OPTICAL INTERACTIVE CHESS BOARD FOR BEGINNERS

Group 6

UCF Senior Design Fall 2023 – Spring 2024

MEET THE TEAM

ALEC BARNO
OPTICS/PHOTONICS ENGINEER

CASSIDY PHILLIPS
ELECTRICAL ENGINEER

VINICIUS RESENDE
ELECTRICAL ENGINEER

ALEJANDRO FELIX
OPTICS/PHOTONICS ENGINEER

NIKOLAI COLETTA
COMPUTER ENGINEER

MOTIVATION & BACKGROUND

- Have a fun project to work on
- Board games are fun and interactive
- Chess is a great strategy game to learn
- Helping people learn how to play a new game is a great experience

GOALS

- Basic goals
  - Detect and identify the different chess pieces
  - Light the LED array underneath the chess board properly so that it shows the player where their selected chess piece can move to and to show a player where their piece cannot move to
- Advanced goals
  - Convey additional information about a player's selected piece using a small built-in display
  - Able to save the game state for players to pick up and resume at a later point in time
- Stretch goals
  - Have an AI opponent for singular players to challenge against
  - Implementing a small speaker into the board that will play sound effects when certain cases arise

OBJECTIVES

- Have LEDs under each piece. This light will be reduced by different filters at the bottom of the piece
- Have different light intensity received by the photodiodes to create different currents enabling us to determine the piece type
- Install RGB LEDs under each square, enabling colors to convey specific messages.
- Determine LED placement for easy control over which are on or off.
- Choose a suitable driver to ensure LEDs receive consistent power without damage.
- 3D print bases to house the LED and filters under each piece
- Built honeycomb structure to prevent light from traveling between squares
- Soldering components to PCB

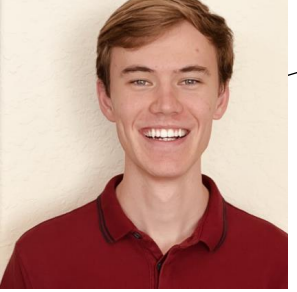
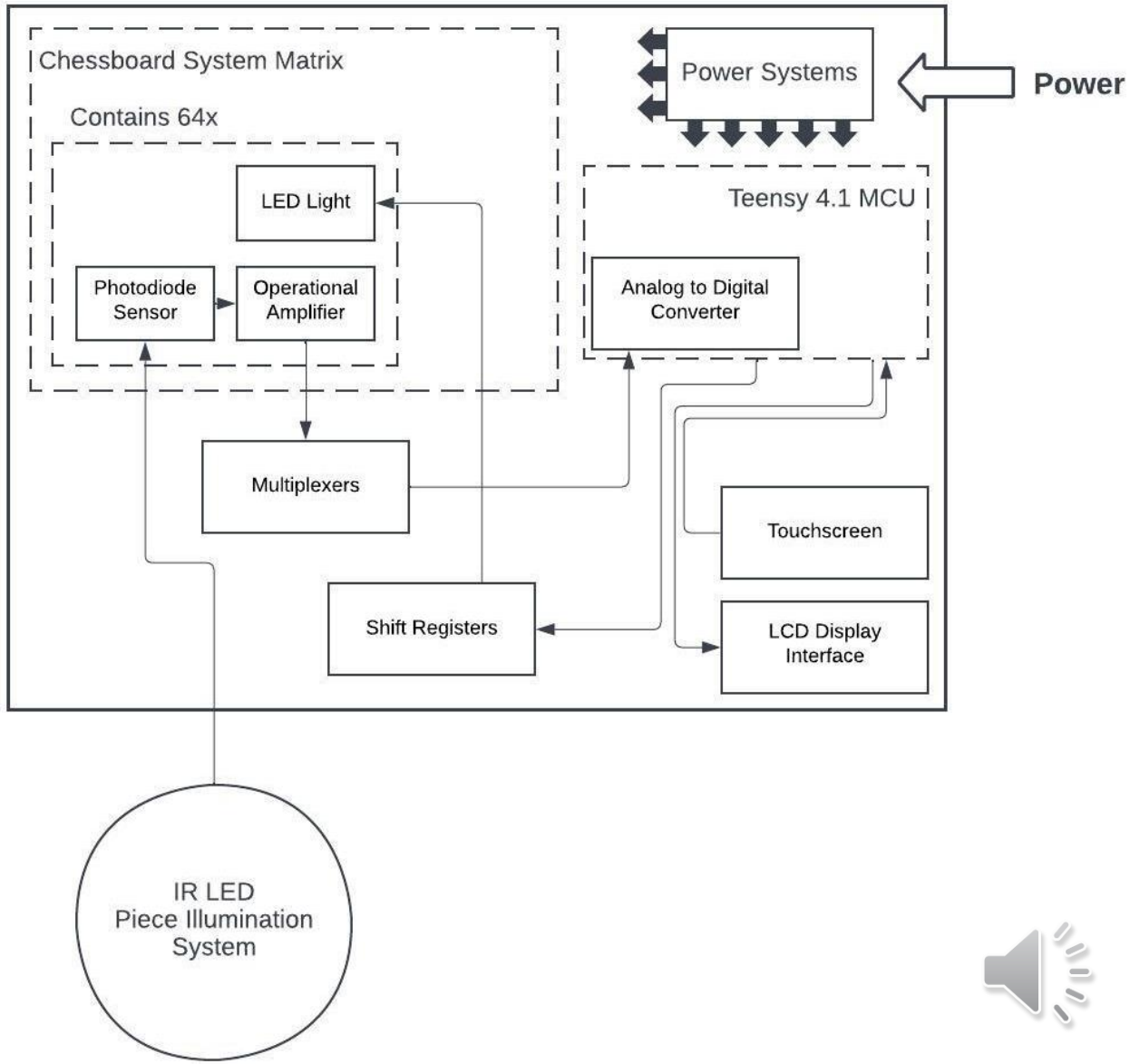


TABLE OF ENGINEERING SPECIFICATIONS

Requirements	Units
Battery Life of the entire chess box	≥ 4 hours
Chess Box Dimensions* (LxWxH)	24 in. × 18 in. × 6 in.
Chess Board Dimensions* (LxW)	18 in. × 18 in.
Weight of the entire chess box	≤ 15 lbs
Delay/Activation from when piece is picked up to when move is shown on the chess board	≤ 3 seconds
Voltages to differentiate the types of chess pieces	7 different voltages
Piece detection accuracy	≥ 95%

HARDWARE BLOCK DIAGRAM



CHESS PIECE IDENTIFICATION SYSTEM: OPTICAL SENSORS TECHNOLOGY COMPARISON

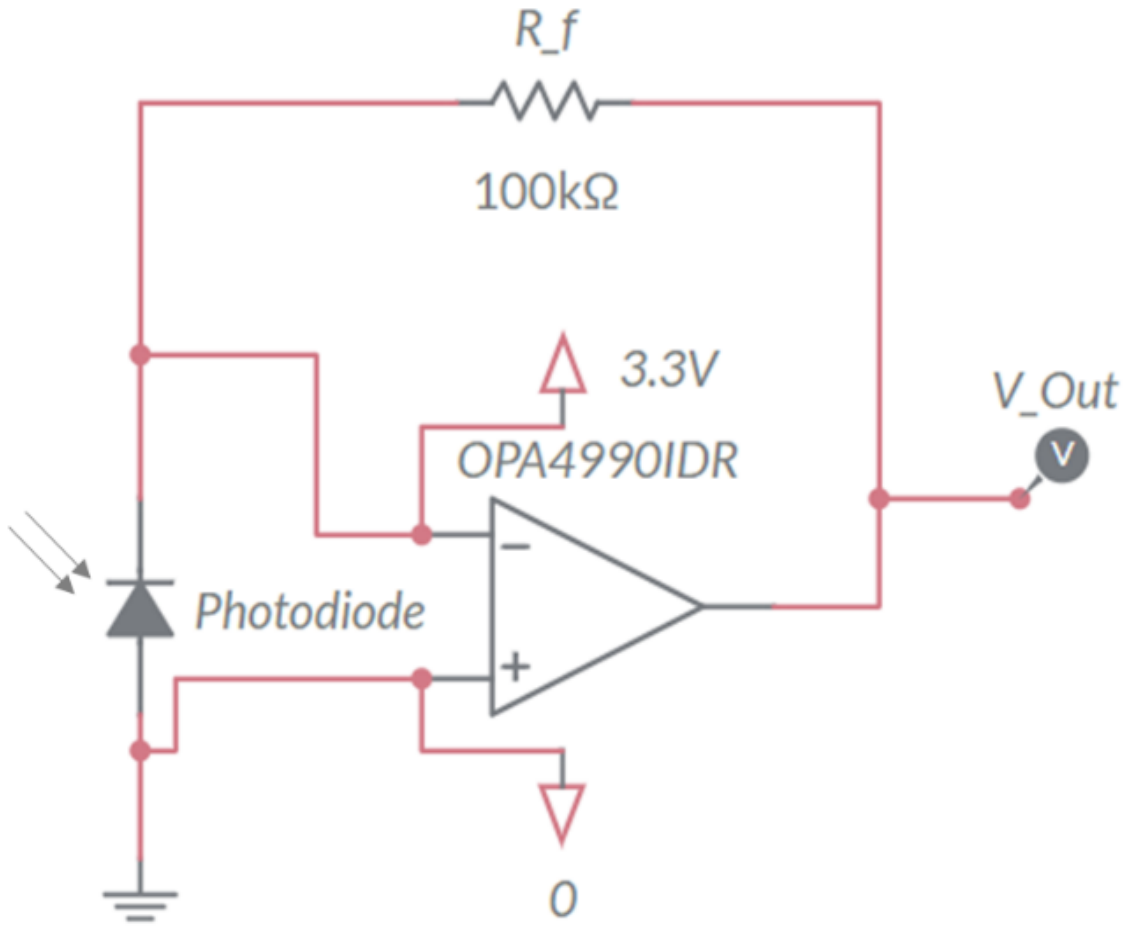
	IR Sensor	Color Sensor/Spectrometer	Photodiodes
Function	Measures IR radiation changes	Measures and determines specific wavelength ranges related to color	Measures intensity of light
Wavelength Range	0.75 µm to 1 mm	≅ 380 nm to 750 nm (Visible Light)	Any wavelength range (specific to diode specs)
Extras/Other Components	N/A	Color filters for each different kind of chess piece	Analog-to-Digital Converter (ADC)
Implementation	Medium to Hard	Hard	Easy
Number of sensors	64	64 - 384	64
Cost (1 sensor)	≅ $1 to $10	≅ $5 to $20 (color sensor) ≅ $100s to $1000s (spectrometer) ≅ $0.50 to $5 (photodetectors)	≅ $0.50 to $5

CHESS PIECE IDENTIFICATION SYSTEM: PHOTODIODES PART SELECTION

Name	Photosensitive Diode	PD 204-6B	SFH 203 P
Brand/Manufacturer	Uxcell	Everlight Electronics	Ams-OSRAM USA INC
Seller	Amazon	DigiKey	DigiKey
Peak Wavelength	940 nm	940 nm	850 nm
Spectral Range	400 – 1100 nm	840 – 1100 nm	400 – 1100 nm
Receiving/Viewing Angle	40°	N/A	150°
Active Area	N/A	N/A	1 mm^2
Price	$0.65 (per diode) $6.49 (10 pcs)	$0.43 (per diode) $2.64 (10 pcs)	$1.00 (per diode) $6.50 (10 pcs) $42.60 (100 pcs)

PHOTODIODE CIRCUIT AND APPLICATION

- Transimpedance Amplifier Circuit (Current to Voltage Converter Circuit)
- 1 Photodiode per Square



CHESS PIECE IDENTIFICATION SYSTEM: DIFFERENTIATING EACH PIECE COMPARISON

	Colors/Color Filters	Materials	Light Filters
Function	To differentiate the chess piece types based on color and wavelength associated to colors	To differentiate the chess piece types based on intensity of reflected light due to the reflectivity values of various materials and objects	To differentiate the chess piece types based on overall intensity of light
Wavelength Range	≅ 380 nm to 750 nm (Visible Light)	Any wavelength range (depends on wavelength of light source)	Any wavelength range (specific to wavelength of light source)
Implementation	Medium	Hard	Easy
Cost	≅ $10 to $30	≅ Free to the price of whatever material is used	≅ $10 to $35

