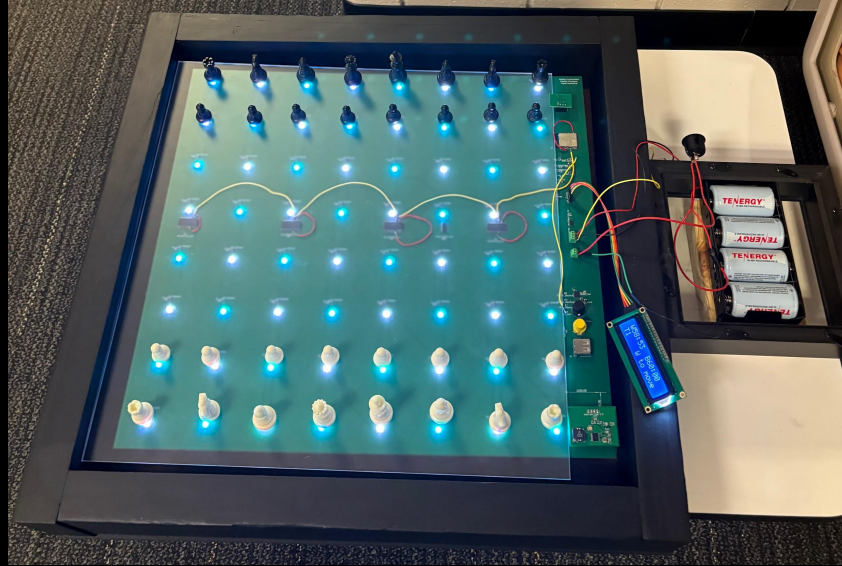


Pathfinder Chessboard



Final Presentation
Group 35

Andres Armendariz
Electrical Engineering

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Members



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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	$\leq 20 \times 20 \times 2$ 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	< 140 °F	Safe for normal indoor operation Thermal measurement
Chess Engine	Game Modes	≥ 3 modes



Engineering Specs (Component-Level)

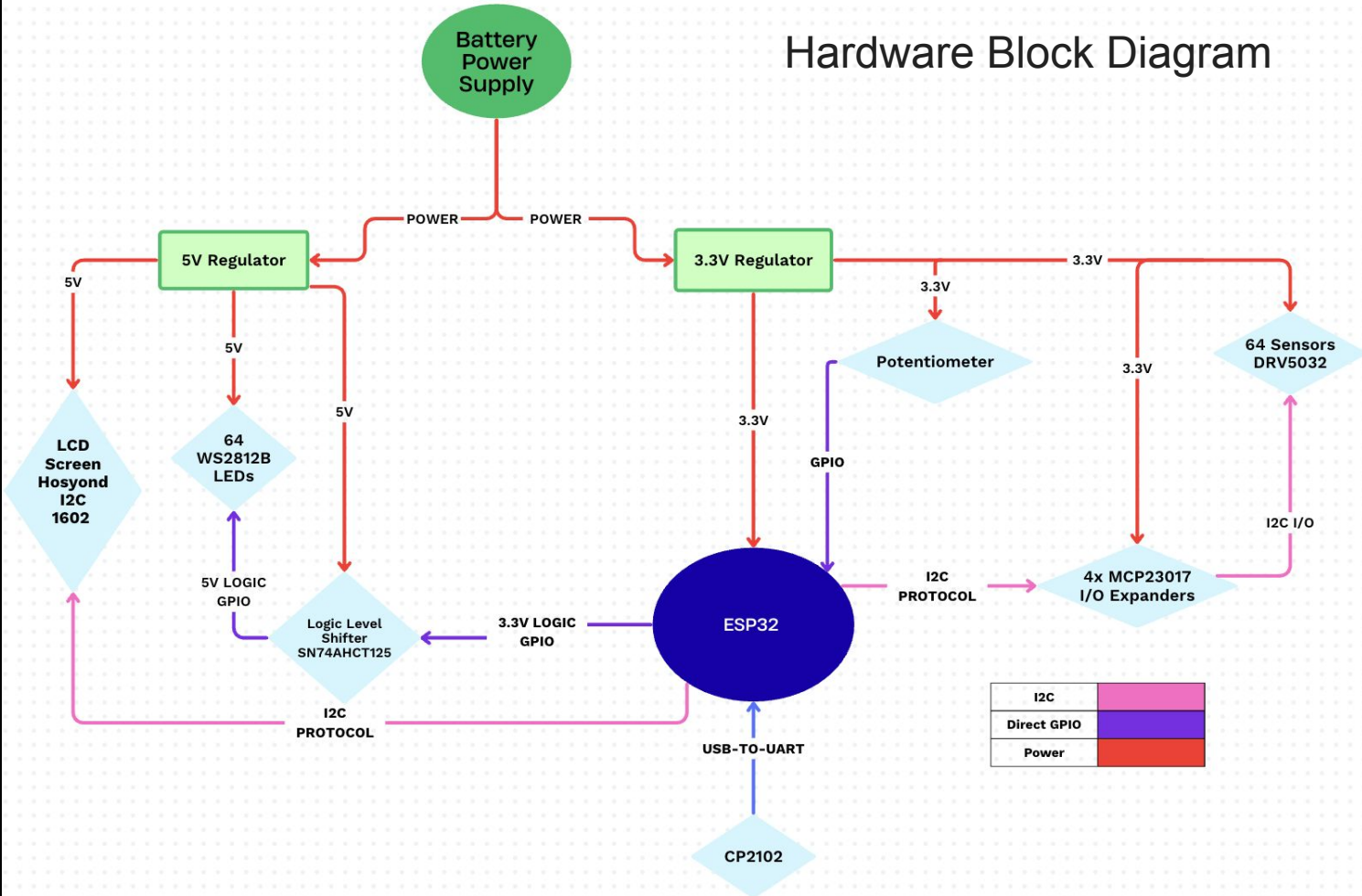


Subsystem	Parameter	Target Value	Notes/Verification Method
LED System	Power Consumption	<22 Watts	Current measurement
LED Response Time	Lift → Illuminate	< 1 sec	Seamless movement
Sensors	Detection Speed	< 500 msec	Consistent detection
Voltage Regulation	3.3V & 5V Stability	±5% variation	Oscilloscope measurement





