Interactive Chess Trainer

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***Abstract* — The Interactive Chess Trainer is a board that presents a platform to learn the game of chess through an interactive method utilizing the integration of combined electronic hardware and software inclusive of traditional chess quality. This device will be capable of interacting with each piece lifted from the board to display the possible moves from any position on the board using LEDs along with alerting incorrect movements attempted. The board will offer multiple game modes to accommodate adding variety for the users.**

***Index Terms* — Analog-Digital Conversion, Battery Management Systems, Microcontrollers, Printed Circuits, Transistors**

INTRODUCTION

Chess players know that there is no replacement for the tactile feeling and weight of moving a chess piece and analyzing a physical sixty-four square chess board. With the invention and advancement of the smartphone, the chess board has moved to the digital screen and has brought artificial intelligence to the game. Smartphones allow you to play chess against an AI and even players from all around the world.

Many people find the game of chess to be extremely complicated and daunting to learn. A digital chess board also allows beginning chess players to pick up the rules of chess intuitively. By lifting chess pieces off the board, possible moves for that chess piece are highlighted on the board with LEDs and the player gets a visual understanding of how each piece moves.

While chess smartphone applications offer numerous advantages for casual players, advanced chess players and chess enthusiasts lose the physical aspect of playing chess. Thus, the motivation for this project was to find a way to intuitively teach how chess is played on a physical board and to create an engaging experience. The advantages of chess played on a smartphone will be applied to a physical chess board. Users will able to see how pieces can move based on available spaces for a piece. Also, a game mode selector will be included so that a player can choose to play against an AI or play against another player.

The Smart Chess Board is a chess board designed with features to teach new players the fundamentals of chess and how the chess pieces move. When pieces are lifted, LEDs will light up to visualize where the chess pieces can move. After each turn made by the user, the chess board will be checked to see that a legal move was made. When an illegal move is made, the LEDs will blink red repeatedly until the illegal move is corrected. Different LED colors will also be used to differentiate between both players and the computer. Each type of piece will also have internal resistors to differentiate which piece the player wants to move.

With this product, users will gain a thorough understanding of how the game of chess is played and how each piece can move. The interaction of the chess pieces and various components will allow users to gain a visual representation of the fundamentals of chess. This overall goal is in conjunction with the goals or remaining low cost and easily manufacturable. We would like to see this system easily affordable for schools and chess clubs to bring a new method of teaching the game to students.

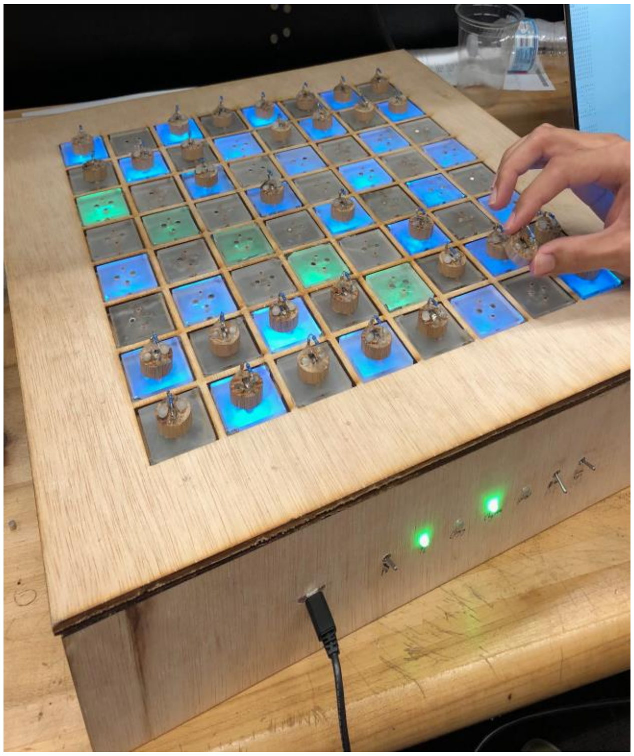

Fig. 1. Interactive Chess Trainer

TECHNICAL OVERVIEW

For the Interactive Chess Trainer to work, there are three main layers that need to come together for correct operation. The interactive layer (Top Layer) is the where the user will be able to physically play the game. Just below that layer is the secondary PCB. In this layer, all the connections for the RGB LEDs, reed switch array, and resistance contacts are nicely organized. The final layer is the primary PCB layer and the heart of all the computation, measuring, and detection. The primary and secondary PCBs can be split up into systems which describes the power system, LED matrix, reed switch matrix, and piece identification system.

