AlzLife: Alzheimer's Disease Therapy using 40Hz Light

Bailey Brake, Ruohui Huang, Emily Lampat, Khang Le, Yuri Zhang

Abstract— Alzheimer's Disease affects more than 6 million Americans to date, where 1 in 3 seniors die from either Alzheimer's or another form of dementia. Current treatments are inconvenient and inaccessible due to patients' hesitation to reach out early, as well as Primary Care Provider (PCP) lack of resources in diagnosing. To help healthcare professionals and neuroscientists in their effort of treating and alleviating the issues of inaccessibility to Alzheimer's treatment, we propose a noninvasive sensory stimulation therapy that exposes patients to 40Hz light, where a LED panel can be attached at the back of any individual's smartphone and have it display white bright light that flickers at a rate of 40Hz. By having patients exposed to this light, it will promote cells and fluids important for various brain waste-clearance mechanisms that are important in eliminating debris and plaques known to cause Alzheimer's.

Index Terms— Alzheimer's Disease, 40Hz light, sensory stimulation, gamma entrainment

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EXECUTIVE SUMMARY

Unfortunately, many American seniors suffer from Alzheimer's Disease or other forms of dementia. Currently, there is no cure for Alzheimer's and only management of symptoms. That is what AlzLife is offering, they have an app that can be used on any smartphone that will help patients who have lowered cognitive abilities due to dementia or Alzheimer's through interactive games. Our team deliverable is to give AlzLife an additional means of managing the decline of cognitive function for their clinical trial patients by creating a device that attaches to their phones and flashes a light at 40Hz. We will do this by programming a controller to flash an LED at 40Hz, with adjustable brightness intensities.

1 INTRODUCTION

1.1 Problem Statement

Currently, there is a notable shortage of research and treatments available for neuro-degenerative diseases. This, in turn, poses significant challenges for individuals living with Alzheimer's disease, as the demand for treatment and care far outweighs the available resources. Additionally, existing Alzheimer's treatments are characterized by their high cost, potential side effects that may limit their use, and a lack of direct targeting of crucial causes for the disease, such as beta-amyloid plaques that are known to play a key role in the progression of Alzheimer's Disease.

In light of these challenges, we are introducing a comprehensive solution. Our product ensures ease of access, affordability, and a noninvasive approach while simultaneously paving the way for future Alzheimer's research. Not only will it contribute to the advancement of the study on the impact of 40Hz light therapy on neurodegenerative diseases, but it will also make this therapy highly accessible to the general public.

Current Alzheimer's therapies predominantly involve invasive medications. Cholinesterase inhibitors and memantine, for instance, can lead to adverse effects like nausea, diarrhea, dizziness, and a range of other health complications. Our product aims to overcome these challenges by offering a noninvasive visual stimulation therapy. This therapy promotes gamma oscillations in the brain, which are known to stimulate the activity of immune cells responsible for clearing debris, a process crucial to the removal of Alzheimer's plaques.

1.2 Clinical Background

The basis on which this project is founded is novel research into gamma frequency sensory stimulation. In summary, recent research has found that stimulation from an external source at a specific frequency of 40 Hz, whether that be light or sound, for extended periods of time can meaningfully improve the sleep and cognitive abilities of those experiencing the early stages of dementia and Alzheimer's disease.

In more detail, two studies conducted at the Picower Institute at MIT tested the safety and efficacy of 40 Hz sensory stimulation. The first study tested the safety and efficacy over a short period of time, with 25 cognitively healthy participants and 16 patients with mild AD dementia participating in a single session. They concluded that "40Hz [sensory stimulation] was safe and effectively induced entrainment in both cortical regions and other cortical and subcortical structures." The second study tested the safety and efficacy of chronic daily stimulation. 15 patients with mild probable AD underwent 1-hour daily 40Hz sensory stimulation for 3 months. They found 40Hz sensory stimulation to be well tolerated, and after 3 months the active group was found to show improvements in several metrics. Such metrics featured in the tests included memory test performance, daily activity rhythmicity, and certain neurological measurements.[3]

1.3 Client Background

AlzLife, co-founded by Dr. Andrey Vyshedskiy and Dr. Andrei Savchenko, cites the recent research described above as the scientific foundation behind their efforts. The company currently offers a mobile application that allows the user to play brain games while administering 40 Hz light and sound stimulation standard, the maximum flicker rate would be 30Hz (half of the maximum 60Hz), not nearly enough to be effective. Thus, this project intends to deliver a device that attaches to and is compatible with a near-universal set of devices. Note that this device is separate from the aforementioned application, and will provide the 40Hz therapy throughout any usage of the phone.

