A Project Report

On

**ALARM CLOCK FOR HEARING IMPAIRED**

BY

**SAI VITTAL BATTULA**

**18XJ1A0238**

**ROHAN KUNTA**

**18XJ1A0234**

**SAI PRANATHI KODAVATI**

**18XJ1A0237**

Under the supervision of

**KR SARMA**

**BHARGHAVA RAJARAM**

**SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS OF**

**PR 301: EMBEDDED HARDWARE PROJECT**

cid:image003.png@01D6594A.2604D070

**ÉCOLE CENTRALE SCHOOL OF ENGINEERING**

**HYDERABAD**

**(MAY 2021**)

# Contents

Title Page …………………………………………………………………. 1

Authorship Contribution Statement ………………………………………. 3

Acknowledgments…………………………………………………………. 3

Abstract …………………………………………………………………….4

Introduction ……………………………………………………………….. 5

Background Work ………………………………………………………… 6

Plausible Design Ideas ………………………………………………6

Introducing Parameters ……………………………………………...7

Consumer Experience Factor ………………………………………..8

Proof of Concept ………………………………………………………….. 9

Strobe Light …………………………………………………………9

Neurostimulator ……………………………………………………. 13

Results and Discussion …………………………………………………….14

Conclusion …………………………………………………………………14

References ………………………………………………………………….15

# Authorship Contribution Statement

**Sai Vittal Battula:** Methodology; Investigation; Circuit Design; Writing.

**Rohan Kunta:** Circuit Schematic.

**Sai Pranathi Kodavati:**

# Acknowledgments

**The completion of this undertaking could not have been possible without the active participation and assistance of Dr. KR Sarma and Dr. Bharghava Rajaram. We express our deep sense of gratitude to the above for their inspiration and timely guidance.**

**Their overseeing, encouragement, suggestions, and very constructive criticism have contributed immensely to the evolution of the design ideas on the project.**

# Abstract

**Focusing on the fact that there is a below-par availability in quality alarm methods for the hearing impaired, a low-power consuming device was designed. The design was deduced after conducting a literature survey and listing out ideas followed by a phenomenological model that was adapted to filter out a plausible design idea. After finalizing the idea based on several factors, implementability was thoroughly discussed. Extensive research was carried out in designing a very effective yet minimalistic Arduino Nano based micro-controller design. Power ratings for each component were considered using which, the total power consumption of the circuit was calculated. The design was ensured to be budget-friendly and long-lasting. Concurrently, research on another plausible idea was discussed upon. The real-world efficacy citing both the advantages and disadvantages for each of these designs was stated which marked the end of our study.**

# 1. Introduction

For centuries, humans have a used sort of a device or external source to wake up. For most of our history, it was our body’s natural sensing rhythm to sunrise in the morning or someone manually waking others up at the desired time. In the BC era, with the rise in human civilizations, ancient Egyptians and Greeks used sundials and towering obelisks that would mark the time with the shadow that moved with the sun. Slowly, after that, humanity started producing hourglasses, water clocks, and oil lamps that calibrated the passing of hours with the movement of sand, water, and oil. It was not until recently, during the industrial and scientific revolution, modern alarm clock rose into existence. These devices quickly became part of the day-to-day lives of many individuals due to the verity that they are easy to use, portable, and give efficient results in waking up that undoubtedly made them popular.

Though several alarms have good functionality, almost all of them are biased towards people who do not have any disabilities. And out of all, they completely neglect the hearing impaired. A very limited number of quality products are available for this set of users. Those people who categorized themselves as deaf or hard of hearing are often unable to perceive auditory alarms when asleep. Some companies have developed specialized alarms that include flashing lights or devices that connect some sort of vibrating devices that are inserted into a pillow or a bed to shake them to wake up the user. Though these ideas look like they are effective enough in solving the problem, in a nutshell, they are not effective. There is a huge dichotomy between normal alarms and alarms that are specifically designed for these sections of the population. The first key issue is that they are not power-efficient and can this factor can be improved by an immense amount with proper scaling. The second issue is that they lack in providing comforts to the end-user or other people surrounding the user’s environment.