Hardware Block Diagram



Microcontroller Comparison



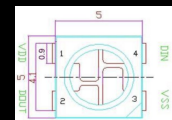
Microcontroller	GPIO Count	Clock Speed	Development Environment	Supported Languages	Cores	Unit Cost
ATmega328P	20	16 MHz	Arduino IDE	C / C++	1	\$2.89
MSP430FR6989	83	16 MHz	Code Composer Studio	C / C++	1	\$7.49
Raspberry Pi Pico RP2040	26	133 MHz	Arduino IDE, Pico SDK	C / C++ / MicroPython	2	\$0.80
STM32F303CCT6	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 WROOM1	45	240 MHz	Arduino IDE, ESP-IDF, PlatformIO	C / C++ (primary), MicroPython	2	\$5.49



Illumination Component Comparison



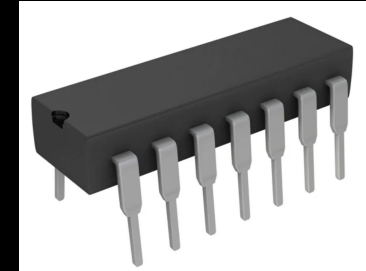
Type	Part	Control Method	Per-square control	External Driver required	Cost	Notes
TFEL	Newhaven NHD-EL12832	AC inverter	No	Yes	\$27-\$30	Not suitable to for 64 squares
Laser Diode	OSRAM PLT5 450B	Constant-current driver	No	Yes	\$8-\$15	Not suitable, beam illumination
RGB LED	Cree CLV1A-FKB	Direct GPIO/multiplexing	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



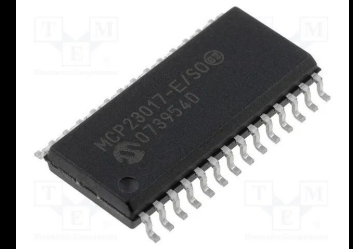
Sensor Component Type	Triggered by	Detection Method	False trigger risk	Impact on Chessboard	Cost
Hall Effect (DRV5032)	Magnetic field	Magnet	Unlikely - responds to magnetic flux above threshold	Simple wiring, magnet in chess piece	\$0.28
Capacitive (AT42QT1010)	Electrostatic change	Dielectric materials	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

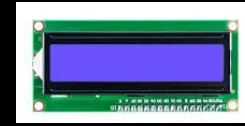




I/O Expander Comparison/Selection

GPIO Expander	Input Voltage Range (V)	Communication 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-WRO-OM-1	3.3 V	380 mA
64 Hall Effect Sensors	DRV5032FBDBZ R	3.3 V	1.8 μ A *64 0.1152 mA
GPIO Expanders	MCP23017	3.3 V	1mA*4 4 mA
LCD Screen	Hosyond I2C 1602	5 V	20 mA
Logic Level Shifter	SN74AHCT125	5 V	10 μ A
LEDs	WS2812B	5 V	60 mA*64*.12 460 mA

Voltage Rail	Current Consumption Total
3.3V	~384 mA
5V	~480 mA
TOTAL	864 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	$\geq 1,200$	\$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



