A Project report on

Urban Nest: A Circadian Rhythm Based Smart Bulb for Optimizing Sleep Cycles

Submitted for partial fulfillment of Engineering Explorations Course
For Bachelor of Technology
Degree in

Computer Science and Engineering

For the academic year 2023-24
By,

Sl no	USN	Name
1	1RVU23CSE483	Suman B R
2	1RVU23CSE385	S A Herdev Anish
3	1RVU23CSE436	Shree Vidhya B
4	1RVU23CSE434	Shobana.S
5	1RVU23CSE342	Prakul Banandur
6	1RVU23CSE395	Sahil Pasha D

Title of the Domain: Home Automation
Name of the Domain Lead: Prof. Chandramouleeswaran Sankaran

प्रज्ञा: ★ धीरा:
RV UNIVERSITY
Go, change the world
an initiative of RV EDUCATIONAL INSTITUTIONS

School of Computer Science and Engineering
RV University
RV Vidyaniketan Post, 8th Mile, Mysore Rd, Mailasandra,
Bengaluru, Karnataka 560059

RV UNIVERSITY

Go, change the world

an initiative of RV EDUCATIONAL INSTITUTIONS

School of Computer Science and Engineering

RV UNIVERSITY

Go, change the world

an initiative of RV EDUCATIONAL INSTITUTIONS

CERTIFICATE

This is to Certify that the project work "Urban Nest: A Circadian Rhythm Based Smart Bulb for Optimizing Sleep Cycles" carried out by Suman B R, S A Herdev Anish, Shree Vidhya B, Shobana S, Prakul Banandur, Sahil Pasha D, USN: 1RVU23CSE483, 1RVU23CSE385, 1RVU23CSE436, 1RVU23CSE434, 1RVU23CSE342, RVU23CSE395, bonafide students of SoCSE in partial fulfillment of the Engineering Explorations course of Bachelor of Technology in Computer Science and Engineering of the RV, Bengaluru, during the academic year 2023-24. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in this report. The project report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the said course.

Title of the Domain: Home Automation

Signature of the Domain Lead

Name of the Domain Lead: Prof. Chandramouleeswaran Sankaran

ACKNOWLEDGEMENT

It is not only individuals' efforts that are crucial for any success, whether academic or otherwise; intellectuals, elders and friends need to be guided, encouraged and helped. We have been assisted in the execution of this project by a series of personalities, both personally and professionally. We'd like to thank all of them for that.

First and foremost we would like to thank **Prof. Chandramouleeswaran Sankaran,** the domain lead of Home Automation for guiding and providing us with valuable insights on developing this project.

We would like to thank **Dr. Harsha B K**, **Prof. Amruthesh Bhat** and **Prof. Durgarao Guttula** for their constant support and encouragement.

Last, but not the least, we would like to thank our peers and friends who provided us with valuable suggestions to improve our project.

Table of Content

Abstract

In this current fast-paced world we often find ourselves immersed in work and spending long hours in closed environments like workspaces or classrooms that can disrupt our circadian rhythm due to insufficient exposure to natural light. Our circadian rhythm is thrown off by this. Circadian Rhythm whose role is to maintain good sleep cycles at night time, telling us when to wake up and to sleep, and make us productive during the day along with many other things will not be able to do so when it is distorted. This project focuses on developing a smart indoor lighting system on enhancing circadian rhythms for optimizing sleep cycles including mood disorder. The device monitors the light intensity in that specific space periodically and alters the light output from the device maintaining a certain amount of light intensity in that specific closed environment. It also provides real-time adjustments to lighting conditions through tunable white light from blue to orange shade of white light from day to night promoting improved sleep at night.

1. INTRODUCTION

1.1 Purpose and Motivation

In this fast-paced world People find themselves working from 9am to 5pm or even late at night. Many industries and different professions have different work schedules, which includes remote work, irregular working hours, shift work making them stay indoors for a long time without providing efficient light exposure. No efficient light distorts our body's internal clock cycle which keeps everything running smoothly thereby, altering and messing with our sleep patterns. Our body needs efficient light exposure to stay healthy and function properly. Blue light in the morning and slightly orange or warmer light in the evening, could stabilize our biological clock (Circadian Rhythm). Blue light is more intense in the morning. Retinal Ganglion cells present in our eye are sensitive to blue light, which is abundant in the morning. The blue light stimulates these ganglion cells to send a signal to the Suprachiasmatic nucleus(SCN) which then interprets the time to wake up and be alert by producing cortisol(awakening hormone) in our body.
The SCN is responsible for coordinating the sleep-wake cycles in our body, in response to light cues. As the day progresses the intensity of blue light decreases and is noticed by our sensitive ganglion cells. The ganglion cells now send another signal to the SCN that it's time to prepare for sleep. In response to the signal, the SCN signals the pineal gland to secrete melatonin (darkness hormone) which prompts the feeling of sleepiness and helps us to have a good sleep at night. The intensity of light also has an impact on our mood. Exposure to bright light makes us feel good.
Conversely, insufficient light exposure can lead to a decrease in serotonin levels. This decrease in serotonin levels can contribute to the rise of sadness or low energy. With the help of tunable white light we can help provide the feel and wavelength of the natural sunlight throughout the day by transitioning from blue light to slightly warmer light in the evening. This helps people in maintaining circadian rhythm in our body without disturbing it. By various studies it is advised to have a certain intensity of light in various spaces like study space, work space and many other places.

