Wirelessly Synchronized LED Mickey Mouse Ears

ECE 445 Design Document

Team 8 - Kaitlin Vlasaty and Ian Napp
TA: Hershel Rege

Spring 2019

Table of Contents

1 Introduction……………………………………………………………………………………………2
1.1 Objective……………………………………………………………………………………….....2
1.2 Background……………………………………………………………………………………...2
1.3 High-Level Requirements………………………………………………………………………..3

2 Design…………………………………………………………………………………………..4
2.1 Physical Design………………………………………………………………………………4
2.2 Block Diagram…………………………………………………………………………………..6
2.3 Power Block……………………………………………………………………………………..7
2.4 Lights Block……………………………………………………………………………………11
2.5 Control Block..…………………………………………………………………………………12
2.6 App Block………………………………………………………………………………………13
2.7 Schematics and Calculations…………………………………………………………………...16
2.8 Tolerance Analysis……………………………………………………………………………19

3 Cost and Schedule……………………………………………………………………………..…20
3.1 Cost Analysis…………………………………………………………………………………..20
3.2 Schedule……………………………………………………………………………………..…21

4 Safety and Ethics…………………………………………………………………………...……22
4.1 Safety Guide………………………………………………………………………...………22
4.2 Ethical Considerations…………………………………………………………..…………22

References……………………………………………………………………...………………24

1 Introduction

1.1 Objective

Visuals are an important component of all Disney products and creations. Everything is carefully crafted to give the audience the best experience, and the theme parks are a great example. Parks and resorts are one of Disney's main revenue sources, bringing in around $20 billion annually [1]. Worldwide, there were over 150 million park visitors in 2017 [2]. Countless details are added to develop the parks' immersive worlds, including well-maintained landscaping, customized manhole covers, and historically accurate building facades [3]. All of these elements are added for good reason; it is estimated that up to 80% of the sensory information we receive comes from our sense of sight [4]. One aspect of creating a visual experience is lighting, which is important in terms of both safety and enjoyment. At night, the need for lighting increases, as does the opportunity to showcase incredible lighting effects. Disney parks are obviously well-lit at night, in part by light parades and light-up toys for children. One of these products is the iconic Mickey Mouse ear hat, which has been modernized to include LEDs.

Rather than solving a problem, we are looking to develop a solution that improves upon the existing design of the Mickey Mouse ears. We found that a pair of the Glow with the Show ears have limited functionality outside of a Disney park. They had one mode, which was to cycle through a set of 3 colors with a single LED in each ear. Our design will consist of a headband with ears lined with RGB LEDs. The user will be able to control the lights using a phone application, and the communication will happen over WiFi within a closed wireless ad hoc network. They will have the option to change the color or choose from a selection of light patterns. We were inspired by Disney magic to create a project that combines our interests in LED wearables and wireless communication systems.

1.2 Background

Light up Mickey ears are not a new product, and they were available as standalone devices before the communication aspect was introduced. Disney introduced Glow with the Show (now called Made with Magic) products to go along with their light shows starting in 2012 [5]. The shows premiered in DisneyLand but are now integrated into all of the parks. The translucent plastic ears are attached to a hat, and each ear contains one LED. The hats are powered by two AAA batteries, and weigh about 110 grams [6]. The controls are based on IR communication: focused emissions are sent to certain parts of the crowd that allow producers to create patterns and dynamic effects throughout the area [7]. However, original models of the ears had limited functionality outside of the parks. The version we purchased was controlled only by the power switch, the LEDs cycled through a predefined set of three colors — orange, yellow, and magenta.

We want to create a similar pair of ears that is implemented with a different approach. The ears will instead communicate via WiFi and be controllable with a mobile app. The app will set the color of the lights, or choose from a selection of light patterns. These effects will include fading, flashing, rainbow gradients, and more. When it is dark and nearing parade time, Disney employees bring out carts of light up toys. While these toys are a fun part of the experience, they may also make it easier for parents to find their kids in a dark crowd, especially if they have recognizable or unique lights on them. For this reason, we have decided to include a distinctive distress sequence that can be initiated either through the app or the headset. Locating lost or separated children is not the primary focus of our project, but it may be a useful feature in certain situations. The original hat has one LED per ear, and therefore requires a large crowd of people wearing the hats to create the lighting effects. Our design includes 7 lights per ear so that patterns can be seen with only one or a few headsets. This allows users to create their own show anywhere they want.

1.3 High-Level Requirements

- The LED-lined ears will be attached to a headband. It will be safe and comfortable to wear, and weigh between 255 and 340 g.
- The PCB has a maximum size of 67 mm by 67 mm, which will fit in the round ear cavities with a diameter of 105 mm. The ear pieces, when snapped together, will have a total width of 16 to 18 mm.
- The app will control the light colors and effects, using an IEEE 802.11b wireless ad hoc WiFi network within a range of 90 - 150 m.

2 Design

2.1 Physical Design

The physical design features a headband with two circular ears attached as depicted in Figure 1, all dimensions shown in Figure 1 are in millimeters. The ears, approximately 65 millimeters in diameter, will be 3D printed using a transparent PETG plastic. This type of plastic was chosen for several reasons. It gives off less fumes when printing than ABS, and can produce smooth, high-quality prints. Each ear will be lined around the inside with the LED strips. One ear will contain the printed circuit board, which is shown in Figure 1 as having the maximum possible size, 67 mm x 67 mm. The other ear will house the battery. The on/off switch, charging port, and the control button for the battery indicator will be accessible on the back of the ear. We chose this ear for the controls because it reduces the amount of wiring that needs to run within the headset. Wires for data, depicted as black lines in Figure 1; and power, depicted as red lines, will run between the ears. The headband will be wrapped with additional fabric to ensure that the wires are covered.

As shown in Figure 2, our design involves ears made of two interlocking pieces each. Since exposure to rain is a concern, we plan on adding a rubber strip in the seam of the ear for waterproofing. This reduces the constraints of waterproofing the individual components as well. Once we have a more finalized idea of the PCB dimensions, we plan on creating areas within the ear cavities to mount the PCB and battery pack. The ears will be attached to the headband via screws. This will create a sturdy connection and avoid the risk of the ears falling off and breaking. These screws would be hidden under the fabric to avoid catching hair or causing irritable skin contact.

