# AUDIOVISIBLE

## An Audiovisual Spectrum Analyzer for an Underserved Audience

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Final Presentation

UCF – Senior Design – Fall 2020

Group 3




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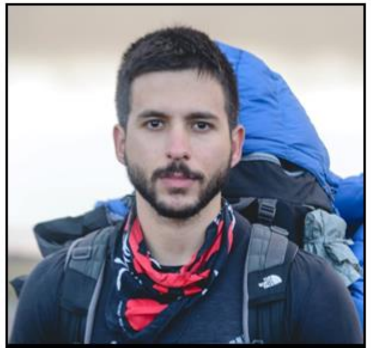
# Motivations

Art is an inherent part of the human condition.

There are still certain forms of art that certain demographics are unable to experience and ultimately enjoy.

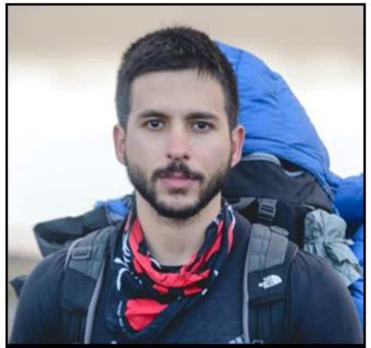
Music is an amazing and enjoyable experience.

People who are deaf or hard-of-hearing can’t enjoy music.


Gus Monaco, CpE

# Objective

To serve an underserved audience, and serve it well, by delivering the visual experience of music.



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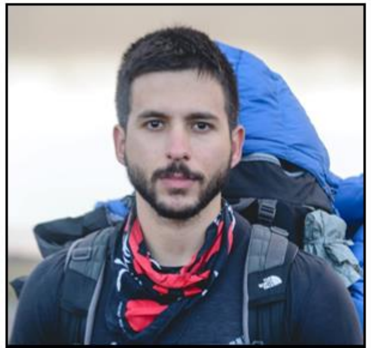
# Features

**CORE**

- Multi-color display
- Audio output

**ADVANCED**

- Waveform Simulation
- Graphic Equalization



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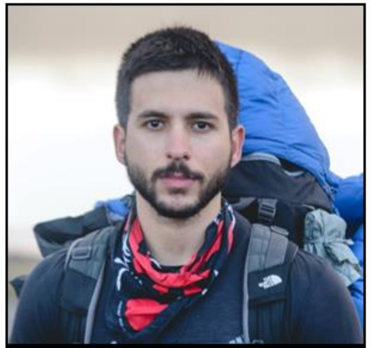
# THE DEVICE



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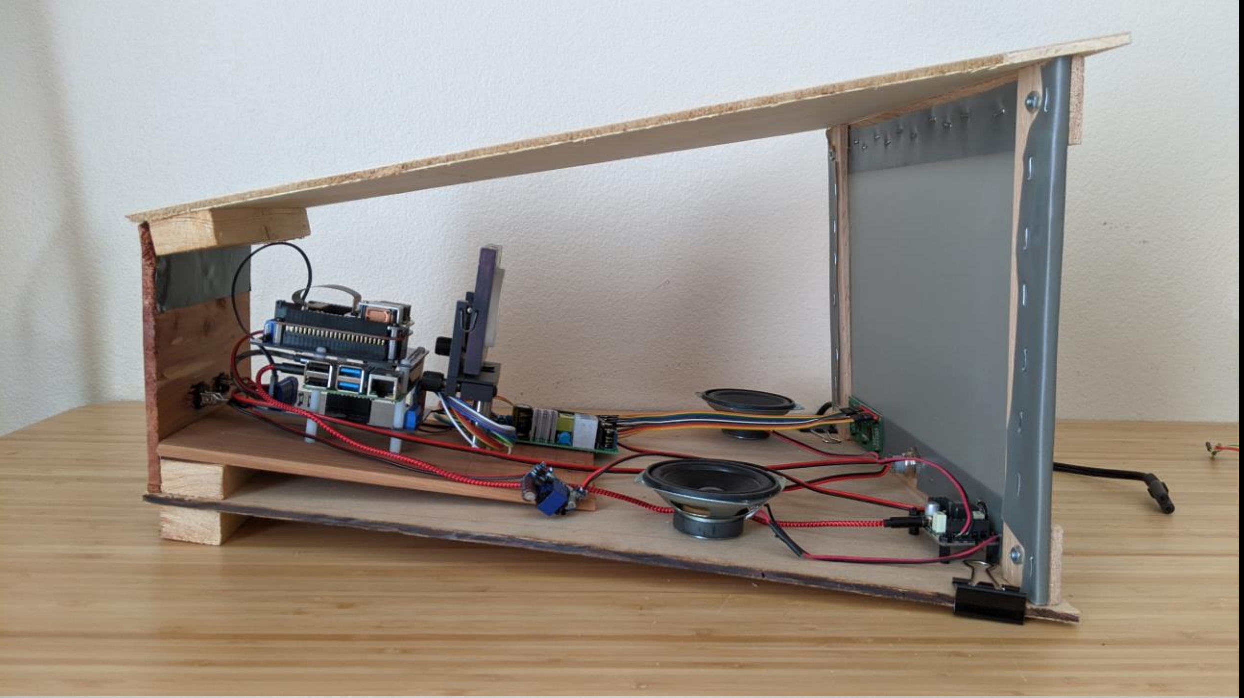

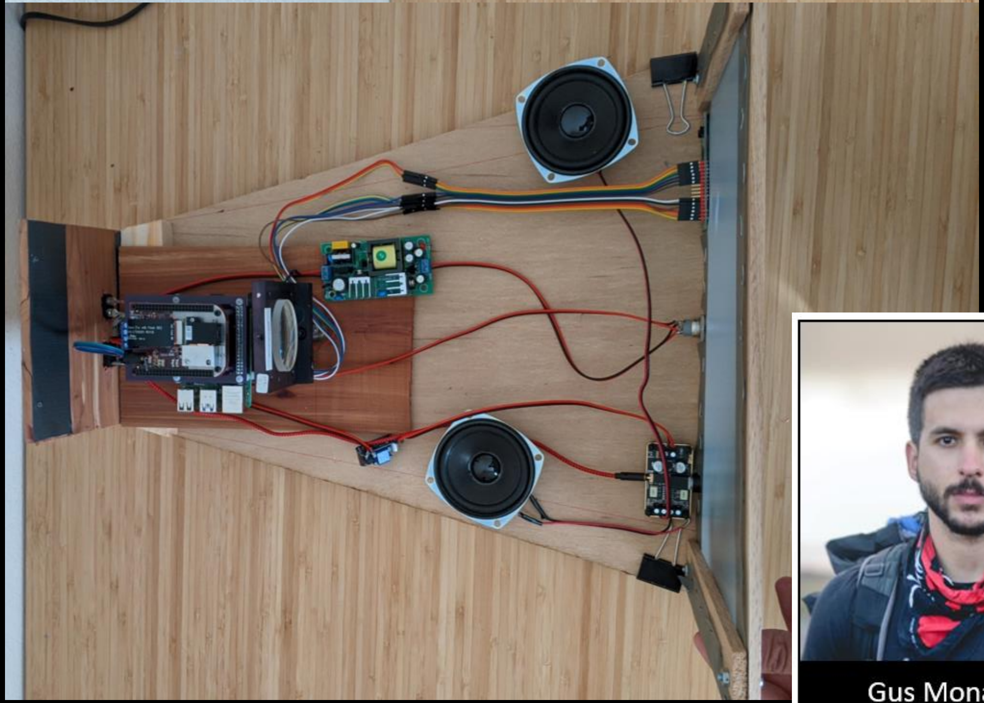

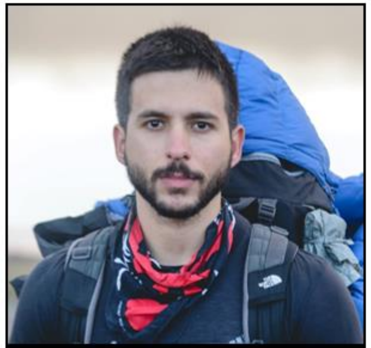

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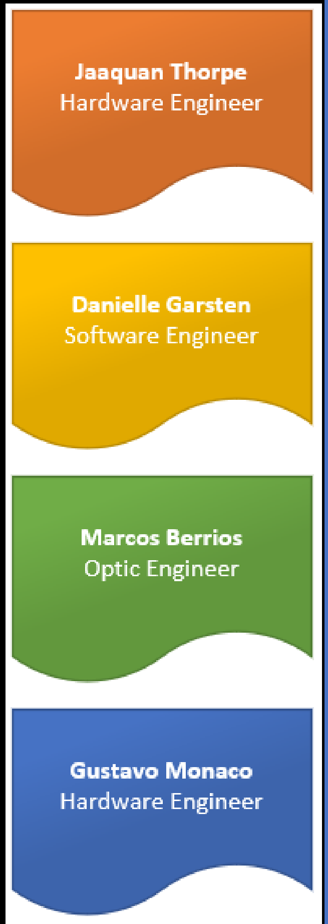
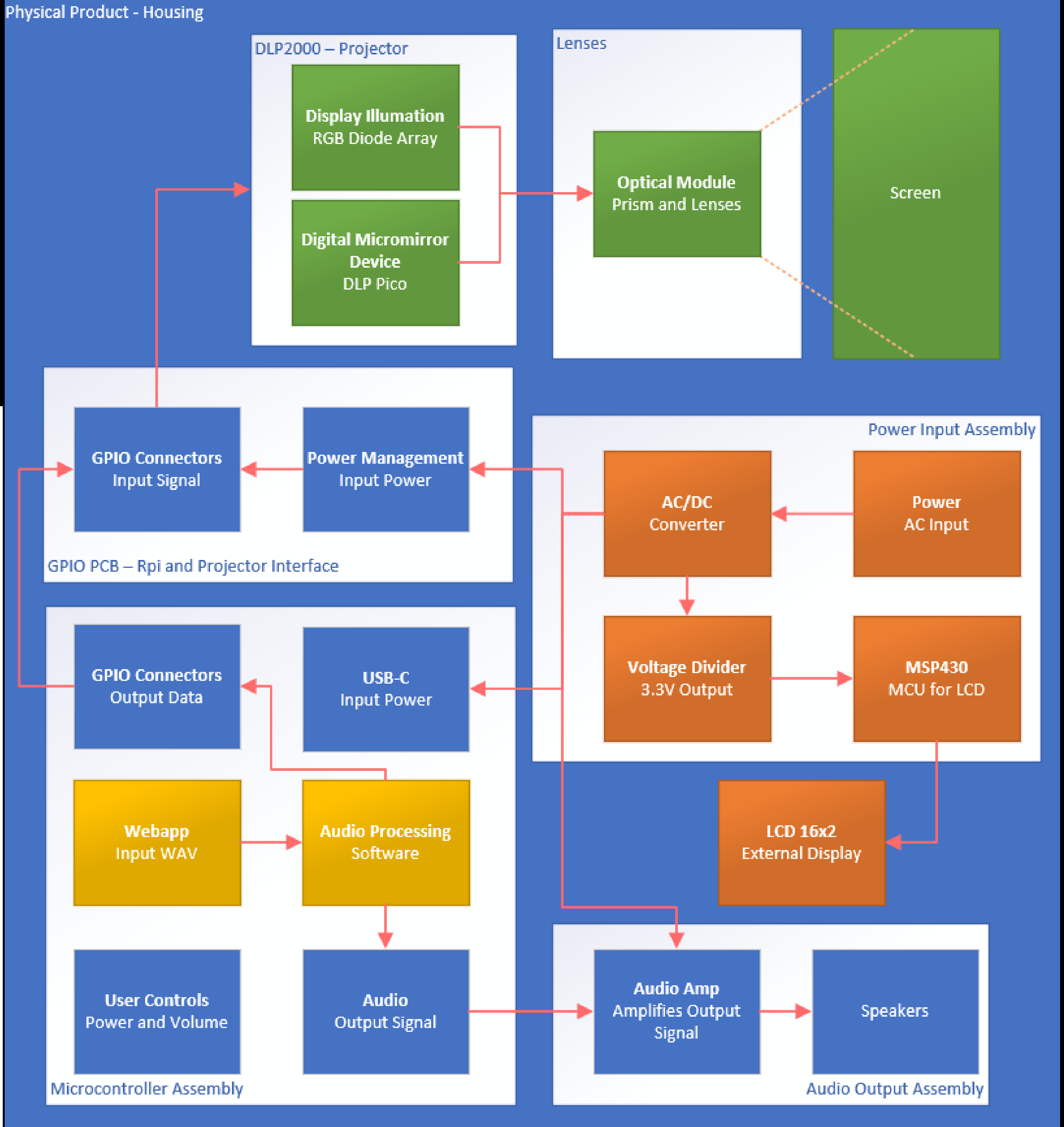
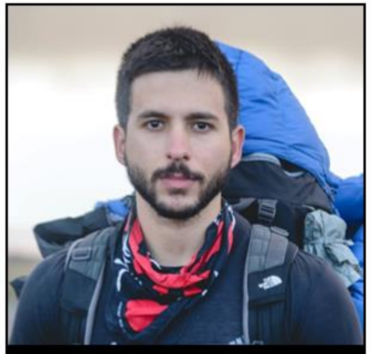
# Block Diagram