1.2 Scope of the project

The scope of this project holds within a comprehensive approach in developing a smart light bulb designed to optimize circadian rhythm by altering light according to time throughout the day and maintaining a certain intensity in that closed environment. Firstly, the intensity of already present light is being calculated and sensed by the BH1750 sensor in unit lux. The user will have to provide a certain amount of light intensity which they want for that space and the smart bulb will emit the light after understanding the amount of light already present and the amount of light it has to emit to make up for that amount of intensity light said by the user. The code running in the Raspberry Pi Pico W will make sure of it. There are around 4 modes which can be changed via phone by connecting the bulb and the phone to the same network and accessing it through the IP address. First mode will be a normal mode where the bulb will glow at the max brightness like any other bulb. second, will be the circadian mode which changes the color throughout the day providing the optimum natural color for a stable circadian rhythm and adjusts the intensity making sure to provide the said amount of intensity accurately. The third mode makes sure to provide a certain amount of intensity according to the work space. May it be study space, work space, living room, office building hallway or public areas with dark surroundings. The fourth will be a power saving mode where the brightness of the bulb will not be at the max but will change its brightness like our mobile's auto brightness mode to optimize power consumption. By providing these, the project aims to develop a smart bulb that prompts healthy circadian rhythm and enhances overall quality of life for the users and provides good sleep at night.

1.3 Literature survey

Much research has been done on the role of light in regulating our sleep patterns and mood. Studies conducted by Cajochen et al. (2011). Brainard et al. (2001) have talked about the importance of light blue light in the morning for waking up and staying alert by increasing the production of cortisol, known as the awakening hormone, and reducing the production of melatonin, known as the sleep hormone. This aligns with the information given on the Andrew Huberman Lab podcast, where Andrew Huberman explains how blue light activates ganglion cells in our eyes, which in turn sends a signal to SCN(Suprachiasmatic Nucleus) which syncs our internal body clocks with the light-dark cycle. Additionally, Huberman talks about the significance of transitioning to warmer light tones during the evening. He mentions how more intensity of blue light in the morning is sensed by the ganglion cells which indirectly promotes in waking up the body. He also mentions how people suffer jet lag when their circadian rhythm is distorted and how it can be improved by implementing these blue light systems in our indoor environments. These findings can be applied to enhance overall health and establish environments that promote healthy circadian rhythms through the use of lighting systems, as discussed on the podcast.

