Pathfinder Chessboard

CDR Presentation

Group 35

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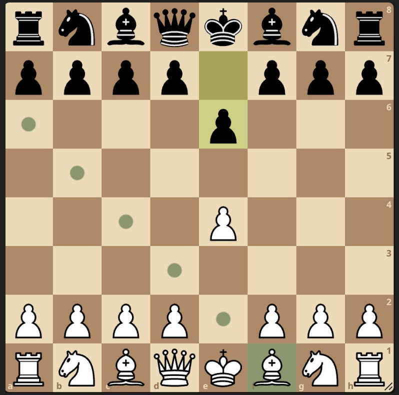
Background & Motivation

Chess has a steep learning curve that often discourages beginners. While online chess platforms provide guidance, it removes the physical experience of traditional gameplay.

The Pathfinder Chessboard seeks to bridge this gap by integrating an embedded system using lights and sensors into a traditional chessboard, to provide real-time move validation and LED-guided feedback directly on the board.



Goals & Objectives

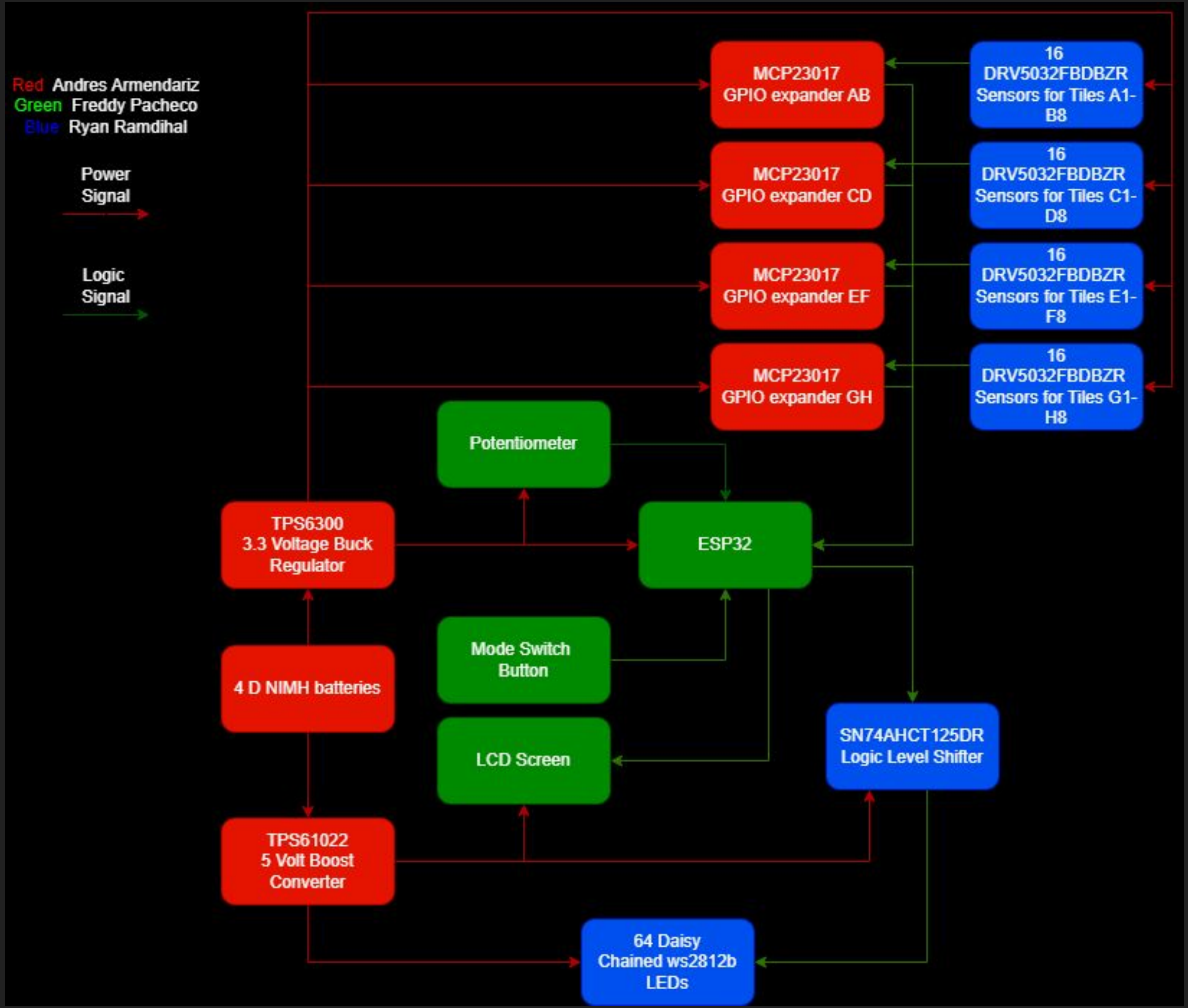
	Goals	Measurable Objectives
Basic Goals	● Accurate Piece Detection ● LED move guidance ● Local two-player mode	● Detect piece presence on all 64 possible squares maintained for a full match duration ● LEDs illuminate correct legal moves & captures ● All chess rules enforced correctly
Advance Goals	● Integrate a computer opponent using a chess engine ● Implement timers for each player ● Implement a speed chess mode	● Integrate chess engine to run locally ● Computer opponent generates valid legal moves displayed via LED guidance ● Adjustable timer via potentiometer
Stretch Goals	● Enhance user experience with further LED animations ● Incorporate sound alerts for in game events ● Online Connection	● LED animations for check/checkmate ● Audio cues synced to game events

Engineering Specs (System-Level)

Parameter	Target Value	Notes/Verification Method
Board Dimensions	≤ 20 × 20 × 2 in	Standard chessboard size with space for PCB components. Physical Measurement
Weight	< 15 lbs	Portability
Battery life	≥ 2 hours	Duration of at least 1 full game session Continuous runtime test
Operating Temperature	< 100 °F	Safe for normal indoor operation Thermal measurement
Modes of Operation	≥ 3 modes	PvP PvE Speed Chess *Checkers

Engineering Specs (Component-Level)

Subsystem	Parameter	Target Value	Notes/Verification Method
LED System	Power Consumption	<22 Watts	Current measurement
LED Response Time	Lift → Illuminate	<= 1 sec	Seamless movement
Sensors	Magnetic Flux	>3.32mT	Consistent detection
Voltage Regulation	3.3V & 5V Stability	±5% variation	Oscilloscope measurement


