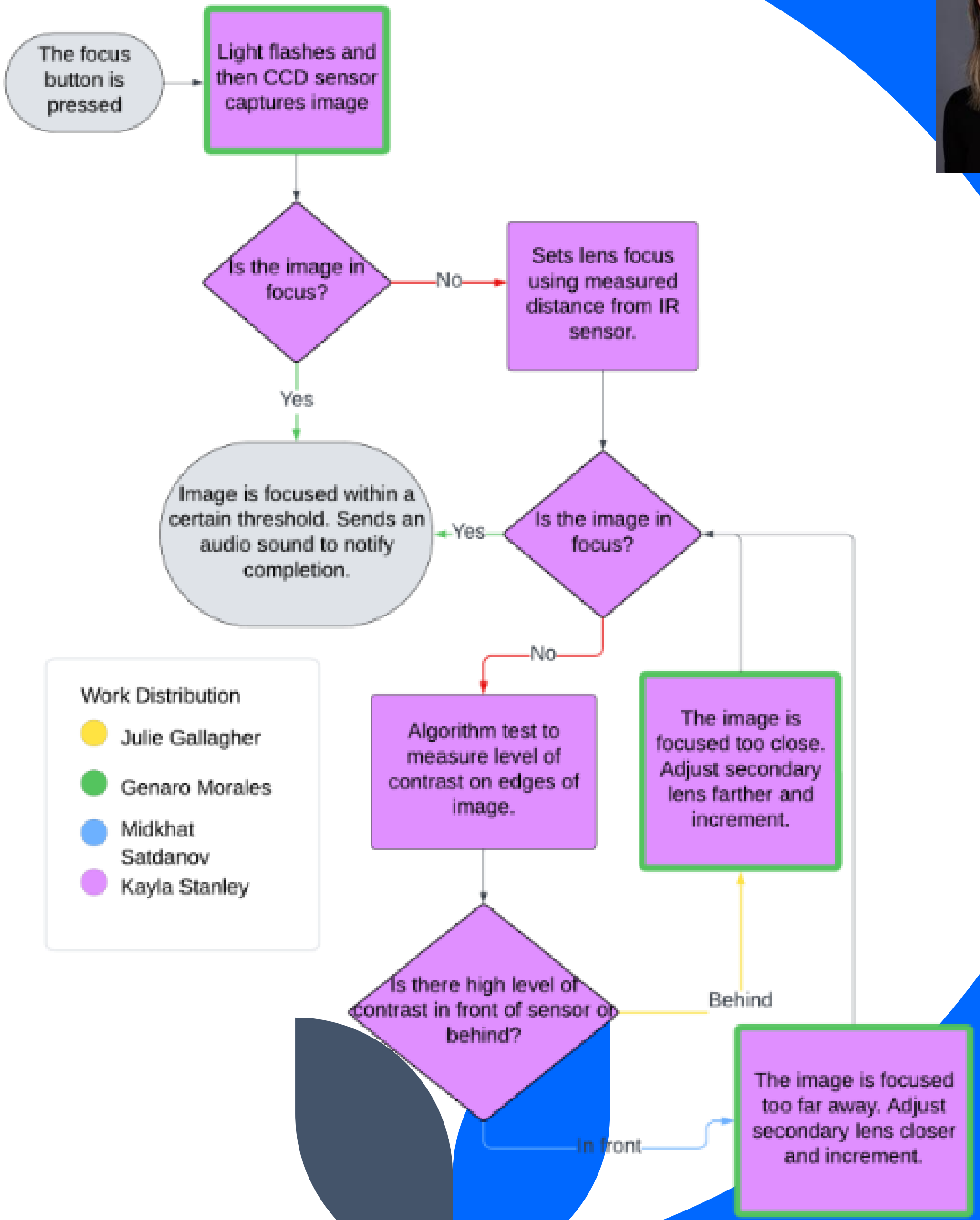


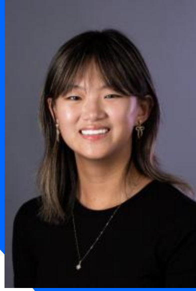
Software Design

Software Flowchart(1)

1. Edge-detection Algorithm

Determine if the image is in focus and if it's not, determine if the image needs to be adjusted to focus further away or closer.