Next-generation alarms are now quickly replacing the market with classic ones. Alarm clocks involving sleep stage monitoring, using sensing technologies such as EEG electrodes and accelerometers to wake people from sleep. Another kind of technology named dawn simulation is being used to mediate effects. It is indeed true that these new technologies would be superior in resolving the needs of hearing-impaired people in this spectrum, but these ideas are far from taking over the current alarm clock market. The users are still facing adaptability issues and these devices still need a vast amount of improvement. Since there is low demand from the consumer end, the supply for these devices remains low too and the cost is relatively high for the tech they include.

The above-mentioned issues provoked us in pursuing this project. A literature survey was carried to list out all the ideas including modifications to the existing products and also products that need to be developed from scratch. To filter out and pursue two design ideas, a unique phenomenological model was made use of. This considers and compares a list of ideas; thereby leaving only the feasible designs at the end of the process. Two of those ideas which are being brought to life include the sunrise/white light simulation in the facial mask environment that the end-user puts on during his sleep and another is a state-of-the-art neurostimulator that simulates the body using electromagnetic radiation. The latter idea is still under research at the time of writing this report and therefore, its detailed implementabilty is not discussed. The former idea’s design and plan of execution are thoroughly talked over.

# 2. Background Work

### **2.1** **Plausible design ideas**

The surveyed design ideas are briefly talked over in this section. These ideas were jotted down after a significant amount of discussions and validations.

### **Neurostimulator via implant**

A microcontroller (preferably Arduino) is made used to transmit a frequency at 2.4 GHz using a transmitter circuit with FM modulation. The receiver circuit receives the triggering signal and triggers the implant devices triggered wirelessly. The implant device would cost around $7000-$10000. [[1]](#_References)

This design will be further represented as from here on.

### **Neurostimulator via shock/transmission**

A microcontroller (preferably Arduino) is made used to transmit a frequency at 2.4 GHz using a transmitter circuit with FM modulation. The receiver circuit receives the triggering signal and completes a “mild shocking circuit” which gives a mild electric shock by utilizing the human body as a capacitor.

Another possibility is transmitting frequencies at a certain wavelength that human bodies respond considerably to in all circumstances.

This design will be further represented as from here on.

### **2.1.3 Wearable with vibrator**

A microcontroller (preferably Arduino) is made used to transmit a frequency at 2.4 GHz using a transmitter circuit with FM modulation. The receiver circuit receives the triggering signal that triggers a DC vibrator which is fixed in a watch-like structure/glove. The difference between this and market-available smartwatches is, the CPU is not present in the wearable which allows the users to interact on the main unit with more freedom whenever they wish to, without the need of wearing the device all the time.

This design will be further represented as from here on.

### **Frequency-based on a personal audiogram (Rife Frequency Device)**

A mobile application is built to first capture the audio profile of the user and then it feeds that data to a server hosted on by a microcontroller (preferably Arduino). Then, based on the frequency by which the user’s ear is most active, frequencies are generated by using a potentiometer-based frequency amplifier using the same microcontroller. Additional functionality can be achieved by generating binaural beats which are illusion beats that wake up the user more easily (but requires headphones in both the ears to be plugged while asleep). [[2]](#_References)

This design will be further represented as from here on.

### **Strobe Light**

A microcontroller (preferably Arduino) is made used to trigger a strobe light fixed in the sleeping mask worn by the user. The strobe light emits colors in the middle visible spectrum (yellow, green, and blue) since the shorter and longer wavelengths of VIBGYOR are either absorbed or scattered. Therefore, a YGB color combination is made used that can be felt even when the eyelids are closed. But this solution is problematic to other people present in the surrounding environment. [[3]](#_References)

This design will be further represented as from here on.

### **Loud Alarm**

A microcontroller (preferably Arduino) is made used to generate a sound at 113 dB. 113 dB is an industry-standard used in hearing-impaired alarm devices right now. On research, it was found out that it was the maximum an unaided ear can hear. Due to its loudness, this design is also very problematic to people present in the user’s nearby environment. [[4]](#_References)

This design will be further represented as from here on.