CHESS PIECE IDENTIFICATION SYSTEM: FILTER SELECTION

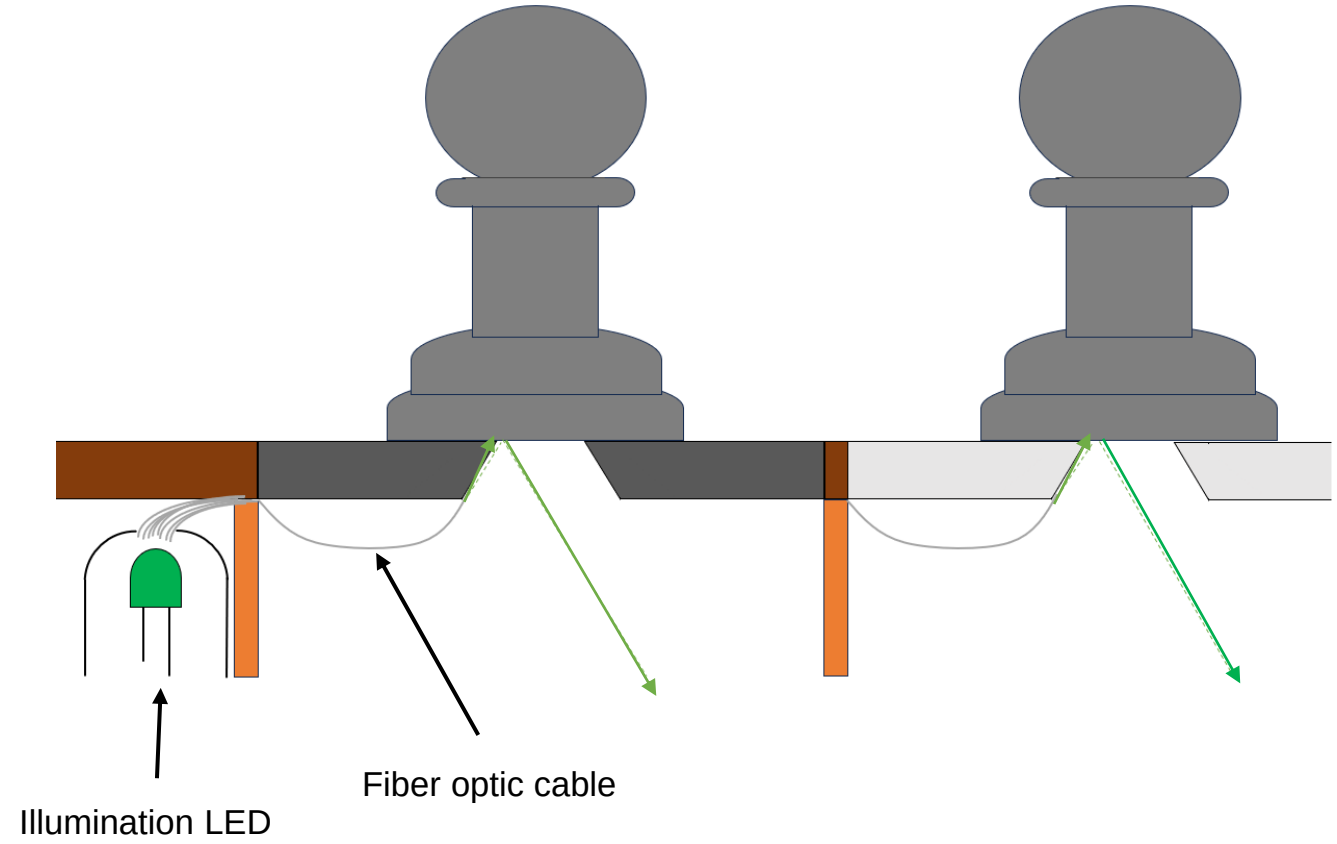
Name	Square Filter Kit	Gel Filters, CTO Transparent Light Sheets	Lighting Neutral Density Gels Filter Sheet
Brand/Manufacturer	SIOTI	Meking	RENIAN
Seller	Amazon	Amazon	Amazon
# of filters	4	4	6 (2 per each kind)
Value of filters	ND2 (½ transmission) ND4 (¼ trans.) ND8 (⅛ trans.) ND16 (1/16 trans.)	1 ½ ¼ ⅛	ND3 (≅48% trans.) ND6 (≅24% trans.) ND9 (≅12% trans.)
Type of filters	Neutral Density (ND)	Color Correcting/Enhancing	Neutral Density (ND)
Material	Pmma	Polyester	Polyester
Price	$22.99	$18.99	$16.98

FILTER VALUES/RANGES

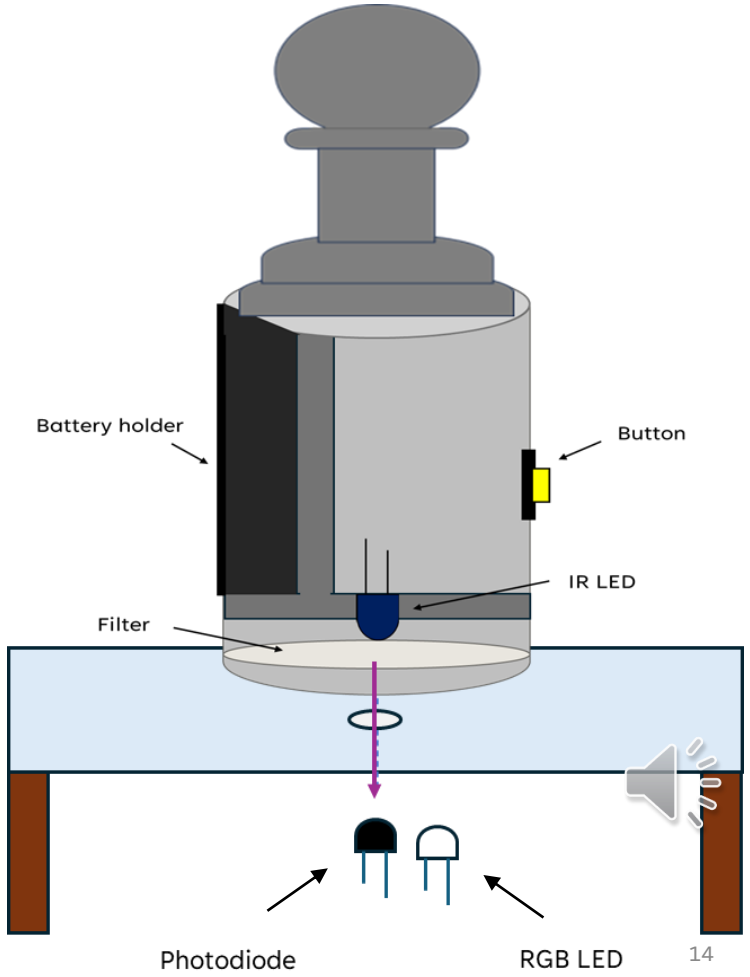
Value	Piece Type	Expected Voltage	Deviation	Filter(s)
1	White Pawn	3.3V	±0.01V	No filter
2	Black Pawn	2.52V	±0.65V	ND8 & ND9
3	Knight	1.57V	±0.28V	ND16 & ND9
4	Bishop	1.11V	±0.17V	ND6 & 2x ND9
5	Rook	0.78V	±0.092V	Blackout
6	Queen	0.56V	±0.05V	Blackout & ND4
7	King	0.24V	±0.015V	Blackout & ND6

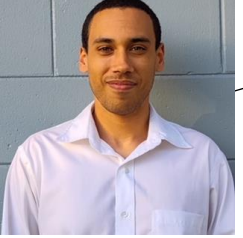
DESIGN PROGRESS

Fiber optic cable illumination design



Cylinder base design





TECHNOLOGY SELECTION: PIECE ILLUMINATION SOURCE

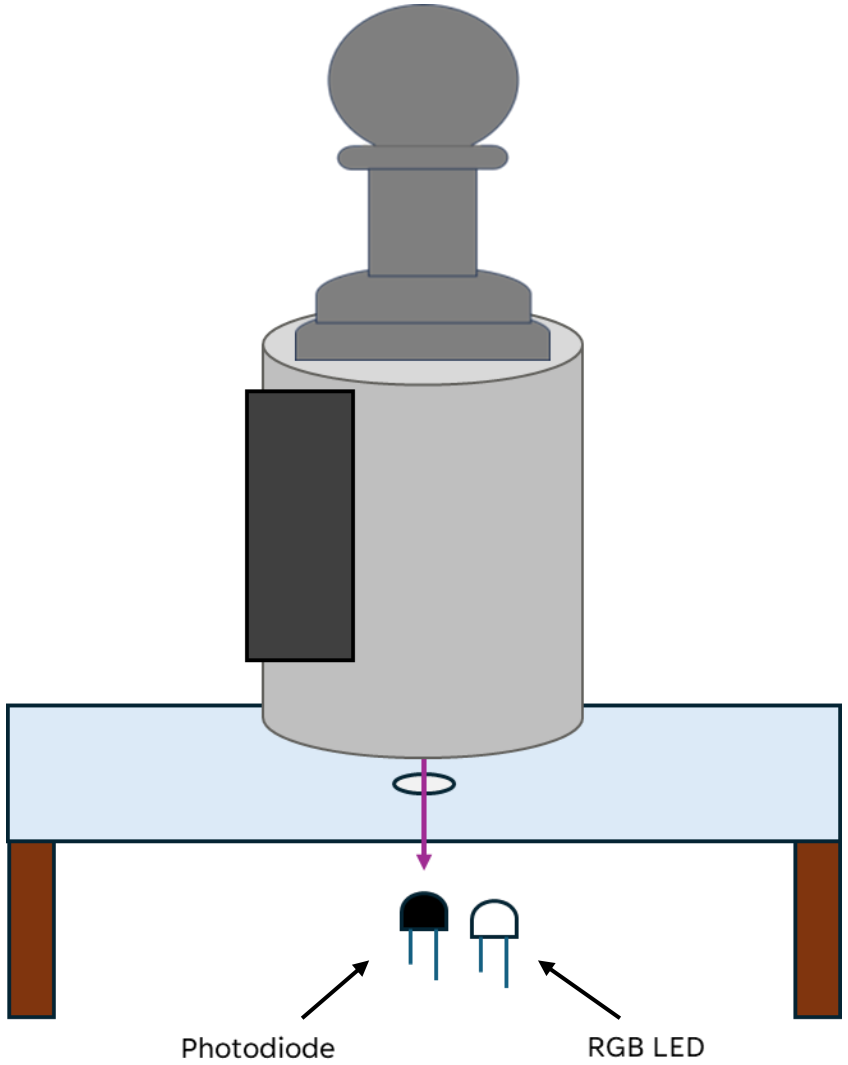
	LED	HeNe Laser	Laser diode	Quartz halogen lamps	Xenon metal halide lamp
Temperature (Heat)	Low	Medium	Medium	High	High
Warmup time	None	10 min	None	None	15 min
Size	0.98 x 0.2 x 0.2 in	1.74 x 1.74 x 10.70 in	0.23 x 0.55 x 3.54 in	3.07 x 0.32 x 3.07 in	2.1 x 5.3 x 2.1 in
Quantity in package	100	1	30	5	1
Minimum quantity needed	1	64	64	1	1
Operating current	<20 mA	6.5 mA	<20 mA	0.83 A	1.25 A
Weight	1.27 oz	0.92 lbs	1.55 oz	1.48 oz	2.08 oz
Output power	2 mW	2 mW	2 mW	100 W	150 W
Cost	$ 6.75	$ 1732.50	$ 12.99	$ 8.99	$ 20.71