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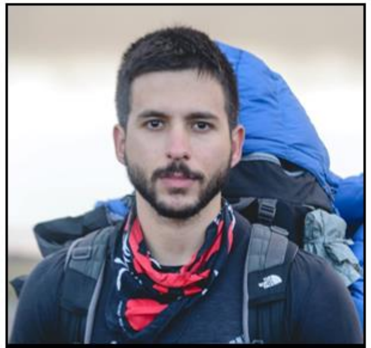
# Raspberry Pi 4 – System On a Chip

WiFi
Audio Input


Video
Output

| | | | |
|---|---|---|---|
| 3.3V | | | 5V |
| GPIO2 SDA | 8 | | 5V |
| GPIO3 SCL | 9 | | |
| GPIO4 | 7 | 15 | TX GPIO14 |
| | | 16 | RX GPIO15 |
| GPIO17 | 0 | 1 | GPIO18 |
| GPIO27 | 2 | | |
| GPIO22 | 3 | 4 | GPIO23 |
| 3.3V | | 5 | GPIO24 |
| GPIO10 MOSI | 12 | | |
| GPIO9 MISO | 13 | 6 | GPIO25 |
| GPIO11 SCLK | 14 | 10 | CE0 GPIO8 |
| | | 11 | CE1 GPIO7 |
| ID_SD | 30 | 31 | ID_SC |
| GPIO5 | 21 | | |
| GPIO6 | 22 | 26 | GPIO12 |
| GPIO13 | 23 | | |
| GPIO19 | 24 | 27 | GPIO16 |
| GPIO26 | 25 | 28 | GPIO20 |
| | | 29 | GPIO21 |



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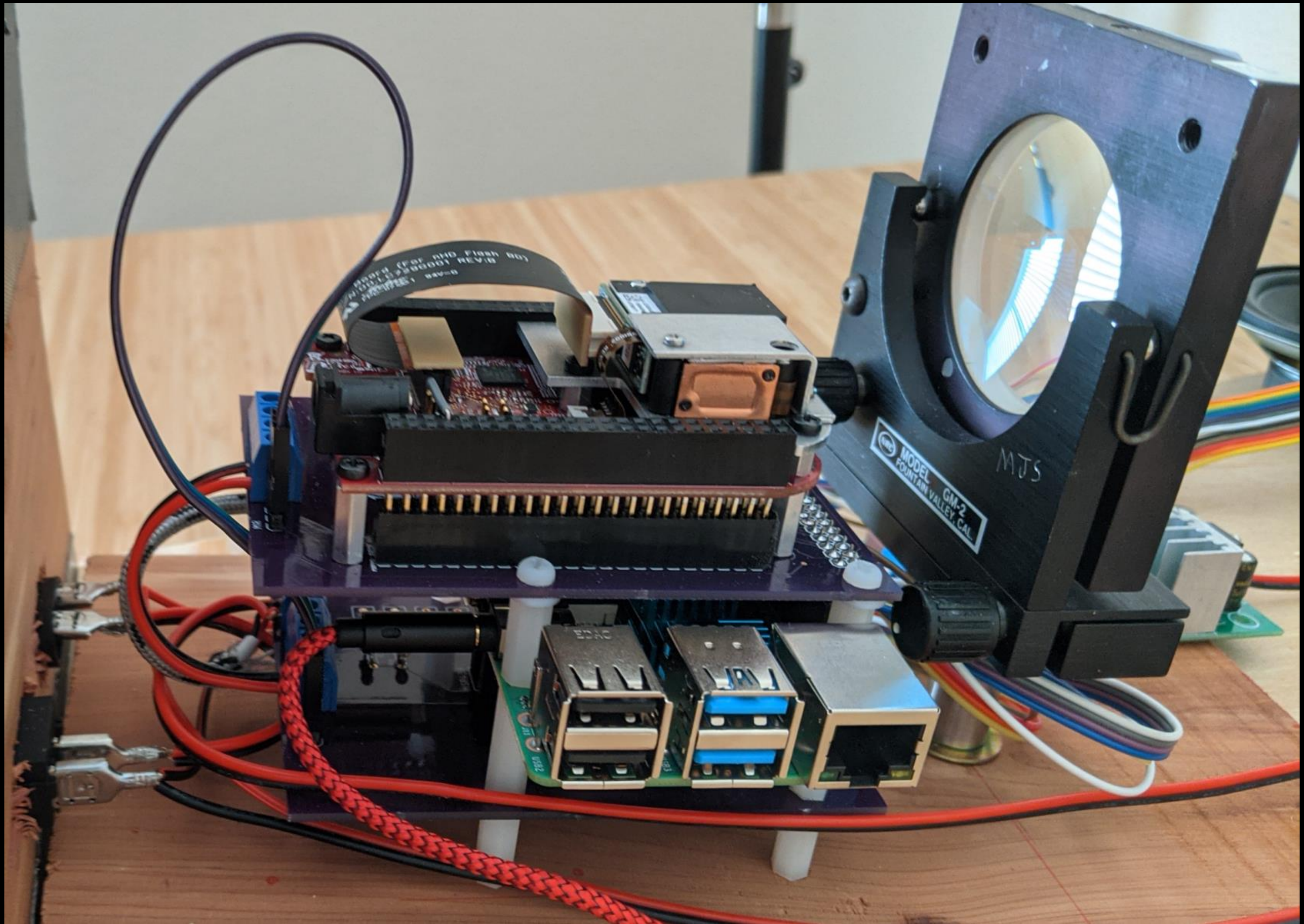
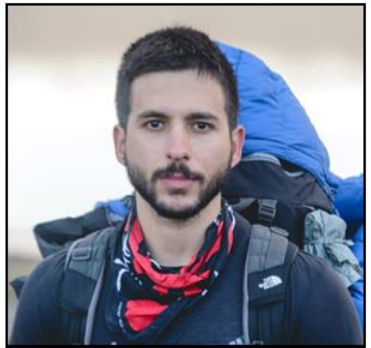
# The Component Stack

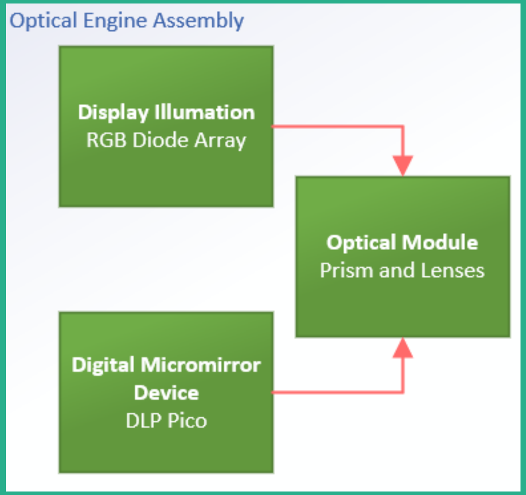


Gus Monaco, CpE

# Marcos Berrios, PSE
# College of Optics and Photonics

- Experience in diffraction-based optical metrology tools
- Current focus in diffractive waveplate technology
- Background in music theory and performance

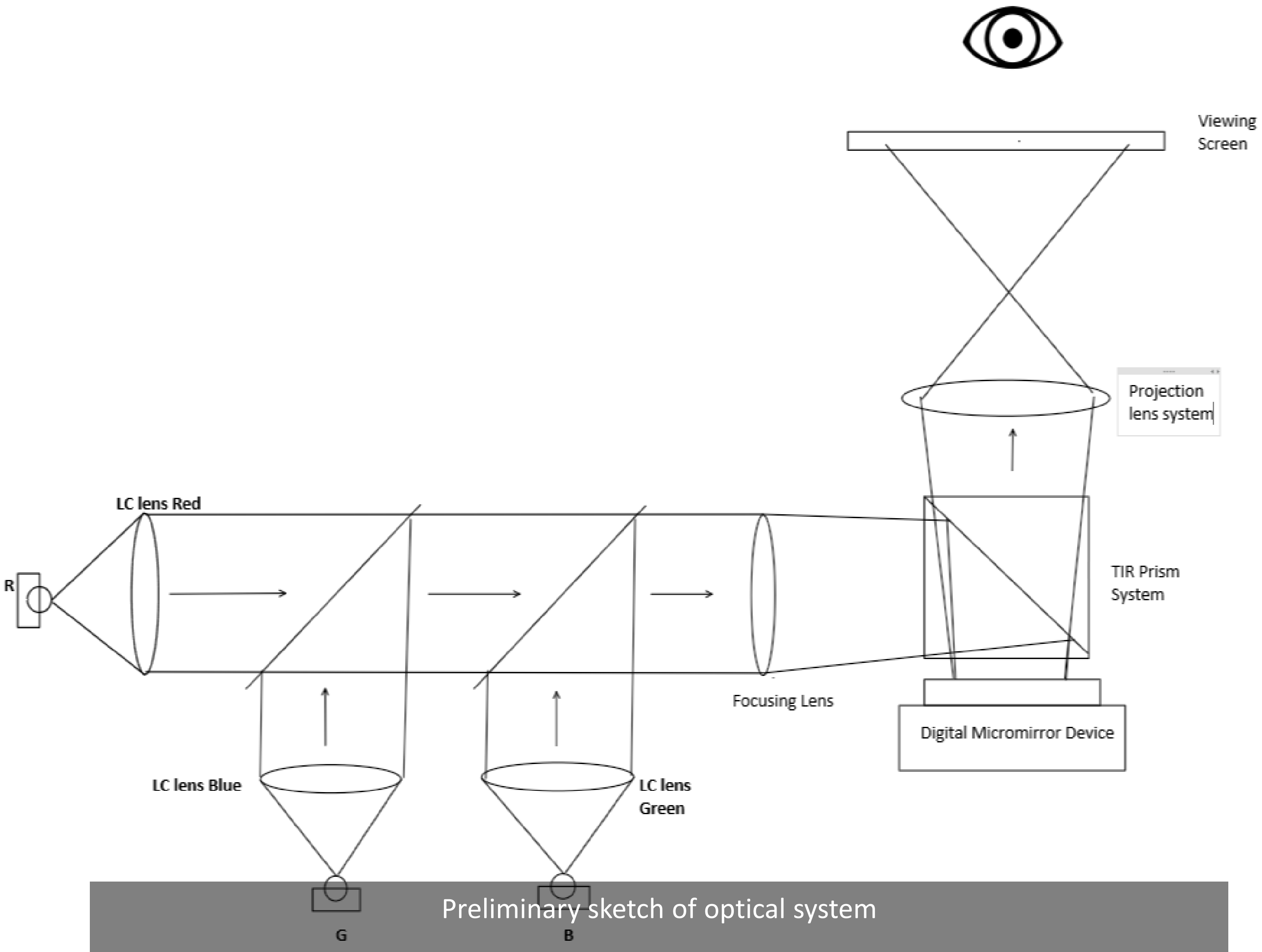



# Optical Engine

# Optical Engine: Overview

The optical engine is a modification of existing Digital Light Processing (DLP) technology.

