## **Purdue ECE Senior Design Semester Report**

## **(Team Section)**

| **Course Number and Title** | ECE 47700 *Digital Systems Senior Design Project* |
| --- | --- |
| **Semester / Year** | Spring 2023 |
| **Advisors** | Phil Walter |
| **Team Number** | 8 |
| **Project Title** | Engineer’s Chess |

| Senior Design Students – Team Composition | | | |
| --- | --- | --- | --- |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Jack Gardel | CompE | Team Leader, Signal Processing, Serial protocols, Linux | May 2023 |
| Tyson Kline | CompE | Systems Engineer, LED matrix experience, soldering, programming and designing embedded circuits | May 2023 |
| Andy Helton | CompE | Hardware Engineer, PCB Design, analog audio input and package construction | May 2023 |
| Bazim Azeem | CompE | Software Engineer, Embedded Systems Software, Serial Protocols | May 2023 |

**Project Description:** Provide a brief (2-3 page) technical description of the design project, as outlined below:

1. Provide a general description of the product to be delivered by this design project.

## This project is a voice activated chess game. The current state of the chess set is displayed on a central 64x64 LED matrix. A player can give an input, such as “Alpha-6 to Alpha-7” to the game. A microphone takes the voice input and transmits it to a Jetson Nano. The Jetson Nano uses that data to determine what move is being requested, then sends that data to the STM32 microcontroller. Programmed logic determines whether the inputted move is legal, then displays feedback through two mirrored LCD text displays. There are multiple buttons to control the flow of the game such as undo buttons and reset buttons. There is also a settable game timer to optionally be used during the game, that is displayed on the feedback LCDs. Two players can play a complete game of chess using only their voices to control the pieces. The PCB is powered through a barrel jack that also sends 5V to the Jetson Nano. A regulator is used to convert the voltage to 3.3V to power the STM32 microcontroller and the LCD text displays.

1. What is the purpose of this product? For whom is it intended?

## The purpose of this product is to provide a new and refreshing way to play a game that so many of us have enjoyed. It is intended for consumers interested in playing chess using voice commands. Those with physical disabilities may also benefit from this product, as long as they have the capability (or a helping hand) to set up the board and press the buttons.

1. Describe how the engineering design process used to create your product was utilized in this project. Include how you were able to develop and conduct appropriate experiments, analyze and interpret data, and use engineering judgment to draw conclusions related to the development of your product.

## We started the engineering process by analyzing the problem we were trying to solve and gathering the requirements needed to solve the problem. Then, we designed a system that could meet the requirements. The first step in implementation was prototyping the different hardware parts used in this product. We ensured that the different hardware components could work simultaneously on the microcontroller. Afterwards, the hardware team created the PCB design around these components, while the software team continued in developing the software components, such as game logic and I/O. Once the PCB design was checked off by our instructors and peers, we proceeded to order the board, debug, and solder the components. Next, we began testing our system while also putting together the packaging for it. Finally, we did end to end tests, checking the voice processing algorithm for common errors (e.g. “ago” instead of “echo”) and iteratively incorporating this into the voice processing logic.

1. Describe the design constraints, and resulting specifications, incorporated into your product (list a minimum of 3).

## Power - The product is intended to run entirely on a conventional power brick normally found with most phones or laptops. In this case, the jack is connected on the inside of the case and can carry 5V at 2A. The sum max current of our components comes out to around 1.56A, well under the specified maximum of the power brick.

## Size - The case of the product is designed to be 292mmx292mm at the base and 61mm tall. The height of the case after construction is around 65mm after adding velcro as a latch mechanism to get easy access to the PCB.

## Cost - Cost of development in materials was around $400. This included several areas of redundancy where things were ordered in bulk such as wood and extra PCBs. The actual cost of the design per unit is around $200 with the single-board computer (Jetson Nano) taking up most of the cost.

1. Describe how each of the following factors influenced your design specifications and constraints.

## **Public Health, Safety, and Welfare:** The product has a few aspects that could concern the public health, safety, and welfare of its users. The device has no off switch, meaning that the user must plug/unplug the device directly. The wattage of the power is very low however, ensuring that the risk of electrical shock is quite low. Another aspect of the project is the LED matrix the chess game is displayed on. This display is very bright and can in certain edge cases flicker quite brightly. This could affect those sensitive to bright lights. One aspect of the project that impacts user safety and welfare is the fact that we are using voice to text software over the internet. This could impact some users if they feel uncomfortable with this technology, but we can ensure that the product only records from the microphone when the record button is pressed.

