Group 15 how.dance Smart Lights

Project Closeout

Aiden K. Bahr, Christopher B. Parker, and Oluwalana Popoola

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1 Design Impact Statement

1.1 Public Health, Safety, and Welfare Impacts

A concern of this product is one of the most destructive forces on earth: fire. The U.S. Fire Administration released a report for 2014-2016 relating to electrical fires and their causes. During this time frame, roughly 24,000 electrical fires occurred where 87.8% were caused by electrical failure or malfunction [1]. These electrical failures or malfunctions can be due to faulty outlets, appliances, extension cords, wiring, space heaters, and light fixtures, all of which cause an electrical failure or malfunction at the source fire if not adequately addressed or distributed [2]. In terms of the project, this area can cause a disadvantage for those who need to distribute their sources of power to their essential appliances (i.e., toaster, coffee maker, internet router, lamps, computer charger) whereby not having the ability to move devices to different power outlets can result in the power outlet failing and causing a fire. At the same time, those who can move appliances to other outlets have the advantage of placing the product where they ideally want it in a space.

1.2 Cultural and Social Impacts

This project's main goal is to create a more immersive experience from your own home. People with a how.dance smart light can create an atmosphere in their living room that was previously only available at large venues. This has the potential to cause a shift in the way artists engage with their audiences. We've already seen artists attempt to do this through virtual concerts during the pandemic, but it is unlikely that these types of concerts will stick around as they exist now. An article from CNBC suggests that the future of at home concerts does look promising [3]. It suggests that streaming services like Netflix could begin hosting them, increasing the audience and normalizing the idea of an at home concert. Our project will add much more value to the at home concert by making the space a part of the "venue." After the pandemic, when people are eager to return to in-person concerts, we hope that the option to host an immersive experience for yourself and friends will encourage the continuation of virtual concerts, increasing accessibility and audience sizes for artists and fans

1.3 Environmental Impacts

LED lighting is popular because of the fun color options and flexibility, but they are also extremely efficient for the amount of light they produce. According to Helm, an incandescent light bulb can result in 4500 lbs of CO_2 emissions annually, while an LED bulb results in only 451 [4]. This makes LEDs the most carbon-efficient lighting source. By giving the user of our device control over the color and brightness of the device at all times, we hope that many users will choose to use our lights as a main source of lighting in their home or room over incandescent bulbs. Since most bulbs in stores have already been replaced with high-wattage LED bulbs, the environmental impact will be smaller but still significant. The average LED light bulb consumes 60 watts of power, while our device at maximum brightness will consume a maximum of 50 watts (for 12 light bars).