Red Andres Armendariz
Green Freddy Pacheco
Blue Ryan Ramdihal
Power Signal
Logic Signal
MCP23017 GPIO expander AB
MCP23017 GPIO expander CD
MCP23017 GPIO expander EF
MCP23017 GPIO expander GH
16 DRV5032FBDBZR Sensors for Tiles A1-B8
16 DRV5032FBDBZR Sensors for Tiles C1-D8
16 DRV5032FBDBZR Sensors for Tiles E1-F8
16 DRV5032FBDBZR Sensors for Tiles G1-H8
Potentiometer
TPS6300 3.3 Voltage Buck Regulator
ESP32
4 D NIMH batteries
Mode Switch Button
LCD Screen
SN74AHCT125DR Logic Level Shifter
TPS61022 5 Volt Boost Converter
64 Daisy Chained ws2812b LEDs

Microcontroller Comparison

Microcontroller	GPIO Count	Clock Speed	Development Environment	Supported Languages	Cores	Unit Cost
ATmega328P	20	16 MHz	Arduino IDE	C / C++	1	$2.89
MSP430FR6989	83	16 MHz	Code Composer Studio	C / C++	1	$7.49
Raspberry Pi Pico RP2040	26	133 MHz	Arduino IDE, Pico SDK	C / C++ / MicroPython	2	$0.80
STM32F303CCT6	37	72 MHz	Arduino IDE, STM32Cube IDE, PlatformIO	C / C++	1	$7.44
ATmega2560	54	16 MHz	Arduino IDE	C / C++	1	$17.59
ESP32-S3 WROOM	45	240 MHz	Arduino IDE, ESP-IDF, PlatformIO	C / C++ (primary), MicroPython	2	$5.49

Illumination Component Comparison

Type	Part	Control Method	Per-square control	External Driver required	Cost	Notes
TFEL	Newhaven NHD-EL12832	AC inverter	No	Yes	$27-$30	Not suitable to for 64 squares
Laser Diode	OSRAM PLT5 450B	Constant-current driver	No	Yes	$8–$15	Not suitable, beam illumination
RGB LED	Cree CLV1A-FKB	Direct GPIO/ multiplexing	Yes	Yes	$0.20–$0.40	High routing complexity
Addressable RGB LED (SPI)	APA102C	SPI (Data + Clock)	Yes	No	$0.30–$0.50	Requires 2 data lines
Addressable RGB LED	WS2812B	Single-wire serial	yes	No	$0.15–$0.30	Simplicity & scalability

Logic Level Shifter Selection

Type	**Direction Type**	**Number of Channels**	**Max Supply Voltage**	**Cost**
SN74AHCT125	Unidirectional	4	5.5V	$0.61
Tx0104	Bidirectional	4	5.5V	~$0.80
BSS138 (MOSFET)	Bidirectional	1	50 V_{DSS} 20 V_{GSS}	$0.23

Sensor Comparison

Sensor Component Type	Triggered by	Detection Method	False trigger risk	Impact on Chessboard	Cost
Hall Effect (DRV5032)	Magnetic field	Magnet	Unlikely - responds to magnetic flux above threshold	Simple wiring, magnet in chess piece	$0.28
Capacitive (AT42QT1010)	Electrostatic change	Dielectric materials	Likely - humidity and hand proximity	Tuning per square & Board thickness	$0.77
Inductive (TI LDC1101)	Electromagnetic	Conductive metals	Moderate-Metal interference	Impractical,Requires coil per square	$2.19
Piezoelectric (Murata 7BB-20-6)	Impact	Changes in force	Unlikely - based on pressure	Detects motion not presence	$0.37
Ultrasonic (Murata MA40S4S)	Reflected sound waves	Sound reflection	Moderate - angles & echo	Cannot scale to 64 squares	$5.77
IR Reflective (Vishay TCRT5000)	IR light	Changes in light	Likely - ambient light interference	Sensitive to LED	$1.19

I/O Expander Comparison/Selection

GPIO Expander	**Input Voltage Range (V)**	**Communicatio n Protocol**	**# of I/O Pins**	**Unit Cost**
MCP23017	1.8-5.5	I2C	16	$1.00
MCP23S17	2.7-5.5	SPI	16	$1.78
MAX7300	2.5-5.5	I2C	28	$4.00

Digital Display Comparison

Display	**Communication Protocol**	**Operating Voltage (V)**	**Usable Display Area (In)**	**Unit Cost**
Hosyond I2C 1602	I2C	5	3.1 x 0.6	$4.33
2.8 Devmo SPI TFT LCD display	SPI	5	1.45 x 1.93	$15.00
1.3 SH1106 128 * 64 OLED	SPI/I2C	3.3 & 5	1.16 x 0.58	$16.99

Power Consumption by ICs

Part	Part #	Voltage Rail Needed	Current Consumption
Microcontroller	ESP32-S3-WROOM-1	3.3 V	380 mA
64 Hall Effect Sensors	DRV5032FBDBZR	3.3 V	1.8 uA *64 0.1152mA
GPIO Expanders	MCP23017	3.3 V	500 mA
LCD Screen	Hosyond I2C 1602	5 V	20 mA
Logic Level Shifter	SN74AHCT125	5 V	10 uA
LEDs	WS2812B	5 V	60 mA*64 3840 mA

Voltage Rail	Current Consumption Total
3.3V	~880 mA
5V	~3,870 mA
TOTAL	4,750 mA

Power Supply Selection

Battery Type	Rechargeability	Capacity (mAh)	Nominal (V)	Complexity	Energy Density (Wh/Kg)
NiMH (D)	Rechargeable	8,000-10,000	1.2	Safe and lower complexity	70-250
Alkaline	Non-Rechargeable	12,000-18,000	1.5	Safe and lower complexity	135-160
Li-ion (21700)	Rechargeable	4,000-5,000	3.7	Requires BMS and protection	150-250

Battery Selection

Type	Capacity (mAh)	Max discharge (mA)	Lifespan (Cycles)	Unit Price
PKCELL	10,000	6,000	≥500	$11.00
EBL	10,000	3,500	≥1,200	$7.21
TENERGY	10,000	10,000	≥500	$6.25

