Final Report

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Abstract

Interactive and innovative entertainment for children needs to be more affordable while also maintaining the benefits that added technology can provide, such as customization. The original solution was to design a pair of Light Up Mickey Mouse Ears which have programmable LEDs that can be configured through a phone app. The Bluetooth Enabled Lightsabers are a device to function as a lightsaber toy which allows the user to select the character he would like to be. Two users will play sword fight, and when the Lightsabers collide, they will emit light and sound depending on the user's selected character. The new project is an improvement to the old due to increase in interactivity while maintaining affordability and portability.

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1. Second Project Motivation

1.1 Updated Problem Statement

The toy industry is extremely vast, reaching $90.4 billion dollars[6] in global revenue during 2018. On average, parents will spend around $250[6]on toys every year for each child in their household. With technology advancing, there comes the opportunity to create toys that are more interactive by adding more features like wifi connectivity or specialized add ons to give the base toy more functionality, and thus creating a more exciting experience for the user. However this can quickly become very costly. Interactive and innovative entertainment for children needs to be more affordable while also maintaining the benefits that added technology can provide, such as customization. In addition to interactivity and affordability, we want these new technologically advanced toys to also be portable for the convenience of parents across the country.

1.2 Updated Solution

1.2.1 Solution

Our solution is to create Star Wars Lightsabers which can be programmed to connect to each other and with several characteristics to make them more customizable to the player.
Each Lightsaber will allow the user to choose a character, and each character has a corresponding set of effects. Whenever the lightsabers collide, they will produce a light sequence and a clashing sound effect. Both the light and sound effects will be different for each character available.
With our solution, each Lightsaber will allow the user to choose a character, and each character has a corresponding set of effects. Whenever the lightsabers collide, they will produce a light sequence and a collision sound effect. Both the light and sound effects will be different for each character available. Tunes 1-4, as shown in Table 1, are short melodies whose qualities will match that of the character chosen. For example, Darth Vader's tune will have a minor tonal quality while Luke's will have a major tonal quality. These Tunes will be played at the start of the game. Upon collisions, general lightsaber noises will be played to mimic a real lightsaber battle.

Character Name	Light Sequence	Sound Effect
Darth Vader	Red hues that move up the blade	Tune 1
Yoda	Green hues that circle around the blade	Tune 2
Luke Skywalker	Blue hues that oscillate in brightness	Tune 3
Mace Windu	Purple hues that fade in and out, flash upon collision	Tune 4

Table 1: Character Choices

1.2.2 Gameplay and Design

Before gameplay, the Lightsabers will pair with each other through Bluetooth so both players cannot have the same character and so the lightsabers can be synchronized.
During game play, the Lightsaber detects a hit due to the switches present around the base connecting the top of the sword to the hilt. These switches have longer triggers and are arranged in a circular manner around the base, as shown in Figure 1. Since the material of the sword is a light plastic, it would move into the trigger during the hit, and trigger the switch, which would send in a signal registering a hit. This hit signal is sent to the next Lightsaber via Bluetooth.