### **Resonance with one of the body parts**

A microcontroller (preferably Arduino) is made used to generate a frequency that resonates with any human body part. Generally, the human body resonates between 5 Hz – 10 Hz. But it is also dangerous because frequencies in this range, especially 7 Hz can cause organ damage. [[5-7]](#_References)

This design will be further represented as from here on.

### **2.2 Introducing parameters**

A new set of parameters are introduced. Good parameters like life, comfort, etc. Bad parameters like cost, power usage, etc. Prefix indicates a good parameter while prefix indicates a bad parameter.

The following table categorizes all the parameters and their assigned values for their respective design ideas. The reasoning behind the assignment of the values is based on the discretion of the authors.

Normalization of each design is done concerning that of since the available technology is already in the market and manufacturing costs are relatively lower. All the normalizing scores are rounded off with an accurate guess.

#### **Table 1. Normalizing and comparing each idea to that of wearable with vibrator**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Parameter | Representation |  |  |  |  |  |  |  |
| Cost |  | 10 | 1 | 1 | 1.5 | 1 | 1 | 0.5 |
| Life |  | 1.2 | 1.5 | 1 | 0.8 | 1.3 | 0.7 | 3 |
| Fashion |  | 5 | 3 | 1 | 0.9 | 0.9 | 0.7 | 4 |
| Comfort |  | 0.5 | 0.5 | 1 | 1 | 3 | 0.8 | 10 |
| Eco-friendliness |  | 0.7 | 0.9 | 1 | 0.6 | 1.2 | 0.5 | 0.4 |
| Power usage |  | 1 | 0.8 | 1 | 2 | 0.9 | 0.8 | 0.5 |
| Support/Service |  | 10 | 0.8 | 1 | 3 | 0.9 | 0.3 | 0.3 |
| Risk of life |  | x | x | x | x | x | x | 1000 |

### **2.3 Consumer Experience Factor**

Now, let us define a ‘*Consumer Experience Factor*’ as follows,

This concept was referred from [[8]](#_References).

Computing using the above-defined formula to get a score for each of the ideas.

#### **Table 2. Computed final scores for each design**

|  |  |
| --- | --- |
| Idea | Score |
|  | 0.021 |
|  | 3.164 |
|  | 1.000 |
|  | 0.048 |
|  | 5.200 |
|  | 0.816 |
|  | 0.192 |

Considering the above scores, the best possible idea is which is approximately five times better than .

Now, based on the above-listed scores, implementation is done for the following designs: **,** .

The finalized ideas turned out to be better than the rest and suited the team’s ability after careful consideration of the restrictions that the team had in size, knowledge, and duration to complete the project in time.

# 3. Proof of Concept

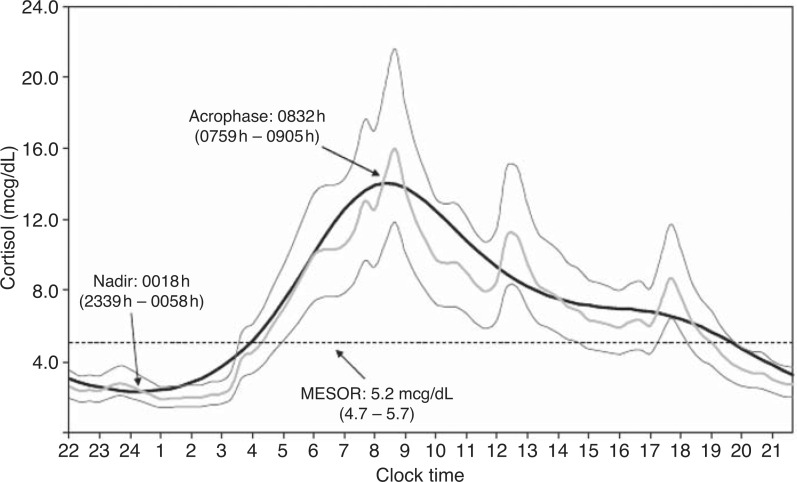
### **3.1 Strobe Light**

This idea is further spliced into two sub-ideas: sunrise simulation and custom frequency studio light focused on the face.