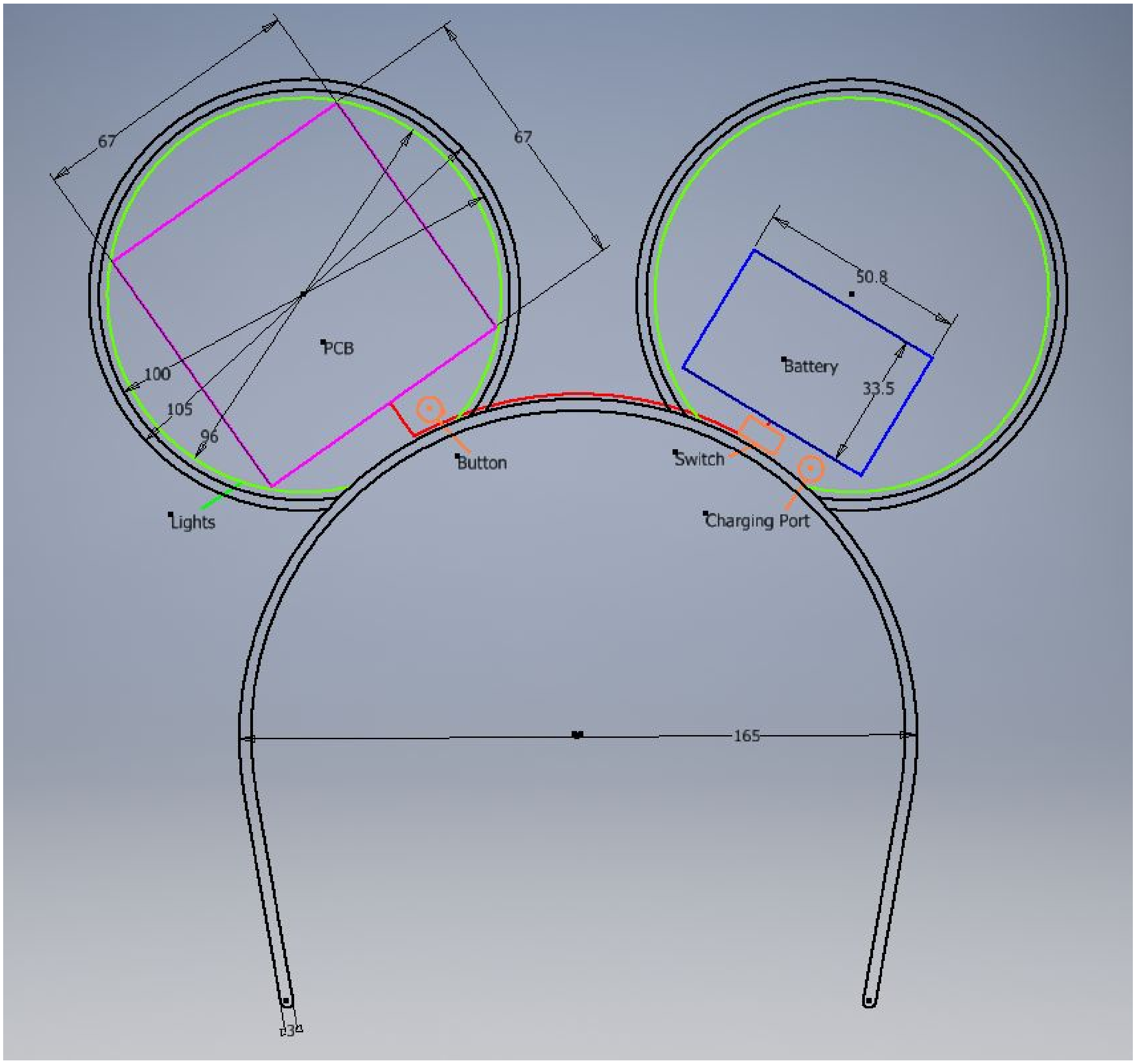

Figure 1. Physical Design and Dimensions of Headset

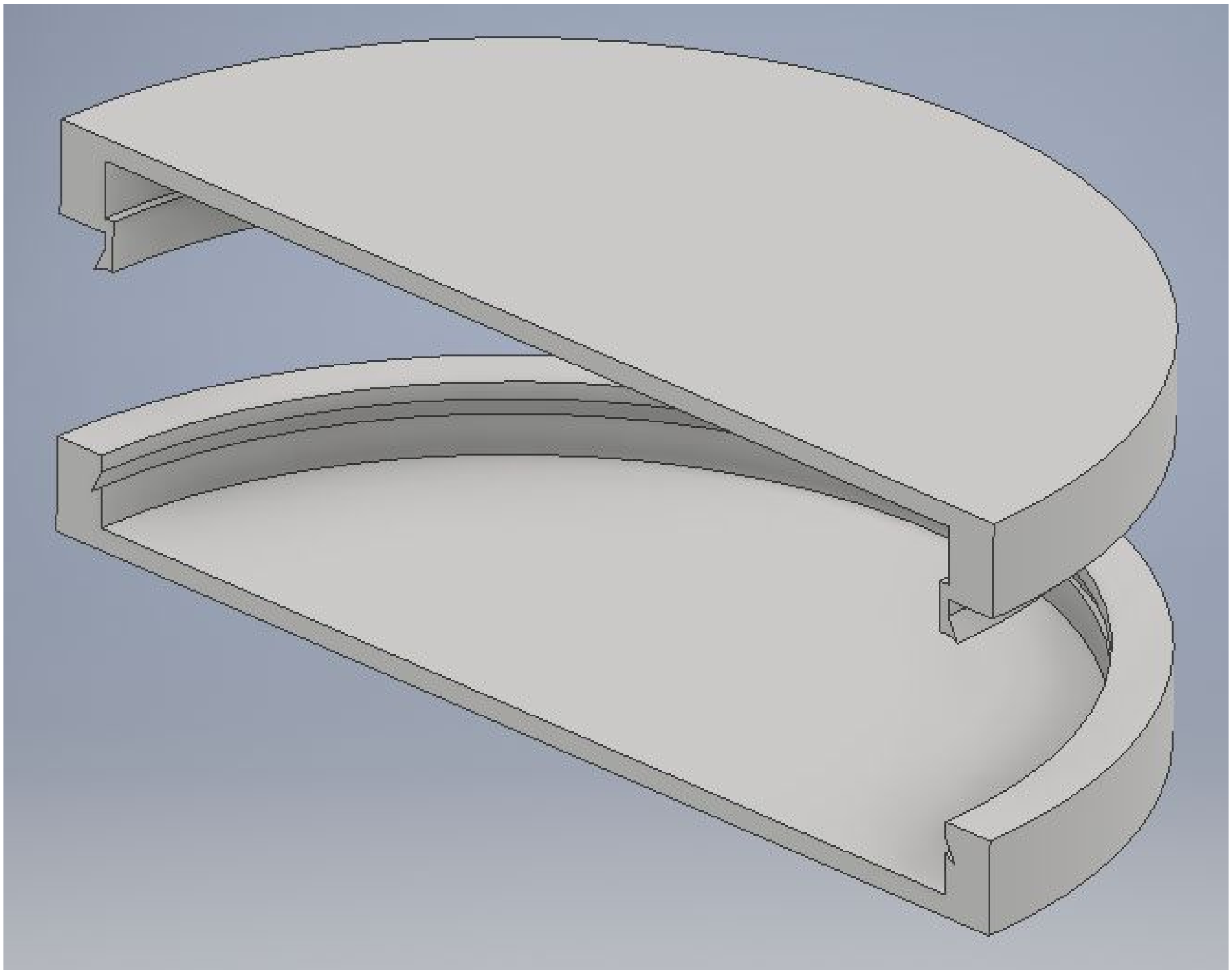

Figure 2. Basic 3D Render of Ears

2.2 Block Diagram

Our headset will be separated into four subsystems: power, lights, control, and a mobile application. The power block is meant to supply a regulated amount of power to each component and provides an interface for charging the battery. The switch will turn the entire headset on and off. The lights are strips of RGB LEDs that will be attached to the inside edge of each ear. The LEDs are individually addressable so they will be able to create a variety of light patterns. The control block contains the module that acts as the WiFi transceiver as well as the microcontroller for the lights. It will manage the connections with other headsets and the mobile app. This connection creates an IEEE 802.11b network with a maximum transmission rate of 7.1 Mbit/s when using UDP, and will work within a range of 300-500 ft [8]. The button, in the control subsystem, is used for both checking battery levels and initiating the distress sequence for the lights. The lights will be controlled from the Android app, which can also be used to initiate and terminate connections. Users will have a choice between solid colored LEDs and a selection of lighting effects. The connections between the subsystems can be seen in Figure 3.

