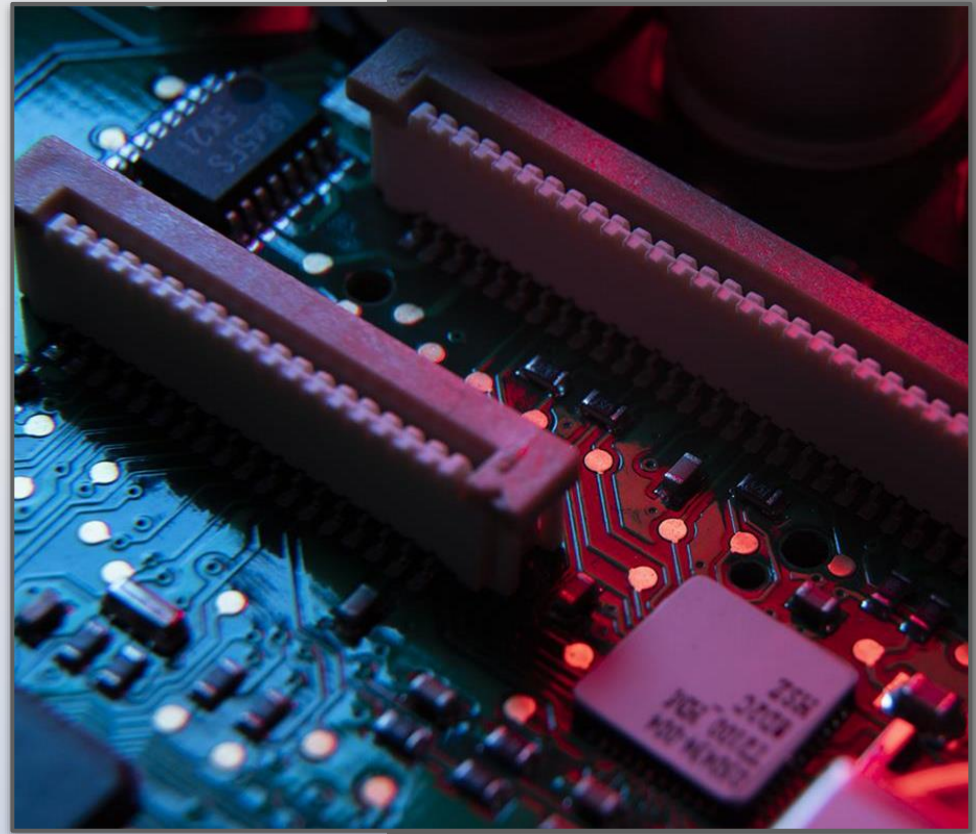
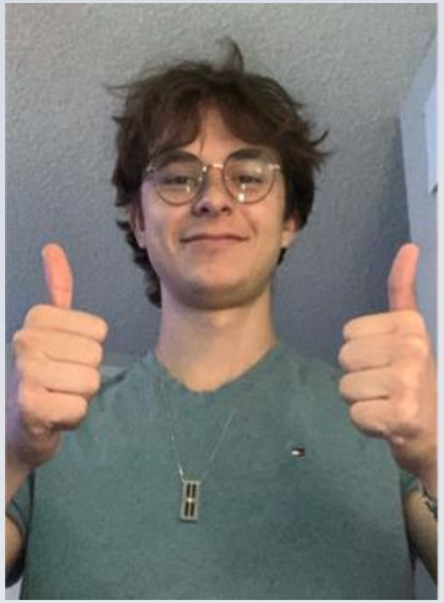
Lensless Digital Holographic Microscope

Group 7



Meet Our Team - Group 7



Nicolas Bonaduce
Photonics Engineer

Parker Crooks
Photonics Engineer

Julian Correa
Computer Engineer

Nick Scarlata
Electrical Engineer

Project Description

Lensless microscope that digitally images holograms onto a computer application

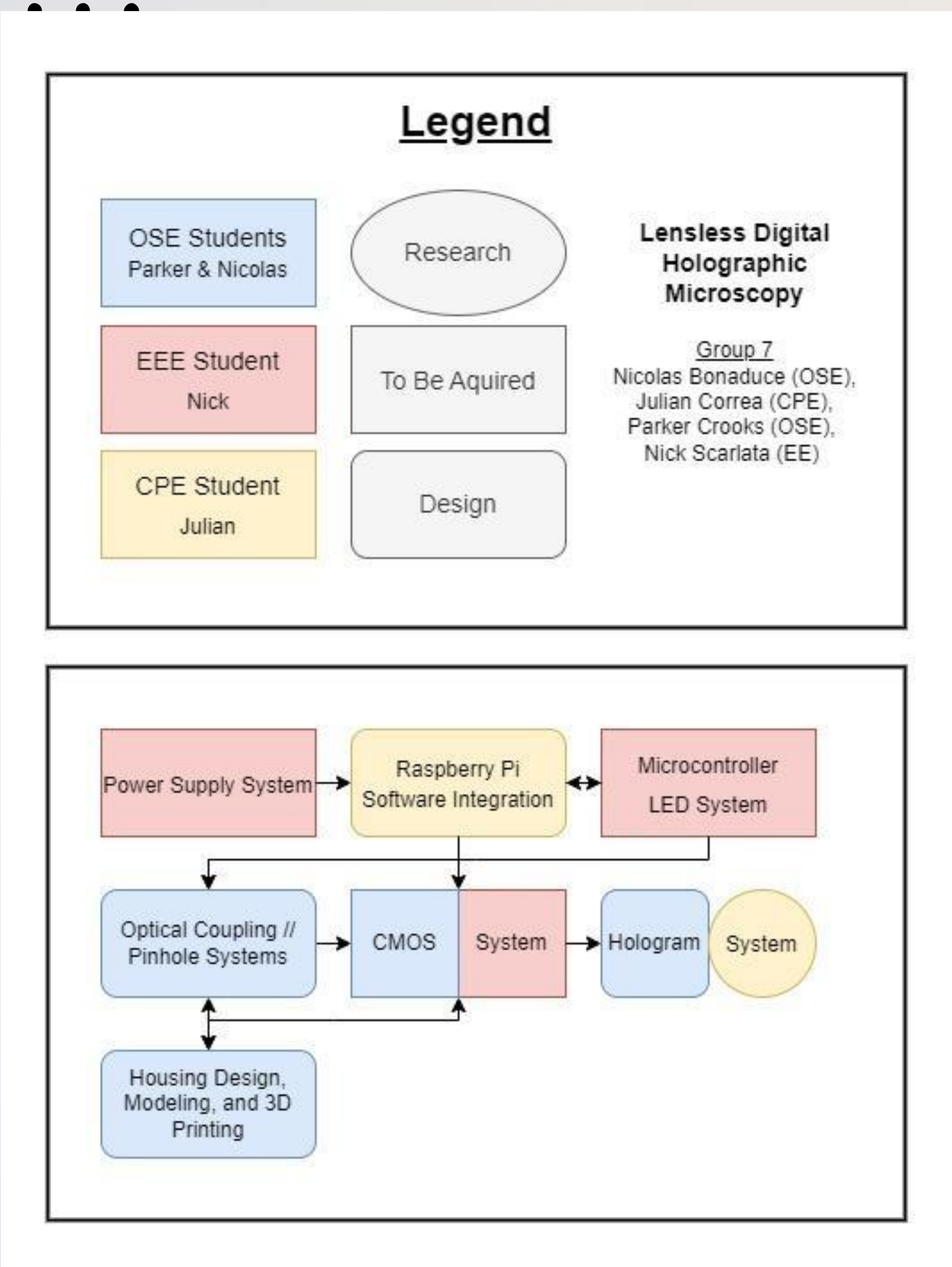
- Microscope 1: High-Power LED (450 nm) with pinhole aperture
- Microscope 2: Fiber optics attached to an LED array
- Back-propagation
- Shift-and-add pixel super-resolution of in-line holograms

Key Goals

- Couple LED array into Fiber Optic Array efficiently
- Sequentially set off the LED's at variable timing (To image in sync w/ CMOS Sensor)
- Calculate formulas for different wavelengths/image-subjects into an excel chart for variable imaging.
- Ensure CMOS works well with a variety of softwares
- Pixel Super Resolve recorded holograms with algorithms
- Ensure power supply is sufficient for the system.

Block Diagram

The following diagram represents the distribution of responsibilities between the group members. The legend outlines the colors and shapes used in the block diagram.



