OPTICAL INTERACTIVE CHESS BOARD FOR BEGINNERS

Group 6

UCF Senior Design Fall 2023 – Spring 2024

MEET THE TEAM

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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 AND OBJECTIVES

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

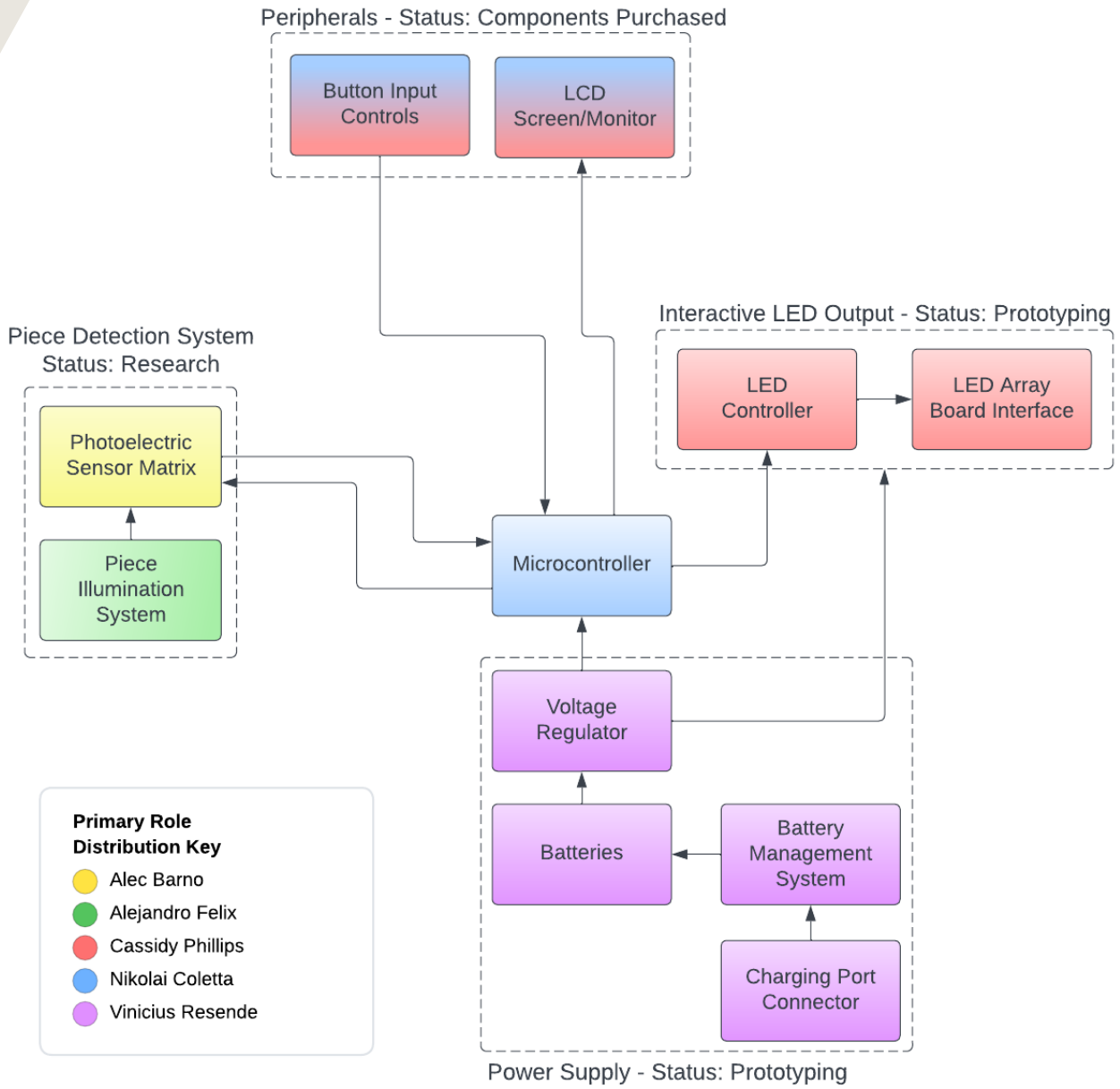
Objectives

- Have LEDs and filters under each piece. light blocked by the filters will be dependent on the chest piece enabling uniformed light intensity for each piece type. Light will come from the bottom of each piece to photodiodes under each square. Different currents will come from the photodiode depending on the light intensity enabling us to determine the piece type
- Implement more than one color LED under each square so that players can associate a certain color with a specific message. determine the best way to place these LEDs so that we can easily control which LEDs turn on and which ones we want to keep off. A driver must then be selected to control the LEDs so that consistent power and current are supplied to them without burning out any of the individual LEDs.

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	≤ 10 lbs
Delay/Activation from when piece is picked up to when move is shown on the chess board	≤ 5 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)

CHESS PIECE IDENTIFICATION SYSTEM: DIFFERENTIATING EACH PIECE COMPARISON

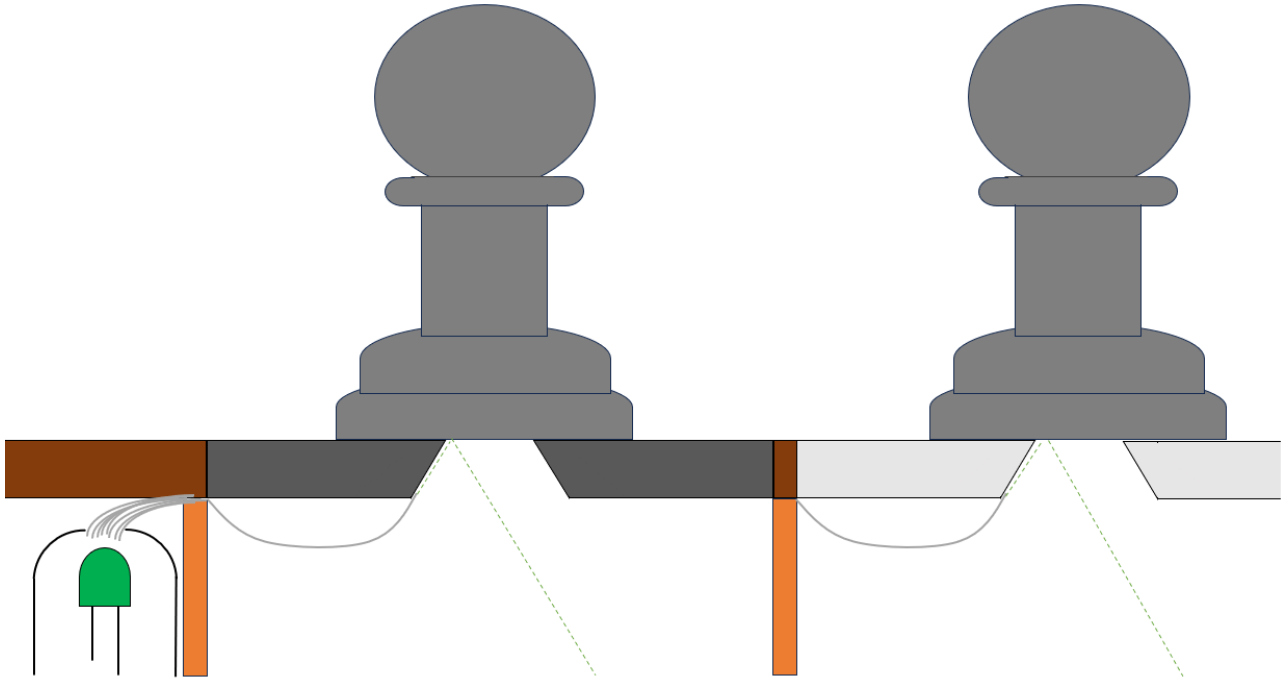
	Colors/Color Filters	Materials	Light Filters
Function	To differentiate the chess piece types based on color and wavelength associated to colors	To differentiate the chess piece types based on intensity of reflected light due to the reflectivity values of various materials and objects	To differentiate 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