This product will provide an easily accessible and universal therapy solution in a growing field of research, with the added possibility of being marketed towards neurologically healthy users alongside those experiencing early stage neurodegenerative diseases.
through the screen of the device, both of which are now proven methods in combating the symptoms of early stage neurodegenerative diseases. However, this app is incompatible with certain devices, which are unable to produce light at 40Hz.

1.4 Proposed Solution

The reason that certain devices are unable to produce 40Hz light is because of the refresh rate that each screen supports. On devices with a refresh rate of 60Hz, which is currently considered the industry standard, the maximum flicker rate would be 30Hz (half of the maximum 60Hz), not nearly enough to be effective. Thus, this project intends to deliver a device that attaches to and is compatible with a near-universal set of devices. Note that this device is separate from the aforementioned application, and will provide the 40Hz therapy throughout any usage of the phone.

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2 Concept Development

2.1 Engineering Requirements *(see Appendix 1)*

In general, the client did not have many concrete, numerical requirements for this project. In light of that, the selection of these parameters was left largely up to the team's discretion and its design decisions. A breakdown of these parameters is below, and are collared in the table in Appendix 1.

2.1.1 Flashing frequency

The flashing light must be as close to 40Hz as possible. From research cited below[3], the cognitive improvement only occurs at a peak surrounding the frequency of 40Hz. Different patients obviously respond differently to therapy, and thus this peak at 40Hz was fairly wide, with reasonable constraints of 40Hz +/-0.9Hz. The client approved of this value.

2.1.2 Brightness

The client requested that the product be as bright as possible, and the light must be visible in clear daylight. In translation to units, that requires a minimum luminance of 300 nits, preferably much higher. With such a high brightness, the team also concluded to have a brightness control function. This will be measured by having at least 3 brightness levels between off and full brightness, but preferably many more, for use in dark and bright environments.

2.1.3 Smartphone compatibility & accessibility

Our client stressed simplicity, as this product must be universal and easily accessible to all users. For one, this means it must attach to all smartphones, which constrains the size of the final package to about 120mm by 60mm, so as to fit within the edges of any phone case. It also must be easy to install, measured by less than 5 installment steps. It must also have a long battery life, at least 12 hours, or alternatively be plugged into a power source. Finally, it must be affordable, at a price point of less than $50 for the final product.

2.2 Conceptual Approach

The conceptual design for the product centers around the two main mechanisms of the product, those being the flashing light itself and the means of integrating the device with the phone.

For developing the flashing function on the LED, the immediate solution was to use a small, low-power microcontroller. This solution is compliant with the requirements, easy to implement, and has the added benefit of allowing more complex features and modules in the future. This is because only one software component is required for this design, which outputs a simple wave to control the LED. From this point, this signal can be adapted to any future requirements purely in hardware. For instance, say the phone battery is not powerful enough to light the LED for the required time. Then the microcontroller can easily be adapted to a higher power using a simple amplifier, which could be powered by a USB or outlet. No change to the software would be necessary.

A more nuanced question was how to implement the light, in terms of placement and size. Our client had few requirements on this front, only that the light must be bright and visible. Therefore, there were a plethora of options to sift through. The first solution presented was to use an LED board, which the phone would latch onto. This option was initially shelved due to a high energy cost and lack of portability. The next was to line the edges of the phone screen with an LED strip, but this presented challenges in compatibility, as phone screens vary drastically in size.. The solution that was then selected for the first prototype was a small string of LEDs placed along top of the phone screen, which is small enough to have a manageable power demand and in the ideal position for visibility, never obstructed by a hand.

On the topic of energy costs, one of the most important requirements is the battery life of the device. Initially, in order to satisfy the requirement of a day-long battery life, the device itself would have a battery, and thus be completely detached from the phone. However, that proved to be redundant and overly complicated for the consumer, who now has to charge two batteries instead of one. Instead, the better solution would be to simply plug the microcontroller directly into the phone. The tradeoff for this solution is that there can no longer be a single product for every phone: now, there must be different products depending solely on the charging port of each consumer's phone. Therefore, there is a crossroads: either use the phone as a power source or a wall outlet or other form of USB. For the preliminary design, it was decided that a USB-C cord would be used to plug into Android phones, and in future models this cord could be changed very easily to a Lightning cable for use with iPhones.