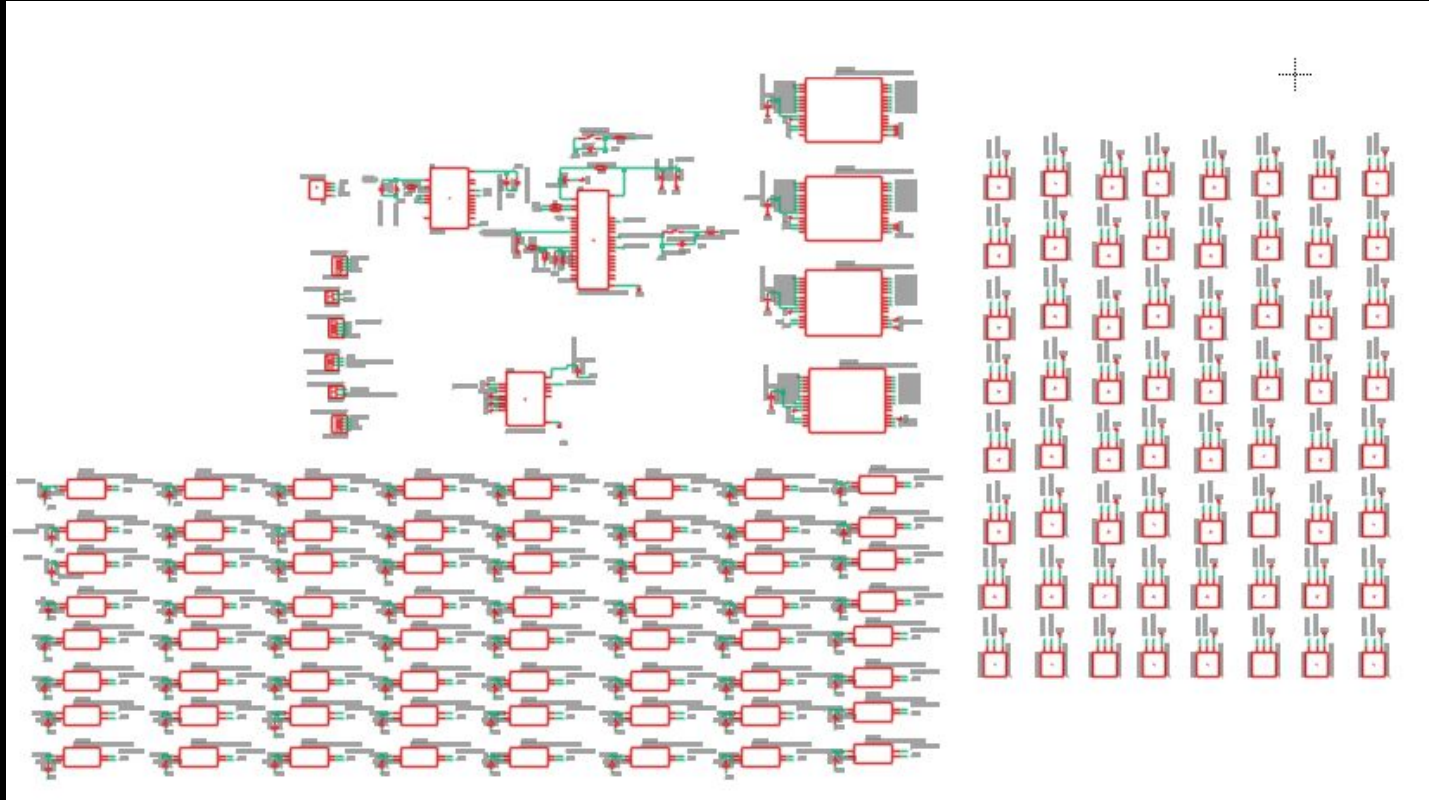


Choosing a Regulator (5V)

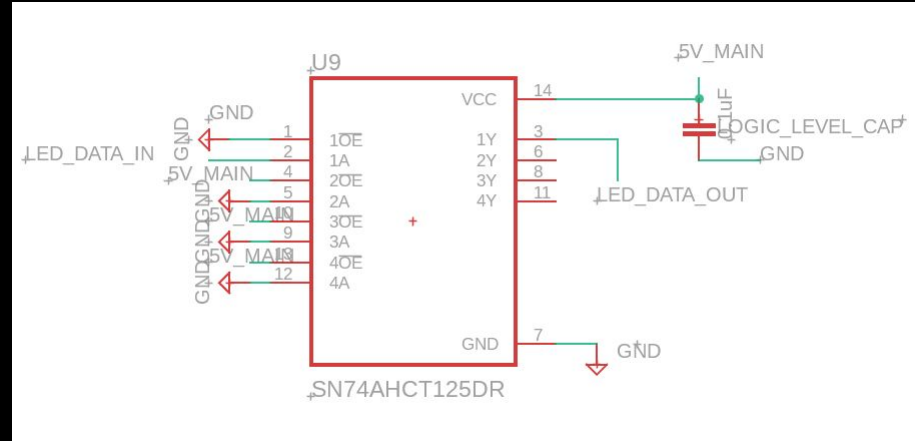
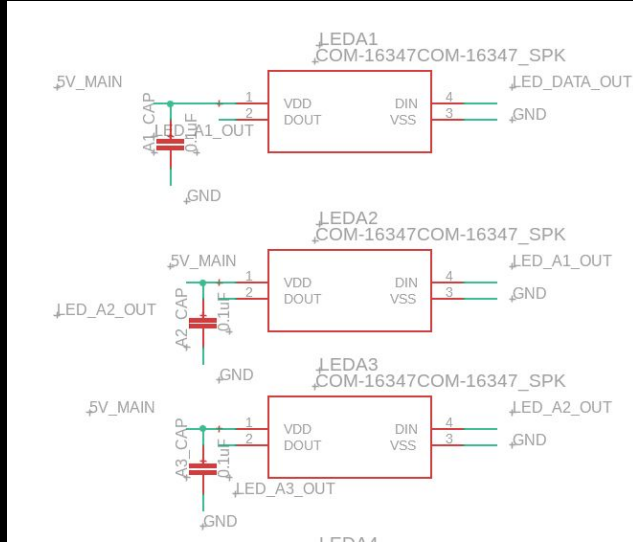
Regulator Type	Input Voltage Range (V)	Maximum Output current (mA)	Switching Frequency
LTC3113 (Buck-Boost)	1.8-5.5V	3000	300 kHz
TPS61022RWUR (Buck-Boost)	0.5-5.5	8000	1 MHz
TPS55289RYQR (Buck-Boost)	3-30	8000	402.82 kHz
LM5155DSSR (Flyback)	2.97-45	Depends on external components	252.41 kHz