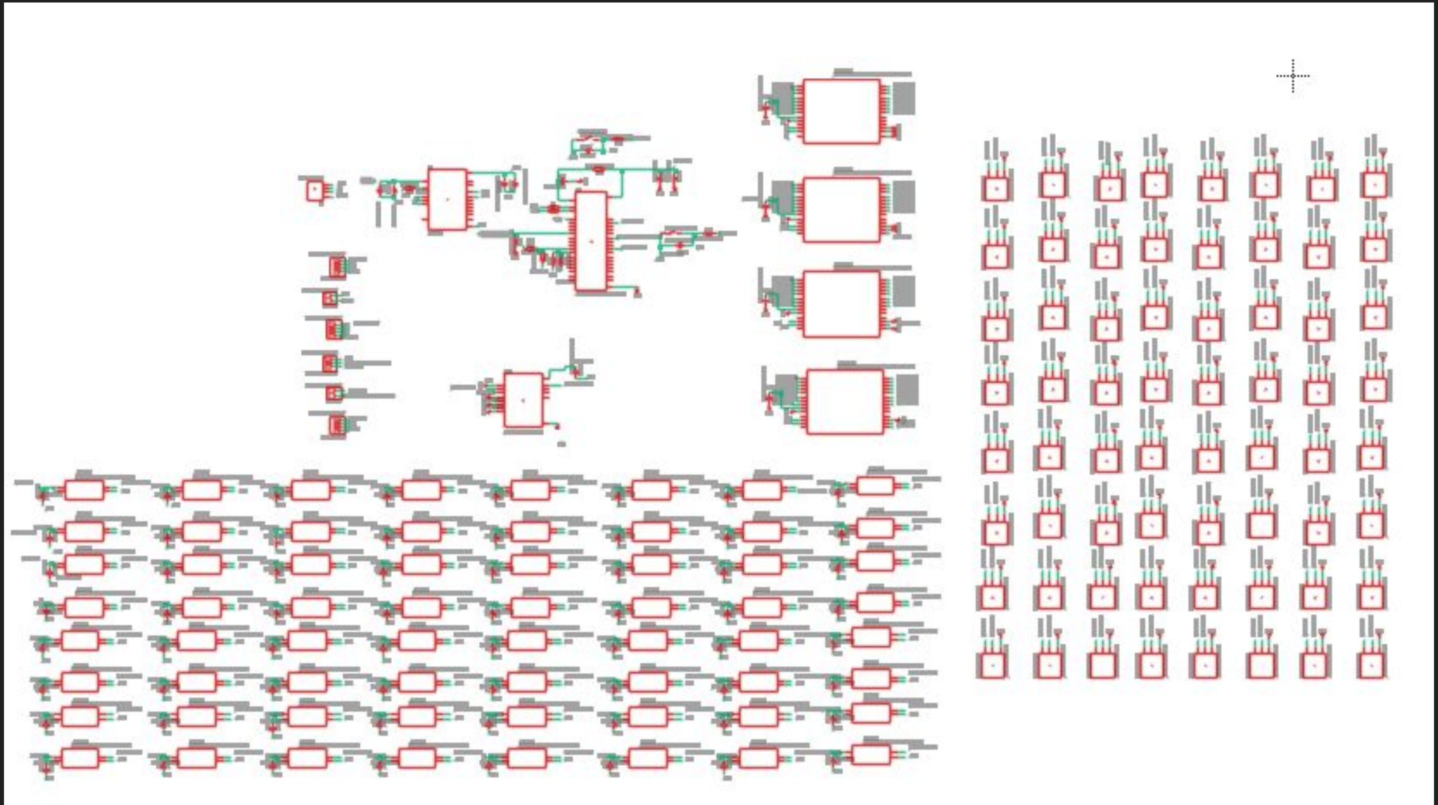
Choosing a Regulator (3.3V)

Regulator Type	Input Voltage Range (V)	Maximum Output current (mA)	Switching Frequency
TPS63000DRCR (Buck-Boost)	1.8-5.5	1200	1.25MHz
TPS75333QPWPREP (LDO)	2.7-5	1500	N/A
LM2576HVSX-3.3/NOPB (Buck)	4-63	3000	52 kHz
LM26003 (Buck)	3-38	2000	324 kHz

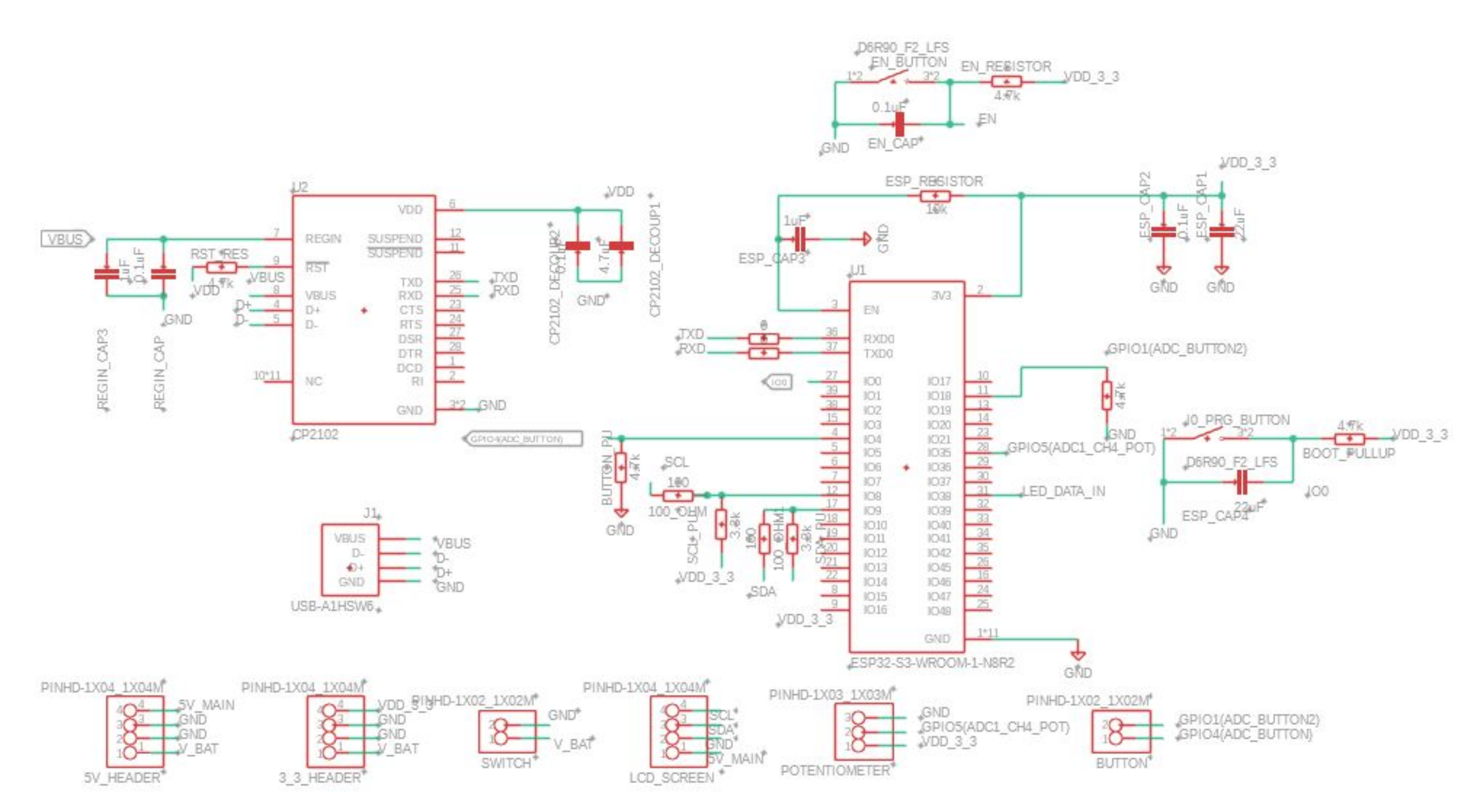
Choosing a Regulator (5V)