All of these design decisions will be explored in much further detail in the following sections. In addition, the specific hardware and software components will be specified.

3 System Description

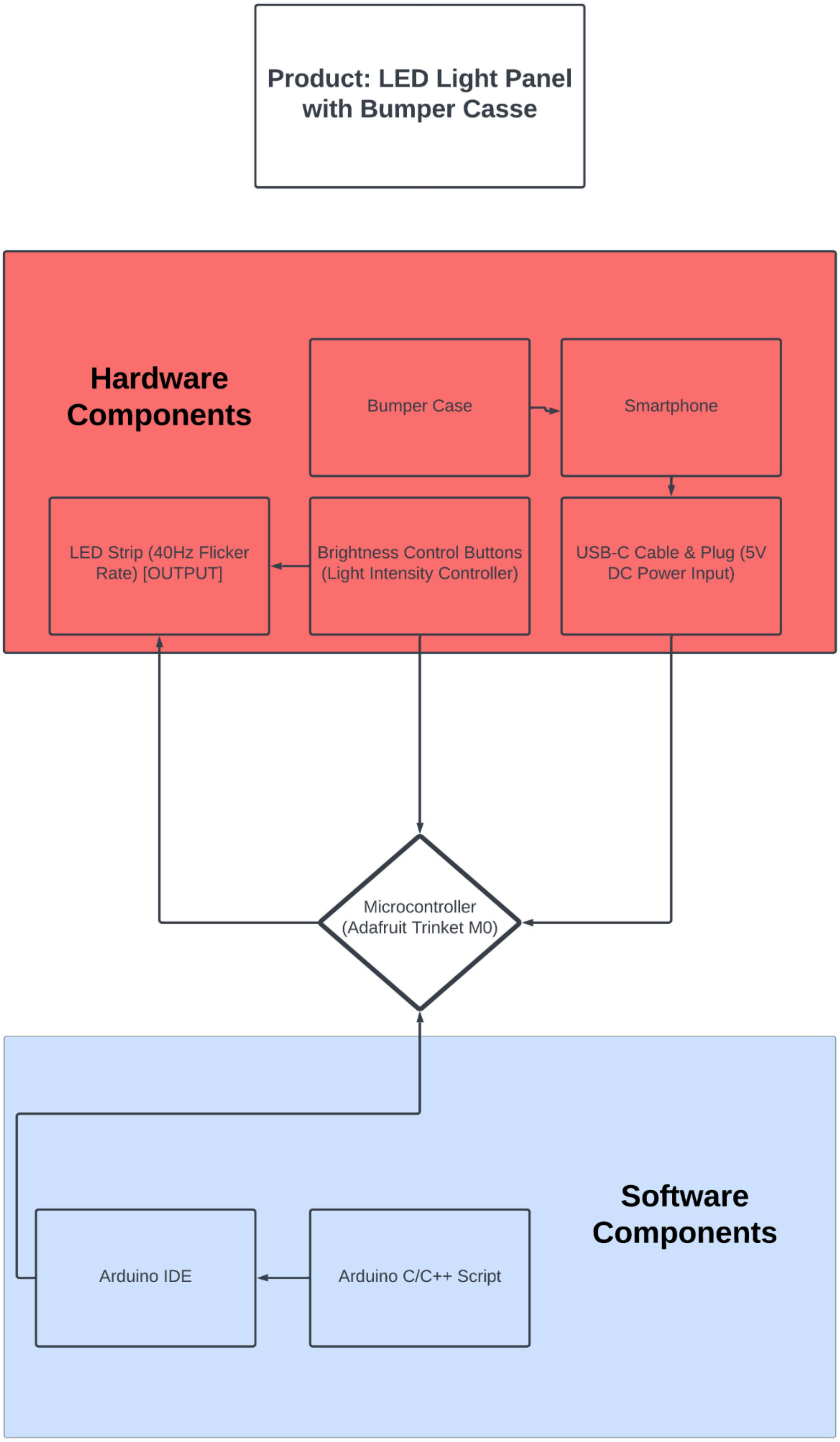


Figure 1: System Block Diagram

This diagram for our system illustrates the data and control flows between the subsystems/functions for our product. The diagram is split into hardware and software components, with a control block in the middle connecting them together. The following section will be divided into those corresponding sub-sections: the hardware component, software component and the microcontroller.

