Direct Music Synced LED Strips

ECE 445 Design Document
Team 1: Daniel Vargas (dvarga27) , Siyan Shaikh (siyans2),
William Reinhard (wdr2)
TA: William Zhang
Fall 2020

1. Introduction

1.1 Objective

Created by renowned University of Illinois Professor Nick Holonyak, Light Emitting Diodes(LEDs) have long been established as a revolutionary technology that has shaped much of the consumer electronics industry. They provide a clean, bright, and customizable source of light that works well in combination with one another to generate everything from screen displays to home lighting. One particular use for LEDs is within LED light “strips”, which are meant to be used as a decorative electronic item to outfit your home with a colorful light display. These light strips often come with a feature to “react” to music and audio, but they have shortcomings performing reliable “audio to light” conversion.

We plan to directly connect the LED strips with music and use FFT analysis to generate broader levels of pitch differentiation. This will allow us to have the LED lights display corresponding to both sound level and pitch. To address the customizability, our goal is to either develop an application that allows for color-based pitch assignment, specific color outputs and other light-frequency related options displayed with aural direction on two separate “left” and “right” LED strips.

1.2 Background

Modern-day LED strips marketing to consumers with audio tracking capabilities are often driven by a microphone that detects sound and simply reflects the changes in sound level as changes in the intensity of the LEDs [10]. As such, there is often quite an extensive delay between when sound is picked up from the microphone and when it is accurately reflected by the LED lights that it is connected to. There is also no filter in place to remove ambient noise and no way to differentiate between someone simply speaking and the intended audio source to display. In addition, only the intensity is changed and not the color, leading to a less impressive experience. Users are limited in what can be displayed by the patterns pre-programmed by the manufacturer, and there is no way to differentiate between left or right side audio output.

Our approach is innovative because it addresses the pitfalls of currently available market products by directly connecting to the music source, enabling us to relate changes within the audio (tone, pitch, frequency, and direction) to the LED strips. We also will enable user customization and input by offering an interface to select and space color themes, patterns, and palettes.

1.3 Visual Aid

A rudimentary design of our overall system, with a computer/phone device communicating with our PCB

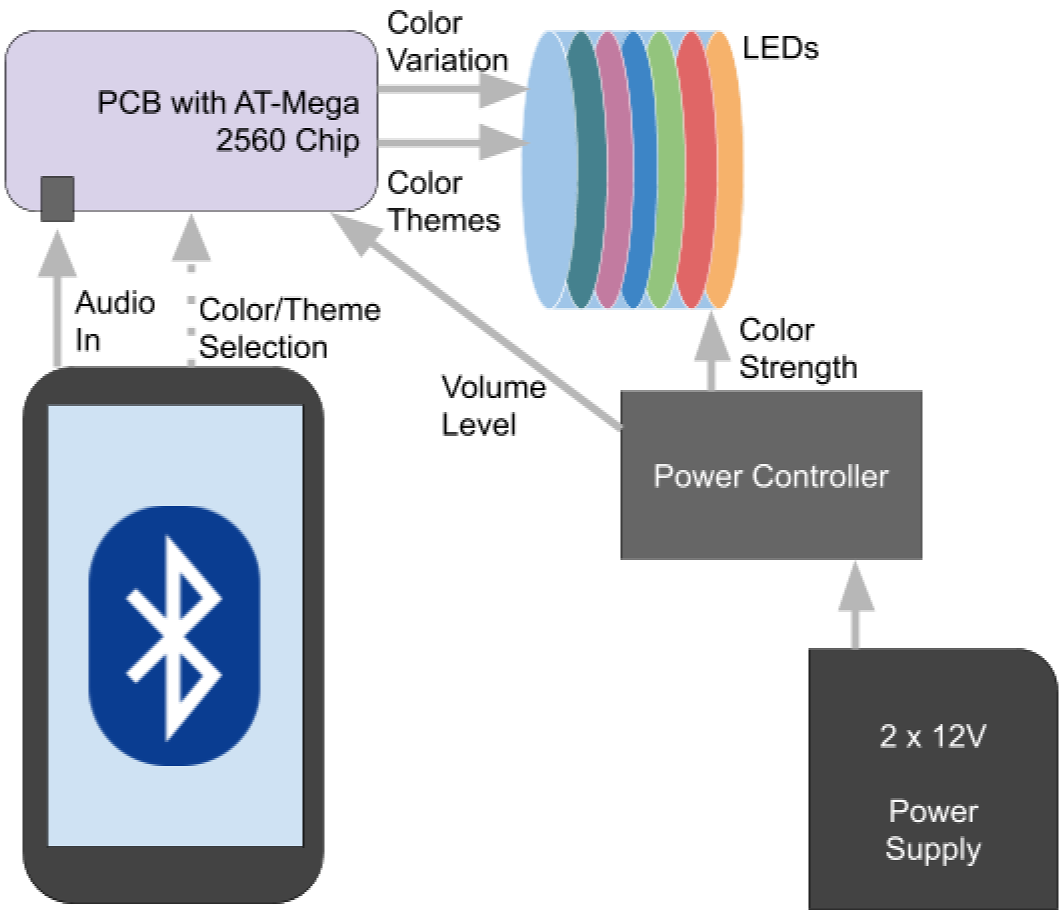

Figure 1: A simple depiction of the connected elements of music synced LEDs

1.4 High-level Requirements

- Our project must be able to reflect changes in frequency and intensity of sound by changing the LED color or change in color strength (power) at about 16 ms faster than microphone based LEDs.
- Our light strip should be able to reflect custom color selections based on five pitch ranges: Bass (20-60 Hz), Low Midrange (250-500 Hz), Midrange (500-2 kHz), High Midrange(2 kHz-4 kHz), and Presence (4 kHz-6.5 kHz), and strobe patterns based on user input from an application.
- The application will allow the user to select “color themes” to prevent colors from blending together.