It takes an image produced by a projector purchased from Texas Instruments, expands the image and projects it through a viewing screen




Preliminary sketch of optical system

# Optical Engine:

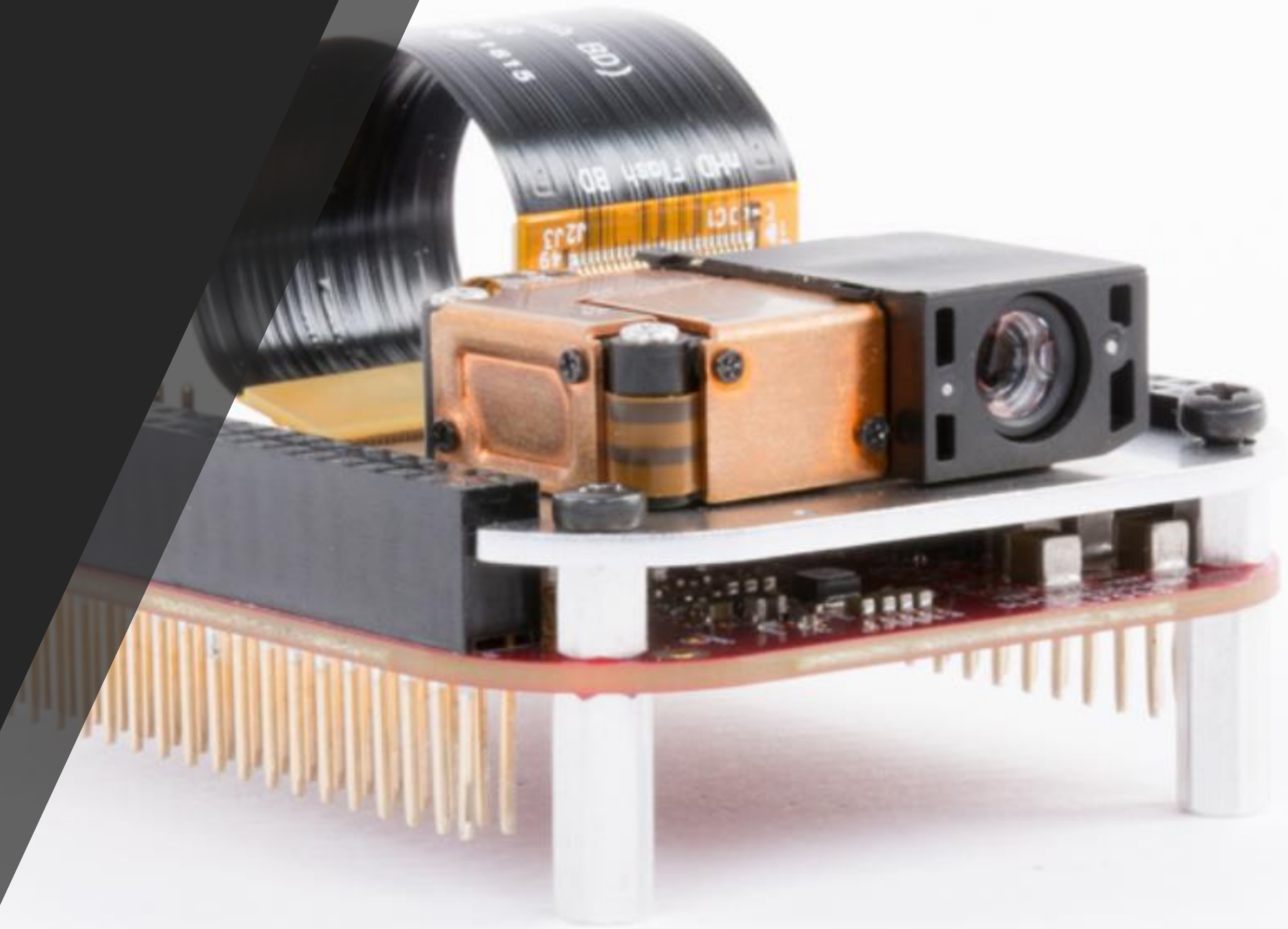
## The Expectation

- Production of an image is critical to the success of the project
- The colors should be bright and easily identifiable
- The image should be bright enough to view by the unassisted eye

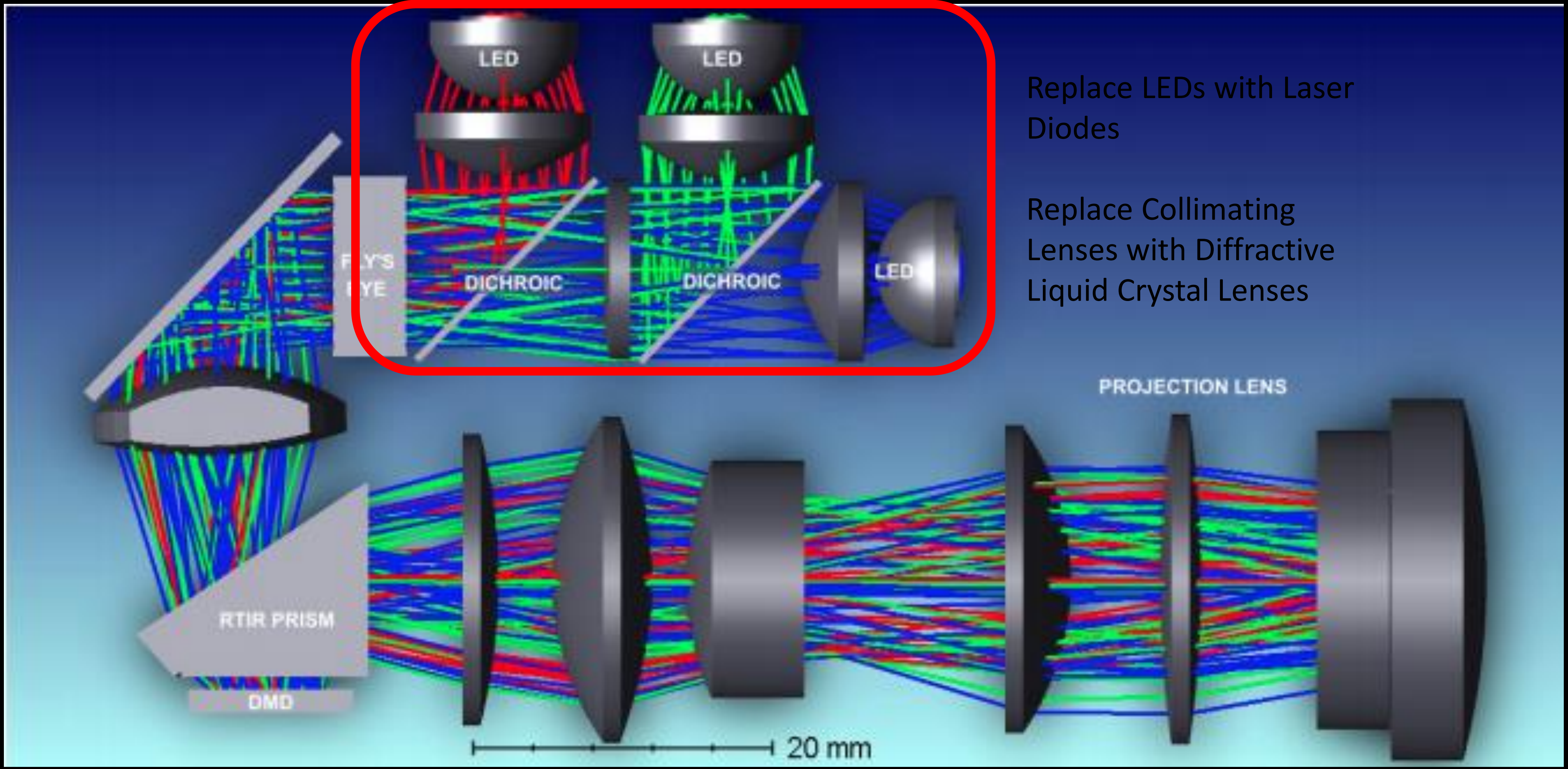
# Optical Engine: The initial plan

We purchased a pocket projector kit from Texas Instruments and intended to utilize the DMD chipset inside, while replacing the illumination optics with optics of our own

- Replacing the illumination LEDs with RGB laser diodes
- Replacing the optics inside with diffractive waveplate lenses provided by BEAM Co., fabricated by the students
- Introduce a beam expansion system to the front of the finished device to shorten the focal plane and enlarge the final image



# Zemax Rendering of the Original Projector System*




Replace LEDs with Laser Diodes

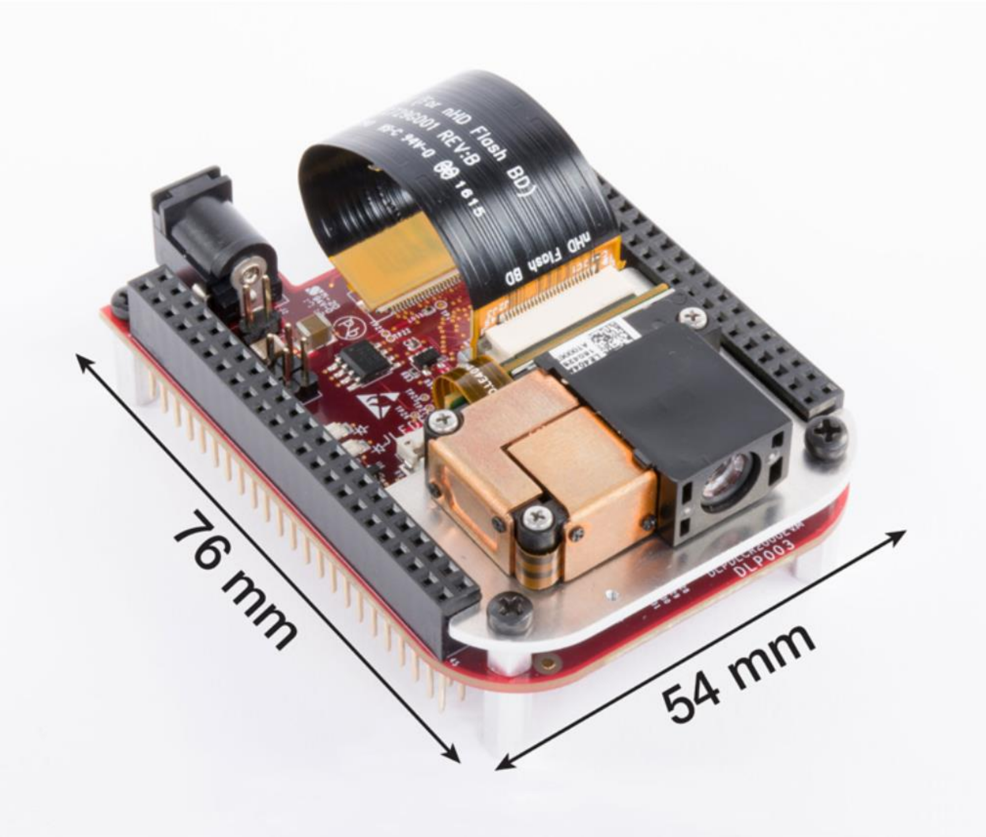
Replace Collimating Lenses with Diffractive Liquid Crystal Lenses

# Lens Design: The Challenge

For proper illumination of the display elements, lasers need to be collimated to a beam diameter no smaller than 5mm. This means that ideally each laser will have a lens with a focal length tuned specifically to it.