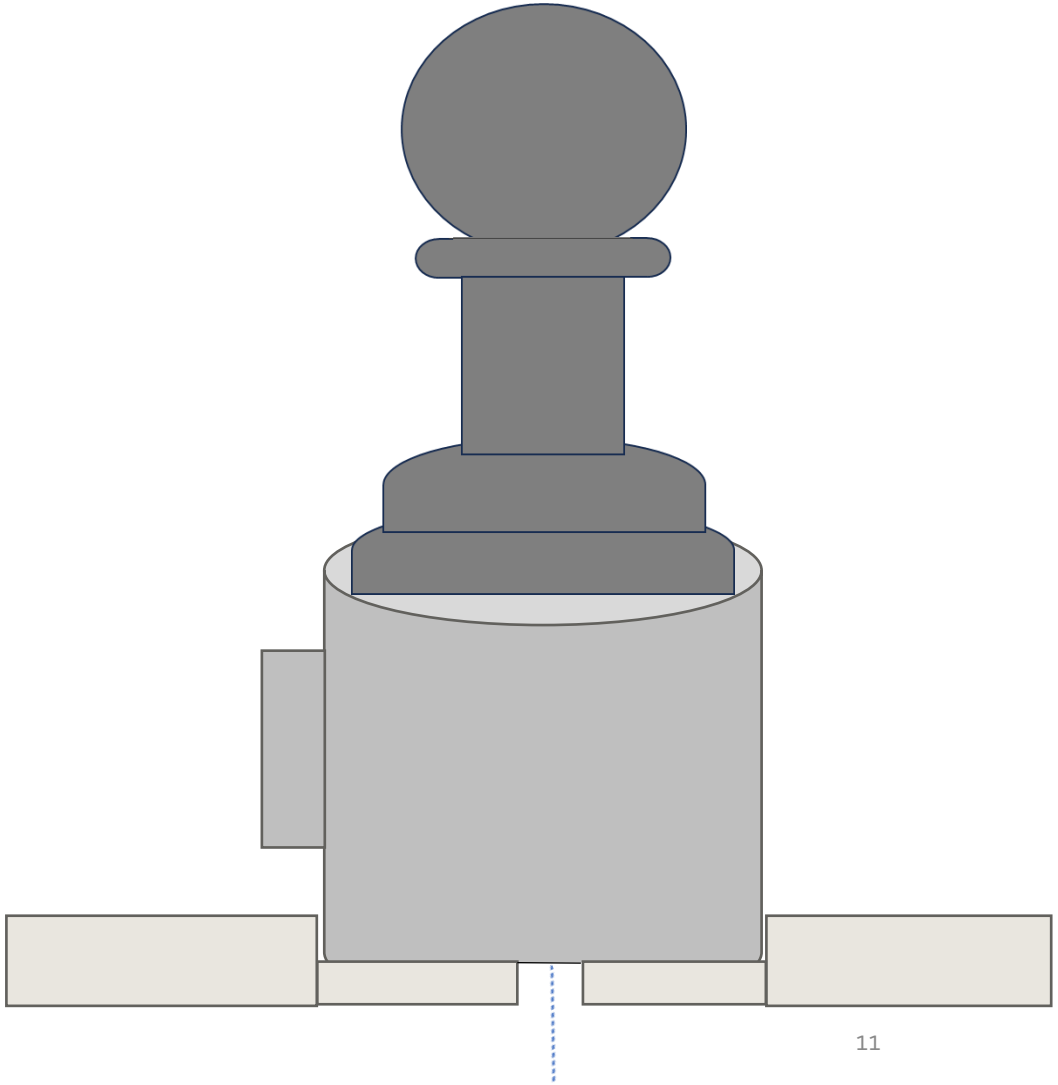
Name	Square Filter Kit	Gel Filters, CTO Transparent Light Sheets	Lighting Neutral Density Gels Filter Sheet
Brand/Manufacturer	SIOTI	Meking	RENIAN
Seller	Amazon	Amazon	Amazon
# of filters	4	4	6 (2 per each kind)
Value of filters	ND2 (½ transmission) ND4 (¼ trans.) ND8 (⅛ trans.) ND16 (1/16 trans.)	1 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

DESIGN PROGRESS

Fiber optic cable illumination design



Cylinder base design



TECHNOLOGY SELECTION: PIECE ILLUMINATION SOURCE

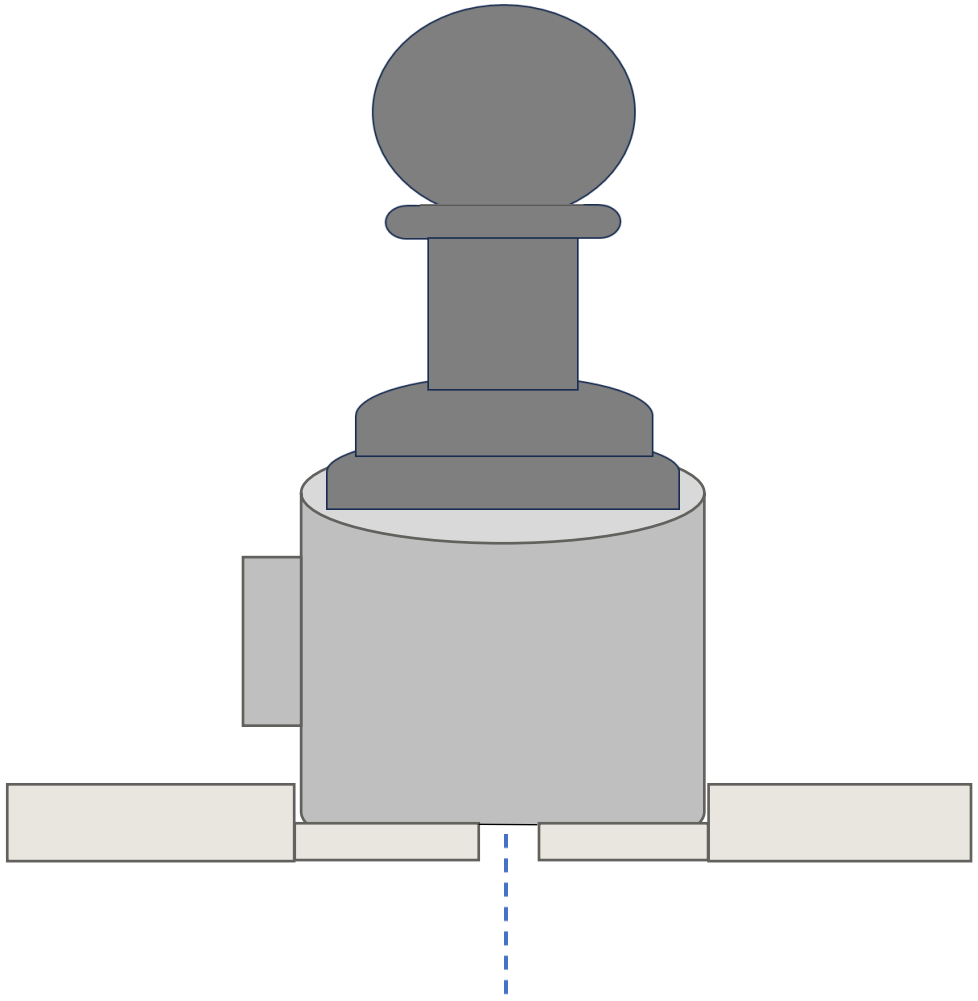
	LED	HeNe Laser	Laser diode	Quartz halogen lamps	Xenon metal halide lamp
Temperature (Heat)	Low	Medium	Medium	High	High
Warmup time	None	10 min	None	None	15 min
Size	0.98 x 0.2 x 0.2 in	1.74 x 1.74 x 10.70 in	0.23 x 0.55 x 3.54 in	3.07 x 0.32 x 3.07 in	2.1 x 5.3 x 2.1 in
Quantity in package	100	1	30	5	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