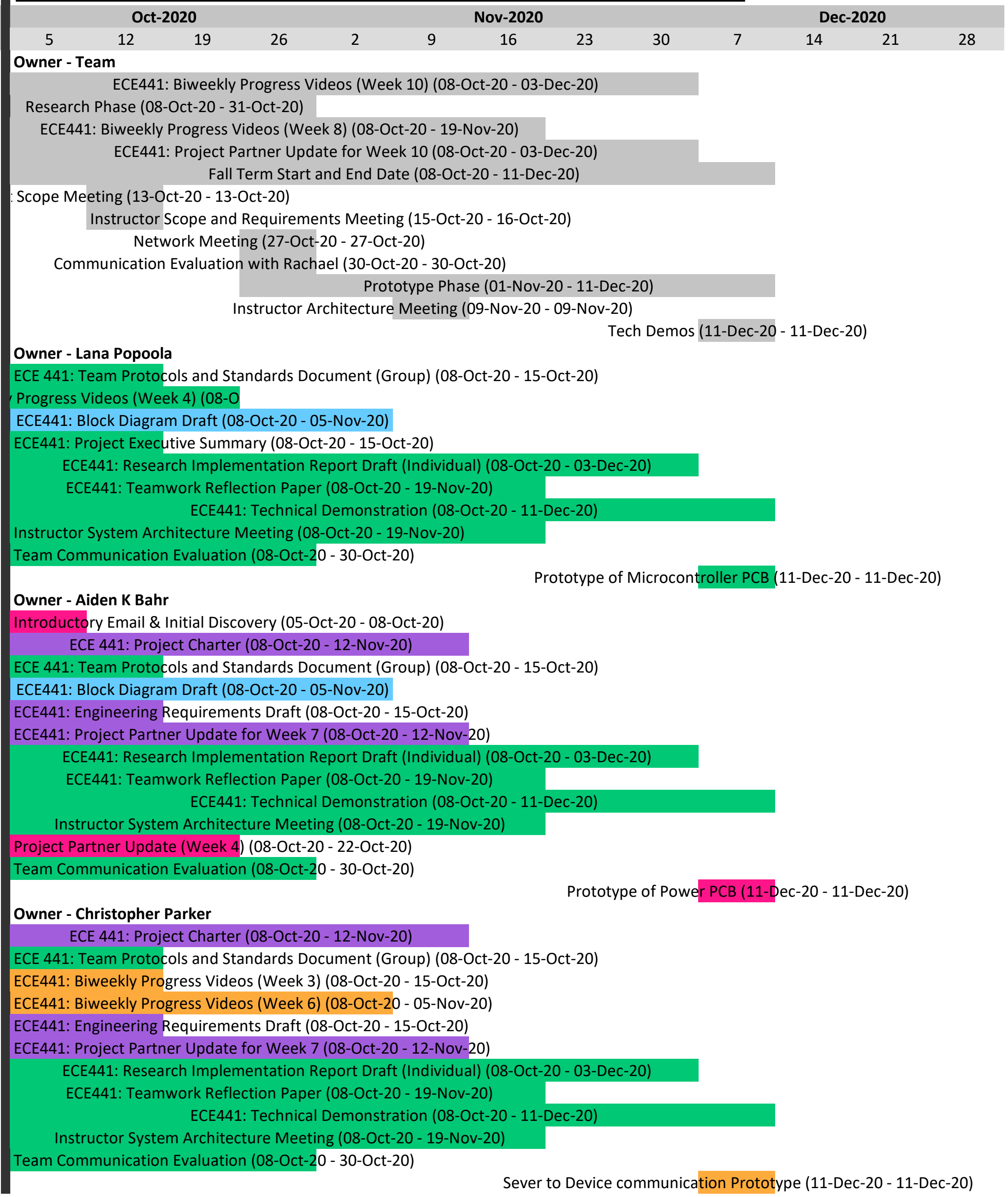
1.4 Economic Factors

A prominent feature of this product is its ability to be wirelessly connected to the internet and controlled either by the end-user or, when connected to a remote concert event, the concert host. This feature requires that the end-user have a broadband internet connection to be sent to the product is not interrupted. According to the Phew Research Center, as of 2019, only 73% of adults have broadband internet at home, roughly 75%-79% of adults living in urban and suburban areas have broadband internet at home, and approximately 61%-66% of adults who are not white have broadband internet at home [5]. If the data is summed together and then averaged, only 71% of adults within the United States will use this product to its full extent. This means that 29% of adults will be at a disadvantage if they fall within all three areas of study and do not have a broadband internet connection.

2 Project Timeline

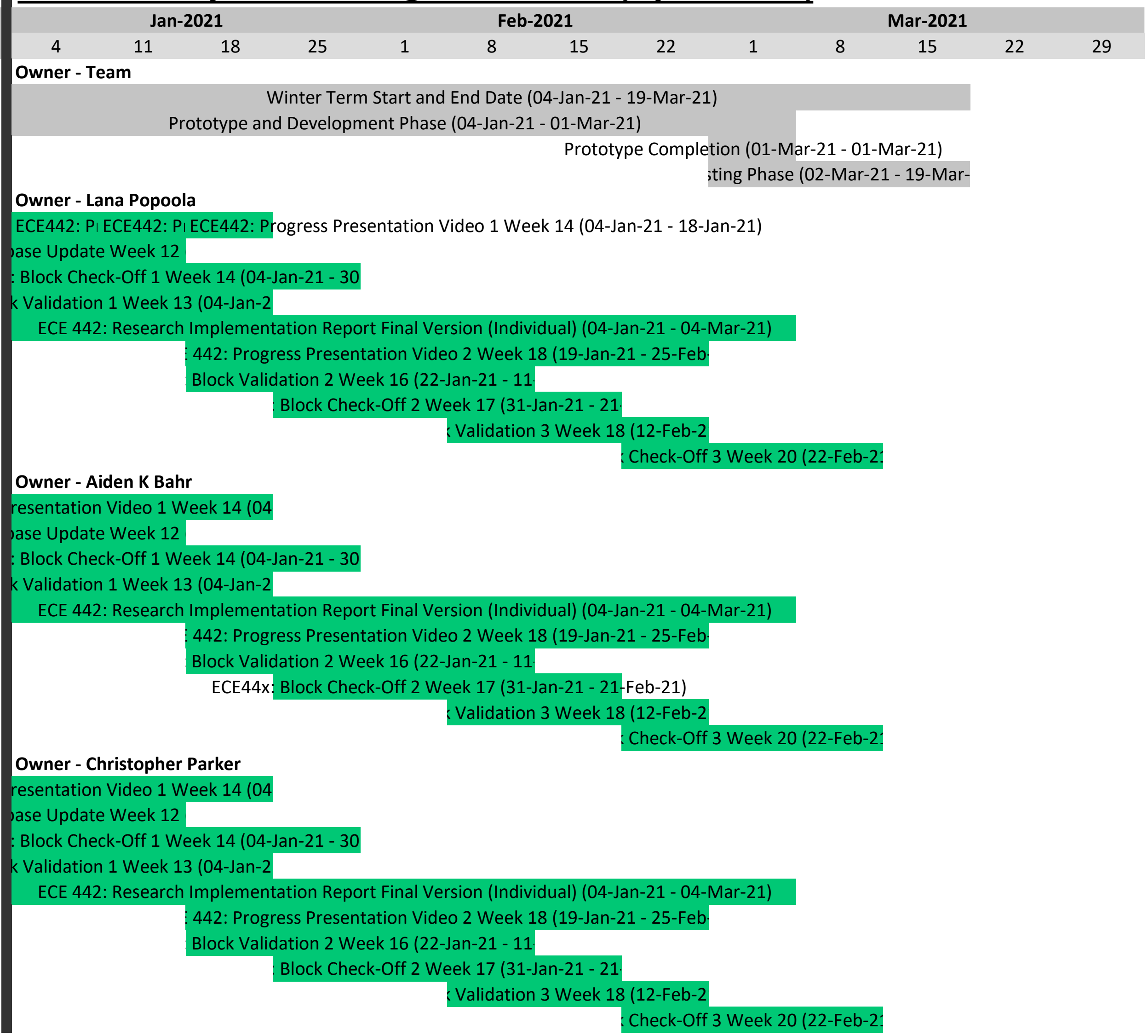
Board - Project Planning For Fall Term (by months)