### **3.1.1 Sunrise Simulation**

The human brain can detect light even when the eyes are closed. It is found that cortisol (hormone level primary stress hormone, increases sugars (glucose) in the bloodstream, enhances brain's use of glucose) increases in the morning around 7-8 am. [[9]](#_References)

#### **Figure 1. Levels of cortisol based on the 24 hour clock time**



Using this as an advantage, simulation of sunrise was discussed upon in section 3.1.3.

### **3.1.2 Custom Frequency Studio Light**

It is found that red light from LED at wavelength 635 nm transmits better through the eyelids when closed than the rest of the wavelengths in the visible spectrum. This enables to tap the end-user with this frequency when in deep sleep. [[10]](#_References)

### **3.1.3 Design**

A single design that has an input option for both Sunrise Simulation and Custom Frequency Studio Light.

An Arduino Nano is used as the preferred micro-controller. Set time button is to set time in the device. Set alarm is defined to set the alarm time. Rotary potentiometer serves as the input in adjusting the time for the above. All of these are showcased as an output on the display.

The power consumption for this design is reported in the upcoming section. Several other factors are also discussed. All this circuit will be included inside a facial sleeping mask; light diffusers/other devices will be used appropriately to even out the light intensity. These measures will protect the user’s eyes.

220 V AC, Single Phase Input. Through adapter

TP4056 Lithium Battery Charging module - Micro USB

2500 mAh, 3.7 V DC

5 V

3.7 V

19 mA, 5 V

5 V

XL6009 Boost Converter

Protection Circuit and Filtering Capacitors

KP-045558 Rechargeable LIPO battery

3.7 V

Arduino Nano

5 V

XL6009 Boost Converter

Resistors

VDD = 5 V V

20x4 LCD Display

VI = -0.5 ~ VDD + 0.5 V

2.5 mA, 5 V

VBAT = 5 V

WS2812B RGB LED Integrated Strips with built-in drivers

DS1307

RTC Module

9 V

VCC = 5 V

60 mA per LED

500 nA, 5 V

Set Time

VDD = 5 V

MJTP1230 Tactile Switch Button

VCC = 5 V

Down

50 mA, 9 V each

Rotary Potentiometer

Up

Set Alarm

MJTP1230 Tactile Switch Button

**All connections will be grounded appropriately. Power consumptions are written below each component.**

The LCD was chosen because of low power consumption compared to other displays.

### **3.1.4 Power Ratings**

##### **3.1.4.1 Microcontroller and other Components Specifications**

Battery ratings were imported from [[11]](#_References).

Arduino Nano ratings were imported from [[12]](#_References).

DS1307 RTC module ratings were imported from [[13]](#_References).

20x4 LCD Display ratings were imported from [[14]](#_References).

RGB LED Drivers and RGB LEDs ratings were imported from [[15-16]](#_References) and based on the calculations provided in the next section of this document.

MJTP1230 Tactile Switch Button ratings were imported from [[17]](#_References).

XL6009 Boost Converter ratings were imported from [[18]](#_References).

TP4056 Battery Charging module ratings were imported from [[27]](#_References).

Considering the strip consists of 10 LEDs and the current consumption of other electrical components in the circuit will be that of Arduino Nano,

Total approximate current consumption = Current(DS1307, LCD Display, Arduino Nano, WS2812B, Other Electrical Components)

= 0.0005 + 2.5 + 19 + 60 \* 10 + 19 = 640.5005 mA

The battery capacity is 2500 mAh.

The LEDs can be lighted up with a battery for about 4 hours. Considering the user consumption, the LEDs will be lighted up only for 15-30 minutes a day, that too with varying intensities. The remaining day, the circuit will be working on the microcontroller or mostly powered off.