Focal lengths

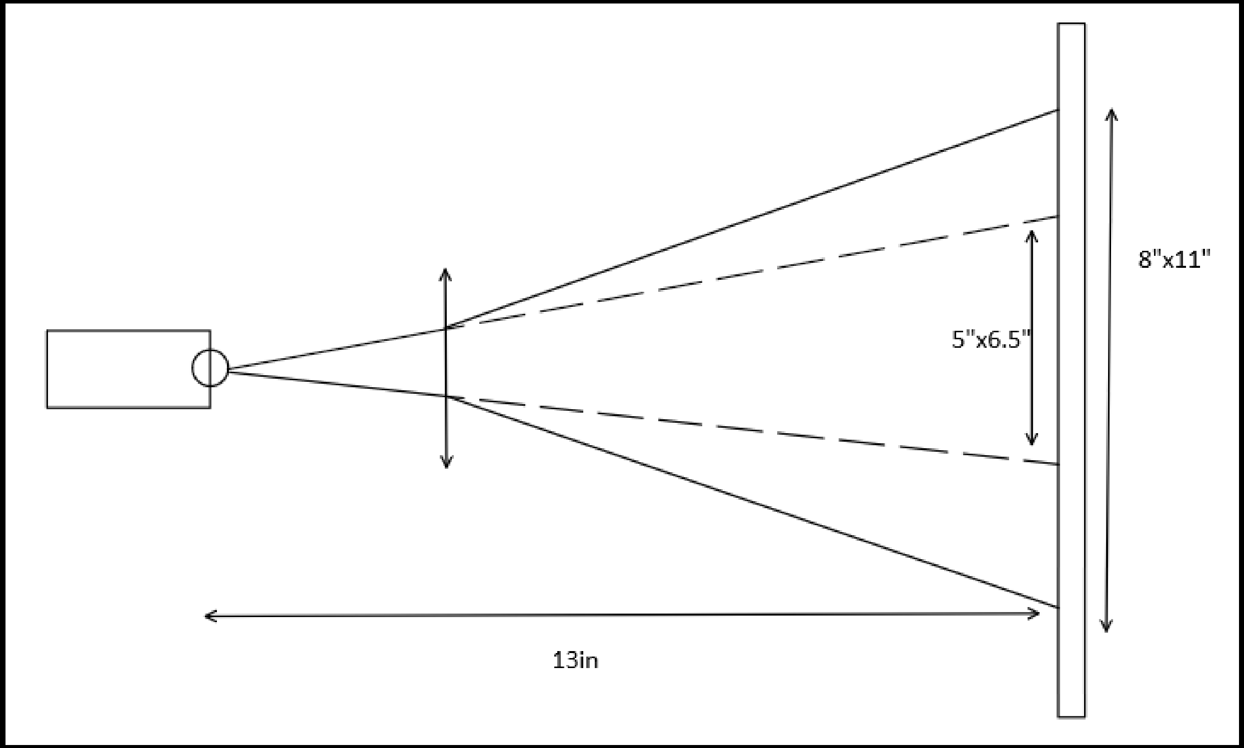
- Red (Slow axis divergence = 7˚): 20 mm focal length
- Green (Slow axis divergence =  5˚): 28 mm focal length
- Blue (Slow axis divergence =  10˚): 14 mm focal length



# Lens Design: Image Expansion

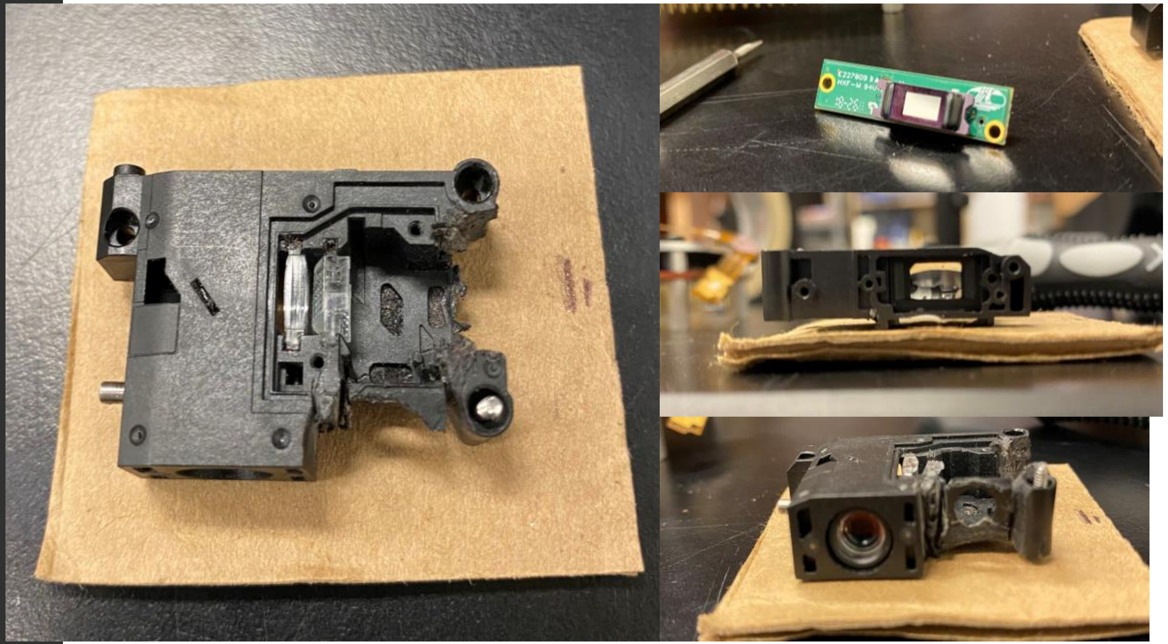
The projector has way too large of a throw ratio. This means that the light exiting the projector does not diverge quickly enough to make a sufficiently large image at short distances.

- Introduce a negative lens at the front of the system which will diverge the light, making it form a larger image at distances between 9”-13”
- Can be small, placed right in front of the projector



# Optical Engine: Issues Encountered

- After disassembling the projector, we found that the diodes could absolutely not be replaced.
- Diffractive optics promised by sponsor could not be fabricated
- Disassembly of projector damaged LED illumination system beyond repair
- Delays in delivery of optics hindered testing for several weeks



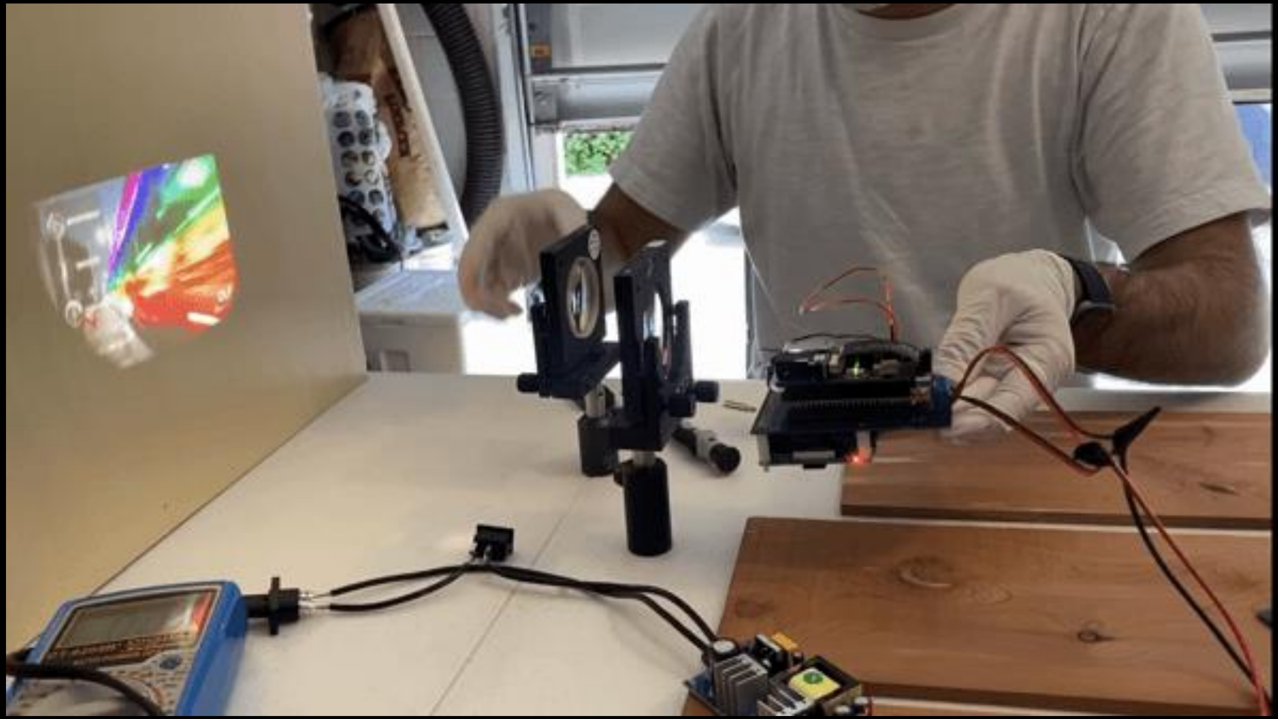
# Optical Engine: Enlargement and Testing

Initial design consisted of a single negative lens EFL = -50mm

- Failure: Although image expanded, it was not at all in focus.
- The lens was too small to be inserted anywhere but directly in front of the projector

Secondary design after calculation consisted of two lenses EFL = -250mm and EFL = 50mm

- Success: The positive lens first focused the light, creating a new virtual object that the second lens could then expand much less rapidly than the previous -50mm EFL lens



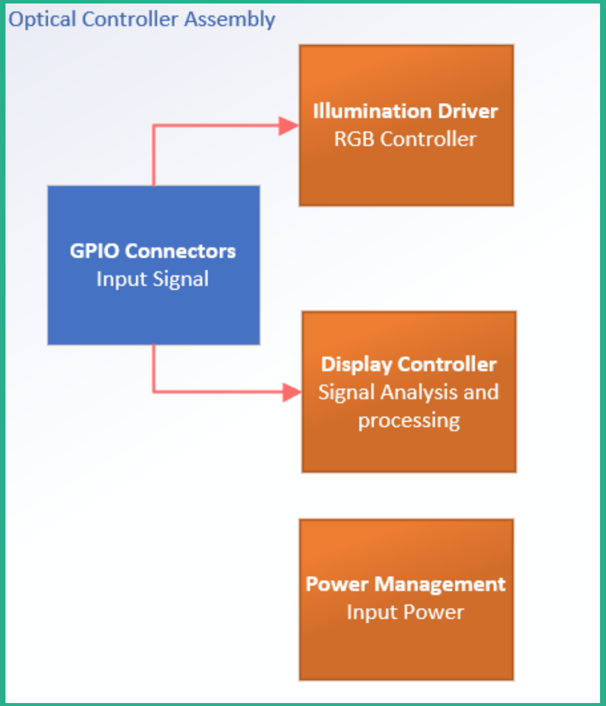
# Optical Engine: Final Design

- Consists of:
  - LED Illuminated, DLP powered mini-projector
  - 50mm EFL lens to provide focus
  - -250mm EFL lens to expand the image
- Produces 8”x11” image at 13” from the nose of the projector
  - Roughly 1.5x magnification