	Start	End
Owner - Team		
ECE441: Biweekly Progress Videos (W	08-Oct-2020	03-Dec-2020
Research Phase(Research Phase)	08-Oct-2020	31-Oct-2020
ECE441: Biweekly Progress Videos (W	08-Oct-2020	19-Nov-2020
ECE441: Project Partner Update for V	08-Oct-2020	03-Dec-2020
Fall Term Start and End Date(Fall Ter	08-Oct-2020	11-Dec-2020
Project Scope Meeting(Project Scope	13-Oct-2020	13-Oct-2020
Instructor Scope and Requirements M	15-Oct-2020	16-Oct-2020
Network Meeting(Network Meeting)	27-Oct-2020	27-Oct-2020
Communication Evaluation with Rach	30-Oct-2020	30-Oct-2020
Prototype Phase(Prototype Phase)	01-Nov-2020	11-Dec-2020
Instructor Architecture Meeting(Instr	09-Nov-2020	09-Nov-2020
Tech Demos(Tech Demos)	11-Dec-2020	11-Dec-2020
Owner - Lana Popoola		
ECE 441: Team Protocols and Standa	08-Oct-2020	15-Oct-2020
ECE441: Biweekly Progress Videos (W	08-Oct-2020	22-Oct-2020
ECE441: Block Diagram Draft(ECE441	08-Oct-2020	05-Nov-2020
ECE441: Project Executive Summary(	08-Oct-2020	15-Oct-2020
ECE441: Research Implementation Re	08-Oct-2020	03-Dec-2020
ECE441: Teamwork Reflection Paper(	08-Oct-2020	19-Nov-2020
ECE441: Technical Demonstration(EC	08-Oct-2020	11-Dec-2020
Instructor System Architecture Meeti	08-Oct-2020	19-Nov-2020
Team Communication Evaluation(Tea	08-Oct-2020	30-Oct-2020
Prototype of Microcontroller PCB(Pro	11-Dec-2020	11-Dec-2020
Owner - Aiden K Bahr		
Introductory Email & Initial Discovery	05-Oct-2020	08-Oct-2020
ECE 441: Project Charter(ECE 441: Pro	08-Oct-2020	12-Nov-2020
ECE 441: Team Protocols and Standa	08-Oct-2020	15-Oct-2020
ECE441: Block Diagram Draft(ECE441	08-Oct-2020	05-Nov-2020
ECE441: Engineering Requirements D	08-Oct-2020	15-Oct-2020
ECE441: Project Partner Update for V	08-Oct-2020	12-Nov-2020
ECE441: Research Implementation Re	08-Oct-2020	03-Dec-2020
ECE441: Teamwork Reflection Paper(	08-Oct-2020	19-Nov-2020
ECE441: Technical Demonstration(EC	08-Oct-2020	11-Dec-2020
Instructor System Architecture Meeti	08-Oct-2020	19-Nov-2020
Project Partner Update (Week 4)(Pro	08-Oct-2020	22-Oct-2020
Team Communication Evaluation(Tea	08-Oct-2020	30-Oct-2020
Prototype of Power PCB(Prototype o	11-Dec-2020	11-Dec-2020
Owner - Christopher Parker		
ECE 441: Project Charter(ECE 441: Pro	08-Oct-2020	12-Nov-2020
ECE 441: Team Protocols and Standa	08-Oct-2020	15-Oct-2020
ECE441: Biweekly Progress Videos (W	08-Oct-2020	15-Oct-2020
ECE441: Biweekly Progress Videos (W	08-Oct-2020	05-Nov-2020
ECE441: Engineering Requirements D	08-Oct-2020	15-Oct-2020
ECE441: Project Partner Update for V	08-Oct-2020	12-Nov-2020
ECE441: Research Implementation Re	08-Oct-2020	03-Dec-2020
ECE441: Teamwork Reflection Paper(	08-Oct-2020	19-Nov-2020
ECE441: Technical Demonstration(EC	08-Oct-2020	11-Dec-2020
Instructor System Architecture Meeti	08-Oct-2020	19-Nov-2020
Team Communication Evaluation(Tea	08-Oct-2020	30-Oct-2020
Sever to Device communication Proto	11-Dec-2020	11-Dec-2020