PART SELECTION: LED ILLUMINATION SOURCE

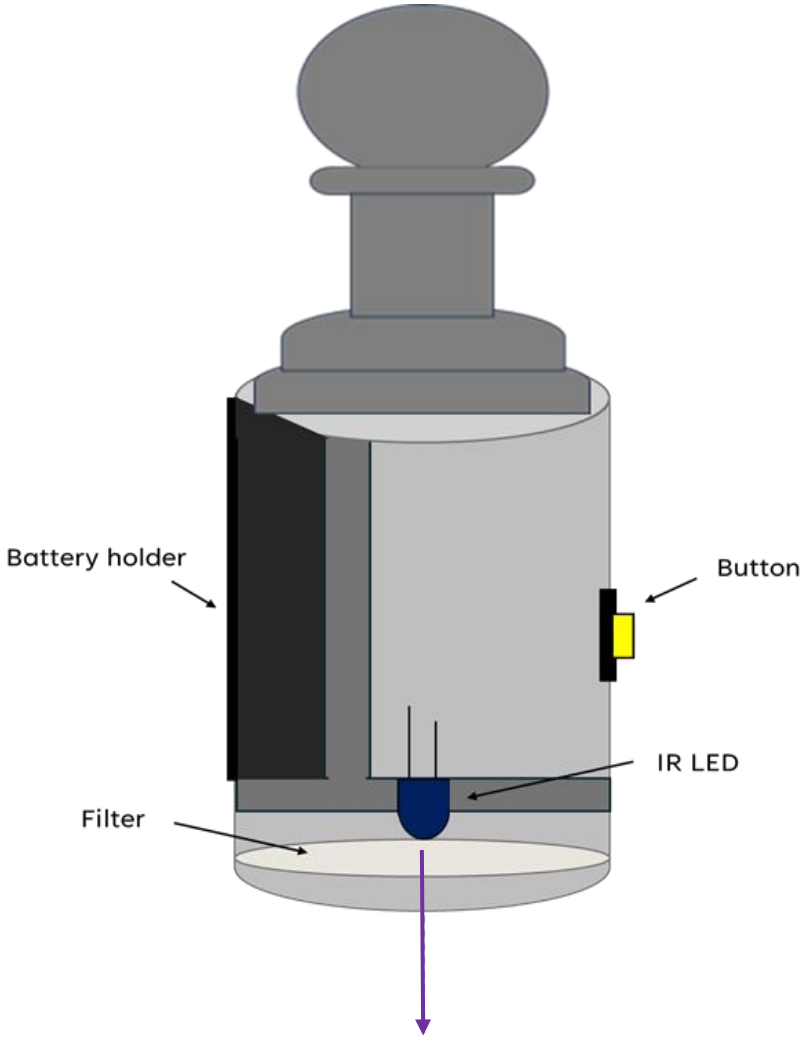
Brand	CO-RODE	Chanzon	CO-RODE	Chanzon	Chanzon
Size	0.197 x 0.197 x 0.689 in	0.228 x 0.228 x 0.728 in	0.197 x 0.197 x 0.689 in	0.152 x 0.152 x 1.161 in	0.197 x 0.197 x 1.043 in
Weight	0.79 oz	0.634 oz	0.79 oz	0.352 oz	0.634 oz
Max Luminous Intensity	15,000 – 20000 mcd	15,000 - 18,000 mcd	4,000 - 5,000 mcd	N/A	N/A
Wavelength	525 nm	515 nm	590 nm	850 nm	940 nm
Volts	3 V	3V	1.8 V	1.4 V	1.2 V
Quantity	100	100	100	100	100
Cost	$6.59	$5.99	$6.49	$8.99	$7.99

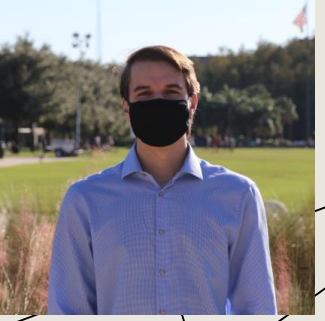
CYLINDER BASE DESIGN

External view



Internal view





TECHNOLOGY SELECTION: MICROCONTROLLER

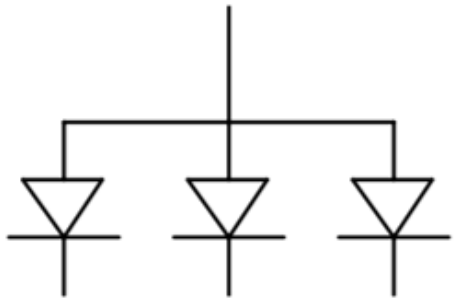
Specifications:	Teensy 4.0	ESP32	STM32	Teensy 4.1*	Arduino Nano**
CPU Speed	600 MHz	240 MHz	168 MHz	600 MHz	240 MHz
RAM	1 MB	4 MB	200 KB	1 MB / 17 MB	512 KB
Flash	2 MB	4 MB	512 KB	8 MB	8 + 16 MB
GPIOs	40	28	50	55	14
Communication Protocols	3 SPI, 3 I2C	4 SPI, 2 I2C, 3 UART	3 SPI, 3 I2C, 3 UART	3 SPI, 3 I2C	1 SPI, 1 I2C, 2 UART
Price	$25	$10	$28	$35 / $38	$19
Delivery Time	< 2 Weeks	< 1 Week	< 1 Week	< 1 Week / < 2.5 Weeks	< 1 Week

**Two values are shown for some of these specifications: values on the left are without the added RAM, values on the right are with the added RAM.*

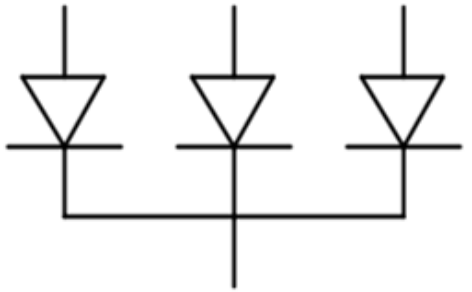
***The two values listed under Flash are for 8 MB of internal flash and 16 MB of external flash. External flash is much slower than internal flash.*

SELECTING LEDS FOR LED ARRAY

- Two different configurations common anode (A) and common cathode (B)
- Both run under the same principal to turn on a specific color
  - Set anode to high
  - Set cathode to low

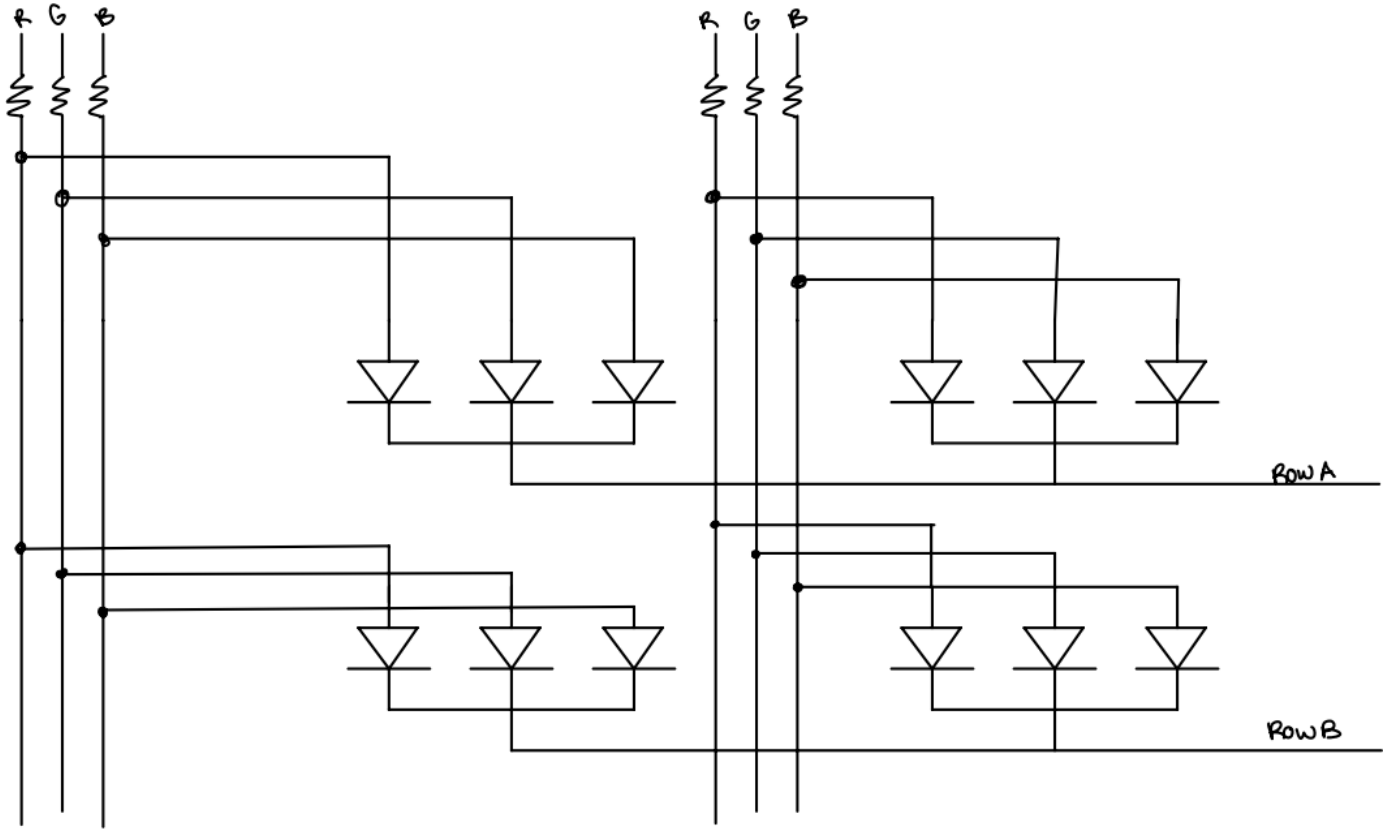


(A)



(B)

BASIC SETUP FOR LED ARRAY



- By using the common cathode configuration, the columns (anodes) can be shared and the rows (cathodes) can also be shared
- To turn on a specific LED color, you would turn the corresponding column to high and the corresponding row to low
- Only one LED can be turned on at a time

LED DRIVERS

- Pros
  - Designed to provide a constant current and voltage to the LEDs
  - Pulse-width modulation to control LED brightness
- Cons
  - Cannot power a full row of LEDs at once

	TPS929240-Q1	TPS92120-Q1	TLC59210
Number of channels	24	12	8
LED current per channel (mA)	100	75	200
Vin min-max (V)	4.5-40	4.5-40	3.3-5.5
Vout min-max (V)	0-40	0-45	0-30
Maximum Frequency	1 MHz	1MHz	1 MHz
Extra Features	Current source Enable/shutdown FlexWire control interface	Current sink PWM control Thermal shutdown	Current sink Thermal shutdown PWM control
Package Type	HTDDOP (surface mount)	HTSSOP (surface mount)	PDIP (through-hole) TSSOP (surface mount)
Price	$3.280	$1.742	$0.697

SHIFT REGISTERS

- Pros
  - Ability to daisy chain to create a bigger shift register
    - Allows access to a bigger shift register for a fraction of the cost
- Needs to be able to handle a current of 20 mA

	SN54LS673	SN74HC595	TPIC6A595
Number of Channels	16	8	8
Max Current (mA)	12	35	350
Vin min-max (V)	4.75-5.25	2-6	4.5-5.5
Clock Speed	20 MHz	24 MHz	10 MHz
Price	$31.592	$0.073	$1.150

MULTIPLEXER FOR ADC

	TMUX8108	TMUX6208	CD74HC4051	CD405X
Vin (single) (V)	12, 16, 20, 36, 44, 72, 100	5, 12, 16, 20, 36	1.8, 2.5, 3.3, 5	Up to 20 V
Input/output continuous current (max) (mA)	100	300	25	10
Packaging	TSSOP (surface mount) WQFN (chip carrier)	TSSOP (surface mount) WQFN (chip carrier)	PDIP (through hole) SOIC (surface mount) SOP (surface mount) TSSOP (surface mount)	PDIP (through hole) TSSOP (surface mount)
Switching time	12 µs	140 ns	10 ns	400 ns
Price	$3.850	$2.432	$0.097	$0.61

ANALOG TO DIGITAL CONVERTER

	Teensy 4.1 (built in ADC)	ADS7138-Q1	ADS1015
Maximum voltage for input pin	3.3 V	5.5 V	~6 V
Input pins	18	8	4
Sample rate	N/A	140 ksps	3.3 ksps
Input voltage	N/A	5.5 V	0-5.5 V
Communication protocol	N/A	I2C	I2C
Resolution (bits)	10	12	12
Price	N/A	$3.57	$1.1

OPERATIONAL AMPLIFIERS

- Needed for the transimpedance amplifier for the piece identification system
- Needed to be able to handle a rail voltage of 0 to 5 V
- Rail to rail to ensure full range of values was accessible for the ADC
- We ended up selecting the OPA4990IDR op amp

DISPLAY SCREEN

Display Selection Criteria

Size and Resolution

Refresh Rate and Response Time

Power Consumption

Support

Cost

Touchscreen Capabilities

TFT LCD Displays

Improved image quality, faster response time, and lower power consumption over traditional LCD.

Thinner and lighter than conventional LCDs.