2. Design

Both the LEDs and Controller Module are powered by 12V power supplies regulated by a power distribution element. Data is generated from user input via the user interface that submits requests to the back-end application, which prepares and generates the necessary data sent over Bluetooth. The actual transmission is handled by the Bluetooth driver and is sent to the FFT and PWM circuits, which in turn generate the necessary output to drive the color, intensity, and functional behavior of both the left and right LED strips.

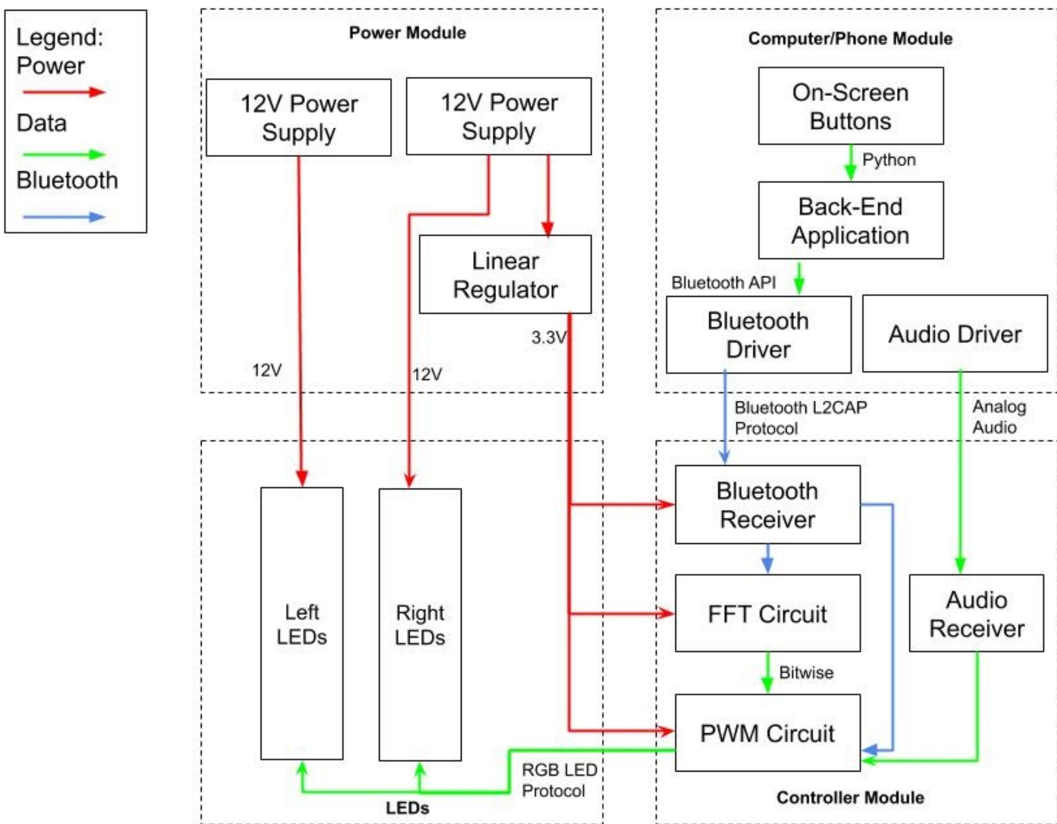

Figure 2: Block diagram of the components and modules

2.1 Power Module

2.1.1 Power Supply

Two of these 12V power supplies are responsible for powering the entirety of our circuit. The high-efficiency power supply will provide the necessary 12V at current of 700mA.

Table 1: Requirements and Verification for Power Supply

Requirements	Verification
1. Provide a voltage output of 12V +/- 5%. 2. Support load of 0.01A to 7A of current with regulation between -3% to 5%. 3. Efficiency should be higher than 85%.	1. Connect terminals to an oscilloscope and verify that the measured voltage is within 5% of 12V. 2. Connect VDD of the constant-current test circuit depicted in Figure 4 to the DC terminal labeled in Figure 3. a. Adjust R_s to deliver a maximum of 7A to the load, verified by a multimeter. b. Measure the voltage across the DC terminal to ensure it never exceeds 12V +/- 5%.

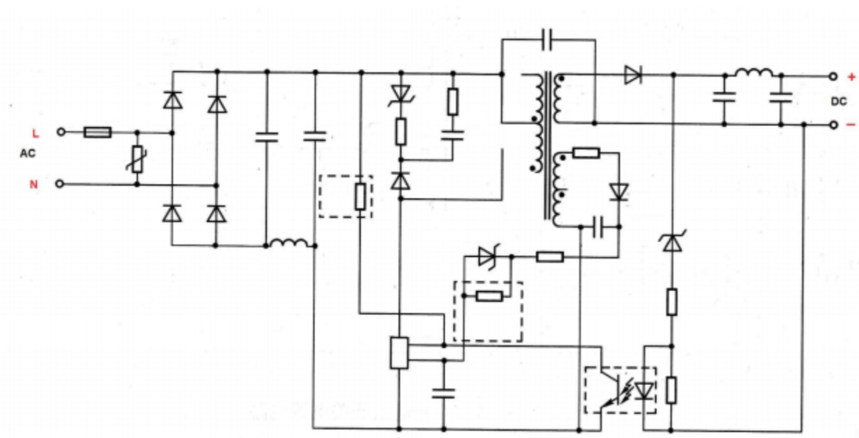

Figure 3: A schematic of the YHY-12005000 12V power supply

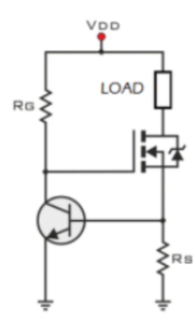

Figure 4: A schematic of the constant-current test circuit where $I_L = .07/R_S$

2.1.2 Linear Regulator

The linear regulator moderates voltage between one of the 12V power supplies and the ATMEGA chip. By stepping the voltage down from 12V to 3.3V, it ensures that we're able to provide the necessary voltage to both our LEDs and our ATMEGA chip, in addition to the Bluetooth receiver.