3.1 Hardware Components

The product control flow will initially start at the hardware components, where it will have bumper case that stores all the components we need (i.e. LED light, microcontroller, USB cable). It will then be attached to our smartphone, which will have a USB-C cable connected to it, allowing it to use the smartphone as a power supply for our Adafruit Trinket M0 microcontroller, the most important and integral part of the product where all the control logic resides. We also have the brightness control buttons as part of our hardware components, as it is connected to the microcontroller, serving it as an input signal for the microcontroller to process and compute the correct corresponding output signal and feed into the LED light, which is the main output of our system.

3.2 Software Components

In order for all of the hardware components to interact with each other and provide a seamless user experience, it needs to be programmed using software that allows it to have an algorithm embedded within itself. This will be done by using the Arduino IDE, where a C/C++ script will be written. The code consists of a for loop that takes in three pin signals that are mapped from the microcontroller, two which are input signals from the buttons and one is the output signal to the LED light. It will compute the correct time interval to toggle the LED status to on or off, whilst recognizing when the user clicks a button that will programmatically adjust a brightness variable installed in the code, and recompute the output signal towards the LED. Finally, the script will be uploaded onto our microcontroller, allowing the hardware and software side to interact with each other.

3.3 Microcontroller

The microcontroller, which is easily the backbone of our project, is the bridge between the software and hardware sides. We have chosen the Adafruit Trinket M0 microcontroller, which we have found to be the most optimal microcontroller for this project, due to its small and compact design, whilst having the adequate voltage amount of output that is required for our LED light. Since we are dealing with a product that is attached to a smartphone, the most important thing when it comes to design is that it would not be large and clunky where it could inhibit the user from simple daily uses. This is why the Trinket M0 dimensions of 27mm x 15.3mm x 2.75mm was ideal for our product. Not only that, it is compatible with the Arduino IDE, making it easy for our team to develop code on, as well as creating our first prototype on the Arduino Nano.

4 FIRST SEMESTER PROGRESS

For our 40Hz light therapy project aimed to mitigate the effects of Alzheimer's Disease such as amyloid plaques and beta tau tangles, we have made significant strides to the improvement in our pursuit of developing a precise product to produce a LED light that flickers at a rate of exactly 40Hz. Before our initial lab prototype testing, we meticulously worked on our first working prototype, which served as a foundation of our 40Hz light therapy research. This prototype consisted of a breadboard, a simple LED coupled with a resistor, and an Arduino microcontroller. In the Arduino Integrated Development Environment (IDE), we programmed the device to emit light pulses at a precise frequency, hovering around 40Hz and 41Hz. To ensure the precision of our flicker frequency, we employed an oscilloscope to measure and verify the frequency by simply connecting its probes to the anode and cathode ends of the LED, allowing us to monitor its flicker frequency by observing the time period interval between the LED turning on and off.

In our first deliverable testing, we had two measurements: Flicker Frequency Measurement and brightness Adjustment Measurement.

4.1 Flicker Frequency Measurement

In order to measure the flicker frequency, we set a time period interval of 25ms on the oscilloscope. This is simply calculated by 1/40Hz = 0.025s = 25ms. A time period interval of 25ms should include a flicker, meaning the LED turns on and off within 25ms, or toggle its on/off status every 12.5ms. Here are the results that we have captured during the testing. *Figure 1* demonstrates the flicker frequency that we have captured during the testing, as we set a time period of 250ms. We did this so we can capture more flickers and test the consistency of the flickering, which we can see that there are exactly 10 oscillation waveforms within the time period interval we have set at the top of the oscilloscope, demonstrating a successful 40 Hz flicker frequency of our LED output.