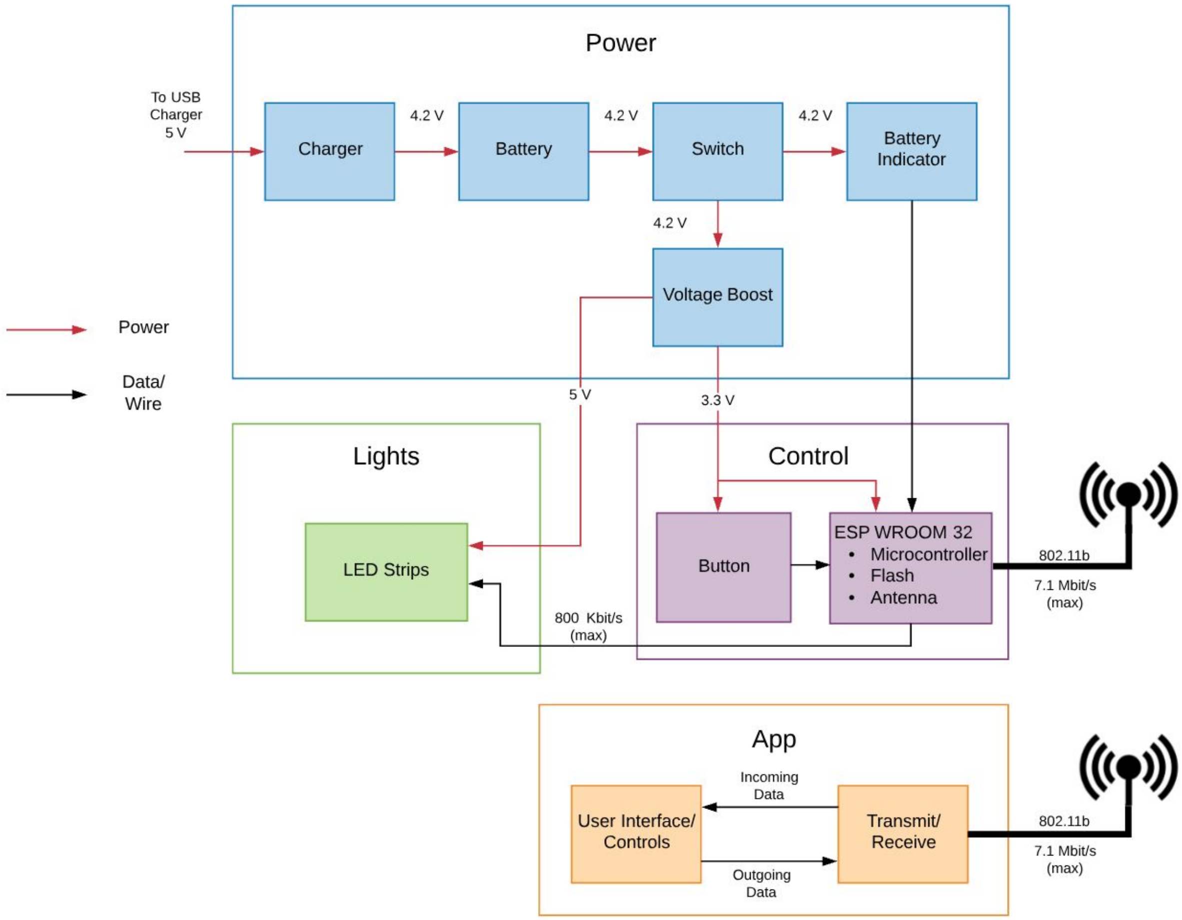

Figure 3. Block Diagram of Headset System Components

2.3 Power Block

2.3.1 Charger

The design of our project confines the battery inside of one of the ears. Since lithium polymer batteries are not meant to be disposable, they need to be charged. We will achieve this through a charging IC, like the MCP73831. This chip is designed to supply 4.2 V at a max current input of 1.2 A when given an input between 4.5 V and 10 V.

Requirements	Verification
1. LiPo battery fully charges to 4.2 V when supplied 4.2 V±1% at no more than 1.2 A.	1. A. Discharge battery completely. B. Recharge battery from output of the MCP73831 chip making sure volt/current is not exceeded. C. When charge status pin goes high the charge cycle is complete, battery will be checked to make sure voltage is at 4.2 V.
2. Battery Charge within 7 to 10 hours.	2. During step 1.B, monitor time to make sure charging cycle is completed within desired time.
3. While charging, temperature stays below 60°C	3. Also during step 1.B, monitor thermals with IR thermometer sensor to make sure IC does not heat up beyond 60°C.

2.3.2 Battery

The battery will power the headset and be able to be recharged after a day's worth of use. A viable option for our design would be lithium-ion polymer (LiPo) batteries. Although they cost more, they are much thinner than AA batteries and can more easily fit into the ears where they will be housed. They are also lightweight, about 52 g per battery, which is very important for our design since it must be comfortable and stable on top of a person's head. We hope to get about 55 Wh from the battery during a standard day of use (6 to 7 hours). We have provided the calculations to get these figures in Section 2.7, Equation 2.1 below.

Requirements	Verification
1. The battery pack can provide up to 4.2 V at 2500 mAh for 6-7 hours, totaling at around 55 Wh.	1. A. Fully charge battery pack to 4.2V and connect to a load simulating LEDs and PCB. B. Drain battery at 2500 mA for 7 hours. C. Confirm that the battery have more than 3 V of charge using a voltmeter.

2.3.3 Switch

The switch will be used to determine what state the headset will be in, either charging, running, or off. It will be located on the headband near the ear that contains the battery pack. It is a single pole triple throw switch that is sufficiently large and easy to switch so that it can be used comfortably.

Requirements	Verification
1. Switch will toggle power to circuit on or off completely, as well as toggle to allow battery to charge properly.	1. Voltage measured using multimeter after the switch will read the current battery voltage if the switch is on. If it is off then the voltage will read 0.