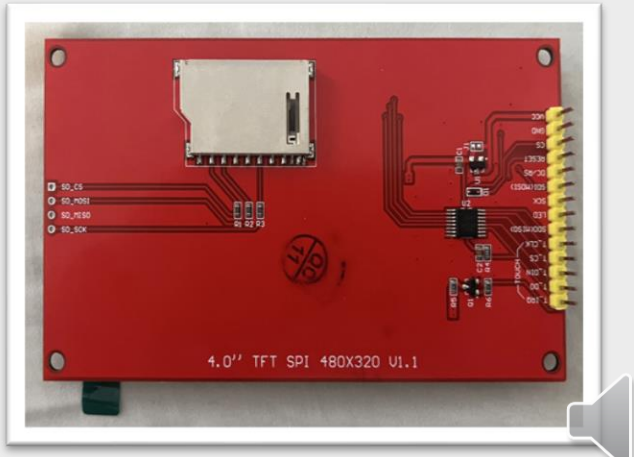
Capable of producing images.

Inexpensive.

Larger screen size.

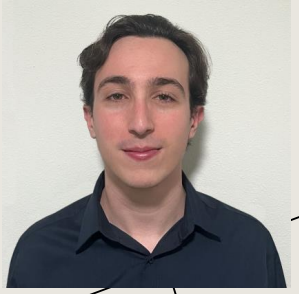
Often include touchscreen.

IMAGE: TFT LCD Display Screen (Top)
Display Connections and SD Slot (Bottom)



DISPLAY MARKET RESEARCH AND COMPARISON

	HiLetgo 2.8" SPI TFT LCD Display	HiLetgo 3.5" TFT LCD Display	Hosyond 4.0” TFT LCD Display
Screen Size & Resolution	2.8" 240 x 320 pixels	3.5” 480 x 320 pixels	4” 480 x 320 pixels
Operational Voltage	3.3V~5V	3.3V~5V	3.3V~5V
Expected Current Consumption	120mAh	150mAh	180mAh
Driver IC	ILI9341	ILI9488	ILI9486
Communication Protocols	SPI	SPI Capability (Not Implemented)	SPI
Touchscreen	Yes (Resistive)	No	Yes (Resistive)
Cost	$16.39	$18.49	$19.99



POWER MANAGEMENT: BATTERIES

Battery Criteria:

- Low Cost
- Durable
- Safe
- Efficient
- High-Capacity

	Lead Acid	Ni-MH	Li-Ion	Li-Po
Cycle Life (Cycles)	200 - 2000	500 - 1000	500 – 2000	> 1200
Efficiency (%)	70 - 90	70	75 - 90	70
Energy Density (Wh/Kg)	30 – 40	30 – 80	100 – 250	130 -200
Weight	Heavy	Medium	Light	Lightest
Total Cost	Low	Medium	High	Medium
Toxicity	Very High	High	Low	Low

BATTERIES (CONT'D)

18650 Battery Cells

- 3.6 Nominal Cell Voltage
- 2500 mAh Cell Capacity

IMAGE: 18650 Li-Ion Cell

Battery Pack Design

Design Formulas:

$$\#\ of\ Parallel\ Cells = \frac{Desired\ Pack\ Capacity}{Cell\ Capacity}$$

$$\#\ of\ Serialized\ Cells = \frac{Pack\ Nominal\ Voltage}{Cell\ Nominal\ Voltage}$$

6-Cell Pack (2 Series / 3 Parallel)

7.2 Volts

7500 mAh

- Expandable

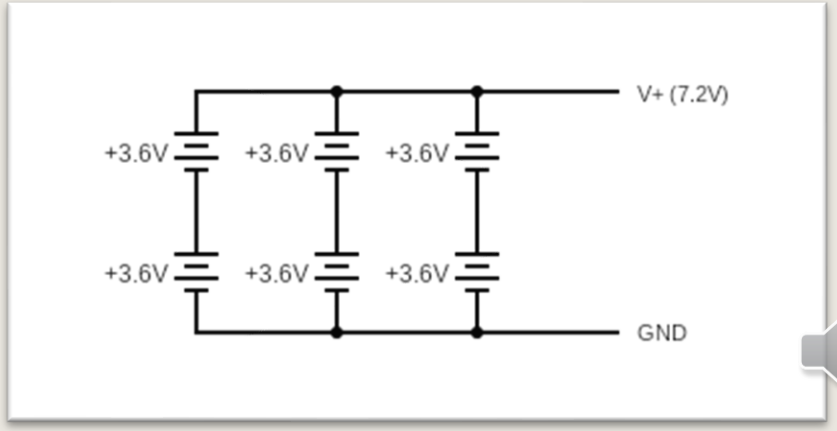
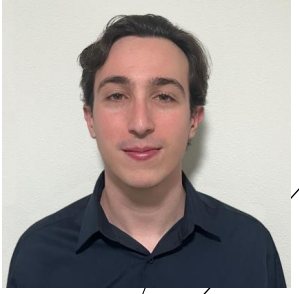


IMAGE: 2S3P Battery Pack Design



BATTERY PACK MANAGEMENT SYSTEM

Monitor, control, and safeguard the battery.

Protection Circuits:

- Short Circuit Protection
- Overcharge Protection
- Overdischarge Protection
- Overcurrent Protection

Cell Charge Balancing

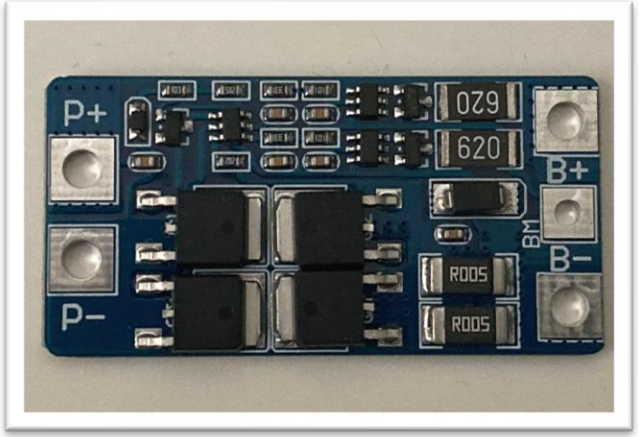
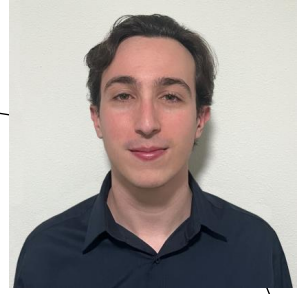


IMAGE: HX-2S-JH20 BMS Board

	HX-2S-A10	HX-2S-JH20	HX-2S-D01
Charging Voltage	8.4V-9V	8.4V-9V	8.4V-9V
Upper Limit Operating Current	8A	10A	8A
Dimensions	41 x 8 x 2.2 (L x W x H in mm)	46.7 x 23 x 3.15 (L x W x H in mm)	40 x 17 x 3.5 (L x W x H in mm)
Charge Balancing	NO	YES	NO
Cost	$9.49 / 5 ($1.898 ea)	$11.99 / 5 ($2.398 ea)	$6.99 / 2 ($3.495 ea)



POWER MANAGEMENT: VOLTAGE REGULATION

These regulators provide consistent and stable voltage levels during operation of the system.

Voltage regulators mainly come in two different forms, linear and switching regulators.

- **Linear Regulators** are simple, low cost, but typically inefficient, inadequate for use on a battery-powered device.
- **Switching Regulators** are highly efficient and plentifully available in the market for diverse uses, though often cost slightly more than linear regulators.

	Linear Regulators	Switching Regulators
Design Availability	Buck	Buck Boost Hybrid (Buck-Boost)
Efficiency	Low	High
Complexity	Low	Medium-High
Total Cost	Low	Medium to High due to cost of external components
Input Voltage Range	Small Range	Wide Range

LM2596

- Controllable Output
- Capable of Driving a Load up to 3A
- Compact
- “Plug-and-Play” with minimum external components

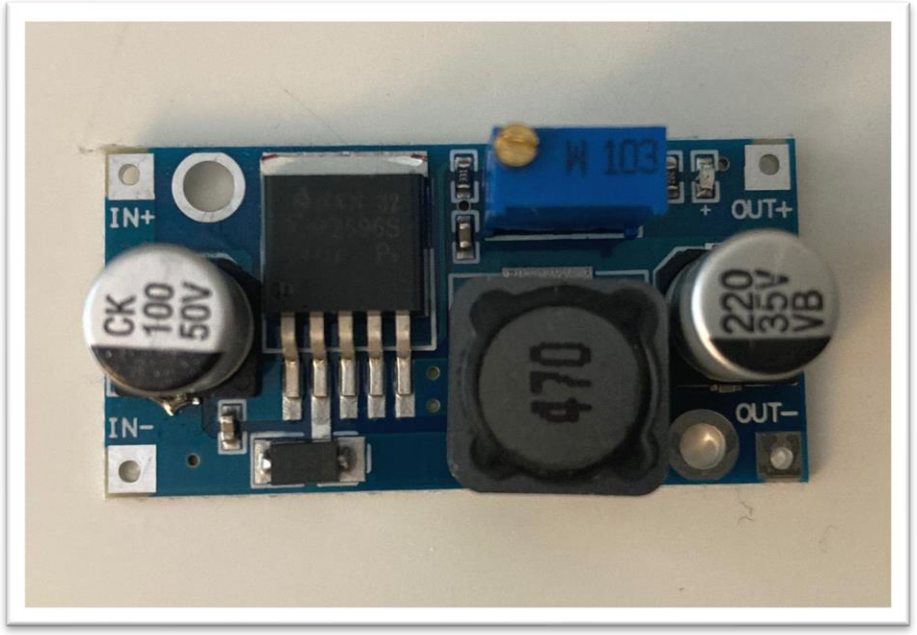
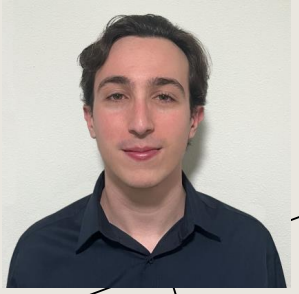


IMAGE: LM2596 Switching Voltage Regulator



POWER MANAGEMENT: BATTERY RECHARGING

We had initially planned on utilizing USB-C to connect our batteries to a power supply.

That plan followed through most of our time working in this project, from the design phase to the prototyping stages. We were utilizing a 9V, 2A PD-capable USB-C charger for charging utilizing a Power Delivery Trigger Board.

The design worked with the prototype version of our battery, but when plugged into our final battery design, it ceased to function as intended.

Thus, we decided it would be best to make a small change in the charging system.

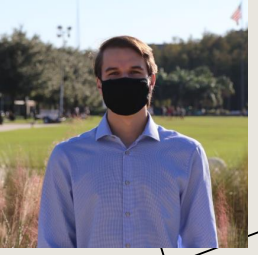
We need a charging voltage of 8.4 to 9V for proper functionality of our battery management system, thus we are now using a DC power adapter with the same specifications as our original intended design of 9V charging voltage with a charging current of 2A.

IMAGE: 9V Power Supply

SOFTWARE DESIGN: IDE & CODE MANAGEMENT

The IDE of choice for this project is also the recommended programming environment for Teensy- the Arduino IDE with Teensyduino. Modifying Arduino's native IDE makes for a great development environment that is easy to use, well documented and maintained, and capable of supporting this project. In addition, the Arduino library manager is especially effective for managing all the libraries being used.

For code management, backup, and version history, a GitHub repository was configured for this project. This allowed for the project to be developed seamlessly by consistently uploading it to that platform.



SOFTWARE DESIGN: FIGMA PROTOTYPE

Title Page

INTERACTIVE CHESS

Senior Design Group 4 - Fall 23/Spr 24

Main Menu

MAIN MENU

New Game

Options

Options Menu

OPTIONS

Timer: 20 min

Autoswitch Turn: OFF

Pause on Illegal Move: OFF

Highlight Moves: ON

Back

Set Up Board

SET UP BOARD

Please place the
PAWNS
on the highlighted squares.