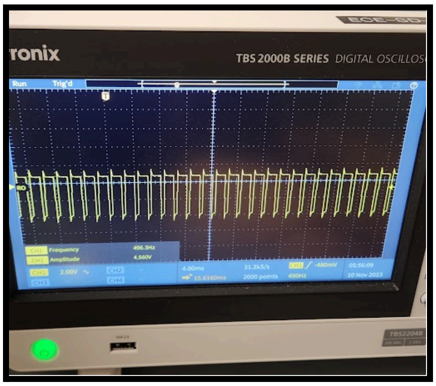


Figure 2: Zoomed-in wave to show PWM

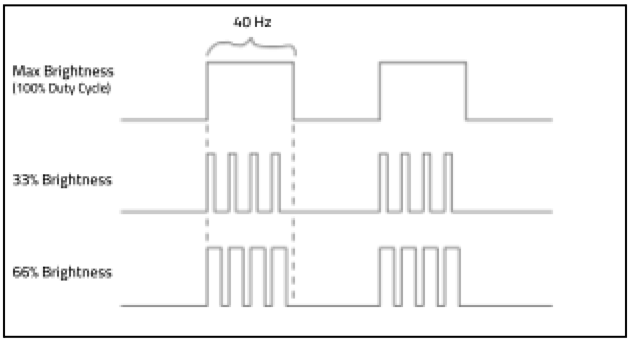


Figure 3: Simplified PWM representation with varying brightnesses

4.2 Brightness Adjustment Measurement

For our brightness adjustment, in order to measure it qualitatively, we had two buttons each designated to increase or decrease the brightness of our LED. During our test, we successfully captured the LED brightness gradually going up and down according to the button that is being pressed. For the decrease button, the brightness goes down until it turns off, and as soon as we click the increase button, it immediately turns on, exactly what we want. We also checked the corner case for the other side as well. When we hold the increase button to its maximum, it stays exactly there at the maximum brightness state until we simply click on the decrease button which immediately turns the brightness down.

4.3 Conclusion

We have recently met with our client, Dr. Andrey Vyshedskiy about our progress this semester. He was overly joyed when he heard about the goals we have met, and where we currently stand in the project. The most integral part of our project, which is to get the algorithm down for the 40 Hz flicker frequency has been achieved, which is now embedded onto our Adafruit Trinket M0 microcontroller, connected to the rest of the system which is our LED strip and control buttons .From here onwards, it is all industrial design of our product and how the final output should look like. Next semester, we will plan on discussing and finalizing design decisions on what type of LED panel we should go for, where it should be placed, what type of power source are we looking at and to eventually have a working product for Dr. Vyshedskiy.

5 Technical Plan

5.1 Overview

This section provides a comprehensive overview of the technical plan for our 40 Hz light therapy device, which is aimed at providing a non-invasive treatment option for Alzheimer's disease. The device, attachable to a smartphone, utilizes a 40 Hz flashing LED to stimulate brain activity and assist in clearing mechanisms that reduce Alzheimer's-related plaques.

5.2 Product Concept

Our device's core concept is a compact, easily attachable unit that emits a 40 Hz flash. This flash is controlled by a low-power microcontroller, ensuring precise frequency and adjustable brightness. The LED strip at the top of the smartphone screen provides visibility and effectiveness while maintaining energy efficiency.

5.3 Energy Efficiency and Battery Life

To maximize convenience and minimize energy consumption, the device draws power directly from the smartphone via a USB connection. This design choice simplifies usage and extends the device's operational time, aligning with the smartphone's battery life. The impact on the phone's battery is minimal, ensuring that the phone and the appliance can function throughout the day without additional charging requirements.

5.4 Design Specifications

We meticulously designed the device to be universally compatible with various smartphone models. The dimensions and connection ports are engineered to accommodate various sizes and charging port types. Technical specifications include:

- Dimensions: Optimized for ergonomic attachment
- Weight: Lightweight for portability
- LED Type: Specifically chosen for optimal frequency and brightness
- Brightness Levels: More than five adjustable settings
- Microcontroller: Adafruit Trinket M0, selected for its reliability and low power consumption

5.5 User Interface and Interaction

The user interface is streamlined for ease of use. Simple controls allow users to adjust brightness levels and turn the device on or off. Feedback mechanisms are in place to indicate the current setting and operational status.

5.6 Future Development and Enhancements

Looking ahead, we envision integrating wireless control capabilities and compatibility with health monitoring applications. Adaptive brightness settings, based on ambient light conditions, are also under consideration for future device iterations.

5.7 Conclusion

In summary, our technical plan for the Alzheimer's Gamma Light Therapy device focuses on ease of use, energy efficiency, and universal smartphone compatibility. By harnessing the therapeutic potential of 40 Hz light stimulation, we aim to provide a significant tool in the management and treatment of Alzheimer's Disease, bringing hope and improved quality of life to those affected.