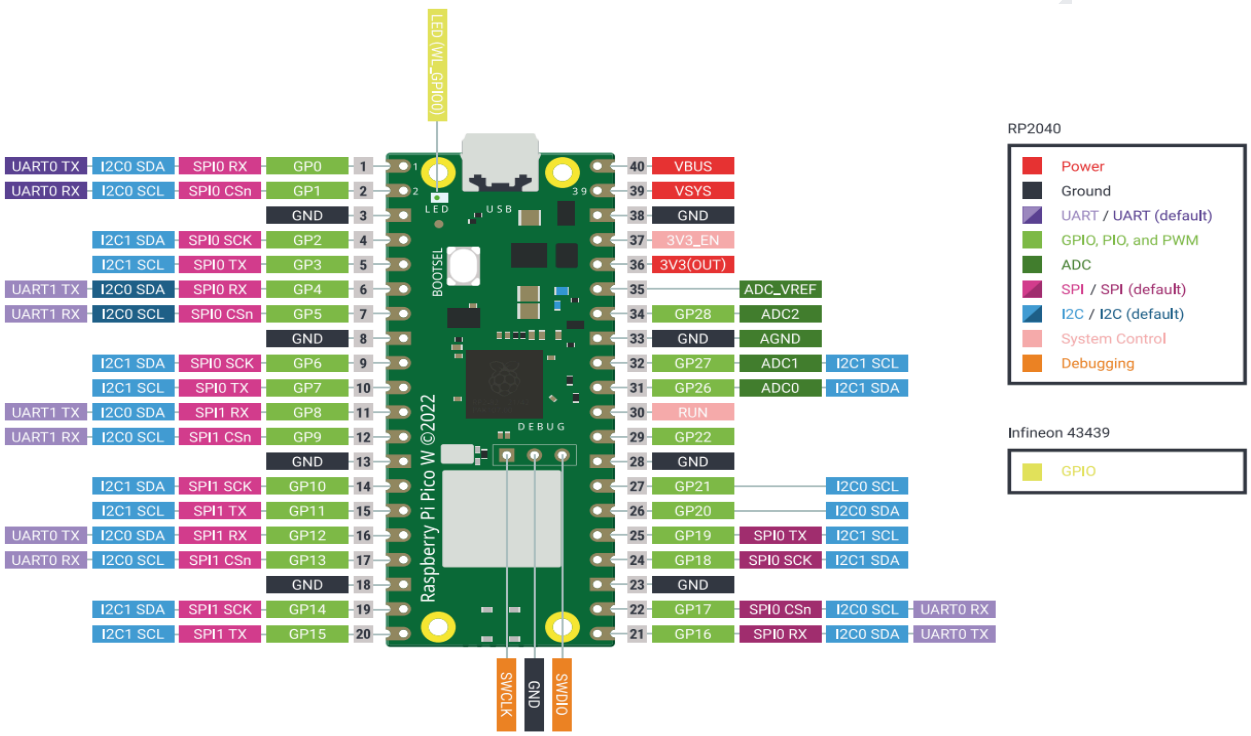
1.4 Accomplishments

In this project we were able to achieve tunable white light ranging from 2000 K to 10000 K from warmer temperature(orange tint) to a cooler temperature(blue tint) respectively to provide and mimic the natural sunlight. This was accomplished by using the 8-bit WS2812 5050 RGB Circular LED by the help of Raspberry Pi Pico W. The intensity was managed and altered by reading the intensity of the light in the surrounding environment through the help of a BH1750 digital light sensor and making changes to the light output accordingly. The Raspberry Pi also takes the inputs from the RTC module which gives the current date and time to set the light intensity specific to that time of the day so as to mimic the natural lighting patterns. The smart bulb can also maintain a constant value of lux in a closed environment based on the user's preference.
Here the user gets to set a specific amount of light intensity which is sent to the Raspberry Pi Pico W which commands the light sensor to measure the light present in that environment and sets the light output accordingly in the RGB led to maintain the intensity specified by the user constantly. The smart bulb can also be connected to the user's mobile phone. This is done by connecting the mobile phone and the smart bulb to the same network by accessing the IP address of the Raspberry Pi board. It also has a power saving mode where the brightness of the bulb can be adjusted just like we adjust our phone's brightness.

2. MATERIALS/COMPONENTS USED

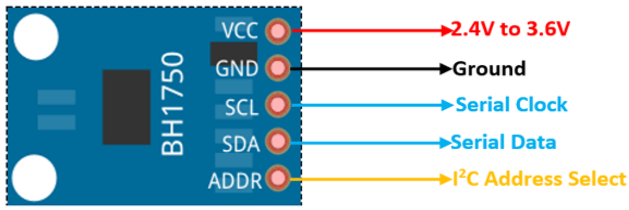
The components that are used for this project are Raspberry Pi Pico W, BH1750 Light sensor, DS1307 RTC Module and 8-bit WS2812 5050 RGB Circular LED.

2.1 Raspberry Pi Pico W microcontroller:



Raspberry Pi Pico W is a high-performance microcontroller. It's working is similar to that of a computer but it is small and contains every processing component mounted on a single chip. Hence called SBC(Single Board Computer). The key features of Pico W include dual core Arm Cortex M0+ processor, Clock speed of 133 MHz, 264kB of SRAM, 2MB flash memory, USB 1.1, 26 multi-functional GPIO pins. The main feature of this is it has a 2.4 GHz onboard wireless LAN, Bluetooth 5.2 and WPA. It acts as core hardware as it interfaces with other peripherals of this project. This project uses I2C(Inter-Integrated circuit) protocol which is master-slave communication which involves two lines: a serial data pin (SDA) over which data can be sent or received, and a serial clock (SCL) used to synchronize all data transfers between the microcontroller and peripherals. There are 12 SDA and 12 SCL pins in Pico W. The SDA and SCL pins of the microcontroller are connected to the SDA and SCL pins of the peripherals like the BH1750 Light sensor and RTC module. The power for all peripherals is given by the 3V3 (OUT) pin of the microcontroller.