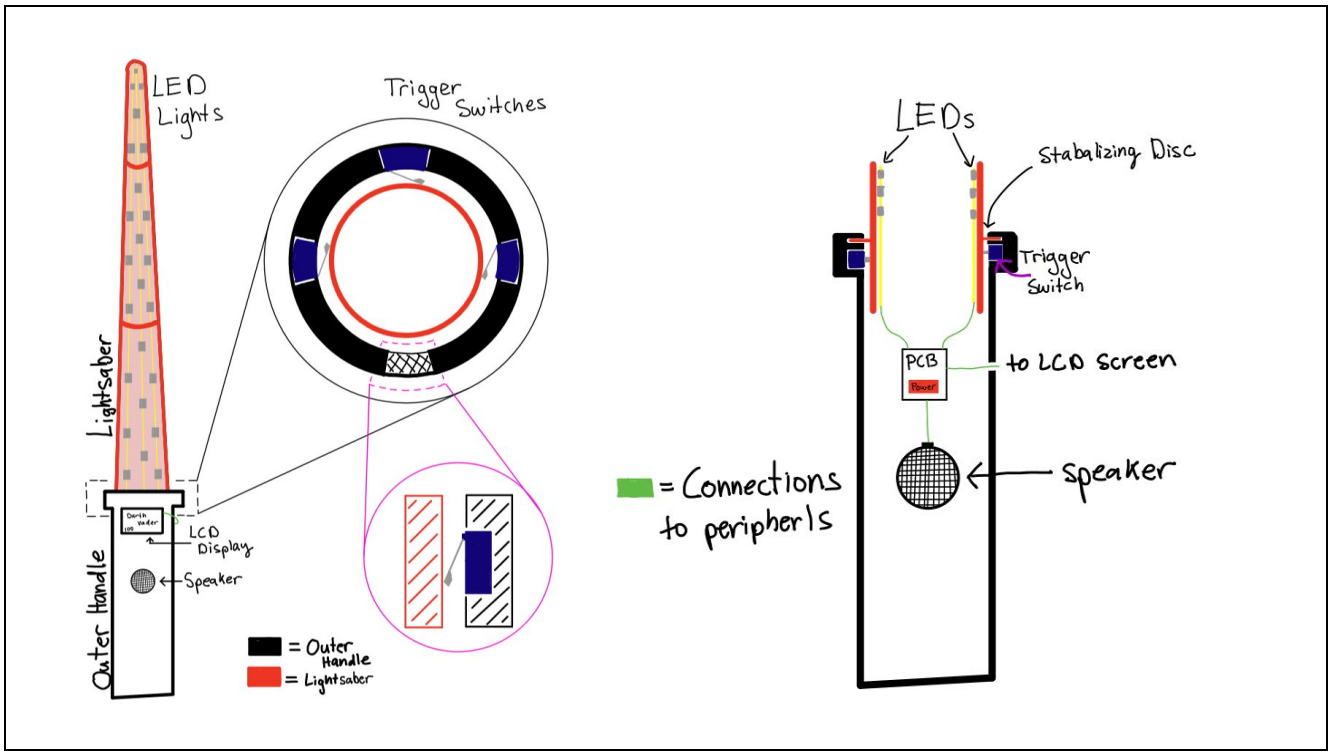

Figure 1: Physical Design

If both lightsabers register a hit, then we know that the lightsabers have had a saber-to-saber collision, and neither player is awarded points.
However, if only one of the lightsabers registers a hit, it will register as a saber-to-person hit; and a hit point will be rewarded. The game ends after one player has reached 100 points, with each hit giving the player 10 points.

1.2.3 Project Differences

The problem statement itself was a broad opportunity to create an entertaining and interactive device.
The project before us, Mickey Mouse Ears, aimed to create a wearable set of headbands with mickey mouse ears on them. These ears could be programmed by an app on the user's phone and would then light up according to the user's choice of lights. In addition, these lights could synchronize with the rest and all the headbands would go through the light patterns synchronously.
The Lightsaber improves on the Mickey Mouse Ears in many ways.
Our project aims to create an interactive game with a set of lightsabers. These lightsabers interact with each other to keep track of who has been hit, and what the scores are so far. In addition, the user can select a character and the other user can choose a different character. Each character comes with a personalized light and sound sequence, which will be chosen with reference to Disney's Star Wars movies.

The Lightsabers have added entertainment values by the sound effects, the interactivity as they come in the form of a game, and in providing the user an option for the users to choose characters they are familiar with.
The largest trade off is that Mickey mouse ears do provide more entertainment to children who are less than 10 years old, as it has less safety requirements. On the other hand, to children above 10 years of age, a game they can interact and run around with might prove to be more enjoyable, and when the rules are followed, provides no risk.

1.2.4 Competing Market Solutions

Our main competitor on the market are the lightsaber toys sold by Disney. These original lightsaber toys fail to provide a fully interactive experience. While they do light up and play sounds, they do not interact with each other, and they are not customizable[7]. In terms of affordability, while they do have options that are fairly priced at $32.99, these options do not provide any customization. Our product allows a user to not only interact with other users through gameplay, but also to customize their own experience by choosing a character, allowing their lightsabers to show varied light and audio displays that are not limited to one color or one sound.

1.2.5 Rules of Gameplay

In order to keep the game affordable and to not overly complicate the gameplay, we plan on having some basic rules for playing. While there may be a different way to check if the users are making contact with each other, such as a specific target on the players, we chose to implement the following rules instead, for the sake of portability and avoiding having too many parts. This will ensure the players can have fun and stay safe while playing the game.
Rules of gameplay:

- Parental supervision is required for children under the age of 10 to prevent safety hazards.
- Players must touch each other and not random objects to gain points.
- Players must wear full sleeves and long pants.

The physical design of the lightsaber will be made of a lightweight plastic, similar to plastics that are used in many toys. This will prevent any serious injuries that could come along with having a heavier material.

1.2.6 Clarifying Physical Descriptions

This section lists some specifications of the Lightsaber. This is essential since it came up when our design was reviewed.

Product Dimensions[11]	2.5 inches * 3.3 inches * 20.2 inches
Item Weight[11] (includes battery, LEDs, speaker)	0.28 kg

Table 2: Physical Specification

1.3 Updated High-Level Requirements

1. The switches must trigger upon hit and have an error rate of less than 10%
2. Once a hit is registered on one or both devices, the other should detect the hit within 10ms for the score update to be instantaneous. This delay adds on to the light and sound delay, so optimizing for less delay here will help with the next requirement.
3. The light and sound effects should begin within 1 second of the collision as it should allow for the time delay of the hit signal processing along with receiving the signal to play the light and sound sequence, and should correspond to the character.