Regulator Type	Input Voltage Range (V)	Maximum Output current (mA)	Switching Frequency
TPS61022RWUR (Buck-Boost)	0.5-5.5	8000	1 MHz
TPS55289RYQR (Buck-Boost)	3-30	8000	402.82 kHz
LM5155DSSR (Flyback)	2.97-45	Depends on external components	252.41 kHz

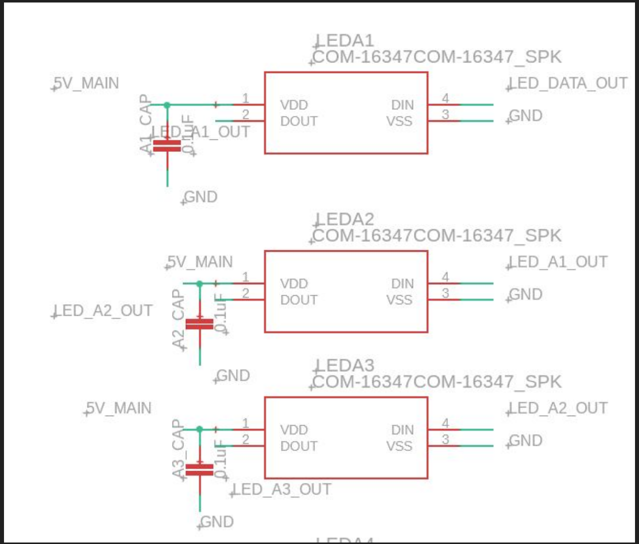
Overall Main Board Schematics

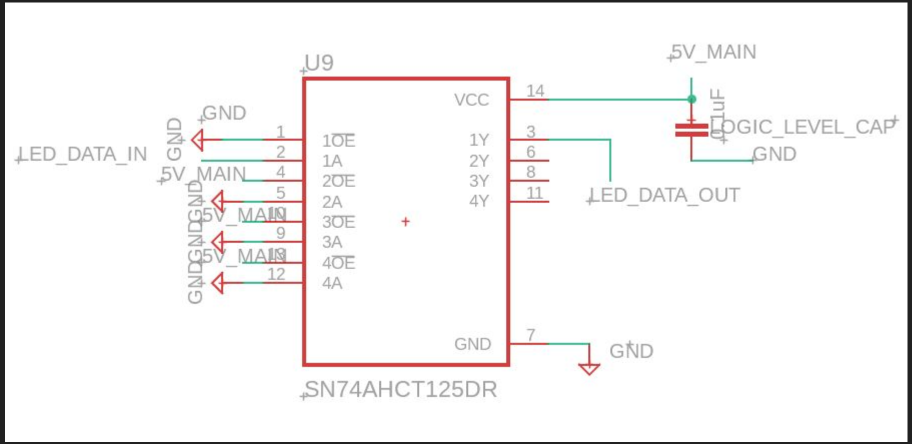


Main board Schematics (ESP32 & Peripherals)