Table 2: Requirements and Verification for Linear Regulator

Requirements	Verification
1. Power the ATMEGA chip by providing 3.3V +/- 2% from a 12V source. 2. Can operate between 0 - 800mA. 3. Can maintain thermal stability between up to 125℃. 4. Efficiency should be higher than 80%.	1. Connect terminals to an oscilloscope and verify that the measured voltage is within 2% of 3.3V to avoid frying the chip. 2. Connect VDD of the constant-current test circuit depicted in Figure 4 to the terminal labeled V_{out} in Figure 5. a. Adjust R_s to deliver a maximum of 800mA to the load, verified by a multimeter. b. Measure the voltage across the DC terminal to ensure it never exceeds 3.3V +/- 2%. 3. During steps 1 & 2, use an IR thermometer to ensure that the chip stays below 125℃.

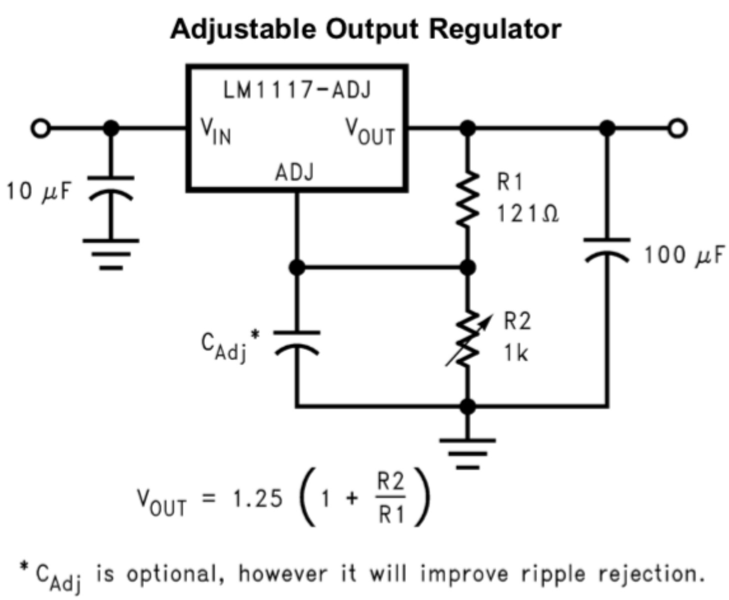

Figure 5: A schematic of a TI LM1117-3.3 linear regulator

2.2 Controller Module

2.2.1 FFT Circuit

The FFT circuit serves to analyze the different frequencies of the music inputted, providing an output that will allow the PWM circuit to determine in which of the 5 ranges the audio was. This will be essential in detecting emphasized frequencies in music.

Table 3: Requirements and Verification for Controller Module

Requirements	Verification
1. Sample at a rate of 9 kHz to obtain frequencies across the 5 different ranges (Bass, Low-Midrange, Midrange, High-Midrange, Presence). 2. Measure decibel level within +/- 5% of real decibel levels.	1. Generate a sample audio file with sounds within each of the frequency thresholds, spanning from 0 kHz to 4.5 kHz. Store the resulting output file and verify that the files are identical. 2. Use the same audio sample on a Python FFT simulation to examine decibel levels and validate that they are within 5% of the original sample.

2.2.2 PWM Circuit

The PWM circuit is one of the most important circuits in the project, as it aggregates signals from the Bluetooth and data from the audio source to determine the rate and intensity of the LED output. This circuit effectively acts as a liaison between the mobile application and the LED output, while also being in charge of determining the output to the LED light strands.

Table 4: Requirements and Verification for PWM Circuit

Requirements	Verification
1. Reflect changes in sound intensity by scaling the amount of light intensity from black to white spectrum. 2. Generate separate color outputs corresponding to whether audio is from the left speaker or right speaker. 3. Send data at speeds of up to 800Kbps.	1. Generate sound input with increasing levels of sound intensity. Verify that light intensity increases directly in accordance with sound intensity. 2. Pick songs like Queen's Bohemian rhapsody that alternate audio from left to right. Generate an input signal into the PWM controller to the LEDs at 800kbps/(2 channels * 16 bits) = 25000 Hz or 25kHz [17]. 3. Attach a multimeter to the line between the PWM circuit and the LEDs and set the multimeter to Ṽ.

	verify the corresponding frequency <25kHz.

2.2.3 Bluetooth Receiver

The Bluetooth receiver is responsible for receiving information from the phone application that dictates the theme color selection of the LEDs. This is the main interface between our PCB design and the user application and will use the L2CAP Bluetooth protocol.

Table 5: Requirements and Verification for Bluetooth Receiver

Requirements	Verification
1. Communicate with UART. 2. Transmission is received up to 80m from the user.	1. Develop a prototype app that sends a signal to the receiver, and probe the V_{in} of the PWM circuit using an oscilloscope to determine if a pulse was registered. 2. Using the same application, send a signal to the receiver, located 80m away, and probe the V_{in} of the PWM circuit to see if it reflects a pulse, using an oscilloscope.