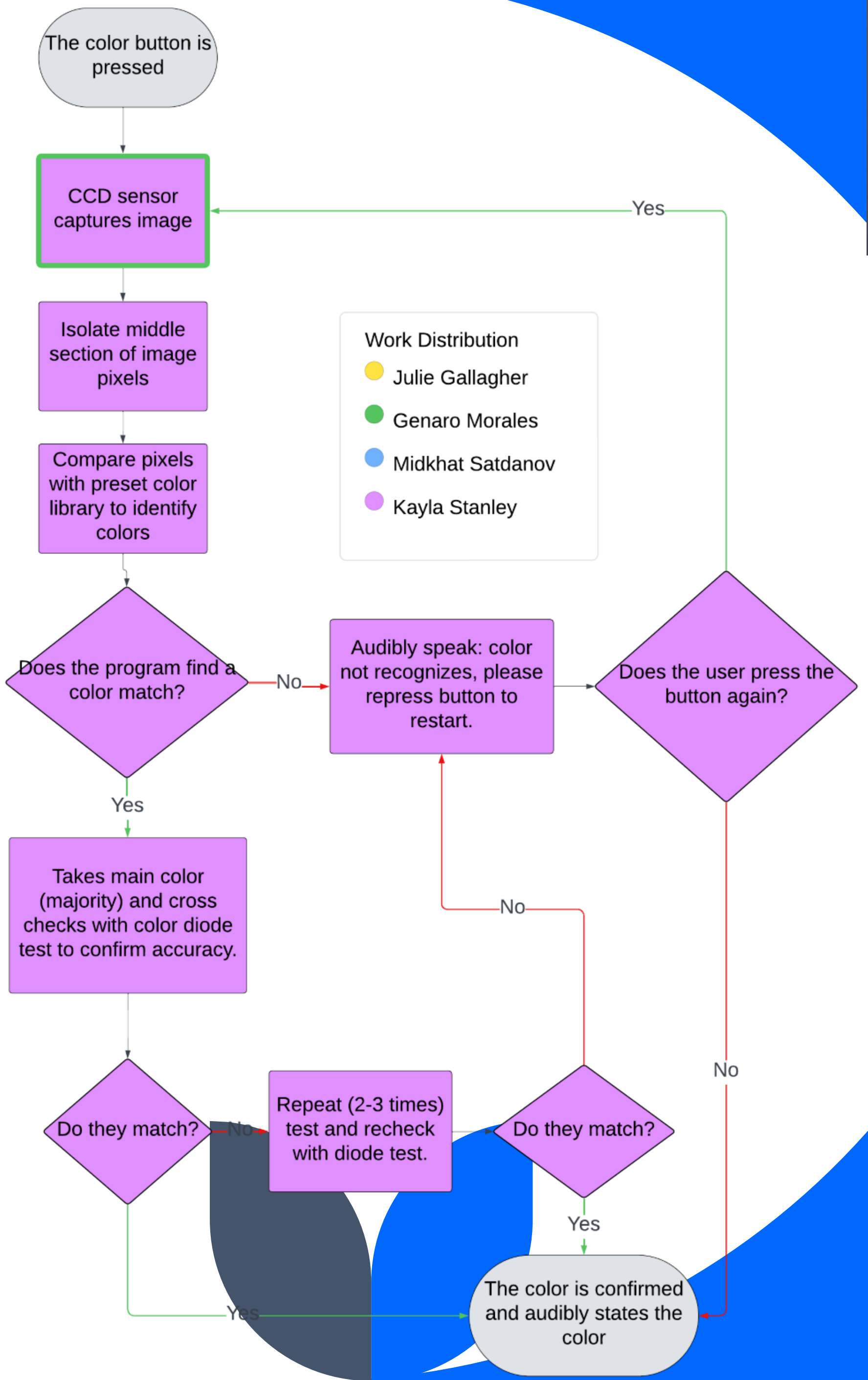


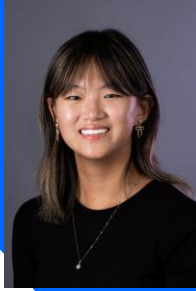


Software Flowchart(2)

2. Color Analyzing Algorithm

Run image processing and compare with preset color library to accurately identify the colors within the picture taken by the CMOS sensor.