Clock Screen

69:69

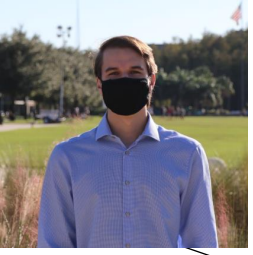
59:59

Gameover Screen

GAME OVER

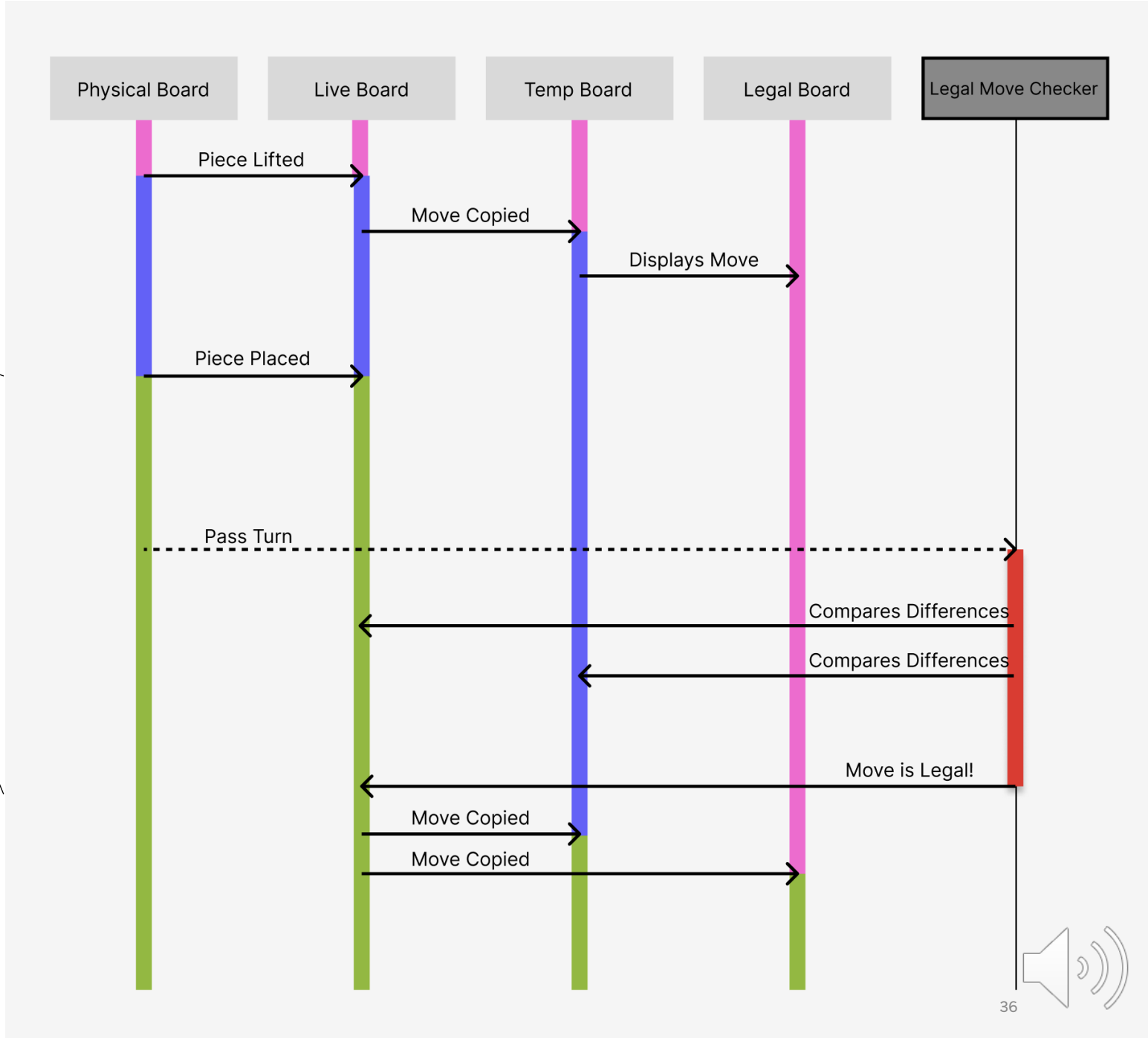
WHITE WINS!

CHECKMATE



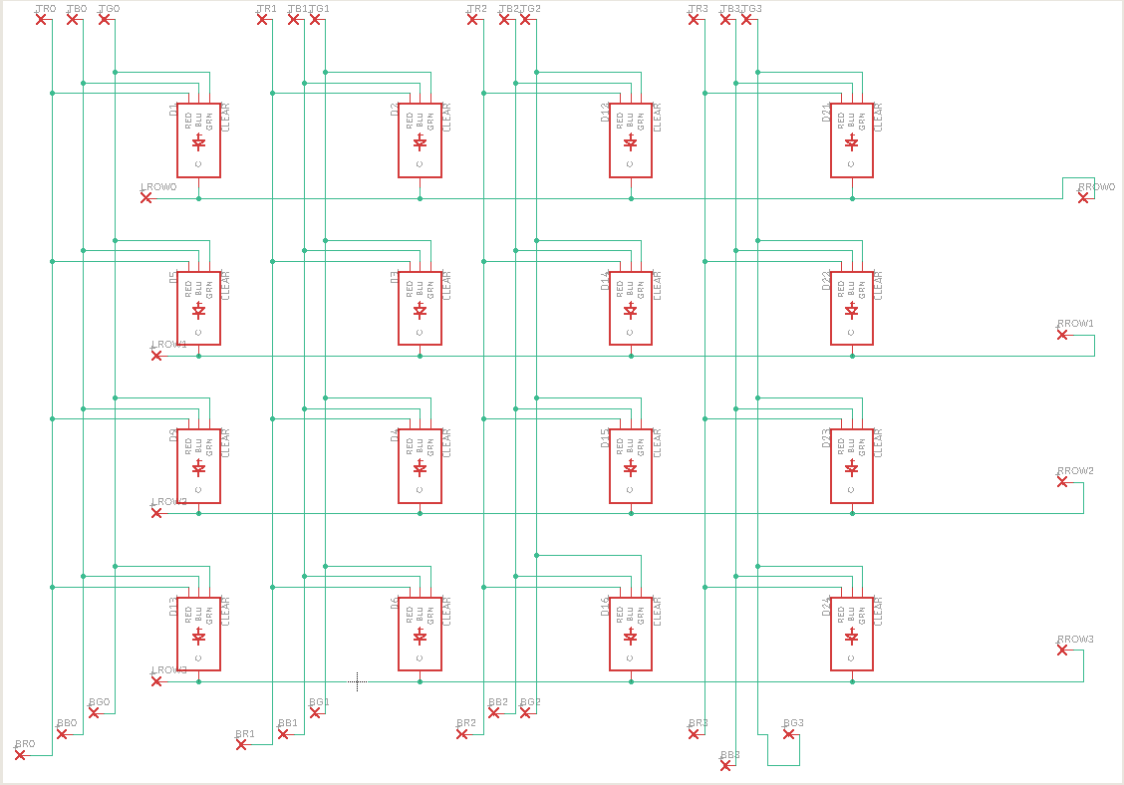
SOFTWARE DESIGN: SEQUENCE DIAGRAM

This diagram displays the flow over the course of one move being made as different boards are memorized. The different colors for the 4 left columns represent unique board states, where at a certain point there is up to 3 different board states memorized.



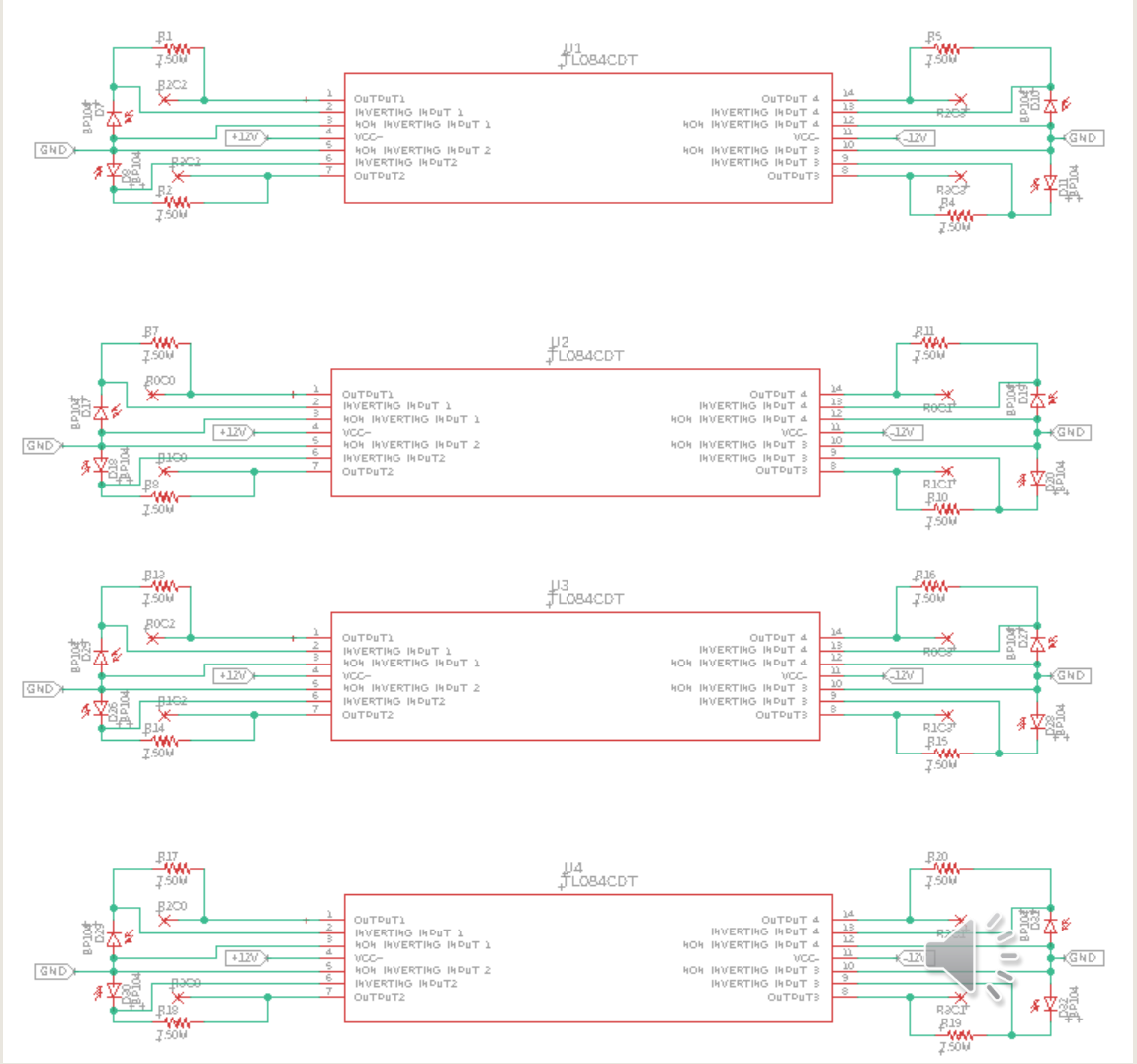
LED MATRIX SCHEMATIC

- 24 total columns
  - Each column is controlled by a pin from a shift register
- 8 rows total
  - Controlled by a separate shift register to sink current
- Simplified to a 4x4 LED array to save on PCB manufacturing costs
  - 4 7”x7” versus a full 14”x14” board
  - Added through holes to allow the single 4x4s to be connected together