Optical Specifications

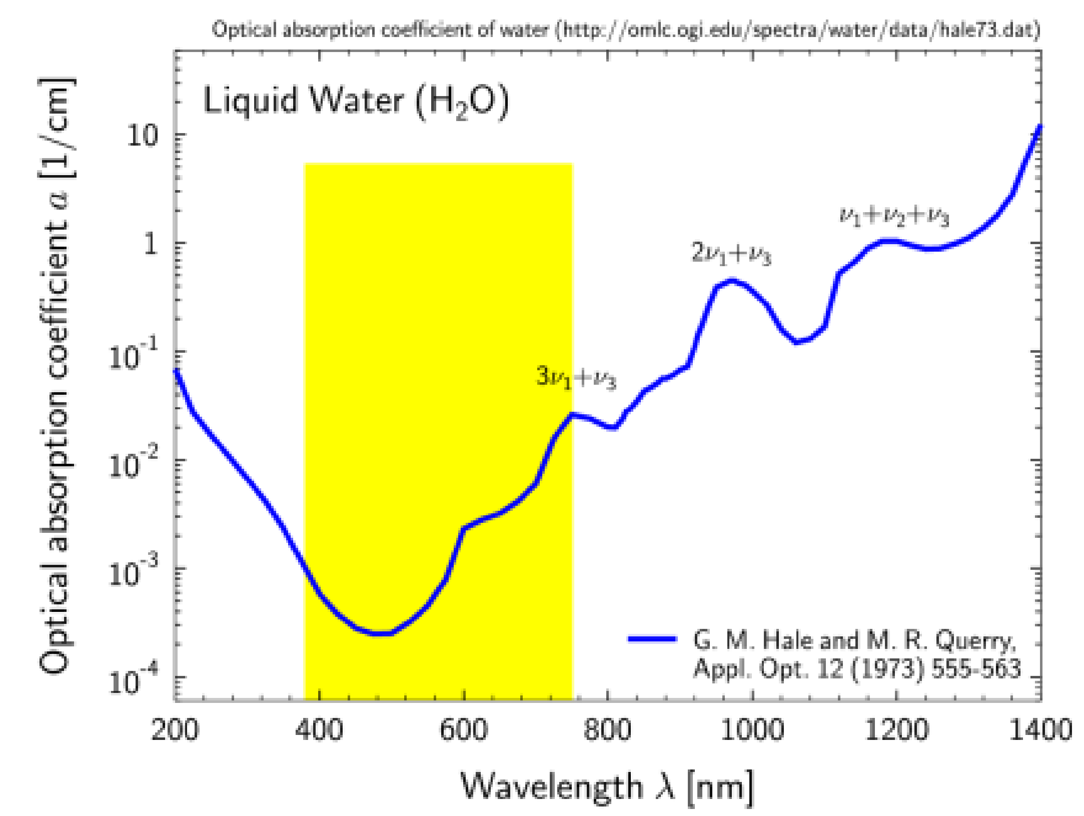
Optical Specifications		
Component	**Parameter**	**Specification**
High Power LED	Wavelength Range	450 nm – 465 nm
High Power LED	Max Drive Current	1 A (1000 mA)
High Power LED	Forward Voltage	3.1 V typical, 3,5 V max
LED	Wavelength	630 nm
LED	Half Angle	20 degrees
LED	Luminous Intensity	125.7 Lumens
LED	Max Drive Current	30 mA
LED	Forward Voltage	2.2 V typical, 2.8 V max
Single-Mode Fiber	Wavelength Range	488 nm - 633 nm
Single-Mode Fiber	Cladding Diameter	125 µm
CMOS Sensor	Pixel Size	3 µm x 3 µm
CMOS Sensor	Number of Effective Pixel	1920x1200
CMOS Sensor	Frame Rate	48 fps @ 1920x1200
CMOS Sensor	Focal Length	3.6 mm

Engineering Requirements

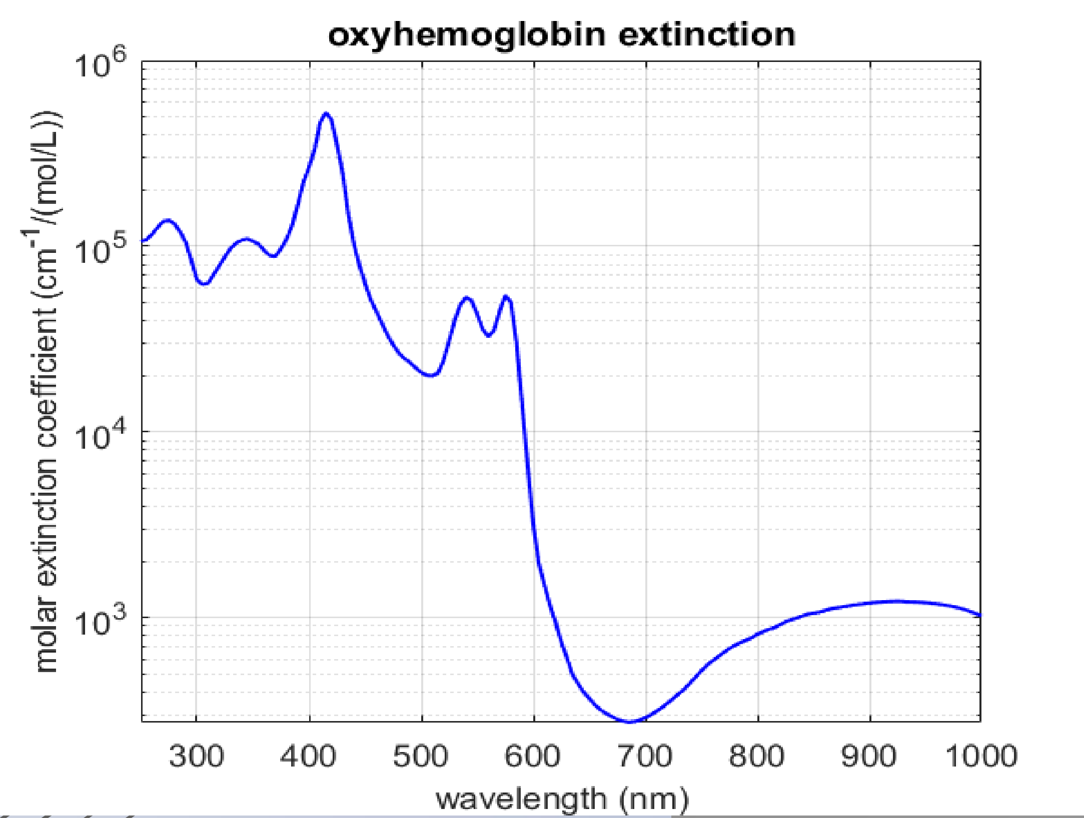
Engineering Requirements	Values
Cost	>$800
Power	<10V
Microcontroller	<40s latency while being able to control the system
Optics	Can visualize a subject between <250 µm
App	<60s latency
CMOS Sensor	Pixel size of >3 x 3 µm
LEDs	An array of 24 at 220 lumens