The interactive layer is comprised of 32 chess pieces and 64 tiles with four connection points. This is the layer where the user will be able to interact and play the games. Underneath the tiles, a green LED will light up for legal moves and red LED will light up for illegal moves. To provide firm contact with copper connections and measure the resistance across the chess pieces; there are two magnets that securely hold in place the pieces in the correct alignment for contact with the copper. The tiles were made with sanded acrylic to provide some dispersion of the LED lights. Right below the tiles, is the reed switch glued on close enough for that the giant magnet in the chess piece can trigger the connected state. The chess piece itself is comprised of five total parts. Two for the magnets, two for the pogo pins which hold the resistor, and one for a big magnet to create a strong enough field to trigger the reed switch.

Fig. 2. 2x2 Matrix of Top Layer

The second layer hosts the secondary PCB which serves to make all the connections with the reed switches to detect localized events, copper contacts to measure and identify the pieces, and RGB LEDs to display all the possible and illegal moves. This would imply that the PCB for the LEDs need to be the same size as the wooden top layer which is 15 by 15 inches. Since the cost of a 15 by 15-inch PCB is relatively high, the PCB was split into four 7.5 by 7.5-inch PCBs that could be interconnected to reduce the total cost.

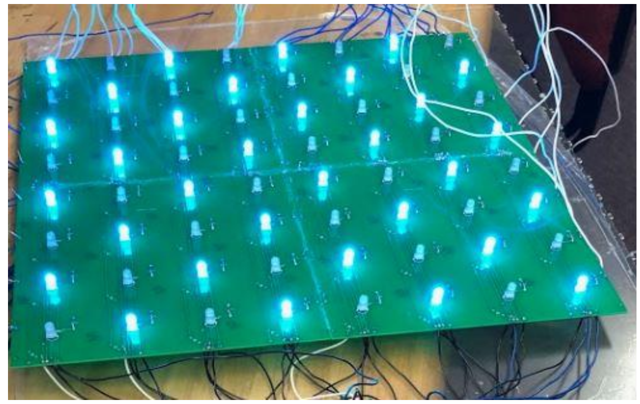

Fig. 3. Secondary PCB for Organization

Connected to the secondary PCB is the primary PCB to receive and send all the necessary data for the chessboard to operate correctly. The primary PCB receives all the data from the copper contacts and reed switches while also doing some background calculations with them to display an output in accordance to the current piece configuration on the board. For the primary PCB to be able perform all these functions it needs to have the appropriate integrated circuits. The primary PCB hosts devices such as a microcontroller, three shift registers, charging circuit, DC/DC boost converter, analog-to-digital converter, eight transistors, and two connectors. The primary PCB acts as the brain which is why all the integrated circuits are on it and the secondary PCB acts as an organizational tool to keep the matrix components organized.

