Purdue ECE Senior Design Semester Report
(Team Section)

Course Number and Title	ECE 47700 *Digital Systems Senior Design Project*
Semester / Year	Spring 2024
Advisors	Phil Walter
Team Number	1
Project Title	The Dungeon Crawler

Senior Design Students – Team Composition			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Landon Carre	CompE	Software, Firmware, Hardware	Spring 2024
Neil Brown	CompE	Software, Firmware, Hardware	Spring 2024
Jackson Luna-McCrocklin	CompE	Software, Firmware, Hardware, PCB Design, CAD	Spring 2024
Grace Whitaker	CompE	Software, Firmware, Hardware, CAD	Spring 2024

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

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

For decades, Dungeons and Dragons (D&D) has been a widely popular role-playing game. The game is facilitated by a Dungeon Master, a person who verbally guides players through the game and any encounters with other characters and enemies. To aid with painting this picture for the players, and to reduce confusion for new players, we created the Dungeon Crawler board. This is an interactive game board that displays a map with walls, players, monsters, and chests and allows players to move around, collect gold and enter combat. This is not meant to be a replacement for D&D, but rather a tool to supplement the game.

This board will feature a 16-by-16 hex-based 2D map that serves as the playing area. The LEDs will change color based on what is happening on the map. Along with the LEDs, there are an array of Hall effect sensors that can detect magnetic tokens moving across the map. This allows us to update player locations and interactions by detecting the location of the tokens on the map. The board also consists of an LCD and keypad to prompt the user and allow them to input information during gameplay. Additionally, we created a custom desktop application that allows the Dungeon Master to create a custom map and characters which then sends this information over USB to be used on the game board. Through the utilization of the application and the game board we hope to make the job of the Dungeon Master easier while making the game more fun for the rest of the players.

(b) What is the purpose of this product? For whom is it intended?

This product acts as a supplemental tool for the role-playing game Dungeons and Dragons. This board will allow the user to retain the creative power that exists within the original game but reduce the number of computations that need to be conducted as well as making it easy to keep track of what is happening on the board. This product will have a target audience of

current Dungeons and Dragons players as well as players hoping to begin playing but are intimidated by the high learning curve. This means that the demographic is a younger audience, consisting of teens and young adults.

(c) Describe how the engineering design process used to create your product was utilized in this project. Include how you developed and conducted appropriate experiments, analyze and interpret data, and use engineering judgment to draw conclusions related to the development of your product.

Our team first outlined the project's scope and what we wanted to accomplish to determine what hardware components we needed. We then prototyped the hardware components, including the LEDs, Hall Effect sensors, USB, and SD card reader, discovering which parts worked best with what protocol, and how big our project could be. We concluded that a 16x16 board would be best, as it would give enough space for varying maps, and the board would be small enough to be portable. This size also allowed the pixels and magnetic sensors to consistently work through our plastic board top. We utilized the 4x4 keypad provided in our lab kit and modified the buttons to expand the capabilities of our project, such as using the asterisk key as a backspace or using A and D to scroll options. Our team often worked in parallel on different parts of the project, but also worked together, where a lead for a specific portion would work with a teammate to debug and understand the work.

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

One design constraint was the number of colors we could effectively display with our pixels. Due to the chosen pixels and the requirement for them to shine through the plastic top, we could not display a lot of discernible colors and were limited to lighter ones. We utilized our timing speed to flash colors to indicate different effects or statuses, rather than utilizing another color. This gave us more variability and freedom to dictate our game. A second design constraint was the current draw of the pixels. At full white and full brightness, the pixels could draw more current than is available in a wall outlet, so we had to limit the brightness as well as refrain from using colors that drew more current to ensure our other components received enough current to operate. A third design constraint was the number of timing channels that could be used to interact with the pixels. Due to conflicting information on datasheets, we designed our PCBs to use one timer channel, each using DMA and PWM. However, when we tried to implement the DMA, we found that only 11 of the 16 could use the DMA at a time. This was due to conflicting streams and lack of ability to use the DMA at all for certain channels. We had to modify our wiring such that we combined the data line for a pair of boards and used one timer channel to control two boards, so we only used half of the original timer channels.