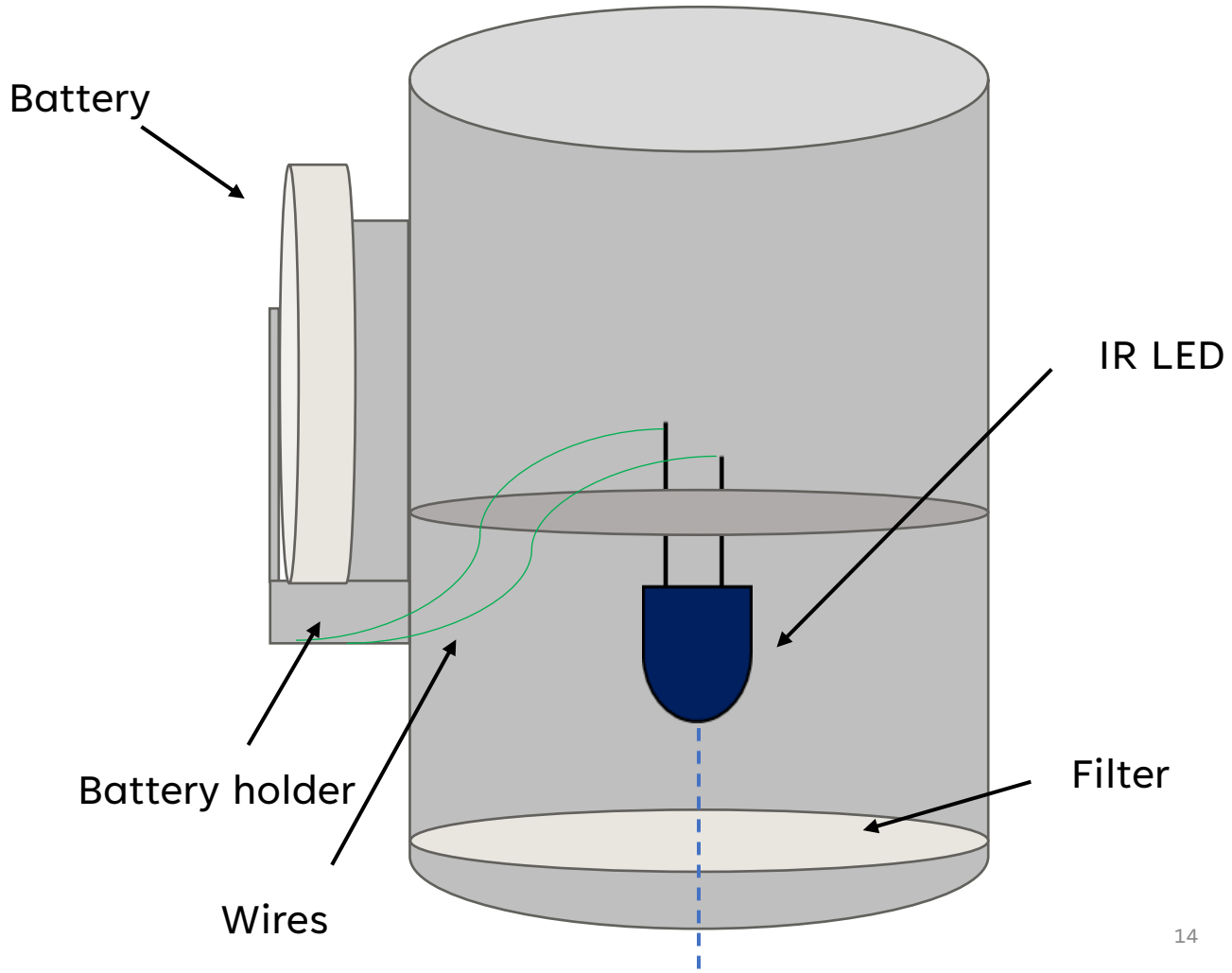
Brand	CO-RODE	Chanzon	CO-RODE	Chanzon	Chanzon
Size	0.197 x 0.197 x 0.689 in	0.228 x 0.228 x 0.728 in	0.197 x 0.197 x 0.689 in	0.152 x 0.152 x 1.161 in	0.197 x 0.197 x 1.043 in
Weight	0.79 oz	0.634 oz	0.79 oz	0.352 oz	0.634 oz
Max Luminous Intensity	15,000 – 20000 mcd	15,000 - 18,000 mcd	4,000 - 5,000 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: CHESS ENGINES

Qualities:	StockFish	Micro-Max	TSCP	GNU Chess
Approximate ELO	3200	1950	1700	2660
File Size	40 MB	6 KB	160 KB	3.2 MB
Requires OS?	YES	NO	NO	YES
*Load Position Feature?	YES	NO	YES	YES

**This quality is true if the given chess engine can load up a chess position rather than only being able to begin from the starting position.*

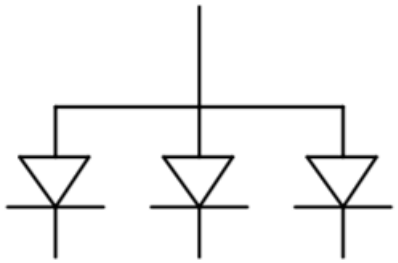
TECHNOLOGY SELECTION: MICROCONTROLLER

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

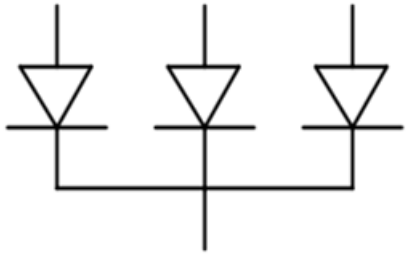
**Two values are shown for some of these specifications: values on the left are without the added RAM, values on the right are with the added RAM.*