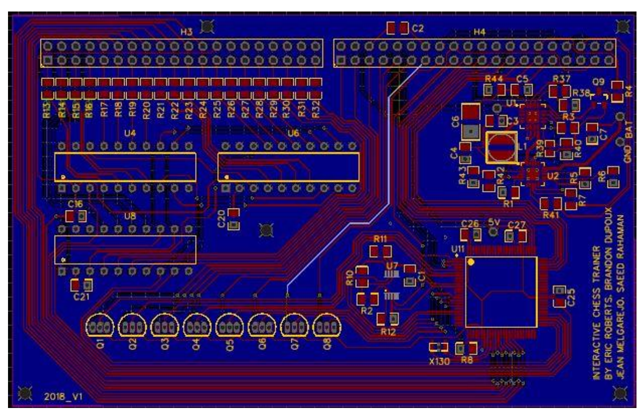

Fig. 4. Primary PCB Schematic

The final step is to incorporate all the systems together. To accomplish this, the ATmega2560 microcontroller needs to control all the integrated circuits through serial communication protocols to prompt the slave devices to read peripheral data and output the desired LEDs in accordance to user input. The systems will essentially work in two parts, with the secondary PCB serving as an organized matrix of information for the inputs and outputs of the user interface; and the primary PCB serving as a centralized area for computing the data and outputting the correct LEDs for the configuration of the board. The reed switch array works by detecting the presence of a magnetic field to localize an event when triggered. This reed switch system works coherently with the LED and piece identification system to detect changes both in the hardware (LEDs lighting up) and software (ADC picking up changes in resistance) level. The final system, the power management system, is the most attractive feature which boosts the voltage of the lithium battery to a more suitable 5.2-V for extra headspace when operating the devices.

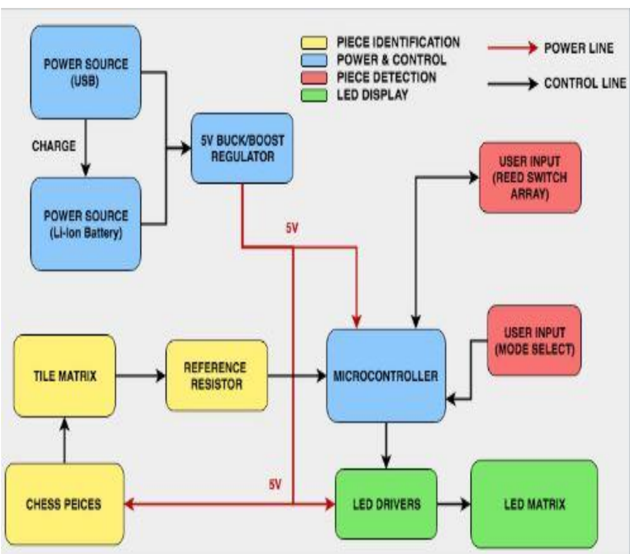

Fig. 5. Total System Block Diagram

Chess Pieces

The chess pieces were created in a way to allow for the group to give a value to each of the pieces. A rectangular hole is made in the bottom of all 32 chess pieces to make room for a circular magnet to be put inside. This circular platform contains a larger magnet in the middle with two smaller magnets on opposite sides, and two pogo pins on opposite sides that surround it. Soldered to the pogo pins is both ends of a through-hole resistor that sits on the top of the circular platform. This is very helpful to the group's system for identification because it allows for a piece to have a unique resistance value. This value is essentially what is used to identify the pieces. There are 12 total unique chess pieces that have different values meaning 6 unique values per team. The magnets that are embedded in the pieces are used to hold the pieces down onto the tiles so that they smoothly snap into place when placed down. The pogo pins that are soldered to the resistors are used to provide for the ADC to read the resistors.

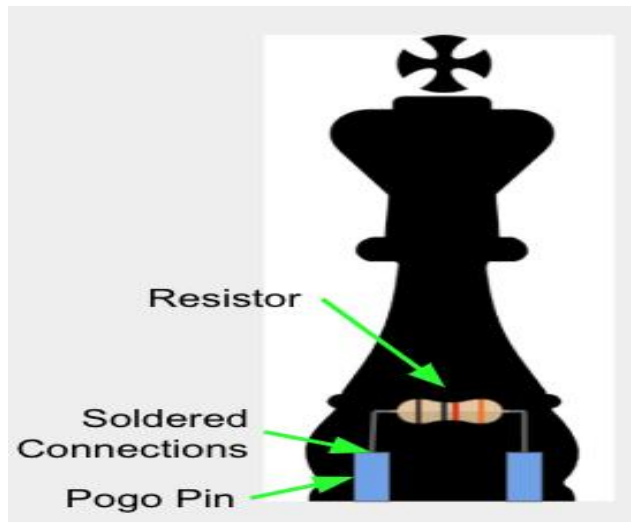

Fig. 6. Chess Piece Electrical Components

Chess Tiles

The chess tiles were created to connect smoothly with the pieces. The tiles contain a reed switch that is mounted underneath the tile, two copper contacts on opposite sides, and two magnets on opposite sides. The reed switch is glued underneath to the tile and is used for the piece detection since it is situated right under a magnet from the actual chess piece. The two copper contacts are used to contact the pogo pins from the chess piece. This allows for the system to read the value of the resistor and connect it to the secondary PCB that houses the 8 by 8 LED array. The two magnets on the tiles are used to provide a secure fit for the chess pieces and to allow for good contact.