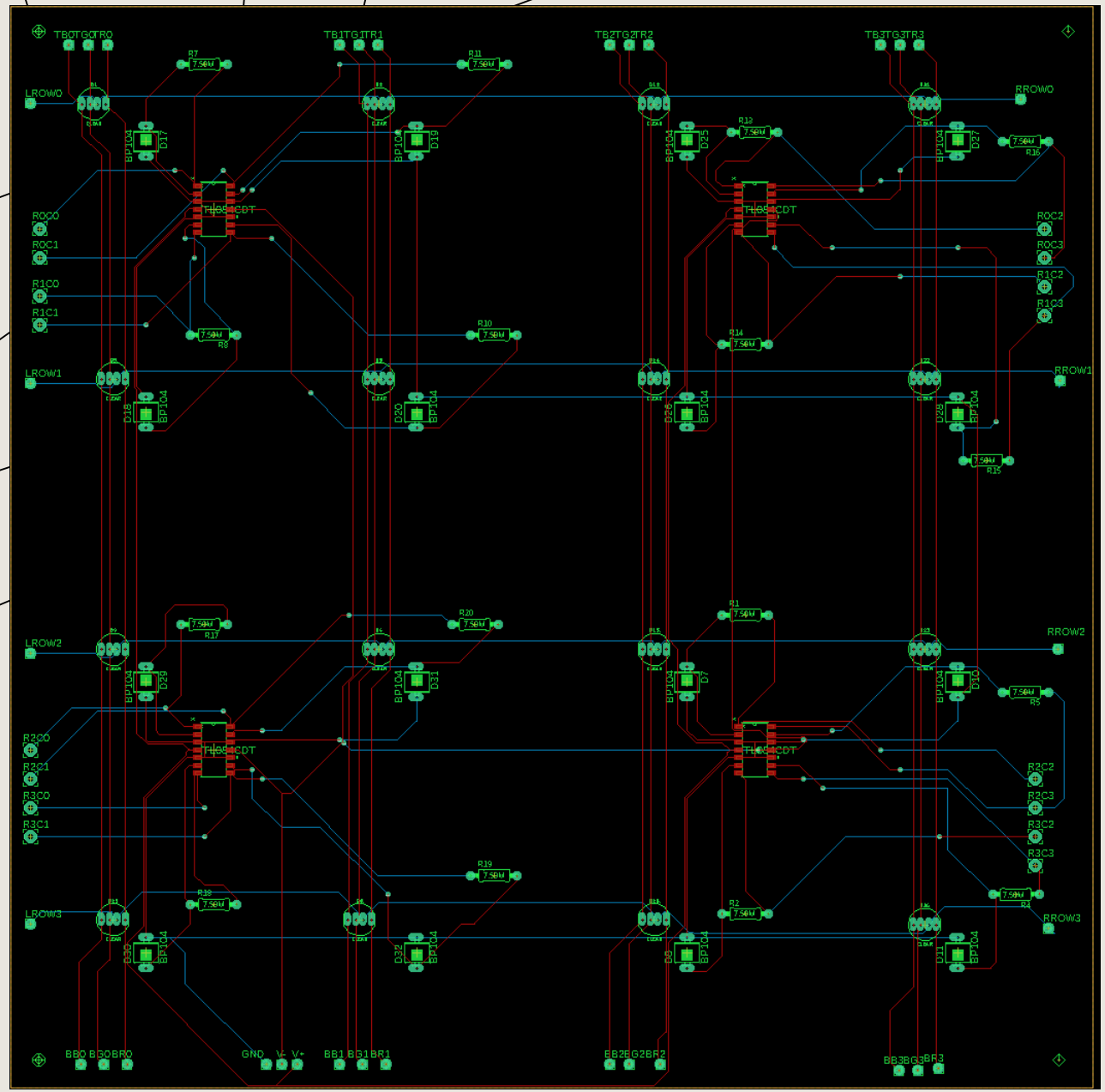


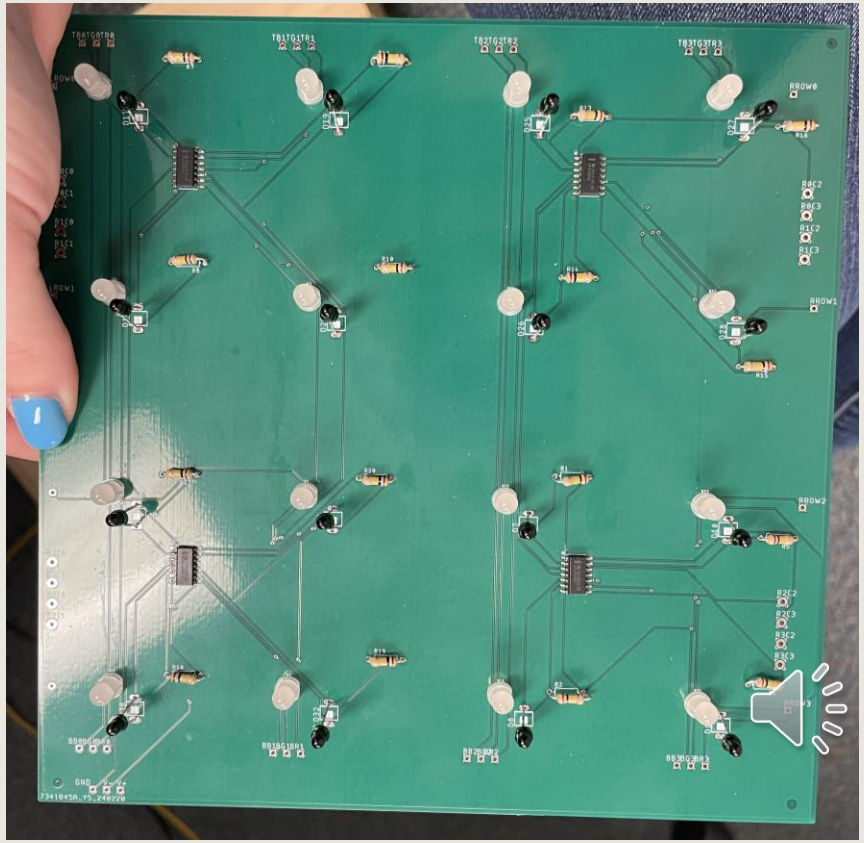
TRANSIMPEDANCE AMPLIFIER FOR PHOTODIODE

- Each output is connected to a pin on the multiplexer
- When the photodiode reacts to light, it provides a current that is then converted to a voltage by this amplifier
- The voltage is then converted by the ADC

