Portable Microscope
Group 27

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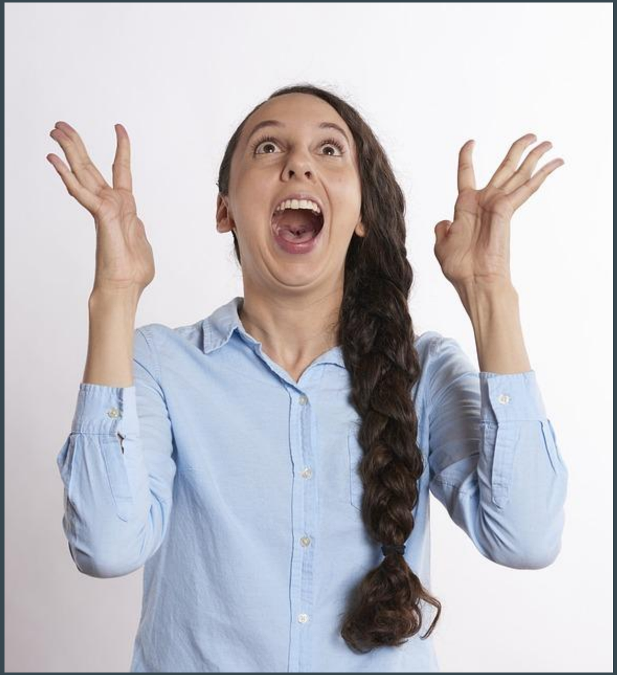
Motivation

- Scientific learning tool
    - Educators, Students
    - Incorporate smart devices
- Encourage involvement in STEM
    - Get people excited about the microscopic world
- Ease of access
    - Untethered
    - Multiple people can view display at once



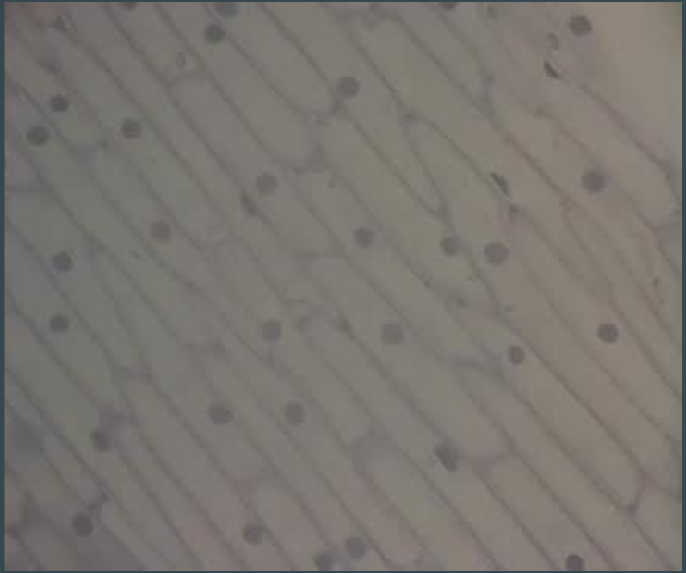
Overview

It is a battery operated microscope that can be used without a stand to explore the surrounding world.

The microscope transmits a live feed via a WAP to an Android app. The user will be able to apply filters, add tags, and save photos and videos of the specimen.

Goals and Objectives

- ✓ Portable and lightweight
- ✓ Wireless
- ✓ Able to resolve an onion cell
- ✓ Imaging in visible
- ✓ App-enabled