## **Global Factors:** In order to use our device, the user would need access to both electricity and ethernet that is hooked up to the internet. While these conditions can be met in a large portion of the world, there are still places that either do not have electricity or access to the internet. The user would also need to have some understanding of the English language, as the voice instructions the player says are in English. This also limits global usage, but phonetic pronunciations can be included in the instructions to accommodate non-English language speakers.

## **Cultural Factors:** Standard chess notation and language (such as Universal Chess Interface or Standard Algebraic Notation) are in English. Therefore, we implemented our voice processing algorithm and packaging to use English vocabulary.

## **Social Factors:** We designed our product to be used by people of any age (so long as they know how to play chess). Therefore, we ensured that the buttons were large enough to be easily pressed and the displays could be easily read. Furthermore, setting up the device is as easy as plugging in two cables.

## **Environmental Factors:** This product, like most electronics, will not have a positive impact on the environment. However, with the way we designed the project, the ability for the electronics within to be recycled or disposed of properly is very simple. The product is also a low wattage wall socket device, so it does not create a lot of electric waste and will have no battery waste either. Besides the electronics, the rest of the package is wood which can be disposed of very safely for the environment.

## **Economic Factors:** While the initial purchase of $350-$450 is quite expensive, we do not expect there to be any maintenance costs. Furthermore, some components (such as the Jetson Nano) can be reused for other purposes.

1. Describe the appropriate engineering standards incorporated into the creation of your product.

Engineer’s chess falls within the scope of several regulatory agencies. The agencies that would definitely have an interest in this product include the IEC, UL, and FCC. These agencies generally focus on things like safety and appropriate power usage, as well as ensuring that our design does not produce noise in frequencies used by other products. If we were to market our product internationally, we would also need to conform to the standards of the CE and RoHS regulatory agencies, which focus on minimizing hazardous materials in our project and reducing interference with other projects.

1. Describe the final status of your product.

Our project is fully completed and meets the specifications listed above. Our PCB and other electronics are enclosed in a wooden box, with holes cut out for buttons, displays, and wiring. Our project is capable of reading in voice input, processing that input, and displaying the results to a display. We have on several occasions completed a full game of chess with no bugs.

1. Describe the makeup of your project team and how you were organized to establish goals, plan tasks, and meet the objectives of this project.

## Our team was organized so that each member had a specific role. Jack Gardel was the team leader; setting up meetings with the course staff and generally organizing the tasks of the project. Tyson Kline was the systems engineer, which meant that he focused mainly on the integration of the hardware and the software so that the two interacted smoothly. Andy Helton was the hardware engineer, which meant that he worked on the design of the PCB, the analog audio input circuit, and the physical packaging of the product. Bazim Azeem was the software engineer, which meant that he handled much of the software relating to game logic on both the Jetson Nano and the microcontroller. Furthermore, he was responsible for incorporating the different software components together. We organized our time so that we met twice a week for lectures and once per week for labs, during which time we would get most of our work done and collaborate on connected parts of the project. We also scheduled times to meet in the lab at other times throughout the semester as needed.

1. Did your project require the production of any written documentation other than this document (i.e., manuals, educational materials, etc.)? If so, describe the types, composition, and nature of the audiences for whom these materials were intended.

## Project Proposal - This document was our initial project proposal. It detailed the functionality of our project, as well as its intended audience. We created several diagrams and preliminary images of the project and detailed our ideas that would make it possible. This audience of this type of document would be a manager or other leader in a company at the very beginning stages of a project.

## Functional Specification - The functional specification was a document that went into further detail on exactly what functions our project could perform, as well as the theory that went into making it possible. It includes more diagrams as well as descriptions of the methods we would use to realize our project. The audience of this document would also be a manager or other project supervisor near the beginning design stages of a project.

## Software Overview - This document was a general overview of the software we were planning to use early on in our design process. It was turned in to our instructors, but in a real-world application it very closely relates to a report that may be made during the design process and given to a manager.

## Electrical Overview - In this document we examined all major components of the design and how much power they draw. We paid careful attention to the Jetson Nano and microcontroller as the primary computational components of our design.

## Component Analysis - The component analysis was a report comparing several different options for each major component and detailing why we chose each option. The audience of this report would be a review engineer or manager that wanted to confirm that we found the cheapest/best value option for each component in our project.

