Bluetooth Enabled Lightsaber

Team # 32

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Table of Contents

1. Introduction

1.1. Previous Project

In Spring 2019, Project #8 : Wirelessly synchronizing LED Mickey Mouse Ears sought to create affordable and entertaining devices for families to use to enjoy with customizable light patterns.

1.2. Problem

A lack of interactive entertainment at affordable prices. We need entertaining devices for family entertainment which can be used in most places without an excessive number of add-ons, since they would increase the prices and reduce the portability.

1.3. Solution Overview

We strive to create a different solution to the affordable entertainment problem that the Project we were inspired by was trying to solve.

Our solution is to create Star Wars Lightsabers which can be programmed to connect to each other.

Each Lightsaber will allow the user to choose a character, and each character has a corresponding set of light sequences and sound effects. Whenever the lightsabers collide, they will produce a light effect (some color change or light flash) and a clashing sound effect. Both the light and sound effect will be different for each different character available.

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 synchronised.

During game play, when a lightsaber detects that it has hit something, it will send out a hit signal via bluetooth.

It 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. (Fig. 3) 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.

If both lightsabers register a hit signal within a certain time frame, then we know that the lightsabers have had a saber-to-saber collision; so neither player is awarded a hit point.

However, if only one lightsabers registers a hit within the time frame, 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.

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 choose 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 13 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.

1.4. Visual Aid

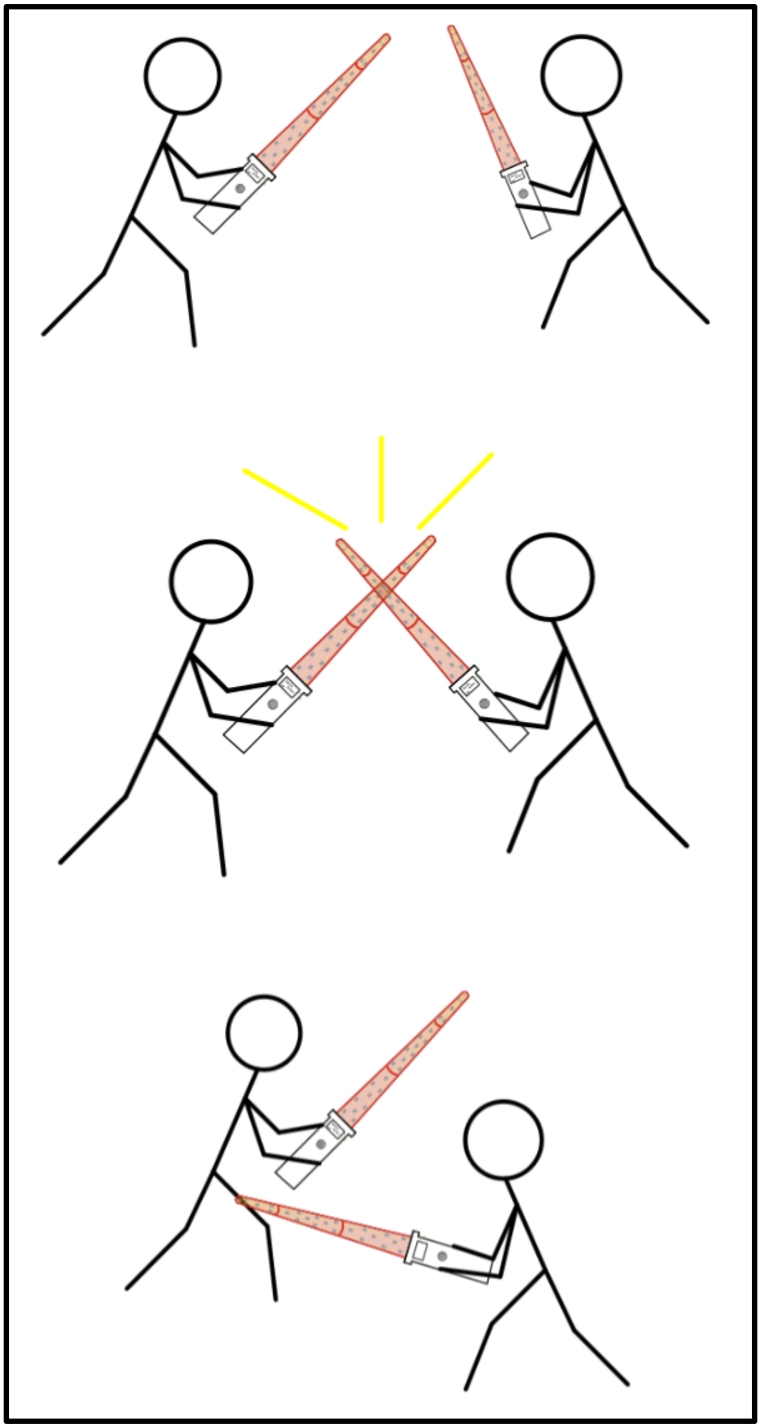

Figure 1: Lightsaber Gameplay Visual Aide

1.5. High Level Requirements

1. The light and sound effects should begin within 1 second of the collision and should correspond to the character.
2. The switches must trigger upon hit and have an error rate of less than 10%.
3. The bluetooth communication should be quick and precise, with a baud rate of at least 38400 bps.