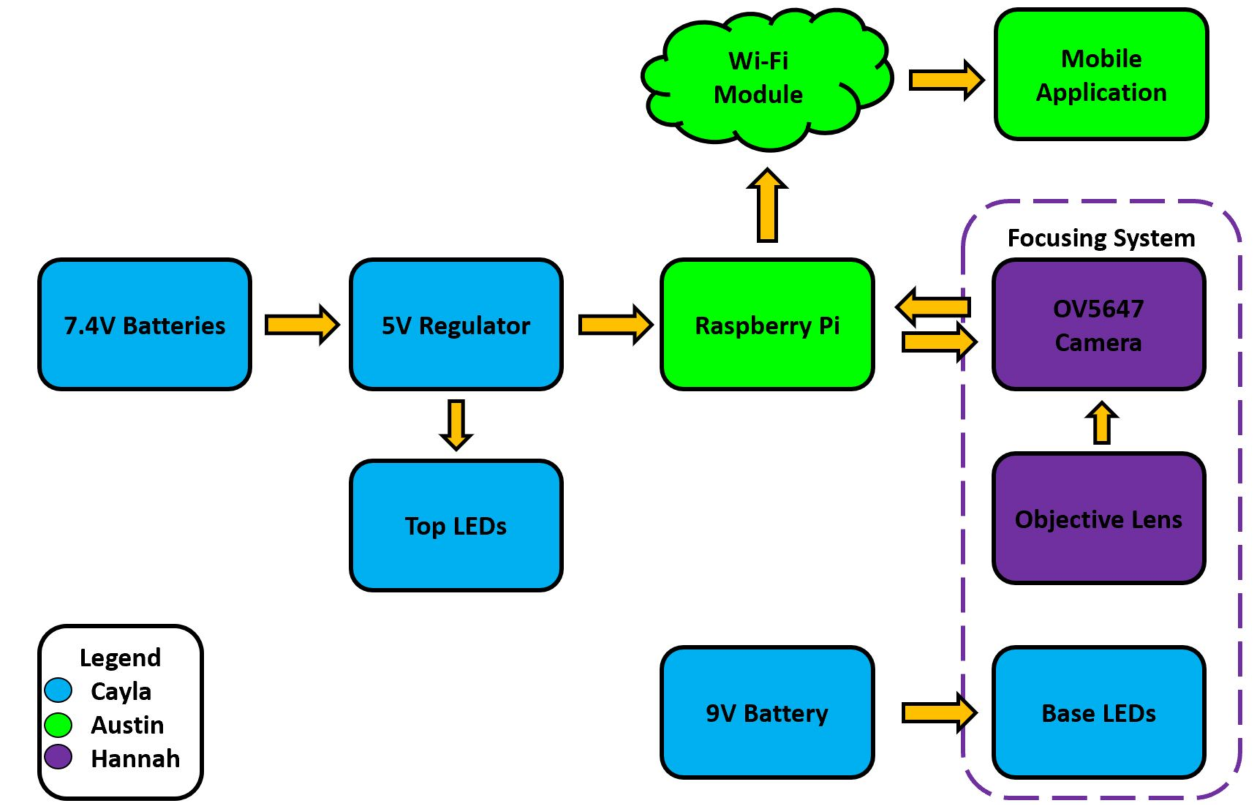


Specifications

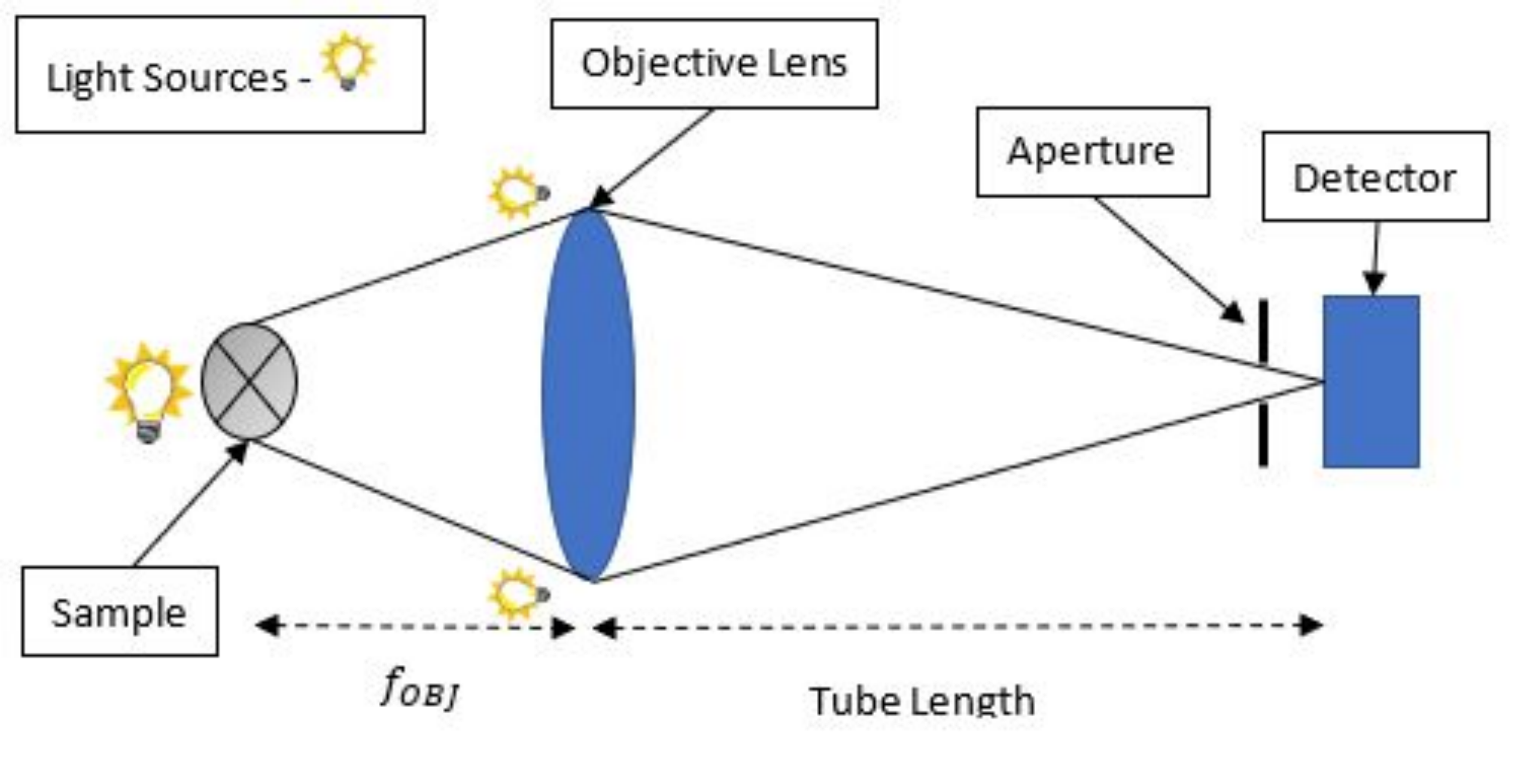
Category	Projected	Actual
Weight	Under 10 lbs	3.75 lbs
Transmission Rate	10 FPS	40 FPS
Resolution	120 um	10 um
Delay Time	< 1 s	< 1 s
Magnification	Up to 10X	Up to 10X
Transmit to Android Device	✔	✔
Battery Operated	✔	✔

Hardware Designs

Hardware Block Diagram

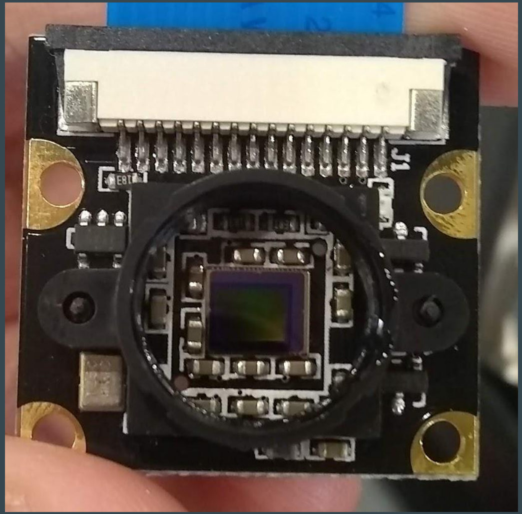


Optical Design



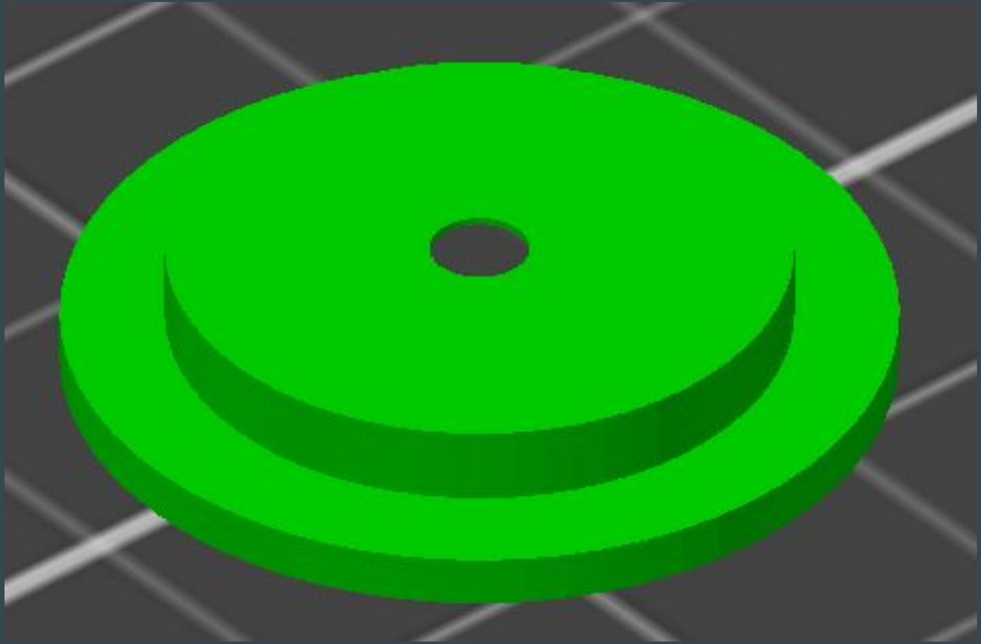
Dorhea Raspberry Pi Camera Module

- 1.4um pixel size
- 5 megapixel
- 2592*1944 pixel array
- Up to 90 fps
- $17
- OV5647



Aperture

- 3mm Diameter Aperture
- Attaches Sensor to Tube
- 4 mm Tall
- Reduces Brightness
- Increases Contrast