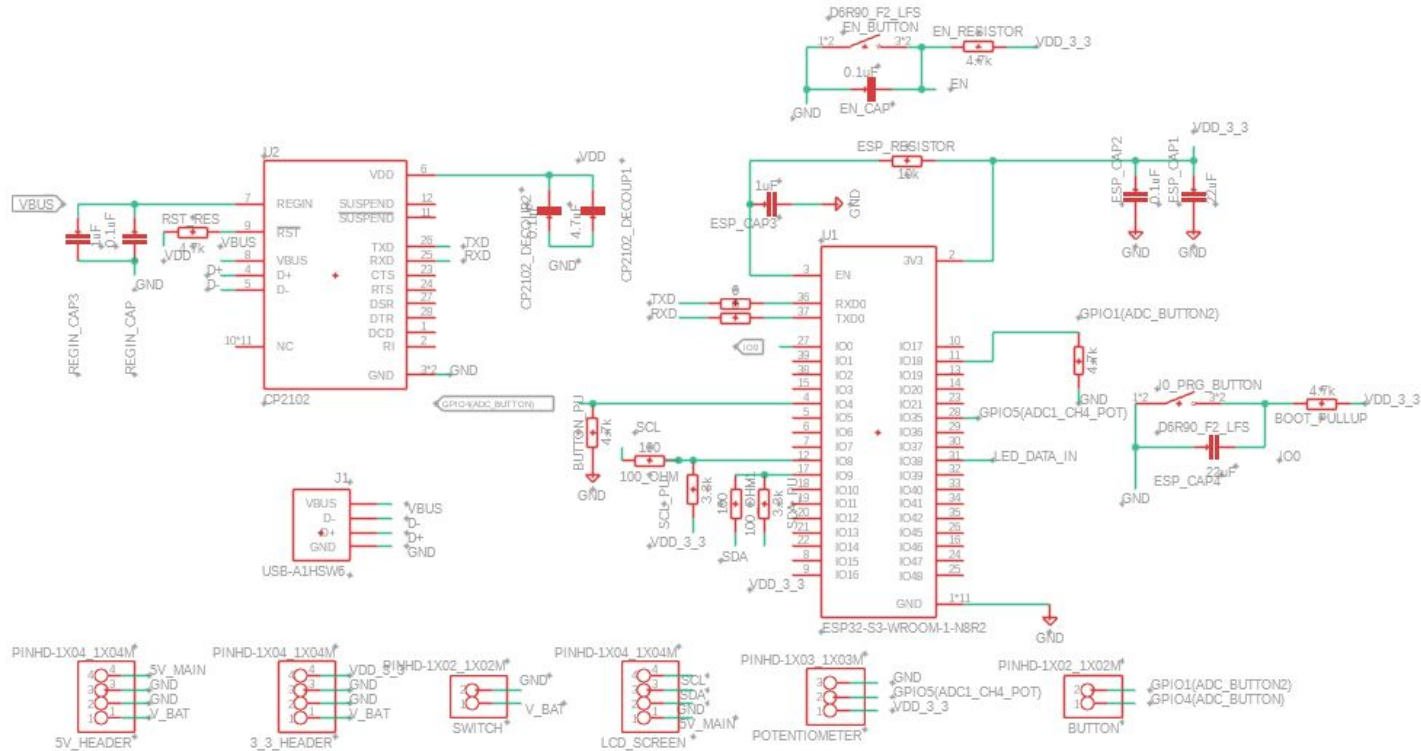
Overall Main Board Schematics



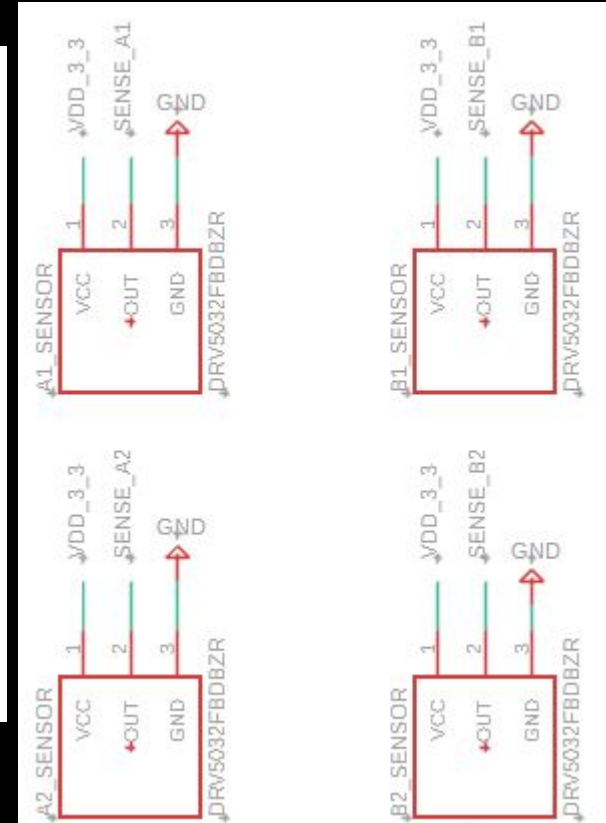
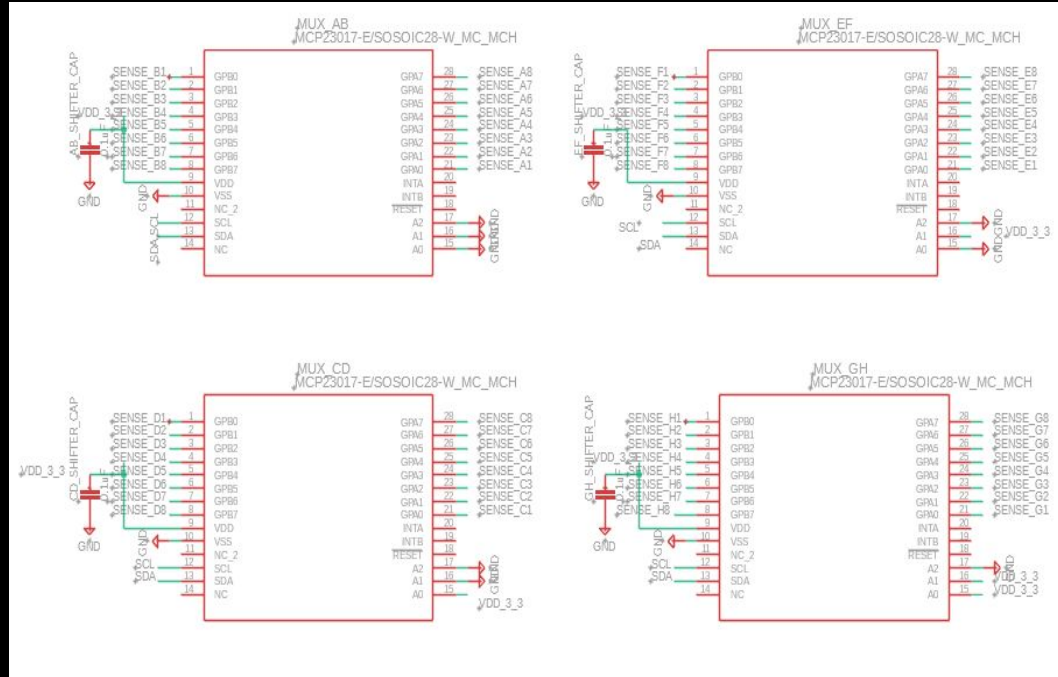
Main board Schematics (LEDs & Logic Level Shifter)