2.3.4 Battery Indicator

To show battery levels in a fun and practical way, the level can be displayed on the ears using the LEDs via a digital lithium polymer fuel gauge. A fully charged battery will light up all of the LEDs, while a low battery will only light a few of them. Since our design will have around fourteen LEDs that means each LED will represent about 7% of the battery. The color of the LEDs will change in different battery ranges as well which can be seen in Table 1. If the indicator is accurate within 5% this will leave a safe margin of error.

Requirements	Verification
1. Battery level must be accurate within ±5% of the available charge.	1. A. Test battery charge at any given amount greater than when it is dead. B. Plug battery into battery level indicator and test to see if the amount it is reading is within the given constraint.
2. LEDs can display the battery level in the manner described in table 1, accurate to the closest multiple of 7% rounded down.	2. A. Use code to display battery level on the LEDs B. Count the number of LEDs to confirm that the displayed percent is consistent with the number of LEDs that should be lit according to the requirement.

Table 1. Battery Level Display Ranges

Battery Percent	Number of LEDs Lit	Color
1 - 7	1	red
8 - 14	2	red
15 - 21	3	red
22 - 28	4	yellow
29 - 35	5	yellow
36 - 42	6	yellow
43 - 49	7	yellow
50 - 56	8	yellow
57 - 63	9	green
64 - 70	10	green
71 - 77	11	green
78 - 84	12	green
85 - 91	13	green
92 - 100	14	green

2.3.6 Voltage Boost

To safely power the components of our design, we plan on using a voltage booster like the VERTER 2190 5 V buck converter. This design can take an input from 3 V to 12 V and step it up to 5 V which is more useful and safe for powering the LEDs and the PCB. We can also get near 1000 mA output at voltages greater than 3 V.

Requirements	Verification
1. Regulator provides a steady 5 V ± 10% output when supplied 4.2 V input. 2. Output current is close to 1000 mA	1. A. Connect battery pack to the voltage regulator and confirm that the input is 4.2 V at 1000 mAh. B. Drain battery though regulator and measure output voltage with a multimeter making sure it stays within required range during discharge cycle. 2. During step 1.B, use multimeter to also measure output current to confirm that it stays near 1000 mA.

2.4 Lights Block

The LEDs are an important part of our design since they are what will be seen by the user. We plan to use Alitove WS2812B LED strips. We decided to step down the amount of LEDs per headset from what we had originally planned due to the power consumption restraints from the battery pack. The calculations for the power consumption are shown in Section 2.7, Equation 2.2 below. We now plan to use 14 LEDs per headset at a much more manageable 9 W/m - half the power of the more dense strips. This design choice also reduces the amount of data that needs to be sent to update all of the LEDs during a light sequence, allowing us to stay well under the maximum data transfer rate of 800 Kbit/s. We believe with this many LEDs we will still be able to create an aesthetically pleasing light show, and also improve on the currently available product by Disney that only uses one LED. Moreover, we are creating a more practical product with the addition of a distress sequence. This is an option the user can invoke to make a headset flash in a specific way to be easily recognized in a crowd for the purpose of say, finding a child who wandered too far away.

Requirements	Verification
1. LED strip must consume at most 0.3 W ± 0.01% per LED or 9 W/m.	1. A. Connect lights to a power source of at least 5 V but no more that 6 V. B. Using a multimeter, measure the power consumption of a 1 meter segment of the strip. C. Confirm that each LED uses the required amount of power by dividing the total power consumed by the number of LEDs.

2.5 Control Block

2.5.1 WiFi IC

The WiFi block mainly consists of the ESP32 WROOM, the WiFi module we have chosen to handle the wireless communication between the headset and the user's phone. The module is low cost, at about $4, and is meant to be a good low-power option for IoT devices and wearable applications. It supports IEEE 802.11b/g/n WiFi and is therefore expected to work with most smartphones. The size is 18 mm by 26 mm, fitting well within the constraints for the PCB. The antenna and supporting hardware for the ESP32 IC are included, which eliminates the need for impedance matching for a separate antenna. We plan to add a USB interface so that software can be uploaded and used easily. The data rate can reach 150 Mbits/s, and the antenna can provide 20 dBm output power [9, ESP32 datasheet, page 30]. The WiFi component will act as a transceiver, and each chip will become a node in the ad hoc network of a phone and one or more headsets. They will be responsible for receiving instructions from the phone and distributing them to other headsets in the network. Because they will all be on one IPv4 /28 subnet within a private range of addresses, there is no need for a complex routing algorithm. We expect most of the data to be sent as broadcast traffic.

Another significant benefit of the ESP32 module is its Xtensa 32-bit LX6 microprocessor. This will be used for handling the control data that gets sent to the LEDs. There is 520 KB of on chip SRAM that will store the instructions for the light sequences. Each sequence will be numbered, and the desired sequence number will be received from the app. The microprocessor will fetch the corresponding data and forward it to the lights. This reduces the required amount of data to be sent, also reducing the stress on the network. The data speed is also compatible with the lights, which have a maximum rate of 800 kbits/s. We decided on the ESP32 WROOM module because it satisfies the requirements for our project and provides several beneficial components.

Requirements	Verification
1. WiFi module can receive data at a rate of 1 Mbit/s.	1. A. Establish a connection between two modules. B. Run test code that sends 1 Mbit of data, and start a timer when data starts sending. C. Stop timer when all data has been received, verify that it took 1 second or less.
2. Two modules can maintain a connection up to 90 m apart.	2. A. Establish a connection around 1 m and confirm data can be sent both ways. B. Begin moving the modules apart,

3. Microprocessor can accurately control the LED strips in both ears.	stopping every 30 m to confirm that the connection still works. C. Continue until the modules are at least 90 m apart. 3. A. Run test code on microprocessor that cycles through several lighting changes. B. Confirm that LEDs in both ears change according to the instructions in the test.

2.5.2 Button

The purpose of the button is to allow the user to see the battery level of the headset. It will be used to send a signal to the microcontroller telling it to run the code to light up the LEDs according to the amount sent to it by the battery indicator.

Requirements	Verification
1. Button can send a high signal when pressed.	1. Insert button into circuit defined in Figure 3. Measure voltage to confirm that when button is not pressed a low signal is read and when pressed the voltage is read indicating an active high signal.

2.6 App Block

The mobile app will be how the user interacts with and controls the lights. For the purposes of proof of concept and based on the constraints of our project, we have decided to develop an Android app only. The goal for the app is to create something that is simple and easy to use. The WiFi chip within the ears will be hosting a network that the user's phone will connect to, and one phone will be able to participate in a network with multiple headsets.

As seen in Figure 4, the UI will consist of several screens and menus. Starting with the home screen, the user can choose between colors, lighting effects, and the options menu. The ability to start and stop the distress sequence is also located here, which would send a signal to display flashing red lights on all of the headsets the phone is currently connected to.