The Aperture is Important

Before

Hair sample at 4X

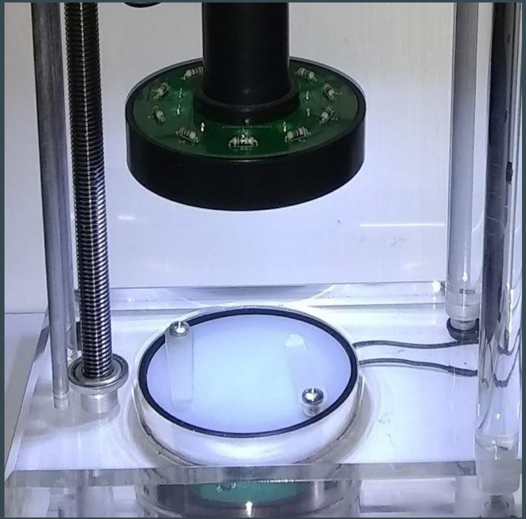
After

Hair sample at 4X

Light Sources

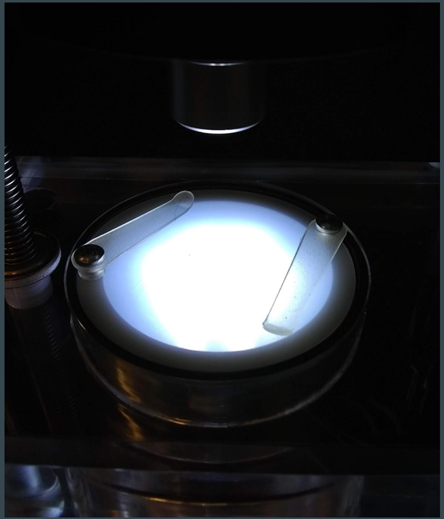
Top Light

- Skirt
- 2 Levels Intensity
- Thick Samples



Base Light

- Diffusion Filter
- Clips For Samples
- Any Magnification

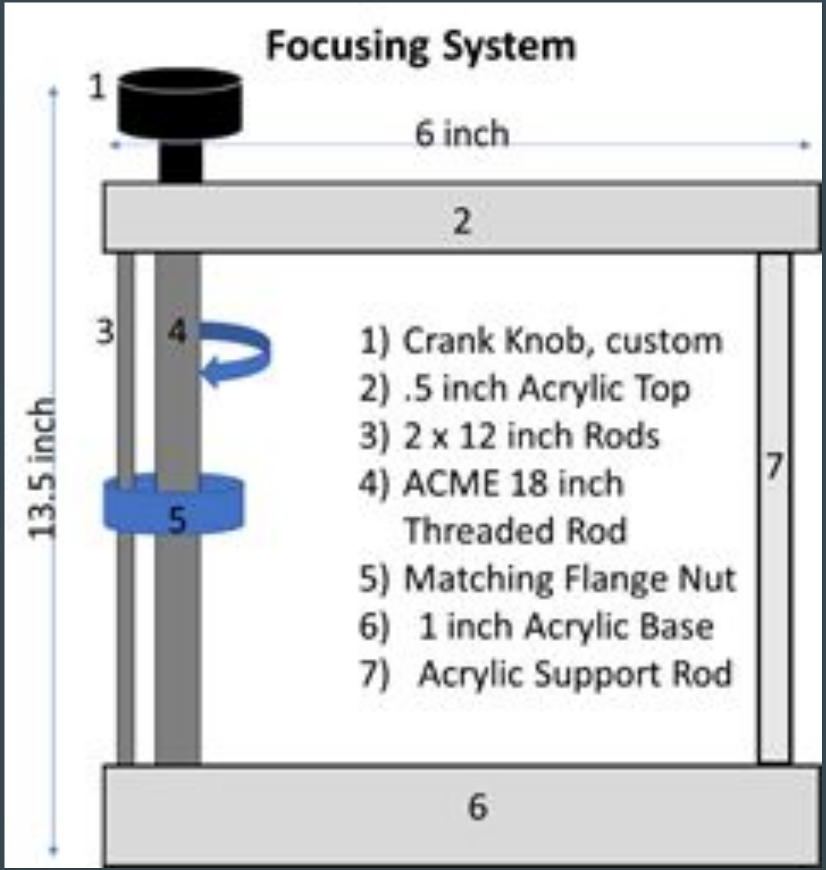


Objective Lens

Pros and Cons of different Objective Lenses

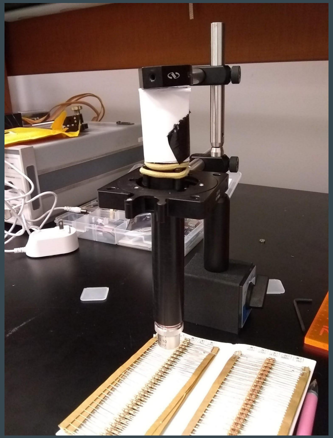
DIN Standard	**Infinity Corrected**
One Component	Requires additional Lens
$20	$140
Fixed Focal Length	Fixed Focal Length
Difficult to Focus	Easy to Focus
Standard Tube Length	Tube Length Varies based on Brand

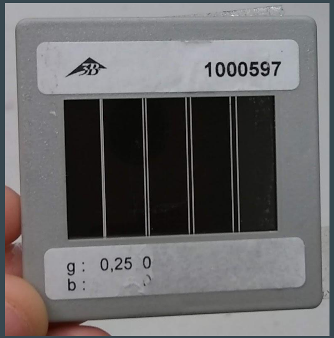
Optomechanical Design Moving Elements

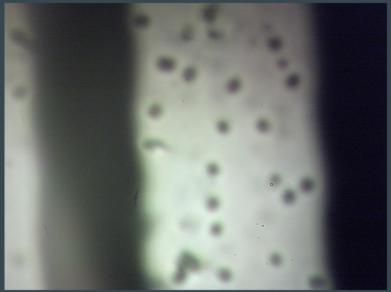


Optical Testing So Far...

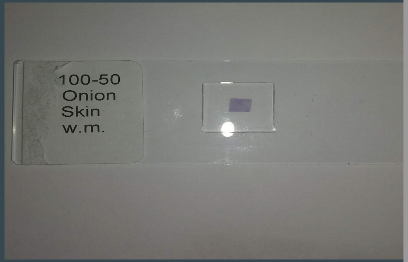
First Semester







Second Semester

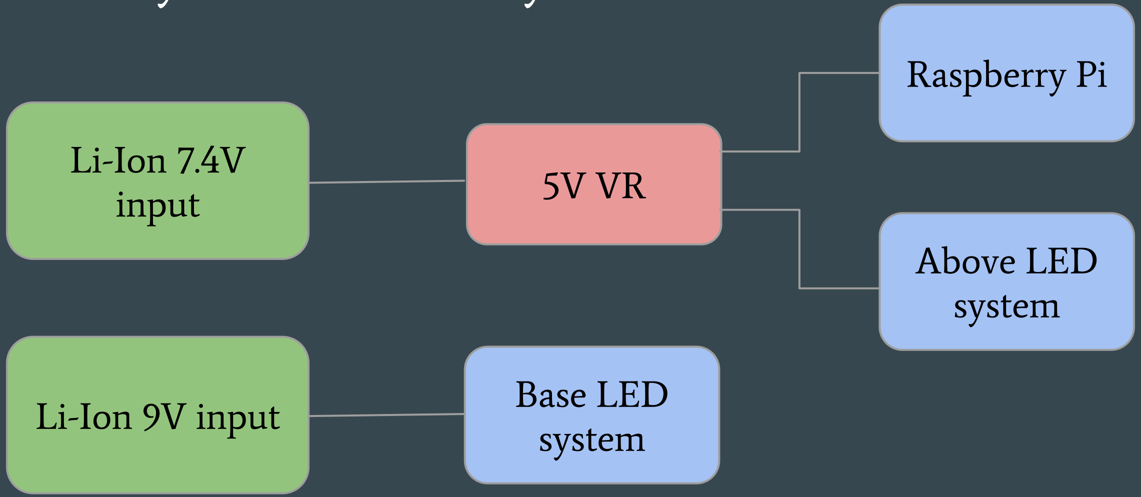


Power Supply Design

- Lithium Ion Batteries Selected
    - High energy density
    - Low self-discharge
    - Durable
    - Lightweight
    - Compact
    - 2 - Lithium Ion with 7.4V combined output