6 BUDGET ESTIMATE

Item	Description	Cost	Note
1	USB powered LED strip	$14.99	
2	Prototype board	$8.99	
3	Adafruit Trinket M0 microcontroller	$8.95	
4	Phone Holder	$9.99	
5	Hardware Storage	$0	($30), provided by Boston University
6	Arduino Nano	$0	($25), donated by team member Bailey Brake
	Total Cost	$42.92	

Table 1: Budget Estimates of Components for Final Product

7 ATTACHMENTS

7.1 Appendix 1: Engineering Requirements

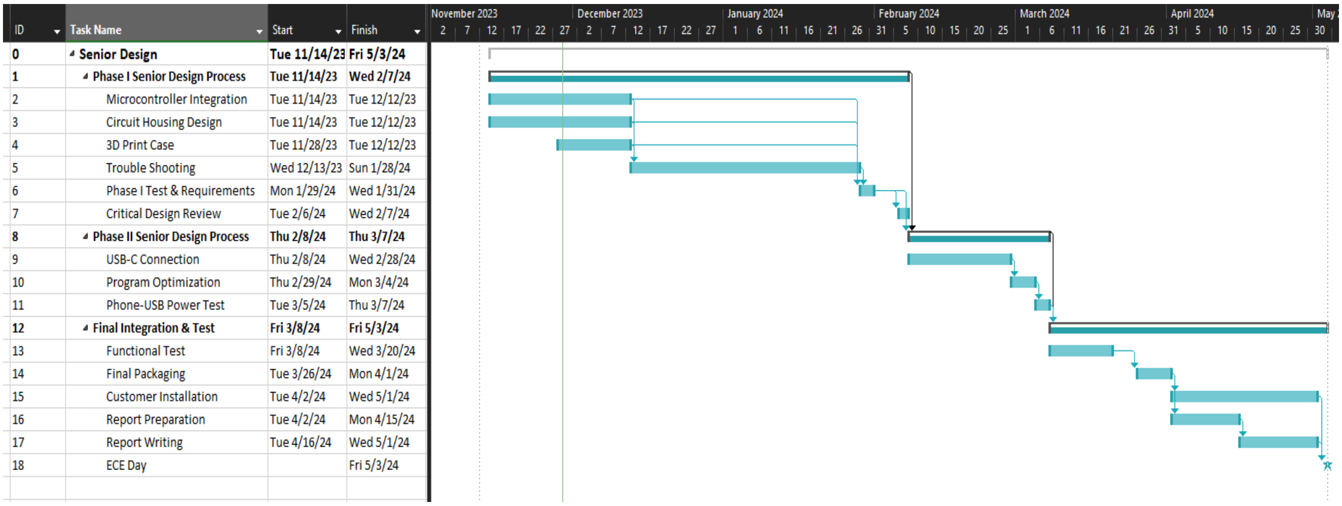
Team # 9 Team Name: OptiSync Therapy

Project Name: Alzheimer's Gamma Light Therapy

#	Function	Metric	Requirement
1	Flashing light	Frequency	40 Hz +/- 0.9 Hz
2	Adjustable brightness	Brightness levels	>3 levels
3	Attach to any smartphone	Size range	H: 120-170 mm W: 60-90 mm
4	Easy to install	Installation steps	<5 steps
5	Affordable	Price	<$50 per unit
6	Day-long battery life	Time	>12 hours
7	Light is visible in all environments	Luminance	>300 nits