***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

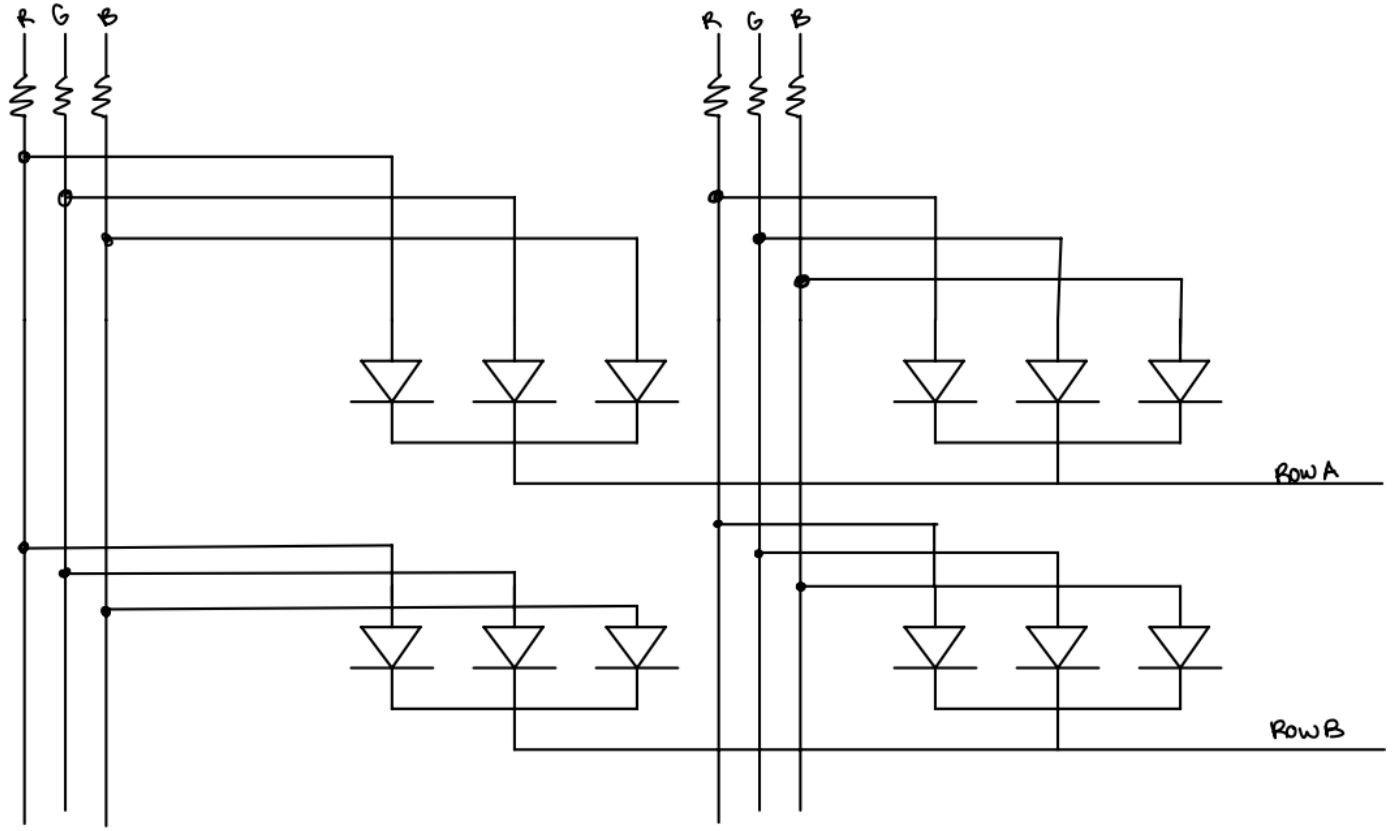


(A)



(B)

BASIC SETUP FOR LED ARRAY



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

DISPLAY SCREEN

TFT LCD Displays

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

Thinner and lighter than conventional LCDs.

Capable of reproducing images.

Inexpensive.

Larger screen size.

Often include touchscreen.

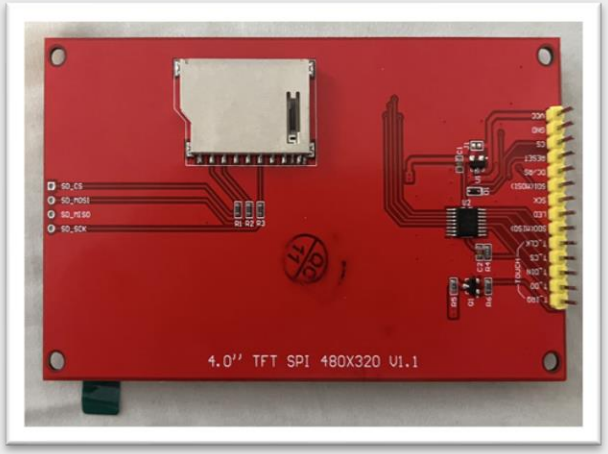


IMAGE: TFT LCD Display Screen (Top)
Display Connections and SD Slot (Bottom)

	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

18650 Battery Cells

- 3.7 Nominal Cell Voltage
- 3250 mAh Cell Capacity

IMAGE: 18650 Li-Ion Cells

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)

7.4 Volts

9750 mAh

Expandable

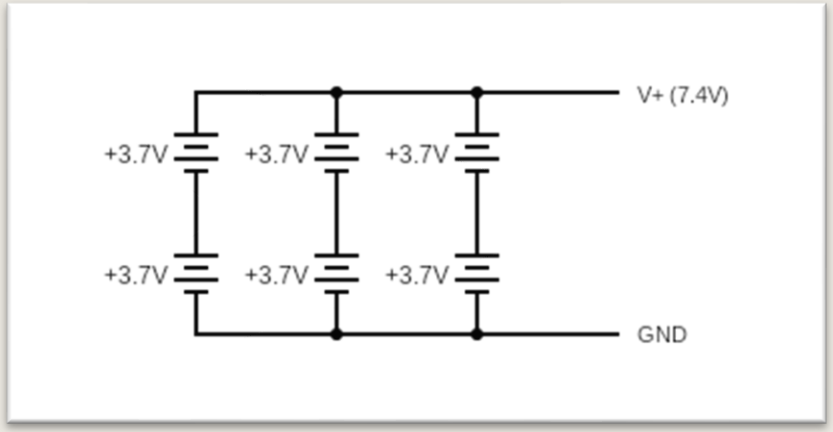


IMAGE: 2S3P Battery Pack Design

BATTERY PACK MANAGEMENT SYSTEM

Monitor, control, and safeguard the battery.

Protection Circuits:

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

Cell Charge Balancing

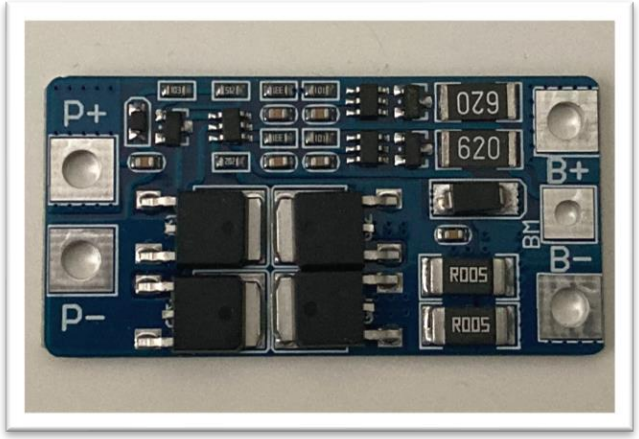


IMAGE: HX-2S-JH20 BMS Board

	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

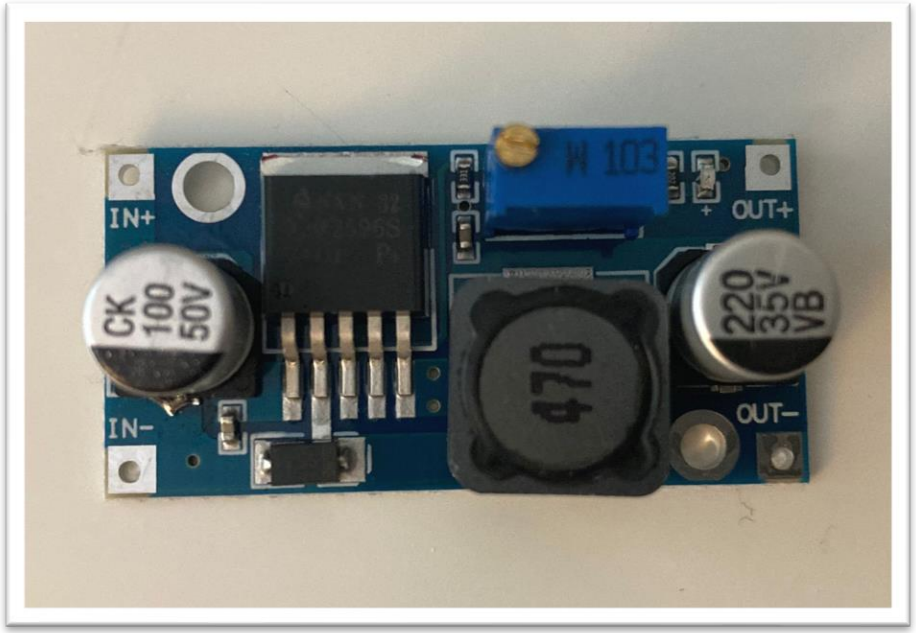


IMAGE: LM2596 Switching Voltage Regulator

POWER MANAGEMENT: BATTERY RECHARGING

USB-C Power Delivery

The USB-C format is compact enough to fit in small of devices like smartphones, while still having enough power transfer capability to charge bigger devices like laptops.