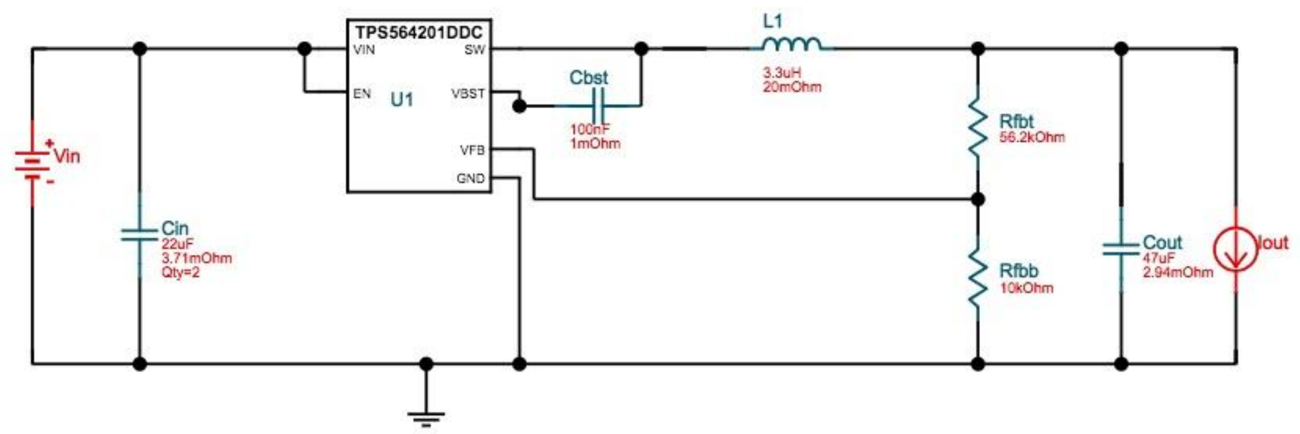
Power Supply Block Diagram

- 2 - 3.7V Li-Ion Batteries
- Voltage regulation needed to protect components
  - One 5V regulator
- 9V Li-Ion Battery for base LED system



Voltage Regulation Designs

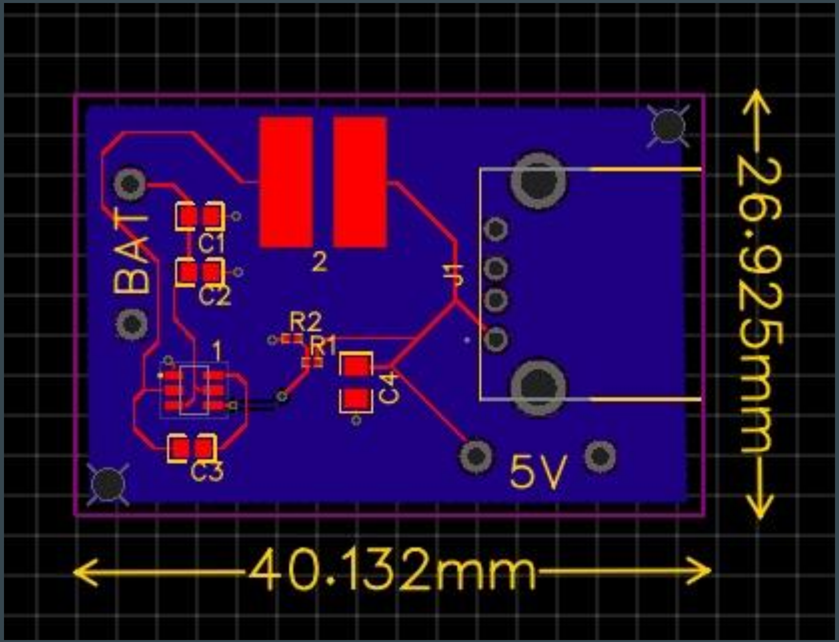
- TI Webench Designs
- 5V Regulator needed for Raspberry Pi and above lighting system

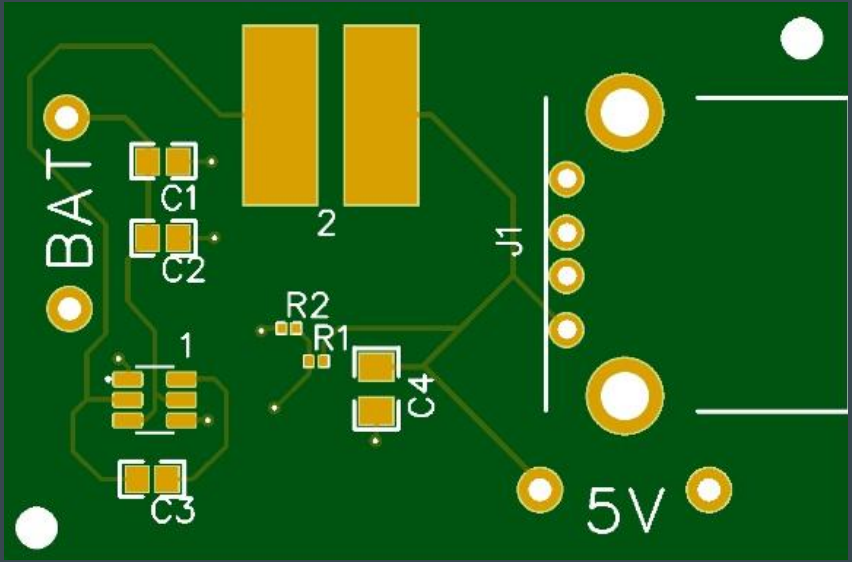


Voltage Regulation Designs

- Regulator Design
  - Switching Regulator
    - 5V with 2.62A output
  - 94.8% efficiency
  - 149 mm^2 footprint
  - 8 total components
- Improves battery life
- Separate circuit board for mounting on side panel