2.2 BH1750 Digital Light Sensor:

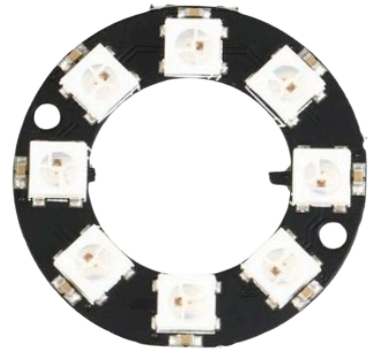


BH1750 is a digital ambient light sensor which measures the intensity of light falling on it. It can measure values from 1 lux to 65535 lux(One lux is the amount of illumination provided when one lumen is evenly distributed over an area of one square meter). It consumes a very small amount of current which is 0.12mA and operates on a voltage range of 2.4-3.6V. This sensor uses a photodiode which senses light and converts it to electricity. This electricity generated is directly proportional to light intensity. The light incident on the photodiode creates an electron-hole pair in the depletion region. Due to the photoelectric effect, electricity is produced. It is further converted to voltage signals via an operational amplifier(Opamp). The analog to digital converter(ADC) in the sensor converts these voltage signals to digital values. These values are then sent to the microcontroller through the SDA pin using I2C protocol. This sensor contains 5 pins namely VCC, GND, SCL, SDA, and ADDR. The VCC, GND, SCL, SDA are all connected to the microcontroller. This sensor helps to get accurate light intensity values which can be used to alter the brightness in RGB to give a constant intensity in a closed space.

The **lux** is the unit of illuminance, or luminous flux per unit area, in the International System of Units (SI).

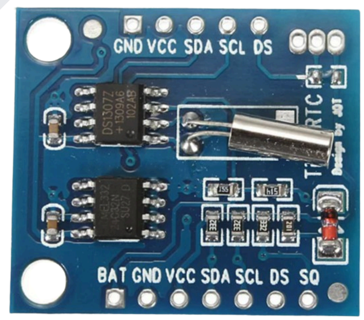
2.3 WS2812 5050 RGB Circular LED:

The WS2812 is a smart LED light source family which integrates the control circuit and RGB chip into a 5050 part package. Each separate red, green and blue led in a single WS2812 unit is set up to shine at 256 lightness levels indicated by an 8-bit binary sequence set from 0 to 255, when combined, each led unit requires three sets of eight brightness bits, or 24 bits of information for full control. Its operating voltage is 5V but they



can often function within a range of 4.5V-5.5V. Each LED typically draws around 20mA (at full brightness for each color, RGB), so for a full RGB LED (all colors are illuminated), it can draw up to 60mA. The WS2812 is an all-in-one RGB led with integrated shift register and constant-current driver; it uses one -wire protocol that sends data to each LED to control its brightness and color. Each LED in the chain interprets the incoming data, extracts its color and brightness information and then passes the rest of the data down the line to the next LED. This cascade effect allows for complex lighting effects to be achieved with relatively simple control signals. The RGB LED has four pins namely VSS, VDD, Din and Dout. The VDD and VSS Of RGB LED are connected to VCC and GND of Raspberry Pi PicoW. The Data In (Din) pin is connected to one of the GPIO pins of Raspberry Pi Pico. This pin receives the control signal allowing you to specify color and brightness.