Power Delivery allows for devices to request from the charger the exact rate of charge they need before transmitting and receiving power.

It is a convenient and universal solution to meet our project's needs.

PD Trigger Board

- Responsible for USB-C compatible input and enabling PD functions of the USB-C adapter.
- Cheap
- Compact

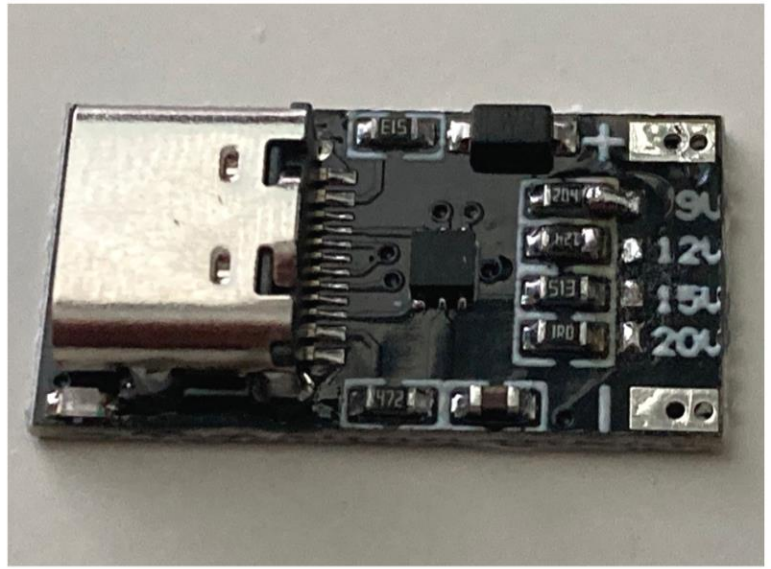


IMAGE: USB-C Trigger Board
(Soldered to a 9V Output Configuration)