## Mechanical Overview - This document outlined the physical side of the product. Including pictures of a 3D CAD model of our chessboard, any potential products that ours would compete with, and the initial size of the PCBs in the board.

## Bill of Materials - This document was a list of all the parts we would need to build the project. It included the names, quantity, and source of each part. The intended audience of this document was a purchaser, or just for a design team to use as a reference throughout the production process.

## Software Formalization - This document laid out the major software components and explained in detail the purpose of each one. Furthermore, we included some diagrams to outline the interactions between these components and the flow of the program from start to finish. The audience for this report is the manager or lead architect of this project

## Legal and Regulatory Analysis - This document was an analysis of how our project was affected by various regulatory agencies, as well as pre-existing patents. It consists of a list of steps necessary to meet several regulatory standards and does an analysis of a few patents related to our project. This report would be given to a supervisor of some kind before our product went to market to ensure that there would be no legal liability or other lawsuit against our product.

## Reliability and Safety Analysis - This document goes over details such as failure rates and safety impacts of various components of the design. It also lists failure modes for each subsystem.

## Ethical and Environmental Analysis - This document details the ethical and environmental impacts of our product.

## User Manual - This document served as a guide for the user to set up and use our product. Furthermore, we included a consumer oriented product description and troubleshooting instructions for common errors. This document was meant for the user.

1. Describe the types, composition, and nature of the audiences in attendance for the final oral design review. Discuss how you prepared for this audience.

## The audience for our final presentation consisted of the course staff, a few teaching assistants, and 8-12 of our peers. We prepared for this audience by practicing our presentation beforehand, as well as learning from our previous midterm design review earlier in the year.

## **Purdue ECE Senior Design Semester Report**

## **(Individual Reflections Section)**

| **Course Number and Title** | ECE 47700 *Digital Systems Senior Design Project* |
| --- | --- |
| **Semester / Year** | Spring 2023 |
| **Advisors** | Phil Walter |
| **Team Number** | 8 |
| **Project Title** | Engineer’s Chess |

| Senior Design Student Completing This Section | | | |
| --- | --- | --- | --- |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Tyson Kline | CompE | Systems Engineer, LED matrix experience, soldering, programming and designing embedded circuits | May 2023 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

## My first contribution to the project was the design of the LED matrix interface, meaning all of the hardware and software necessary to take the virtual game state stored in the microcontroller and send it to and display it on the LED matrix. Also, I created the original breadboard prototype for proof-of-concept testing. Finally, I completed the soldering and assembly of the PCB, and assembly of some of the final packaging.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## For the LED matrix interface, I used the knowledge I had gained from my ECE 36200 mini project. I used a similar LED matrix for that project, so I knew how to program and control it. For the prototype, I used knowledge I had gained in several circuit design courses, such as ECE 27000 and ECE 36200. I also depended on coding knowledge I had gained from several programming classes.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

## Some new knowledge I learned that I applied to this project included PCB design knowledge, good design practices (designing for debugging, etc.), and power use. This information came from lectures. I also did research on the internet to gain other knowledge, such as how to operate and optimize different ICs that we used.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

## My ethical and professional responsibilities as related to this project include the safety and reliability of our design. We worked to ensure that these standards were met. There are no exposed electrical components on our project. Every sensitive component is well enclosed in our packaging. We also ensured that we had plenty of vents in our packaging so that heat would not build up inside our project.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgment as to your product’s impact in each of these four contexts?

## Economic - This product is unlikely to have a large impact on economic contexts. The cost would be much more expensive than the average chessboard, but it is comparable to similar novelty chess sets. We did research to determine what price range similar products were offered at, and we used that to set our budget.

## Environmental - We considered several factors when considering the environmental impact of our project. PCBs are known to be hard to recycle, so we wanted to make our PCBs last for as long as possible. The packaging is wooden instead of plastic, so it should be much more environmentally friendly to dispose of or recycle.

## Societal - For societal contexts, we considered the fact that our project could be used in chess competitions. We did everything possible to ensure that our designs met the standards for competitive chess. This included conforming to rules like timers and having similar notations for describing piece locations.

## Global - If we wanted our project to have a global impact, we would need to make several updates. First, we would need to make our speech recognition recognize different accents better. Currently, it performs well with clear English, but not as consistently with different accents. We also could add support for different languages.