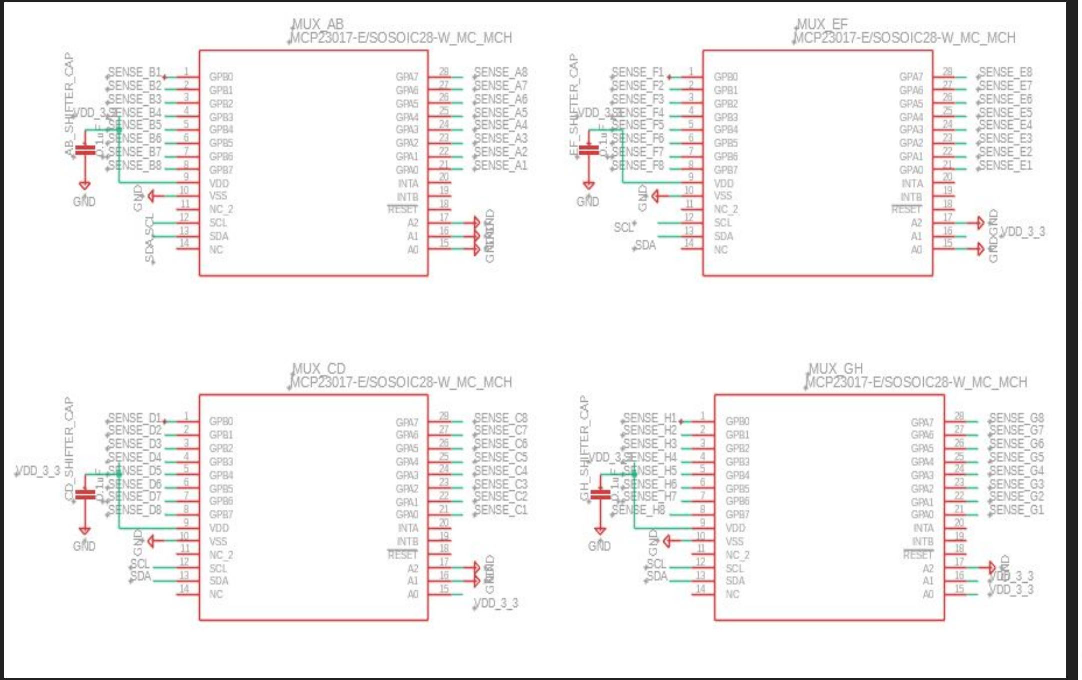


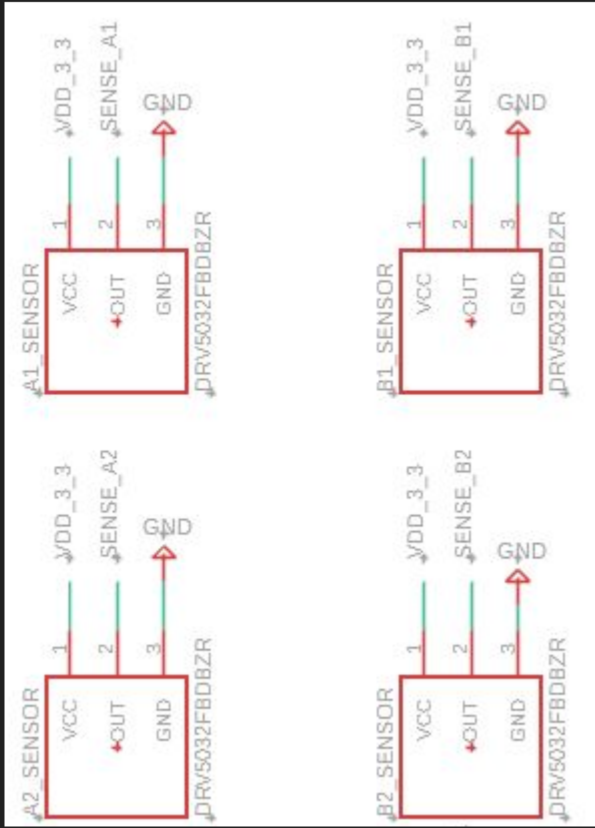
Main board Schematics (LEDs & Logic Level Shifter)



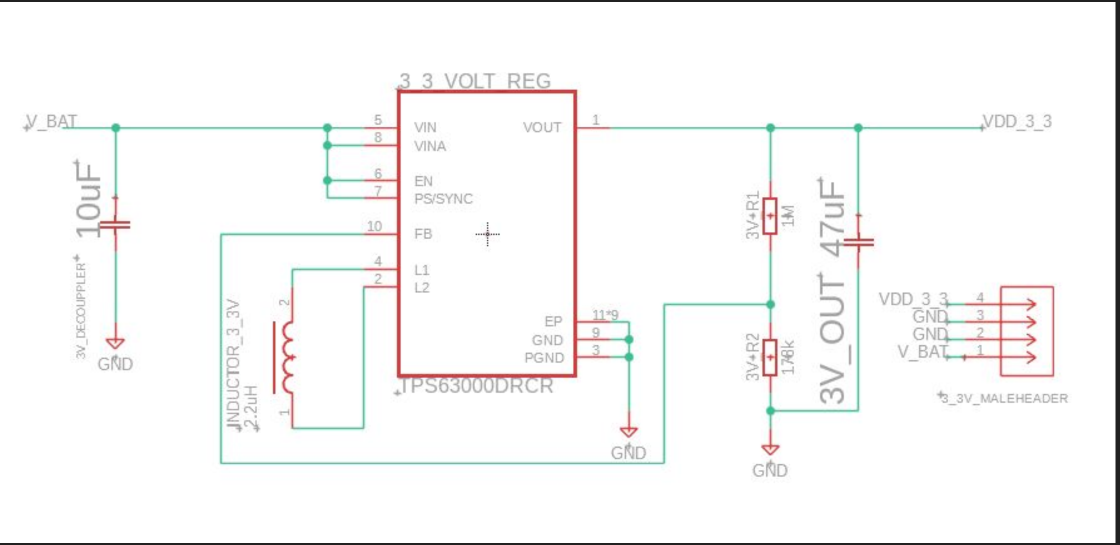


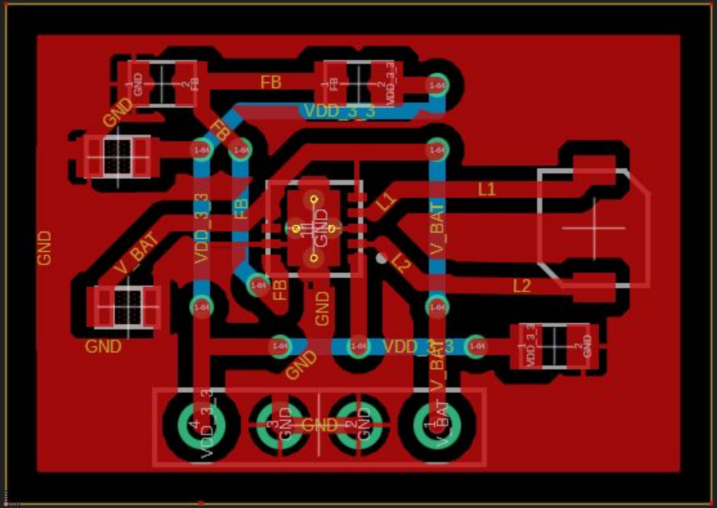
Main board Schematics (GPIO expanders & Sensors)