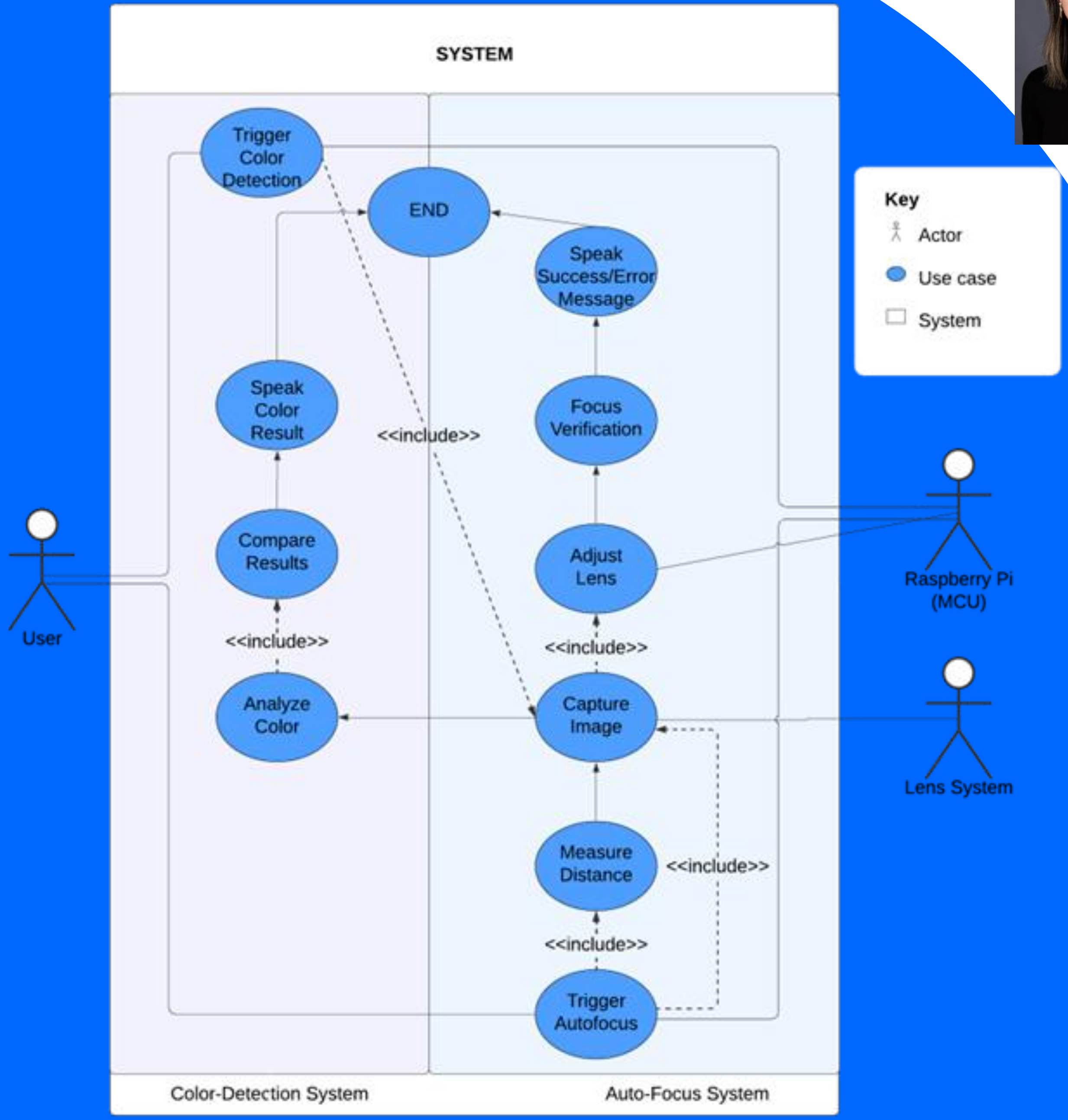


Use Case Diagram

This UML diagram is focused on the how the system interacts with the internal and external parts.

The main goal of the diagram is to define the scope of the system by highlighting its interactions and giving the basic plan for system design.