SOFTWARE DESIGN: IDE & DISPLAY LIBRARY WITH PIN CONFIGURATION

```
TEENSY 4.1 INTERACTIVE CHESS – PIN LAYOUT
11.27.2023

PIN 00:
PIN 01: Shift Register ST_CP
PIN 02:
PIN 03:
PIN 04:
PIN 05:
PIN 06:
PIN 07:
PIN 08: Display RST
PIN 09: Display DC
PIN 10: Display CS
PIN 11: Display MOSI
PIN 12:
PIN 13: Display SCLK
PIN 14: PID Analog 0
PIN 15: PID Analog 1
PIN 16: PID Analog 2
PIN 17: PID Analog 3
PIN 18: PID Analog 4
PIN 19: PID Analog 5
PIN 20: PID Analog 6
PIN 21: PID Analog 7
PIN 22:
PIN 23:
PIN 24:
PIN 25:
PIN 26: Shift Register DS
PIN 27: Shift Register SH_CP
PIN 28:
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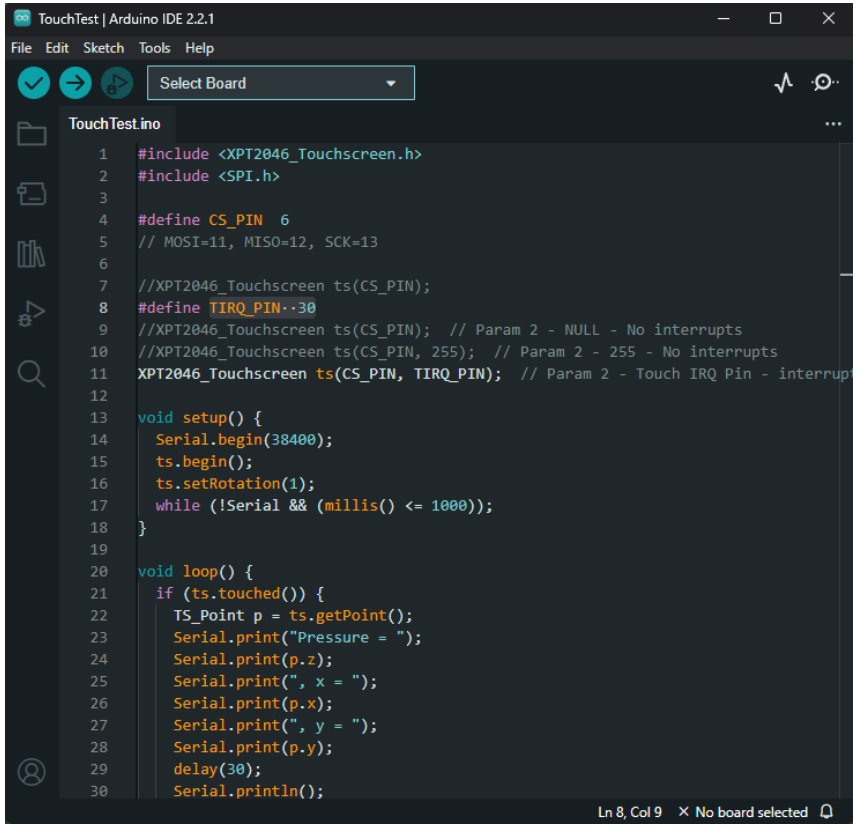
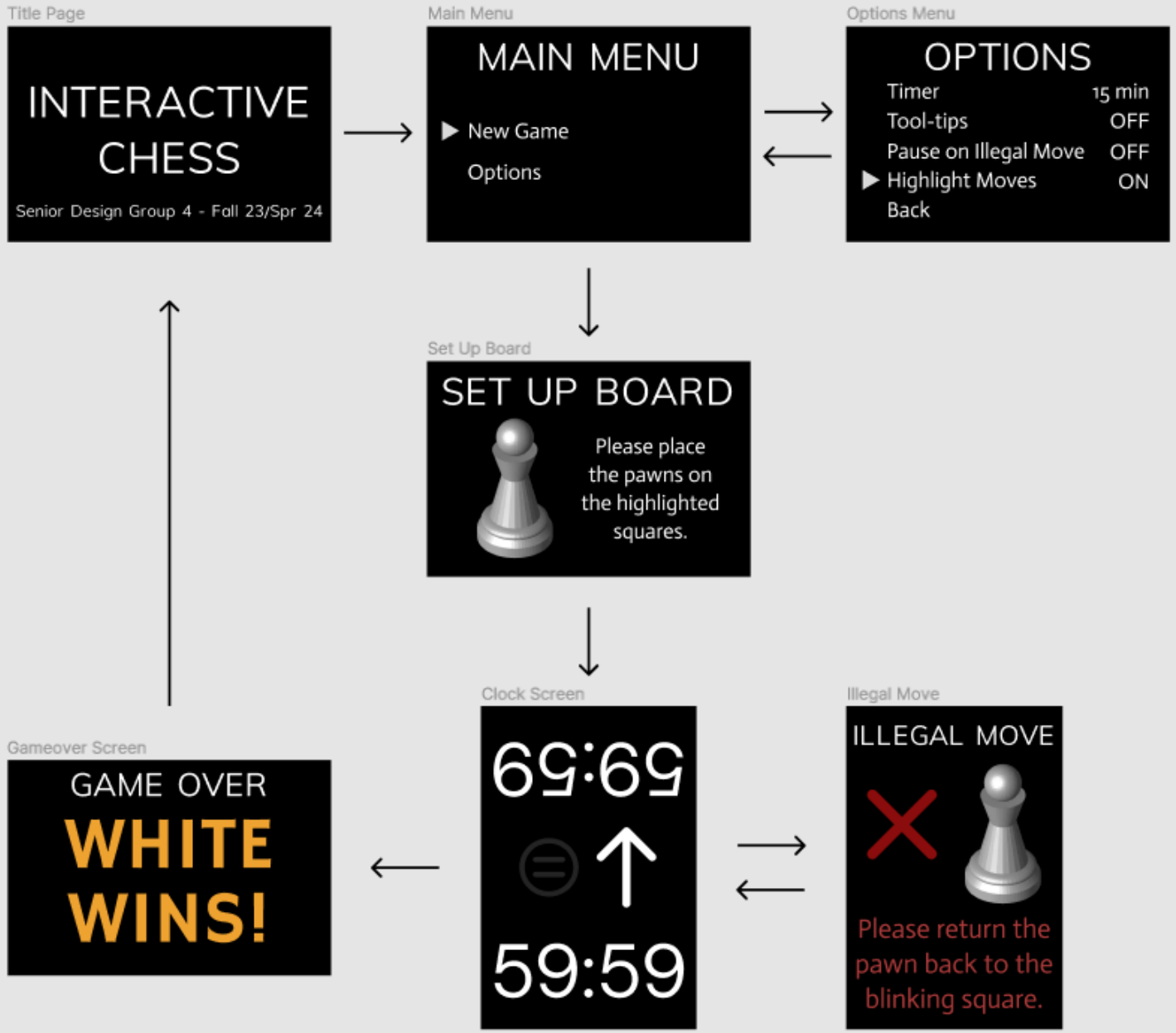