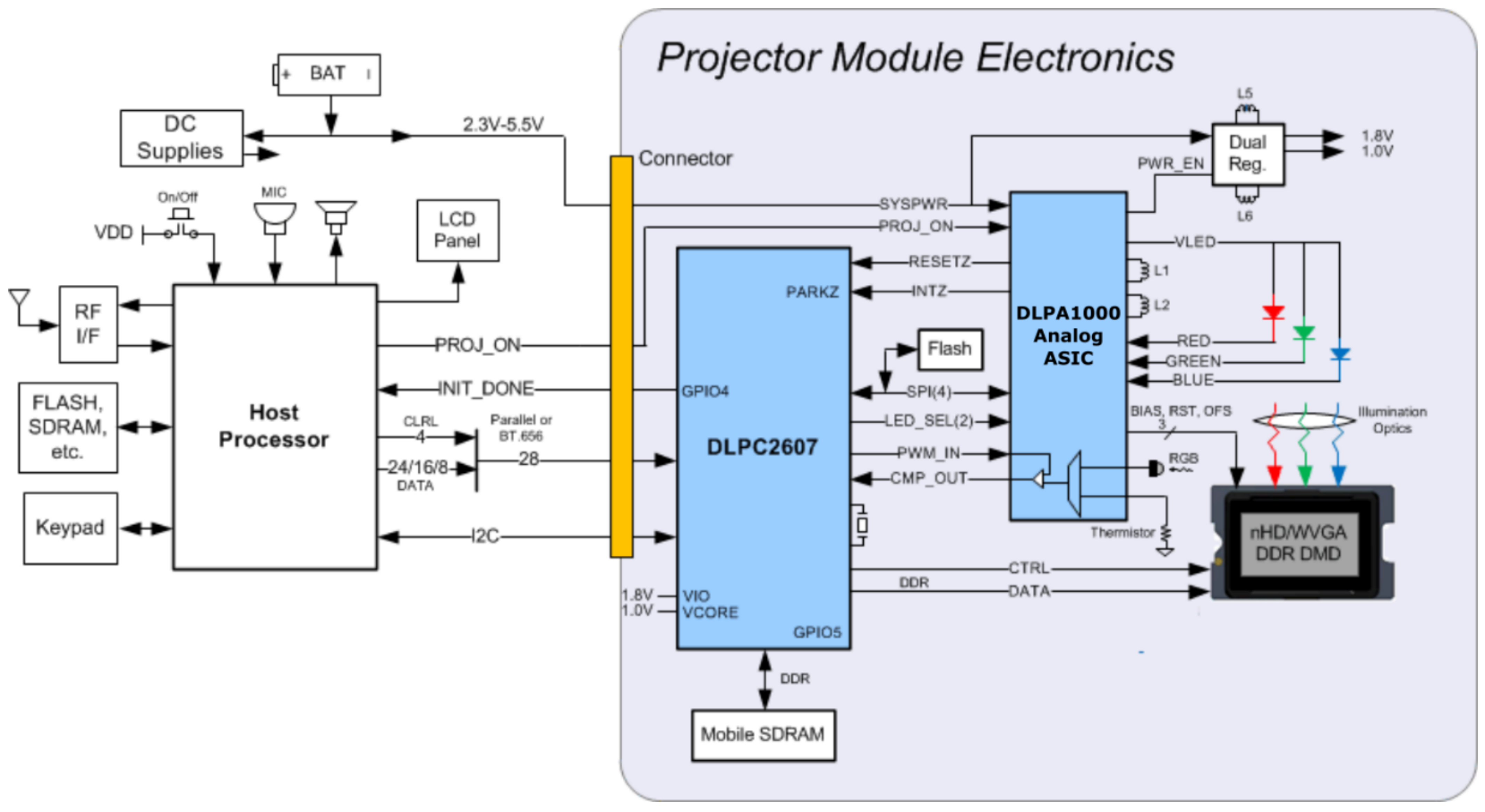
# Jaaquan Thorpe, CPE Department of Electrical and Computer Engineering

Area of focus:

- Embedded Systems
- Web Development
- Cloud Computing




# Optical Controller



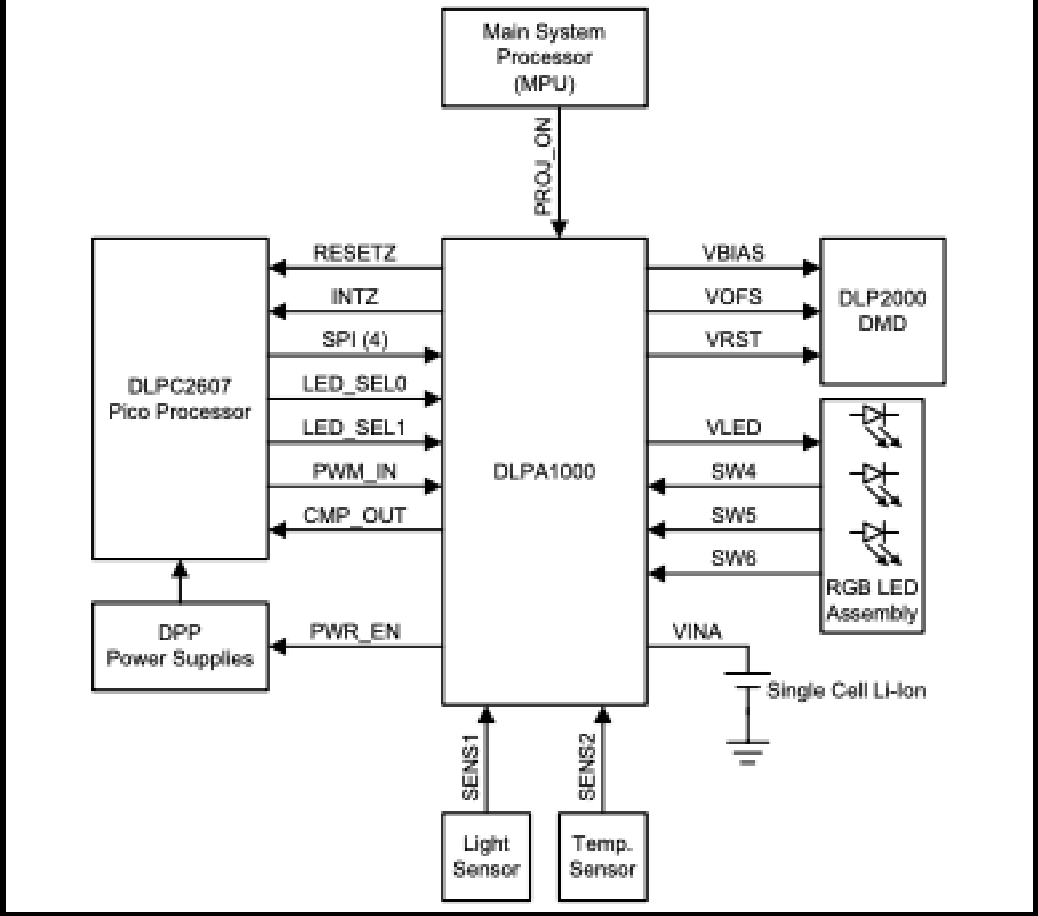
Projector Module Electronics
BAT
DC Supplies
2.3V-5.5V
Connector
On/Off
VDD
MIC
LCD Panel
RF I/F
FLASH, SDRAM, etc.
Keypad
Host Processor
PROJ_ON
INIT_DONE
CLRL
4
Parallel or BT.656
24/16/8 DATA
28
I2C
SYSPWR
PROJ_ON
RESETZ
INTZ
PARKZ
GPIO4
DLPC2607
Flash
SPI(4)
LED_SEL(2)
PWM_IN
CMP_OUT
DLPA1000 Analog ASIC
Dual Reg.
PWR_EN
L5
L6
1.8V
1.0V
VLED
L1
L2
RED
GREEN
BLUE
BIAS, RST, OFS
3
Illumination Optics
RGB
Thermistor
nHD/WVGA DDR DMD
CTRL
DDR
DATA
1.8V
1.0V
VIO
VCORE
GPIO5
DDR
Mobile SDRAM


# DLPC2607 Controller

- Low-powered digital controller for display applications
- Supports Pixel Clock up to 33.5MHz
- Supports up to 60Hz Frame Rates
- Must be used in conjunction with DMD for a reliable operation of the DMD
- Uses an external SPI serial flash memory device for configuration support.
- The device will be programmed over I2C.
- Has two functional modes controlled by a single pin:

1. If pin set to high, projector powers up and projects image.
2. If pin set to low, projector powers down to save power.


TEXAS
INSTRUMENTS

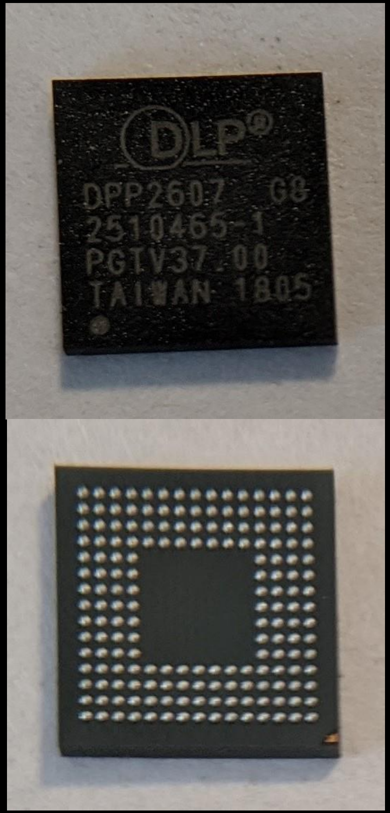

Main System
Processor
(MPU)
PROJ_ON
DLPC2607
Pico Processor
RESETZ
INTZ
SPI (4)
LED_SEL0
LED_SEL1
PWM_IN
CMP_OUT
DLPA1000
VBIAS
VOFS
VRST
DLP2000
DMD
VLED
SW4
SW5
SW6
RGB LED
Assembly
DPP
Power Supplies
PWR_EN
VINA
Single Cell Li-Ion
SENS1
SENS2
Light
Sensor
Temp.
Sensor

# DLP2000 0.2 nHD D

- Is a digitally controlled micro-opto-electromechanical system (MOEMS) spatial light modulator (SLM)
- With the proper optical system, a image or video is displayed
- Well-suited for portable equipment where small form factor and low power is importan
- Is an array of highly reflective aluminum micromirrors (up to 8 million mirrors).