2. Design

2.1. Block Diagram

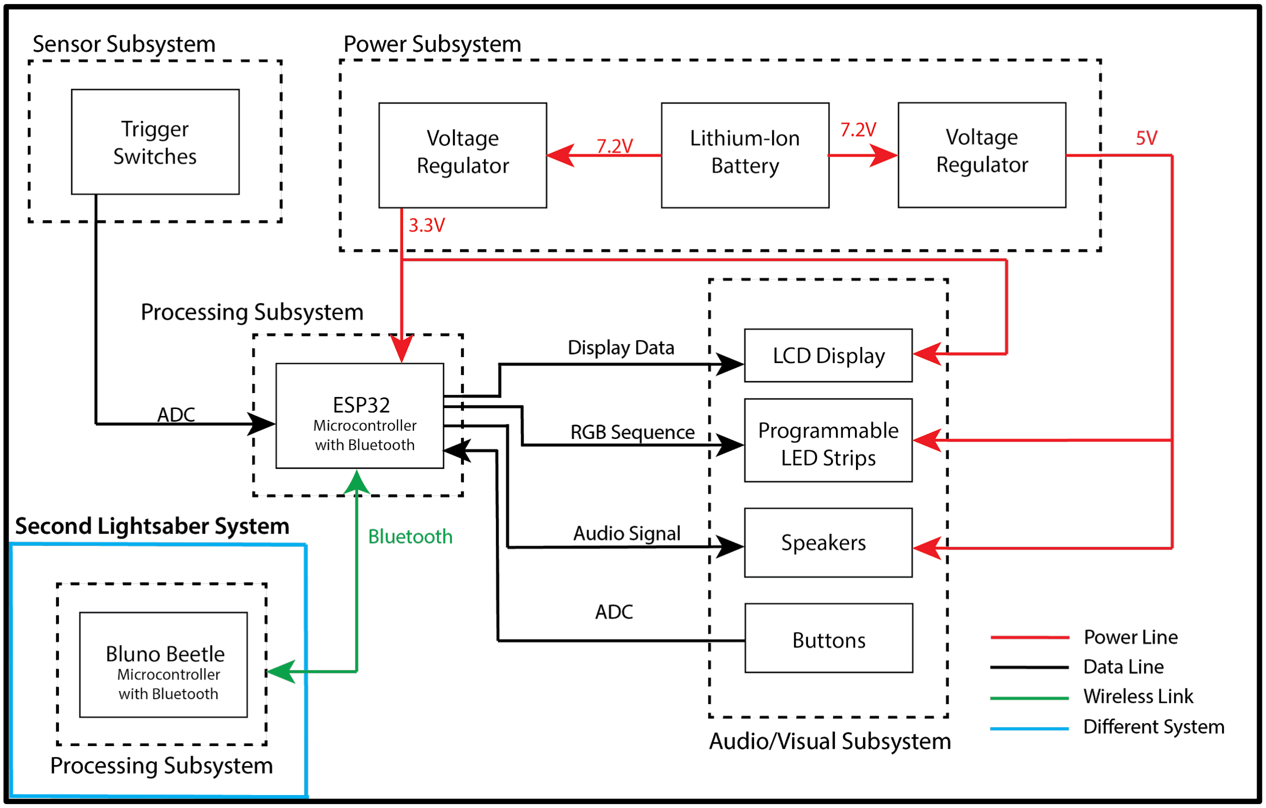

Figure 2: Block Diagram

2.2. Physical Design

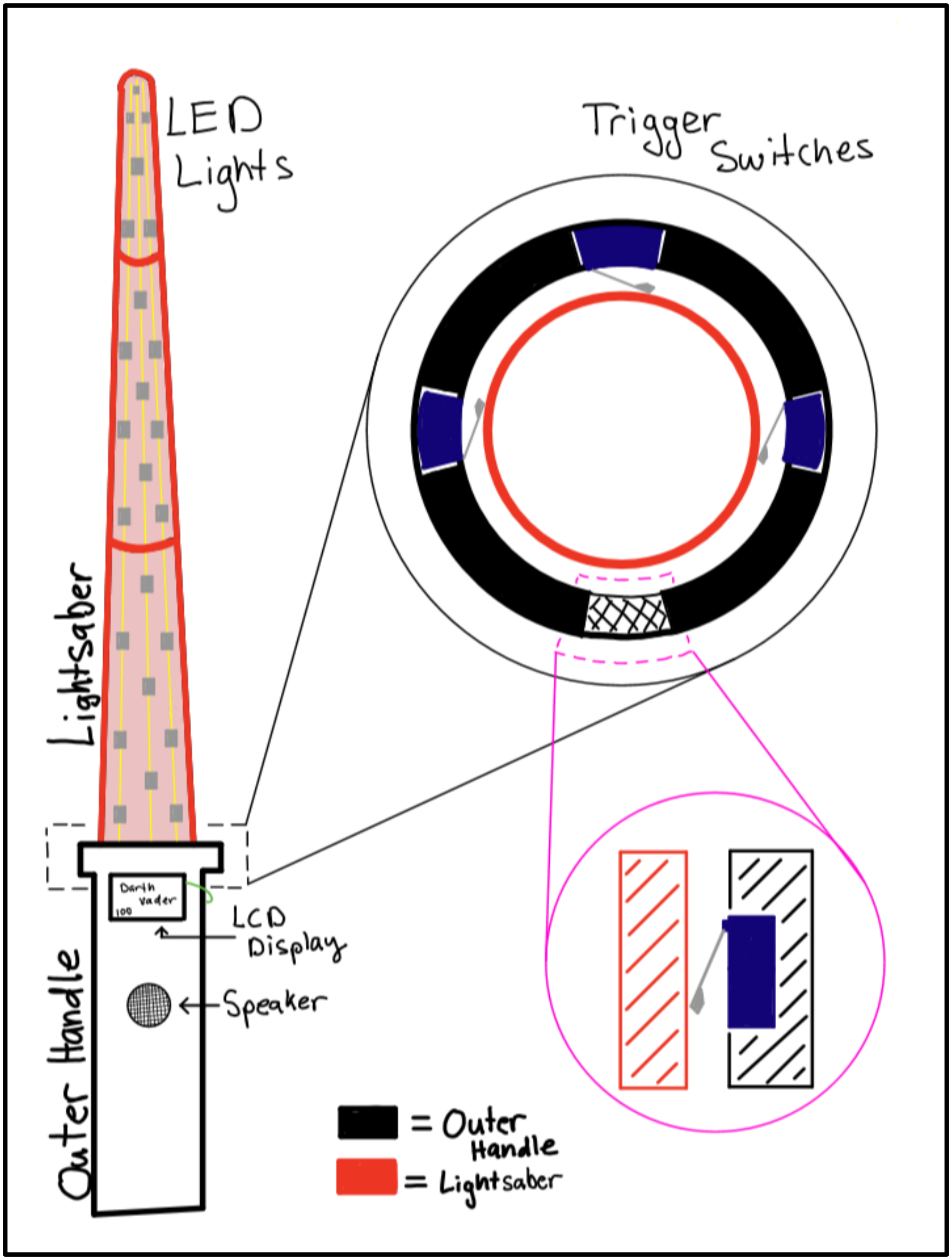

Figure 3: Upper View Lightsaber Internals

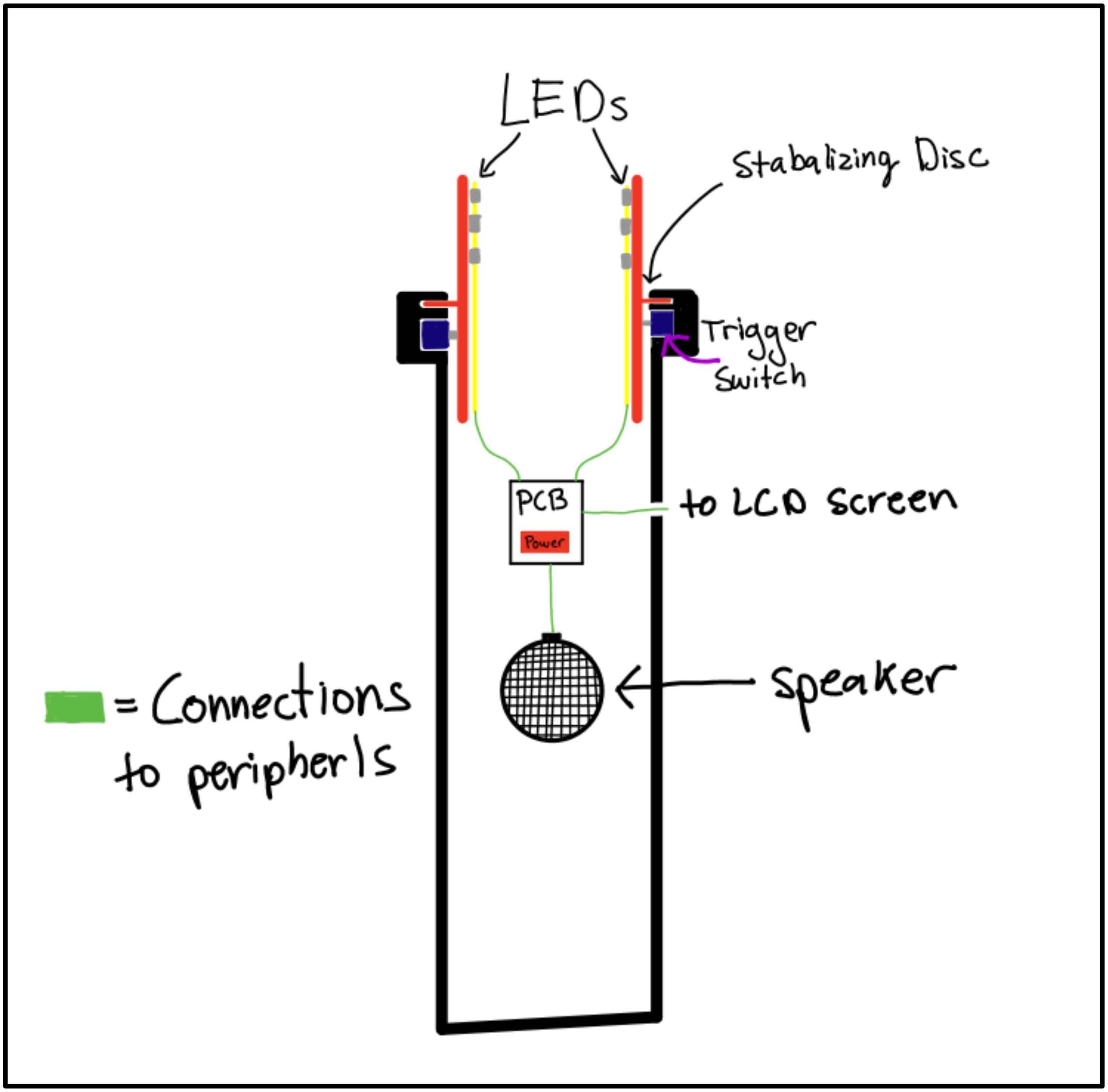

Figure 4: Internals of Outer Handle

2.3. Sensor Subsystem

The sensor subsystem is responsible for detecting when the lightsaber has made contact with another object. This is accomplished via a set of switches surrounding the base of the lightsaber blade. When the lightsaber blade makes contact with another object, the blade will be slightly pushed due to the impact, this will cause the base of the blade to trigger one or more of the surrounding switches. Therefore, whenever the lightsaber makes contact with another object a switch will be triggered; thus detecting when the lightsaber has made contact. The buttons will then send the detection signals to the Bluno Beetle microcontroller to be processed by the processing subsystem.

2.3.1. Trigger Switches

There will be four trigger switches surrounding the base of the lightsaber blade as seen in figure 3.

Requirement	Verification