The IDE of choice for this project is also the recommended programming environment for Teensy- the Arduino IDE with Teensyduino. Modifying Arduino's native IDE makes for a great development environment that is easy to use, well documented and maintained, and capable of supporting this project. In addition,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

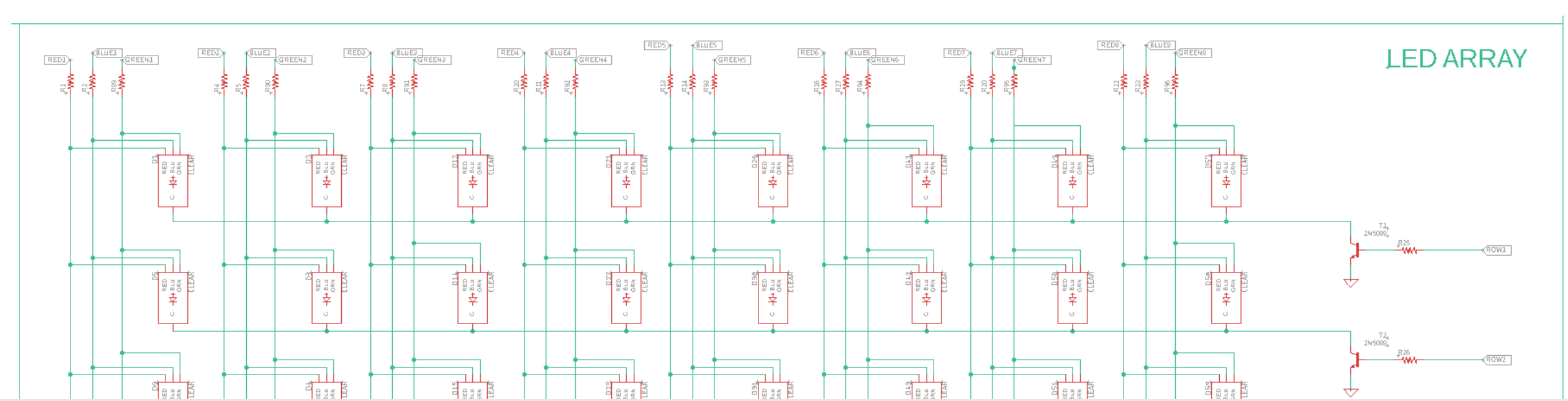
Through tedious testing and configuring until its functionality was achieved, the library that worked was the "TFT_eSPI" library. The library will effectively connect the Teensy board to the ST7796 Driver, the driver that is on the display.

SOFTWARE DESIGN: FIGMA PROTOTYPE



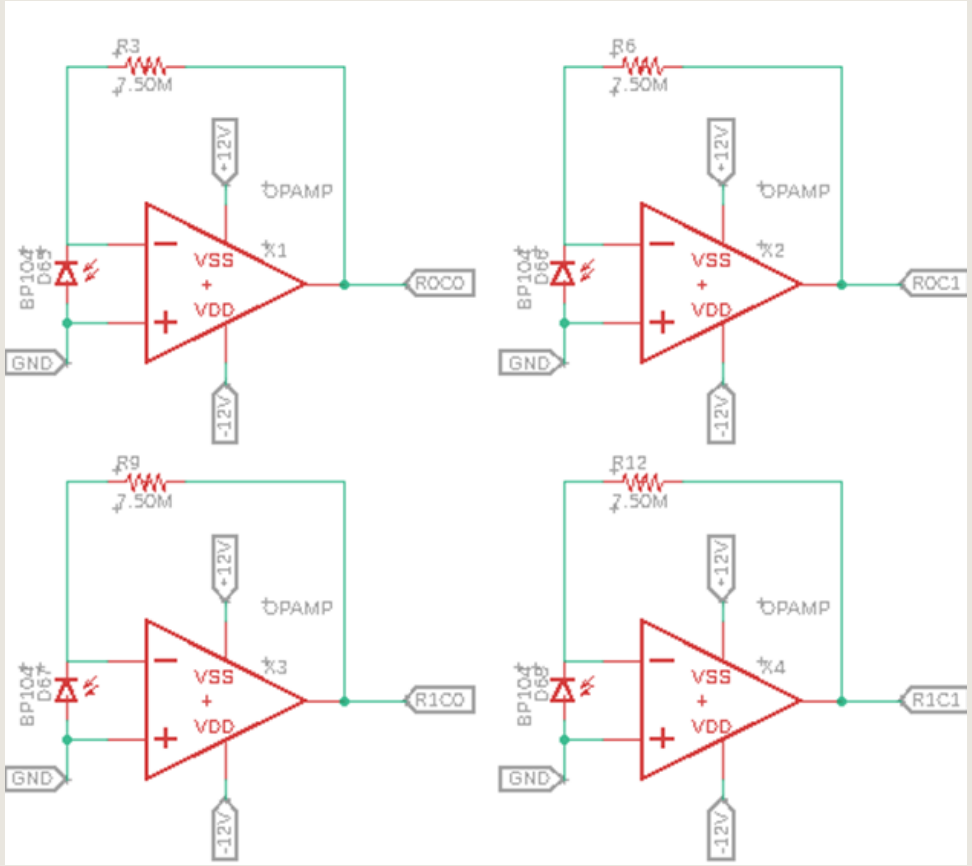
LED MATRIX SCHEMATIC