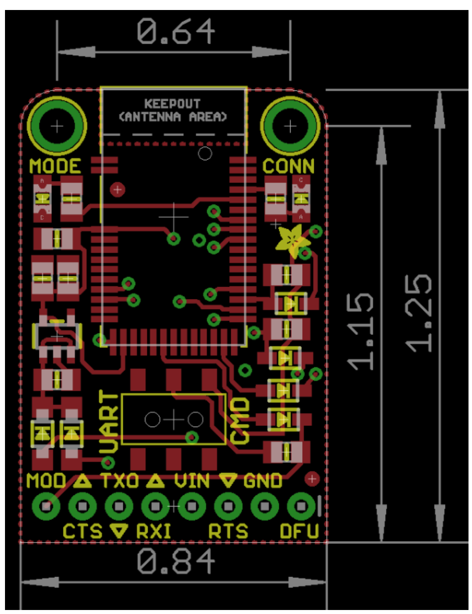

Figure 6: A schematic of a TI LM1117-3.3 Linear Regulator

2.3 LED

2.3.1 LED Strips

The LED block is made up of two sections, the Left and Right LED blocks in parallel. They are identical in every way except in the data that they receive. These blocks are made up of LEDs in parallel that will receive RGB data from the controller to change colors as the controller input changes. This will be aligned with the analog music data and match the audio being played.

Table 6: Requirements and Verification for LED Strips

Requirements	Verification
1. Receive data at speeds of up to 800Kbps to maintain color. 2. Can maintain thermal stability between -25℃ and 80℃. 3. LEDs should not visibly flicker and be able to be photographed.	1. Generate a signal from the PWM controller to the LEDs at 800kbps/(2 channels * 16 bits) = 25000 Hz or 25kHz. We should see transitions between light colors without flickering [17]. 2. During step 1, use an IR thermometer to ensure that the LEDs operating juncture never exceeds 80℃. 3. Generate a signal from the PWM controller to the LEDs at 1400kbps/(2 channels * 16 bits) = 25000 Hz or 25kHz. We should be able to record video of transitions between light colors without flickering [17].

2.4 Computer/Phone Module

2.4.1 Application

The application is the main interface with the user; allowing them to decide what theme they would like to see the LEDs show. Users will be able to choose from five different themes, each of them corresponding to a specific range from 0-4.5kHz.

Table 7: Requirements and Verification for Application

Requirements	Verification
1. Allow users selection of 5 unique themes for their LED lights. 2. The user interface should be intuitive and encourage use. 3. The interface sends out Bluetooth signal at 9600 baud. 4. Communicate with UART.	1A. Select the bass theme for the light colors. 1B. Prepare a song sample that has a significant bass component and play it. 1C. Visually inspect the LEDs to verify that they match the color of the theme selected. 1D. Repeat for Low Midrange, Midrange, High Midrange, and Presence. 2A. Develop a prototype app that sends a signal to the receiver. 2B. Attach a multimeter to the line between the Bluetooth receiver and the V_{in} terminal of the PWM circuit. 2C. Set the multimeter to $\tilde{V}$ and verify corresponding the frequency = 9600Hz. 3. Develop a prototype app that sends a signal to the receiver and probe the V_{in} of the PWM circuit using an oscilloscope to determine if a pulse was registered.