The colors menu displays a variety of colors that, when chosen, will show up as solid lights on the LEDs. We think that about 16 different colors will be sufficient for giving the user enough choice and freedom with their lights. We may expand the design to include a color wheel or slider that would provide even more options. When a color is selected, the corresponding RGB value will be sent out so that all ears on the network will be set to that color. Similarly, the light effects menu allows the user to pick a lighting pattern or effect, such as a rainbow gradient. In this case, each effect will be numbered, and only the number of the effect chosen will need to be sent as data. The lighting cues will be stored in memory on the ears and the correct instructions are sent to the LEDs from there. This will minimize the amount of data being sent, and will therefore require a lower transmission rate. Similar to the WiFi IC, the app will use a 2.4 GHz connection in accordance with IEEE 802.11b [10]. This specifies a maximum raw data rate of 11 Mbit/s, but we do not expect to need a speed anywhere near this limit, instead operating around 800 kbps.

The options menu provides some settings for the app. The connect button will send out request packets to find and join a nearby network. The disconnect button will terminate all connections, and the number of currently connected headsets will be visible. Finally, the about screen will contain a brief description of the app and the project.

Requirements	Verification
1. The app is able to connect to a headset and control its lights.	1. A. Use the connect button to join the network of a headset that is within 100 ft of the phone. B. Verify that the headset's MAC address is listed within the app. C. Use the app to change the color or light effect several times and confirm that it produces the correct result.
2. The app does not introduce significant latency into the system, there should be no more than 2 seconds of delay.	2. A. Start a timer with precision of at least 100 ms when a button is pressed on the app for a solid color. B. Stop the timer when the lights on the connected ears change to the correct color.