The tiles originally came with a very transparent texture, like looking through a clear glass. It was decided to sand down the tiles rather than have them stay with their clear, see-through texture. This technique would help allow light through the tiles but also give it a nice dispersion of light through the tiles. If left clear, the tiles would not distribute the light given from the RGB LEDs to most of the tile. It would remain central to where the RGB LED is placed underneath the tile instead.

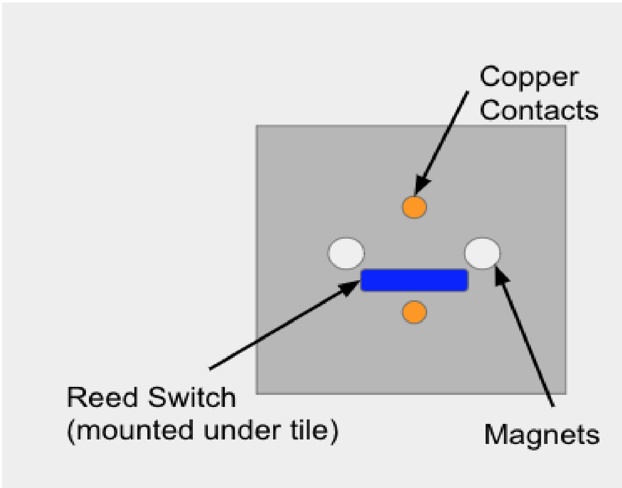

Fig. 7. Tile Component Diagram

POWER SYSTEM

One very important feature of the Chess Trainer is its ability to be made portable for ease of play. To be able to accomplish this, many electrical systems need to come together to create an environment for charging, load balancing, and battery level indicator. Using a 2.7 -4.2 V Lithium battery supply as the starting point, much research was completed to design a circuit schematic that met all the required specifications.

Initially, a 5-volt linear regulator and lithium-ion battery charging circuit was going to be designed with two batteries in series. However, the load balancing required to charge these two batteries and inefficiencies with full battery capacity at 8.4 volts was going to be too difficult to accomplish. Another circuit schematic needed to be created to boost the voltage of just one lithium battery instead of two. That way the complexity of balancing two loads would reduce to just balancing one.

To remedy this problem, a circuit with a built-in load-sharing battery charging circuit and DC/DC boost converter regulator needed to be designed. Other features include extra 5.2 output volts for “headroom” in long cables, 2 A internal switching, 90% operating efficiency, and smart load-sharing for when more than one power source is plugged in.

Adding this circuit onto our own PCB design was simple since all the documentation was published online for our convenience. The only thing required of us was connecting all the necessary pins to the appropriate locations on the ATmega2560 chip. Aside from the USB and micro USB ports, the TPS61090 and MCP73871T-2CCI required some detail with connecting the pins. Careful consideration was taken for the correct polarizations, type of capacitors, and resistors for setting voltage output.