Voltage Regulation Design

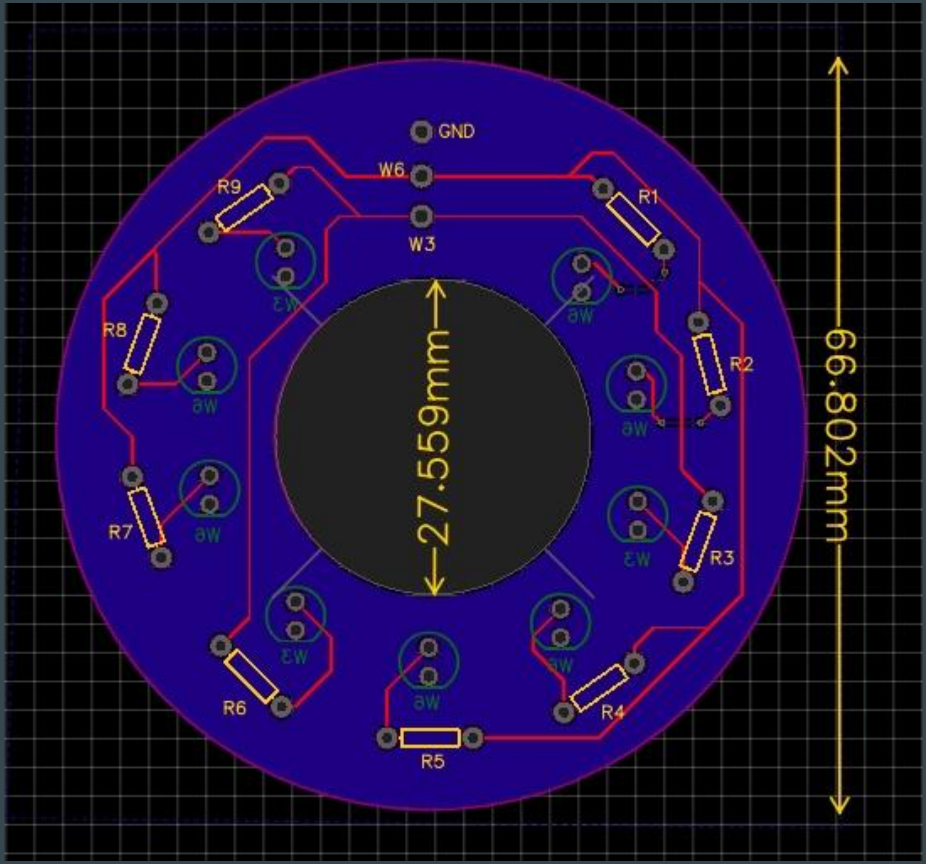




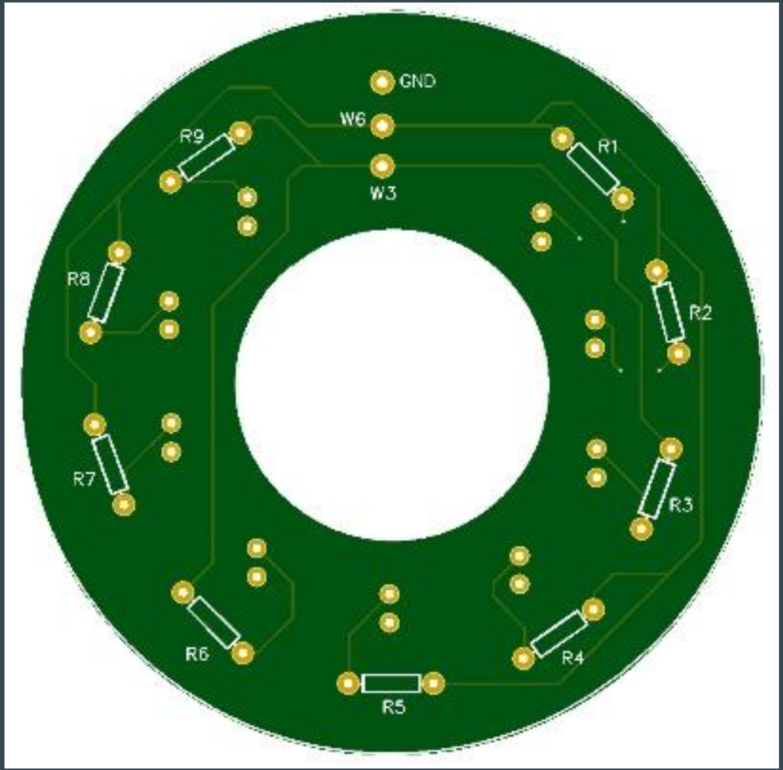
Above LED Design

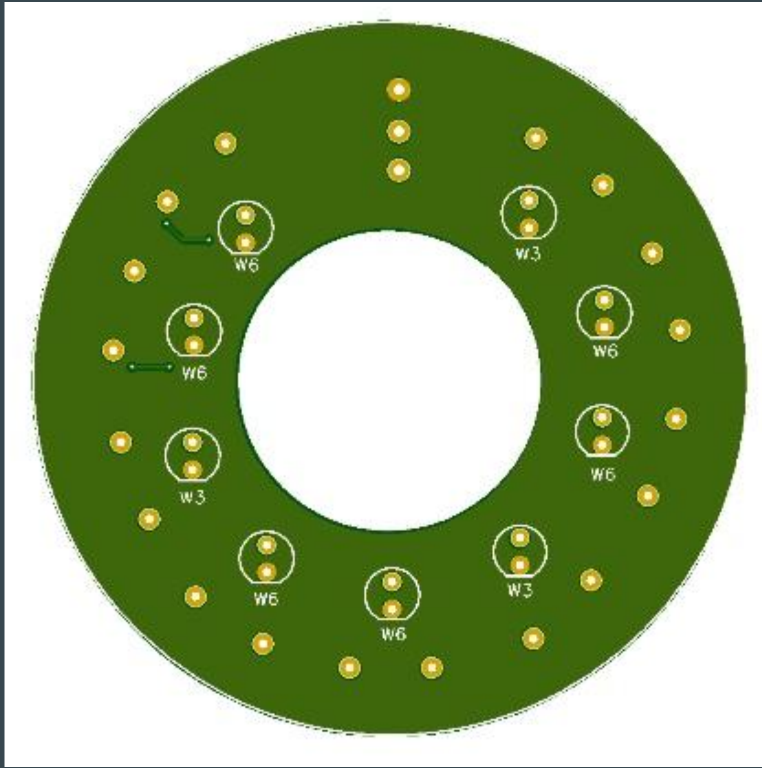
- Above light adds illumination from above
- On-off-on switch allows option for 3 or 6 diffused LED illumination
- Lights will face towards observed sample
- Able to be adjusted depending on lens used

