Initial Project Proposal

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1.0 Description of Problem:

Adding a visual element to audio playback creates a deeper connection in the audience. This allows for the creation of an *experience*, rather than just an occurrence. It is often difficult to create an audio-visual experience within economic constraints. Existing solutions are often expensive, non-customizable, and non-modular. Customers desire an inexpensive, customizable plug-and-play device that instantly connects with their smartphones for use with streaming services.

2.0 Proposed Solution:

The team proposes an alternative device to the current audio-visual enhancing devices that are currently being produced. Our device would create a solution that incorporates a system of LED lights and generates synchronous outputs that would elevate the visual impact in response to music.



The functional evaluation of our prototype would be based on the following criteria:

* The ability of our LED devices to be controlled by a mobile device, verified through the demonstration of visual effects in response to inputs from the mobile device.
* The ability of our LED devices to respond to audio inputs, demonstrated by visual effects in response to music inputs from the mobile device.
* The ability of our device to provide a synchronized visual output with multiple LED lights.
* The ability of our device to capture and adapt to specific frequencies in musical inputs and generate a visual response based on the tempo of specific frequencies.
* The ability for an end user to install and establish a bluetooth connection with our device with minimal complexity.

3.0 ECE477 Course Requirements Satisfaction

3.1 Expected Microcontroller Responsibilities

Our device would use the microcontroller for the following functions: on-board signal processing; i.e. frequency filtering/isolation, frequency assignment to LED patterns and colors, and establishing an I/O connection with a mobile device through an external bluetooth device.

3.2 Expected Printed Circuit Responsibilities

We will develop a PCB with following features:

1. Power Regulator
2. External Bluetooth Device
3. LED Drivers
4. Microcontroller

Other functionality may be included as the ECE477 design semester progresses.

4.0 Market Analysis:

In 2021, over 20 million students were enrolled in higher education [1]. A popular past-time of this demographic is house parties, where loud music is a staple in a party environment. Our device would appeal to this demographic, transforming a mostly-audio experience into an audio-visual experience. Spotify alone has 195 million subscribers worldwide [2]. Users of streaming apps such as Spotify would be able to instantly use our device to create audio-visual experiences. This device could also appeal to establishments like restaurants and bars that wish to enhance the experience of their customers. Similarly, stadiums could use this device to help create excitement for events.

5.0 Competitive Analysis:

5.1 Preliminary Patent Analysis:

Prior art proposing the idea of music reactivity or visualization through displays exists previously, and the relevant patents to their designs are described below. Our project is expected to function similarly to them, and so their existence helps protect against any possible patent infringement.

5.1.1 - China Patent Application CN2261133Y:

**Patent Title:** “Music-light electronic changer”

**Patent Holder:** Expired **Patent Filing Date:** 3 December, 1994

This patent [3], describes “A signal pickup and decomposition circuit is used for analyzing a music signal into a sound intensity, sound height and sound quality signal which can represent the details of music.”, which is very similar to what our proposed system is trying to accomplish. The patent goes into detail of how to create an audio-visual experience, combining music theory and colorimetry theory. This is done by having the characteristics of the music playing: loudness, pitch, and tone) be the parameters used to control the colored lights’ elements: brightness, tone, and color saturation.

Our design hopes to give much more customizability of the color response of the display, while still creating a vibrant audio-visual experience through realtime music reactivity of the lights.

5.1.2 - US Patent Application US9561449B2:

Patent Title: LED lighting device and wireless speaker

**Patent Holder:** Zhejiang Shenghui Lighting Co Ltd

**Patent Filing Date:** 3 September, 2014

This patent [4], is most similar to our proposed design, comprised of “...an LED light source module configured to emit light…”, as well as “...a DLNA wireless communication module configured to receive and process audio signals and commands transmitted from a smart terminal… [to control] the LED lighting device…”, and “and a speaker unit configured to play audio signals received”, as well as all the relevant power sources needed to drive these parts. The mentioned “smart terminal” is later specified as being “...a smart phone, a smart television, a tablet, a desktop, etc…”.

For our design, much of the audio signal processing will be done by microcontroller, while our “smart terminal”, a phone app in this case, would be a device controlling color and other parameters. as it aims to function very similarly to our proposed project.

5.1.3 - US Patent Application US8461443B2:

**Patent Name:** Control of light in response to an audio signal

Patent Holder: TP Vision Holding BV

**Patent Filing Date:** 25 October, 2007

This patent [5], has a similar functionality to our project design, but goes into much more detail of the functionality of the light control parameters designed to “...allow musical content and lighting to be freely combined, especially for a very wide range of audio signals…” and “...to provide a method and apparatus that can automatically control lighting such as ambient lighting so that changes in lighting perceptually correspond to changes in audio signals…”. This “method” referenced throughout is described as being able to extract relevant “semantic content of the audio signal” and translate that into “[l]ighting control parameters”.

A major advantage that is highlighted in this patent is “[t]he ability to provide time aligned lighting effects…”. Synchronizing our LEDs’ visual response with our audio was a major discussion point, and hopefully this patent will be able to point us in the right direction.