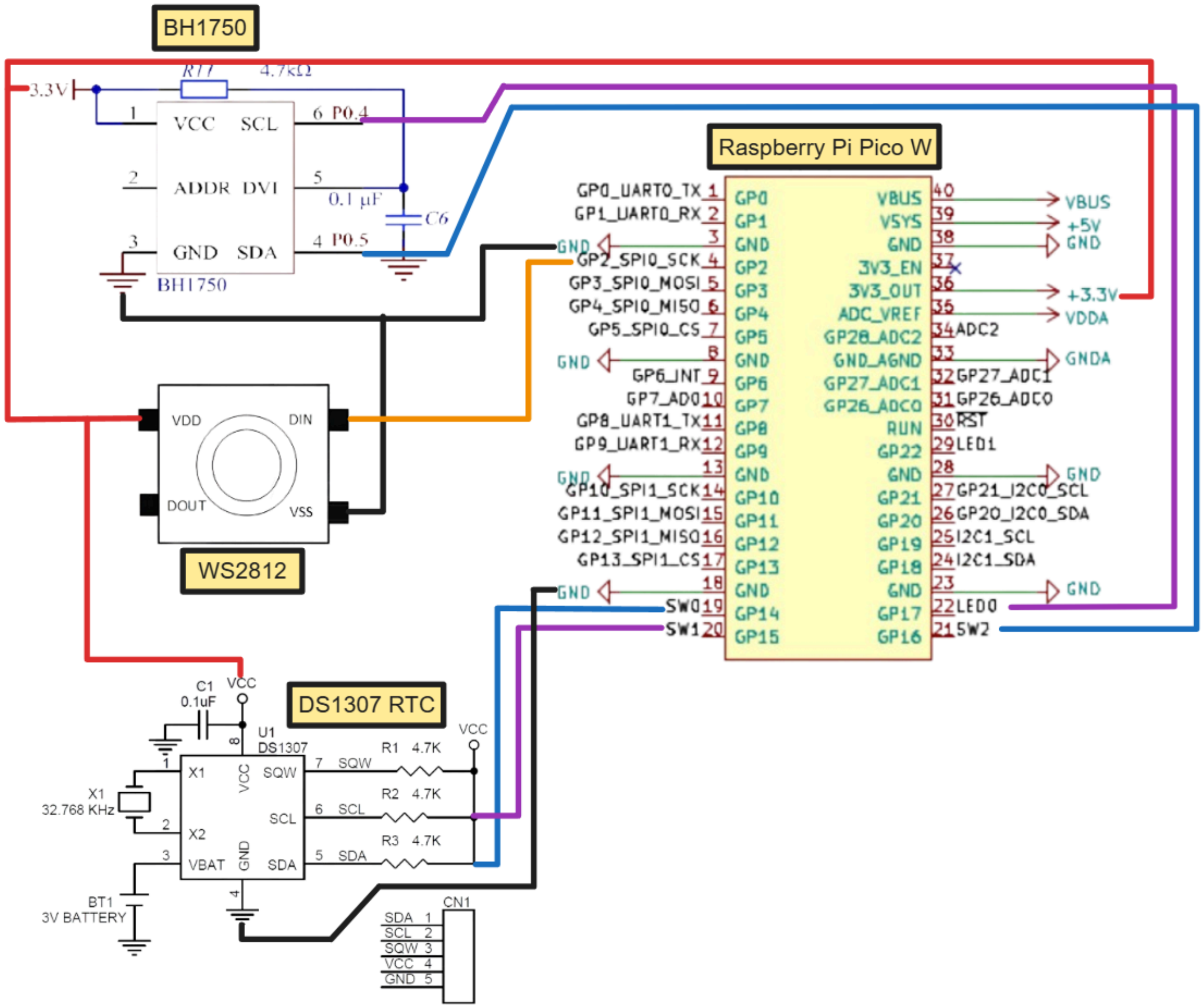
2.4 DS1307 RTC I2C Module:



The DS1307 RTC I2C module, coupled with an AT24C32 EEPROM and a backup battery,The DS1307 RTC serial real-time clock is low power, fully binary coded decimal(BCD)clock/calendar plus 56 bytes of NV SRAM.Address and data are transferred serially through an I2C, bidirectional bus.The clock/calendar provides seconds, minutes, hours, day, date, month and year information.The end of the month date is automatically adjusted for months with fewer than 31 days,including corrections for leap year.The clock operates in either the 24-hour or 12 hour format with AM/PM indicator.The DS1307 has a built in power-sense circuit that detect power failures and automatically switches to backup power supply. The backup battery, typically a CR2032 coin cell, ensures data is retained even when power is out. Communication between the microcontroller and this module occurs seamlessly via the I2C protocol, streamlining setup, time adjustment, and data retrieval. The DS1307 module includes AT24C32 EEPROM for reliable non-volatile storage of user settings and configurations. This module contains 8 pins namely X1(crystal oscillator input), X2(crystal oscillator output), Battery input, GND, SDA, SCL, SQW/OUT, VCC. The SCL,SDA of RTC Module are connected to GP19 and GP18 of Raspberry Pi Pico W. The VCC and GND of the peripherals like RTC Module are connected to VCC and GND of the Microcontroller.

