ELDERLY LOCATION AND LOGISTICS INTERFACE (ELLI)

HOUSTON ENGINEERING CENTER
TEAM HEC16

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We certify that all the work contained within this submission represents our original work, except where we have acknowledged the ideas, words, or material of other authors/creators.

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Most of all, we would like to thank our family for all of their support during this very strenuous endeavor. We are only successful because of their exceptional support.

EXECUTIVE SUMMARY

The Elderly Location and Logistic Interface (ELLI) is a system composed of different smart devices connected and working to address problems facing Assisted Living Facility health care patients. ELLI combines commercially available tools with some additional insight and design to address issues facing Healthcare Agencies providing care in an Assisted Living Facility setting. ELLI focuses on improving patient care and mitigating risk factors facing these agencies. The ELLI architecture consists of a network of individual components, a Smart Lock, Wearable Smart Device, Bluetooth Beacon, and smart LED Lighting Source, all centered around a Central Control Hub (CCH). By incorporating these components, ELLI tracks patient data and controls access throughout the facility.

The system prevents the patient from accessing restricted areas such as staff areas, and restricted medical supply cabinets using a smart Bluetooth lock. The Central Control Hub helps care providers access patient's information and visit verification. An integrated circadian LED light maintains the patient’s circadian rhythm and communicates with the wearable device to detect a patient's positioning. The patient’s proximity triggers the light to adjust the lighting to follow a designed circadian rhythm protocol. The Bluetooth beacon doubles as a signal extender allow enhanced flexibility.

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INTRODUCTION

Background

Assisted living health care eases the cost of managing patients with chronic illness and disabilities. By providing routine care and a living environment for their patients, these facilities work to ease the load on the health care system. Roughly 1,600,000 people are living in approximately 17,000 licensed nursing homes and another 900,000-1,000,000 living in estimated 45,000 residential care facilities [1]. Private assisted care companies, licensed by the state government, facilitate the care process for patients in assisted care health care programs. These companies must balance effective measures aimed at improving the care process and reduce risk factors while strictly adhering to government regulations.

The Department of Health and Human Services (DHHS) and The Center for Medicare and Medicaid Services (CMS) are government regulatory bodies that are responsible for auditing Healthcare Agencies and ensuring compliance [2]. This verification process helps to reduce falsified employee hourly billing. The EVV mechanism's main objective is to verify the caregivers are physically present at the time reported and billed by the agency. The purpose of developing ELLI proof of concept is to leverage commercially available devices to address issues facing healthcare agencies. The most common lawsuits facing healthcare agencies are medication and dosage error, failure to report abuse, fall or illness of the patient, and failure to follow primary physicians' orders [3]. Healthcare Agencies are looking for ways to have more oversight on their care providers and patient’s progress without violating the patient's privacy. Scheduled and random government audits look for any inconsistencies in the documentation or practices of the agency. The consequence of failing a government audit can range from a fine to losing the state-issued license[1]. The leading cause of audit failure is usually poor documentation such as

timesheet error, poor notes, failure in executing patient care plans, and regulatory violations. The incorporation of the ELLI system architecture streamlines several aspects of the care process. While designed to meet the objectives and requirements of the care providing companies, ELLI also works to enhance patient quality of life. Designing an efficient system required an understanding of how the interactions between the patient and care providers affect the quality of care.

Project Scope

The objective of this project centers on patient health and safety. the provision of care implementations and effective monitoring/evaluation processes impact the patient's health and safety. The provision of care is a treatment planning process that is composed of four core components: assessing patient's needs, planning patient care, providing and coordinating care. Monitoring and evaluation of the patient are vital to the effectiveness of care plan, ELLI aids in this process by implementing a smart wearable device. This device tracks the patient's vital signs such as heart rate and blood pressure, the patients' sleep patterns, and step data. Excessive fluctuations in the patient's vital signs could be an indication of a health issue, and this can prompt care providers to check on the patient and administer care if needed. Tracking patient's vital data is also useful because it gives health care professional insight on patient's health and helps them make necessary adjustments to the care plan.