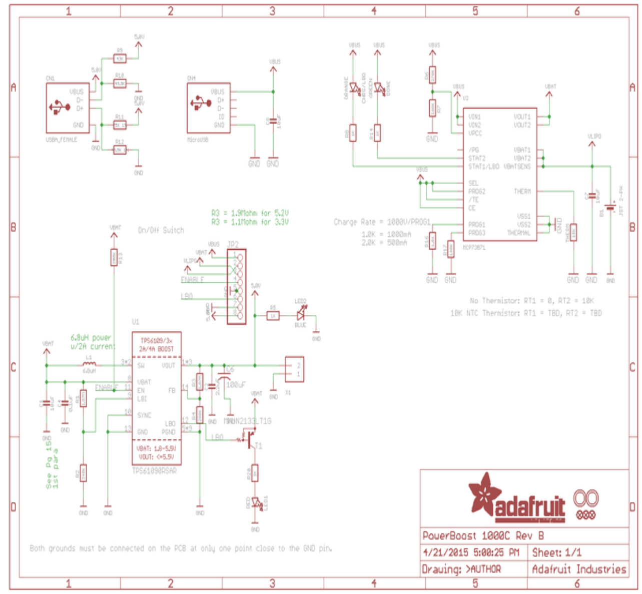

Fig. 8. Open Source Power Management Schematic

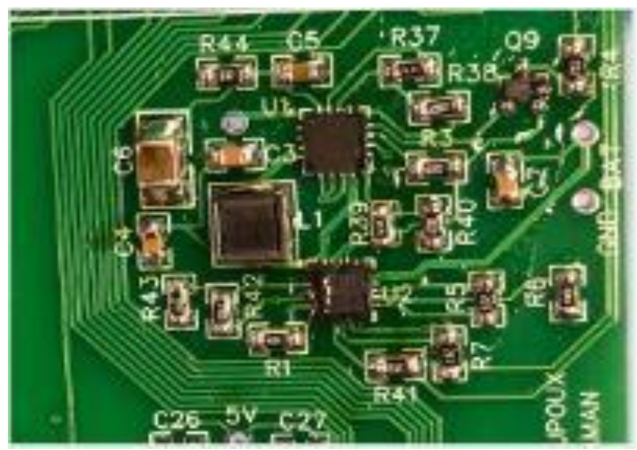

Fig. 9. Power Management Circuit on PCB

RGB LED

When selecting the type of LEDs that would be used, much was taken into consideration. In particular, the LED for this design will indicate several different things to alert the players during gameplay. First off, the LED will light up whenever a prediction is being made by the chess engine. There will have to be multiple LED color possibilities to indicate different movements and errors.

With this color scheme indication, it is evident to see that multiple color LEDs will be needed to in order to satisfy the requirements. Aside from that, it is also important to note how many LEDs will be needed in order to satisfy the populating of the full chess board. The initial thought is to have a single LED under each of the 64 squares on the board. After realizing that we would want multiple colors to indicate certain scenarios, it became apparent as to what type of LEDs would be chosen.

It was settled that the RGB LEDs would serve our purpose best since it provides a red, a blue, and a green LED all in one. RGB LEDs can either be common cathode or common anode. Common cathode means that when the circuit is setup, the common anode terminal will be tied to ground. Common anode means that when the circuit is setup, the common anode terminal will be tied to a voltage input rather than ground. A visual representation of the terminals and physical component of an RGB LED is shown below:

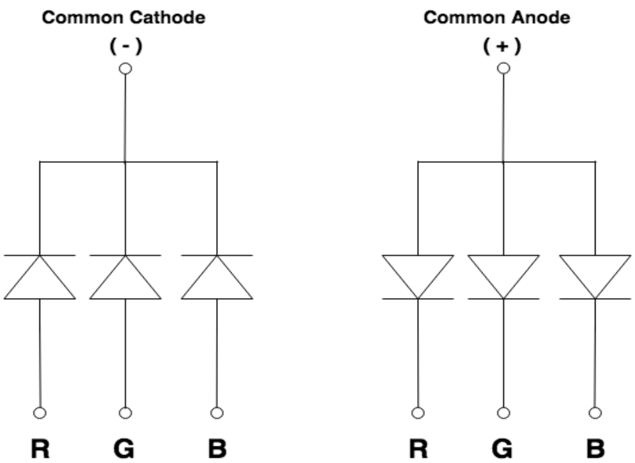

Fig. 10. Types of RGB LED

The LED can also have other attributes that contribute to its selection. Another consideration for selecting the correct LED was the way that the light would emit from a top view underneath another material. The RGB LEDs will be underneath the chess board, so the clarity of the light and its distribution of the light must be considered too. This is where the option of a clear or frosted tip RGB LED came up. The clear tip underneath the board would provide more of a point of light, as if it were a single beam focused on a pinpointed area. This is not what would be desired for a whole square underneath a chess piece because the visibility of light from the RGB LED would prove to be insufficient. However, the option of the frosted tip proves as a better choice in this situation. A frosted tip RGB LED will be able to have a more well-rounded dispersed display of light from underneath the board as opposed to the clear tip which would prove to be enough for this design choice.