2.5 Schematics

2.5.1 Overall Schematic

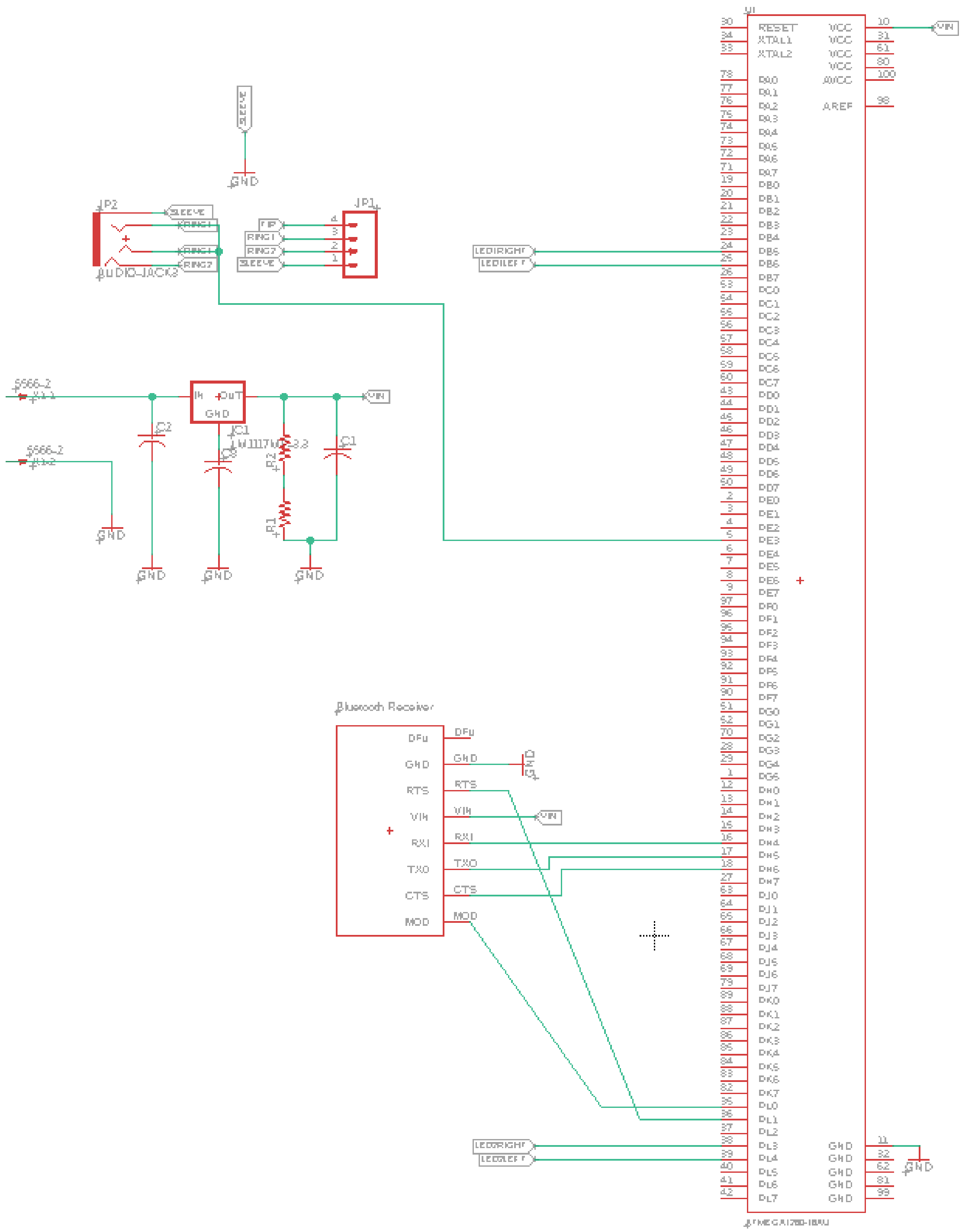

Figure 7: Total circuit schematic

2.6 PCB Layout

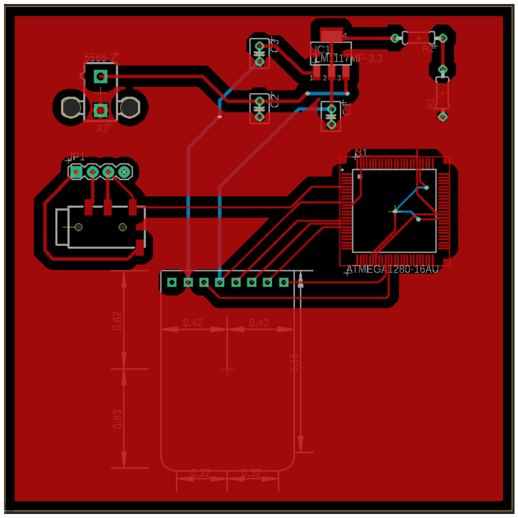

Figure 7: PCB layout diagram

2.7 Software

2.7.1 Software Flow

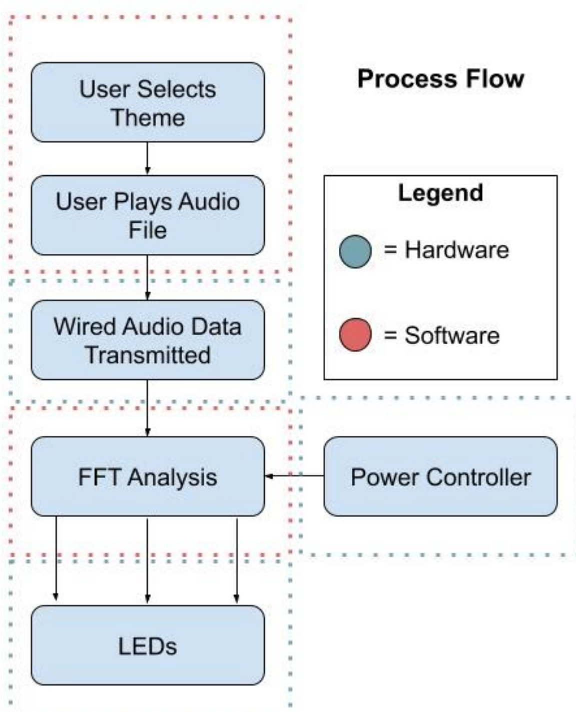

Figure 8: A flow diagram of hardware and software components

2.8 Tolerance Analysis

The most important part of our design relies on effective real-time Fast Fourier Transform (FFT) analysis of the music being played. Our sensitivity to frequencies and frequency range will depend on our FFT size, and sample rate. We must follow with the Nyquist Theorem:

$$X_c(j\Omega) = 0 \qquad \text{for } |\Omega| > \Omega_N.$$

Then $x_c(t)$ is uniquely determined by its samples $x[n] = x_c(nT)$, $n = 0, \pm 1, \pm 2, \ldots,$ if

$$\Omega_s = \frac{2\pi}{T} > 2\Omega_N.$$

Equation 1: Nyquist Theorem for sampling frequency

Equation one reads that for a sample rate Ω_s we must make sure it is greater than twice the highest frequency of the sample, Ω_s to avoid aliasing.

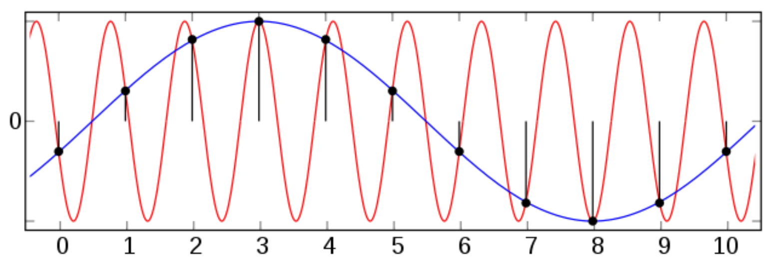

Figure 9: Example of undersampling which causes aliasing

This means our sampling rate must be double the maximum frequency we wish to measure. This will also impact our latency, as will be discussed later. The FFT is a faster version of the Discrete Fourier Transform (DFT):

$$X_k = \sum_{n=0}^{N-1} x_n e^{-i2\pi kn/N} \qquad k = 0, \ldots, N-1,$$

Equation 2: DFT equation

The DFT is where we take a finite duration signal and convert it to frequency readable spectrums.
We plan to have an FFT bin size of 256 to fit our ATMega2560 flash memory size (256 KB), and sampling at about 9000Hz. This means we can capture up to 4500Hz, which is around the upper limit of presence sound types. This also means our FFT bin size will be about 35Hz, small enough to capture pitches and distinguish between the 5 pitch ranges. These ranges are bass (20-60Hz), low midrange (250-500Hz), midrange (500-2kHz), high midrange (2k-4kHz), and presence (4kHz-6.5kHz). We have decided to cut out much of the presence range to preserve memory and processing time. Presence is based mostly on harmonics, which will be already

captured at lower frequency ranges. Our ATMega2560 will be capable of handling these calculations as it can run on a 16MHz clock cycle, and has plenty of storage for the FFT logic.