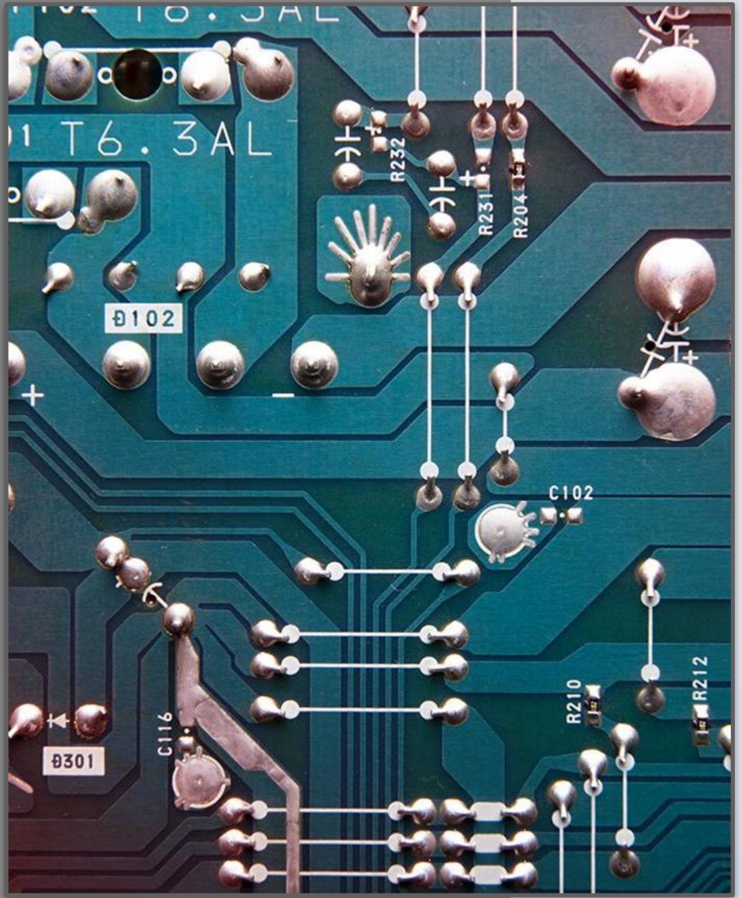
Absorption Spectrums of our Samples

Absorption Spectrum of Water



Absorption Spectrum of Blood





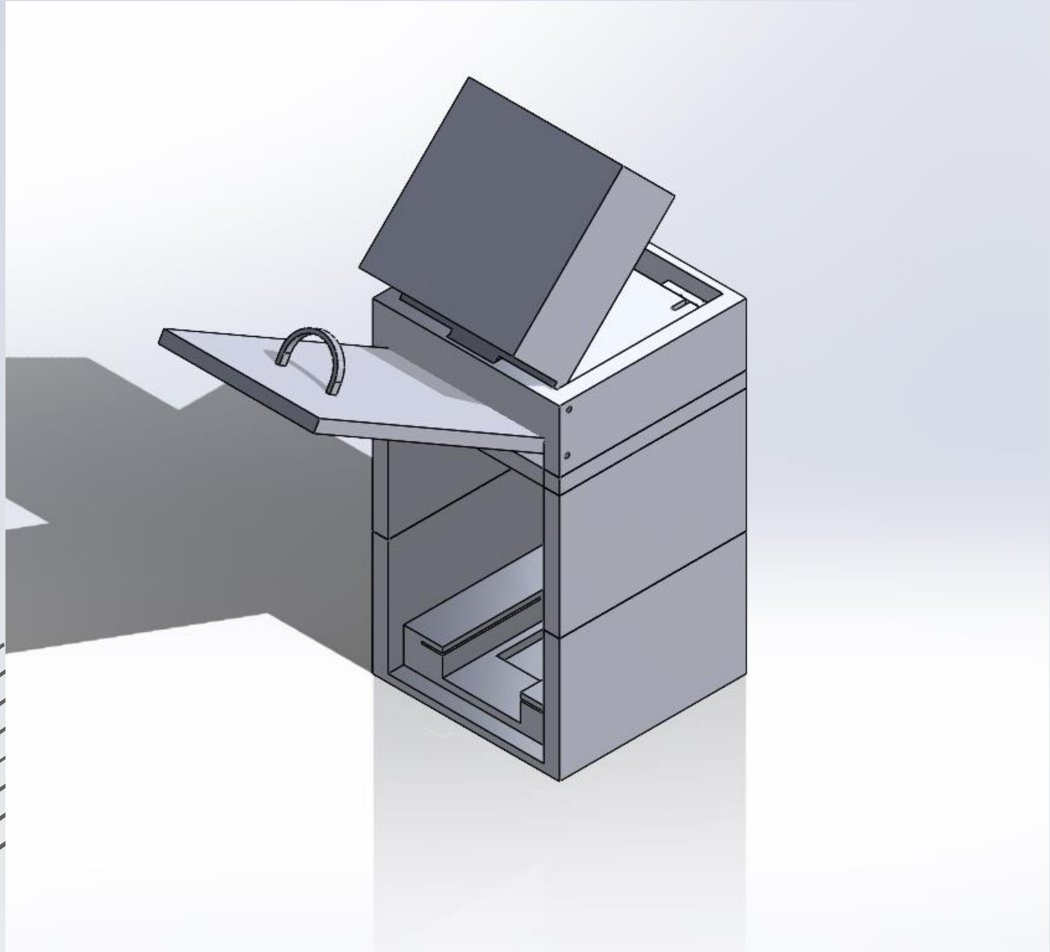
01

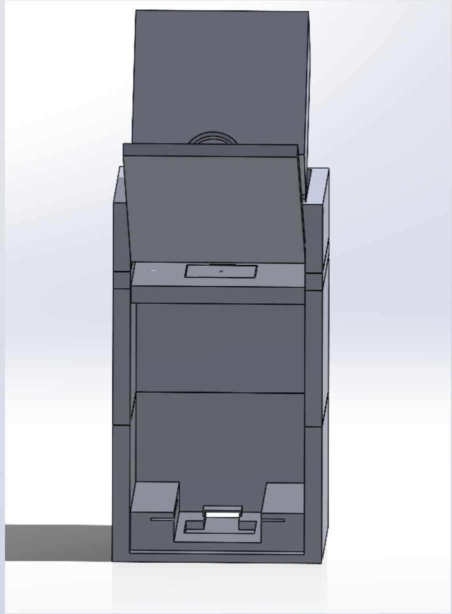
Chassis

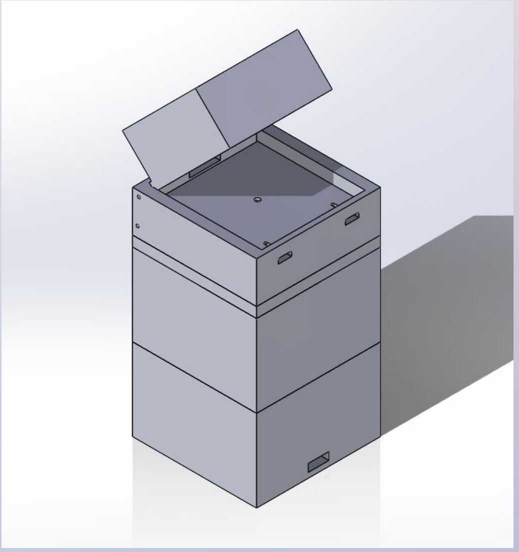
Design

Chassis Design

Overall Schematic - Pinhole Microscope

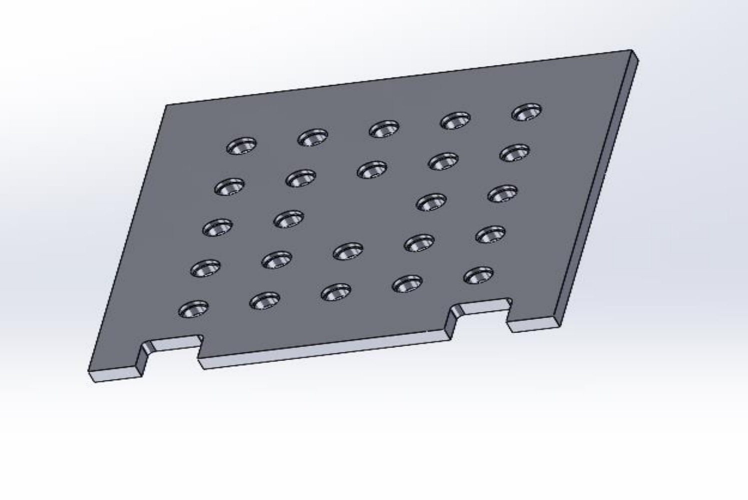




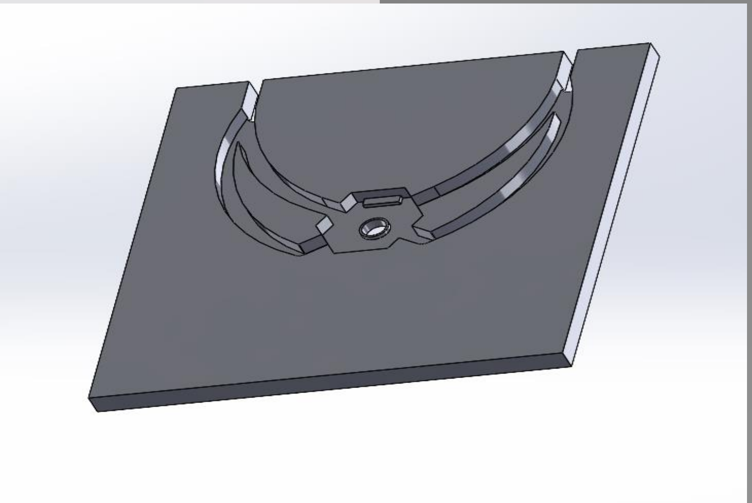


Chassis Design

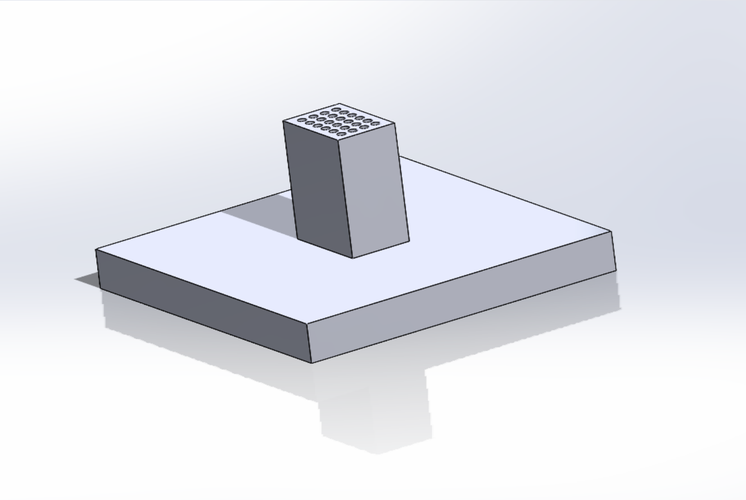
Array Planes



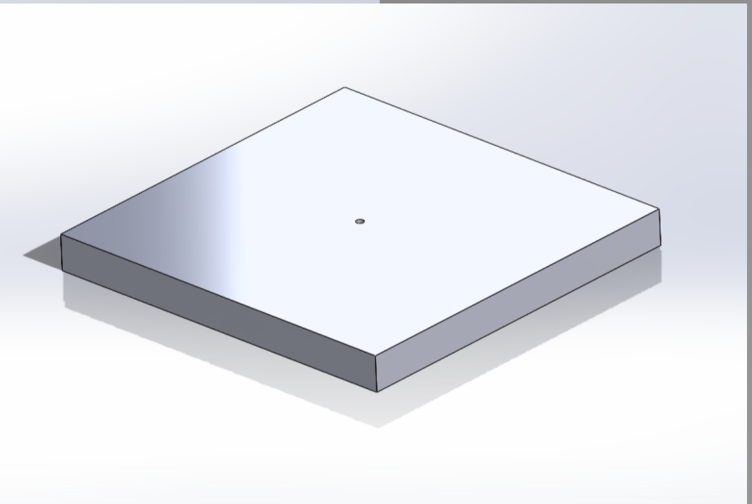
Sequentially Firing LED Array



High Power LED Array



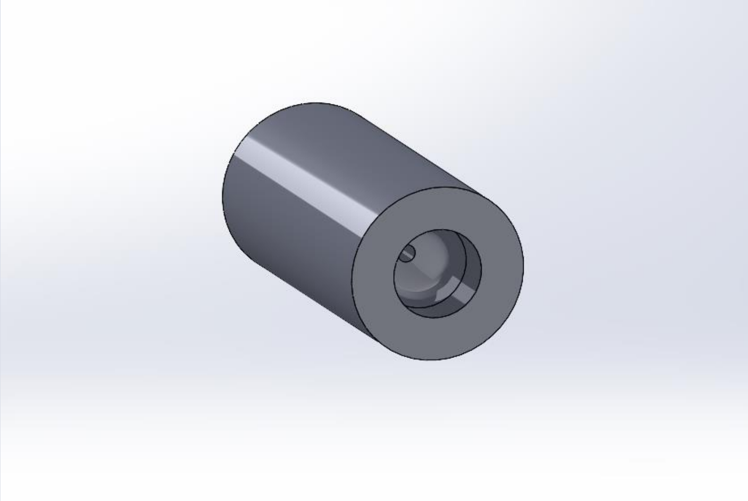
Fiber Optic Array