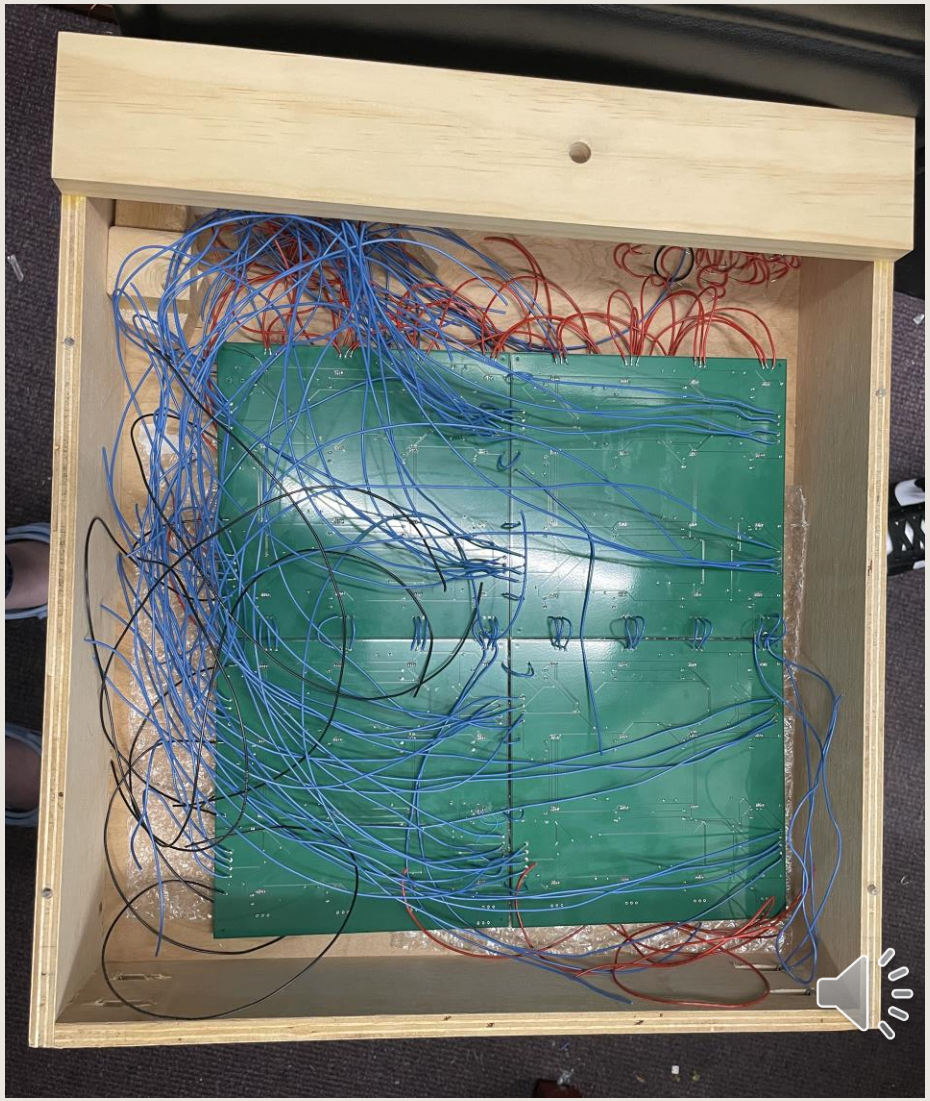


PCB 1 LAYOUT: RGB LED ARRAY AND TRANSIMPEDANCE AMPLIFIER

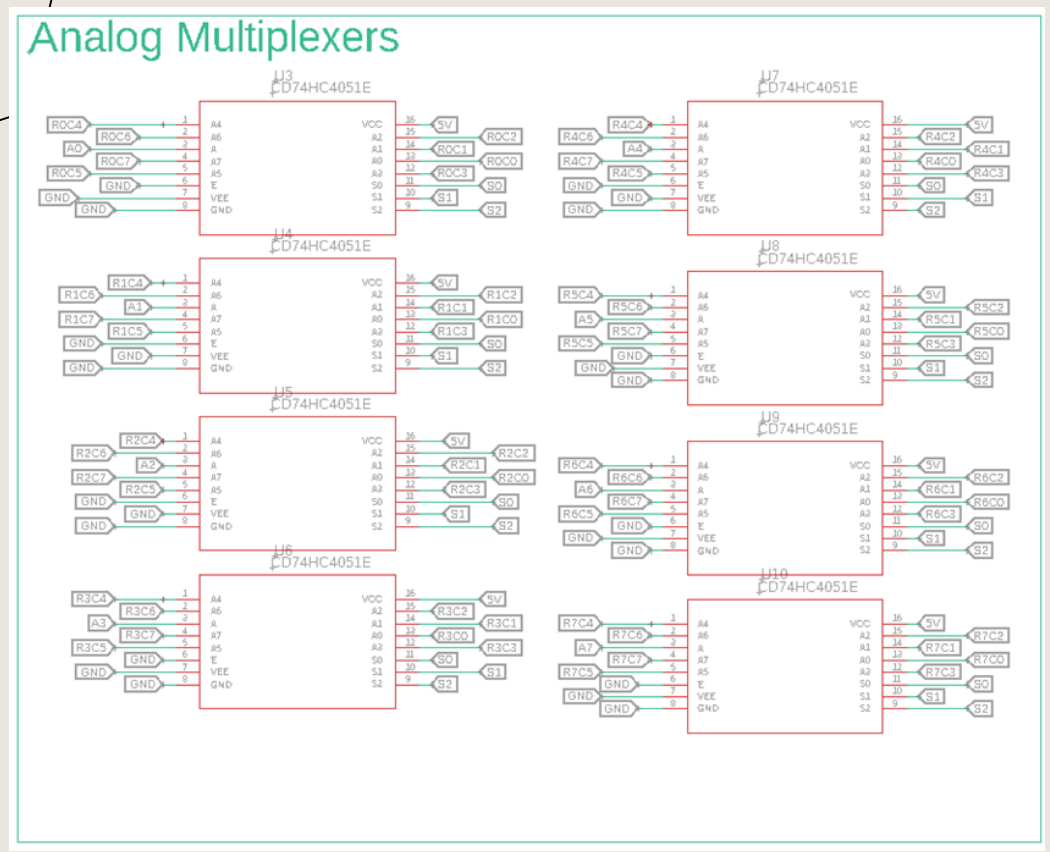


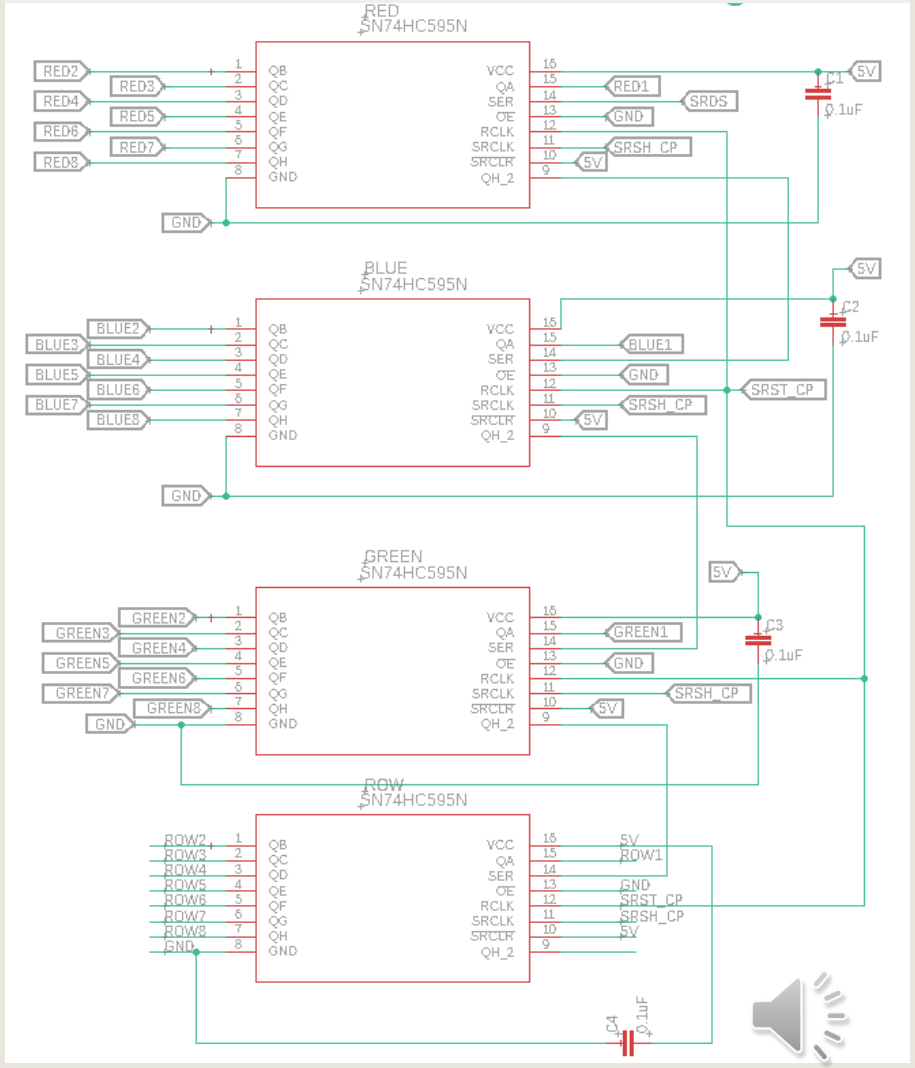


FULL 8X8 PCB



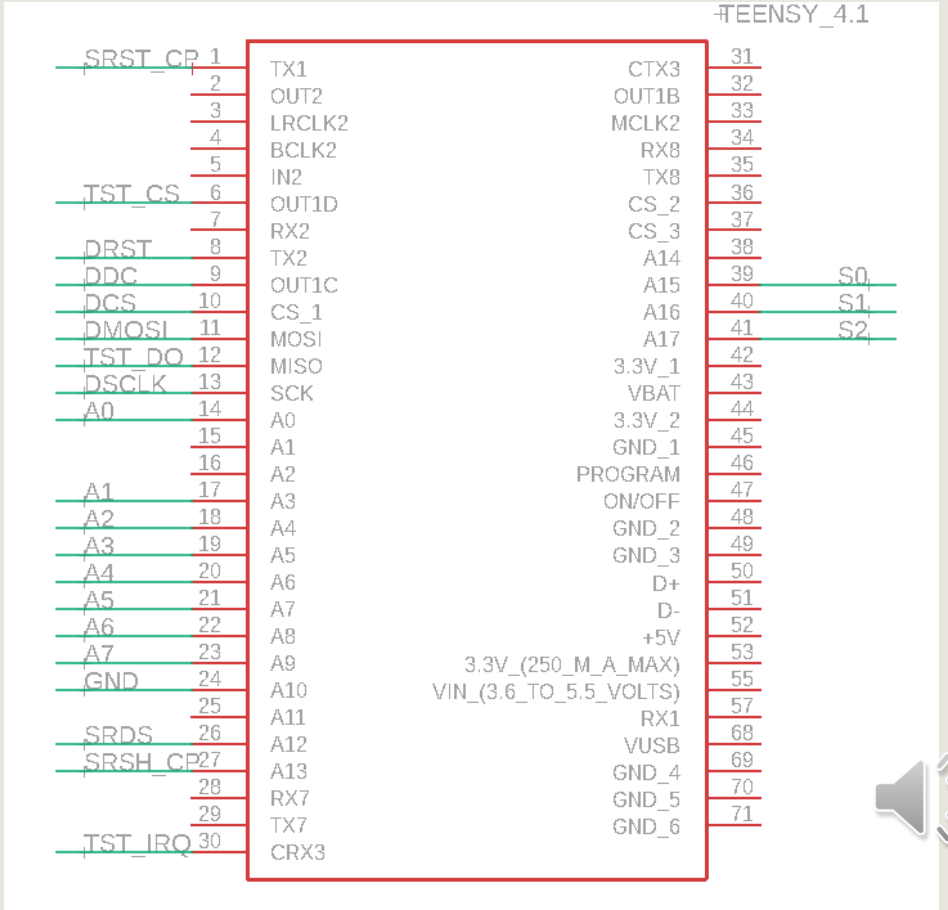
PINOUTS FOR INTEGRATED CIRCUITS

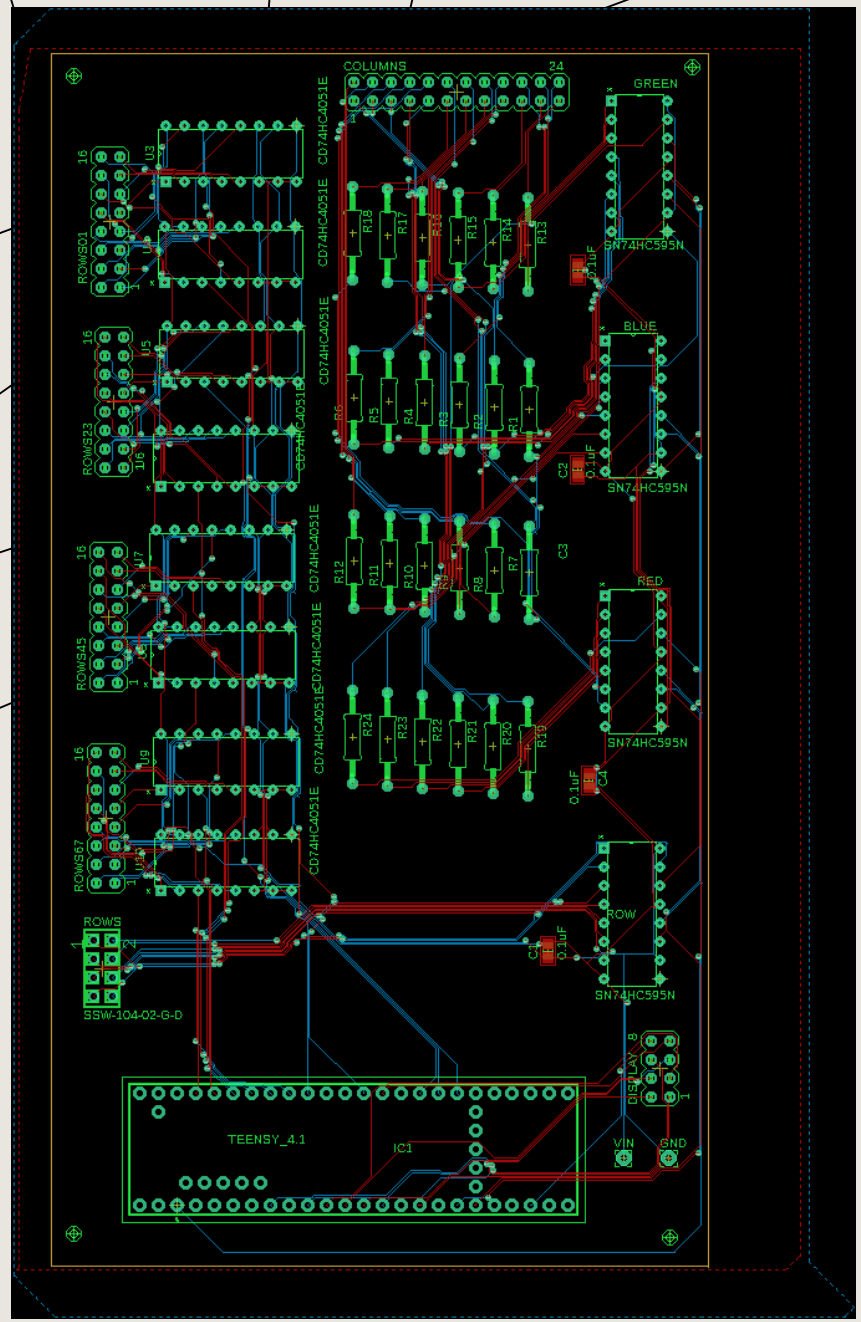




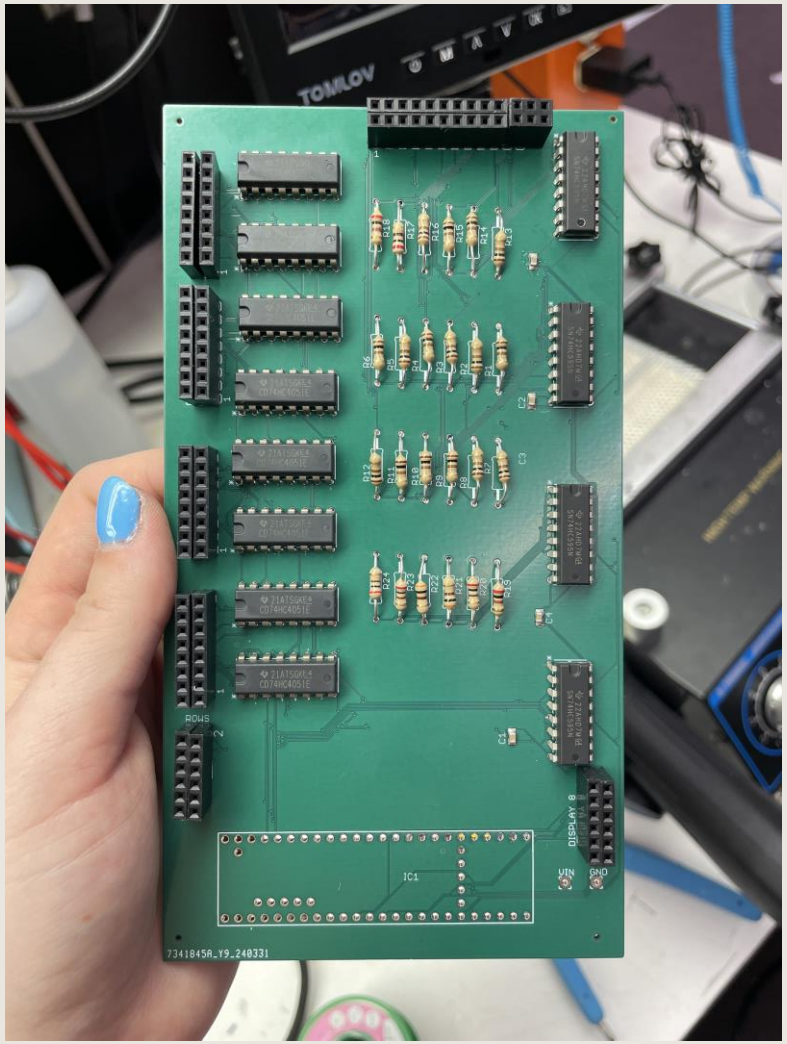
MICROCONTROLLER PINOUT

- 3 pins used to control multiplexers
- 8 pins used to read analog inputs
- 5 pins used for display
- 3 pins used for shift registers





PCB 2 LAYOUT: ICS AND MICROCONTROLLER



WORK DISTRIBUTION TABLE

	Alec	Alex	Cassidy	Nikolai	Vinny
Piece Identification System	Primary	Secondary		Secondary	
IR Illumination System	Secondary	Primary			
Software			Secondary	Primary	Secondary
Microcontroller			Secondary	Primary	Secondary
Power	Secondary	Secondary			Primary
PCB Design			Primary	Secondary	Primary
LED Array	Secondary	Secondary	Primary		
System Fabrication	Primary	Secondary	Secondary	Secondary	Secondary