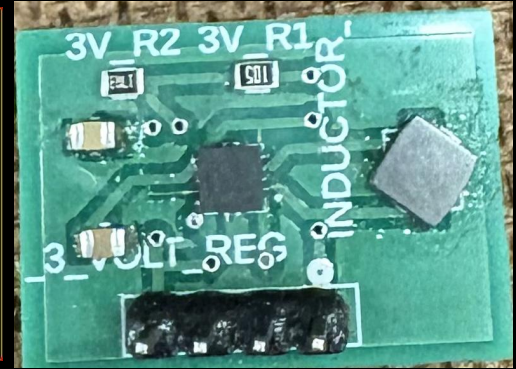
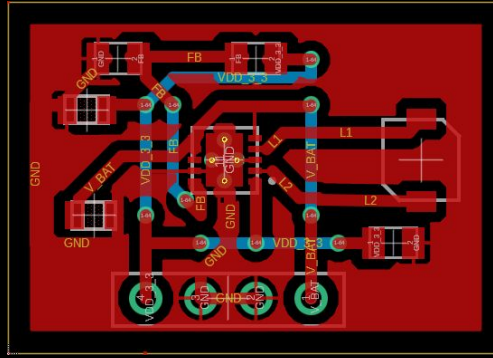
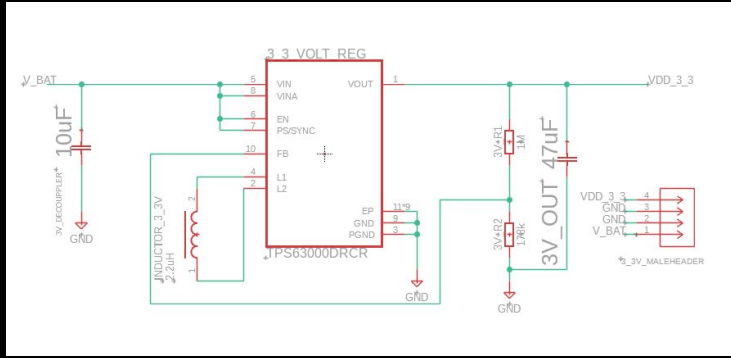
Main board Schematics (ESP32 & Peripherals)



Main board Schematics (GPIO expanders & Sensors)



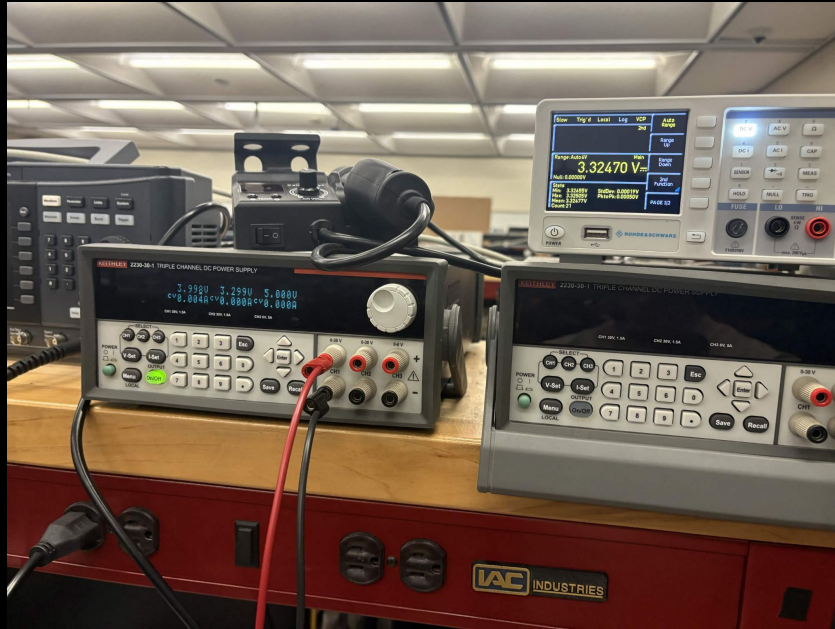
3.3V Buck Regulator Schematic & PCB Design





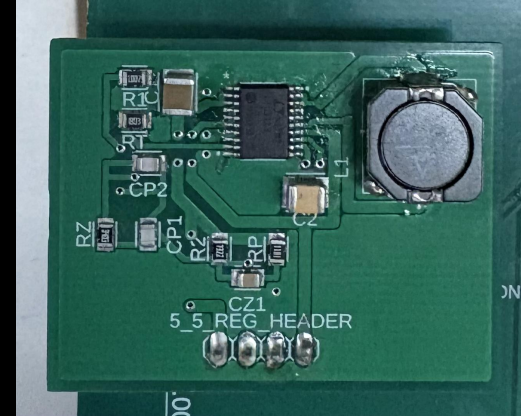
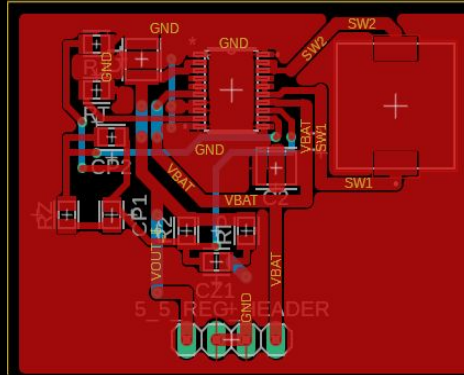
Testing 3.3V Regulator