1.4 Updated Visual Aid

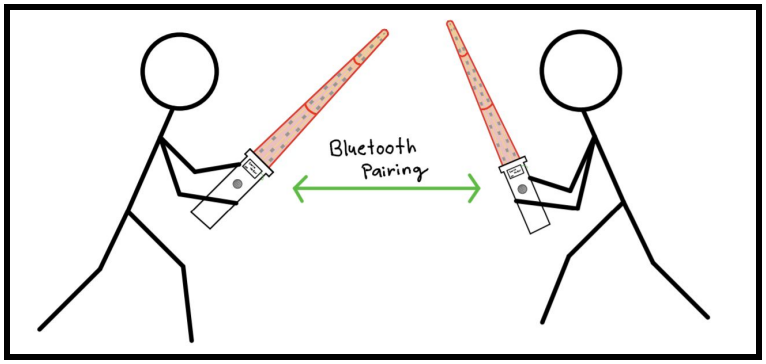

Figure 2: Game Setup

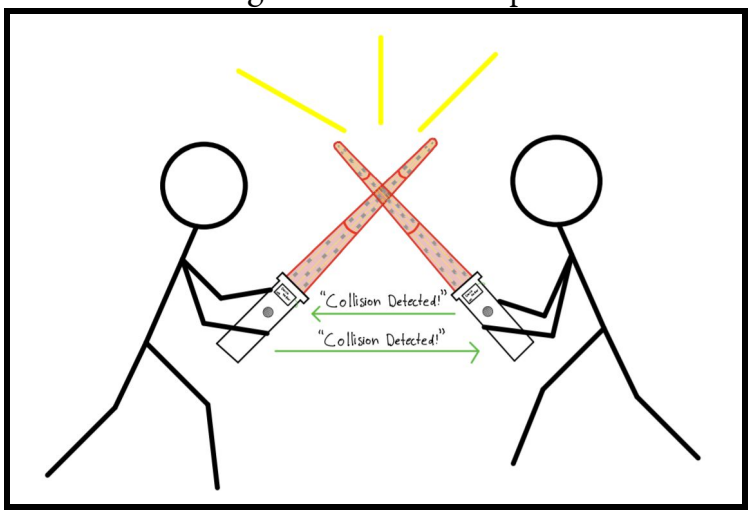

Figure 3: Lightsaber-Lightsaber Collision (+0 Points)

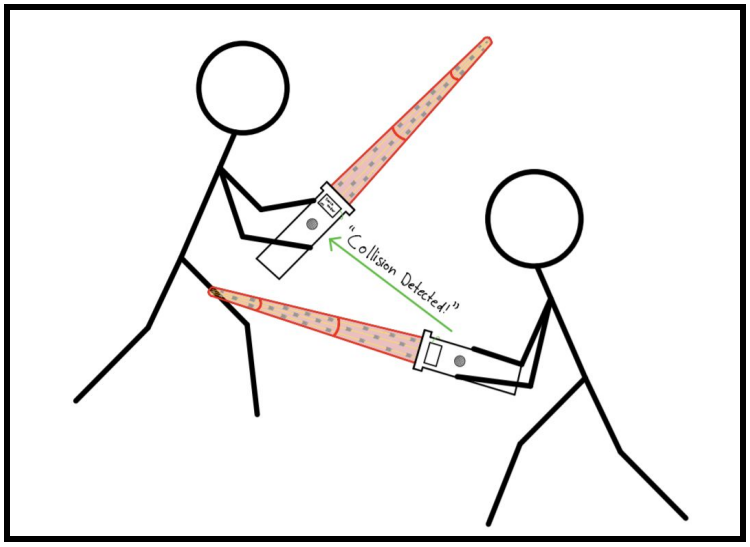

Figure 4: Successful "Hit" to Right Player (+10 Points)