Current consumption with LEDs off = 40.5005 mA

In a day, consumption will be ((40.5005 \* 23.5) + (640.5005 \* 0.5)) mAh = 1272.012 mAh

2500/1272.012 = 1.96 days

**Therefore, with the worst use-case scenario, the battery will last for 2 days.**

In a day, optimal consumption, ((40.5005 \* 11.5) + (640.5005 \* 0.5) + (0 \* 12)) mAh = 786.006 mAh

2500/786.006 = 3.18 days

**Considering this, the optimal use will result in the battery lasting for 3.18 days.**

The charging time of the designed battery would take 4 to 5 hours. In theory, the battery will last more than 3 days for this design since we didn’t consider the changing intensities of the LEDs.

**Input Energy = (2500 \* 3.7)/1000 = 9.25 Wh**

9.25 Wh energy lasts for 3.18 days. For a year, the energy used will be 1061.7138 Wh.

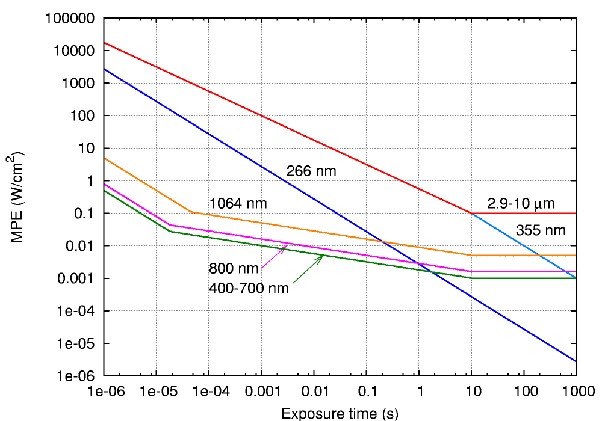
**Therefore, yearly energy consumption will be approximately equal to 1 kWh.**

The prototype will be built on the above block diagram. Once the prototype is working and is successfully demonstrated, the same Arduino will be used as an in-system programmer to program the ATtiny84a micro-controller and is replaced, therefore. A PCB design will be made based on the working bread-board prototype circuitry which will be sent for fabrication.

##### **3.1.4.2 Lumen and other specifications on LEDs**

Defining maximum permissible exposure for the eye based on intensities 10% of the intensity required for a 50–50 chance of damaging the eye. These are functions that vary with wavelength and the length of time that an experimenter stares at the light source. [[19]](#_References)

#### **Figure 2. Maximum Permissible Exposure plotted against Exposure Time**



One person admitted he looked into the beam of a 140-lumen flashlight at arm’s length for about 0.25 seconds. He reported flash blindness and exhibited watery eyes and disorientation for half an hour or more. [[20]](#_References)

Given an average flashlight beam size of 25 sq. cm and a pupil of 0.1 sq. cm, he probably got less than a lumen into his eyes. But he said it hurt a lot more than looking into the sun.

Considering the facial area covered by the mask roughly about 70 sq. cm. Suppose the consumer needs to get exposed to the light from the power source for 1000sec (approximately 15 minutes). Then, MPE will be 0.001 W per sq. cm. Therefore, 0.1 W (approximately) will be the direct power of the light source (only direct power of the light source which is not related to light generated by electric power).

WS2812B RGB LEDs have an average luminous intensity of 3.05 Cd [[15][21]](#_References). Also, LEDs are not isotropic and are directional. Usually, 30° is subtracted for the base obstruction. On top of this, the RGB LEDs used in the strip are likely indicator LEDs where the apex angle might be 120° (180° – 2 \* 30°) or less. Using this calculator, we get 9.58 lumens per LED [[22]](#_References).

At maximum working capacity, these LEDs draw 60 mA at 5 V. Therefore, the electric power consumed is 300 mW or 0.3 W. But since the derived the radiant power should be 0.1 W, the LEDs will be operated at half of their rating so that the emitted light intensity will not harm the user.