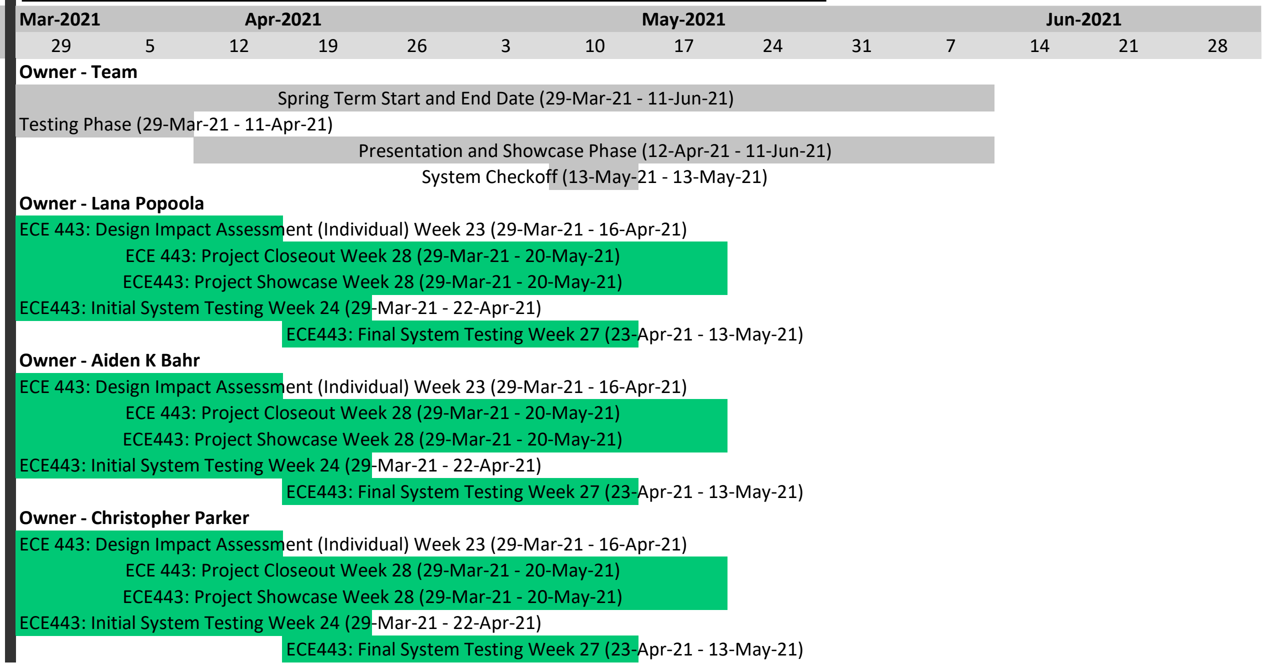
Board - Project Planning For Winter (by months)