(e) Describe how each of the following factors influenced your design specifications and constraints.

Public Health, Safety, and Welfare: We designed our project such that it could dissipate heat, reducing the chance of burning the packaging. We had to keep this in mind due to the number of electrical components that exist in our project, which is well over a thousand parts.

Global Factors: Given that D&D is a very popular game worldwide, we decided to use its rules as a basis for our board, rather than developing our own rules or using the rules of a less popular game.

Cultural Factors: The world is quickly integrating electronics into everything, so we thought that D&D could use a modern update, introducing the usage of an electronic board to help

visualize the classic dungeon crawling experience.

Social Factors: Many people play D&D online due to the resources available to easily customize maps and characters, but we thought that the true experience of playing games like this comes from the in-person experience, so this board essentially utilizes the features of online role-playing simulator and turns it into a physical product to bring back the face-to-face experience of classic D&D.

Environmental Factors: Our board could potentially use a lot of energy, so we limited the voltage needed for certain parts, such as the LCD and Hall Effect sensors, where we chose components that use 3.3V instead of 5V and reduced the brightness of the pixels so that they use less energy. This game will be played in a household or anywhere indoors. This led to a portable design with little consideration for protection from weather conditions since it should rarely be outside apart from transportation.

Economic Factors: We thought that our project could be developed into a product that could be sold to tabletop players everywhere, so we did our best to keep the functionality of every component as user-friendly as possible, keeping the instructions on the LCD simple, and utilizing the pixels to clearly indicate what was happening in the game. We also designed our application to be intuitive, such that anyone with role-playing game experience could use it without too much instruction. In the current iteration of the product, the cost is very high. High quality hall effect sensors were purchased driving the price up. Also, the I2C expanders that were used were expensive even though there were only 16 of them. In future iterations of this product, different hall effect sensors would be tested to try to bring down the price. The goal for a final product would be to get the price to around $200.

(f) Describe the appropriate engineering standards incorporated into the creation of your product.

For this project we had to ensure that our product adhered to safety and environmental standards pertaining to consumer electronics. First, the product must be safe for use by the end user. We have developed a safe product with little to no risk of injury. The box has sharp corners which could be potentially dangerous and overheating components could also pose a risk, while very unlikely.

Next, the product is RoHS compliant, making it safe for the environment. The team made sure to avoid toxic substances such as lead and bromine in our components and the solder used to put the board together. The packaging is also made of wood, so it is easily recyclable when the product has reached the end of its use.

The product would also need approval from the FCC as a Class B device. No RF communication is used in this product making this approval simple. The clock that we use on the board does not emit frequencies that could interfere with other important technologies ensuring that this product would get Class B approval. This product also follows the standards in terms of safety and environmental for approval from the UL and CE.

(g) Describe the final status of your product.

The final prototype was able to complete all the desired functions. The final prototype can successfully control rows of LED strips via DMA and PWM, control an array of Hall Effect sensors using I2C I/O expanders, customize maps and characters using a unity-based app, port map and character data from the app to the board using USB OTG, and finally simulate

turn-based combat using pathing algorithms and an object-oriented class system. The final prototype is also equipped with an LCD and keypad. These enable the user to navigate through menus and gameplay including options to enter either dungeon master mode or playing mode. In dungeon master mode, you can import maps and character data from the app. In playing mode, a game initialization is running that guides the setup according to data given to it by the app. The players are prompted by the LCD to place tokens. Once the game is started, the LCD then instructs players to move around the board, fight enemies, and collect gold from chests as they traverse the dungeon. While traversing the dungeon during a player's turn, they can only see the portion of the map their character can see. Once all enemies are defeated, the game is won by the players.

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

The team's makeup was largely software-based when it came to skills already possessed. The team split into two pairs. One pair, Grace(software lead) and Neil(systems lead), focused more on software whereas the other pair, Jackon(hardware lead) and Landon(team lead), focused more on hardware. For the first half of the year work was more divided and in our team meets we would spend time updating each other on what we have completed as well as any changing requirements for our part of the project. While each pair had a primary focus, everyone filled in and problem-solved in other areas of the project when necessary. The team was divided into these groups roughly until PCB construction started. Once PCB construction started, the team mixed equally and worked on hardware and software to meet the team's needs on a week-to-week basis to finish the project on time. Our team meets changed to a more collaborative work environment where we would work usually in pairs to either solder PCBs, complete mechanical construction, or debug software.