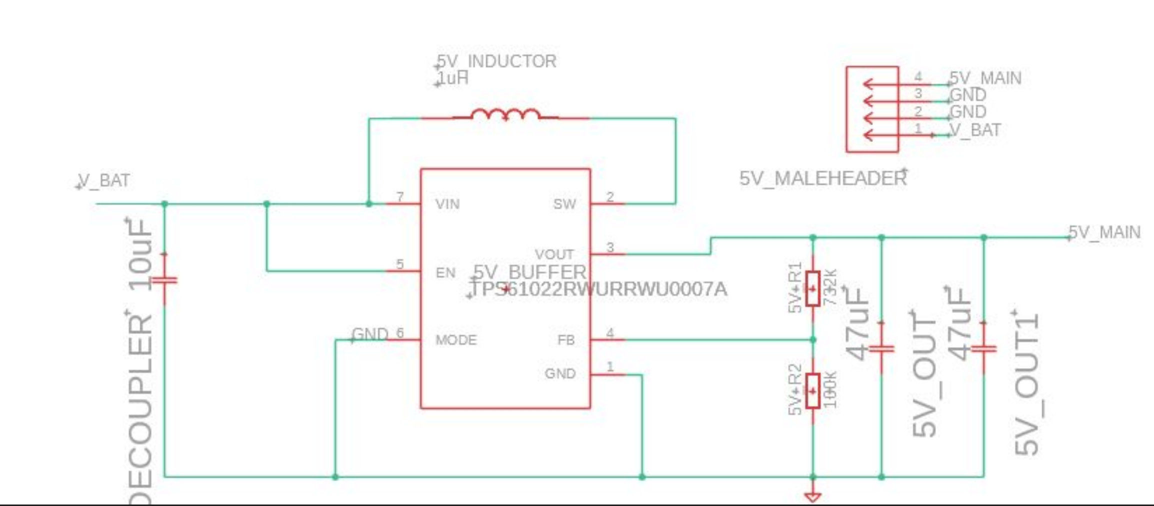


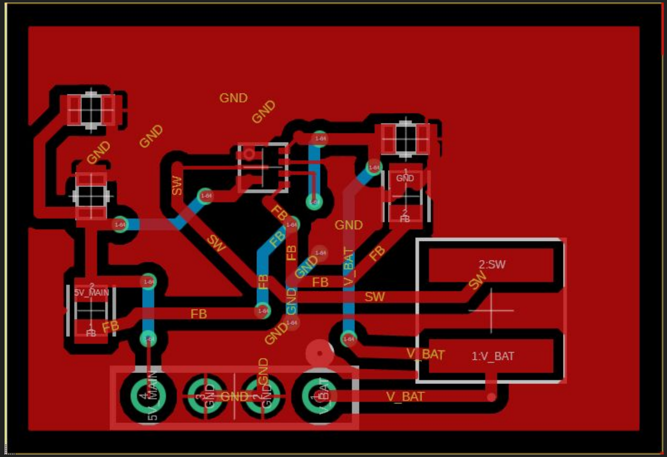
3.3v Buck Regulator Schematic/PCB Design