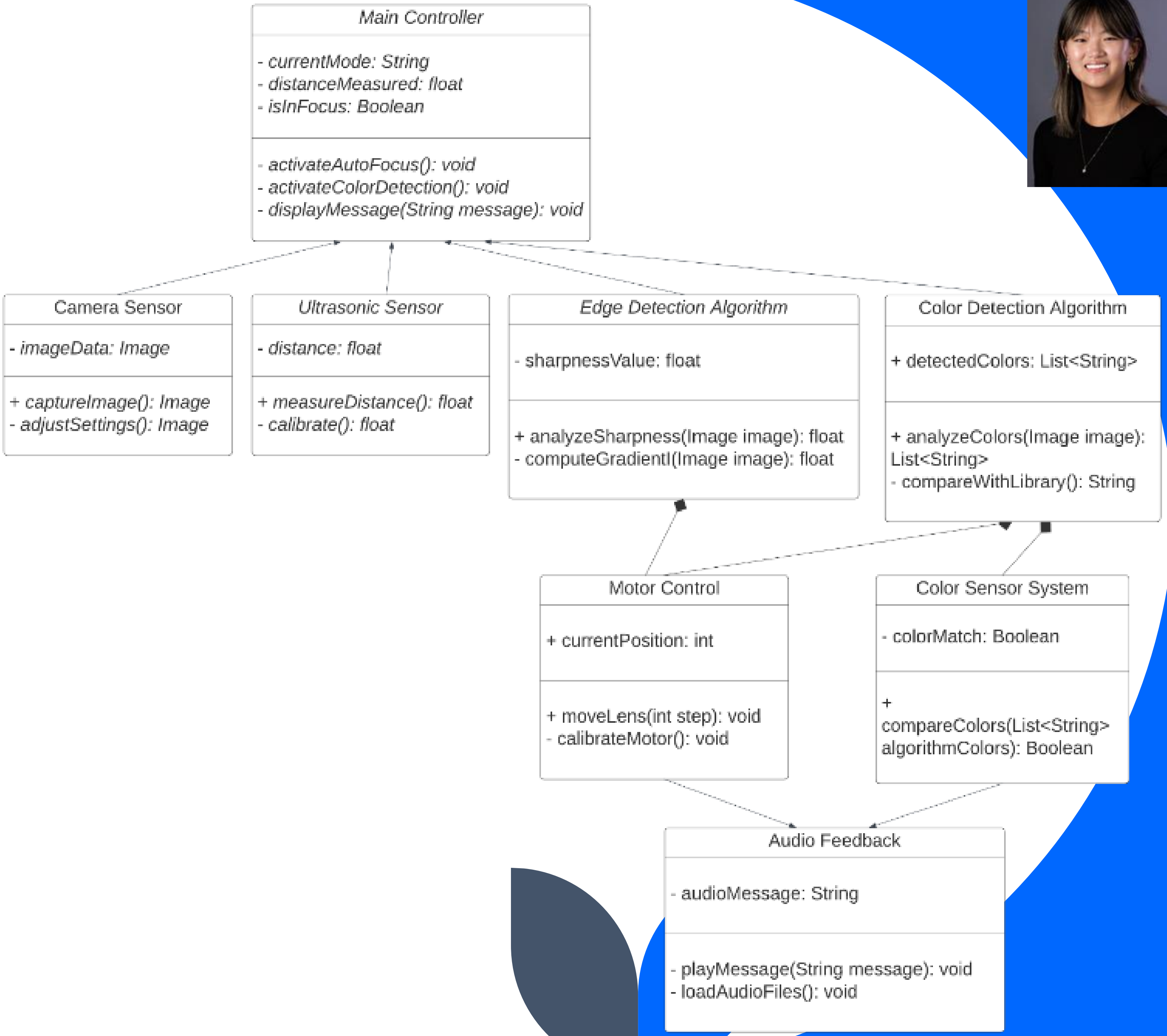
For this project, we have 3 main "Actors". These being the user, the Raspberry Pi, and the lens setup.



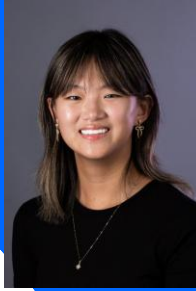
Class Diagram

The class diagram is the UML model used to show the structure of a program by splitting up all the classes and how they interact.