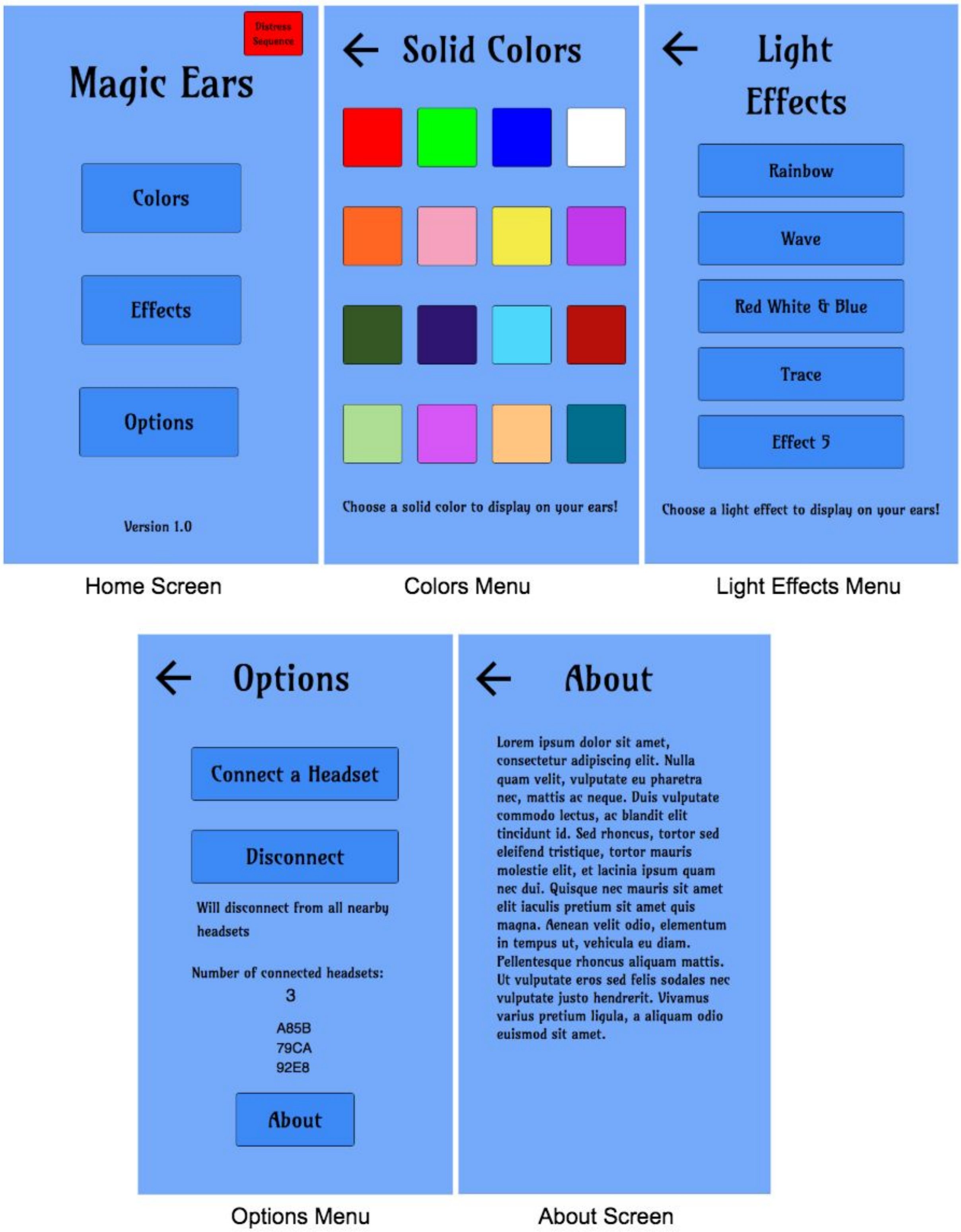

Figure 4. App Mockup

2.7 Schematics and Calculations

2.7.1 Schematics

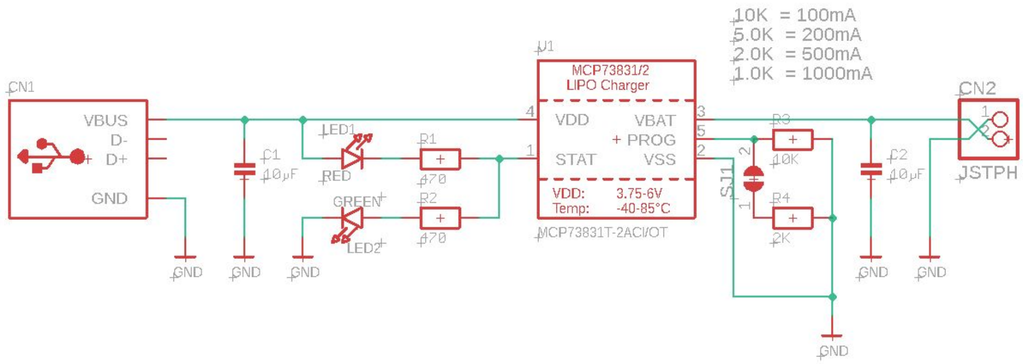

Figure 5. LiPo Charger Schematic

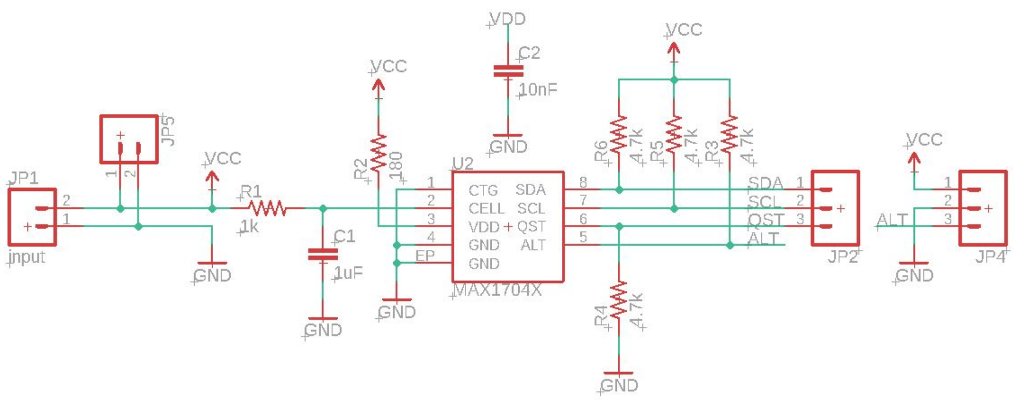

Figure 6. Battery Indicator Schematic

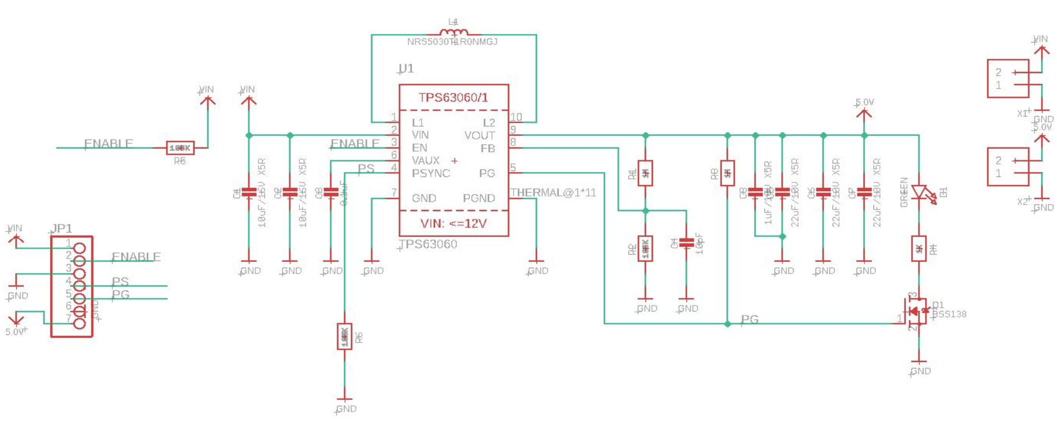

Figure 7. Voltage Regulator

2.7.2 Power Calculations

The first calculation (2.1) is how much power the lithium polymer battery will supply in a standard day's worth of use. The second equation (2.2) is the worst case power consumption for the LED strips. If the LEDs are not operating at full brightness, they will consume less power. This leaves at least 11.6 Wh to power the rest of the board during the 6 hour operational period.

$$3.7\ V \cdot 2.5\ Ah \cdot 6\ h = 55\ Wh \tag{2.1}$$

$$\frac{0.266\ m}{ear} \cdot 2\ ears \cdot \frac{9\ W}{1\ m} \cdot 6\ h = 32.8\ Wh \tag{2.2}$$

2.7.3 Network and Data Flow Diagrams

Shown in Figure 8 is an example of a network topology for our system consisting of three headsets and a phone. We will use an ad hoc network type, so the routing is distributed and every device on the network is connected to every other device. All IP addresses will be assigned within a private range on a /28 subnet. With one network address and one broadcast address, this leaves 14 host addresses. Our system can therefore accommodate one phone and up to 13 headsets. The network will have no access to the public internet because it is a closed private network with no gateway address. Packets will be sent using UDP, because of the smaller packet size and broadcast nature of the communication.

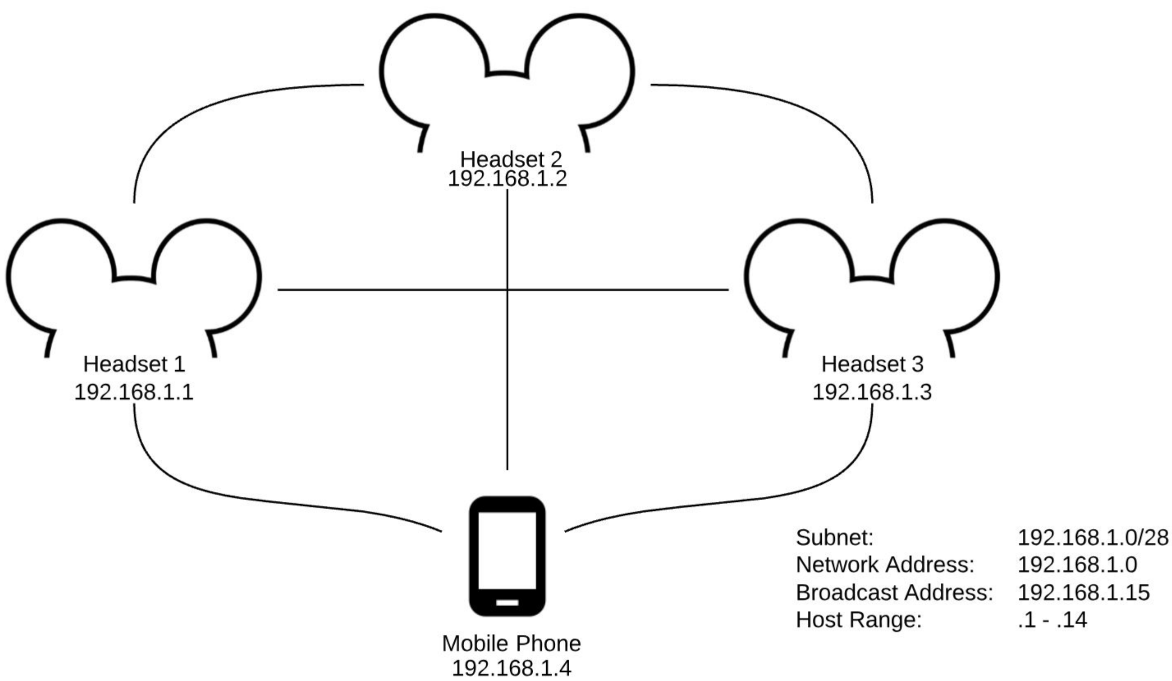

Figure 8. Example network topology

There is also a flow of data that must occur for the system to function properly. A simplified version of this data flow is shown in Figure 9. This version assumes the network is already fully connected. The flow is initiated when a user selects either a color or light effect within the app. The choice is sent out to all headsets on the network; the headsets interpret the message and display the correct lighting on the LEDs.