The switches should only trigger after the lightsaber has had an impact.	1. Once the switches are connected to the microcontroller we can monitor if they are detecting impact. 2. Hit the lightsaber against an object to see if the switch gets triggered from an impact. 3. Swing the lightsaber around without hitting anything to ensure sure the switches do not get triggered without an impact. 4. Adjust the positioning of the switches accordingly. So that they will trigger on impacts, but not from just swinging the lightsaber around.

Table 1: Trigger Switch R&V

2.4. Processing Subsystem

The Processing Subsystem is tasked with

(1) receiving hit signals from the Sensor Subsystem,

(2) sending and receiving bluetooth signals to/from the paired lightsaber

(3) instructing the Audio Visual System on what to display and what sound and lights to produce

2.4.1. Microcontroller

We will be using an ESP32 WROOM-32D as our microcontroller. We will be using its bluetooth capabilities to send and receive signals from the other paired lightsaber. It will also send signals to the peripherals to instruct them on what to do.

Requirement	Verification
1. Can send and receive data over Wi-Fi above 115kbps to prevent audible delay	1. a. Connect ESP-32 to power and upload arduino program to send a 30 byte packet to computer b. Receive packets on computer end c. Confirm that the data rate is above 115kbps
2. Can receive data over I2C at a minimum rate of 400kps: the max data rate I2C on the accelerometer/gyroscope	2. a. Connect microcontroller to a arduino via I2C b. Program arduino to send the microcontroller a 0.5Mb packet of data, and time how long it takes. c. Program microcontroller to echo back data d. Check RTT and data integrity upon receiving data back to arduino.

Table 2: Microcontroller R&V

2.5. Power Subsystem

The power subsystem is responsible for providing and regulating power for the Microcontroller (ESP32), LCD Screen, Programmable LEDs, and Speaker. The power subsystem consists of a 7.2V lithium-ion battery attached to two voltage regulator circuits. The LED strips, switches, and speaker require a consistent voltage of 5 V, while the LCD Screen and ESP 32 require 3.3 V. Thus we need two voltage regulator circuits, one that outputs a steady 5 V and one that outputs a steady 3.3 V. The total current draw for all the components needing power falls into the range 603.16 - 603.22 mA . These calculations are based on the power consumption of the ESP-32 (500 mA), LED Strips (1 μA), LCD Screen (160-220 μA), Speaker (100mA), and Switches (3mA) datasheets.