Above LED PCB Design



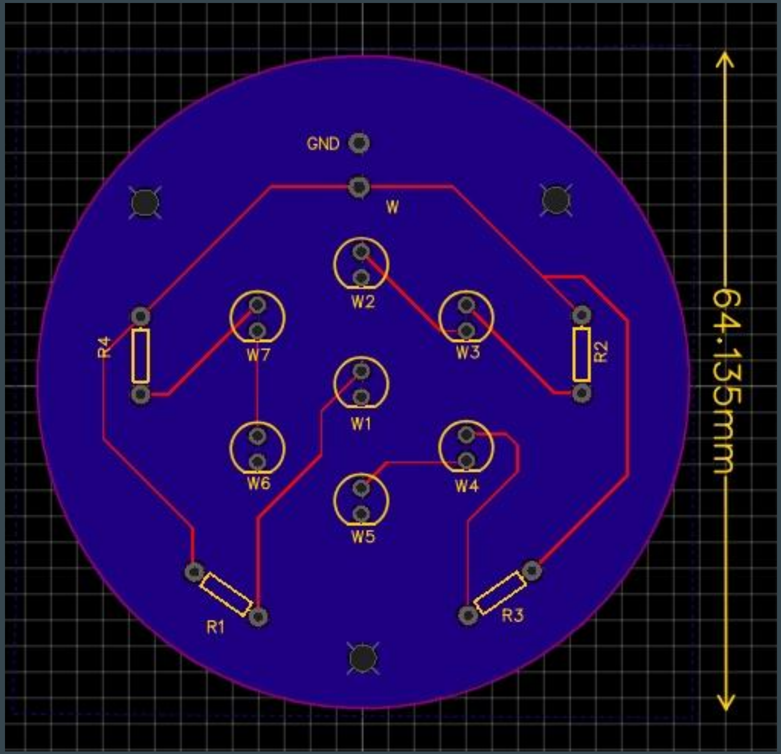
Above LED PCB Design



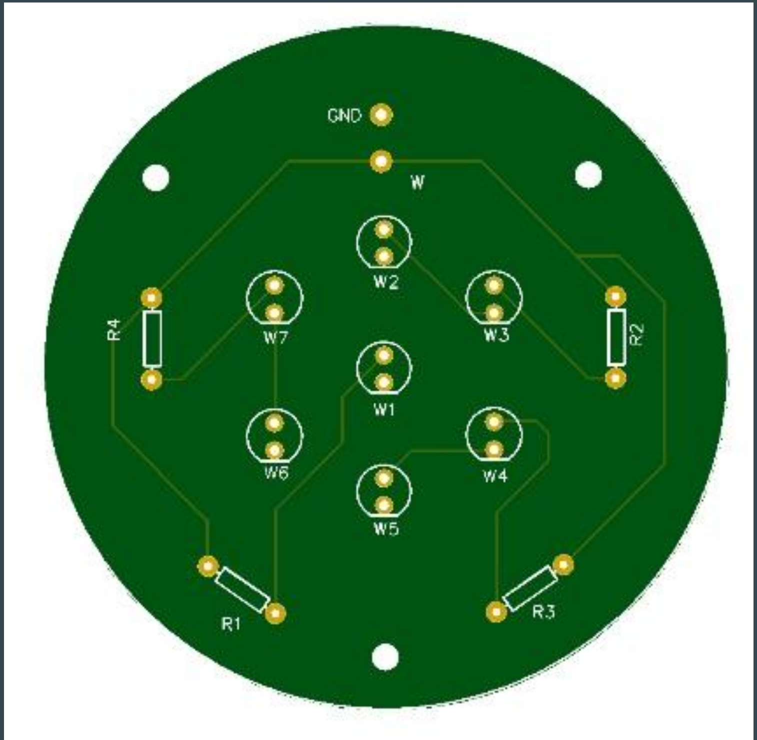


Base LED Design

- Used for illuminating slide samples from below
- Seven diffused LEDs powered by a 9V Li-Ion battery
- Removable disc with diffusion filter evenly distributed light

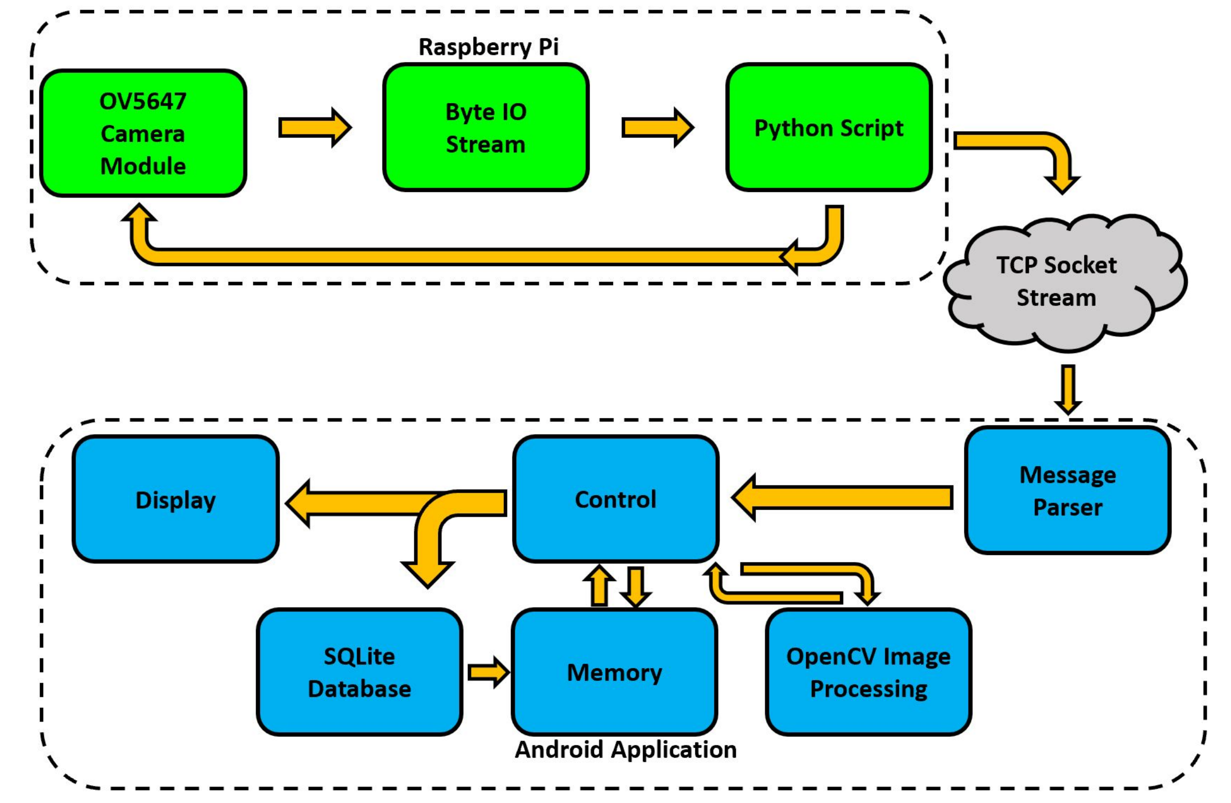


Base LED PCB Design



Software Designs

Software Block Diagram



Raspberry Pi Image Acquisition

- Python script that grabs images from OV5647 camera module
- Socket connection is established
  - JPEG images are sent over socket connection
  - ~40 FPS is attainable using this method
- Script is started as a service when the Pi boots up
  - Allows the script to be run headlessly

Mobile Application Overview

- Android Application
  - Written in Java
  - SQLite, OpenCV
- Connect, Stream, Modify, Store
- Image Processing, Data Storage/Manipulation

Mobile Application Wi-Fi

- Wireless Access Point (WAP) hosted on Raspberry Pi
  - Range & stability benefits
- Why WAP instead of Wi-Fi direct?
  - Reliably connect devices with WAP
  - Connection process is much simpler for the user

Mobile Application Wi-Fi (Continued)

- Data received from Raspberry Pi
  - Sent via TCP socket connection
    - IP address, port number
  - Blocks of bytes are received
  - Bytes stored and encoded into JPEG format

User Interface Design

- Goal was simple and intuitive
  - Keep user experience in mind
  - Not overbearing
- Use-case
  - Classrooms, hobbyists
- Emphasis on launch to stream time
  - Core functionality is streaming

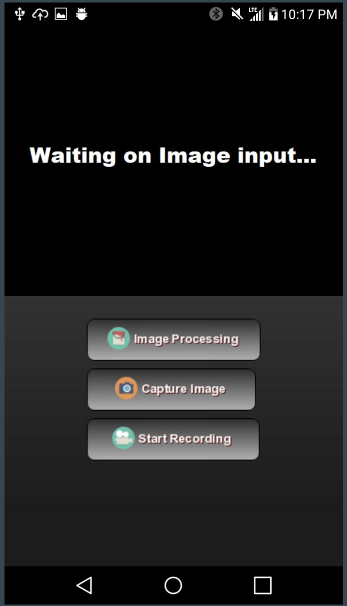


Image Processing

- OpenCV4 Android SDK
  - Massive Image Processing Library
    - Gaussian Blur, Edge Detection, etc.
- Performed directly on media files
  - Displayed in ImageView
- High level of granularity
  - Processing parameters can be fine-tuned