Minimum Voltage



Maximum Voltage







Testing 5V Regulator

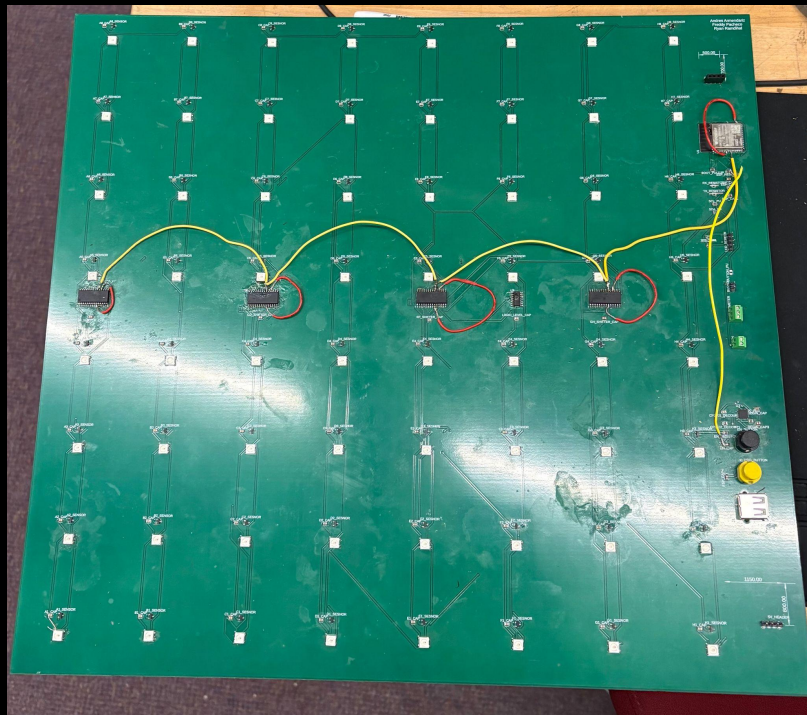
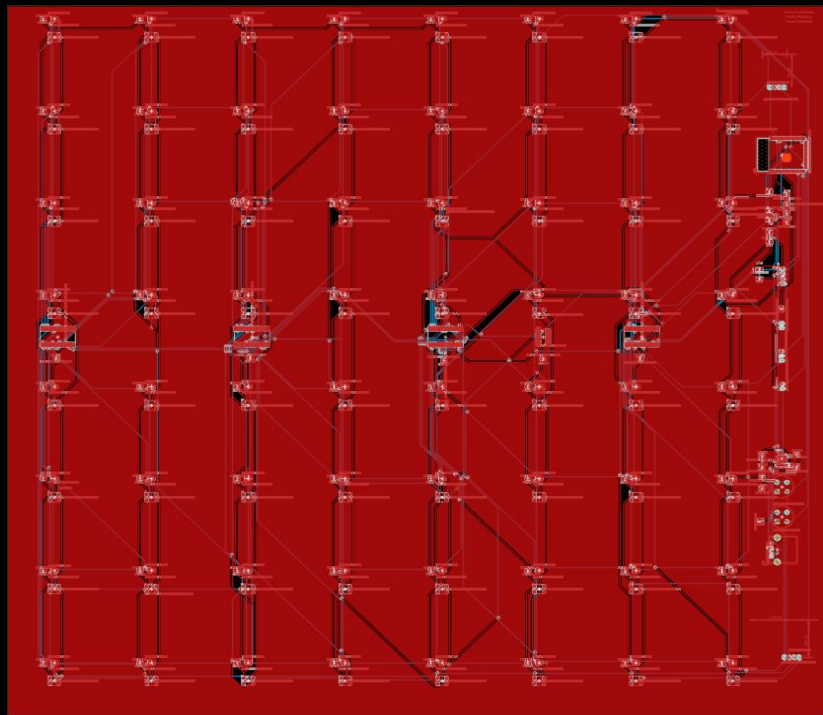
Minimum Voltage