	Start	End
Owner - Team		
Winter Term Start and End Date(Wint	04-Jan-2021	19-Mar-2021
Prototype and Development Phase(Pı	04-Jan-2021	01-Mar-2021
Prototype Completion(Prototype Con	01-Mar-2021	01-Mar-2021
Testing Phase(Testing Phase)	02-Mar-2021	19-Mar-2021
Owner - Lana Popoola		
ECE442: Progress Presentation Video	04-Jan-2021	18-Jan-2021
ECE 442: Project Database Update W	04-Jan-2021	14-Jan-2021
ECE44x: Block Check-Off 1 Week 14(E	04-Jan-2021	30-Jan-2021
ECE44x: Block Validation 1 Week 13(E	04-Jan-2021	21-Jan-2021
ECE 442: Research Implementation R	04-Jan-2021	04-Mar-2021
ECE 442: Progress Presentation Videc	19-Jan-2021	25-Feb-2021
ECE44x: Block Validation 2 Week 16(E	22-Jan-2021	11-Feb-2021
ECE44x: Block Check-Off 2 Week 17(E	31-Jan-2021	21-Feb-2021
ECE44x: Block Validation 3 Week 18(E	12-Feb-2021	28-Feb-2021
ECE44x: Block Check-Off 3 Week 20(E	22-Feb-2021	14-Mar-2021
Owner - Aiden K Bahr		
ECE442: Progress Presentation Video	04-Jan-2021	18-Jan-2021
ECE 442: Project Database Update W	04-Jan-2021	14-Jan-2021
ECE44x: Block Check-Off 1 Week 14(E	04-Jan-2021	30-Jan-2021
ECE44x: Block Validation 1 Week 13(E	04-Jan-2021	21-Jan-2021
ECE 442: Research Implementation R	04-Jan-2021	04-Mar-2021
ECE 442: Progress Presentation Videc	19-Jan-2021	25-Feb-2021
ECE44x: Block Validation 2 Week 16(E	22-Jan-2021	11-Feb-2021
ECE44x: Block Check-Off 2 Week 17(E	31-Jan-2021	21-Feb-2021
ECE44x: Block Validation 3 Week 18(E	12-Feb-2021	28-Feb-2021
ECE44x: Block Check-Off 3 Week 20(E	22-Feb-2021	14-Mar-2021
Owner - Christopher Parker		
ECE442: Progress Presentation Video	04-Jan-2021	18-Jan-2021
ECE 442: Project Database Update W	04-Jan-2021	14-Jan-2021
ECE44x: Block Check-Off 1 Week 14(E	04-Jan-2021	30-Jan-2021
ECE44x: Block Validation 1 Week 13(E	04-Jan-2021	21-Jan-2021
ECE 442: Research Implementation R	04-Jan-2021	04-Mar-2021
ECE 442: Progress Presentation Videc	19-Jan-2021	25-Feb-2021
ECE44x: Block Validation 2 Week 16(E	22-Jan-2021	11-Feb-2021
ECE44x: Block Check-Off 2 Week 17(E	31-Jan-2021	21-Feb-2021
ECE44x: Block Validation 3 Week 18(E	12-Feb-2021	28-Feb-2021
ECE44x: Block Check-Off 3 Week 20(E	22-Feb-2021	14-Mar-2021



Board - Project Planning For Spring (by months)

	Start	End
Owner - Team		
Spring Term Start and End Date(Sprin	29-Mar-2021	11-Jun-2021
Testing Phase(Testing Phase)	29-Mar-2021	11-Apr-2021
Presentation and Showcase Phase(Pr	12-Apr-2021	11-Jun-2021
System Checkoff(System Checkoff)	13-May-2021	13-May-2021
Owner - Lana Popoola		
ECE 443: Design Impact Assessment (	29-Mar-2021	16-Apr-2021
ECE 443: Project Closeout Week 28(E	29-Mar-2021	20-May-2021
ECE443: Project Showcase Week 28(E	29-Mar-2021	20-May-2021
ECE443: Initial System Testing Week :	29-Mar-2021	22-Apr-2021
ECE443: Final System Testing Week 2	23-Apr-2021	13-May-2021
Owner - Aiden K Bahr		
ECE 443: Design Impact Assessment (	29-Mar-2021	16-Apr-2021
ECE 443: Project Closeout Week 28(E	29-Mar-2021	20-May-2021
ECE443: Project Showcase Week 28(E	29-Mar-2021	20-May-2021
ECE443: Initial System Testing Week :	29-Mar-2021	22-Apr-2021
ECE443: Final System Testing Week 2	23-Apr-2021	13-May-2021
Owner - Christopher Parker		
ECE 443: Design Impact Assessment (	29-Mar-2021	16-Apr-2021
ECE 443: Project Closeout Week 28(E	29-Mar-2021	20-May-2021
ECE443: Project Showcase Week 28(E	29-Mar-2021	20-May-2021
ECE443: Initial System Testing Week :	29-Mar-2021	22-Apr-2021
ECE443: Final System Testing Week 2	23-Apr-2021	13-May-2021



3 Scope and Engineering Requirements Summary

3.1 Universal Requirements

The universal constraints are requirements that all projects had to follow. The requirements ensure that all projects are held to a professional standard while encouraging original and well-planned work.