5.2 Commercial Product Analysis:

Comprehensive web searches through Google and online marketplaces, such as Amazon, were done to find commercial products that perform similarly to our proposed project design. The products described below are ones that we felt were functionally similar to our project, and/or provided us with inspiration for said project.

5.2.1 Philips Hue

Philips’ line of Hue Lights [6] were the main inspiration for this project, being the most widely-known product line that accomplishes the audio-visual mix that we are proposing.

Philips offers a wide variety of lights, from smart bulbs to LED strips, allowing for customers to find the product that fits their specific needs. The ecosystem of these products allows for modularity of these lights, but at the cost of full customizability for the user. The user can use bluetooth to connect multiple lights, but this comes with the cost of limited functionality. It highly recommended to use the proprietary Bridge device for full functionality, which is another item you have to add to your cart.

Our product hopes to be as modular and self-integrated as the Hue lights are; if we want to add more than one or two lighting fixtures to our design, it should be seamless and hassle-free to do so.

5.2.2 Douk Audio LED Audio Level Display

This product [7] offers a much more basic package and functionality than the Philips Hue Lights, but with that comes cost effectiveness and an all-in-one package. The audio visualization is done through environmental sound detection through a microphone on the back of the device, and the different Audio Displays come with varying levels of definition, from a 16-bit display, all the way up to a 128-bit display. This leads to the product needing audio to be played through speakers (not included), being subject to ambient noises, and means that there is no separation between different frequency bands.

Our project hopes to be able to be an all-inclusive design, while also having a much more fleshed out visual display that reacts to the audio being played.

5.2.3 ViVi - Visual Vibes

This product [8] is most similar in direction and purpose to our design, with the multiple modular offerings like the Philips Hue. The most expensive of the three in terms of per piece of equipment, and utilizing the proprietary controller idea, this product is similar in function to ours, but hopefully not cost.

This product is not “commercial” in the traditional sense, as it was crowdfunded through Indiegogo, and its availability is questionable, but from a design perspective, it is claiming to do everything that we are setting out to do as well: bluetooth audio connectivity, precision beat recognition and frequency association, and a plug-and-play final product.

5.3 Open Source Project Analysis:

The idea of combining music with reactive visualization through lights or other forms of displays is an ever-expanding idea throughout tech, with LEDs becoming cheaply available and processing power increasing yearly, making concurrent audio signal processing much more feasible. These factors allow hobbyists to make projects akin to ours, and provide those similarly interested with the resources they used.

5.3.1 Audio Reactive LED Strip

This project [9] is licensed under MIT license. The only requirement is the original license and copyright notice must be preserved. This project outlines two forms, the first uses a computer application to run all signal processing and LED visualization calculations. It then sends this information through WiFi to the microcontroller which only sends the visualization routines to the LEDs. Our project would run the calculations on the microcontroller itself. This would allow us to generalize our audio input to any bluetooth stream. We can consider using the WiFi connection for LEDs to app synchronization for our project. The project’s second form is more similar to our intended project, it uses a USB audio-in connected to a microcontroller to drive the LEDs. Both forms result in a very interesting 1-D visualization which we can consider implementing a similar form in our project.

5.3.2 LedFx

This project [10] is licensed under GPL-3.0. Requirements for use include preservation of original license and copyright notice, changes must be stated, the source must be disclosed, and GPL-3.0 license must be used. This project is similar to our intended project, but requires a computer app, LedFx. Our device will instead use bluetooth streams and therefore can accept input from any device with bluetooth capabilities including computers and phones. Their project also has an API used for driving LEDs and changing configurations quickly. If time allows, this is a good addition to our project to make it easier for users to customize from the phone app.

5.3.3 Retro LED Strip Audio Visualizer

This project [11] does not have a license. It is very stylized and uses acrylic/trash bags over the LEDs for a diffusion effect. Where our project will have a bluetooth module and a power regulator on our PCB, this project uses a prebuilt logitech bluetooth to AUX device, a prebuilt power regulator, and a breadboard. All of these differences make the project’s electronics look less professional than our intended project. Their project uses a fast fourier transform on the original signal where we will plan to use low pass filters to isolate common percussion notes.

6.0 Sources Cited:

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[6] “Sync with music”. Philips-Hue. <https://www.philips-hue.com/en-us/explore-hue/propositions/entertainment/sync-with-music> (accessed Dec. 17, 2022).

[7] “Douk Audio Music Levels Light RGB LED MIC Sound Level Meter Audio Spectrum Display Analyzer”. Douk Audio & Nobsound. <https://doukaudio.com/collections/led-display/products/douk-audio-music-levels-light-rgb-led-mic-sound-level-meter-audio-spectrum-display-analyzer> (accessed Dec. 17, 2022).

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[11] “Retro LED Strip Audio Visualizer”. Yours for the making - Instructables. <https://www.instructables.com/Retro-LED-Strip-Audio-Visualizer/> (accessed Dec 17, 2022).

Appendix 1: Concept Sketch