BUDGET

	Parts	Price per part ($)	Quantity	Cost ($)
1	LED’s	$0.06-3	96*	$5.76-288
2	Photodiodes	$0.30-7	64*	$32- 448
3	Power supply	$30-110	1	$19.20-110
4	PCB	$10-25	6	$60-150
5	Microcontroller	$20-40	1	$20-40
6	Chess board material	$7-25	1	$7-25
7	Chess pieces set	$2.50-60	1*	$2.50-60
8	Batteries for pieces	$0.20-3	32*	$6.40-96
9	Battery holder	$0.30-3	32*	$9.60-96
10	Display screen	$10-$90	1	$10-90
11	Charging controller	$20-80	1	$20-80
	Total			**$192.46-1483**

BUDGET FOR FINAL PROJECT

Person	Total	# of items	Item Name/Description
Alec Barno	$69.91	3	48 pack of Energizer AAA Batteries
Alec Barno	$12.64	20	PD204-6B Photodiode 940nm from Digikey
Alec Barno	$19.94	100	PD204-6B Photodiode 940nm from Digikey
Alejandro Felix	$28.87	50	SFH 4544 IR LED Emitter 940nm from Digikey
Alec Barno	$23.76	6	Loctite super glue
Alec Barno	$2.68	1	5 colored rolls of electrical tape
Alec Barno	$4.99	1	Plaskolite plastic cutter
Alec Barno	$19.99	2	3ft 1.5"x1.5" poplar hobby board and multicolored pushpins
Vinicius Resende	$7.99	5	LM2596 DC to DC Buck Converter
Alec Barno	$24.39	1	SIOTI square filter kit with ND2, ND4, ND8, and ND16 filters
Alec Barno	$18.38	1	Lighting Neutral Density Gels Filter Sheet with ND3, ND6, and ND9 filters
Alec Barno	$20.32	1	Cloudray 900-1600nm IR Detection & Alignment Visulizer Card
Alec Barno	$42.12	1	Clear Acrylic Sheet 1/4'' Thick 18"x36"
Alec Barno	$16.06	2	FolkArt Top Coat Frost Effect, 8oz
Alejandro Felix	$42.17	4	12 pack LAMPVPATH AAA Battery Holder, 2 x 1.5V AAA
Alejandro Felix	$19.42	2	mxuteuk 30pcs Micro Push Button Switch
Alec Barno	$8.55	1	FLANCCI LED Light Blocking Stickers (Blackout stickers)
Alejandro Felix	$5.85	100	EDGELEC 100pcs 56ohm Resistor
Alec Barno	$19.16	1	ELEGOO PLA 3D Printer Filament 1.75mm Space Grey 1KG
Alec Barno	$16.97	1	AMEROUS Upgraded Weighted Chess Pieces with 3 inch King
Alec Barno	$69.91	3	48 pack of Energizer AAA Batteries
Alec Barno	$12.64	20	PD204-6B Photodiode 940nm from Digikey
Alec Barno	$19.94	100	PD204-6B Photodiode 940nm from Digikey
Alejandro Felix	$28.87	50	SFH 4544 IR LED Emitter 940nm from Digikey
Alec Barno	$23.76	6	Loctite super glue
Alec Barno	$2.68	1	5 colored rolls of electrical tape
Alec Barno	$4.99	1	Plaskolite plastic cutter
Alec Barno	$19.99	2	3ft 1.5"x1.5" poplar hobby board and multicolored pushpins

Total Cost: $733.07

Person	Total	# of items	Item Name/Description
Nikolai Coletta	$33.82	1	Teensy 4.1 Development Board
Cassidy Phillips	$33.45	1	PJRC Teensy 4.1 ARM Cortex-M7Processor at 600 MHz with a NXP iMXRT1062
Cassidy Phillips	$0.59	2	Header 24*1 For Teensy 4.1 PCB
Cassidy Phillips	$1.18	6	SN74HC595N (Shift registers)
Cassidy Phillips	$0.57	12	CD74HC4051E (Multiplexers)
Cassidy Phillips	$1.77	20	OPA4990IDR (Op amps)
Cassidy Phillips	$1.38	5	SN74HC595N (Shift registers)
Cassidy Phillips	$38.34	1	PCB Order 3 (Backup Boards)
Cassidy Phillips	$54.19	1	PCB Order 1 (LED PCB plus other board V1)
Cassidy Phillips	$17.76	1	Micro USB adaptor
Cassidy Phillips	$13.58	1	0805 Inductors
Vinicius Resende	$13.60	10 ft.	Heat Shrink Wrap for Batteries
Vinicius Resende	$6.99	5	ON/OFF Switches
Vinicius Resende	$4.99	1	Thermal/Insulating Tape
Vinicius Resende	$12.31	1	9V Power Adapter & Jack
Vinicius Resende	$15.68	1 (6 Pack)	Wire
Vinicius Resende	$29.52	6	Batteries (2nd Order)
Vinicius Resende	$10.21	5	Battery Protection Board
Vinicius Resende	$18.99	1	4" Display
Vinicius Resende	$7.99	5	LM2596 DC to DC Buck Converter
Alec Barno	$24.39	1	SIOTI square filter kit with ND2, ND4, ND8, and ND16 filters
Alec Barno	$18.38	1	Lighting Neutral Density Gels Filter Sheet with ND3, ND6, and ND9 filters
Alec Barno	$20.32	1	Cloudray 900-1600nm IR Detection & Alignment Visulizer Card
Alec Barno	$42.12	1	Clear Acrylic Sheet 1/4'' Thick 18"x36"
Alec Barno	$16.06	2	FolkArt Top Coat Frost Effect, 8oz
Alejandro Felix	$42.17	4	12 pack LAMPVPATH AAA Battery Holder, 2 x 1.5V AAA
Alejandro Felix	$19.42	2	mxuteuk 30pcs Micro Push Button Switch
Alec Barno	$8.55	1	FLANCCI LED Light Blocking Stickers (Blackout stickers)
Alejandro Felix	$5.85	100	EDGELEC 100pcs 56ohm Resistor
Alec Barno	$19.16	1	ELEGOO PLA 3D Printer Filament 1.75mm Space Grey 1KG
Alec Barno	$16.97	1	AMEROUS Upgraded Weighted Chess Pieces with 3 inch King

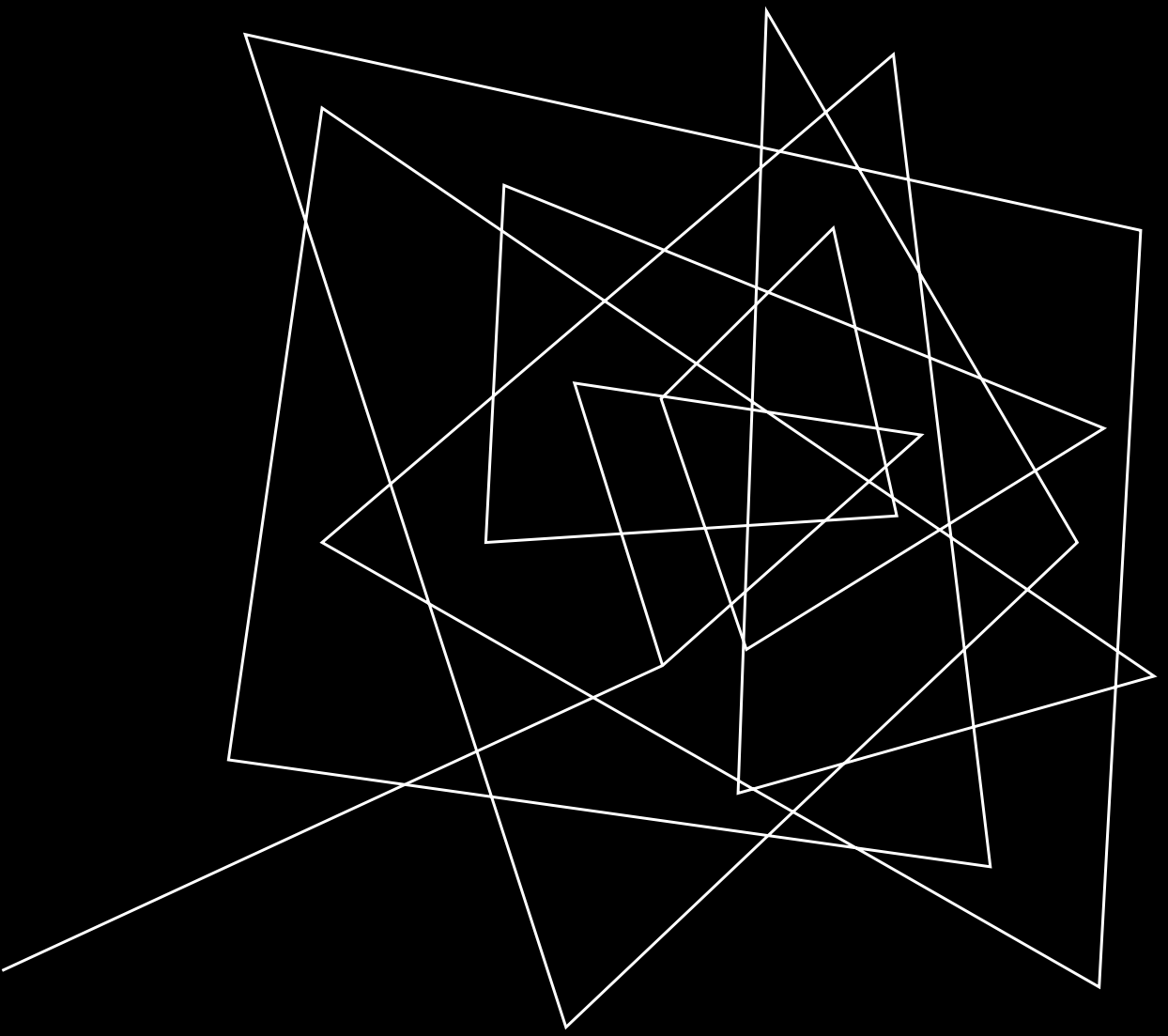
BUDGET FOR FINAL PROJECT

Person	Total	#/of items	Item Name/Description
Nikolai Coletta	$6.39	1	USB C to Micro USB Cable
Cassidy Phillips	$4.99	1	MCIGICM 10pcs Male Header strip (2.54mm) for Arduino Connector
Cassidy Phillips	$12.98	1	Glarks 112pcs 2.54mm Male and Female Pin Header Connector Assortment Kit
Cassidy Phillips	$7.99	1	10 pcs CD4051 CMOS Analog Multiplexers/Demultiplexers
Cassidy Phillips	$6.99	1	BOJACK LM324N Quadruple Operational Amplifier LM324
Cassidy Phillips	$6.25	5	MKL02Z32_t4_QFN16
Cassidy Phillips	$1.20	5	W25Q64JVXGIM_DFN8
Cassidy Phillips	$1.56	6	TLC59210IN
Cassidy Phillips	$203.91	1	PCB Order 2
Vinicius Resende	$13.63	10	Batteries (1st Order)
Vinicius Resende	$5.78	2	USB-C Connector
Vinicius Resende	$114.02		Various Tools for Soldering, Welding, Etc.
Alec Barno	$6.95	10	uxcell 10pcs photodiode, 3mm clear round head

Total Cost: $547.21

Total Cost of Everything: $1,280.28

Person	Total	# of items	Item Name/Description
Alec Barno	$6.95	10	uxcell 10pcs photodiode, 3mm clear round head
Alec Barno	$7.45	3	uxcell photodiode module with digital and analog output, 3pcs
Alec Barno	$8.46	5	uxcell photodiode, 5mm round head
Alejandro Felix	$10.57	1	AKEPO PMMA END Glow Fiber Optic Cable Kit with 100pcs
Alejandro Felix	$7.17	100	Ultra Bright 5mm Round Transparent Green LED
Alec Barno	$13.77	10	10mm LED Optical Lens, Smooth Convex
Alejandro Felix	$8.51	100	3mm IR 940nm LED, Clear Transparent Round Head
Alejandro Felix	$22.32	3	12 pack LampVPath CR2032 Coin Cell Battery Holder
Alejandro Felix	$10.69	40	PGSONIC CR2032 3V Lithium Battery
Alec Barno	$7.19	5	VTP9812FH Photodiode 580nm from Digikey
Alec Barno	$10.34	10	SFH 203 P Photodiode 850nm from Digikey
Alejandro Felix	$9.69	10	5mm IR LED 940nm 30 Degree Viewing Angle from LEDSUPPLY
Alec Barno	$32.00	1	VIS Light Diffusing Film 100x100mm
Alec Barno	$6.41	1	Electrial tape



THANK YOU!

QUESTIONS?