The main classes included for our project are the camera sensor, ultrasonic sensor, edge-detection algorithm, color detection algorithm, motor control, color sensor system, and audio feedback.



Hardware Testing



Ultrasonic Sensor

10 mm	1 in	1 ft	1 m	2 m	5 m	10 m
9 mm	0.95 in	11.8 in	1.02 m	1.95 m	4.9 m	9.8 m

Setup

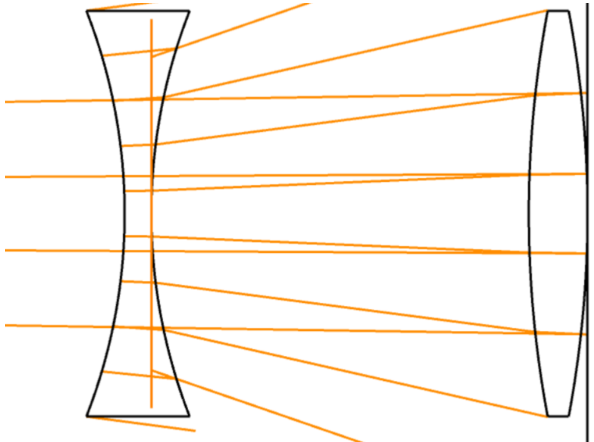
- Utilized pre-set code from junior design to test the accuracy of distance measurement on the ultrasonic sensor.
- Code uploaded from MSP board and breadboard to power and connect to a LED display.
- Tested at various distances to determine accuracy

Results

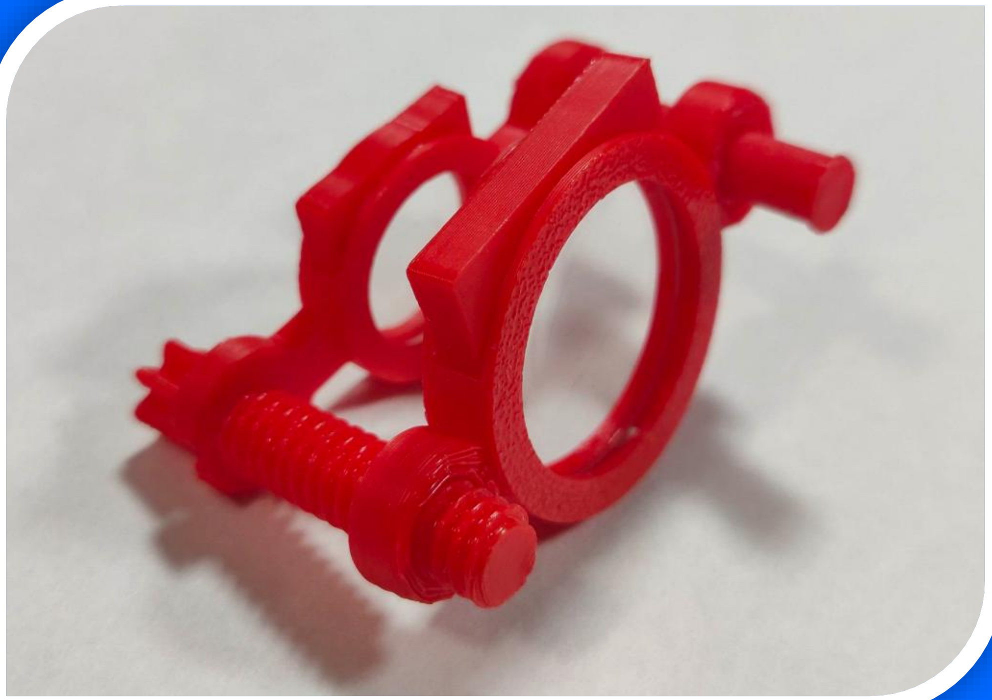
- In terms of measurement, it works fairly accurate up to about a couple meters and as close as 1mm.
- Not the most accurate but for adequate enough for our project given we only need a rough estimate within our budget