(i) 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.

This project required written documentation that covered the software and hardware aspects of our project's design, along with several documents analyzing legality, environmental and ethical impacts, and the safety of our product.

The first portion of these documents comprised of the final project proposal and functional specification. These documents provided an overhead view of the entire project, and we specified the functionalities desired in the final product. These materials were primarily written for the course staff, so they could understand and verify that our project goals met course standards and were still achievable by the end of the course. They also provided us with feedback and ideas for each project goal based on these documents.

The second portion of the documentation focused on the software and hardware design of the project. Different team members completed an electrical overview, software overview, mechanical overview, and software formalization. These documents were more detailed, as they covered the more technical specifications of the different portions of the project. These documents were written with course staff and other engineers in mind, as they have the technical knowledge to understand the project's more complex components.

Finally, our last portion of documents covered the analysis of the legality, safety, and environmental impacts of our product. There also is a user manual to describe product use and help users troubleshoot any potential issues. These documents were written for the course staff and potential investors or sponsors. Since this project is just a prototype, these analysis documents provided a view of future considerations and concerns if the product ever

heads to market. For the user manual, the primary focus was for consumers using our product to prevent any frustration and warn of possible hazards during use.

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

Keeping in mind that we will be presenting to ECE course staff, we have prepared in a way that will allow for full inspection of the hardware, firmware, and software of our product. We fully intend to show off our product's finished, polished capabilities, but we also wanted to highlight what is inside it. To do this, we designed our packaging to allow easy access to see the main components we control over. We also plan to fully highlight any challenges we overcame during the development. This includes difficulties while debugging software and hardware, as well as challenges faced during team and project management. This way, we can highlight not only the completed product, but also the development process for creating a successful product.

Purdue ECE Senior Design Semester Report
(Individual Reflections Section)

Course Number and Title	ECE 47700 *Digital Systems Senior Design Project*
Semester / Year	Spring 2024
Advisors	Phil Walter
Team Number	01
Project Title	The Dungeon Crawler

Senior Design Student Completing This Section			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Landon Carre	CompE	Software, Hardware	2024

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

(a) Describe your personal contributions to the project.

My contributions to the project are in the areas of hardware, software, and mechanical packaging. For hardware, I oversaw figuring out how to properly control WS2812B LEDs. I did research to figure out how to control the LEDs and wrote this part of the code that is responsible for controlling our LEDs. I also was responsible for researching, testing, and writing the software for the MCP23017 IO expanders controlled via the I2C. Given that I did a lot of research for the hardware configuration and software for the LEDs and IO expanders, I was made responsible for designing the PCB for the IO expander, LED, and Hall Effect Sensor boards of the project. I also helped with physical construction via soldering of the boards along with the rest of the team. I helped write parts of the gameplay software including the movement and combat systems of our turn-based gameplay. I also helped with manufacturing our physical packaging such as attaching all the LED display boards to a piece of wood backing.

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

The contribution made to the project built directly onto my earlier coursework at Purdue. Researching, testing, and writing code for different microcontroller protocols such as the DMA and I2C was greatly expedited due to the curriculum received in our ECE 362 microcontroller class. Additionally, my ECE 39595 focused on Object Oriented Programming in C++ prepared me greatly for this project. Due to our project having many layers, we wanted it to be designed in an object-oriented fashion. Having experience using these industry-standard programming concepts in ECE 39595 made developing and integrating many parts in software stage of this project much easier.

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

To acquire new knowledge and apply it I did lots of research. I did lots of research online looking for both official and unofficial documentation. I would normally like to find a one source that seemed a bit more formalized from a company or official development website and then I would cross-compare that with knowledge from more unofficial sources like YouTube

tutorials. I found that finding a good YouTube tutorial explaining either microcontroller concepts or PCB design using KiCad was normally a very valuable resource. I found that persevering on and finding more than one or two sources was normally optimal because something small was usually left out. When concepts are extremely new, and it is something, I had little experience in this was very important because some of the little things I had no way of knowing unless pointed.