1. All wire connections to PCBs and going through an enclosure (entering or leaving) must use connectors.
2. The final system must contain one (formerly two) of the following: a student designed PCB, a custom Android/PC/Cloud application, significant utilization of a specialized software required by the project.
3. The project must meet the required 'Work-level' of 56.
4. The system may be no more than 50% built from purchased 'modules.
5. The system may not include a breadboard.

3.2 Engineering Requirements

Short Name	Project Partner Requirements	Engineering Requirements
Configurability	Must be configurable	The system must display at least 4 different brightness levels for a minimum of 15 seconds that work for each animation (reactive and nonreactive).
Device Power	The device must have only one power input	The system will power 3 sets of 20 LEDs.
Modularity	Must be modular	The system will consist of at least 3 LED bars, where each bar has 20 LEDs on it.
Reacting to Sound	Must react to sound	The system will have at least one animation that reacts to a frequency range from 60 to 250 Hz.
Responsiveness	The device must change in real-time with the host's commands	The system responds to host commands within 100 ms.
User Friendly	Must be user friendly	The system must be usable by 9 out of 10 people within 10 minutes of beginning setup.

Short Name	Project Partner Requirements	Engineering Requirements
Variety	The device must have a variety of animations for hosts to choose from	The system will have at least 10 animations (sound reactive or non-reactive)
Wireless Communication	Must communicate wirelessly	The system will receive hexadecimal color data from a wireless host and change color accordingly

Table 1: Engineering Requirements for the how.dance project

3.3 Summary

Our project can be broken down into three main parts depicted by the requirements written above. First, it is an LED light strip that a consumer must have full control over. The user interface must allow for a variety of colors, animations, and brightness levels to be chosen for this part of the project to be successful. Requiring the device to be modular and user-friendly also falls under this category, since consumers expect an LED strip to be easy to use in their unique space. The device power requirement ensures that no matter where a user sets up their light strip, they will only need access to a single outlet. This is a pitfall for many existing LED products, making our light bars a more desirable option.

Secondly, our project is an audio visualizer. For these reasons, we require that the system will react to sound, specifically bass frequencies. This requirement ensures that our device will behave the way a user would expect it to when concert music is playing. The lights must move to the beat of the music; otherwise, the animations will look random and unpleasant to the eyes.

Finally, our project is a wireless synchronized light system. For this aspect of the project to work, we require that our system can communicate wirelessly and responsively. When a concert host changes the light color on their computer, they expect everyone's LED strip to react the same way. Likewise, if a DJ wants to switch animations at the exact moment the beat drops in the song, we need a system to be responsive. Our requirements ensured that every message would be encoded in a way that could be transmitted wirelessly and every receiving device could translate correctly. Requiring a response time of less than 100 ms ensures that the lights will always change when the host wants them to. With all of these requirements combined, we have created a unique goal that combines three ambitious projects into a single functional product.

4 Risk Register

4.1 Risk Register Table

Risk ID	Risk Description	Risk Category	Risk Probability	Risk Impact	Performance Indicator	Responsible party	Action Plan
R1	Time Management	Timeline	75%	M	Missed project Milestones or late/unsubmitted assignments	Aiden	Reduce
R2	Procrastination	Timeline	50%	M	Incomplete artifacts or lack of team member communication	Aiden	Reduce
R3	Team member contracts COVID-19	Health	10%	H	Symptoms of COVID-19	Chris	Avoid
R4	Project Compatibility	Technical	20%	H	Project Blocks are not compatible	Chris	Reduce
R5	Faulty PCB	Technical	60%	M	PCB doesn’t behave as expected	Emanuel	Reduce
R6	Communication Disruption	Communication	5%	H	Communication between the project partner and the team is disrupted	Aiden	Reduce

Table 2: Risk Register table

4.2 Evaluation of Risks

After drafting the project requirements that would guide what the project needed to do, our project team created a table of possible risks that could occur during the research, design, and implementation phases of the project. Over the past nine months, only two of the six risks occurred, both of which had the anticipated impacts on the project. The first risk that occurred was Risk ID R2, Procrastination of a team member. Given that each team member has many responsibilities such as work, school, family, and extracurricular activities, this risk was expected. Since this risk was expected, it didn't affect the project in a major way; however, it did require the team to meet to reestablish expectations and offer assistance. These meetings also served as a way to gather progress updates from each team member.