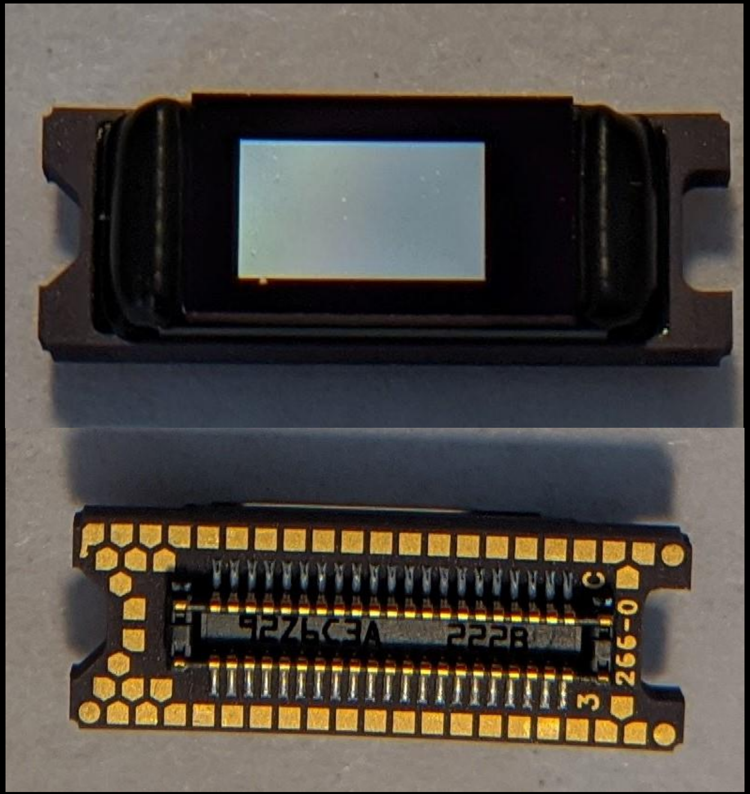
# DLP Optical Module

**DLPC2607 Controller**



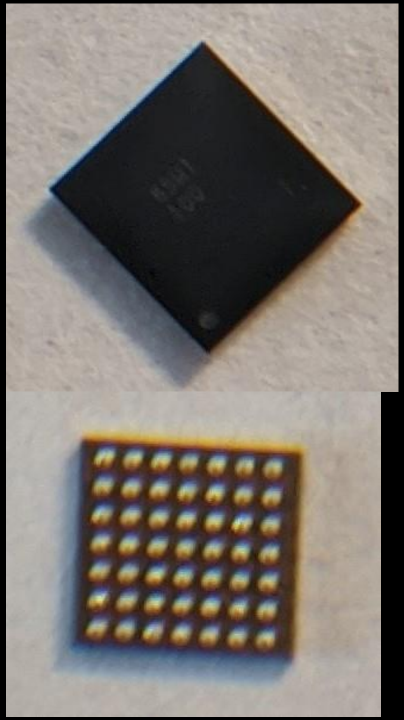

Digital Image Processor

**DLP2000 0.2 nHD DMD**



The display device producing the projected image.

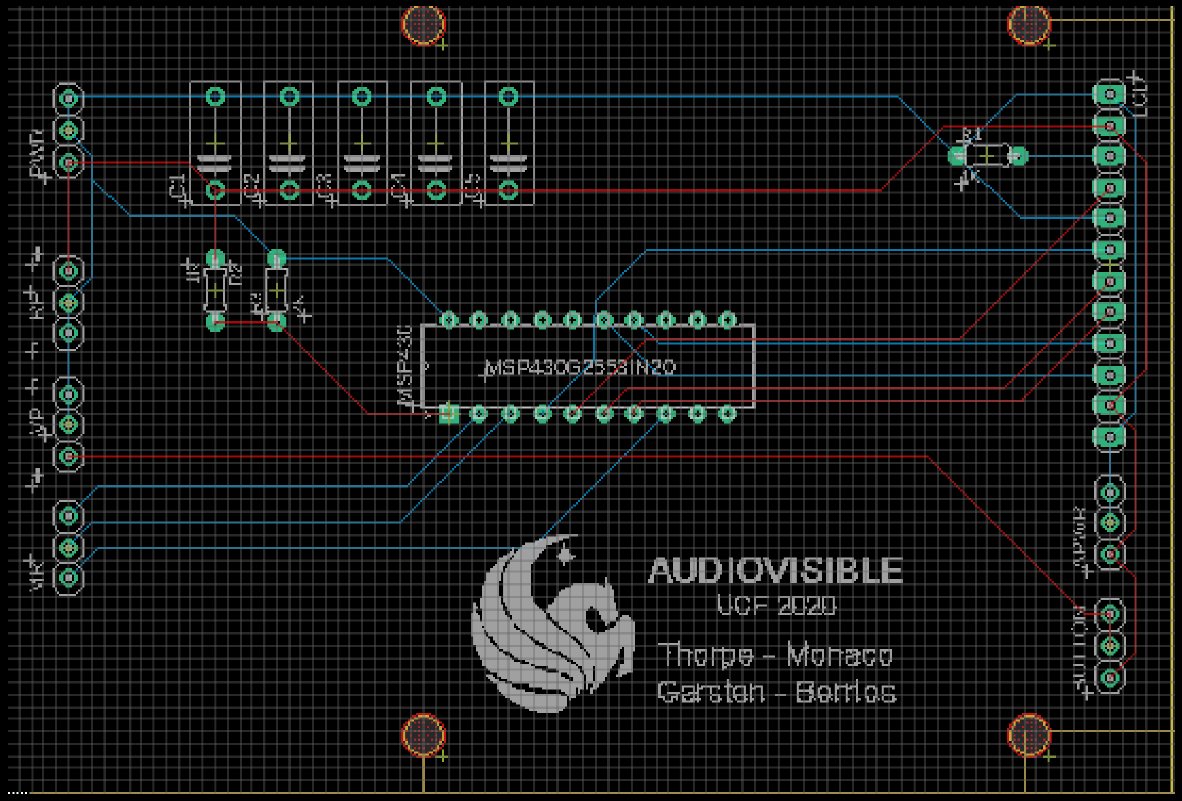
**DLPA1000 PMIC/LED Driver**

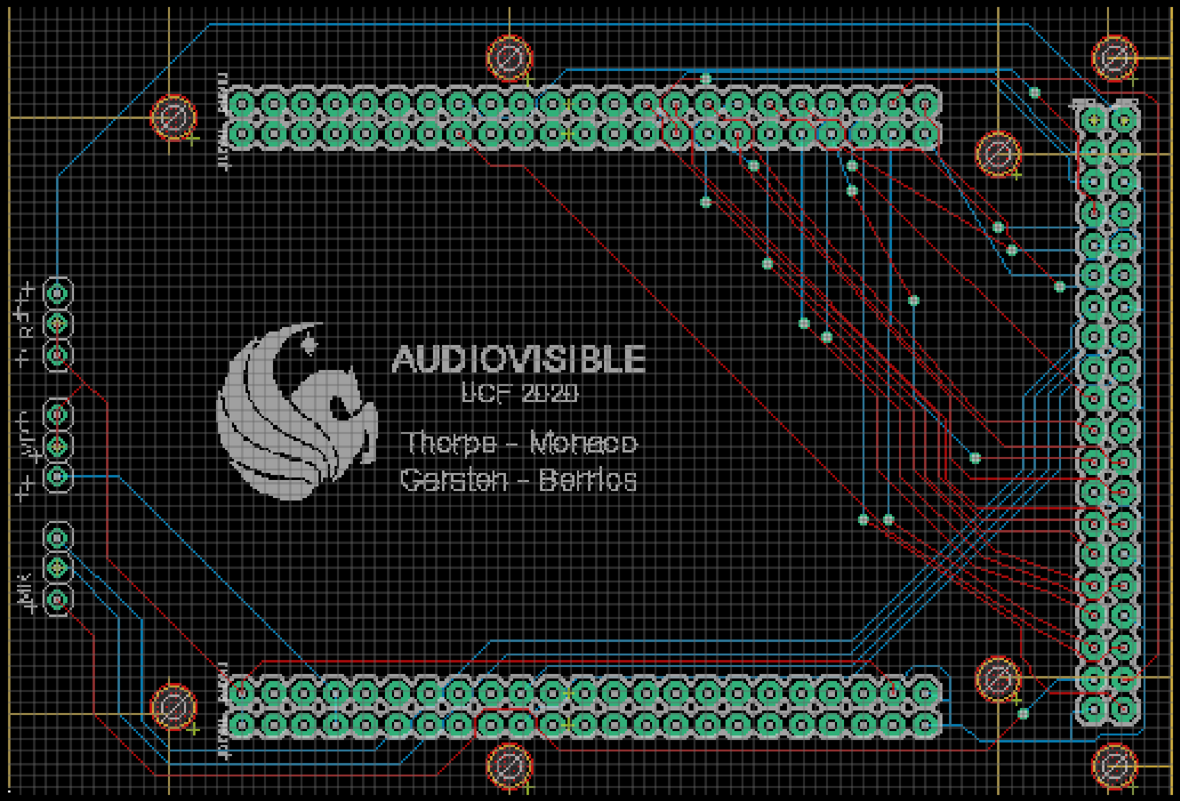


Provides the needed analog functions for the projector

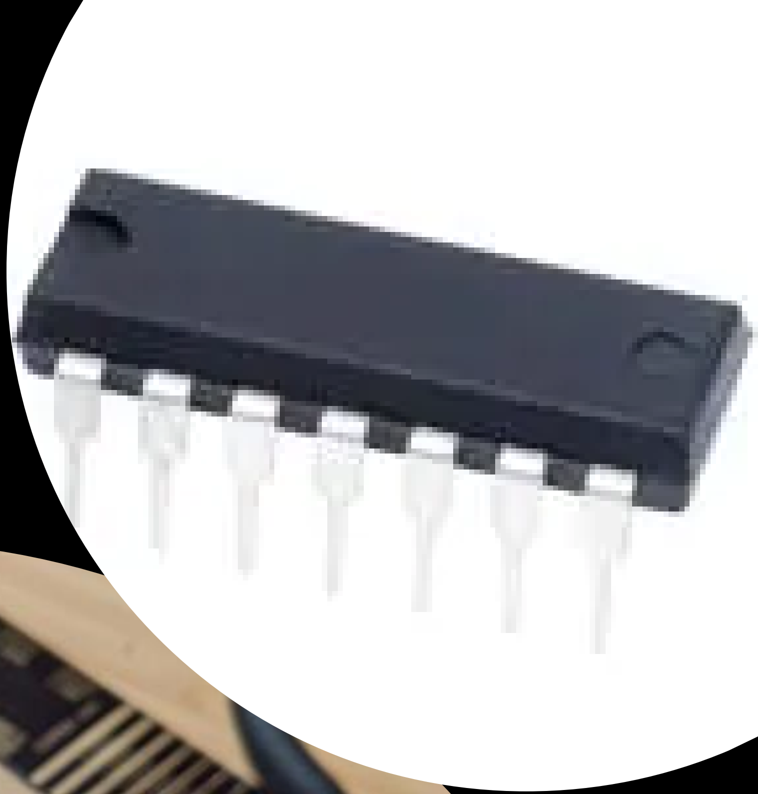
# PCB designs

- Left: Microcontroller receives messages from Raspberry Pi to display to the LCD screen.
- Right: GPIO pins to allow the Raspberry Pi to communicate with the EVM