(d) Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

The ethical and professional responsibilities during this project were multiple. Firstly, as a member of a team I had a professional responsibility to each of my teammates to do my part of the project to enable them to create the vision we all agreed upon. Other than that, we also had responsibilities to, if intending to create a product as if intended for the market, a safe product that can be used without threat of harm by its users. We also had to keep in mind any existing products and any possible infringements that our product may have.

(e) 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 judgement as to your product's impact in each of these four contexts?

The product we made is a board design for role-playing games like Dungeons & Dragons. Our board, if successful, could potentially have an economic impact by creating a new device that role-playing game fans, board game fans, and even new players excited to play role-playing games that they used to think inaccessible would potentially spend money on and buy. In addition, this creates a new product in the role-playing game and board game market space that could potentially shift markets away from other products or companies if very successful. Environmental impacts include the cost to make such a product with many electronic components and the energy usage it requires. Societal impacts include how well adopted this product is in society. If well adopted it could become a household gaming staple as common as a PS4 or Xbox. In a global context, the product has an impact on how it is introduced into different global markets and if eventually mass-produced where and how it is then manufactured.

Purdue ECE Senior Design Semester Report
(Individual Reflections Section)

Course Number and Title	ECE 47700 *Digital Systems Senior Design Project*
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Advisors	Phil Walter
Team Number	1
Project Title	The Dungeon Crawler

Senior Design Student Completing This Section			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Neil Brown	CompE	Software, Hardware, Firmware	Spring 2024

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

(a) Describe your personal contributions to the project.

Throughout the semester I have had the opportunity to contribute to the project in many ways. At the beginning of semester the first task that I worked towards was achieving successful USB communication between a laptop and the microcontroller. I started by using a development board to try to achieve successful communication. I researched the USB on the go protocol to create a basic program to receive communication and copy it into a buffer that could be viewed in debugging mode. After successfully sending data to the microcontroller through USB, I began working on the gameplay code. Jackson had already worked significantly on the gameplay code before the semester began so I spent time reorganizing this code into different sections, and then extending the code to fit the needs of our project. The most significant contributions were the path finding algorithm used in the project as well as the parsing function for all the USB data. After doing this, it was reaching the midpoint of the semester where I aided in PCB design and manufacturing for several weeks. After the boards were assembled, I went back to USB work to ensure it worked properly on the final hardware. After around a week of debugging this, I worked with Grace to finish the USB protocol by ensuring we could parse in larger messages. After this I worked on some of the gameplay code that was living on the microcontroller, deriving from the code I worked on earlier in the semester. To end the semester I worked on the packaging for our project by adding the nuts to attach to PCB to the wood as well as drilling the holes for the LCD and keypad.

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

This project built on many of the knowledge and skills I have acquired through my time in ECE. The class ECE 368 (Data structures and algorithms) was helpful when writing the pathfinding algorithm and testing and debugging C code. ECE 39595 (C++ object-oriented programming) helped me develop the C++ code used for many of the data structures found in our project. When it came to the hardware and firmware, the knowledge I gained from ECE 362 (Microcontrollers), ECE 20001 (EE fundamentals 1) and ECE 20002 (EE fundamentals 2) were invaluable.

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

While the knowledge I had going into this project was very helpful, there was also lots that I had to learn along the way. The different datasheets and manuals are all written in a similar manner, so learning how to read and interpret these correctly was helpful. I also improved at finding Youtube tutorials for tasks I was trying to complete. I am a visual learner, so these helped me learn faster. The most valuable resource was asking for Joe's help in the lab and learning from him.

(d) Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

My most significant professional responsibility in this project is to my teammates. I need to make sure that I am not only completing the work that I promised, but communicating what needs to be done and what I am working on with the rest of my team. I think it is also important to set boundaries and communicate what you are not able to complete to avoid further conflict. I have an ethical responsibility in this project to create a final product that is safe for the end user as well as creating a product that is compliant with standards like the RoHS standard to ensure it is safe for the environment.

(e) 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 judgement as to your product's impact in each of these four contexts?