The Second risk that occurred was Risk ID R6, Communication Disruption between the project team and project partner. Given that the probability of this risk occurring was low and anticipated, the project team was impacted immensely as this disruption occurred while needing to revise two engineering requirements that needed project partner approval. Even though this risk occurred, the project team responded appropriately by contacting the Course Instructors and requesting assistance. This assistance came in the form of a Course Instructor inheriting the Projector Partner title and approving the request to modify the Engineering Requirements. We are still unsure what caused the communication disturbance between the team and project partner, only that the projector partner missed scheduled meetings and stopped communicating via their email.

5 Future Recommendations

5.1 Improve Current output of the Power Converter

Currently, the power converter implemented within this system has a maximum current output of 1.5 Amps dc. This maximum current output limits the number of LED bars that can be plugged into the system at once without an LED bar connector being connected to the output side of an LED bar. While our original goal was to allow users to connect as many LED bars together as necessary without an LED bar connector, users are now limited to connecting one bar followed by an LED bar connector and repeating that process until the desired number of LED bars is reached. This is due to our design of the electrical circuit as the LED bars require 5 volts to be supplied to have the highest light brightness. To achieve this, for every 20 LEDs, 5 volts is added from a 12 volt line to keep the brightness constant regardless of the number of LED bars connected to the system.

Recommendations

When doing the design of the power converter, do not use a Buck Convert that has an output limit of 1.5 Amp as this is what limits the number of LEDs that can be connected to the system. Instead, plan to use a voltage converter that converts 12 volts to 5 volts with a higher current output that fits the number of LEDs that you want to have connected in a single strip. You will still need to run a 12 volt voltage line as 5 volts will need to be reintroduced into the system to keep the brightness of the LEDs constant.

5.2 Decrease Power PCB Footprint

Currently, the Power PCB is 56mm x 41mm x 1.5mm that contains nine different electrical components and six sets of header pins. While there was no original size specification that the Power PCB had to be, every PCB revision resulted in a smaller footprint. The current version of the PCB utilizes mountable surface components; however, the components that were chosen to be mounted on the PCB were not placed by a pick and place machine. Instead, the components were hand solder onto the board, which required the components to be big enough to be soldered using a soldering iron. This resulted in the footprint of the PCB being larger than that of a PCB footprint the utilized a pick and place machine.

Recommendations

When researching and designing a new Power PCB, design the Power PCB with the utilization of a pick and place machine in mind. This will enable the footprint of the PCB to be reduced. Also, three of the six sex of headers pins can be eliminated as they are to be used for debugging the PCB.

5.3 Use Different Connectors

Currently, the system uses Phoenix Connectors to connect the LED bars to the main box and the LED bar connectors. In comparison, our original goal was to use magnetic connectors to make plugging and unplugging the LED bars from the system easier on the end-user. However, we could not invest in using magnetic connectors as a majority of the funding was invested in our enclosure and PCB. Therefore, we had to find an alternative connector type to use: four pin and three pin Phoenix Connectors.

Recommendations

When assigning funding for the project, assigned funding for the research and design of magnetic connectors to be used. Using magnetic connectors will make the setup process for the end-user easier as no force will be required to plug in the LED bars to the system. Using magnetic connectors will also make the product stand out when compared to top LED brands such as Phillips hue, which does not use magnetic connectors [6].

5.4 Decrease System Enclosure Footprint

Currently, the System Enclosure is 140mm x 150mm x 34mm and contains two Power PCBs, the Microcontroller PCB, and connectors for the input and output. While there was no original size specification that the System Enclosure had to be at the time of planning, the desire to make the encounter as small as possible was sought after. The ideal size that had been thought of was 77mm x 77mm x77mm to make the system as inconspicuous as possible; however, as components were developed, the System Enclosure increased in size house those components.

Recommendations

If the recommendations concerning using different connectors and decreasing the Power PCB footprint will directly affect the final size of the System Enclosure. Knowing this, ensure that the dimensions for the Power PCB, Microcontroller PCB, and connectors are finalized before designing the enclosure. Since the current version of the enclosure houses three different PCBs (two Power PCBs and a Microcontroller PCB), these three PCBs could also be combined into a single multi-layered PCB to reduce the footprint size of the System Enclosure.