Focusing System Testing

	Surface Type		Comment	Radius		Thickness	Material
0	OBJECT	Standard	Object	Infinity		Infinity	
1	STOP (aper)	Standard	Lens1F	-52.100		2.500	N-BK7
2	(aper)	Standard	Lens1B	52.100	P	0.000	
3		Standard	~37.5	Infinity		35.352 V	
4	(aper)	Standard	Lens2F	103.0...		5.500	N-BK7
5	(aper)	Standard	Lens2B	-103....	P	0.000	
6		Standard	Space	Infinity		-1006...	
7	IMAGE	Standard	Image	Infinity		-	

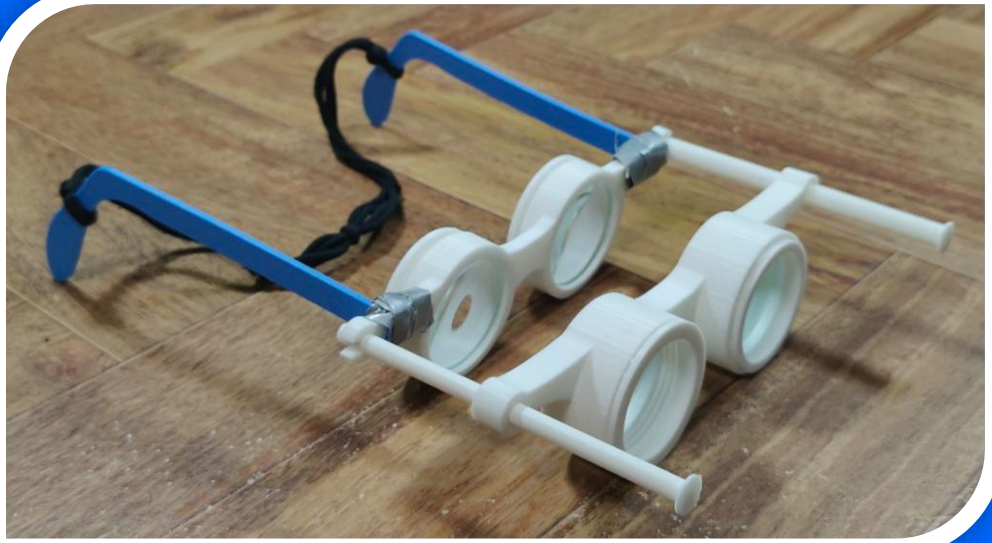


Focusing System Initial Test



- Setup
  - Align a positive and a negative lens in an adjustable frame with variable lens separation
  - Adjust lens separation such that an object at a far distance (infinity) produces an image in focus at various focal lengths
- Lens Specifications
  - Diverging Lens: -69 mm focal length
  - Converging Lens: 78 mm focal length
- Expectations:
  - Optical Power Range: -1.5 D to 2.5 D
  - Effective Focal Length: -667 mm to 400 mm
- Observations:
  - Optical Power Range:
    - Approximately -0.5 D to 3.5 D
  - Effective Focal Length:
    - Approximately -2000 mm to 286 mm
- Conclusions:
  - Demonstrates functionality, but requires refinement to account for deviations from calculations