Data Storage

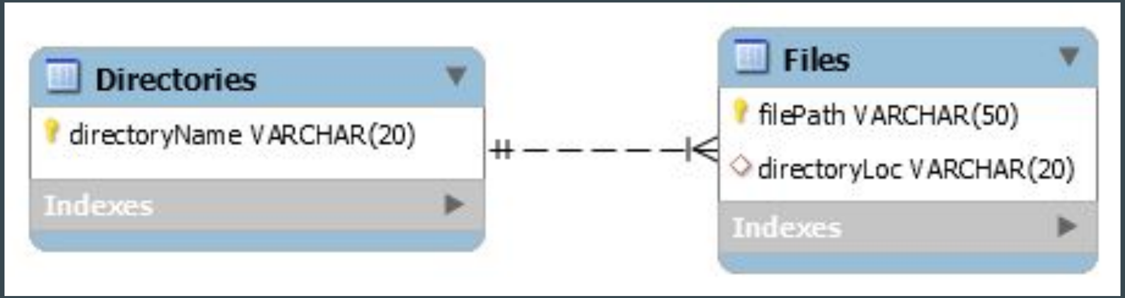
- Captured media files must be stored somewhere
  - Allow user to choose location and categorize as needed
- Device's external storage will be used
  - On Android OS, internal storage is only usable by app
  - User might want to access media outside of app
  - Files won't be deleted when the app is uninstalled

SQLite Data Storage

- SQLite
  - Relational Database Management System
  - Self-contained, no remote server needed
- Why SQLite?
  - Tagging allows for users to access files without having to view the entire filesystem
  - Remote database introduces unnecessary overhead

SQLite Schema Breakdown

- References to file paths will be stored
  - All files must have parent directory
  - If none specified, default is “Unfiled”
  - Dynamically updated when queried



Administrative Content

Work Distribution

	Optical System	PCB Design	Power Design	Body Construction	Mobile App	Image Processing
Cayla EE		P	P	S		
Hannah PSE	P			P		
Austin CS					P	P

Research Costs

Product	Price
Pocket Microscope	$14
USB Microscope	$32
Raspberry Pi accessories	$26
Raspberry Pi	$43
Camera Module	$45
PCBs	$60
Circuit Parts	$45
5mm white LEDs	$5
Ribbon Cable	$6
Pi Case	$8
Optical Design	$88
Objective Lenses	$48
Li-Ion Batteries (3 sets)	$43
Charger	$18
USB cable	$8
Acrylic	Donated by CREOL machine shop
Delrin	Donated by CREOL machine shop
Sample Slides	$31
Android Program	$25
Battery Packs	$15
Total	**$560**

Production Costs

Product	Price
Raspberry Pi	$43
Camera Module	$15
PCBs	$30
Circuit Parts	$15
5mm white LEDs	$5
Ribbon Cable	$6
Pi Case	$8
Optical Design	$88
Objective Lenses	$48
Li-Ion Batteries	$14
Charger	$18
USB cable	$8
Application	$5
Acrylic	$20
Delrin	$5
Total	**$328 per unit**

Issues

- Electrical
  - Working with new components and custom footprints
  - Overall PCB design software
  - Wire solder connections
- Optical
  - Mechanical Design
  - Increasing contrast for better images
- Computer Science
  - Designing UI so that it is intuitive but still looks sleek
  - Minor bugs in connection process

Upcoming

- Electrical
  - Working with wire connections to ensure stable wiring
- Optical
  - Demoing the microscope for kids in the community
- Computer Science
  - Work on allowing multiple connections at once

Questions?

Microscope Embedded Systems

Adam Bush - Computer Engineer

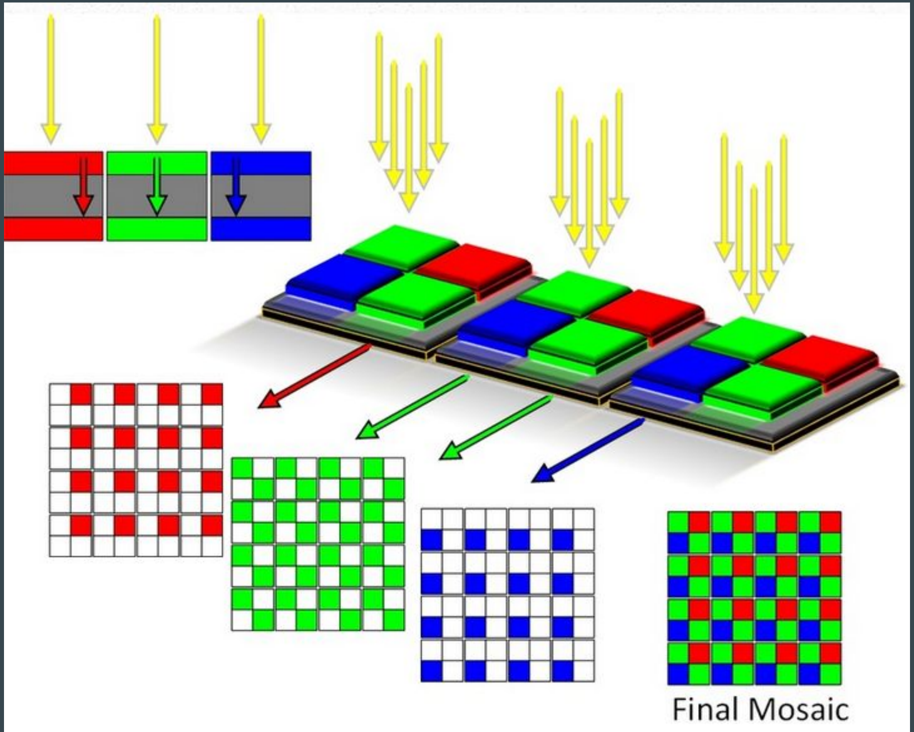
Image Sensor - AR0237IR

- Capable of sensing near-IR light
- 12-bit, parallel data output (synchronous)
- 30FPS at its maximum 1080P (with parallel output)

One other similar sensor was found on the market, the OV9738, but it had a 10-bit output (1/4th the output range of our choice)

Image Sensor - AR0237IR

Standard Sensor Matrix [ref 1]