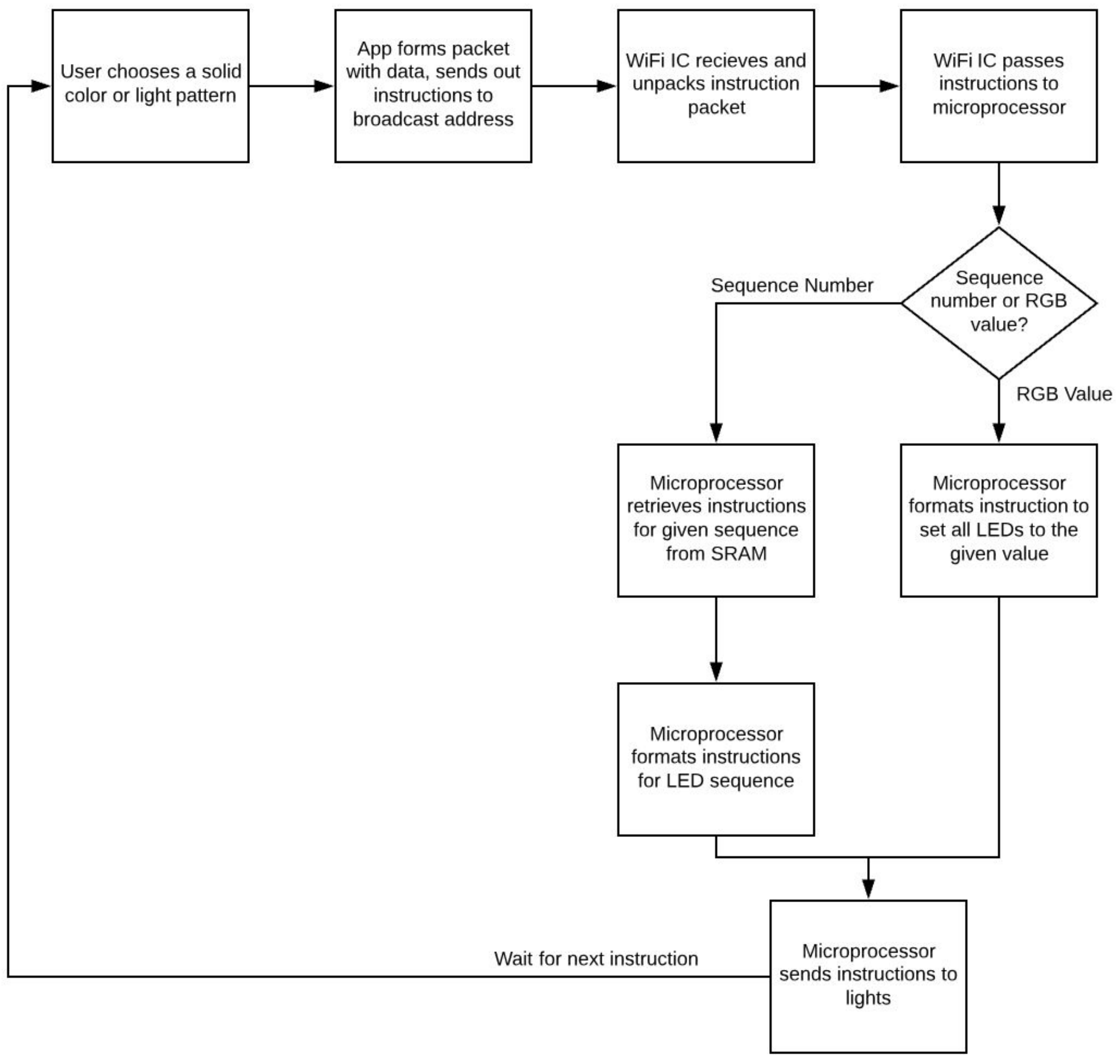

Figure 9. Proposed Data Flow for Light Instruction

2.8 Tolerance Analysis

A crucial tolerance we must maintain is the voltage regulation between components and blocks within our design. Since our headset runs on batteries, it was necessary to use the biggest batteries possible that fit within the physical constraints of the ears to be able to power them for multiple hours. This poses the problem, however, that a lot of power will be flowing out of the batteries. If not properly regulated, the power could damage the circuitry.

The two lithium polymer battery we chose to power our design will output up to 4.1 V at 2.5 A. The LEDs are rated for 5 V and can sustain damage when supplied more than 6 V. The raw power from the batteries could easily overload the LEDs or circuit board, so it is paramount we monitor how much power certain blocks are receiving. One example of this is inserting an active high button into the circuit and wiring it directly from the batteries to the microcontroller. Although this would have technically provided a high signal, the button would have passes all 4.2 volts and to the microcontroller rated for 3.3V, potentially damaging the part.

Charging is another big stress point as LiPo batteries have the potential to overheat or explode. The power fed to them needs to be within the rated amount. According to datasheets on common LiPo chargers, charging batteries of our calibur can handle up to 500 mAh input. However, our design has two batteries in series to provide enough voltage to the LEDs which requires extra consideration. Most chargers are rated for one battery which will work for our design. However, given the size of our battery it might take longer than say a smaller 1000 mA battery.

$$E\ (Wh) = I\ (A) \cdot V\ (V) \cdot t\ (h) \tag{2.3}$$

3 Cost and Schedule

3.1 Cost Analysis

We assumed a salary of $35/hr based on the average entry-level electrical engineering position in Chicago, IL [11]. Given 12 weeks to work on the project and 8 hours of work per week for two people, we estimate the development cost to be $16,800.

$$2 \cdot \frac{\$35}{week} \cdot \frac{8\ h}{week} \cdot 12\ weeks \cdot 2.5 = \$16,800 \tag{3.1}$$

Table 2. Part Prices

Part Name	**Part Number**	**Cost (individual)**	**Cost (bulk)**
WiFi module	ESP-32 WROOM 32 (Mouser)	$3.80	$3.80
LED Strip	ALITOVE 16.4ft WS2812B RGB LED Strip Lights 150 Pixels (Amazon)	$25.99	$3.17
3D Printed Ears - 4 pieces per headset, 142 grams total	Translucent Clear PETG Filament 1.75 mm	$11.88	$2.81
Lithium Polymer Battery	Adafruit 328	$14.95	$14.95
PCB (PCBWay)		$7.80	$0.42
Battery Charger	MCP73831	$0.58	$0.43
Battery Indicator Subsystem	Maxim MAX17043	$9.95	$9.95
Voltage Regulator Subsystem	TI - TPS63060	$9.95	$9.95
Small components (button, switch, etc)		$10.00	$1.00
Headband	Loneedy 1 inch wide headband	$1.67	$1.67
Total		$96.57	$48.15

Grand Total = Labor + Parts = $16,800 + $386 = $17,186

Assuming we pay individual part prices and make four prototypes, this would cost $386. The total estimated development cost comes out to $17,206.