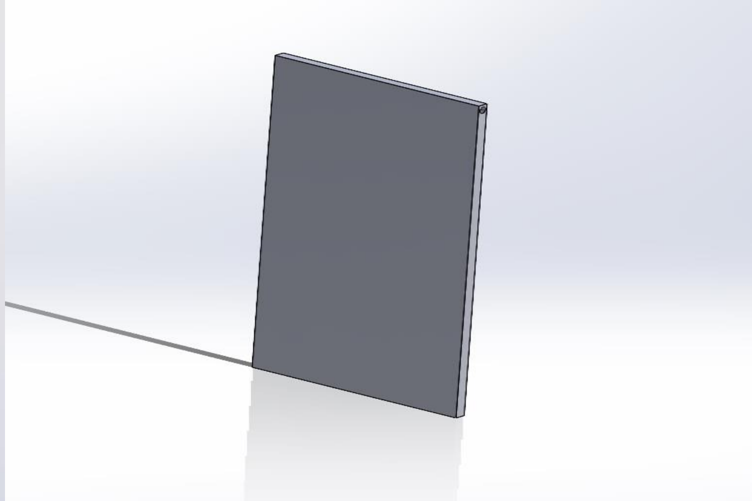
Pinhole Array

Chassis Design

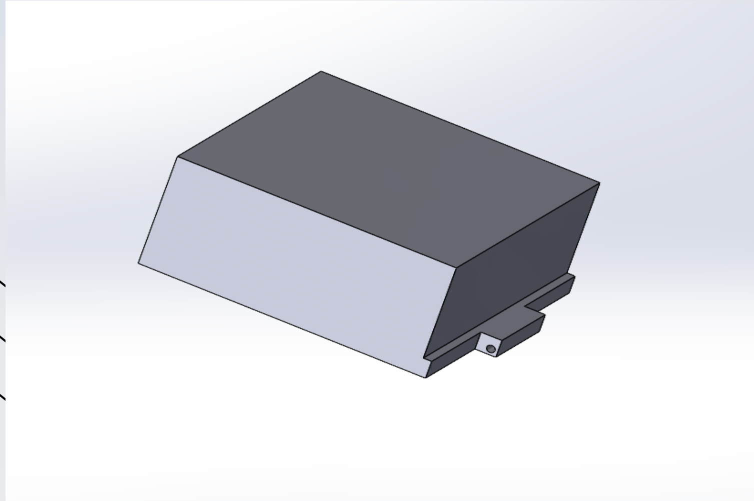
Other Parts



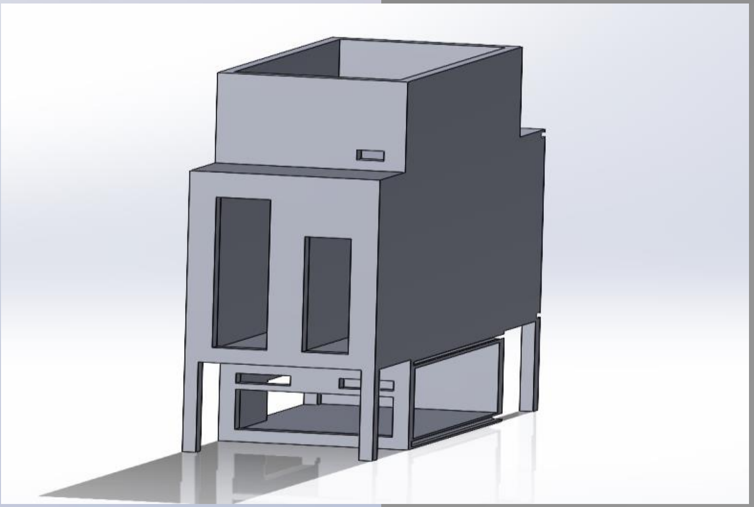
Fiber Chuck



Front Door Hatch



Top Hatch



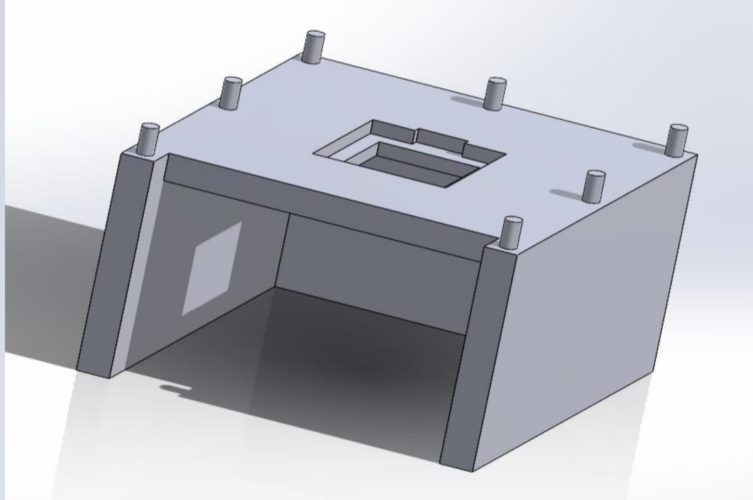
Electrical Box

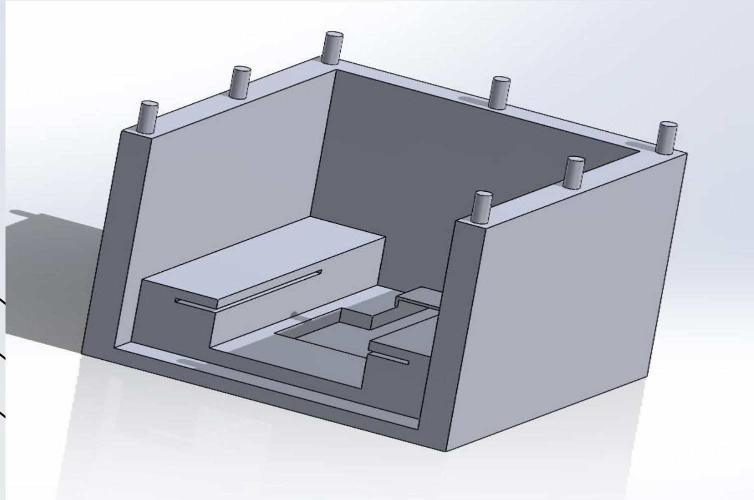
02

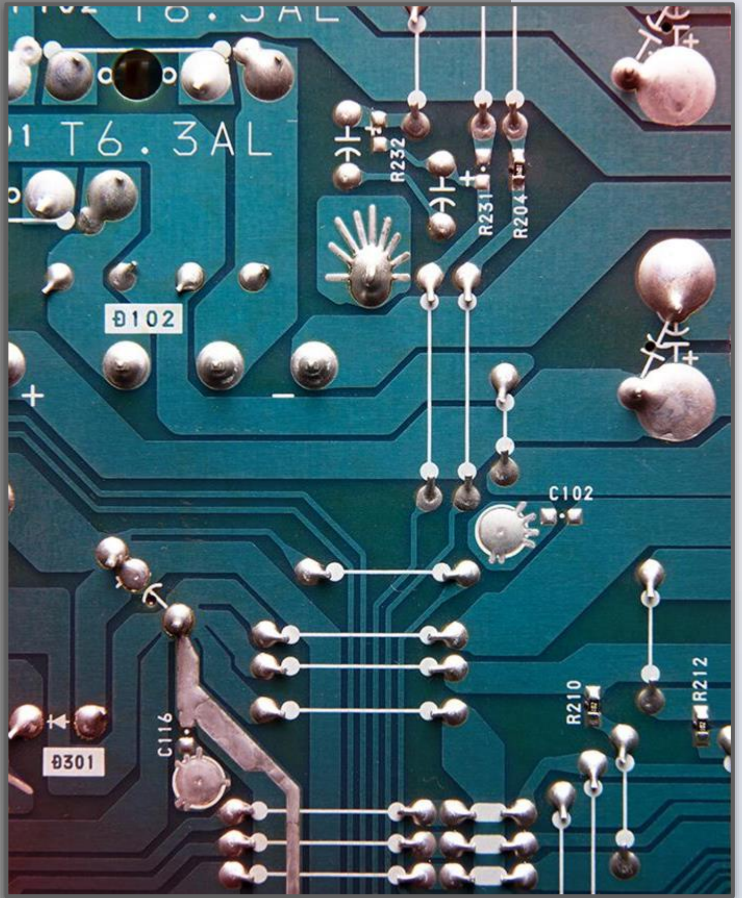
Chassis

Construction

Chassis Construction







03

Electrical

Design and Integration

Electrical Goals and Objectives

Goals

- Have a source of power either on board or using the device it is mounted to for power
- Find a reasonable CMOS sensor
- Find a microcontroller that can accomplish the tasks of the device
- LEDs (25)