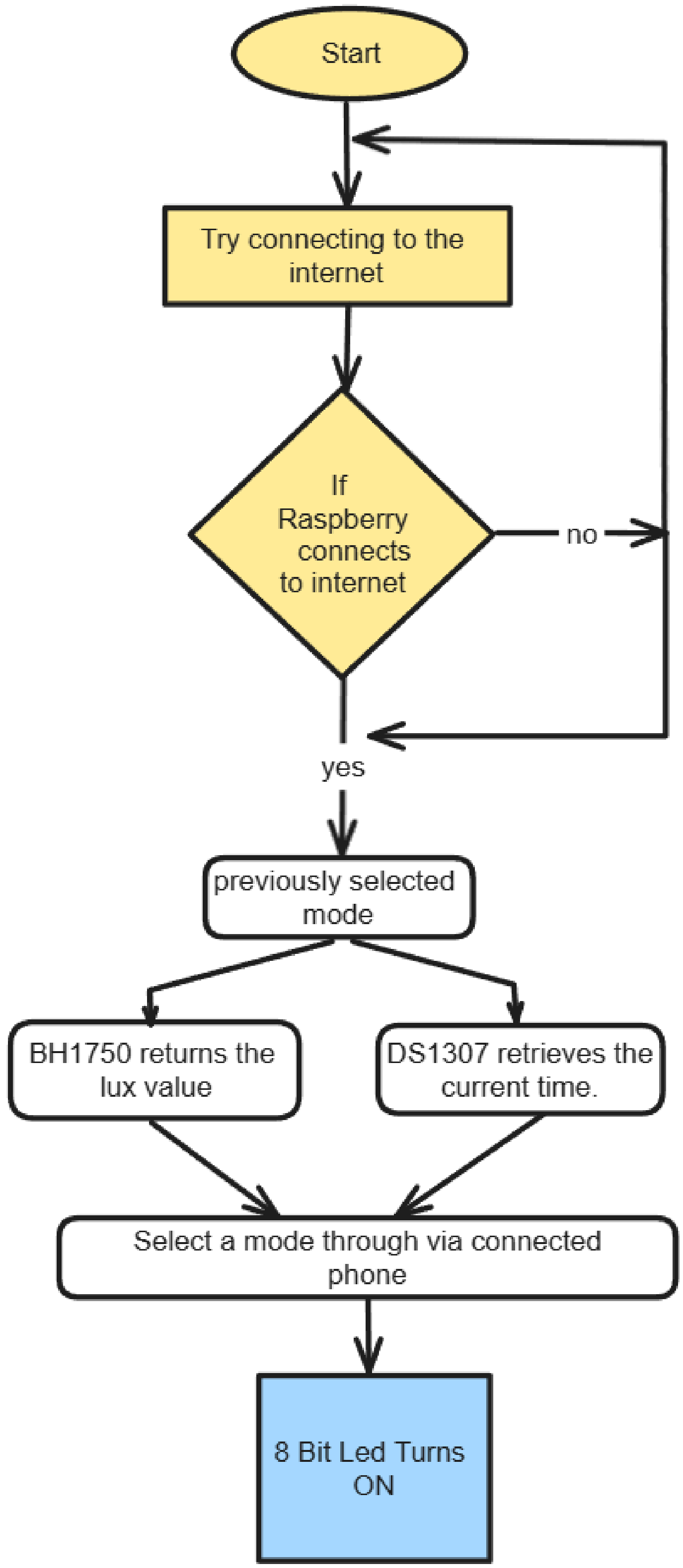
3. CIRCUIT AND FLOWCHART

3.1 Detailed and labeled circuit diagram

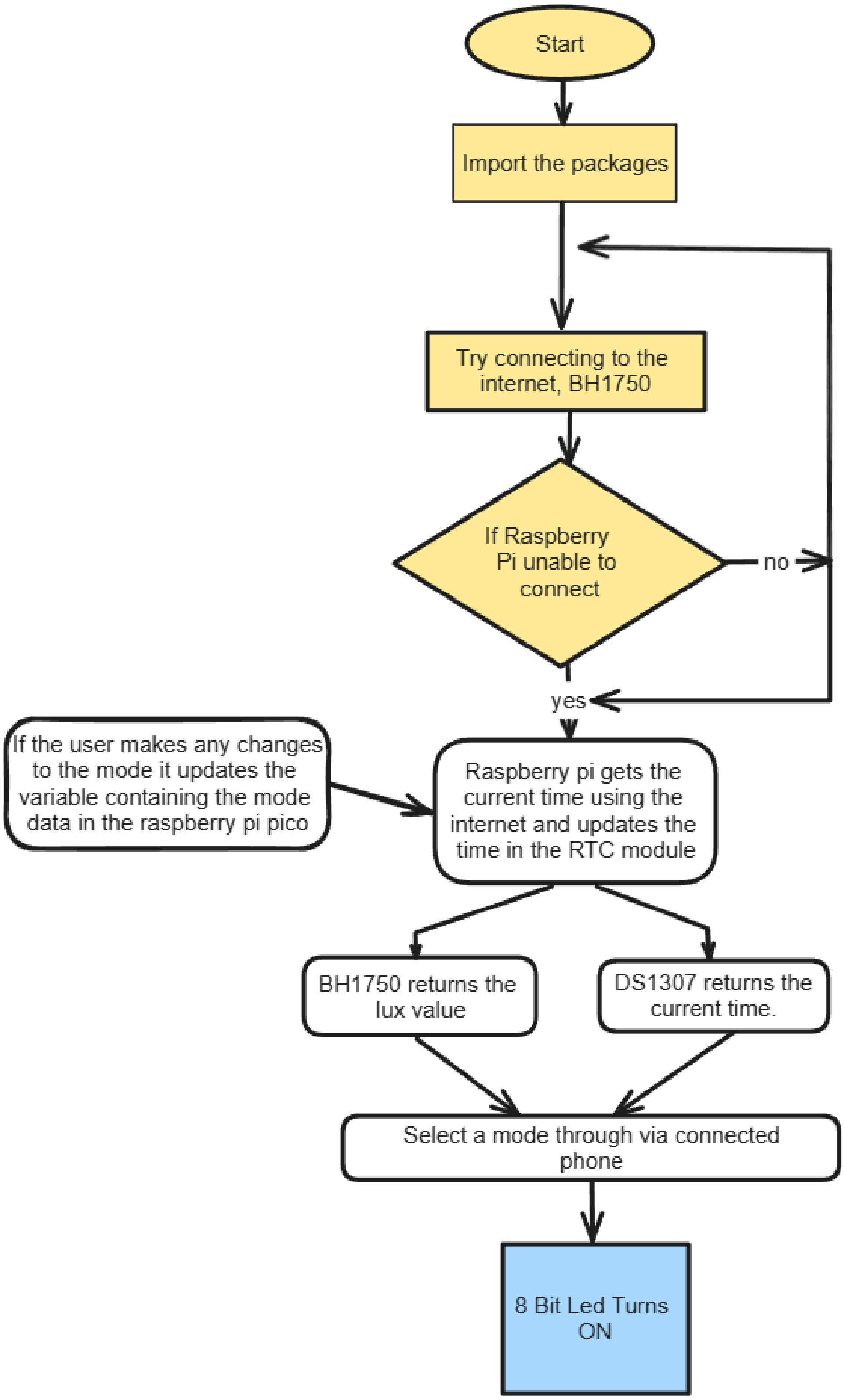


Red: VCC
Black: GND
Blue: SDA
Violet: SCL