To create an accurate FFT, we will use a Python spectrogram to analyze the precision of our FFT to separate between five different pitch ranges. We will use the spectrogram to address our sampling rate to see what ranges are most typical in mp3 music files. This will also help us develop what dB cutoff to identify pitch, or find general volume increases.

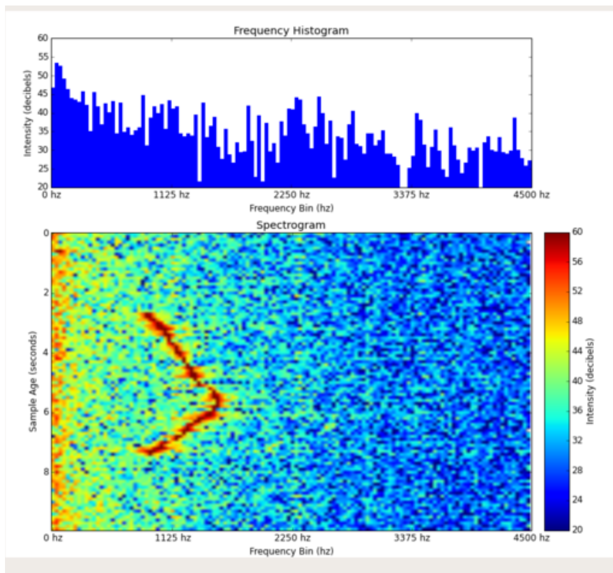

Figure 10: An example spectrogram from the resulting histogram

A significant deliverable is our faster speed as compared to microphone based LEDs. To calculate the latency of microphones, we start with the assumption that sound moves at 1100 ft/sec [14], and that the microphone is placed at about 12 in away for ideal sound pickup [12]. This will result in a pickup time of about 0.9ms. Microphones also include general latency of 2ms when going through their ADC [12]. Our audio jack can convert the digital signal to analog input in close to 0.01ms [8]. We can see an initial 2.98ms advantage in simply picking up the signal. When inspecting the controller used by general LED music converters, they run a sampling frequency of 40kHz with a 256 bin size [18]. Smaller bin size would indicate that they can fill their bin sizes faster, however, FFT calculation speeds are smaller with our 12MHz processor, with an FFT size of 256 resolved in about 16ms [16].

$$ExecutionTime = k_{FFT} N \log_2 N$$

Equation 3: FFT execution time

Equation 3 demonstrates the execution time calculation for the FFT algorithm. N is the number of bins, in our case 256, and k_{fft} is the time it takes to carry out a single FFT bin, in our case ~12 microseconds [16]. Competitors use weaker processors, running under 2MHz, relating to a

k_{fft} of about ~15ms [16]. This will result in an execution time of about 29ms. Here we can see a clear advantage of a faster processor, on top of the faster data acquisition time. Both designs use PWM circuits to relay the RGB data to the LEDs, and so will have negligible differences in timings. We want to be about 16ms faster in outputting our LEDs.

3. Cost and Schedule

3.1 Cost Analysis

3.1.1 Labor Costs

We determined our total labor cost to be $18,750, based on the labor rate of 3 graduate-level engineers at $25/hour, working 10 hours per week over the course of 10 weeks.

$$3\ Engineers\ *\ \frac{\$25}{hour}\ *\ \frac{10\ hours}{week}\ *\ 10\ weeks\ *\ 2.5\ =\ \$18,750$$

Equation 4: Total cost analysis of labor

Equation 4 demonstrates how we came to our labor cost.

Table 7: Cost Analysis Table: Labor

Partner Name	**Number of Hours**	**$ per hour**	**2.5x Multiplier**	**Total**
Daniel	100 hours	$25.00	2.5	$6,250
Siyan	100 hours	$25.00	2.5	$6,250
William	100 hours	$25.00	2.5	$6,250
Total				**$18,750**

3.1.2 Component Costs

The following chart depicts all components required to be purchased to meet all the outlined project requirements.

Table 8: Cost Analysis Table: Components

Part Name	**Description**	**Manufacturer**	**Part Number**	**Quantity**	**Part Cost**
ATMEGA2560	8-bit AVR RISC-based microcontroller	Microchip	ATMEGA2560-16AUR	2	$11.99 [3] (Digikey)
SparkFun TRRS 3.5mm Jack Breakout	3.5mm audio jack	SparkFun	TRSS_Breakout_v1	1	$3.95[13] (Amazon)

3.5mm Headphone Jack Splitter	1 female to 2 male 3.5mm headphone splitter	Koopao	M4S-BR	1	$5.99 [8] (Amazon)
BTF Lighting WS2815	144/m individually addressable LED strip	BTF Lighting	WS2815B	2	$29.88 [4] (Amazon)
Adafruit Bluefruit LE UART Friend - Bluetooth Low Energy (BLE)	A low energy Bluetooth controller with an ARM Cortex M0 core running at 16MHz, 256KB flash memory, and 32KB SRAM	Adafruit	nRF51822	2	$17.50 [2] (Amazon)
12V Power Supply	120W, 12V switching power supply.	Shenzhen Yinghui Yuan Electric Co.	YHY-1200500 0	2	Already Acquired
12V to 3.3V Low-Dropout Linear Regulator	A board that accepts up to 15V and outputs a fixed voltage of 3.3V	Texas Instruments	LM1117	2	$1.11 [6] (Digikey)
Resistor Set	Resistor set for circuit building	ECE Department	Various	1	Already Acquired
Capacitor Set	Capacitor set for circuit building	ECE Department	Various	1	Already Acquired
Crystal Oscillator	Oscillator for ATMega	TXC CORPORATIO	9B-16.000MB BK-B	4	$0.30 (Digikey)