# Texas Instrument MSP430G2553



# LCD Screen

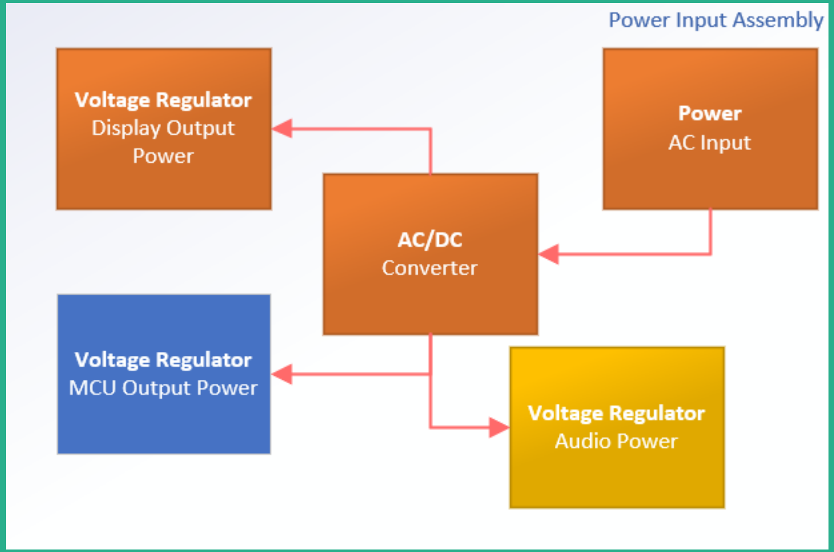
# Audio Output


Audio Output Assembly

# Speakers

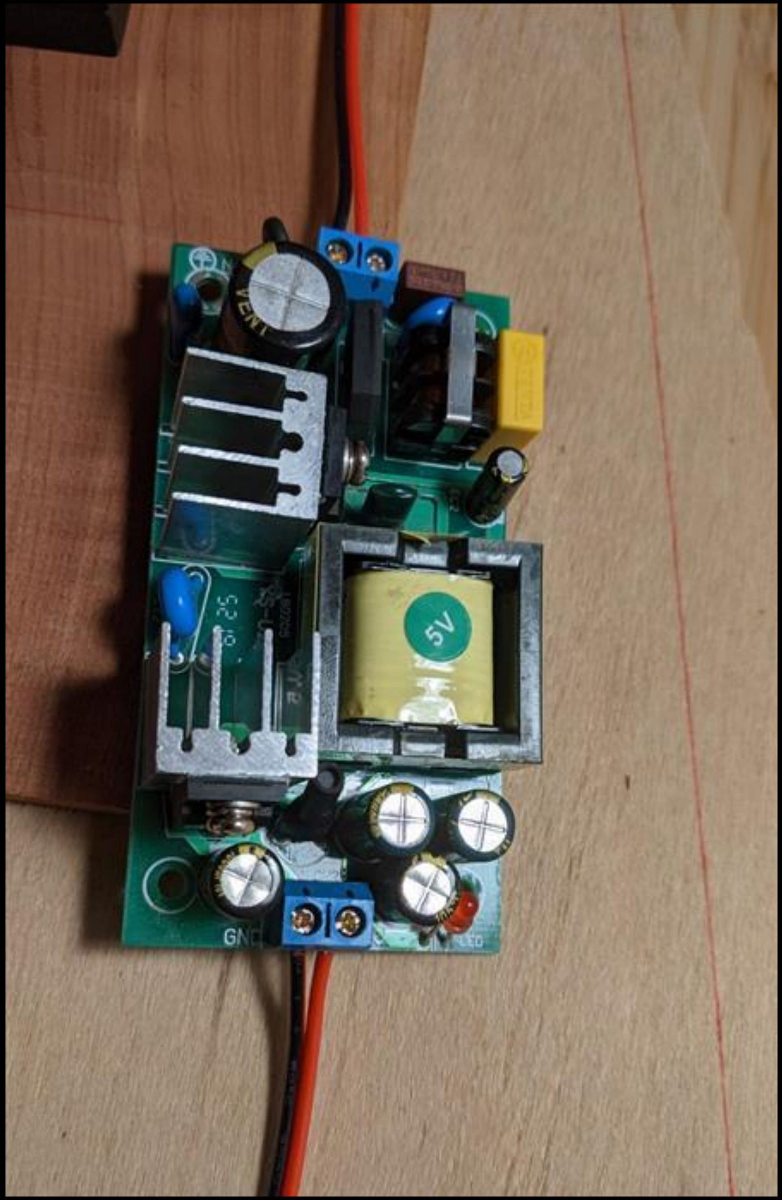
- Our device has two 4 ohm/5 W speakers connected  to the Raspberry Pi to detect accuracy and show the intention of essential features.

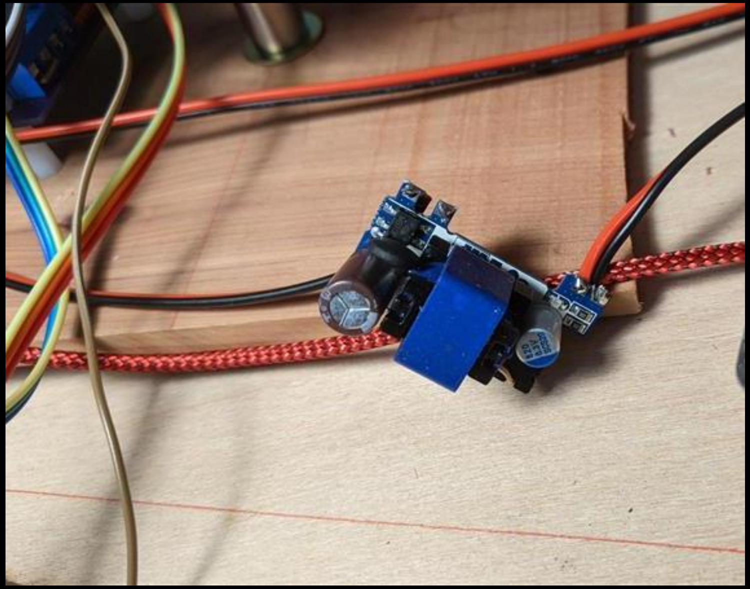
# Power Input

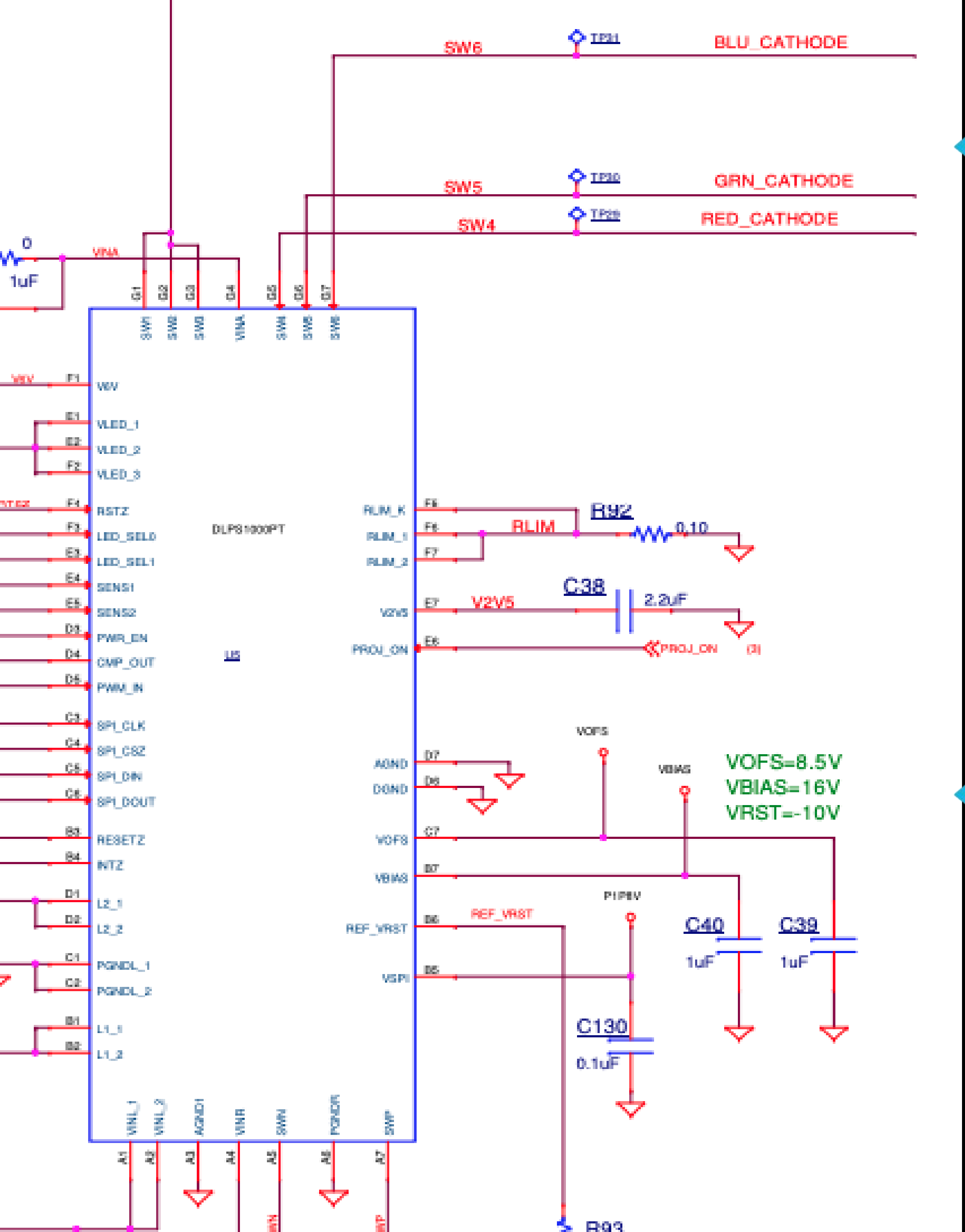

Power Input Assembly
Voltage Regulator
Display Output
Power
Power
AC Input
AC/DC
Converter
Voltage Regulator
MCU Output Power
Voltage Regulator
Audio Power

# AC/DC Power Adapter w/ USB-C ports

- We used an two 5V AC adapter and USB-C port to power the devices.
- The adapter is plugged into the Speakers, while the charger is connected to the Raspberry Pi that  is connected to the Evaluation module.



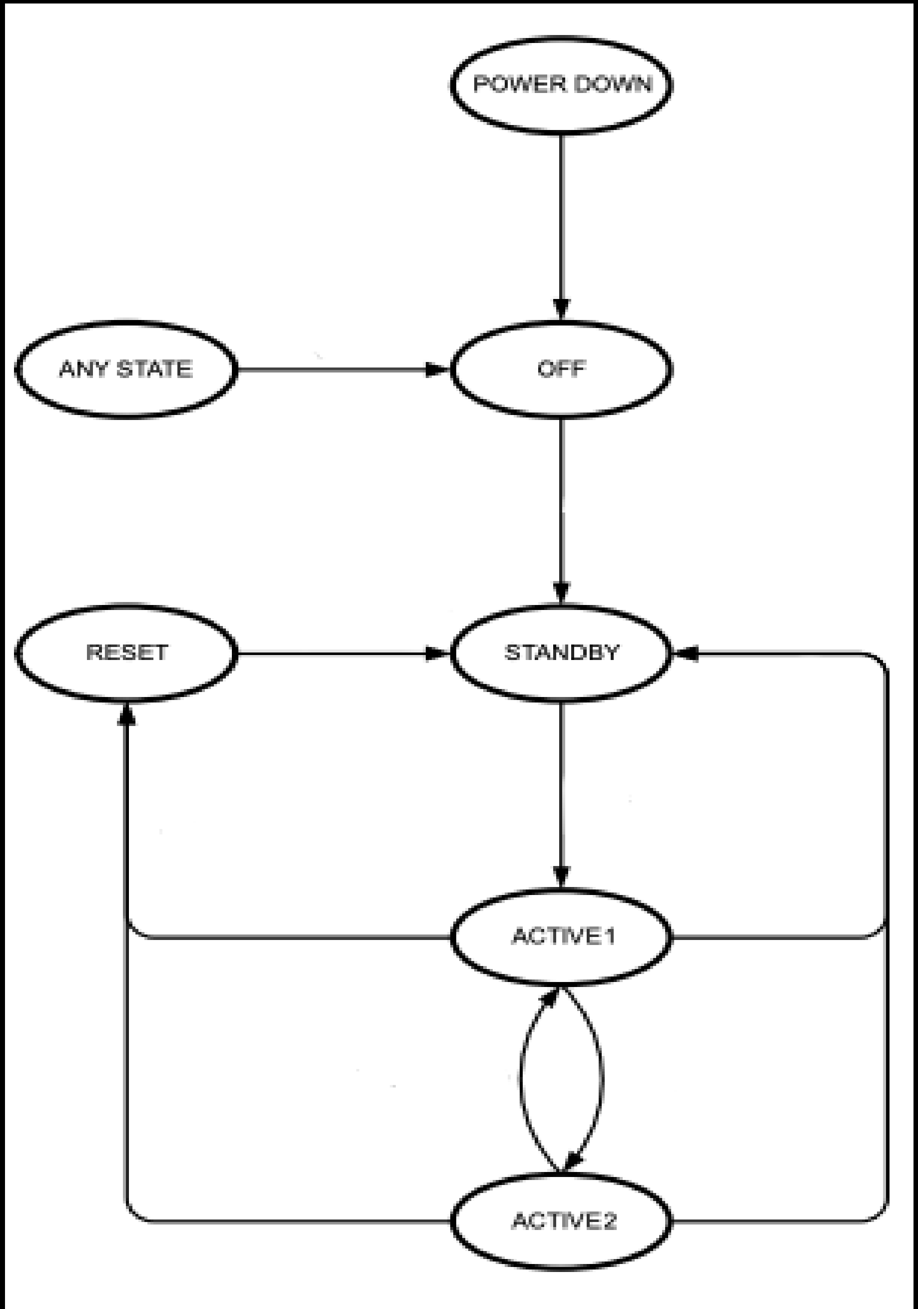



Strobe Decoder: six NMOS switches

DMD Regulators: Only 5 modes of operation.