## **Purdue ECE Senior Design Semester Report**

## **(Individual Reflections Section)**

| **Course Number and Title** | ECE 47700 *Digital Systems Senior Design Project* |
| --- | --- |
| **Semester / Year** | Spring 2023 |
| **Advisors** | Phil Walter |
| **Team Number** | 8 |
| **Project Title** | Engineer’s Chess |

| Senior Design Student Completing This Section | | | |
| --- | --- | --- | --- |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Jack Gardel | CompE | Team Leader, Signal Processing, Serial protocols, Linux | May 2023 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

## Early in the project, I looked into creating a custom speech recognition model. After this, I decided to use an API to a pre-existing software and integrate that into the design. I chose this third-party API due to the difficulty of setting up a voice-recognition model myself. I set up the OS for the Jetson Nano and all the tools that would help us develop on it including SSH and other systemctl utilities. I aided in the PCB design by creating the smaller boards for our user interface and debugging the design for the main board. I designed a protocol for communication between the Jetson Nano and STM32 and implemented it. I also looked into using an off-board ADC with SPI and digital low-pass filters for the speech-to-text algorithm.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## A lot of what I put into designing the protocols and the PCB are things I’ve learned from work in my embedded systems course: ECE 362. My knowledge of Linux was a result of almost all prior coursework (ECE 264, ECE 20875, ECE 362, ECE 368, ECE 337, etc), as I use Linux for the majority of my classes to develop on. This OS knowledge is what helped me set up the environment on the Jetson Nano.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

## This semester, I used the Jetson Nano extensively and had to learn about kernel-enabled IO. I researched to configure the main header and use pins in a Python script. I also learned a couple of useful libraries to make this happen, some of which did not have good documentation so I had to scrutinize the API carefully.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

## While designing the PCB, separate planes had to be made for the power section as well as the analog section. This helped with reducing noise and helping keep parts of the board protected, reducing the probability of electrical damage or injury to the user. Electrically, I made sure that the design did not draw more current than the wall outlet could handle, as to not cause overheating anywhere. Proper loading ensures that the product is safe to use and is non-hazardous during normal operation.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgment as to your product’s impact in each of these four contexts?

## The economic impact of this design will be fairly restricted, as a voice-activated chess board would only attract a niche audience that enjoys the aesthetic of what we made. Professional chess players would still prefer an ordinary physical chessboard. Given you can buy a regular chessboard for a much lower price, this product is expected to sell less. Since the product’s case is made of wood, we expect this to produce less E-waste than other electronic devices made of plastic. The societal impact has the potential to be large, especially for disabled people who have a difficult time using their hands. In the future, this device could be operated with no buttons whatsoever, further developing the impact it has on these people. There is not much use for this product outside of the realm of English-speaking chess players, so the global impact is fairly low as well.

## **Purdue ECE Senior Design Semester Report**

## **(Individual Reflections Section)**

| **Course Number and Title** | ECE 47700 *Digital Systems Senior Design Project* |
| --- | --- |
| **Semester / Year** | Spring 2023 |
| **Advisors** | Phil Walter |
| **Team Number** | 08 |
| **Project Title** | Engineer’s Chess |

| Senior Design Student Completing This Section | | | |
| --- | --- | --- | --- |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Andy Helton | CompE | Hardware Engineer | May 2023 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

## My contributions consisted of analog input circuit design, PCB schematic and design, and the construction of the package. My work on the analog input circuit was what I worked on at the start of the project, initially it was going to be a part of the project but it got moved to a stretch goal. This part of the project was later dropped when constructing the PCB itself. I also did most of the work towards finishing the PCB schematic and design. In the last weeks, I focused mostly on the packaging of our project and put in effort to make it look as good as I could manage.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## The circuit that I had designed for the audio jack input had built off what I learned in ECE 20001 and 20001, some of the earliest undergrad classes I took at Purdue: basic analog signals, low pass filters, and analog to digital converters. The area I gained a lot of knowledge in, was the design of the PCB. In my undergraduate experiences, I had only seen PCB design once before and it was a small part of ECE 36200. I now feel relatively confident in my ability to design a PCB and for it to work.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

## My work on the packaging was very unrelated to previous coursework, but I learned a lot about laser printing and other woodworking tools. I learned this through being trained by someone who had experience with laser cutting and was able to show me the software the machine required and how I could laser cut the wood on my own.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

## The ethical and professional responsibilities that I had were in the design of the PCB. I had to ensure that this was a safe to use design that would have as few problems as possible during nominal use. With the physical packaging, I had to make sure the box was not sharp or have any irregularities that could harm someone while manipulating the product.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgment as to your product’s impact in each of these four contexts?