1.5 Updated Block Diagram

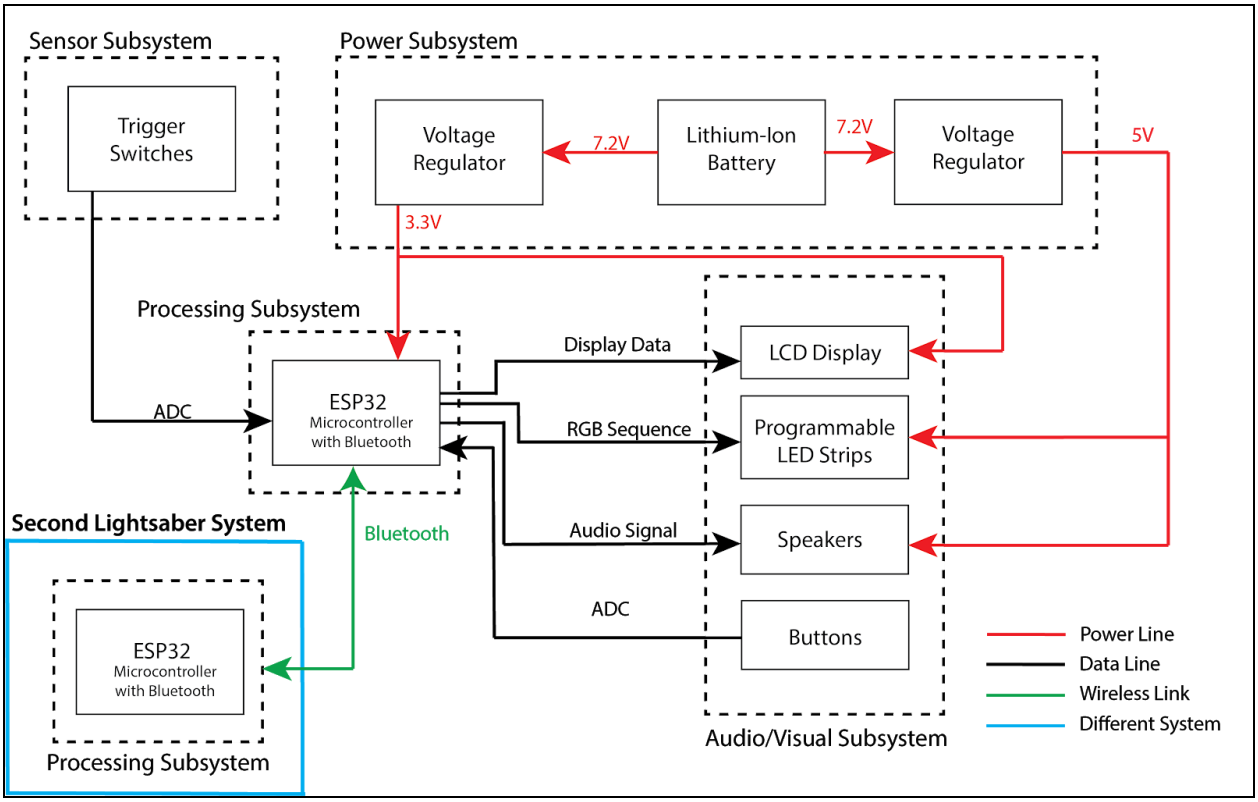

Figure 5: Block Diagram

2. Second Project Implementation

2.1 Implementation Details and Analysis

2.1.1 Schematics

These are the schematics for the PCB for our second project. These are necessary for our project if it were to be fully implemented because it lays out the necessary connections for our processor to be able to communicate with our peripherals. This portion of our implementation supports our high level requirements because it allows for the connections to the processing subsystem to be made. Without that, nothing would happen.
We also have the schematics for the power subsystem. These are essential because without power, nothing would work. The processing subsystem needs power in order to fulfill our high level requirements.