### **3.2 Neurostimulator**

From the extensive secondary study that was researched upon the internet, it was found that our body can be wirelessly triggered only at low frequencies. High frequencies will not simulate the human nervous system. During this research, it was also noted down and reaffirmed that the simulation efficiency and increased sensitiveness of living things are near to extra-low-frequency periodic stimulations which are in the range of 1 Hz to 10 Hz. [[23]](#_References)

Several research studies and even patents [[25]](#_References) were found stimulating the brain using implants. The authors think in the same lines of a recent study that is highly sophisticated and requires a rechargeable implant [[26]](#_References). Recently, an MIT study was successful in simulating a mouse’s brain to wiggle its ears, paws, and whiskers using electrodes on its head. The basic idealogy here too remains the same as the above-discussed theory. A signal of 4000 Hz is sent from one side, and 4001Hz from another side. These two signals interfere in the brain which will create an electrical wave envelope at 1 Hz, which is again in the low-frequency range to excite neurons. [[24]](#_References)

Though this method seems fancy and from the next generation; it should be stressed that the main problem behind this is the imposition of the risk. Extra low-frequencies might be neuro-simulating but they resonate with human organs. And in extreme cases, these might cause organ rupture causing a loss of life. To tackle this, the above-mentioned studies used a focused area approach which might solve this issue. They essentially transmitted the signal in one area of the whole body. But, this method might have more drawbacks when immense research is done on it. At this moment, very few studies were reported, and on reading, it was determined that to pursue this, a very high budget was needed to come up with a design that is not risky, and also, a vast amount of time is needed.

On the other hand, a cheap yet effectual design would be that of a straightforward mild shocking circuit using the human body as a capacitor. But this study too was deemed risky because the current flowing might overwhelm the body which might result in serious injury or casualty.

# 4. Results and Discussion

A basic version of the above-discussed design circuit was developed in the Fritzing.

Due to the ongoing pandemic, it became difficult to implement the hardware but soon enough, when conditions ease and the required components are available, this project will be demonstrated in the form of a hardware prototype. The authors seek to complete this phase of the project even after the enclosed deadline.

The proposed cost by the authors for building a single device in production mode is **Rs. 2500 or $35.** The budget required to build in testing mode/prototype would be 4 to 6 times greater than that since multiple quantities of each component will be bought and minor adjustments thereon. These costs are based on the initial round of component acquirement.

#### **Figure 3. Basic prototype circuit built on Fritzing (just for reference, not the final design)**

# 

# 5. Conclusion

This study aims at analyzing several ideas and the competition between the same. After identifying several effective ideas, research was done to discuss the implementation of these ideas in the real world.

The circuit was designed accordingly to the specifications and simulations were carried out to check the feasibility of the design. The majority of corner cases were identified and are addressed during the development phase.

There is no doubt that the current analysis opens an express route to bring this product into the market. If the idea is failed to be implemented given the current scenario and time constraints, those who find this report in the future can make use of the information provided to fabricate a PCB design and couple it with a pertinent facial mask (which is the entirety of this project).