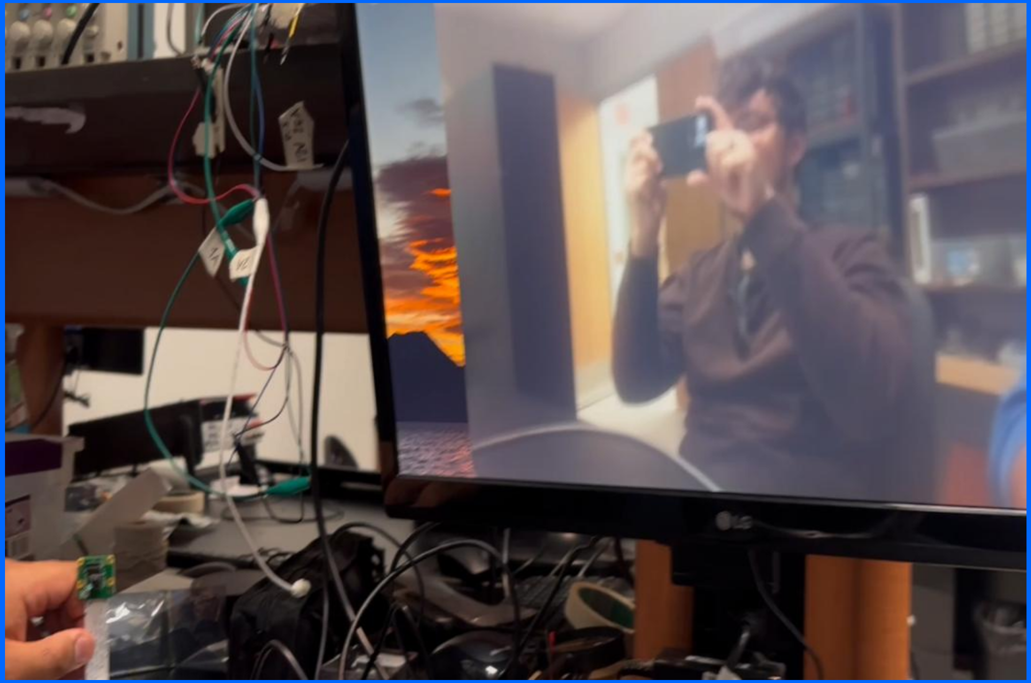
Focusing System Version 2 Test



- Setup
  - Align a positive and a negative lens in an adjustable frame with variable lens separation
  - Adjust lens separation such that an object at a far distance (infinity) produces an image in focus at various focal lengths
- Lens Specifications
  - Diverging Lenses: -50 mm focal length
  - Converging Lenses: 100 mm focal length
- Expectations:
  - Optical Power Range: -10 D to 10 D
  - Effective Focal Length: -100 mm to 100 mm
- Observations:
  - Optical Power Range:
    - Approximately -5 D to 13 D
  - Effective Focal Length:
    - Approximately -250 mm to 83 mm
- Conclusions:
    - Surpasses our requirements
    - Continues to demonstrate functionality
    - Deviates from calculations

Software Testing

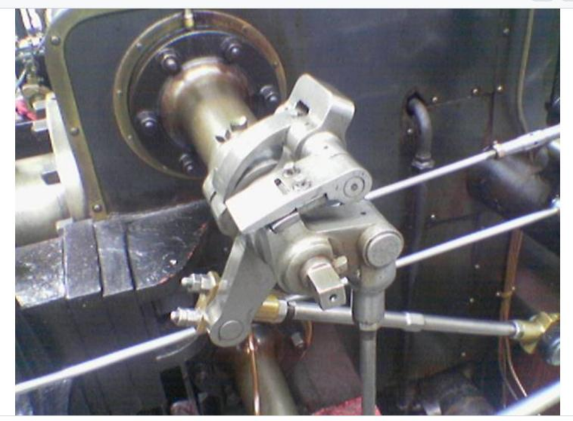
Raspberry Pi Camera Module

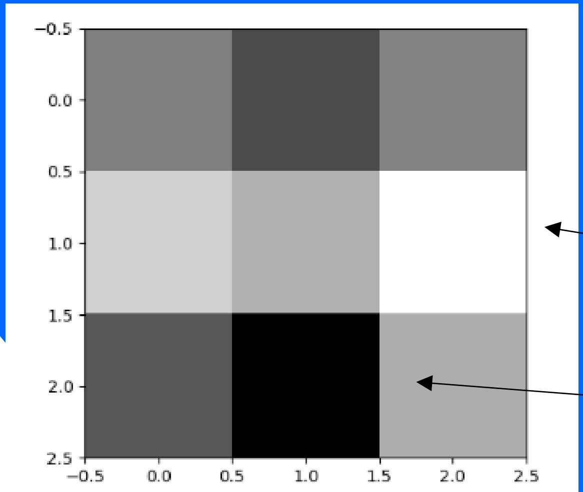


- Setup
  - We connected the Camera Module v2 to the RaspberryPi via the CAMERA port
  - Then enabled camera functionality in the command window using: `pi@raspberry:`

    `~ $ sudo raspi-config`
- Testing
  - To take photos we imported the picamera module and created test images as shown

Edge-detection





Setup

- Recycled GitHub code implementing a Sobel Filter
- Measures the contrast of an image and identify which sides of the pixels were the edge
- The top photo is the image inputted and the bottom image is the 3x3 matrix output
- The darker the output box, the more in focus it can be determined to be.