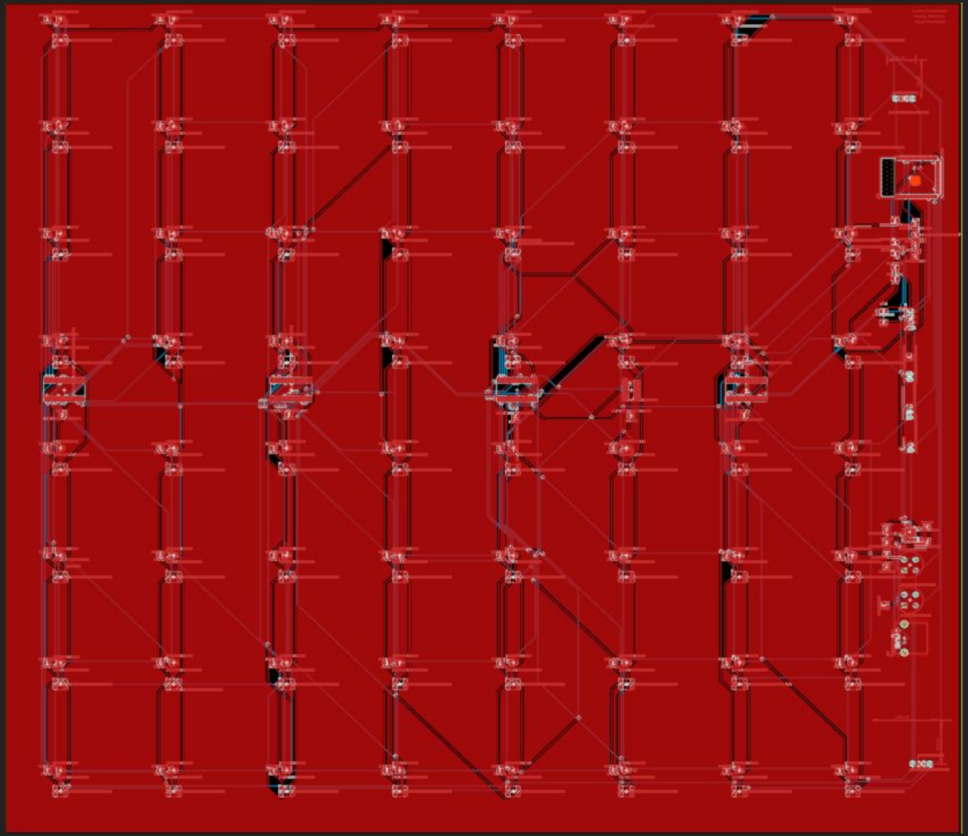


5v Boost Converter Schematic/PCB Design





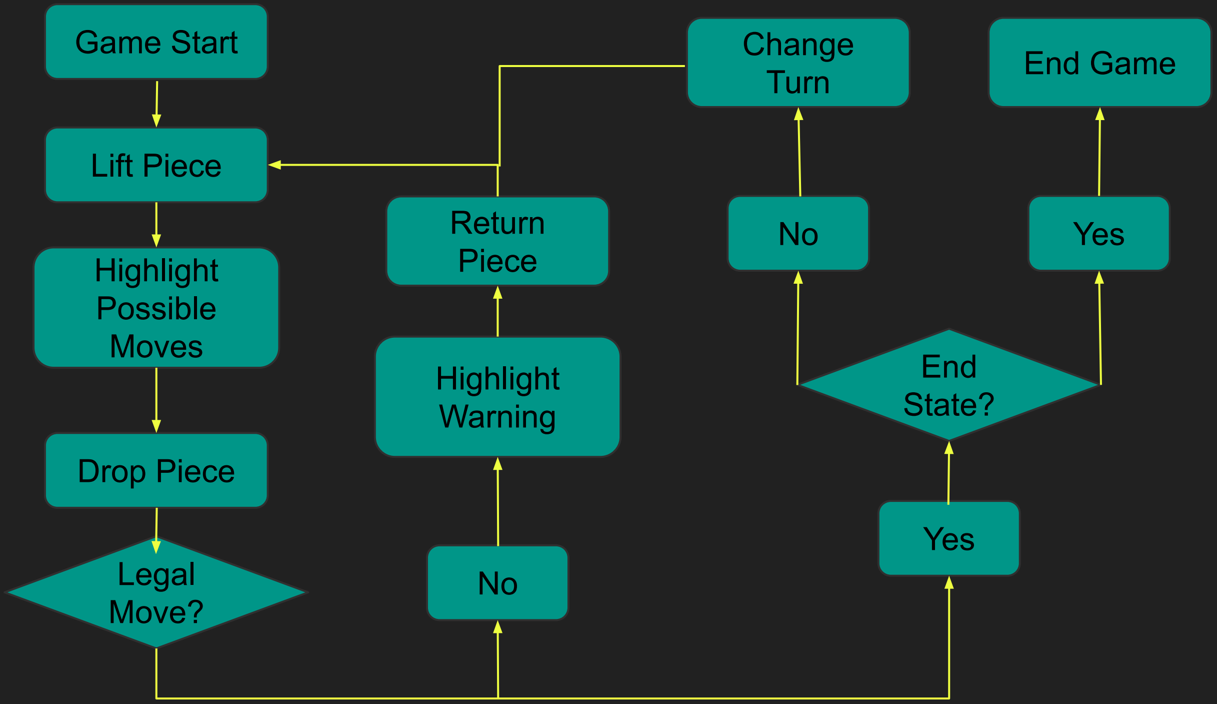
Main Board PCB



Software Architecture/Functionality

- The Pathfinder Chessboard works through the use of the MCU-Max chess library interacting with 64 Hall Effect sensors and multi colored LED
- When users lift a piece the sensors are activated, notifying which piece was removed and highlighting the available spots to move
- The LEDs shine different colors depending on the context, for example red to show an invalid move, green to show possible moves
- The LCD screen provides information to the user, such as time remaining and showing which piece to upgrade their pawn to

Software Diagram



Chess Library Comparison

Engine	Resource Draw	Ease of Integration	Language	Player Strength
MCU-Max	Low	High	C	Medium
Stockfish	High	Medium	C++	High
Sunfish	Low	High	Python	Medium
Custom Made	Medium	Low	C++	Medium

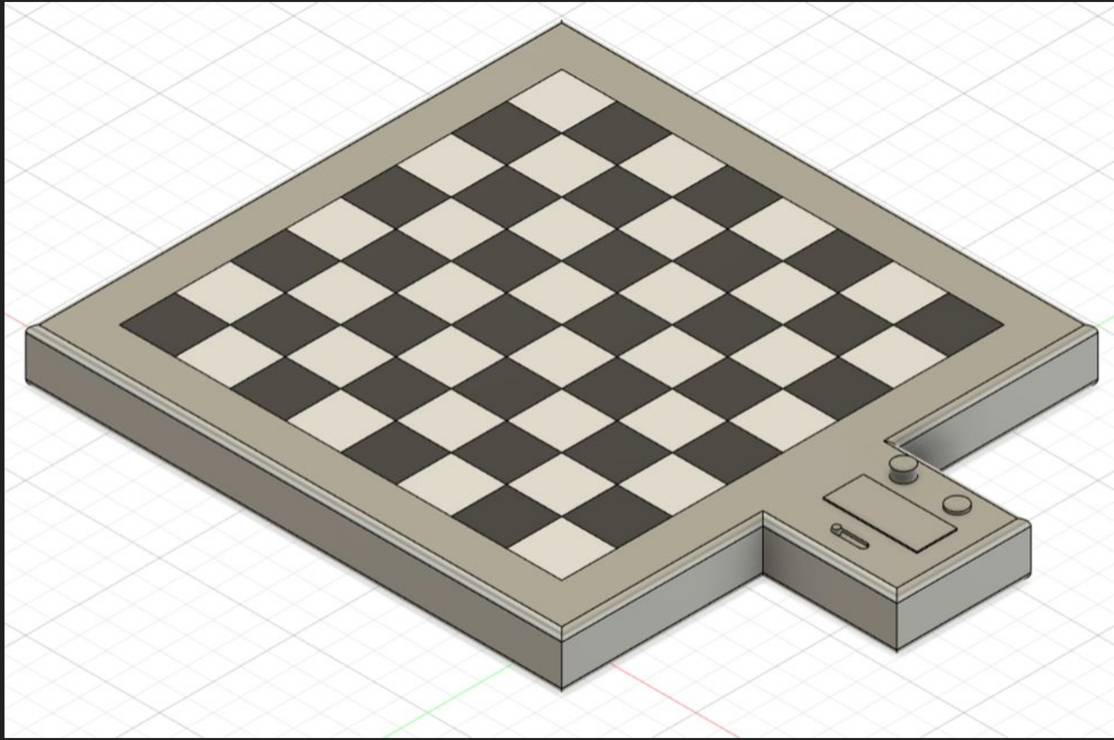
MCU-Max Explanation

- MCU-Max is a chess engine based on the Micro-Max engine, a very compact and efficient engine, made to be easier to read and implemented into projects
- It includes all game logic and can generate legal moves, evaluate board positions, and choose moves for the computer opponent
- For the computer player, we can change the difficulty of the player depending on how powerful we want it to be