# References

1. Richard L. Weiner, Carlos Montes Garcia, Niek Vanquathem. A novel miniature, wireless neurostimulator in the management of chronic craniofacial pain: Preliminary results from a prospective pilot study. Scandinavian Journal of Pain. Volume 17, 2017. Pages 350-354. <https://doi.org/10.1016/j.sjpain.2017.09.010>.
2. Society for Neuroscience. "Binaural beats synchronize brain activity, don't affect mood: Auditory illusion may not have effects different from other sounds." ScienceDaily. ScienceDaily, 17 February 2020.
3. <https://ocean.si.edu/sites/default/files/2020-12/lightinthedeepsea.pdf>.
4. Bowers, L., Dostal, H., McCarthy, J., Schwarz, I., & Wolbers, K. (2015). An analysis of deaf students’ spelling skills during a year-long instructional writing approach. Communication Disorders Quarterly, 27, 237-253. doi: 10.1177/1525740114567528.
5. Brownjohn, J. M. W. and Zheng, X. Discussion of human resonant frequency. Second International Conference on Experimental Mechanics. 2001, vol. 4317, pp. 469–474. doi:10.1117/12.429621.
6. Wu Ren, Bo Peng, Jiefen Shen, Yang Li, Yi Yu, "Study on Vibration Characteristics and Human Riding Comfort of a Special Equipment Cab", Journal of Sensors, vol. 2018, Article ID 7140610, 8 pages, 2018. https://doi.org/10.1155/2018/7140610.
7. <https://www.ndt.net/article/ultragarsas/Vol.64-No.3-2009_06-Guzas.pdf>.
8. Presidential BEEF, Difference of Light Technology. ElectroBoom. <https://youtu.be/nycAujdp708>. (accessed 25 March 2021).
9. Chan S, Debono M. Replication of cortisol circadian rhythm: new advances in hydrocortisone replacement therapy. Ther Adv Endocrinol Metab. 2010;1(3):129-138. doi:10.1177/2042018810380214.
10. Andrew Bierman, Mariana G. Figueiro, Mark S. Rea, "Measuring and predicting eyelid spectral transmittance," J. Biomed. Opt. 16(6) 067011 (1 June 2011). <https://doi.org/10.1117/1.3593151>.
11. <https://sharvielectronics.com/product/lipo-rechargeable-battery-3-7v-2500mah-kp-045060-model/>. (accessed 20 April 2021).
12. <https://store.arduino.cc/usa/arduino-nano>. (accessed 20 April 2021).
13. <https://datasheets.maximintegrated.com/en/ds/DS1307.pdf>. (accessed 20 April 2021).
14. <http://www.systronix.com/access/Systronix_20x4_lcd_brief_data.pdf>. (accessed 20 April 2021).
15. <https://cdn-shop.adafruit.com/datasheets/WS2812B.pdf>. (accessed 20 April 2021).
16. <https://www.hobbyelectronica.nl/product/led-strip-ws2812b-rgb/>. (accessed 20 April 2021).
17. <http://www.farnell.com/datasheets/1598766.pdf>. (accessed 20 April 2021).
18. <https://datasheetspdf.com/pdf-file/775384/XLSEMI/XL6009/1>. (accessed 20 April 2021).
19. Delori, François & Webb, Robert & Sliney, David. (2007). Maximum permissible exposures for ocular safety (ANSI 2000), with emphasis on ophthalmic devices. Journal of the Optical Society of America. A, Optics, image science, and vision. 24. 1250-65. 10.1364/JOSAA.24.001250. <https://www.researchgate.net/publication/6399926_Maximum_permissible_exposures_for_ocular_safety_ANSI_2000_with_emphasis_on_ophthalmic_devices>.
20. <https://www.quora.com/How-many-watts-of-light-can-damage-the-human-eye-or-how-many-watts-of-light-can-blind-a-human/answer/Bill-Otto-5?ch=10&share=8765c5b4>. (accessed 20 April 2021).
21. <https://electronics.stackexchange.com/questions/377723/how-efficient-are-rgb-led-strips>. (accessed 21 May 2021).
22. <https://www.rapidtables.com/calc/light/candela-to-lumen-calculator.html>. (accessed 21 May 2021).
23. Salansky N, Fedotchev A, Bondar A. Responses of the nervous system to low-frequency stimulation and EEG rhythms: clinical implications. Neurosci Biobehav Rev. 1998 May;22(3):395-409. doi: 10.1016/s0149-7634(97)00029-8. PMID: 9579328.
24. https://www.eurekalert.org/pub\_releases/2017-06/cp-dbs052517.php. (accessed 18 May 2021).
25. <https://patents.google.com/patent/US20090248119>. (accessed 18 May 2021).
26. The Korea Advanced Institute of Science and Technology (KAIST). "Wirelessly rechargeable soft brain implant controls brain cells: Researchers have invented a smartphone-controlled soft brain implant that can be recharged wirelessly from outside the body." ScienceDaily. ScienceDaily, 26 January 2021. [www.sciencedaily.com/releases/2021/01/210126113658.htm](http://www.sciencedaily.com/releases/2021/01/210126113658.htm).
27. <https://dlnmh9ip6v2uc.cloudfront.net/datasheets/Prototyping/TP4056.pdf>. (accessed 22May 2021).