Orange: DIN for RGB

3.2 Detailed flowchart of hardware working



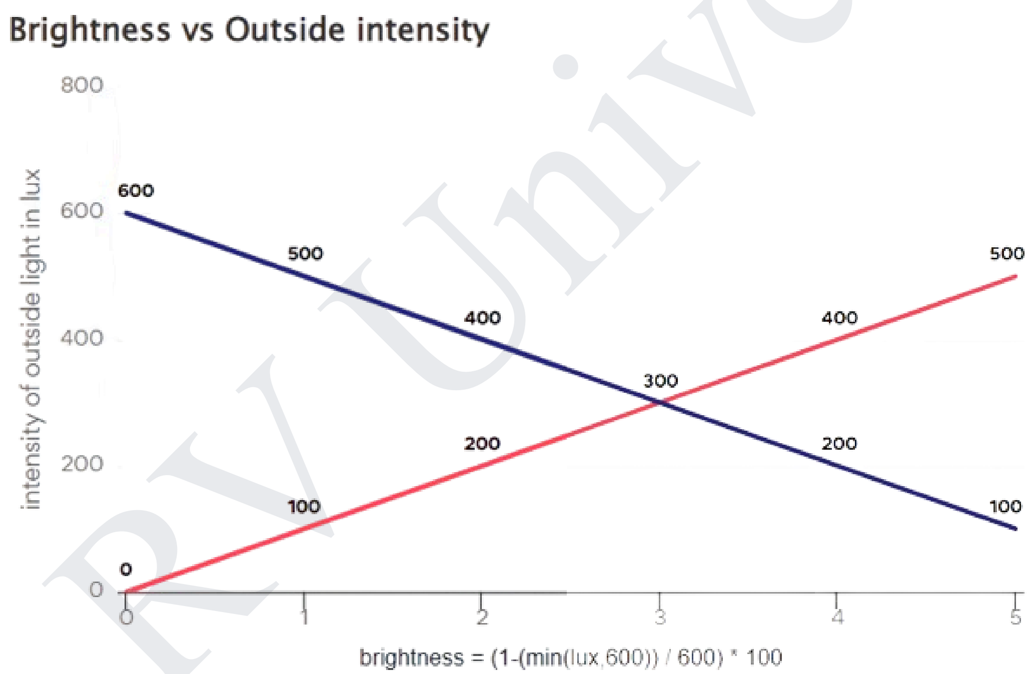
3.3 Flowchart of your code



4. DATA

From BH1750 (Light intensity sensor):