This product could influence the market for Dungeons and Dragons. There is no market for digital game boards for D&D so adding a product like this to the market could create opportunities for other entrepreneurs to make similar products. The more serious economic impact of this product is its cost. To ensure high precision in the magnetic sensing, high quality hall effect sensors were purchased which were expensive. Also, the I2C expanders were not cheap. These expenses combined with the sheer quantity of parts means that the product is expensive. This causes the entry to play with this game board to be very expensive. This product would have little to no environmental impact as it does not benefit or harm the environment. This could have a societal impact by changing the way that teenagers and other D&D fans engage with this game that has remained the same for decades. The global impact would be the same as the societal impact, changing how people interact with D&D.

Purdue ECE Senior Design Semester Report
(Individual Reflections Section)

Course Number and Title	ECE 47700 *Digital Systems Senior Design Project*
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Advisors	Phil Walter
Team Number	01
Project Title	The Dungeon Crawler

Senior Design Student Completing This Section			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Jackson Luna-McCrocklin	CompE	Software, Firmware, Hardware, PCB Design, CAD	May 2024

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

(a) Describe your personal contributions to the project.

I started my work prior to the semester starting and developed the groundwork of our object-oriented programming and class definitions for our hexagons and characters, as well as implemented several path finding algorithms modified for hexagonal maps. I then worked on prototyping, helping with determining the acceptable range of distances for the magnet engaging with the Hall Effect sensors. After that I helped with prototyping the pixels with Landon, verifying the timing and DMA protocol. Using the distance measurements, I got when working with the Hall Effect sensors, I designed the hexagonal grid in CAD, as well as a rough draft of the entire packaging. I used KiCad to design the PCB the microcontroller would sit on, as well as researched for the various specifications of what components need what pins, such as the LCD, keypad, and ST-Link. I also helped design the power system with Neil. While waiting for the PCBs to come in, I programmed the base functionality of the keypad and LCD, developing helper functions that could be used to develop the gameplay, as well as laid out the foundation of the interrupt system for key presses. Once we got our PCBs, I soldered the main board, as well as helped with the other PCBs Landon had designed. After the soldering was done, I designed the packaging and sent the measurements off to be manufactured. I laid the framework for how our code runs, implementing a state system based on the software flowchart I had helped create. I programmed most of the user interaction and menu software. Throughout the entire process I helped my teammates debug different parts of the project.

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

Most of my programming experience involving the developing of the class and object-oriented systems stemmed from my work in ECE 39595, where I learned C++. My firmware experience came from ECE 36200, where I did a mini project where our team developed an audio player. This is where I learned how to do user interrupts and program the LCD. From ECE 20007, ECE 27000, and ECE 36200 I learned how to debug electronic systems and use an oscillator and multimeter to diagnose issues.

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

Rather than watch long videos or read manuals to learn KiCad and AutoCAD, I instead worked in the program myself, and looked up information as I had questions. This saved a lot of time as I did not have to learn material I would not need for the scope of this project. For KiCad specifically, a lot of the research was done with Landon, so as one person learned a new feature, either from online videos or in lecture, they would tell the other. This divided the research and led to less duplicate work. For STM32CubeIDE, I spent a lot of time looking for videos and forums that worked on the specific parts I wanted to interact with, since it usually involved a library of some sort, and finding the specific library I needed saved hours of developing code.

(d) Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

One major ethical responsibility was making the product safe, designing it so it is user-friendly, keeping in mind that our product housed a lot of objects, and the scope of our user base may not necessarily have the electronic experience we have, so I designed the packaging so that it was protective of the components without being too heavy. I also spread out the placement of different components so there is not too much heat generated in one location. Professionally, I wanted to design the packaging so that it looked great and high level. This involved finding a new plastic top for the playing area, as the old one was ruined with glue, which took a couple hours to find, cut, and reprint the hexagonal dividers. I also outsourced the packaging to someone with more experience to guarantee a higher quality of work.

(e) 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 judgement as to your product's impact in each of these four contexts?