# Modes of Operation

| Mode | Description |
|---|---|
| OFF | This is the lowest-power mode of operation. All power functions are turned off, registers are reset to their default values and the IC does not respond to SPI commands. RESETZ and PWR_EN pins are pulled low. The IC will enter OFF mode whenever the PROJ_ON pin is pulled low. |
| RESET | Logic core and registers are reset to default values, the IC does not respond to SPI commands, RESETZ and PWR_EN pins are pulled low, but the analog reference system is kept alive. The device enters RESET state when the input voltage drops below the UVLO threshold. |
| STANDBY | All power functions are turned off, but the IC does respond to the SPI interface. The device enters STANDBY mode when PROJ_ON pins is high, but DMD_EN bit is set to 0. Also, device enters STANDBY mode when a fault on the DMD regulator occurs or the temperature increases above thermal shutdown threshold (TSD). |
| ACTIVE1 | The DMD supplies are powered up but LED power (VLED) and the STROBE DECODER are disabled. PROJ_ON pin must be high, DMD_EN bit must be set to 1, and VLED_EN bit set to 0. |
| ACTIVE2 | DMD supplies, LED power and STROBE DECODER are enabled. PROJ_ON pin must be high and DMD_EN and VLED_EN bits must both be set to 1. |



# Danielle Garsten, CPE Department of Electrical and Computer Engineering

- Focus on AI and MR
- Future Software Engineer at JP Morgan & Chase
- Aspiring to pursue a Masters or PhD

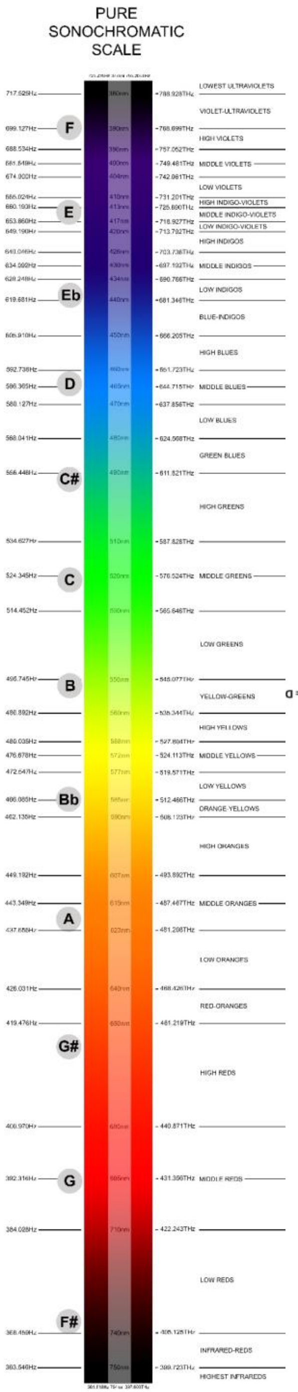
# Software Approach

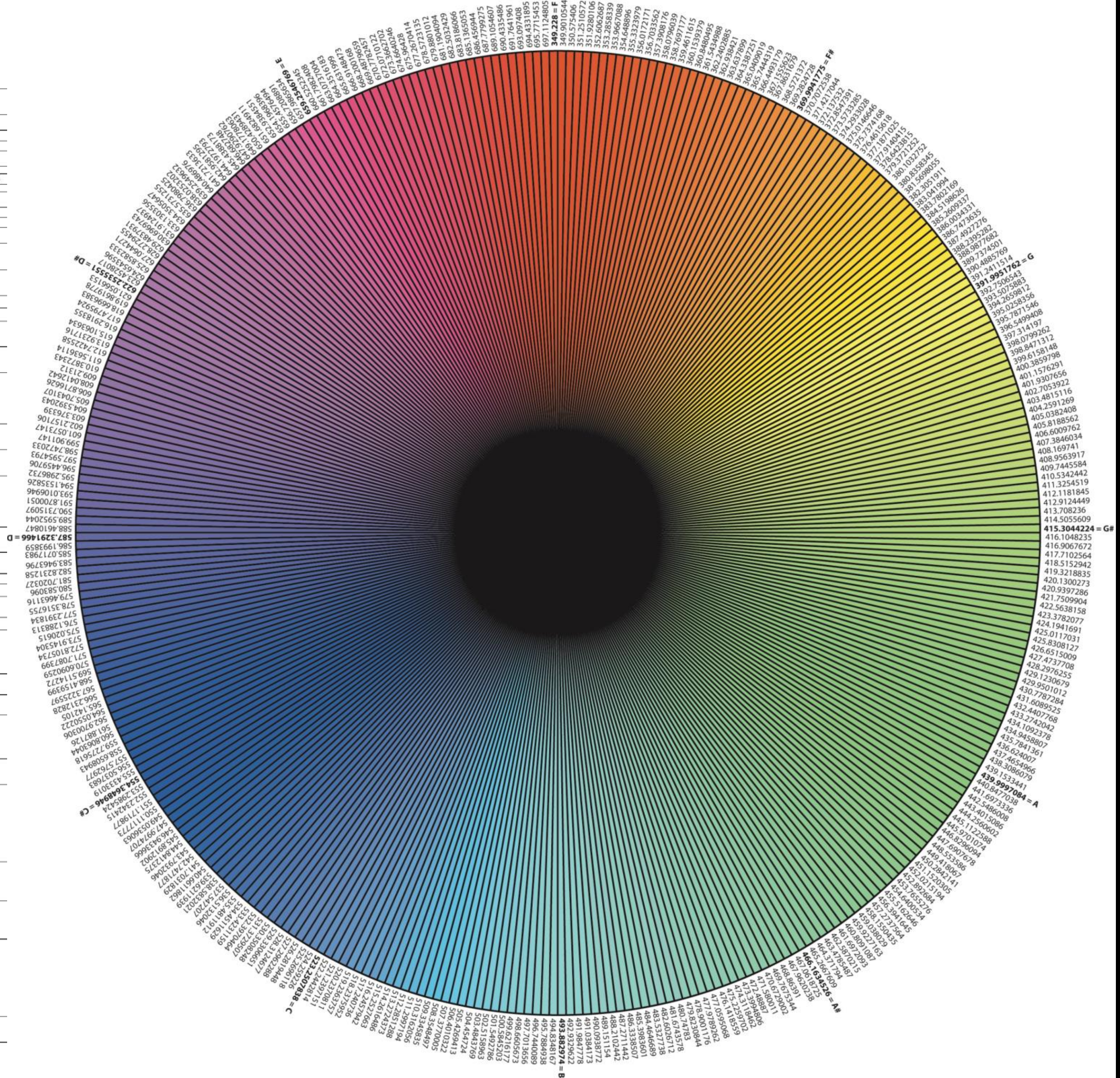
1. For the Python code to be able to perform GET/POST requests
2. Make a simple visual on a computer
3. Be able to set up this code on the Raspberry Pi
4. Make sure the visuals are projecting alongside the music

# Software Design

- Our Python code will be able to read in a song played over website file upload.
- It will then be able to detect the tones from the music and correlate a color to it.
- Then, the embedded piece will be able to allow the software to run in the hardware and for the optical module to operate under the Python code.

# Sonochromatic Scale


PURE
SONOCHROMATIC
SCALE
F
E
Eb
D
C#
C
B
Bb
A
G#
G
F#
LOWEST ULTRAVIOLETS
VIOLET-ULTRAVIOLETS
HIGH VIOLETS
MIDDLE VIOLETS
LOW VIOLETS
HIGH INDIGO-VIOLETS
MIDDLE INDIGO-VIOLETS
LOW INDIGO-VIOLETS
HIGH INDIGOS
MIDDLE INDIGOS
LOW INDIGOS
BLUE-INDIGOS
HIGH BLUES
MIDDLE BLUES
LOW BLUES
GREEN BLUES
HIGH GREENS
MIDDLE GREENS
LOW GREENS
YELLOW-GREENS
HIGH YELLOWS
MIDDLE YELLOWS
LOW YELLOWS
ORANGE-YELLOWS
HIGH ORANGES
MIDDLE ORANGES
LOW ORANGES
RED-ORANGES
HIGH REDS
MIDDLE REDS
LOW REDS
INFRARED-REDS
HIGHEST INFRAREDS


349.228 = F
369.9941775 = F#
391.9951762 = G
415.3044224 = G#
439.9997084 = A
466.1634526 = A#
493.882974 = B
523.2507838 = C
554.3648946 = C#
587.3291466 = D
622.2535551 = D#
659.2549694 = E

# Budget and Finance

| Item | Qty | Vendor | Amount |
|---|---|---|---|
| PCB Board Kit | 3 | OSHPark | $20 |
| DLP LightCrafter Display 2000 EVM | 1 | Texas Instrument | $99 |
| DLP Display Controller | 1 | Texas Instrument | $17 |
| Raspberry Pi 4 | 1 | | $55 |
| DLP 0.2 nHD DMD | 1 | Texas Instrument | $27 |
| Audio Speaker (4ohm) | 1 | SkyCraft | $2 |
| PMIC/LED driver | 1 | Texas Instrument | $2 |
| Semiconductor Laser Diode | 3 | CivilLaser | $65 |
| MSP430 Launchpad Dev. kit | 1 | Texas Instrument | $10 |
| Projector Screen | 1 | eBay | $14 |
| Total Donations | 1 | BEAM Engineering Co. | ($100) |
| | | Subtotal | $211 |
| | | Initial Budget | $500 |
| | | Budget Available | $289 |

# Completed Tasks

- All software, hardware, and optical assignments are complete
- Lenses are attached
- Software is setup in Python
- Hardware is assembled

# Successes & Difficulties

Successes

- Being able to communicate in a professional manner
- Respect
- Bluntness
- Scheduled meetings

Difficulties

- Lack of time
- Coordinating meetings sometimes
- Recursive mistakes, mostly on the thesis
- Lack of decisive planning
- Gustavo diagnosed with COVID-19

# Plans for Success

1. Graduate UCF
2. Further advance the device
3. Use it for future get-togethers
4. Possibility of business with it