After figuring out the exact type of LED we would want to implement, it was important to seek another route as a backup. The group's initial thought to this design was to have an LED for each color underneath each square before inquiring on a 3-in-1 RGB LED option. Although this route would clearly be more expensive and contain more parts, it was still an option to be looked at.

LED SYSTEM

The LED system is comprised of RGB LEDs situated in an 8 by 8 array controlled by shift registers and GPIO pins from the MCU. This is one of the only communication methods that the Interactive Chess Trainer possesses in order to communicate with the user. Due to the system being the most visible to the user, it is essential that it performs with a much higher success rate than the other systems present in the design. Along with its high percent of success, the LED system also strives to keep a low-cost, inexpensive design.

This LED system works with an array of RGB LEDs that sit under every tile on the chess board and provide an illuminated output that the user can understand. The theory behind this design is to have a connection between the rows and the columns and switch the rows one at a time. When switching through the rows, a specific pattern will be lit up and then so on till it cycles through all 8 rows. The key to this method is the refresh rate of the rows. The refresh rate here is referring to the amount of time it takes the rows to switch through a whole cycle. It is imperative to make sure the refresh rate of the rows is switching fast enough so it is undetectable by the human eye. When this is achieved, it should cycle through the rows fast enough that all tiles on the board appear lit up all at the same time. The rows are connected from the ATMEGA 2560 to an NPN transistor that connects via emitter to a connector on board. These signals are then carried off-board to connect to a secondary PCB which houses all 64 RGB LEDs.

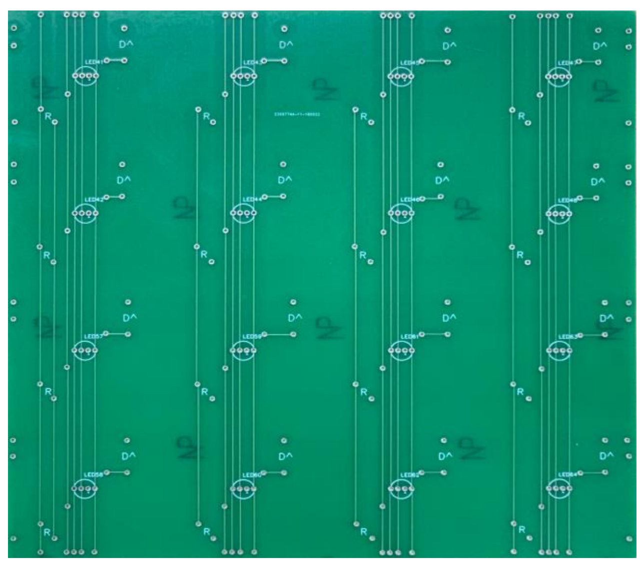
Fig. 11. Portion of 8 by 8 LED Array

The ATMEGA 2560 is the MCU that controls the rows of the LED system and the TPIC6B595 shift registers control the columns. The shift registers are daisy chained together to accommodate the fact that the LEDs being used are RGB LEDs instead of a single-color LED. The RGB LED utilizes red, green, and blue to create whatever color scheme is desired so this means that a single RGB LED will have 4 pins as compared to a regular single LED. Altogether, there is a total of 24 outputs from the daisy chained shift registers to control the eight columns of the RGB LEDs.

TPIC6B595

The TPIC6B595 was an important part to getting this design to correspond with the RGB LEDs. Previously, an LED driver containing 24 outputs was going to be used to control the columns of the secondary PCB that houses the 8 by 8 LED array. After testing, it was determined that the shift registers would be a better fit for this matter because the shift registers would allow for the fastest programming speeds based on the ATMEGA 2560 being chosen as the MCU. The shift registers support programming speed of up to 5 microseconds to program 8 channels which serves the groups purpose. When paired with the chess engine and other programming for the other parts, high speeds were needed to accommodate. Also, the TPIC6B595 supported daisy chaining which allowed for the three shift registers to be linked together in a sequence. So instead of just having 8 outputs each on three separate shift registers, it now becomes like one large shift register with 24 outputs.