2.5.1. Lithium Ion Battery

A 7.2V lithium-ion battery will be used to supply power for all of the components.

Requirement	Verification
The 7.2V lithium-ion battery should last at least 3 hours	1. Connect battery to a voltmeter 2. Plot voltage over span of 3 hours 3. Ensure voltage levels do not drop below 5 volts over this timeframe

Table 3: Battery R&V

2.5.2. Voltage Regulator 1

A voltage regulator will be attached to the lithium-ion battery in order to regulate the supply voltage and ensure that it never exceeds 5V.

Requirement	Verification
Voltage supply should not exceed 5 volts	1. Connect the voltage regulator circuit to a power supply at 7.2V to mimic the battery. 2. Use a voltmeter to monitor the voltage. 3. Ensure the output voltage remains around 5 V

Table 4: Voltage Regulator 1 R&V

2.5.3. Voltage Regulator 2

A voltage regulator will be attached to the lithium-ion battery in order to regulate the supply voltage and ensure that it never exceeds 3.3V.

Requirement	Verification
Voltage supply should be 3.3 volts	4. Connect the voltage regulator circuit to a power supply at 7.2V to mimic the battery. 5. Use a voltmeter to monitor the voltage. 6. Ensure the output voltage remains around 3.3 V

Table 5: Voltage Regulator 2 R&V

2.6. Audio Visual Subsystem

The audio visual subsystem provides the interactive elements for the user. We begin with the LCD Screen and the buttons. The LCD Screen will consist of text options to let the user choose their character as well as display the score. There will be buttons below the screen to allow the user to choose said character or to restart the game.

Upon the selection of the character, the information will be sent to the processing subsystem. Now upon a hit, since a character has been registered, the programmable LEDs and speakers will react accordingly with the pre-assigned sound and light sequences.

2.6.1. LCD Screen

A simple LCD screen capable of showing two lines of text, the first with the character name and scrolling arrows on either side, and the next to display the score. It will be connected to the buttons and to the processing subsystem.

Requirement	Verification
No inconsistencies in display, should display text completely upto maximum character limit (16 characters).	Send in a 16 character word, ensure proper display.
Change in values must be registered and displayed.	Send data in a loop, changing values every 1 second. Ensure that changing values are observed. [5]

Table 6: LCD Screen R&V

2.6.2. Programmable LEDs

LED strips are convenient since light sequences can be well programmed and every LED is programmable. As a result, we will be able to provide quality entertainment with multicolor LED strips and lighting patterns. The LEDs will be connected to the processing subsystem as well as the power subsystem.

Requirement	Verification
LED strips must be able to display a sequence of lights.	Connect the strips to a microcontroller and send in a changing color pattern. Observe fading and overall pleasant viewing and make sure there is no rapid or inconsistent blinking of lights.
LEDs must respond to a hit within a delay of 1 second.	Provide test code and print time delay from receiving value till change in LED.

Table 7: LEDs R&V

2.6.3. Speaker

A speaker should be able to play sounds as soon as a hit is registered. It will also be connected to both the processing and the power subsystem.

Requirement	Verification
To be able to play a small tune upon hit.	Create a code to provide pre-selected notes and ensure they can be played in a sequence.

Table 8: Speaker R&V

2.6.4. Buttons

We require 2 push buttons, one to scroll to the right to choose a character, and another to start/restart the game. These will be connected to the processing subsystem.

Requirement	Verification
The push of a button should be registered	1. Verify button connections by

by the processing subsystem.	connecting to any microcontroller and receiving confirmation. 2. Connect to a working processing subsystem and print when pressed.