Maximum Voltage



Main Board PCB



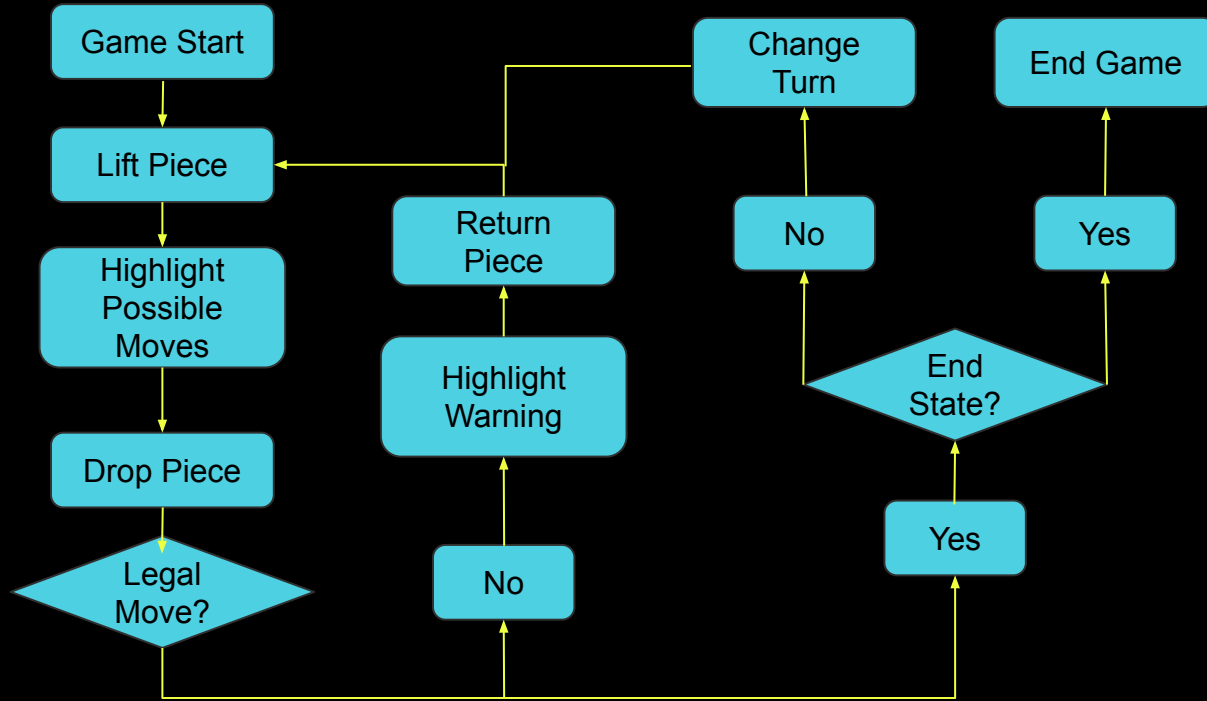
Software Architecture/Functionality



- 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



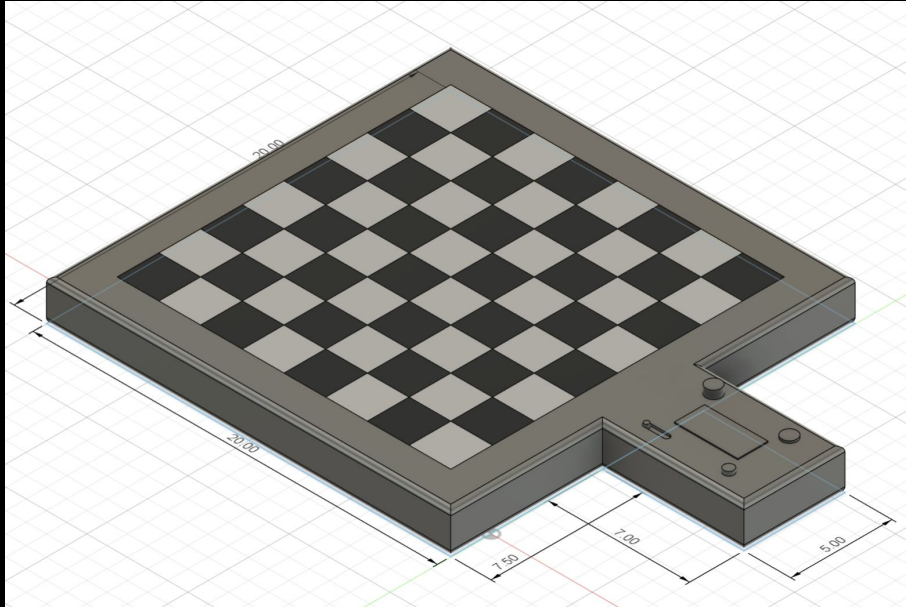
MCU-Max AI Logic Explanation



- 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.



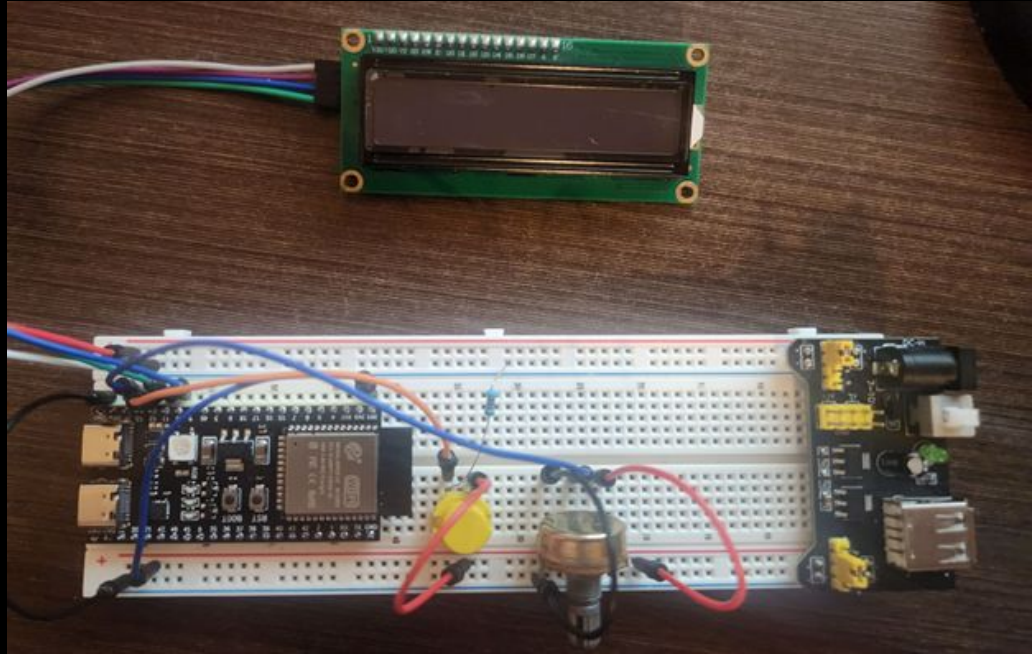
Prototype Design



Testing User Setup

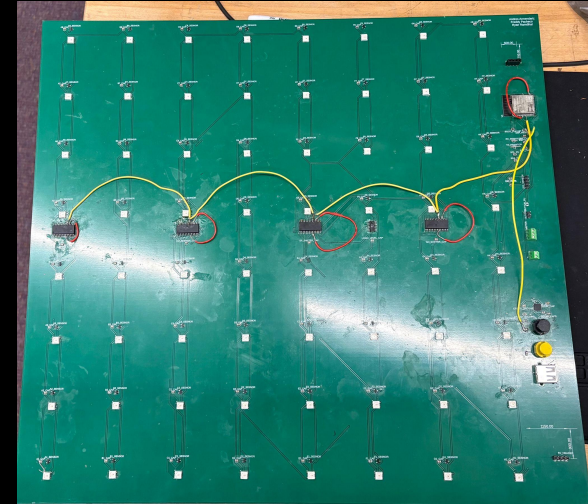


- Here we test user input and the LCD screen to ensure they can setup the initial chessboard