Objectives

- Find a reasonable power source for all the electrical components
- Ensure the wiring of said components is correct according to a Schematic diagram

Microcontroller

Part Name	Cost	Power-consumption	Number of Pins	Processing-speed	Coding-Language
STM32WB55VCQ6	$10.92	3-5.5 V	Too few	64 MHz	Linux device
Raspberry PI 2B	$35 - $200	5 V	Too few	1.5 GHz	C+
RM48L952DPGET	$44.65	1.2-3.3 V	Enough	220 MHz	C+
MSP-EXP430F5519	$6.81	1.8-3.6 V	Enough	25 MHz	C+
XMC4800F100 K2048AAXQMA1-ND	$35.64	3.13- 3.63 V	Enough	144 MHz	Open

Raspberry PI

On board computer, the main connector for the rest of the system electrically
Able to take,store, and send pictures via the CMOS sensor

MSP430F5519

Simple PCB design enabling a simple control over the LED array

CMOS Sensor

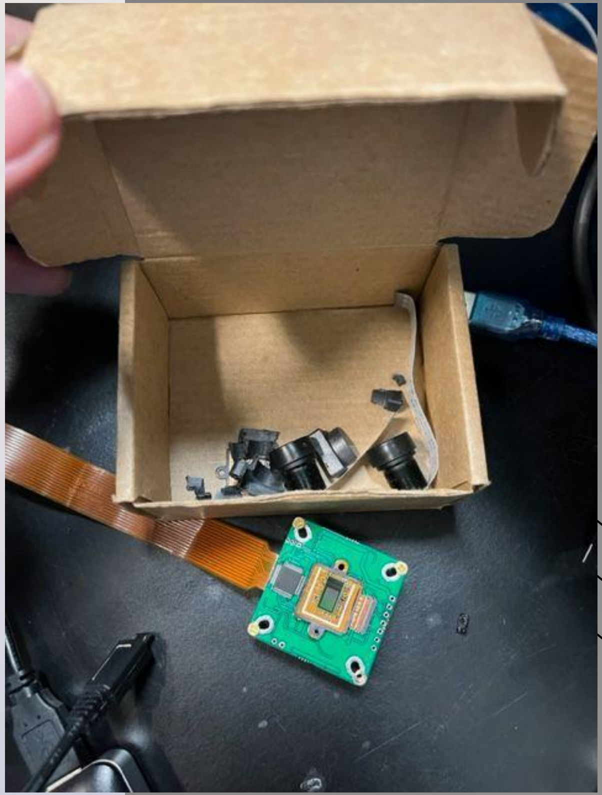
AR0234

Meets the specifications and is able to be implemented

Interesting Process

This was a part with a lens originally which has been removed entirely, by somewhat destructive means.

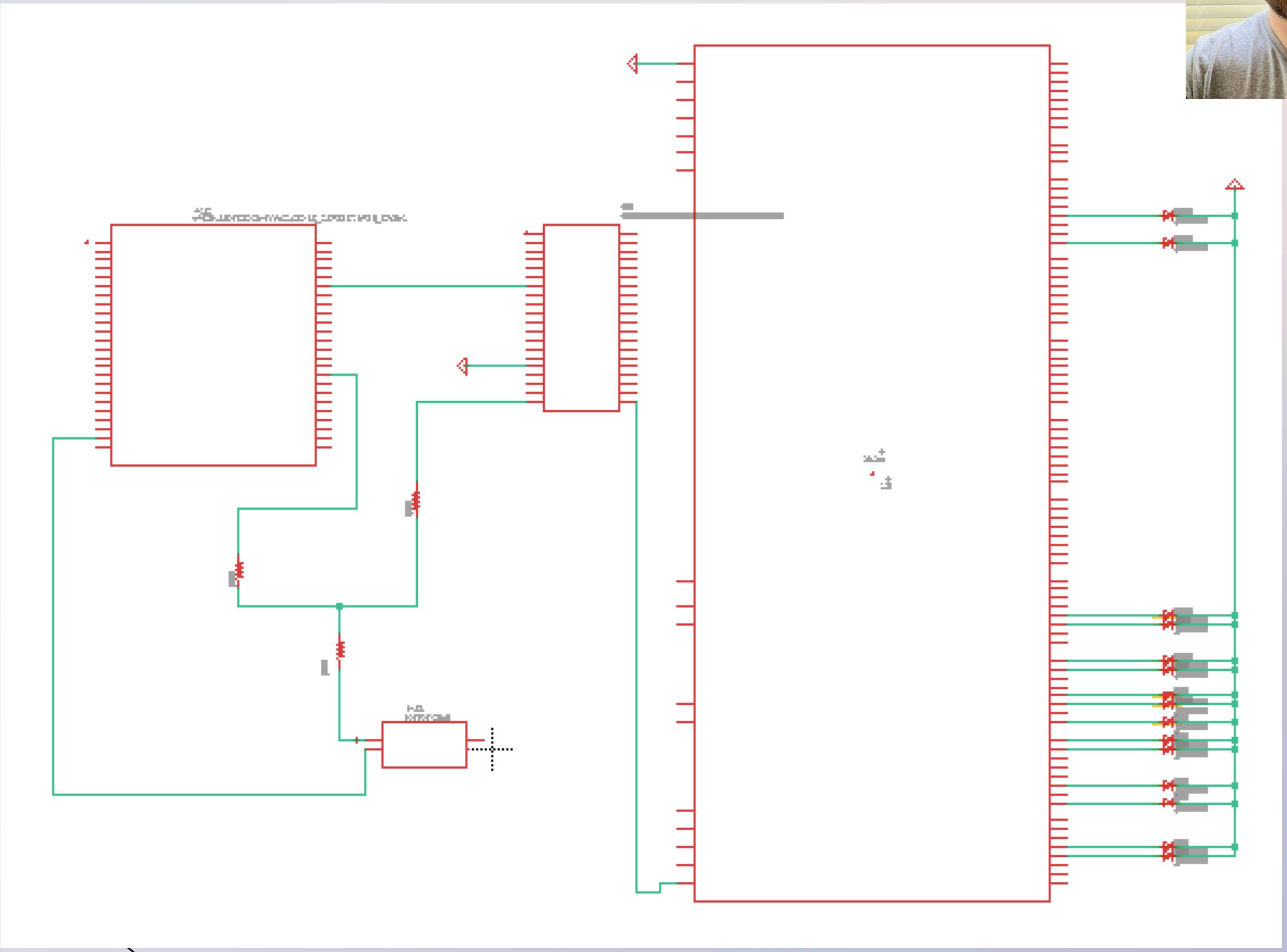
Part Name	Cost	Power consumption	Pixel Resolution	Pixel Size	Frame Rate	USB
NOII4SM6600A-QDCOS-ND	$264.00	2.5 – 3.3 V	2210 x 3002	3.5 x 3.5 µm	5 fps	No
MT9P031I12STC-DP	$26.76	1.7 – 1.9 V	2592 x 1944	2.2 x 2.2 µm	53 fps	No
08529-01	$995.00	5 V	5472 x 3648	2.4 x 2.4µm	20 fps	No
Arducam AR0234	$99.99	3.3 V	1280 x 800	3 x 3 µm	120 fps	Yes
4016C002	$329.12	3.3 V	2592 x 2056	3.4 x 3.4 µm	120 fps	No



Circuit Design

From left to right:

- CMOS sensor
- Power Source 5V @2A
- Raspberry PI
- MSP430
- LED array

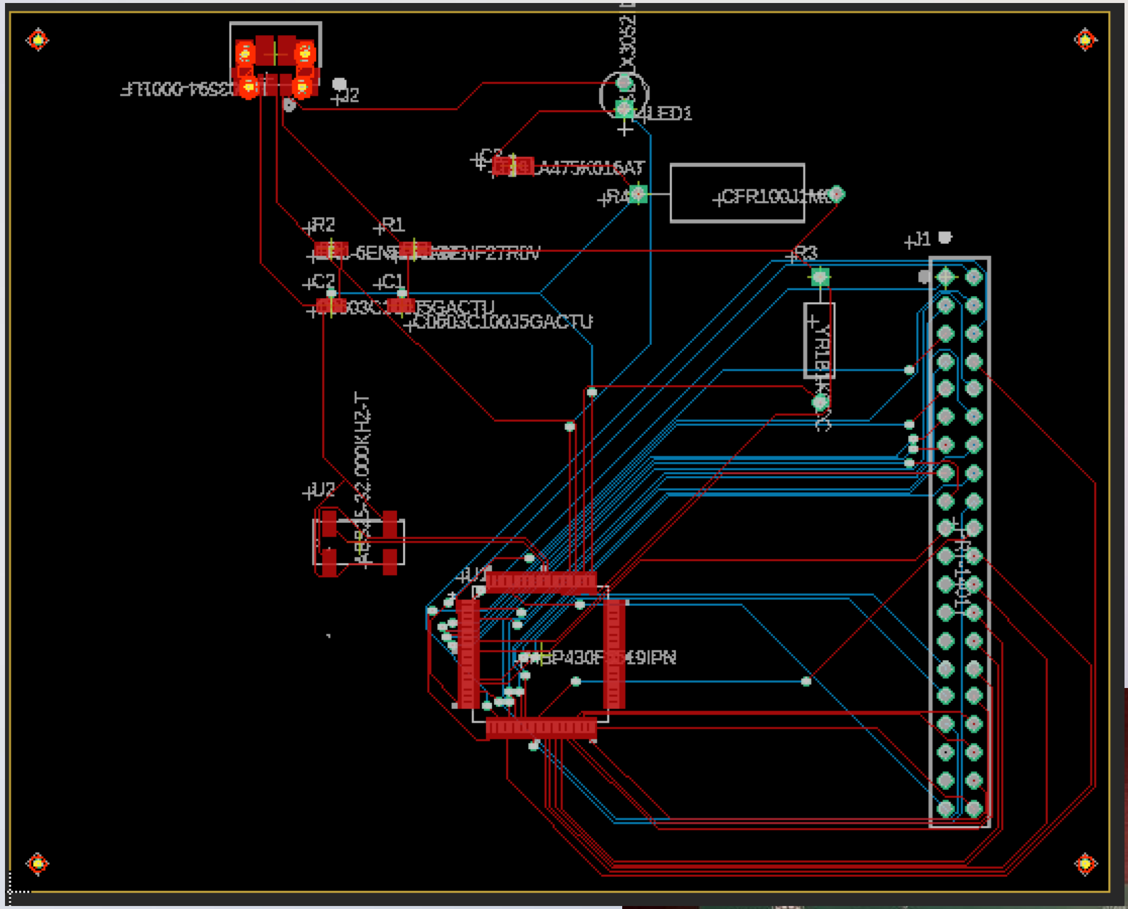


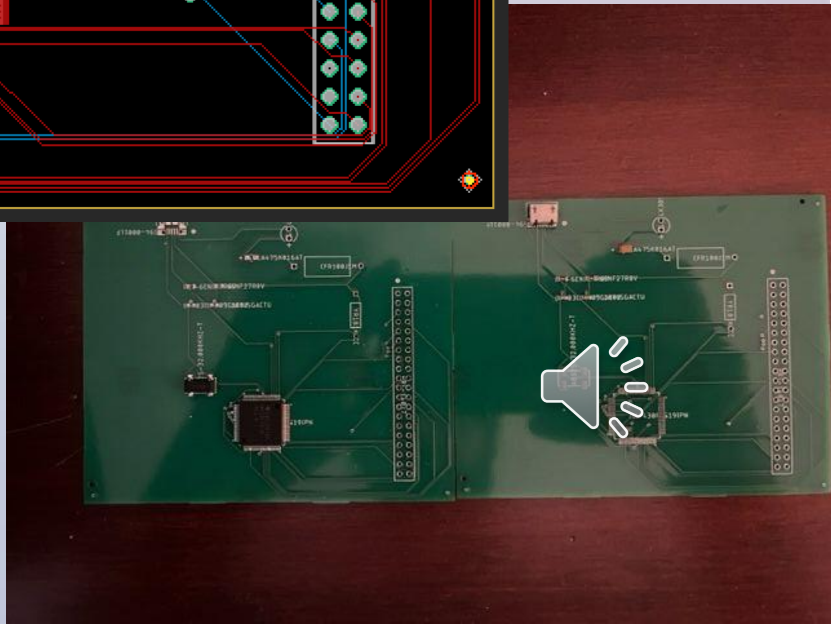
PCB

This is the PCB that contains the MSP430F5519 microcontroller, between shipping delays, and manufacturer errors I was unable to get this part working for testing.

For the purposes of testing and demonstration the MSP430FR6989 was used instead.

This part should work and would save around seven dollars in costs, not counting shipping.





Power Supply

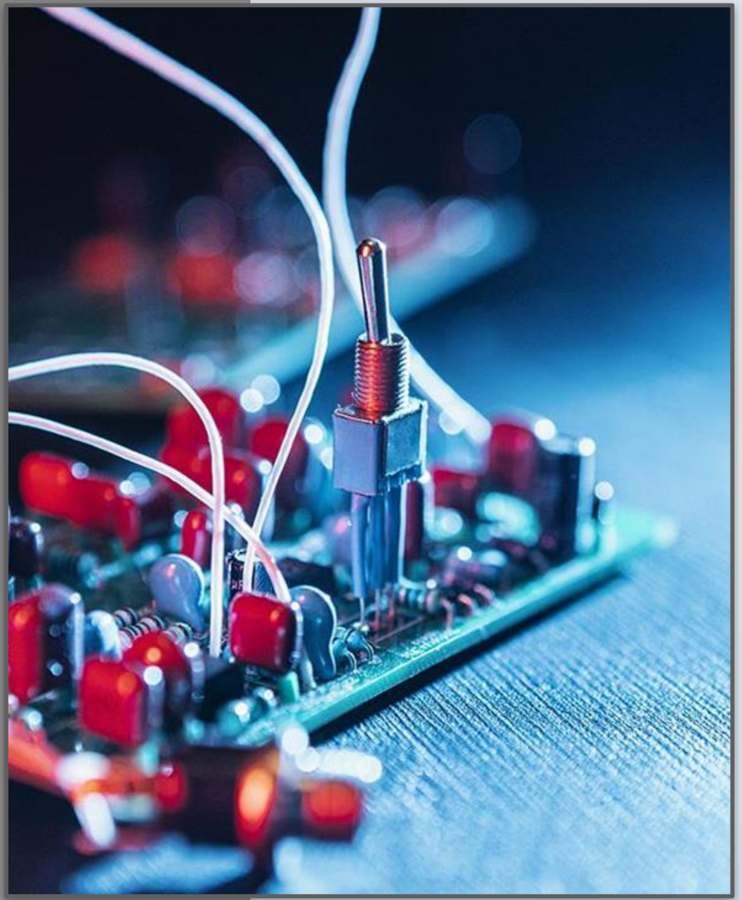
Part Name	Cost	Voltage Specifications	Battery Life	Connections
Folken Wall charger	$4.00	5V @ 2A	Constant	Wall to micro -USB
RP-PB19	$45	5V @ 2A	100+ hours	Rechargeble to micro-USB
A1271	$49.99	Up to 20V @ 4.8A	92+ hours	Rechargeble to micro-USB
HYD007	$14.99	5V @ 2A	20+ hours	Rechargeble to micro-USB
MPM 10-5	$13.17	5V @ 2A	Unknown	On board/ Pin-to-pin

In short the goal of this power source is to meet the voltage and current requirements of the Raspberry PI 2B
This just requires 5 V @ 2 A, we did the testing and pretty much any rechargeable battery with a USB port fills this role very well

A pin-to-pin connection works just as well put the power sources are less reliable than the micro-USB connection
We went with a more expensive version to make development more convenient, but a cheaper version works just as well.

LED Connection

Due to the LEDs needing to be fired sequentially we only need to power each pin on at a time
The microcontroller that we are using has more than enough female pins allowing for a direct F-M connection with the LED, and a M-M connection to a line leading to ground



04

Software

Design

Code Comparison

	C	C++	C#	MATLAB	Python
Paradigm(s)	Imperative	Imperative,object-oriented, generic	Imperative, object-oriented, generic, reflective, functional, event-driven	Procedural, imperative, array programming	Functional, imperative, reflective, array
Type Discipline	Static, weakly typed	Static, dynamic, weakly typed	Statically typed, dynamic (for interop)	Dynamic	Strong, Dynamically typed
Parameter passing methods	By value, by reference (through pointers)	By value, by reference (through reference types)	By value, by reference (through managed pointers [explicitly in, out, or in-out])	By value	By value (Call by object reference)
Intended use	System, Embedded	System, Embedded	System, Embedded	Numeric computation and visualization	System, Embedded
Best For	Scripting of system applications, web services, and web applications	Supporting object-oriented programming features	Development of desktop applications, web services, and web applications	Engineering and scientific applications like data analysis, signal and image processing, control systems, wireless communications, and robotics	Data analytics, machine learning, even design
Advantages	Fundamental block for many other programming languages, portable language, middle-level and structural language, built-in functions	Mid-level programming language, high portability, fast and powerful, standard library, multi-paradigm	Effective memory management, fast and powerful, standard library, object-oriented	Highly suitable for scientific and technical data analysis, Ease of use, Platform Independence, Device-Independent Plotting, Graphical User Interface, MATLAB Compiler	Enhanced productivity, easy to learn and write, dynamically typed, vast library support, hassle-free portability, High versatility and data visualization

Software Goals

Goals

- Implement phase retrieval with the use of deep learning
- Have the ability to generate an in-line hologram/ Gabor Hologram
- Create a focused image with the use of simple backpropagation in order to create a focused and defocused image (two-image artifact)
- Implement the “shift-and-add” in order to take low-resolution holograms and up-sample, shift, and digitally add them in order to create a good image
- Implement digital hologram reconstruction (digital back-propagation) with the method of angular spectrum method

Software Design Approach

Data transmission and processing:

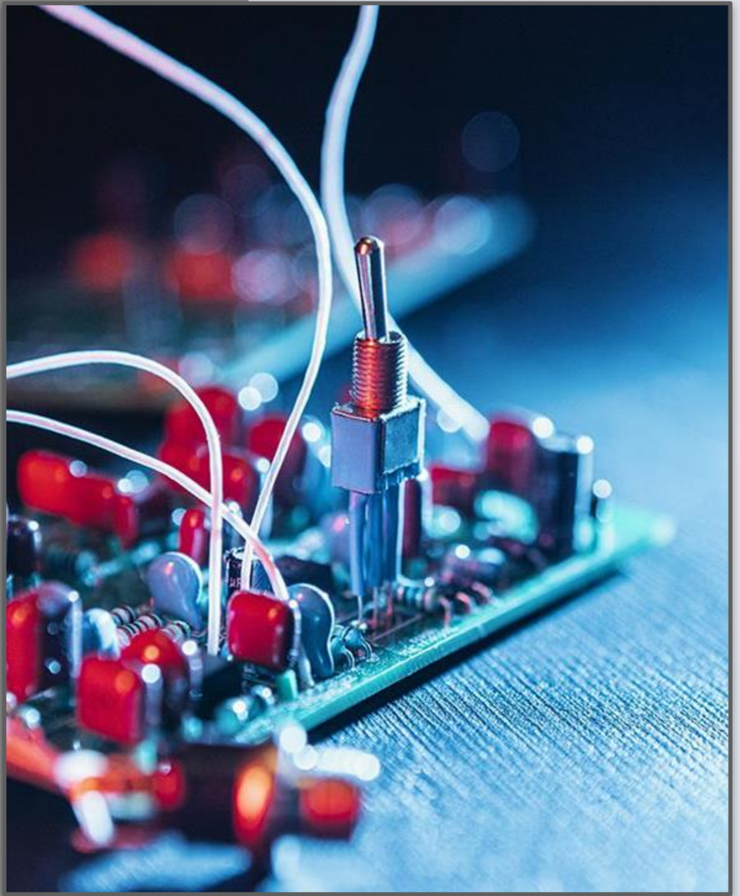
- Be able to transmit the images from the CMOS Sensor to the computer to use the algorithms and principles in order to get a image to show

MATLAB:

- Use for testing and creation of algorithms and equations

Coding:

- The coding for the CMOS Sensor and its algorithms will be done in python
- Microcontroller coding will be done in C



05

Software

Integration

Image Capturing Process

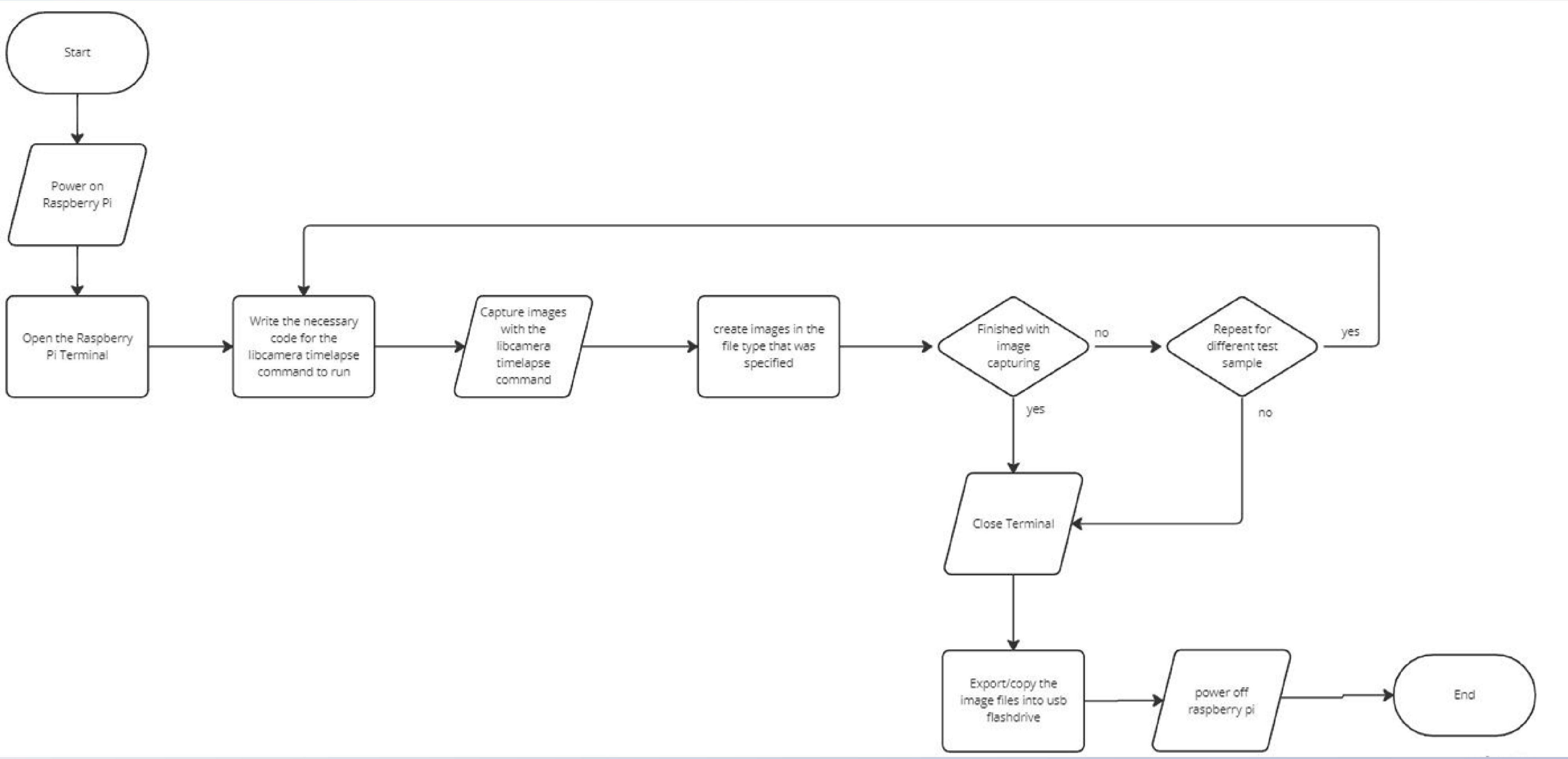
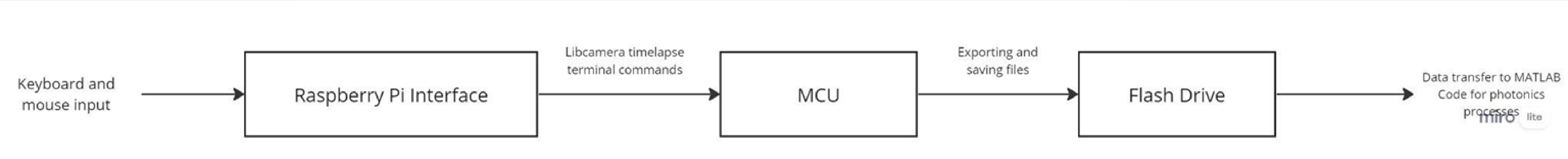


Image capture data processing



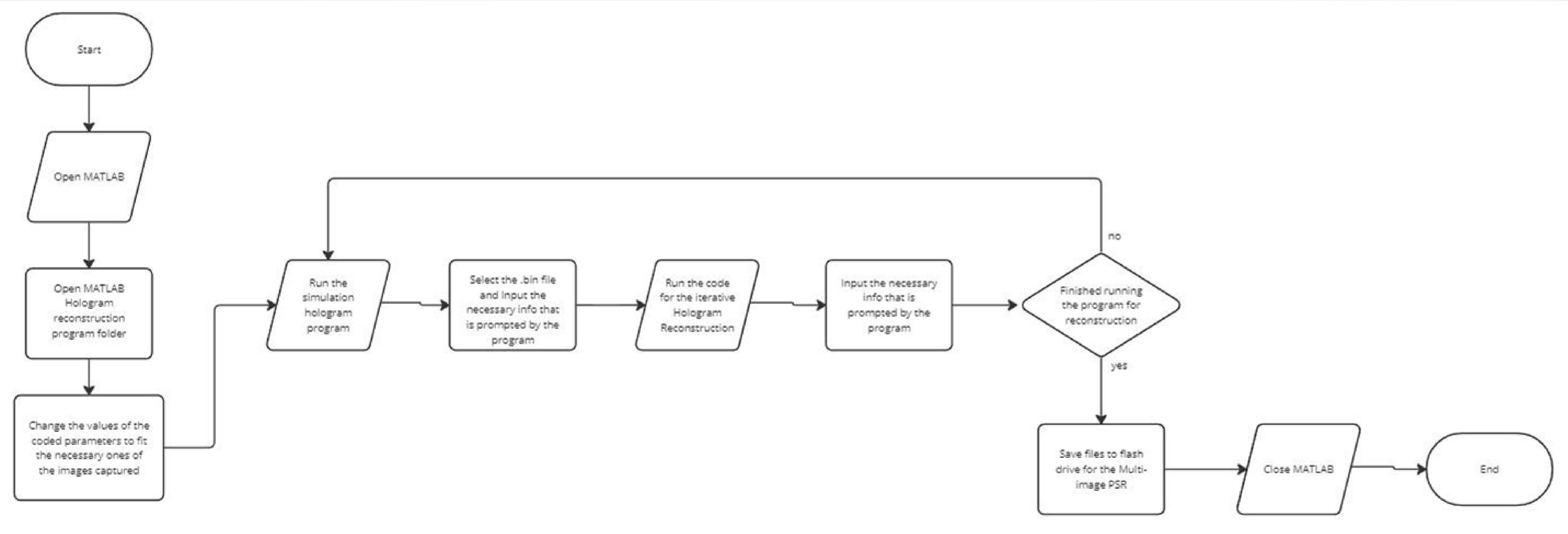
Photonic Methods and Principles

- Holography and Digital In-Line Holography
    - Gabor in-line holography
- Propagation and Back-Propagation
- Angular Spectrum Method