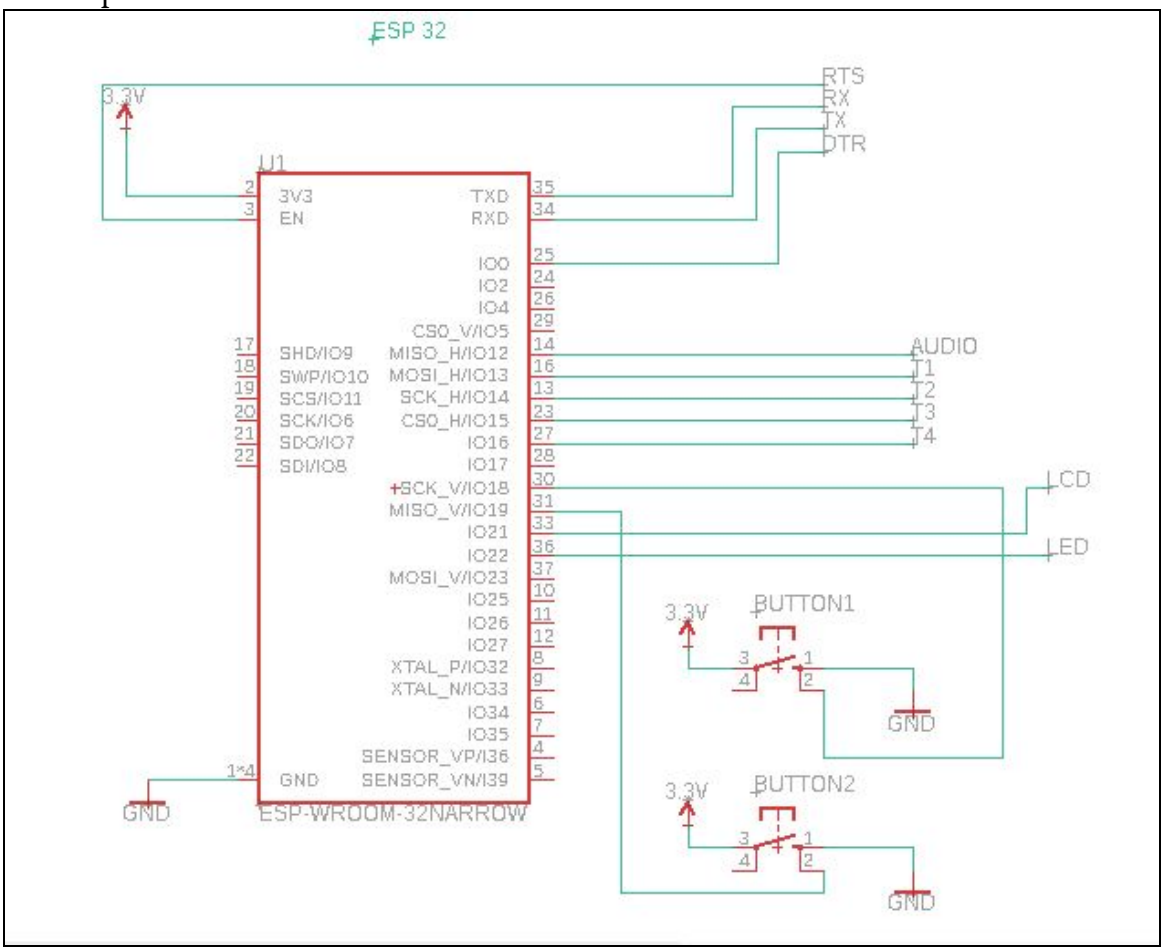

Figure 6: ESP32 Microcontroller schematic

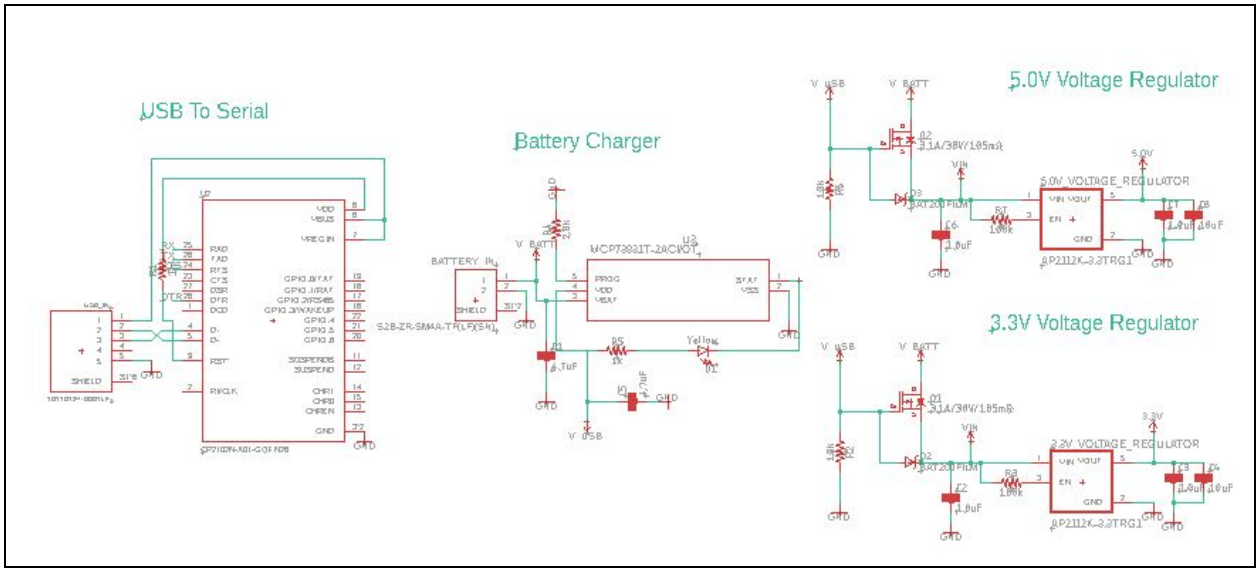

Figure 7: Power Supply Schematic

2.1.2 Board Layout

This is the board layout for our PCB. This is essential because we need our PCB to be able to fit inside the premade lightsaber. The PCB we have designed should be small enough to fit inside the handle of the lightsaber. The PCB is of the microcontroller and components connected. It will execute the game control logic and send signals for the rest of the Lightsaber to make the necessary light and sound effects, choose a character and detect hits. The microcontroller also has the bluetooth capability to communicate with the other Lightsaber.