LED DRIVER

Prior to this current design, the rows of the LED array had been controlled by a shift register that was receiving inputs from the MCU. The design changed once the LED driver that had controlled the columns was replaced by the TPIC6B595 shift registers mentioned previously.

The current design used to drive the LEDs comes from the 2N2222 BJT's. The ATMEGA 2560 is still the MCU that controls the GPIO pins that send signals through the BJT's. These BJT's are what will act as a switch to turn on the source to each row of the LED array. This BJT is helpful since it supports high current capabilities of up to 800 mA. The max current that the LEDs will draw is 720 mA so the 2N2222's will prove worthy to support the group's specifications.

REED SWITCH SYSTEM

To localize events on an 8x8 matrix, some sort of electrical measuring device is required to detect when an event occurs. The best method for such a detection would be digital in logic and have high degree of accuracy. The device would also need to be relatively inexpensive since there would be 64 of them for each individual tile of the chessboard. The team agreed that the best solution to this problem would be magnetic reed switches.

Reed switches work on the principal of a magnetic field. When an outside magnetic field is detected near the reed switch, the two contacts inside the device are forced together to make contact and create continuity. Depending on the presence of a magnetic field, the ATmega2560 will read either a "1" or a "0" for the state of the reed switch on the GPIO. It's through this information that the microcontroller will be able to detect whether a chess piece is placed on a location on the matrix.

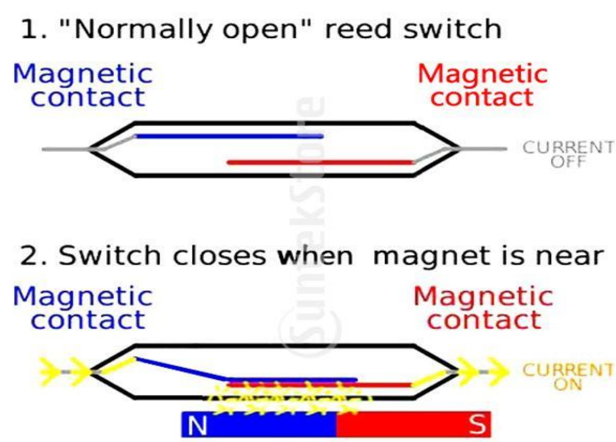

Fig. 12. Reed Switch Theory

It's essential that the reed switch array work hand in hand with the piece identification system since the switches can only read discrete values on the 8x8 matrix. Essentially, the reed switch will be used to measure localized events and the piece identification system will be used to measure analog signals for piece differentiation.

PIECE IDENTIFER SYSTEM

The bulk of the computational burden on the microcontroller will occur when measuring the analog values of the individual pieces on the board. This is due to the smoothing function that will be necessary to give consistent numerical values that don't fluctuate randomly. To make these possible, individual resistors will be inserted into the chess piece to give an electronic signature for each different unit and team. The final part of the system will include a 16-Bit ADC to measure the changes in total resistance when a unit is subtracted from the chessboard.

RESISTANCE CONFIGURATION

An understanding of how the resistors of the chess pieces, reference resistor, ADC pin, VCC, and GND is required before diving into the PCB. The first fact to note is that all the chess pieces will contact copper rivets to make a connection with the resistors inside of them and the secondary PCB board. All the connections on the tiles hook up the resistors in parallel with VCC on one side and the ADC pin on the other. The Voltage is then divided by a reference resistor which is connected to ground and the voltage across that resistor is measured to calculate the total resistance of the board.