Economically, I tried to develop our project such that it could be a legitimate prototype for an electronic tabletop version of D&D. In our research for similar products, we found no real competitors that have entered the market, so we thought there could be a real demand for a project like ours. Environmentally, if we were able to develop a second prototype, we would try and decrease the size, so less material is used, and thus less damage to the environment. Societally, I hope to expand the number of people that play D&D with our product, as I can easily see how someone could be interested in the game, but not have the ability to visualize what is happening. Globally, our project would only make an impact if somehow it was developed into a real product and sold worldwide. I hope this does happen, but the odds are small.

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Advisors	Phil Walter
Team Number	01
Project Title	The Dungeon Crawler

Senior Design Student Completing This Section			
Name	**Major**	**Area(s) of Expertise Utilized in Project**	**Expected Graduation Date**
Grace Whitaker	CompE	Software, Firmware, Hardware, CAD	May 2024

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

(a) Describe your personal contributions to the project.

In this project, a large portion of my work involved the development of the Unity-based app that interfaces with the board via USB. I designed and programmed a map creation page that allows users to create their own map that corresponds to our board, and a character creation page to send characters to the board as well. Once the app was built, I worked with Neil on porting all the information via USB to the board. On my end, I needed to parse out the hex information and character information in a specific string format that would be read by the microcontroller and send this information out via a serial port on the computer. I also helped program some USB firmware to ensure all strings were correctly read into the microcontroller. Throughout this app building process, I also helped with the construction of our hardware. I worked with Neil and Landon to hot plate our large PCB strips, and I hand soldered the Hall Effect sensors on some of the strips, as they could not be attached through hot plating. After the PCBs were completed, I moved on to the mechanical construction of the board top and hex dividers. I used AutoCAD to model a full set of hex dividers based on the size and spacing of our PCBs and the brightness of the LEDs. I then divided the full model into six pieces and 3D-printed them. I also worked with the Bechtel center to laser cut our board top to fit the design of the box. Once the PCBs were functioning correctly, I had plywood cut to mount the PCBs and dremeled cutouts to fit our PCB connectors. Throughout this mechanical construction process, I also helped move Neil's gameplay code to the microcontroller and expanded on Neil's previous work. I worked on adding code for the LCD to display a menu for uploading a map and characters from the app, and display character statistics. Throughout the entire project, I helped with debugging firmware issues with my teammates.

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

A lot of my previous courses involved programming in C or C++ for both software and firmware. ECE 362 provided me with knowledge of how to use C and Assembly to program a microcontroller, and how to use different protocols such as SPI to interface with other hardware components. ECE 368 and ECE 39595 helped a lot with writing the C++ logic and using data structures to optimize and organize our code. For hardware, our fundamental

courses ECE 20001, ECE 20007, and ECE 20002 helped with understanding of our PCB design and with debugging firmware using multimeters and oscilloscopes.

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

I have never previously worked with interfacing between a computer and a microcontroller outside of an ST-Link. I needed to learn how to communicate through my app with a serial port, which primarily involved some internet searching for different built-in C# functionalities for serial port communication. I also learned a lot about soldering and hot plating. My knowledge primarily came from course staff and other teammates who had already had practice soldering. I also practiced hand-soldering on extra PCBs around the lab before working with our team's PCBs. I also learned how to use CubeIDE and AutoCAD through online video tutorials and through reading documentation as I worked.

(d) Discuss your ethical and professional responsibilities as they relate to this engineering design experience.

My ethical responsibility in this project was to help create a product that was safe and reliable for users. My app needed to be easy to use, and the team overall needed to ensure that our electronic components would not be a danger to the user. Professionally, I was responsible for working well with my teammates and communicating what has been done and what needs to be done. As a teammate, I needed to help my teammates wherever I could and be willing to ask for help if needed. I ensured that the portion of the project I intended to complete was completed and high quality.

(e) 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 judgement as to your product's impact in each of these four contexts?

Our product is designed to be marketed for use with tabletop games, so economically our product could be a competitor in a relatively unexplored market. There aren't many products that have the same functionality as our product, so we wouldn't face much conflict with other competitors. Environmentally, 3D-printing hex dividers could be environmentally friendly as a lot of available filaments are made from recycled plastics. Societally and globally, tabletop gaming is a very popular hobby, so we designed our board to be approachable to a wide audience. If the product became popular, it could make tabletop gaming easier to access for newcomers.