Table 2: Engineering Requirements

7.2 Gantt Chart



ID	Task Name	Start	Finish
0	**Senior Design**	**Tue 11/14/23**	**Fri 5/3/24**
1	**Phase I Senior Design Process**	**Tue 11/14/23**	**Wed 2/7/24**
2	Microcontroller Integration	Tue 11/14/23	Tue 12/12/23
3	Circuit Housing Design	Tue 11/14/23	Tue 12/12/23
4	3D Print Case	Tue 11/28/23	Tue 12/12/23
5	Trouble Shooting	Wed 12/13/23	Sun 1/28/24
6	Phase I Test & Requirements	Mon 1/29/24	Wed 1/31/24
7	Critical Design Review	Tue 2/6/24	Wed 2/7/24
8	**Phase II Senior Design Process**	**Thu 2/8/24**	**Thu 3/7/24**
9	USB-C Connection	Thu 2/8/24	Wed 2/28/24
10	Program Optimization	Thu 2/29/24	Mon 3/4/24
11	Phone-USB Power Test	Tue 3/5/24	Thu 3/7/24
12	**Final Integration & Test**	**Fri 3/8/24**	**Fri 5/3/24**
13	Functional Test	Fri 3/8/24	Wed 3/20/24
14	Final Packaging	Tue 3/26/24	Mon 4/1/24
15	Customer Installation	Tue 4/2/24	Wed 5/1/24
16	Report Preparation	Tue 4/2/24	Mon 4/15/24
17	Report Writing	Tue 4/16/24	Wed 5/1/24
18	ECE Day		Fri 5/3/24

Figure 4: Timeline of our goals

7.3 Other Appendices

7.3.a Technical references

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7.3.b Drawings

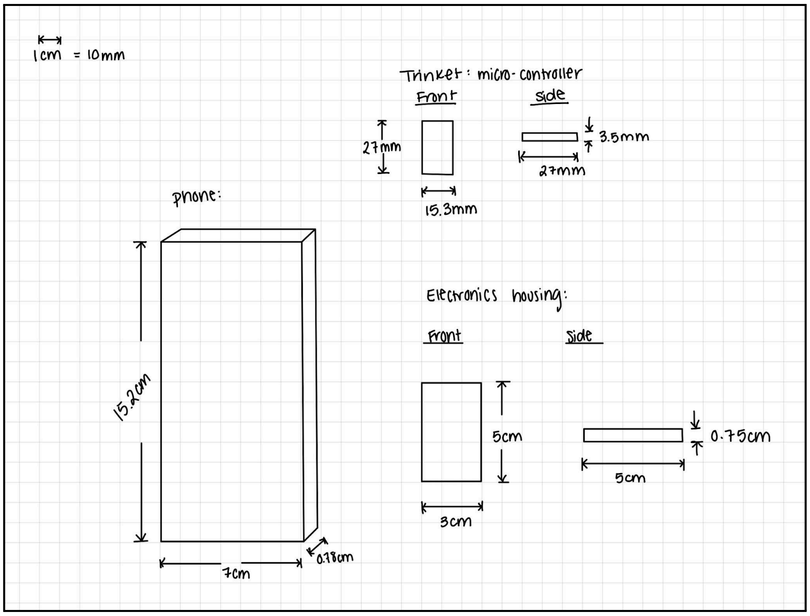

Figure 5: Initial drawing and dimensions of a smartphone, components, and housing.

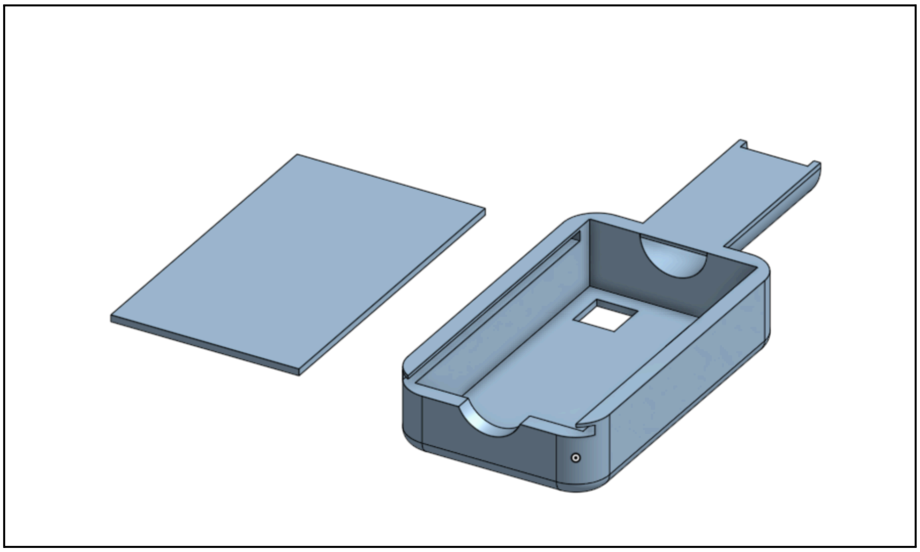

Figure 6: Current CAD model of electronics housing, designed in Onshape.

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