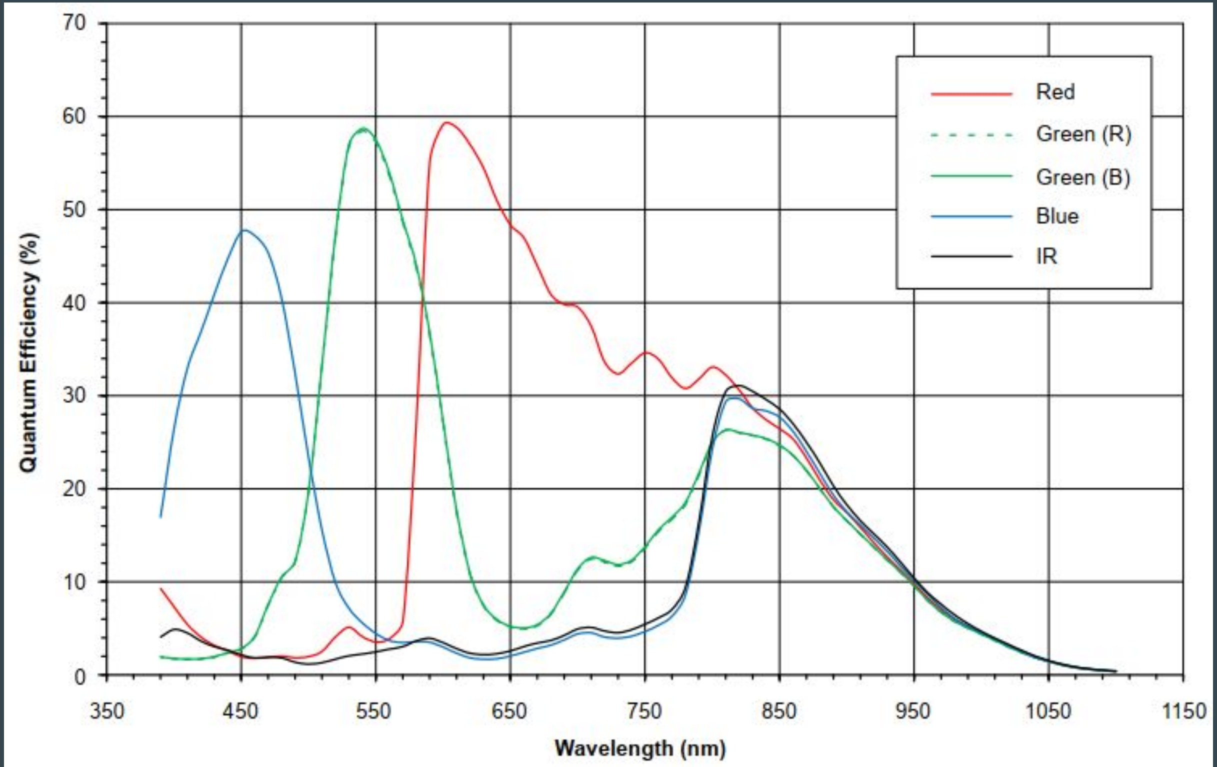


AR0237IR Matrix [ref 2]

B	G	R	G	B	G	R	G
G	IR	G	IR	G	IR	G	IR
R	G	B	G	R	G	B	G
G	IR	G	IR	G	IR	G	IR

Image Sensor - AR0237IR

Sensor Sensitivity [ref 2]



STM32H753ZI - Microcontroller

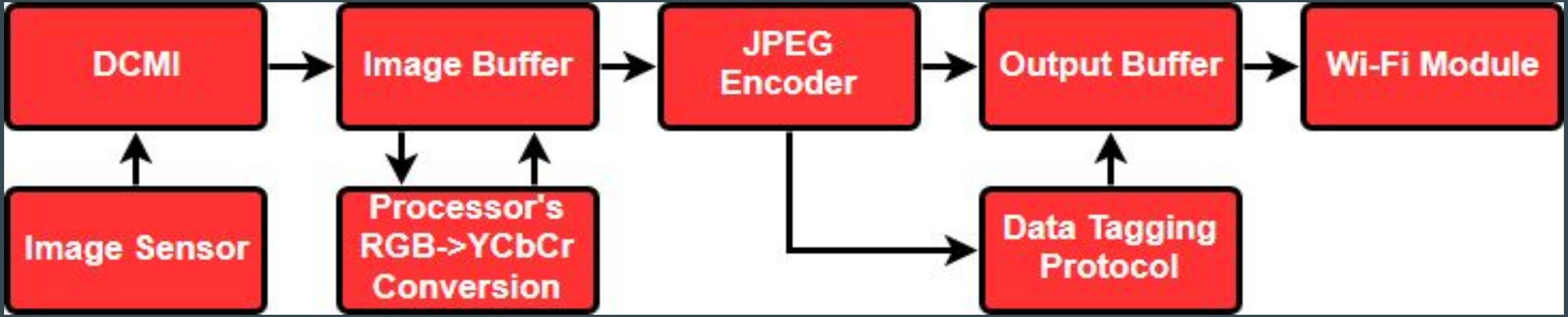
- 400MHz superscalar ARM Cortex-M7 core
- 1MB of RAM with further 2MB R/W Flash memory
- Embedded JPEG codec
- Direct Camera to Memory Interface
- Hardware Abstraction Layer library providing implementation assistance for most required tasks
- Supported, inexpensive development board, the NUCLEO-H743ZI

GS2101M Wi-Fi Module

- Dual-core ARM Cortex-M3, 120MHz, ~500kB RAM each
- 4-bit serial data interface (as SDIO slave)
- TCP throughput tests (Module to Receiver) > 1MB/s
    - Note: calculated throughput need of approx. 700kB/s
- Supports Wi-Fi Direct and (currently unused, needed for a realized product release) encryption

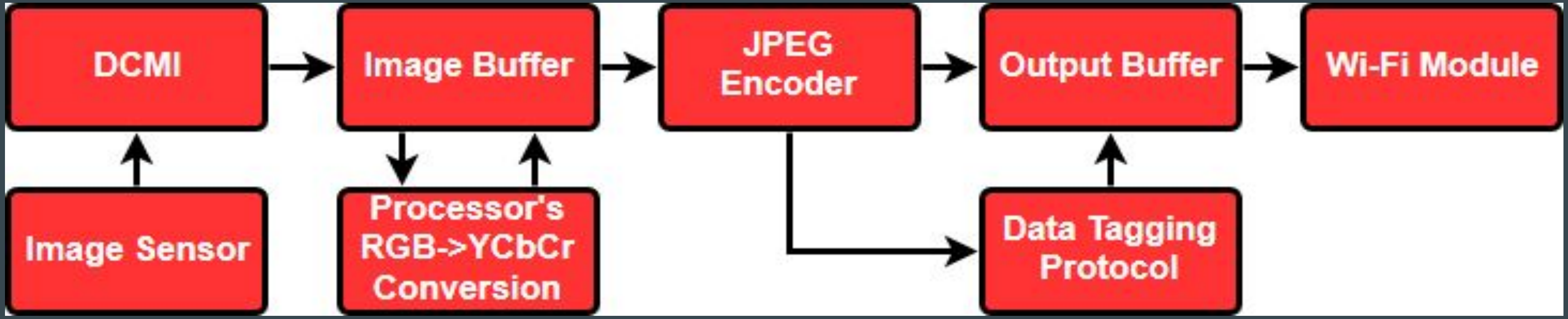
MCU Program Flow (Part 1)

1. DCMI transfers incoming image to 512kB buffer
2. DMA transfers in-memory image to processor's tightly-coupled memory (block by block)
3. Processor converts RGB to YCbCr (for JPEG step)
4. DMA returns data to JPEG encoder buffer



MCU Program Flow (Part 2)

5. Processor triggers JPEG encoding, which takes ~4ms
6. DMA transfers converted image to output buffer (2x128kB)
7. Processor adds header (for mobile application) and initiates transfer to Wi-Fi module



Wi-Fi Module Setup and Use

- Largely developed by configuring manufacturer’s SDK
- Programmed through UART by host microcontroller
- Dual-Interface configured through human-readable AT Commands sent by UART
- Wi-Fi connection initiated by prompt
- Data transfer initiated by UART prompt, carried out over 4-lane serial (SDIO) interface
- Further development and use of the module’s limited processing capabilities is not planned

References

1. "Analogue Video Capture", https://www.causewaysecuritysolutions.com/analogue-video-capture.html
2. AR0237 series product overview