Results

- Raspberry Pi 4 runs the code with no time issues
- Given the iterations necessary, there might be issues with runtime given this method
- Other methods such as High-pass filtering or Fourier transform might be more time efficient

This would be the least in focus given the lightest shade.

The darker the box, the more the contrast. This would also be an indicator of it being more in focus.

Difficulties & Problems Table

Problems/ Difficulties	Proposed Solution
Latency between inputting the command to take a photo and receiving the photo itself from the CMOS code.	Optimized loop statements to improve this latency.
The Raspberry Pi 4 development Board utilizes a wall plug limiting mobility.	Acquire a lightweight, portable power supply
Large/heavy components such as motors restricted movement and reduces comfort	Testing smaller and lighter alternatives until a suitable compromise is found
Initial focusing system lenses required large distances between the lenses resulting in a very large lens system	Tested various alternative lenses until a more reliable and reasonably sized system was developed

Budget

Component	Name	Price	Quantity	Total Price
CMOS Sensor	Raspberry Pi Camera Module v2	$13	1	$13
Primary Lenses	Eisco Biconvex Lens (+ 100 mm Focal Length)	$12	3	$36
Secondary Lenses	Eisco Biconcave Lens (– 50 mm Focal Length)	$14	3	$42
Railing	Linear Rail Guide Linear Sliding Guideway with 1pcs Linear Bearing Sliding Block	$12.80	2	$25.60
Buttons	Adafruit mini	$0.50	5	$2.50
Frame	3D Printed	-	1	N/A
Motor	MG996R- Servo Motor [4-Pack]	$16.99	1	$16.99
Colorimeter	TCS3200	$20	1	$20
Raspberry Pi 4	Raspberry Pi 4 4GB Starter PRO Kit – 4GB RAM	$139.99	1	$139.99
PCBs	ESP32-WROOM-32D, 5V Regulator, TCS3200	$70	3	$70
PCB components	SMT,SMD, LEDS, etc.	$45	N/A	$45
Power Supply	Talentcell Rechargeable 12V 6000mAh/5V 12000mAh DC Output Lithium ion Battery Pack	$32.99	1	$32.99
3D-Printer Filament	Elegoo PETG	$14.99	2	$29.98
Total Cost				~$474.05

Work Distribution

	Task	Primary Responsibility	Secondary Responsibility
Auto-Focusing Feature	Set up a lens system for variable optical powers	Genaro Morales	Midkhat Satdanov
	Set up a secondary lens system for the CMOS sensor	Genaro Morales	Midkhat Satdanov
	Adjustable movement between lenses	Genaro Morales	Julie Gallagher
	Programming to detect focus and adjust lens separation as necessary	Kayla Stanley	Genaro Morales
Color Identification Feature	Setup up colorimeter to accurately detect colors	Midkhat Satdanov	Julie Gallagher
	Design lens system to improve color detection	Midkhat Satdanov	Genaro Morales
	Correlate colors detected by CMOS and colorimeter to accurately identify the color present	Kayla Stanley	Midkhat Satdanov
Software	Set up Raspberry Pi to communicate with hardware	Kayla Stanley	Julie Gallagher
	Program buttons to initiate appropriate features	Kayla Stanley	Everyone
	Program audio response system to give appropriate responses	Kayla Stanley	Everyone
Hardware	Design a PCB for our system	Julie Gallagher	Kayla Stanley
	Design an appropriate power supply system	Julie Gallagher	Kayla Stanley
	Ensure interconnectivity of components	Julie Gallagher	Kayla Stanley
	Design frames for multiple systems	Genaro Morales	Everyone

Progress and Plan

Senior Design 2	
Week	Goal
1	Regroup and begin purchasing of any remaining components
2 – 3	Complete PCB design, then place order Continue testing components and order any components that are being replaced
4 – 6	Critical Design Review Design and 3D print housing and structural design Assemble auto-focusing system (test and adjust as necessary)
6 – 9	Assemble color-identification system (Test and adjust as necessary) Assemble full prototype (Test and adjust as necessary) Midterm Demo
11 – 12	Finalize prototype
13	Senior Design Showcase Video Submission
14	Final Demo Senior Design Showcase
15	Submit Final Report

Thank you

Team P.A.U.L.* appreciates your attention

*Not to be confused with Paul Weiner. Group 6's views are not representative of Paul Weiner's views