3.2 Schedule

Week	Kaitlin	Ian
2/25	Breadboard and test with modules	Breadboard and test with modules
3/4	WiFi module research, write WiFi code	Create overall circuit schematic, research 3D printing
3/11	Write and test light sequences/controller code	Make and order PCB, create 3D print ear model
3/18 (Spring Break)	Android Studio Tutorials, plan app code	Order ear prints
3/25	Write app code - UI	Solder first round circuit board
4/1	Write app code - TX/RX	Prototype assembly and testing
4/8	Debug app	Board revisions
4/15	2nd round prototyping and testing	2nd round prototyping and testing
4/22	Demonstration, work on final paper	Demonstration, work on final paper
4/29	Presentation, finish final paper	Presentation, finish final paper

4 Safety and Ethics

4.1 Safety Guide

Our project requires that the Lithium Polymer battery be charged and discharged many times throughout their use. Since our project is designed to be worn on the head, this necessitates certain safety considerations. We plan to consider the following factors for our batteries while designing and building this project:

- Batteries must not be drained of current at a rate faster than it is rated for (1 A).
- Batteries must not be charged quicker than they can handle (~500 mA).
- Batteries must not charge above their maximum voltage (4.2 V).
- Batteries must not discharge below their minimum voltage (3.0 V).
- Batteries must operate within rated temperatures (-20°C to 60°C).
- Avoid leaving battery in high temperatures for risk of expansion and possible explosion.
- Do not submerge battery in water.
- Do not short battery terminals.
- Do not reverse polarity of battery when installed.
- Check batteries before use for potential points of failure.

4.2 Ethical Considerations

As with any project of a significant scale, considerations must be made for the ethics of the design. We understand the IEEE Code of Ethics and accept the obligation to be honest and safe with our work [12]. With our project being used as headgear, it is important that we are very aware of the well-being of the users. This is consistent with Code #1: “to hold paramount the safety, health, and welfare of the public…”. Additionally, this project will be developed for personal use only. We have no intention of mass-producing or selling the headbands commercially, therefore we will not infringe on Disney’s copyright. We also make no claims about the headbands as safety devices, they are not intended to aid finding lost children.

Since our project will require the use of batteries we acknowledge the risks involved with Lithium-Ion batteries. If too much power is drawn from the battery pack too quickly or the circuit is shorted it can cause a spike in temperature beyond safe operating standards [13]. This can cause the battery pack to expand and possibly explode which could result in bodily harm. It could also have the potential of starting an electrical or chemical fire, either of which can be dangerous and hard to extinguish. The electronics of the headset can also short and potentially cause health risks. This is why we plan to waterproof our project to the extent it can withstand rain for a period of time before sustaining damage or failing completely. We assume the user will protect the headset before too much exposure to moisture causes degradation.

Any electronics using wireless communications must adhere to regulations set forth by the Federal Communications Commision (FCC). Since we plan on using WiFi to allow our headsets to communicate, they fall under Part 15 of the Electronic Code of Federal Regulations [14]. This states that private consumers have the right to use WiFi frequencies near 2.4 GHz without the need to register the device with the FCC provided that they are a low power device, which our headset meets. We plan to create a closed network for these headsets to operate in for the purpose of controlling lights remotely. This means that in the event of a hack, the hacker would merely be able to change the color of the headsets and not be able to gain access to sensitive information, like for instance, the location of the users. There was the possibility of adding GPS capabilities to the headsets which would have been visible from the app. However, we decided the risks involved with including location tracking, especially on headsets worn by children, outweighed the benefits in the event of a hacking incident.

In accordance with IEEE Code #6, “to maintain and improve our technical competence…”, we are undertaking this project primarily as a learning experience. We believe that the components of this project each provide a valuable opportunity to explore the technical capabilities as well as a way for us to grow as engineers.

References

[1] Bell, T. (2019). *The Walt Disney Co. 4th Quarter Earnings Report Shows Record Revenue*. [online] Wdwinfo.com. Available at:
https://www.wdwinfo.com/news-stories/the-walt-disney-co-4th-quarter-earnings-report-shows-record-revenue/ [Accessed 6 Feb. 2019].

[2] Disney News. (2019). *Annual Disney Park Attendance Statistics and Charts*. [online] Available at:
https://disneynews.us/disney-parks-attendance [Accessed 5 Feb. 2019].

[3] Sim, N. (2019). *101 Amazing Little Details You Probably Never Noticed at Walt Disney World*. [online] Theme Park Tourist. Available at:
https://www.themeparktourist.com/features/20150505/30229/101-amazing-little-details-you-probably-never-noticed-walt-disney-world [Accessed 6 Feb. 2019].

[4] Zeiss.com. (2019). *Why Good Vision Is So Important*. [online] Available at:
https://www.zeiss.com/vision-care/us/better-vision/health-prevention/why-good-vision-is-so-important.html [Accessed 5 Feb. 2019].

[5] Glover, E., Kevin Rafferty, J., Britton, M. and Ramirez, M. (2019). *Disney California Adventure Park Guests Will 'Glow with the Show'*. [online] Disney Parks Blog. Available at:
https://disneyparks.disney.go.com/blog/2012/06/disney-california-adventure-park-guests-will-glow-with-the-show-at-disney-california-adventure-park/ [Accessed 6 Feb. 2019].

[6] "Disney Mickey Mouse and Friends Light-Up Made With Magic Ear Hat", *Amazon.com*, 2019. [Online]. Available:
https://www.amazon.com/Disney-Mickey-Mouse-Friends-Light-Up/dp/B01B26NXPE. [Accessed: 13- Feb- 2019].

[7] "Disney explains the 'Glow with the Show' Mickey hat technology", *Theme Park Insider*, 2019. [Online]. Available:
https://www.themeparkinsider.com/flume/201208/3149/. [Accessed: 08- Feb- 2019].

[8] J. Mrazek, "Testing the WiFi range of ESP32", *Blog.honzamrazek.cz*, 2019. [Online]. Available:
https://blog.honzamrazek.cz/2017/08/testing-the-wifi-range-of-esp32/. [Accessed: 19- Feb- 2019].

[9] "ESP32 Series Datasheet", *Espressif.com*, 2019. [Online]. Available:
https://www.espressif.com/sites/default/files/documentation/esp32_datasheet_en.pdf. [Accessed: 19- Feb- 2019].

[10] "IEEE 802.11", *En.wikipedia.org*, 2019. [Online]. Available: https://en.wikipedia.org/wiki/IEEE_802.11#802.11b. [Accessed: 18- Feb- 2019].

[11] "Entry Level Electrical Engineer Salary in Chicago, Illinois | PayScale", *Payscale.com*, 2019. [Online]. Available: https://www.payscale.com/research/US/Job=Electrical_Engineer/Salary/b4b23e80/Entry-Level-Chicago-IL. [Accessed: 20- Feb- 2019].

[12] "IEEE Code of Ethics", *Ieee.org*, 2019. [Online]. Available: https://www.ieee.org/about/corporate/governance/p7-8.html. [Accessed: 20- Feb- 2019].

[13]"Lithium-ion battery", *En.wikipedia.org*, 2019. [Online]. Available: https://en.wikipedia.org/wiki/Lithium-ion_battery. [Accessed: 22- Feb- 2019].

[14]"eCFR — Code of Federal Regulations", *Ecfr.gov*, 2019. [Online]. Available: https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=752c648e754360a36c89c602d54ea9f9&mc=true&n=pt47.1.15&r=PART&ty=HTML#se47.1.15_1247. [Accessed: 22- Feb- 2019].