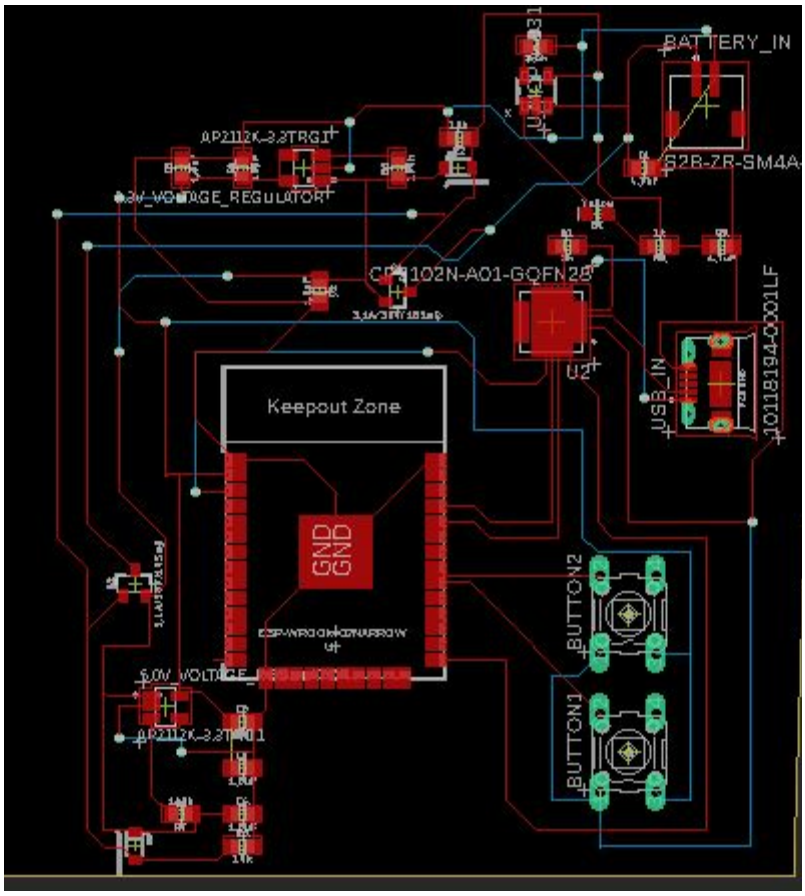

Figure 8: PCB Layout

2.1.3 Sound Effect Code

With the unavailability of the required components, the sounds required were tested with the help of the following code [10]. A piezo buzzer connected to an Arduino was used, and the following sound sequences were played. The complete file including the Arduino notes and 10 Sound sequences took up 4KB of space.

This code was the most we could test in terms of the light and sound effects. It's implementation provides insight into how these subsystems will work and how much memory of the microcontroller will be used.

```
/* Audio Tones */
const int c = 261;
const int d = 294;
const int e = 329;
const int f = 349;
const int g = 391;
const int gS = 415;
const int a = 440;
const int aS = 455;
const int b = 466;
const int cH = 523;
const int cSH = 554;
const int dH = 587;
const int dSH = 622;
const int eH = 659;
const int fH = 698;
const int fSH = 740;
const int gH = 784;
const int gSH = 830;
const int aH = 880;
```

Figure 9: The audio tones to be used to generate sounds

```
// Sound Sequence 1
  beep(f, 250);
  beep(gS, 500);
  beep(f, 350);
  beep(a, 125);
  beep(cH, 500);
  beep(a, 375);
  beep(cH, 125);
  beep(eH, 650);

  delay(500);
```

Figure 10: Sound Sequence 1

```
//Sound Sequence 2
  beep(f, 250);
  beep(gS, 500);
  beep(f, 375);
  beep(cH, 125);
  beep(a, 500);
  beep(f, 375);
  beep(cH, 125);
  beep(a, 650);

  delay(650);
```

Figure 11: Sound Sequence 2

```
//Sound Sequence 3
  beep(a, 500);
  beep(a, 500);
  beep(a, 500);
  beep(f, 350);
  beep(cH, 150);
  beep(a, 500);
  beep(f, 350);
  beep(cH, 150);
  beep(a, 650);

  delay(500);
```

Figure 12: Sound Sequence 3

```
void beep(int note, int duration)
{
  /* Play tone on buzzerPin,
   * which is the arduino pin
   * that the buzzer is connected to */
  tone(buzzerPin, note, duration);
  delay (duration)
  //Stop tone on buzzerPin
  noTone(buzzerPin);
  delay(50);
}
```

Figure 13: The function used to play these sounds

2.1.4 Game Control Pseudocode

For the complete game, the following is the algorithm that the game will loosely follow. This is essential since the complete gameplay is governed by this algorithm. It also provides insight into memory taken up on the microcontroller. We estimate for such code, the space taken up would be about 16KB (based on space taken up by a similar file with 500 lines of code). Since the microcontroller contains around 4Mb or 500KB of memory, we can be certain we will not encounter any memory related issues. This file will access light and sound sequences which will be present on a file similar to the one provided in section 2.1.3.

```
1. On startup
  1.1 go to light and sound startup sequence
  1.2 display LCD screen welcome text
  1.3 display character choosing screen on LCD screen
  1.4 Connect to 2nd bluetooth device
2. On character selection
  2.1 Change LCD screen display to character chosen
  2.2 Initialize score to 0
3. Loop
  3.1 If enemy score is 100:
        play losing sequence(character)
        STOP
  3.2 If self score is 100:
        play winning sequence(character)
  3.3 Send self hit data to 2nd bluetooth device
  3.4 Receive enemy hit data from 2nd bluetooth device
    3.4.1 If enemy hit:
            if self hit:
                play collision sequence(character)
            else:
                play hit taken sequence(character)
    3.4.2 If not enemy hit:
            if self.hit:
                play winning hit sequence(character)
                score += 10
```

Figure 14: Algorithm for game control logic

3. Second Project Conclusions

3.1 Implementation Summary

We were able to implement four items in the 10 days we've had to complete our implementation.
First, Kushal designed the subsystem schematics which were necessary to complete our board layout, which was the second item we were able to complete.
Tulika completed the third item, which was implementing the code to produce the sound effects as well as implementing the game control code, which was the fourth item.
The board layout was significant because, as stated in the previous section, it would be necessary if we were to actually fully implement this project. Without a board layout, we would not be able to order a PCB, and thus we would not be able to complete the project. It houses the microcontroller and provides information about the subsystem connections as well. With clean and efficient design, components have been placed to make optimal use of space to ensure the board fits into the base of the saber.
The two code implementations are also significant because they are large portions of the functionality of our project. The sound effect subsystem provides an essential part of gameplay, allowing for the players to immerse themselves.
The second code implementation is even more important because it controls the game logic, meaning what sounds to play given a chosen character, and when to send a hit signal to the paired bluetooth lightsaber.
Both code sections provide insight into how much memory the code takes up on the microcontroller's flash storage, which is about 500KB. We've ascertained that together they take up about 20KB of space, which confirms there will be ample memory space remaining.