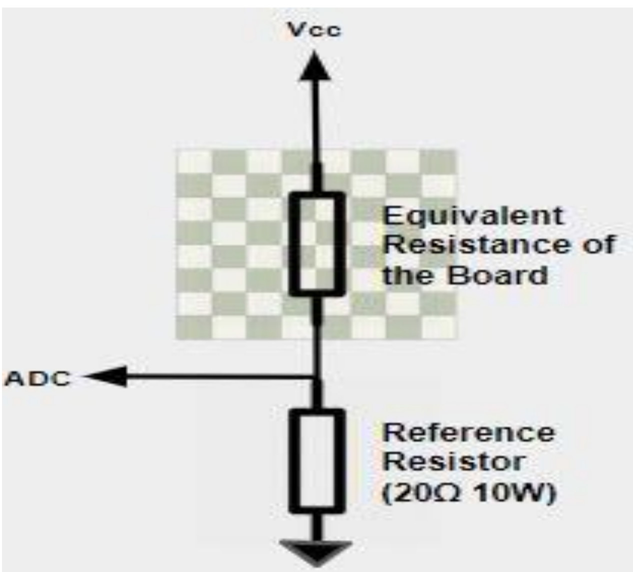

Fig. 12. Resistance Configuration

ANALOG-TO-DIGITAL CONVERTER

Now that the resistance configuration is understood, the piece identification system can be further explained. The system basically works on the voltage divider principle. Keeping the reference resistor constant, the resistance of the board is the only changing variable. All the resistances on the chess pieces are in parallel so therefore the equation required to calculate expected resistance across the board is simply the reference resistor divided by all the resistors in parallel and the reference resistor. Knowing that, creating a prediction model for resistance change when a piece is removed was relatively straight forward. Then using the ADC to measure that delta change of resistance would be required to differentiate between the units. Although the ADC had 16-bit accuracy, it required additional circuit configuration to attain a differentiable measurement so instead the 15-bit single-ended measurement was used. After correctly hooking up the ADC IC to communicate with the microcontroller using I2C serial communication protocols, the circuit was ready to simulate. The coding procedure to obtain correct resistance changes was simple but some optimization was required to choose resistance values that would be appropriate for the power consumption and element spread of the final product.

GAME MODES

The Interactive Chess Trainer will offer multiple modes that the user can make use of. First off, the Interactive Chess Trainer will offer the game modes of Player versus Player (PvP) and Player versus Computer (PvC). For PvP, this will be like your traditional chess game where two people will go head to head against one another until an end game scenario takes place. In the PvC mode, it will follow the same method as the PvP mode except the user will have to physically move the piece for the computer after the computer uses the LEDs to exhibit where it would like to move.

Although primarily being a chess driven project first, the group decided to add on a checkers game mode as an extra feature. This game mode will follow the same possibilities as the chess mode with support for only PvP modes.

The game modes will be accessed conveniently through the side of the Interactive Chess Trainer from a flip of the switch.

CODE

The main portion of the coding for the scope of the project is associating all the systems with the open source chess engine. The difficultly with associating all the different integrated circuits with the chess engine arises from the fact that so many different systems need to come together simultaneously to detect a change to the system. Thus, creating a code that can interact coherently as one unit with the chess engine was the objective. To localize events on the chessboard, an 8x8 matrix was created in the memory to output LEDs based on the position of the chess pieces on the board. The microcontroller would also take in data in accordance to this localized matrix to detect exactly where the pieces are positioned.

CONCLUSION

The Interactive Chess Trainer has been an overall successful project implemented to design specifications. Though this project has met the expectations and goals set by the group, it does not limit the potential of possibilities for further enhancements. Over the course of the project new improvements and features were thought of which could bring other aspects to the user's experience. These possibilities include, but are not limited to, voice activation, automatic moving chess pieces, and a smartphone application. Implementation of these possible add-ons would require extra capital but could prove to be very enjoyable for the user.

Upon completion of this senior design project, the group has had a positive experience throughout. The value of teamwork, PCB design, circuit implementation, software design, and documentation are some of the improved skill set that has been gained from this experience.

ACKNOWLEDGEMENTS

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BIOGRAPHY

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Saeed Rahaman is currently a senior at the University of Central Florida and will receive his Bachelor of Science in Electrical Engineering in December of 2018. He accepted a data analysis job in New Jersey. He eventually plans to pursue a Master's after acquiring more work experience.

Brandon Dupoux is currently a senior at the University of Central Florida and will receive his Bachelor of Science in Electrical Engineering in December of 2018. He has attended the University of Central Florida for 3 years and plans to pursue a Master's in Electrical Engineering or Business Administration. He has accepted a position at Lockheed Martin for Electrical Engineering Associate.

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