We are getting the ambient light intensity of the environment, using which we are controlling the brightness of the RGB bulb so that it is power efficient. The BH1750 provides real-time data on the Lux value of the environment and the data is transferred serially through an I2C. It continuously returns the Lux value to the Raspberry Pi Pico W where it is directly being substituted in a formula to determine the optimal brightness of the bulb. We are storing the lux value only temporarily until the pico board gets the new lux value.
Referring to research, it is known that the best lux value for studying is 400-500 lux. Similarly for other places like living room, office room there are different lux values best suited for that situation and place. So using BH1750 suppose we want 600 lux in the room and there is already 600 lux present, then we turn the led off, else if something like 400 lux is present we increase the brightness of the RGB LED so that they together make 600 lux in the room.
This is lux value from BH1750 VS the brightness of the RGB:



From DS1307 RTC (Real Time Clock):

We are getting the time and date information. The RTC module returns the current second, time, date, and year continuously to the Raspberry Pi Pico W through an I2C. The data is being stored temporarily in a variable that is being updated continuously. Based on this information we slightly change the color of the RGB suitable to that situation ie. from blue to orange shade of white light from day to night.

From the Client:

We are getting which mode to select either normal, circadian or power saver. So, basically the Raspberry Pi Pico W hosts a web server and using that IP address we can connect our smart phones to command the light bulb. Whenever the user wants to change the mode or brightness he/she makes those changes in the website and through that the raspberry pi pico w receives the data and makes the changes accordingly. So, the mode data it receives is stored in a variable.

5. CONCLUSION

5.1 Problems And Solutions

The main problem encountered was to find a suitable LED in which the implementation of circadian lighting that adjusts its brightness and intensities at different times of the day had to be done. Problems were also faced in making the system react to real time changes like progression in time and light intensity changes. To tackle these problems integration of WS2812 RGB LED and RTC Module were made in this project. The WS2812 RGB LED provides control over brightness and color while RTC Module ensures accurate time tracking for lighting adjustments based on the circadian rhythm. By combining these components we created a lighting system that is capable of adapting to surrounding environmental changes.

5.2 Applications

Maintaining a circadian rhythm is a must to have quality sleep and be free of extreme daytime sleepiness. Hence this bulb can be used in all educational institutions, workspaces, residentials. People who work overtime or in closed environments will not have exposure to natural light which disrupts their circadian rhythm. Hence, they may find it difficult to sleep. This smart bulb, if used in these kinds of workspaces, can expose them to natural lights without them going out and hence helps to maintain their circadian rhythm. Also, for people who work on night shifts they don't get to see the sun, so their circadian rhythm is totally off which affects their health, this smart light bulb also aims to help them.

5.3 Future Works

This project can be improved by letting the users have their own personalized schedules to set their wake up and bedtime. And it can have different modes to make sure that it can be compatible with any geographical area. The residents of places where the sun never sets or stays hidden for a long time will have an irregular circadian rhythm, hence maintaining it would be a great help for them. Further this project can be integrated with health trackers which can send the user's activity levels, sleep quality and other relevant data to the device which can then adjust its lighting patterns accordingly to further maintain circadian rhythm.

6. References

Electronics-Lab.com.(n.d.).DS1307RTCSMDModule.[online]AvailableAt: https://www.electronics-lab.com/project/ds1307-rtc-module/#google_vignette [Accessed 10 May 2024].

Anon, (2022). *Arduino with BH1750 Ambient Light Sensor | Random Nerd Tutorials. [online] Available at: https://randomnerdtutorials.com/arduino-bh1750-ambient-light-sensor/.*

ElProCus - Electronic Projects for Engineering Students. (2019). BH1750 Ambient Light Sensor - Specifications & Applications. [online] Available at: https://www.elprocus.com/bh1750-specifications-and-applications/.

Macfos (2024) *Buy real time clock DS1307 RTC I2C module AT24C32 with battery online at robu.in, Robu.in | Indian Online Store | RC Hobby | Robotics. Available at: https://robu.in/product/rtc-ds1307-i2c-real-time-clock-module-battery/ (Accessed: 27 March 2024).*

Google.co.in. (2024). Role of melatonin in the regulation of human circadian rhythms and sleep. [online] Available at: https://scholar.google.co.in/citations?view_op=view_citation&hl=en&user=e9oJ1vgAAAAJ&citation_for_view=e9oJ1vgAAAAJ:u-x6o8ySG0sC [Accessed 10 May 2024].

Codes: https://github.com/SumanBR321/Urban-Nest-Circadian-Rhythm-based-smart-bulb

Videos: https://drive.google.com/drive/folders/1kSV1q5kjWZhel6lupN8nEroDgrNU39k5?usp=sharing