Design Challenges Encountered

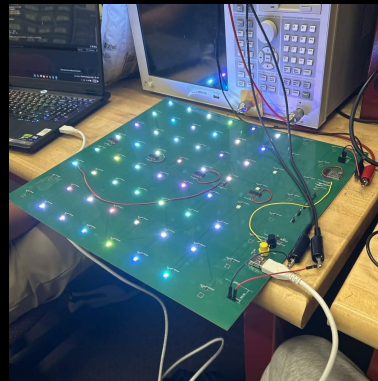
- **PCB Size Limitations as a Chessboard**
 - Increased routing complexity and overall assembly time
- **MCP23017 Reset Pin issue**
 - Expanders were not functioning correctly due to floating RESET pin
 - Added complexity during initial development and testing
- **Programming Interface Constraints (CP2102)**
 - Required USB-A to USB-A connection cable for programming
- **LED Pin Layout Discrepancy**
 - Asterisk marking on PCB was misinterpreted as the correct orientation of the WS2812B LEDs, leading to an incorrect placement
 - Required resoldering each LED to the correct layout
- **ESP32 Pin Conflict with Potentiometer**
 - Potentiometer initially routed to GPIO 35 (reserved for internal SRAM)
 - Required rerouting to GPIO 7
- **I²C LCD Instability (Hosyond 1602 Display)**
 - Display produced garbage values after extended operation
 - periodically re-initialize LCD Screen as our solution
- **MCU-Max Integration**
 - Difficulty adapting existing chessboard logic to MCU-Max structure
 - Required aligning physical board state with engine state





Testing Functionality of Components

- Implemented test code to validate sensor-to-LED mapping
- Sensor activation from magnet triggering the corresponding LED with random color output
- Confirms successful integration of Hall sensors, MCP23017 expanders, and LED control.

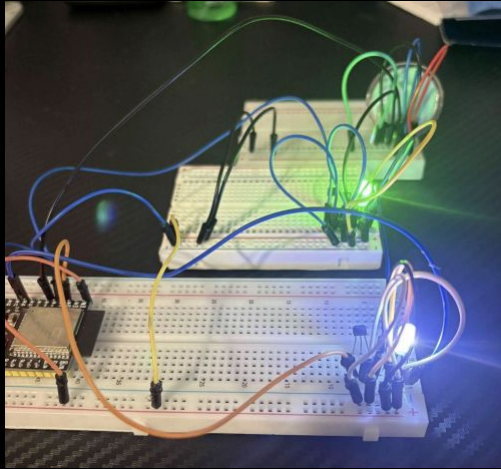


```
void loop() {
  if(holder)
  {
    detachInterrupt(digitalPinToInterrupt(INTPIN));
    holder = false;
    Serial.println("Interrupt Triggered!");
    for(int i=0; i<4; i++)
    {
      int pin = mcp[i].getLastInterruptPin();
      if(pin != 255)
      {
        uint16_t value = mcp[i].getCapturedInterrupt();
        Serial.printf("MCP %d, Pin %d changed state.\n", i, pin);
        updateLED(i, pin);
      }
    }
    attachInterrupt(digitalPinToInterrupt(INTPIN), testInterrupt, FALLING);
  }
}

void updateLED(int chip, int pin){
  int led = abs((chip*16) + pin - 2);
  pixels.setPixelColor(led, pixels.Color(random(256), random(256), random(256)));
  pixels.show();
}
```

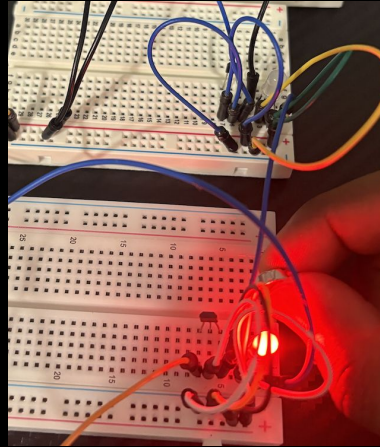


Software Testing of Logic from Breadboard to PCB

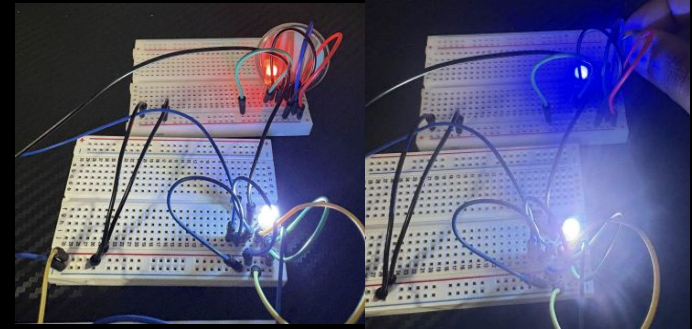


White: Piece lifted from

Green: Available placement



Illegal move: blinking red
animation



White: Piece lifted
Red: Available capture

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

Work Distribution



Andres Armendariz	Hardware Research PCB Design + Construction Hardware Testing
Freddy Pacheco	PCB Construction Software Research Hardware Testing
Ryan Ramdihal	Software Research Hardware Testing Software Integration



Bill of Materials



Item	Part Name	Quantity	Price
PCBs	Main board/Regulators	3	\$366.29
Peripherals/Small Components/ICs	N/A	N/A	\$362.48
Frame Casing	N/A	1	\$67.95
Acrylic Sheet	N/A	1	\$42.59
TOTAL:			\$839.31



PROJECT TIMELINE

PATHFINDER CHESSBOARD