Table 9: Buttons R&V

2.7. Schematics

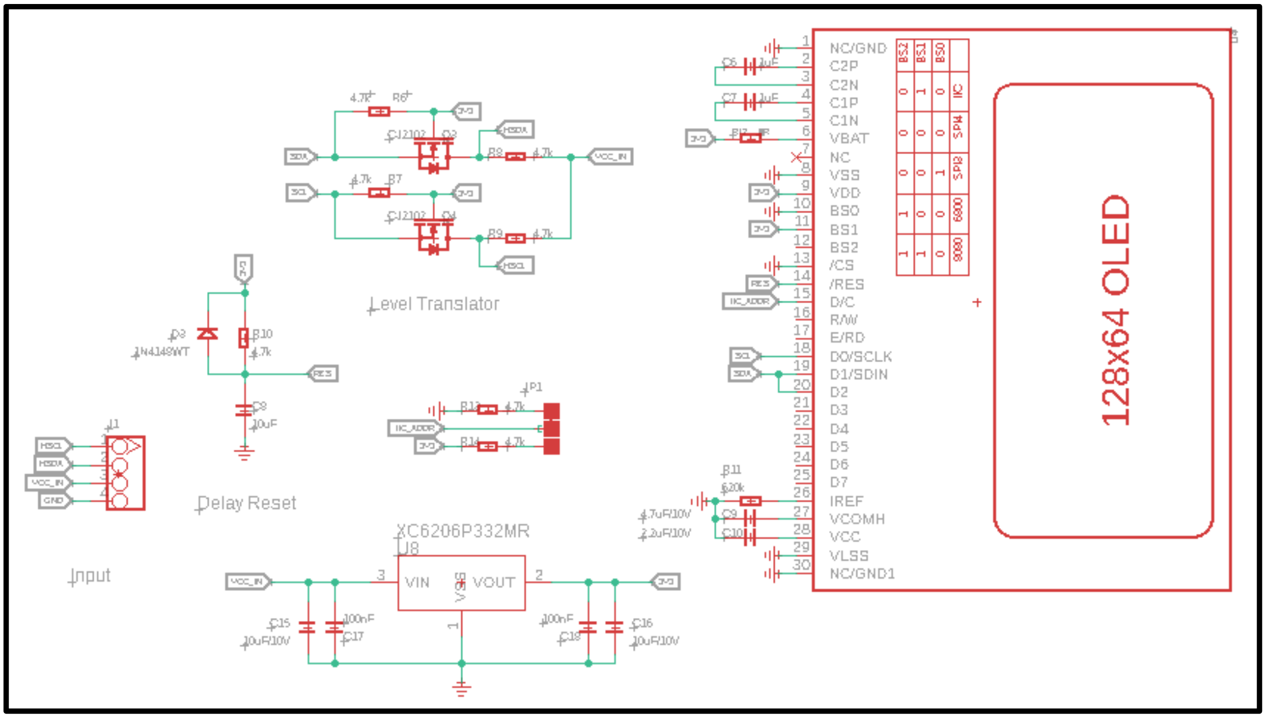

Figure 5: LCD Display Schematic

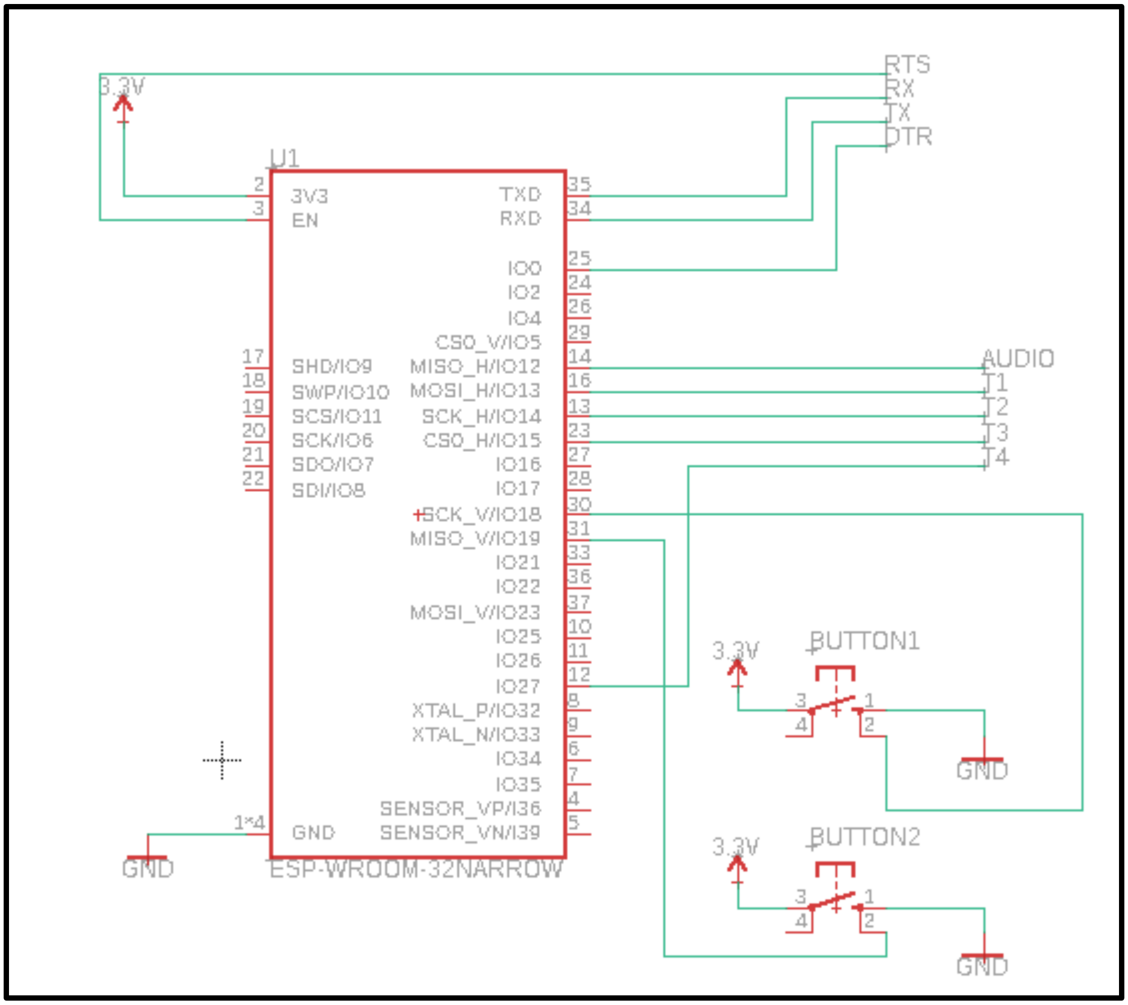

Figure 6: Microcontroller Schematic

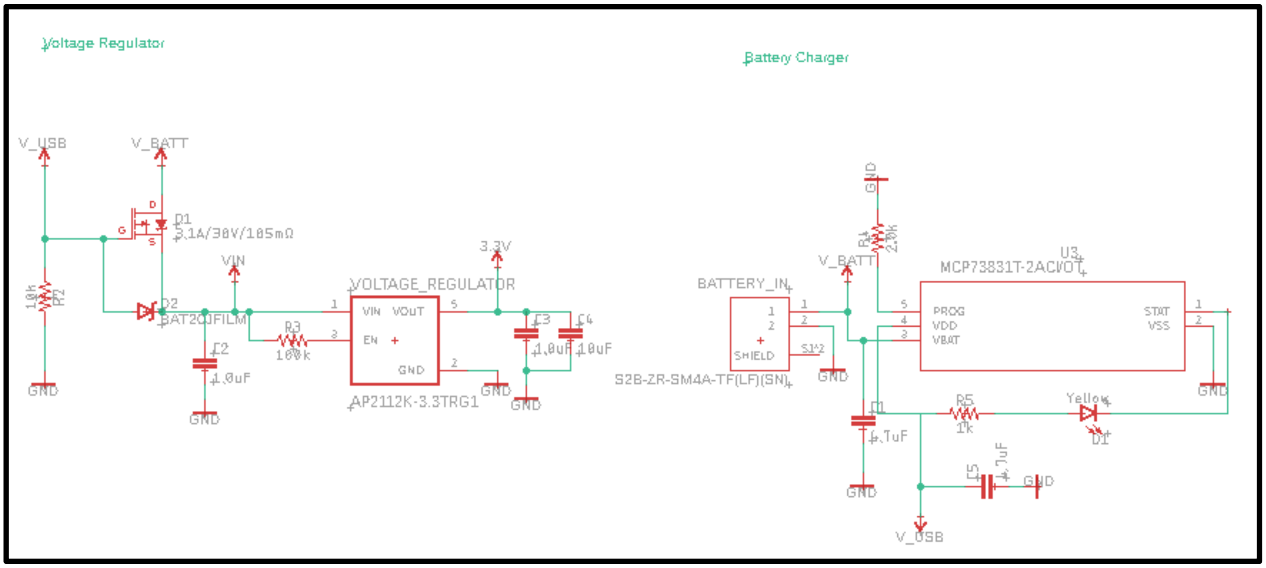

Figure 7: 3.3V Voltage Regulator Schematic

2.8. Tolerance Analysis

The trigger switches (D2F from Omron Electronics) we have decided to use have an operating force of 1.47 N. This means it requires 1.47 N of force to trigger the switch, and in our case send a signal to the processing subsystem that there has been a collision. The weight of the lightsaber portion of our product (the part in red in our visual aide), is around 100g which is 0.10kg. Using Newton's laws of physics, we can calculate the average force of a "hit".

$$F = m \times a \qquad \text{\_\_\_(2.8.1 Eq1)}$$

$$1.47N = 0.1kg \times a \qquad \text{\_\_\_(2.8.2 Eq2)}$$

$$14.7 m/s^2 \qquad \text{\_\_\_(2.8.2 Eq3)}$$

This would mean that in order to trigger a hit by just moving around, a person would need to swing the lightsaber at least 14.7 m/s^2. A person of height 4'10" weighing in around 40 kg (similar to a young child), can move their arm at an average rate of 2.86m/s^2 (according to our trials noted below). As a player moves around, swinging the lightsaber around, this will not trigger the switches. There should not be enough force to trigger switches unless there is a physical collision that provides the extra force required to trigger the switch with 1.47 N.