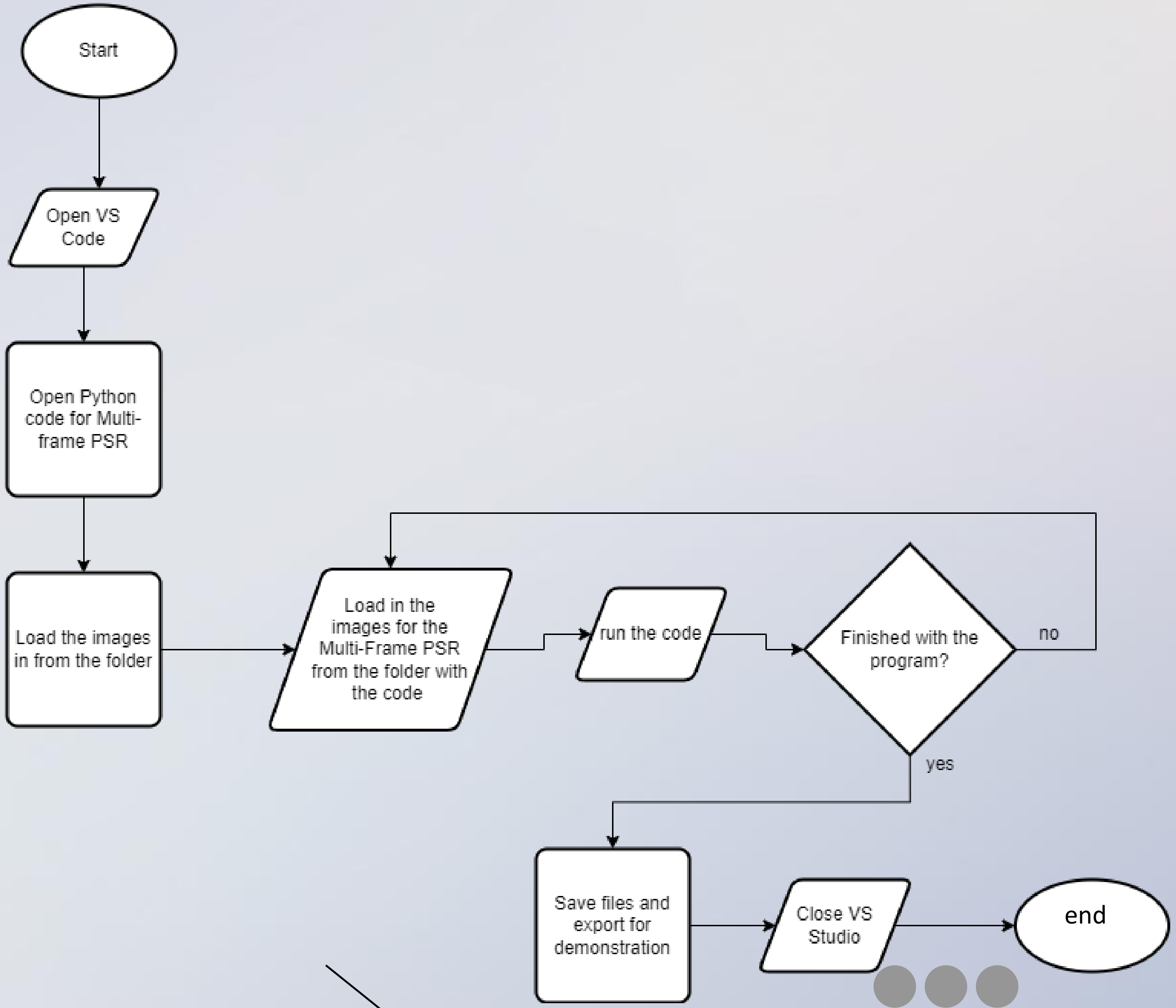
Photonics Methods and Principles cont.

- Twin image Artifact Removal
- Pixel Super-Resolution
- Spatial Convolution
- Phase Retrieval
- Pixel Pitch

Hologram Reconstruction Process



Multi-image Pixel Super Resolution process



Constraints

These constraints help highlight the various concerns and limitations that play a crucial role in part of the schedule and the selection of parts that make up our project,

- Economic
  - Self funded by group
- Environmental
  - Having microcontrollers and CMOS sensors all RoHS (Restriction on the use of Hazardous Substances) compliant
- Social
  - Affordability
- Ethical
  - Does not infringe on any existing projects and patents

- Health & Safety
  - Eye health and safety
  - Electrical components connections
- Manufacturability
  - Availability of parts
- Sustainability
  - using RoHS approved parts
- Time
  - Length of the Semester
  - Testing parts
  - Delivery Time for parts
  - Individual schedules

Standards

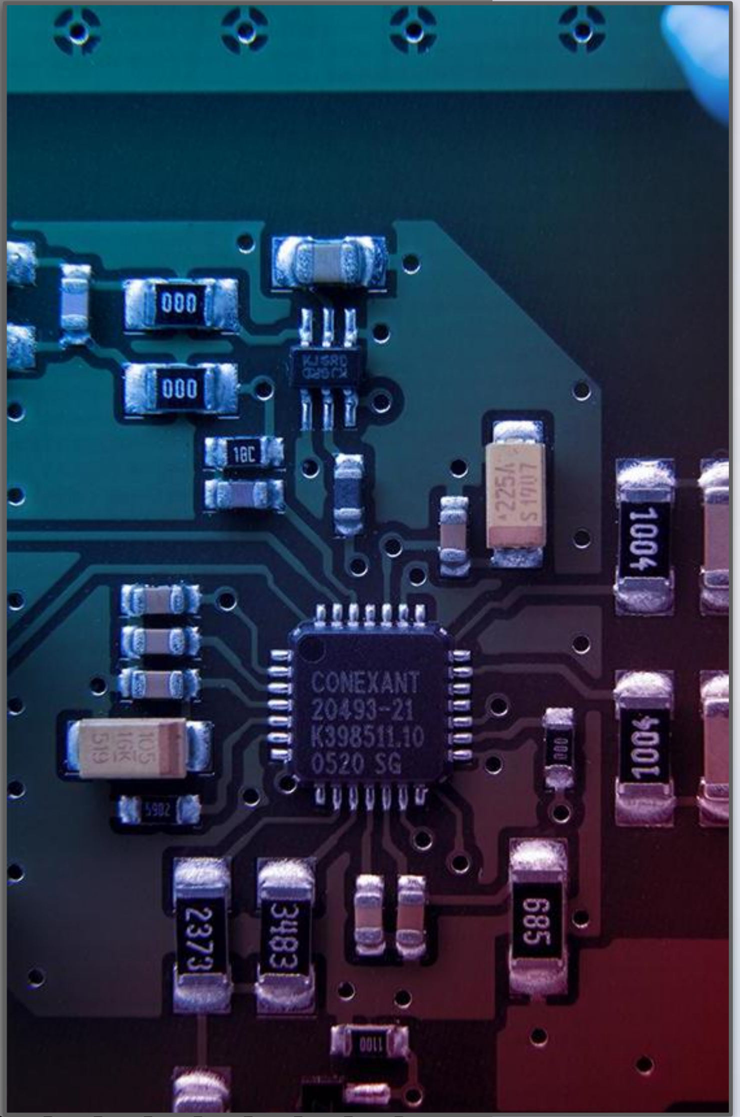
LEDs
LEDs have radiation emission limits as per the FCC. Between 30MHz and 10000 MHz. LED suppliers must also fill out FCC Supplier Declaration of Conformity (SDoC) Heavy metal limits. Florida is one state that *does* regulate the amount of heavy metals in LEDs
C language
ISO/IEC 9899:2011 which specifies the form, structure, and establishes the interpretation of programs that are written with the C programming language
Electronic Components
Following the RoHS Directive
Photonic Components
IEEE Photonics Society which covers the the scope of which is to cover standards in areas that are : lasers, optical devices, optical fibers, and associated lightwave technology and their applications in systems and subsystems, in which the quantum electronic devices are key elements. We will also be following Laser safety standards set by OSHA and ANSI standards for laser us

Project Budget

Component Quantity	Quantity	Total Cost
LEDs	25	TBD
Small amount of multimode fiber	TBD	TBD
Fiber Chucks	Approx. 8	3D Printed
Fiber Clamper	1	TBD
Fiber Cleaning Wipes and Alcohol	1	TBD
UV Resin	2	$19.99
UV Flashlight	1	$6.99
Microcontroller	2	$15.50 + $35.00
CMOS Sensor	1	$110
Total ($)		<$800

Future Work

- Quicker snapshots
- Seamless integration of file transfer
- Different pinhole sizes and distances for different wavelengths of light.



Thanks!