		N			
Reset Button	Square 12mm button for debugging	SparkFun	COM-09190	1	$0.50 (Need to Order)
Catch Diode	A catch diode is used to eliminate flyback	Diodes Inc.	DFLS240L	4	$0.42 (Digikey)
5V Step-Down Converter	An IC that efficiently steps voltage down from 12V to 5V.	Linear Technology	LT3685	4	$9.57 (Digikey)
TOTAL (pre-tax)					**$70.42**

$$Grand\ Total\ =\ Labor\ +\ Parts\ Cost\ =\ \$18,750.00\ +\ \$70.42\ =\ \$18,820.42$$

Equation 5: Total cost analysis of labor and parts

Equation five realizes our total costs by combining both labor costs and our parts costs, which are our incurred expenses for making a singular version.

3.2 Schedule

The following schedule outlines a week-by-week schedule leading up to the full completion of our project and accompanying paper.

Table 9: Schedule Breakdown

Week	Daniel	Will	Siyan
9/27/20	Refine PCB	Begin developing color selection software	Select parts and order
10/4/20	Finish PCB and order	Finalize UI and connect to Bluetooth API	Verify spectrogram frequencies for ideal FFT specifications
10/11/20	Connect audio shield to controller and	Bluetooth	Assemble linear regulator the and

	verify clean signals		verify integrity
10/18/20	Start controller/FFT logic	Establish Bluetooth connection to phone and controller	Breadboard power systems to components to verify
10/25/20	Continue FFT logic and verify with LEDs	Continue Bluetooth related software	Continue FFT logic
11/1/20	Verify music amplitude to LED power relationship	Finalize color software and verify transfer via Bluetooth	Verify music amplitude to LED power relationship
11/8/20	Prepare mock demo	Prepare mock demo	Prepare mock demo
11/15/20	Verify solder connections	Solder PCB components together and verify	Test response with different music mixes
11/22/20	Test LED response speeds	Clean UI on app	Clean UI on app
11/29/20	Prepare final report	Prepare final report	Prepare final report

3.3 Contingency Plan

In the event that we are unable to return to campus and no longer have access to intended resources, we will shift our work environment to our personal homes and aggregate all physical parts together such that one partner has full access to all components. All software requirements remain unchanged, as we can easily upload/update software with online version control. Hardware assembly will be our only obstacle, so we will have to find access to a soldering station and workbench equipped with a power source, electrical measurement equipment, and a suitable audio generator (which are all available to one of our team members). Our high-level requirements and overall project design will remain the same and we will continue to work as planned on the above schedule, utilizing virtual Zoom meetings and, if needed, in person meetings for partners living nearby.

4. Discussion of Ethics and Safety

When developing this product, it is crucial to keep in mind the end users, and how our design might have an overall impact on their safety when using the product. By incorporating electrical components into our overall design, we must adhere to ethical standards and disclose any components that could potentially cause harm to the users [8].

4.1 Overheating Hazards

LEDs can reach junction temperatures up to 80°C when operating at manufacturer-recommended currents, where junction temperature is a function of ambient environment temperature, current through the LED, and amount of heat sinking material around the LED [7]. With this last parameter in mind, we aim to encase the LEDs in a translucent heat sinking material to prevent contact with skin or other sensitive objects while still providing desired exposure to light.

4.2 Electric Shock Hazards

The maximum amount of current is drawn when the three LED colors (RGB) are active, powered by a 12V supply. Each of these LEDs draws ~20mA of current, meaning that for the color white, our LED strip draws 60mA of current per segment. For a proposed LED with 20 segments per meter, the maximum current draw is 1.2A/meter [9]. This amount of current is more than enough to end a human life, so it is imperative that we ground the LED strips at multiple points to ensure multiple layers of redundancy and therefore minimize risk of our end users. In accordance with OSHA 1910.304 standards, we will ensure all wiring is properly grounded and circuits are closed loop as to prevent any shocks or other electrical hazards [5].

4.3 Seizure Warning

Users with photosensitive epilepsy may have seizures triggered by flashing lights and bold and over intensive light patterns, both of which can be produced by the LED strips featured in our design [11]. In particular, flashes between 3-60Hz are known to trigger seizures for this with underlying conditions [1]. In order to provide proper warning, we will include an epilepsy warning within our user interface to ensure users are aware of the potential light exposure. In addition, we will design our LED strips to operate at no less than 25000Hz to prevent visible flashing when in use.

4.4 Sharp Edges

In accordance with OSHA standards 1917.112, we will take necessary precautions of protecting consumers from sharp edges and pointed corners that may lead to unintended puncture wounds [15]. WIthin our project, we will ensure all exposed pins and connector edges are properly soldered or bent in place to prevent scratching or puncturing.

4.5 User Liability

We are not responsible for any misuse or purposely harmful implementations of our project's product. This project is intended for use as a leisure device and is not intended for any other purpose. We take no responsibility for unintentional injury or harm caused by the mishandling or abuse of our device. Users should take care to avoid the above listed hazards and take necessary safety precautions to handle any component of our project.

References

[1] A. by Anonymous, “Photosensitive epilepsy,” *Epilepsy Society*, 21-Aug-2020. [Online]. Available: https://www.epilepsysociety.org.uk/photosensitive-epilepsy#.XkYCtWhKiUk. [Accessed: 17-Sep-2020].

[2] A. Industries, “Adafruit Bluefruit LE UART Friend - Bluetooth Low Energy (BLE),” *adafruit industries blog RSS*. [Online]. Available: https://www.adafruit.com/product/2479. [Accessed: 01-Oct-2020].