MCU-Max AI Logic Explanation

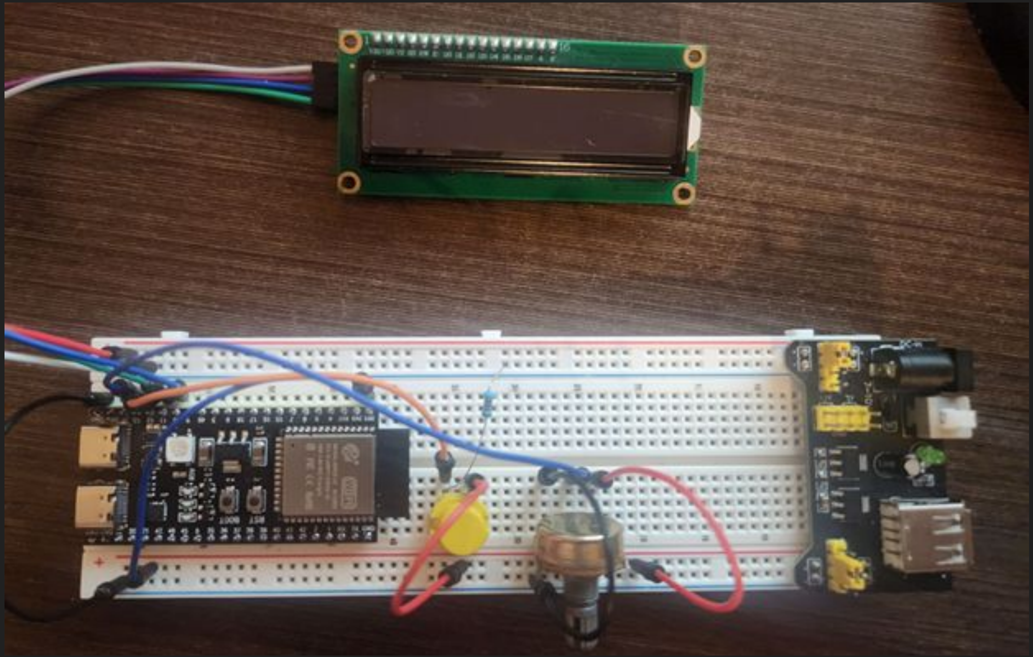
- The AI logic system is built around an alpha-beta negative minimax searcher
  - The system works by holding the best score so far, alpha, and the lowest tolerable score, beta. With this system, we only need one algorithm for both players, we just negate the algorithm when we swap players.
  - It cuts off unnecessary branches when obviously worse moves are found
  - A quiescence search is performed, meaning the computer will not be blindsided by captures or poor moves which happen outside the range of its searches
- The toughness of the system is defined by the depth and node limit
  - The depth determines how many moves ahead the engine looks, ranging from 2 to 10, where higher numbers use more memory
  - The node limit determines how many board position the engine can check before it has to make a move, meaning lower node counts lead to faster, but less thought out, moves.

Prototype Design

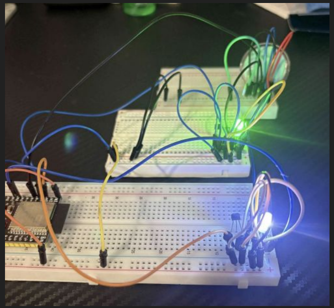


Testing User Setup

- Here we test user input and the LCD screen to ensure they can setup the initial chessboard



Testing Functionality of Piece Movement



White: Piece lifted from

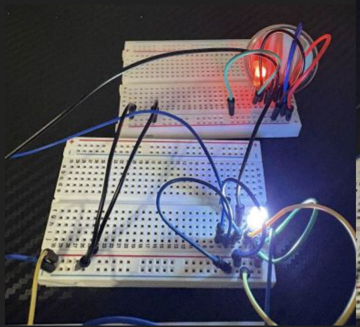
Green: Available placement

Validating

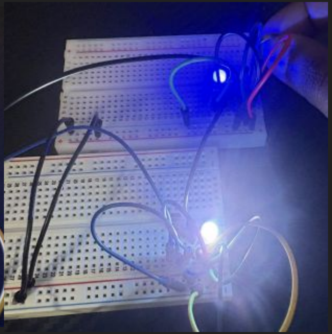
- Wiring
- Hall Effect Sensor + Magnet
- WS2812 Daisy-Chain

Demonstration Scenarios

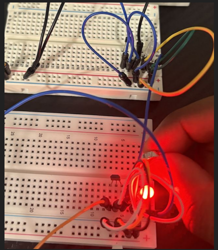
- Pawn piece lifted
- Piece Lifted + Capture Available
- Capture Completed
- Invalid Move



White:Piece lifted
Red: Available capture



White: Piece lifted from square
Blue *blinking: Capture complete LED animation

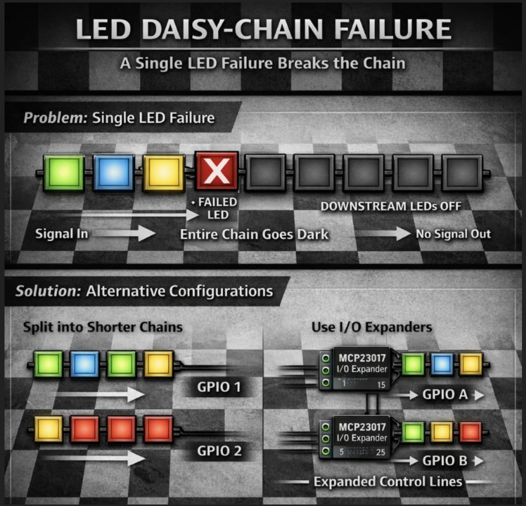


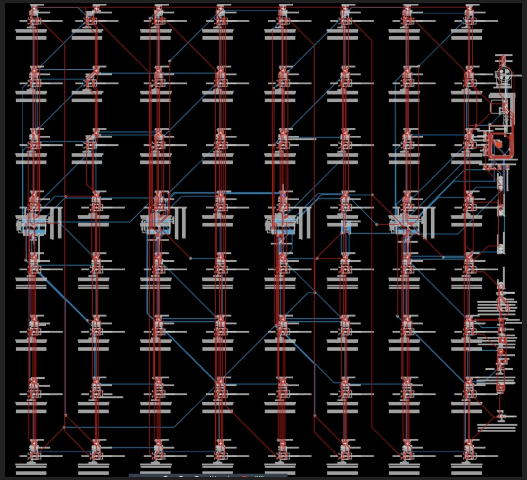
Illegal move: blinking red animation

Design Challenges

- **LED Daisy-Chain**
  - Single LED failure disables downstream LEDs
  - Failure easily identifiable at last illuminated square
  - Mitigation: Split into shorter chains

- **PCB Size Limitations as a Chessboard**
  - Higher assembly time
    - Part placement/Soldering complexity
  - Mitigation: Dividing PCB into quadrants and interconnect





Work Distribution

Andres Armendariz	Hardware Research PCB Design
Freddy Pacheco	Software Research Software Testing
Ryan Ramdihal	MCU Research Hardware Testing

Bill of Materials

Item	Part Name	Quantity	Price
Microcontroller	ESP32-S3-WROOM-1	1	$5.71
PCBs	Main board/Regulators	3	$366.29
Peripherals/Small Components/ICs	N/A	N/A	$96.74
LEDs	WS2818b	64	$57.59
3d Print Filament & Frosted acrylic top	N/A	N/A	~$45
TOTAL:			**$571.32**

PROJECT TIMELINE