In order to provide some data on the force at which an average child can swing their arm, we conducted some trials in our apartment. Since we are quarantined and we do not have access to proper tools, we made do with a measuring tape and a timer to measure and calculate the average acceleration a child-sized person can swing their arm. Because Tulika is child sized, she served as an ideal subject for these trials.

Trial #	Distance	Time	Acceleration
1	1.22 m	0.89 s	1.54 m/s^2
2	1.22 m	0.53 s	4.34 m/ s^2
3	1.22 m	0.62 s	3.17 m/ s^2
4	1.22 m	0.71 s	2.42 m/ s^2
		Average	**2.86 m/ s^2**

Table 10: Trials for average acceleration

3. Differences

3.1. Overview

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.

3.2. Analysis

The core problem to be solved was a lack of quality entertainment. We break this down into a set of qualities: interactiveness, affordability and portability. Based on these qualifications, the previous project provided light effects on a headband, where the light effects were customizable. We chose to improve the factor of interactiveness, where we shaped the product to be a game so the users can enjoy themselves, with added LCD screens and light and sounds and characters. The affordability and portability also remain good, the game can be played anywhere with a large enough area.

4. Cost Analysis

4.1. Labor

- Labor: (For each partner in the project)
  - A Computer Engineering Major from the University of Illinois at Urbana Champaign makes an average salary of $84,250 a year[4]
  - This is about $40.5 per hour, which is our chosen labor cost
  - Estimated work time is 5 hours/week for 15 weeks, which is 75 hours to complete.
  - With the given equation, cost per hour x 2.5 x hours to complete = TOTAL:
    - $40.5/hour x 2.5 x 75 hours = $ 7593.7
- Labor for all the partners in the project:
  - $ 7593.7/partner x 3 partners = $22,781.25
- So, our final estimated cost of labor is $22,781.25

4.2. Parts

Part	Manufacturer	Part #	Quantity	Total Cost ($)
Snap Switch	Omron Electronics Inc-EMC Div	SW1046TR-ND	4	$8.04
ESP32 WiFi Module	Espressif Systems	1904-1025-1-ND	2	$9
LCD Screen	Seeed Technology Co., Ltd	1597-104020208-ND	1	$3.98
Speaker	CUI Devices	102-3851-ND	1	$3.61
Programmable	HKBAYI	WS2812B	1	$22.99

LED Strips				
Lightsaber	Disney	B2915AS0	1	$19.99
Battery	Jauch Quartz	1908-1346-ND	1	$28.08
			Total:	$95.69

Table 11: Cost Analysis

4.3. Total Costs

- Total Costs

= Labor + Parts

= $22,781.25 + $95.69

= $22,876.94

5. Schedule

Week	Kushal	Shayna	Tulika
1.	Place order for parts	Research and understand PCB design requirements and specifications	Research and understand PCB design requirements and specifications
2.	Talk to Machine Shop about modifying lightsaber to fit our components	Design the PCB layout for the Processing Subsystem	Design the PCB layout for the Sensor Subsystem
3.	Design the PCB layout for the Power Subsystem	Design the PCB layout for the Audio/Visual Subsystem	Design the PCB layout for the Audio/Visual Subsystem
4.	Test for confirmation of sensor subsystem r/v	Test for confirmation of A/V subsystem r/v	Finalize PCB Layout and put in order request for PCB
5.	Program microcontroller to send hit signal upon trigger switch	Begin fitting parts into the handle base	Once the PCB arries, begin soldering the components onto it
6.	Program game logic onto microcontroller	Fit PCB and rest of components into the lightsaber	Begin initial test for confirmation of processing subsystem r/v
7.	Fit PCB and rest of components into the lightsaber	Fit PCB and rest of components into the lightsaber	Program peripheral control onto the microcontroller (lcd display, speaker, and leds)
8.	Refine and test, catch up if fallen behind schedule	Refine and test, catch up if fallen behind schedule	Refine and test, catch up if fallen behind schedule
9.	Final Demo, work on final presentation	Final Demo, work on final presentation	Final Demo, work on final presentation
10.	Final Presentation	Final Presentation	Final Presentation

Table 10: Schedule

6. Ethics and Safety

6.1. Ethics

We do believe our product is both ethical and safe to use, if used properly under the conditions we have stated in our background section. One ethical consideration we do have would be players intentions for playing this game. 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.

6.2. 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.

7. Risk Analysis

Of all our subsystems, the processing subsystem possesses the highest risk. The processing subsystem is charged with receiving the signals from the trigger switches and immediately sending output signals to the audio visual subsystem all within a very small delay. It also has to send a hit signal via bluetooth to the other lightsaber, so it can also send a signal to its own audio visual subsystem. This bluetooth communication is where our highest risk lies. If the communication fails, if the pairing drops, or if the signal is not sent fast enough, there will be audible and visual delays in the sound and light effects that will negatively impact the performance of the product and also customer satisfaction.

8. Citations

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

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