3.2 Unknowns, uncertainties, testing needed

In terms of implementation, we were unable to complete the physical design of our project mainly because we did not have any of the required parts in hand. If we were able to order parts under normal circumstances, we would order them accordingly and build and test in our apartments using the equipment we have. Even if we could order parts, we would not be able to build the entire device because we do not have a lab space or soldering tools, so we would not be able to solder parts onto our PCB or modify the lightsaber to fit our parts. Furthermore, we would not have been able to test our PCB design due to the lack of a lab. However, if we could've ordered parts, we would have been able to build the external components like the LED Array and program them separately.
We were also not able to test our switch based collision detection system, which would've been a good addition to our implementation. While this was covered in the tolerance analysis

of our design, we would've liked to test the setup for possible improvements. We would've used these tests to confirm the right number of switches needed to cover all possible directions a collision may occur from. Since we did not have switches or a saber and cannot make any connections, we are unable to test this.
With the absence of microcontrollers, we couldn't test delay times for bluetooth communications between two microcontrollers and delay in light and sound sequence execution. They remain purely theoretical for now which is a concern since they are a large part for smooth gameplay.

3.3 Ethics and Safety

3.3.1 Ethics

As our implementation hasn't changed, we do believe our product is still both ethical and safe to use if players adhere to the conditions we have stated in our background section. Intentions is one ethical consideration that we have considered. IEEE Code of Ethics number 9 states that we should "avoid injuring others, their property, reputation, or employment by false or malicious action." While our game is a mock fighting game, it is not intended to facilitate violence or injury. We aim to make the lightsaber out of a lightweight plastic so that it cannot be used to seriously injure any of the participants. Though we understand that young children often do not know these limits, and that is why we have put an age restriction and also advise parental guidance. This can ensure that young children do not injure each other while playing this game. All other codes in the IEEE Code of Ethics we believe we comply fully with.

3.3.2 Safety

In terms of safety, we have similar concerns mainly with the intent of the players and also the age. While we cannot control the intent of the players, we have placed restrictions on age and parental supervision for young people who will likely accidentally cause harm to themselves or the other player. We have also said that we will make the lightsaber very lightweight so that it cannot cause much physical injury. Another safety concern we have is with the battery. If the battery were to fail or overheat, this would result in "thermal runaway which is a reaction within the battery causing internal temperature and pressure to rise at a quicker rate then can be dissipated". Once a battery goes into thermal runway, it can cause enough heat to induce thermal runway in other batteries ultimately resulting in a fire. These fires are more difficult to put out and thus make this uniquely dangerous[2]. Other safety concerns could arise from open or uncovered wires that could potentially cause electric shock to the wearer of the device[3]. This is why our design will have all wires covered and away from the handle of the lightsaber; thus adhering to the first rule of the IEEE code of ethics[1] by ensuring the safety of the user. The implementation phase did not introduce any new safety concerns.

3.4 Project Improvements

1. We would design and build the frame of the Lightsabers ourselves. The current prototype involves buying a Lightsaber and adding the electronics to it. By designing the frame ourselves we could lower costs and improve the look and feel of the Lightsaber to be more marketable.
2. We would buy the parts needed, such as the speakers and microcontroller boards, in bulk. This would reduce the costs by more than half [9] and add to the affordability of the product.
3. We would do further research on collision detection. While we're confident that the method we're using would work, we would like to put in more time to figure out if we could find a cleaner, more efficient solution with a smaller error rate. If we decide using the switches is best, we would still like to do multiple trials to figure out the right number of switches and their orientations to detect hits from any direction.

4. Progress made on First Project

We were able to complete our PCB Design after our first Design Review. We had two PCB designs ready: the general one which held the control unit for our design as well as the accelerometer/gyroscope PCB, which served a part of our sensor subsystem design. The PCB designs are separate as they are to be attached to different regions of the gloves.