- 24 total columns
  - Each column is controlled by a pin from a shift register
- 8 rows total
  - Connected to ground by a NPN transistor
  - Microcontroller controls the transistor

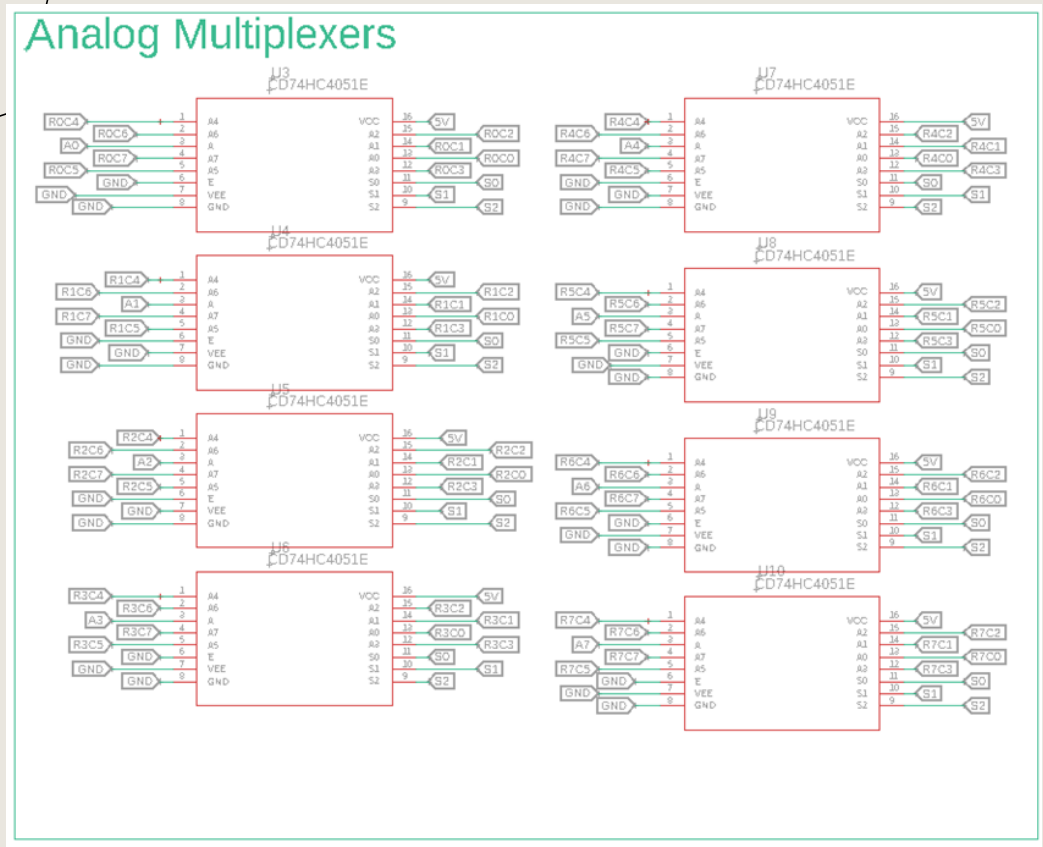


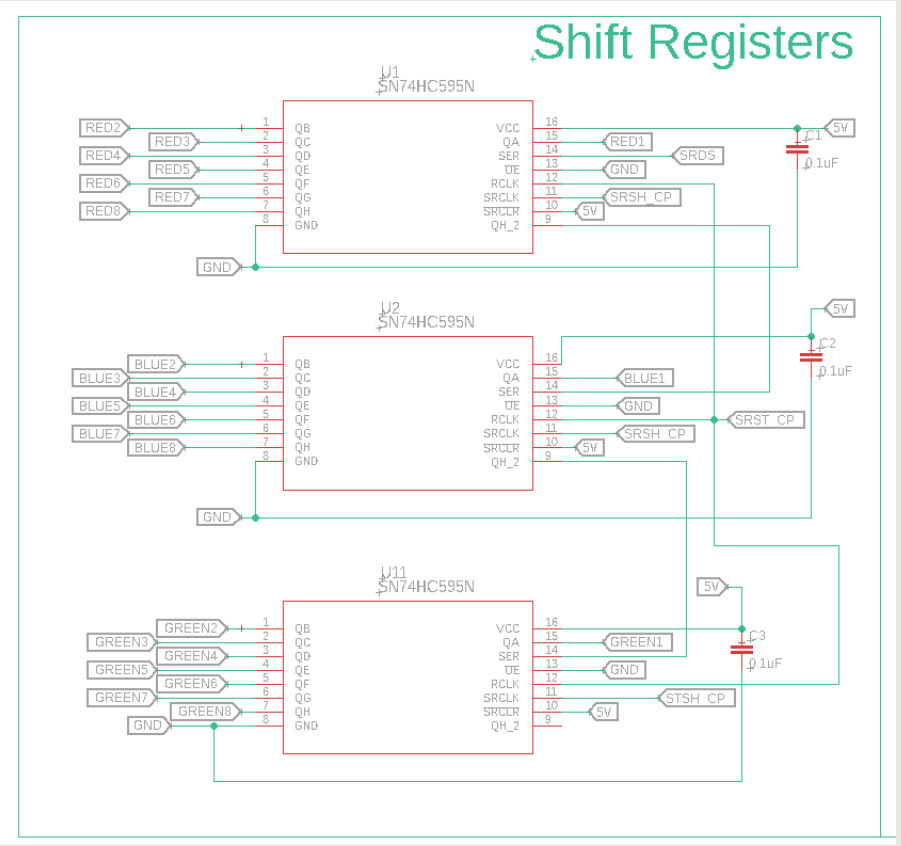
TRANSIMPEDANCE AMPLIFIER FOR PHOTODIODE

- 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



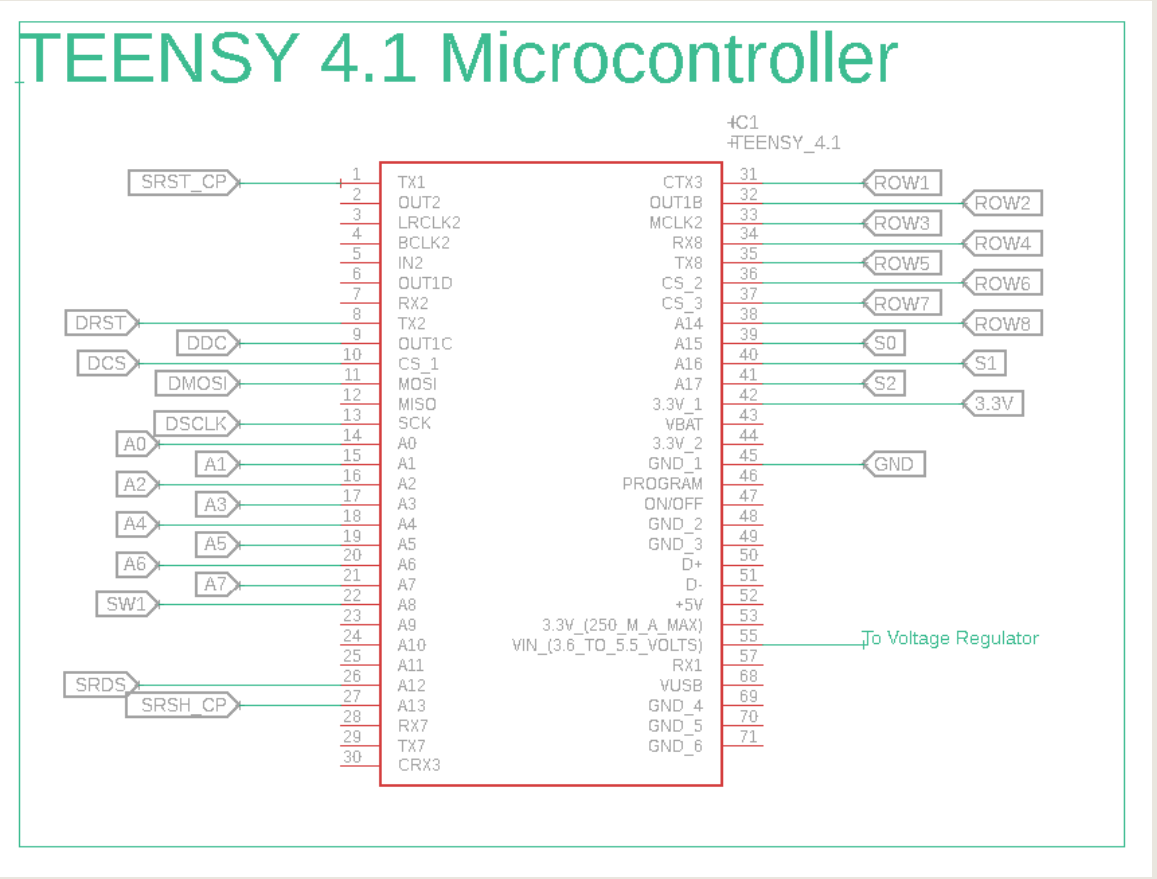
PINOUTS FOR INTEGRATED CIRCUITS



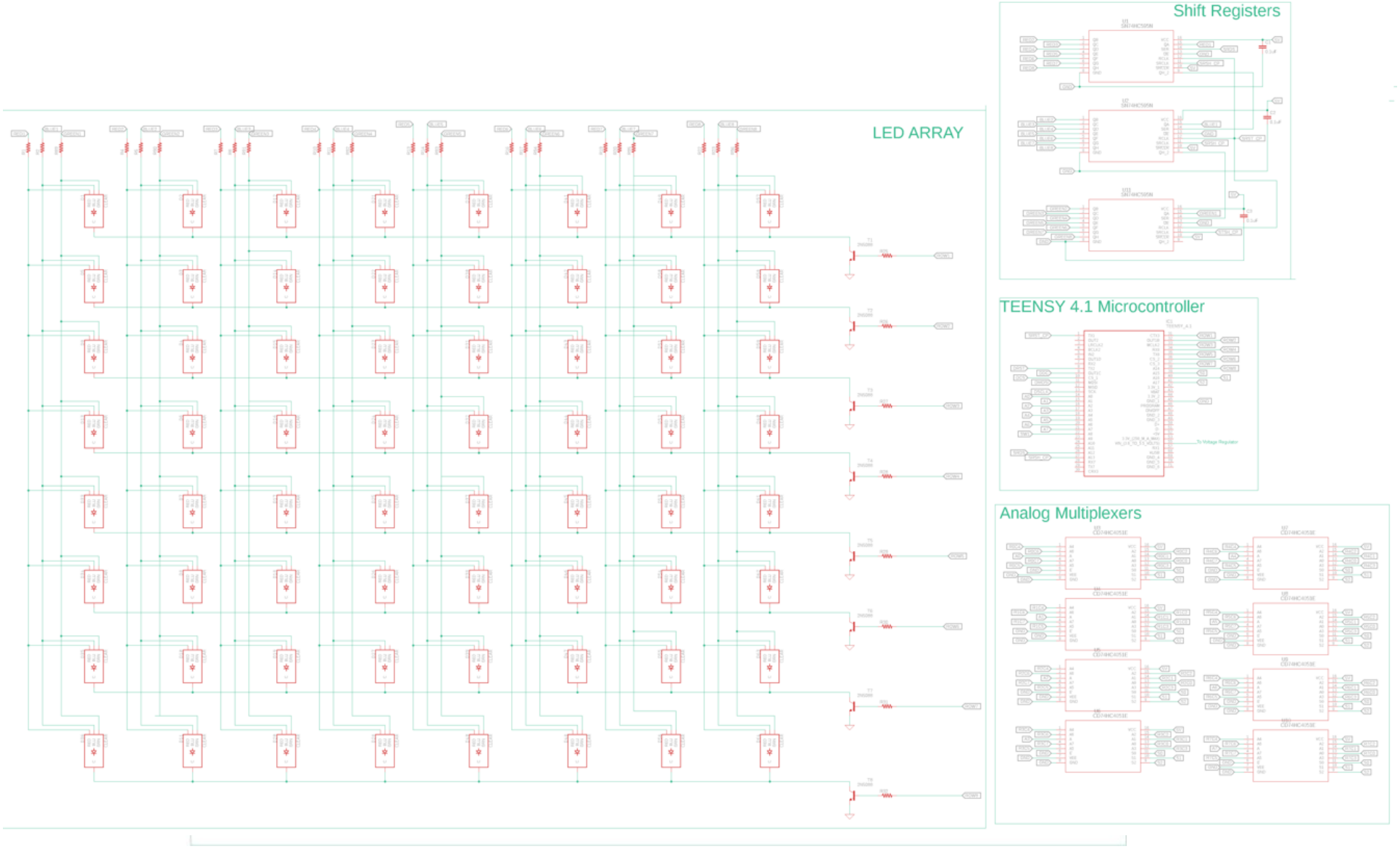


MICROCONTROLLER PINOUT

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



OVERALL PCB LAYOUT

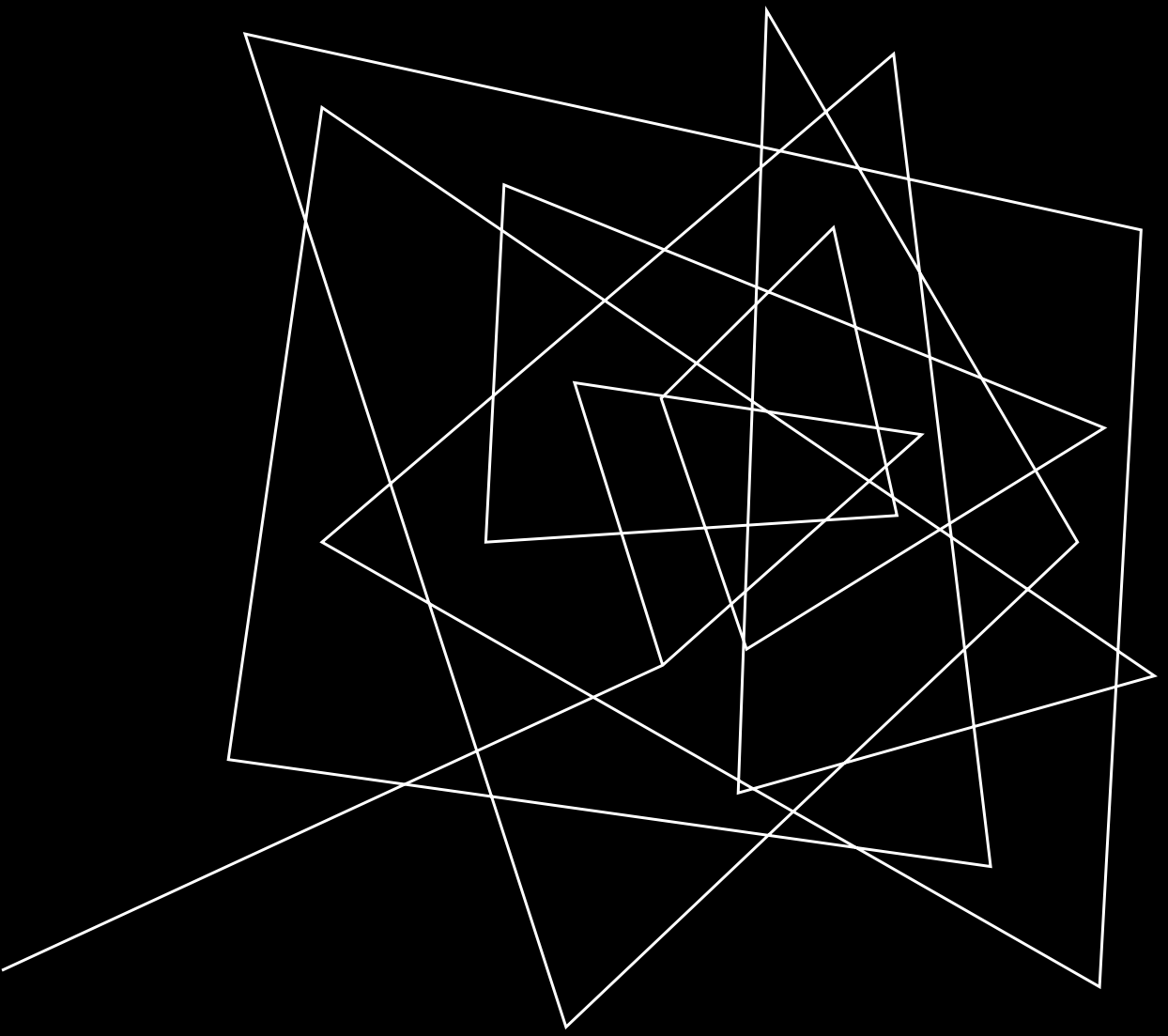


WORK DISTRIBUTION TABLE

	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**



THANK YOU!

QUESTIONS?