5.5 Use an Asynchronous Web Server

The system was originally meant to run on a synchronous web server, meaning the user interface web app ran independently from the animation code. This had to be changed due to an implementation requirement for the captive portal WiFi login screen. The asynchronous web server must be refreshed as part of the main loop in the Arduino code running on the device. This causes delays in receiving messages and weird stutters in the animations, and poor reactiveness from the microphone.

Recommendations

Rewrite the captive portal login code to use an asynchronous web page. For the portal to behave the same as the current version, use PHP to develop the web page. Using a prewritten library for this part ensures the captive portal will open correctly when a user connects their phone to the device, but it doesn't allow the flexibility that writing an asynchronous version does.

5.6 Have the User Interface Communicate Locally

The user interface and wireless host both communicate through PubNub in the current state of the project. It is entirely unnecessary for the user interface to communicate this way, since the interface web page is hosted directly from the ESP-32. This causes the latency that the wireless host sees to be seen by the user as well.

Recommendations

Rewrite the user interface webpage to communicate directly with the ESP-32. Since the board is already connected to wifi, messages can be sent over the network directly to the IP address of the device. If you use a static IP address this will never change. Using a static IP has the added benefit of ensuring that every user's setup process is the same since the web page is hosted at a randomly assigned IP in the current state.

5.7 Avoid the PubNub Arduino SDK

While most of the code documentation for PubNub is great, their Arduino SDK is not. The limitation of the service on Arduino is the feature set. All you can do is send a message to a channel and listen for messages from a channel. This sounds fine since all this project needs PubNub for is receiving messages. The problem is that there is no way for the Arduino to tell that there isn't a new message to receive, and it should carry on with what it was doing. In the current project, the only way to prevent the Arduino from getting stuck in an infinite loop while waiting for a message is to send another message. This means that whenever an animation is playing, the PubNub host is constantly sending the same message repeatedly. This is a waste of bandwidth and money, since PubNub charges based on the number of messages sent.

Recommendations

Don't use PubNub for a future version of this project. If you want to market a scalable, low latency, real-time communicating LED strip, it would be best to host the communication servers yourself. This way, you have total control over what data gets sent, how it gets sent, and how it gets received at the other end. You also have full control over encryption and don't have to worry about another company tracking the data from your customers.

5.8 Interface Improvements

The interface of the current version meets the engineering requirements of the project, but they don’t allow for the most convenient use of the product. In order for the product to be an instant hit when it goes to market, people need to be able to use it for whatever their unique needs are without having to complain to customer service first. The first addition to the user interface needs to be a method to input concert host codes. The device currently operates on a single channel, rather than having a separate channel for each device and each host.

Recommendations
To change hosts controlling a device, add an HTML input box that takes the channel name. Then, in the Arduino code, check to see if that box is populated and set the PubNub channel to that string instead of the default. Additional changes:
Add a queue button to the wireless host. This way, DJs can plan their light shows before their show and while they are performing all they need to do is press next. A save and load feature on top of this would also be nice. In the user interface, add a way for users to save their favorites for easy access. More animations are necessary before an official release.

6 References

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[2] R. Engel, “5 common causes of electrical fires,” *Fire Rescue 1*, 24-Jul-2020. [Online]. Available: https://www.firerescue1.com/fire-products/firefightingtools/articles/5-common-causes-of-electrical-fires-olFt6TUMOsWg7re2/. [Accessed: 18-Jan-2021].

[3] D. Russo, “Chris Martin, John Legend, Bono and the future of the live streamed concert beyond coronavirus,” CNBC, 20-Mar-2020. [Online]. Available: https://www.cnbc.com/2020/03/19/chris-martin-bono-and-future-of-virtual-concert-after-coronavirus.html. [Accessed: 19-May-2021].

[4] E. Helm, “Benefits of LED Technology in Industrial Facilities,” Facility Executive, 05-Feb-2020. [Online]. Available: https://facilityexecutive.com/2020/01/benefits-of-led-technology-in-industrial-facilities/#:~:text=Due to their low energy,pounds of CO2 per year. [Accessed: 19-May-2021].

[5] “Demographics of Internet and Home Broadband Usage in the United States,” *Pew Research Center: Internet, Science & Tech*, 12-Jun-2019. [Online]. Available: https://www.pewresearch.org/internet/fact-sheet/internet-broadband/. [Accessed: 18-Jan-2021].

[6] Philips Hue, “Lightstrip Plus base V4 80 inch,” Philips Hue. [Online]. Available: https://www.philips-hue.com/en-us/p/hue-white-and-color-ambiance-lightstrip-plus-base-v4-80-inch/046677555337#features. [Accessed: 18-May-2021].