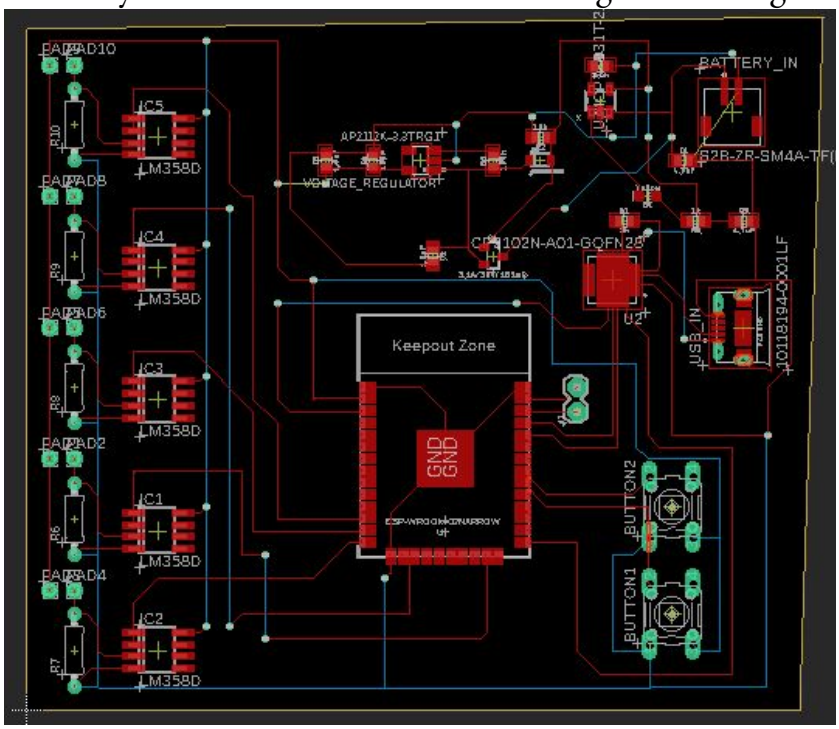

Figure 15: Maestro Mittens PCB Layout

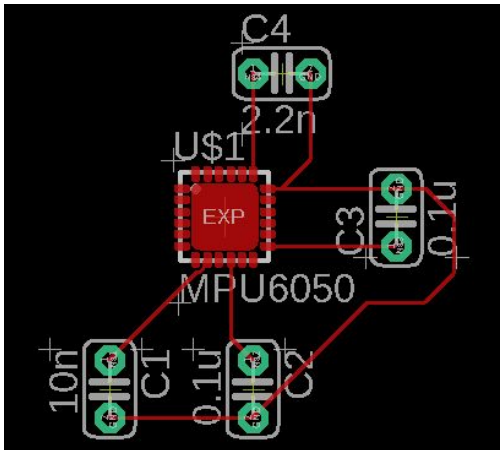

Figure 21: Accelerometer/Gyroscope PCB Layout

5. References

[1] “IEEE Code of Ethics”, ieee.org. 2020. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html.[Accessed: 17- April- 2020]

[2] “Lithium Ion Battery Safety for Consumers,” Lithium Ion Battery Safety for Consumers. NFPA, 2017. Available: https://www.nfpa.org/-/media/Files/Public-Education/Resources/Safety-tip-sheets/LithiumIonBatterySafety.ashx [Accessed: 17- April- 2020]

[3] “The Hazards of Lithium Batteries”, Viceprovost.tufts.edu.(2020). [Online]. Available: https://viceprovost.tufts.edu//ehs/files/The-Hazards-of-Lithium-Batteries.pdf [Accessed: 17- April- 2020].

[4] E. I. T. S. Services, “Salary Averages,” Salary Averages :: ECE ILLINOIS. [Online]. Available: https://ece.illinois.edu/admissions/why-ece/salary-averages.asp. [Accessed: 17- April- 2020].

[5] Basic Character LCD Hookup Guide. Sparkfun. [Online] Available: https://learn.sparkfun.com/tutorials/basic-character-lcd-hookup-guide. [Accessed April 17, 2020.]

[6] E. Duncan, “Topic: Toy Industry,” www.statista.com. [Online]. Available: https://www.statista.com/topics/1108/toy-industry/. [Accessed: 23-Apr-2020].

[7] “Kylo Ren Lightsaber – Star Wars: shopDisney,” shopDisney.com. [Online]. Available:https://www.shopdisney.com/kylo-ren-lightsaber-star-wars-461064746998.html?isProductSearch=1&plpPosition=3&searchType=regular. [Accessed: 23-Apr-2020].

[8] K. Vlasaty and I. Napp, “Wirelessly Synchronized LED Mickey Mouse Ears,” courses.engr.illinois.edu. [Online]. Available: https://courses.engr.illinois.edu/ece445/getfile.asp?id=14705. [Accessed: 22-Apr-2020].

[9] K. Vlasaty and I. Napp, “Wirelessly Synchronized LED Mickey Mouse Ears,” courses.engr.illinois.edu. [Online]. Available: https://courses.engr.illinois.edu/ece445/getfile.asp?id=14705. [Accessed: 22-Apr-2020].

[10] Arduino Project Hub. 2020. Star Wars On A Buzzer. [online] Available: https://create.arduino.cc/projecthub/HiHiHiHiiHiiIiH/star-wars-on-a-buzzer-0814f2 [Accessed 8 May 2020].

[11] M. Brake and J. Chase, “The Science of Star Wars: the Scientific Facts Behind the Force, Space Travel, and More!,” Amazon, 2016. [Online]. Available: https://www.amazon.com/Star-Wars-Darth-Electronic-Lightsaber/dp/B01N3AXU3H/ref=sr_1_10?dchild=1&keywords=lightsaber&qid=1588980902&sr=8-10. [Accessed: 08-May-2020].