[3] “Atmega2560-16aur,” *MicroChip Direct*. [Online]. Available: https://www.microchipdirect.com/product/ATMEGA2560-16AUR?dfw_tracker=64197-ATMEGA2560-16AUR. [Accessed: 01-Oct-2020].

[4] Btf-Lighting, “Btf-Lighting WS2815 (Upgraded WS2812B) 3.2ft 144 Pixels Individually Digital Addressable RGB Dual Signal LED Flexible Strip Light 5050 SMD IP30 Non-Waterproof Magic Dream Color DC12V Black PCB,” *Amazon.com*, 15-Feb-2016. [Online]. Available: https://www.amazon.com/dp/B07LG5JG3Z/ref=sspa_dk_detail_1?spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUFERzdGSDVIR01XNjQmZW5jcnlwdGVkSWQ9QTAwNTcxNjIxSkFBVVNMWTZCVTZEJmVuY3J5cHRlZEFkSWQ9QTAwNzIyNDUyODBPNklPNTMwTlVZJndpZGdldE5hbWU9c3BfZGV0YWlsMiZhY3Rpb249Y2xpY2tSZWRpcmVjdCZkb05vdExvZ0NsaWNrPXRydWU&th=1. [Accessed: 01-Oct-2020].

[5] “Department of Labor logo United States Department of LAbor,” *1910.304 - Wiring design and protection. | Occupational Safety and Health Administration*. [Online]. Available: https://www.osha.gov/laws-regs/regulations/standardnumber/1910/1910.304. [Accessed: 01-Oct-2020].

[6] “Electronic Components,” *Mouser*. [Online]. Available: https://www.mouser.com/ProductDetail/Texas-Instruments/LM1117MPX-33-NOPB?qs=X1J7HmVL2ZHRbBIxXi4utg. [Accessed: 01-Oct-2020].

[7] “How are LEDs affected by heat?: LED Lighting Systems: Lighting Answers: NLPIP,” *How are LEDs affected by heat? | LED Lighting Systems | Lighting Answers | NLPIP*, May-2003. [Online]. Available: https://www.lrc.rpi.edu/programs/NLPIP/lightingAnswers/LED/heat.asp#:~:text=An LED operating in an ambient environment at,to 80°C. Junction temperature is a function of: [Accessed: 17-Sep-2020].

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

[8] Koopao, “Headphone 3.5mm Splitter Mic Cable for Computer, Koopao Headset 3.5mm Female to 2 Dual Male Microphone Audio Stereo Jack Earphones Port to Gaming Speaker PC Adapter,” *Amazon.com*, 12-Jan-2015. [Online]. Available:

https://www.amazon.com/Headphone-Splitter-KOOPAO-Microphone-Earphones/dp/B084V3TRTV/ref=sr_1_4?dchild=1&keywords=Headphone+Splitter&qid=1601244731&sr=8-4. [Accessed: 01-Oct-2020].

[9] L. Ada, T. Cooper, and T. DiCola, "RGB LED Strips," *Adafruit Learning System*, 26-Nov-2012. [Online]. Available: https://learn.adafruit.com/rgb-led-strips/current-draw. [Accessed: 17-Sep-2020].

[10] Minger, "Minger LED Strip Lights, 16.4ft RGB LED Light Strip 5050 LED Tape Lights, Color Changing LED Strip Lights with Remote for Home Lighting Kitchen Bed Flexible Strip Lights for Bar Home Decoration," *Amazon.com*, 24-Mar-2018. [Online]. Available: https://www.amazon.com/MINGER-Changing-Lighting-Flexible-Decoration/dp/B07JP5375R/ref=sr_1_5?dchild=1&keywords=led+light+strips&qid=1601516240&sr=8-5. [Accessed: 01-Oct-2020].

[11] "Photosensitive Epilepsy: Causes, Symptoms, and Treatment," *WebMD*, 11-Nov-2018. [Online]. Available: https://www.webmd.com/epilepsy/guide/photosensitive-epilepsy-symptoms-causes-treatment. [Accessed: 17-Sep-2020].

[12] S.C.A. 2, S. Ciccarelli, and A. 2, "Microphone Setups - How To Properly Use A Microphone," *Voices.com*, 23-May-2019. [Online]. Available: https://www.voices.com/blog/microphone_sweet_spot/. [Accessed: 01-Oct-2020].

[13] "SparkFun TRRS 3.5mm Jack Breakout," *BOB-11570 - SparkFun Electronics*. [Online]. Available: https://www.sparkfun.com/products/11570. [Accessed: 01-Oct-2020].

[14] "Speed of Sound," *NASA*. [Online]. Available: https://www.grc.nasa.gov/www/k-12/airplane/sound.html. [Accessed: 01-Oct-2020].

[15] "United States Department of Labor," *Occupational Safety and Health Administration*. [Online]. Available: https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=10398. [Accessed: 01-Oct-2020].

[16] W. Smith, "The Scientist and Engineer's Guide toDigital Signal ProcessingBy ," *Speed and Precision Comparisons*. [Online]. Available: http://www.dspguide.com/ch12/4.htm. [Accessed: 01-Oct-2020].

[17] W. Staff, "An Introduction to Flicker Free LED Strip Dimming," *An Introduction to Flicker Free LED Strip Dimming | Waveform Lighting*, 08-Jun-2018. [Online]. Available: https://www.waveformlighting.com/film-photography/an-introduction-to-flicker-free-led-strip-dimming. [Accessed: 01-Oct-2020].

[18] XLED, “LC-LF-1RGBM-WR LED Music Controller,” *amazonaws.com*, 02-Mar-2015. [Online]. Available: https://s3.amazonaws.com/cdn.ecolocityled.com/downloads/LC-LF-1RGBM-WR.pdf.