## Economically, the product is quite expensive. Only those willing to spend a few hundred dollars on a chessboard would be willing to purchase the product we made. This means that the economic impact will be relatively minor. The likelihood of this product causing a disruption in the chessboard marketplace would be unlikely. Unfortunately, due to the relatively high cost of the product it will only be purchased by those that can afford luxury items. Perhaps with more time and later iterations the product could go down in price and reach more people that may want to play voice controlled chess that can not afford it in its current state. Our product has many of the pitfalls that all modern day electronics have. Depending on how the electronic components were made, they could have a varying environmental impact. It is up to us, the manufacturer of our product, to buy electronics that come from sources that are reliable and environmentally friendly. Once the product has reached its end of life, it can be disposed of like how most electronics can be, taken to a recycling center that handles electronics. Besides the electronics in the chessboard, the other components are wood, glue, and some metal screws. These are fairly common waste materials and have very low end of life environmental impact if disposed of through the proper channels. Socially, our product is very low profile. This is not designed to radically change the chess playing world. It was designed for general use, which gives players a fun and unique way to play a game in a way they may have never played before. Globally, our product has fairly good reach. Chess is known throughout the world, with the only limiting factors towards using our product is having electricity, access to the internet, and familiarity with the English language.

## **Purdue ECE Senior Design Semester Report**

## **(Individual Reflections Section)**

| **Course Number and Title** | ECE 47700 *Digital Systems Senior Design Project* |
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| **Semester / Year** | Spring 2023 |
| **Advisors** | Phil Walter |
| **Team Number** | 8 |
| **Project Title** | Engineer’s Chess |

| Senior Design Student Completing This Section | | | |
| --- | --- | --- | --- |
| **Name** | **Major** | **Area(s) of Expertise Utilized in Project** | **Expected Graduation Date** |
| Bazim Azeem | CompE | Software Engineer, Embedded Systems Software, Serial Protocols | May 2023 |

**Individual Reflection:** Provide a brief (1-2 page) individual reflection of the design project, as outlined below:

1. Describe your personal contributions to the project.

## I started off by prototyping the OLED feedback displays and communicating to it via SPI from the microcontroller. Then, I implemented the game logic on the Jetson Nano using the python-chess library. I also implemented much of the UART protocol between the Jetson Nano and the microcontroller. This included sending packets on button presses and other interrupts from the microcontroller and sending feedback from the Jetson Nano. Finally, I refactored all the microcontroller code to be more readable and maintainable.

1. Describe how your contributions to this project built on the knowledge and skills you acquired in earlier course work.

## The two main courses that were relevant to this project were ECE 40862 (Embedded Systems Software) and ECE 36200 (Microprocessor Systems and Interfacing). In ECE 40862, I learnt about the different approaches to writing embedded software, such as the interrupt driven approach. This is what I ended up using for the microcontroller code, where the main loop was empty with all the logic being handled in interrupts. In ECE 36200, I learnt about the functions of different peripherals and communication protocols. These were used to send and receive data from different I/O devices and the Jetson Nano.

1. Describe how you acquired and applied new knowledge as needed to contribute to this project. What learning strategies did you employ to do so?

## Much of the knowledge I acquired for this project was related to using different libraries on the Jetson Nano. This knowledge was gained by reading the appropriate documentation for the libraries.

1. Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

## My main ethical responsibility was ensuring that the product was usable for the desired audiences. Therefore, I had to include appropriate feedback so the users could know the current status of the game. In addition, I designed an intuitive user interface that was easily understandable to most of the users of our product. This meant that the users had an easier time using our product and that it worked as expected.

1. Consider what the impact of the product of this engineering design experience could have in economic, environmental, societal, and global contexts. Discuss how you would make (or did make) an informed judgment as to your product’s impact in each of these four contexts?

## In the economic context, our product will be quite expensive as compared to normal chess boards. It is not designed to be bought by normal chess players, but rather people who have the money to spare for a niche product. In regard to the environment, our product packaging is made of wood and some components (like the Jetson Nano) are reusable. Our product may be used by disabled people to play in chess competitions, resulting in a positive societal impact. In the global context, our board does not offer languages apart from English, as English is the standard language for chess.