The smart lighting fixture improves sleep patterns by manipulating light variables such as light intensity (illuminance), wavelength, and correlated color temperature to maintain the patient circadian rhythm. The circadian rhythm biologically regulates an individual's sleep-wake cycle and repeats roughly every 24 to 25 hours [4]. Within this process, the correlated color temperature that is radiated is processed by the body and directly leads to an increase or decrease in the

production of melatonin. The neurons inside of the human eye contain a “photopigment called melanopsin (with an absorption peak of the light at a ~480 nm) and are involved in various reflexive responses of the brain and body to the presence of (day)light, such as the regulation of circadian rhythms, pupillary reflex, and other nonvisual responses to light” [5]. The retina, the photoreceptor cells synthesize melatonin, cortisol, and dopamine. These hormones assist in regulating blood sugar to give the body the appropriate amount of energy that is required throughout the day. The human body reacts to the ambient light structures by producing cortisol to increase activity or melatonin to calm and sedate the body[6]. The correlated color temperature (CCT) is “the temperature of the Planckian radiator whose perceived color most closely resembles that of a given stimulus at the same brightness and under specified viewing conditions” [7]. Illuminance, measured in lux, is the amount of light that is cast on a surface. The total output of visible light from a light source is measured in lumens [8].

The impact lighting has on a patient’s health can often be neglected; therefore, adequate lighting is installed to improve the patient’s cognitive responses and energy levels. Additionally, the lighting fixture has Bluetooth proximity sensors that turn the light on/off based on the localization of the patient. The light Bluetooth sensors search for patients using the Bluetooth MAC address of their wearable device; the wearable devices also serve a Bluetooth key that secures or access patient’s private areas by locking or unlocking the Bluetooth smart locks. Controlling access via Bluetooth devices makes the system attractive to agencies that operate large living healthcare facilities.

Healthcare agencies' goals are to administer adequate care while working with the patients to implement a long-term plan of care. ELLI give the agencies more control and accountability over their care providers through a series of administrative protocols on the user interface.

Biometric information will secure patient's data and verify care provider visits, helping Healthcare Agencies comply with government EVV regulations. The ability of the system to log and store data helps the agencies in successfully going through the extensive government auditing process.

REQUIREMENTS & SPECIFICATIONS

- The facility lighting source needs to maintain the patient's circadian rhythm.
    - The lighting fixture activates depending on the proximity detection of the patient's wearable device.
    - The lighting fixture adjusts to the circadian schedule designed for that individual patient based on the specific Bluetooth MAC address of the patient's wearable device.
- Touch-to-Activate Bluetooth locks to prevent access to restricted areas (50%)
    - Patient Rooms
    - Staff Areas
- Design a set of Bluetooth Beacons to track the location and movements of patients.
    - Two Patients / 4 Beacons
    - Location monitoring created on the triangulation of Bluetooth signal strength.
    - Acts as Bluetooth range extender.
- Design a wireless Communication network for the entire system architecture.
    - Centralized Hub – 7" Capacitive touch screen with attached Raspberry Pi 4
- Integrate a smart wearable device to monitor patient vital signs
    - Alarm for deviations of vital signs.
- Implement a biometric lock to the user interface
    - Fingerprint module

DESIGN CONCEPT

ELLI integrates a smart wearable device that tracks patient movement and vital signs. Bluetooth locks prevent the patient from accessing restricted areas. The system features a user interface located on the Central Control Hub that the care provider can use to monitor the patient. ELLI also features an electronic visit verification mechanism that ensures the caregiver is physically there for the duration of their shifts through fingerprint authentication. The fixture communicates with the wearable device. It detects the patient's proximity to the fixture and turns on/off as the patient moves in and out of the room. The light source maintains the circadian rhythm to help improve the patient sleep cycle. The following figure is the concept design layout.

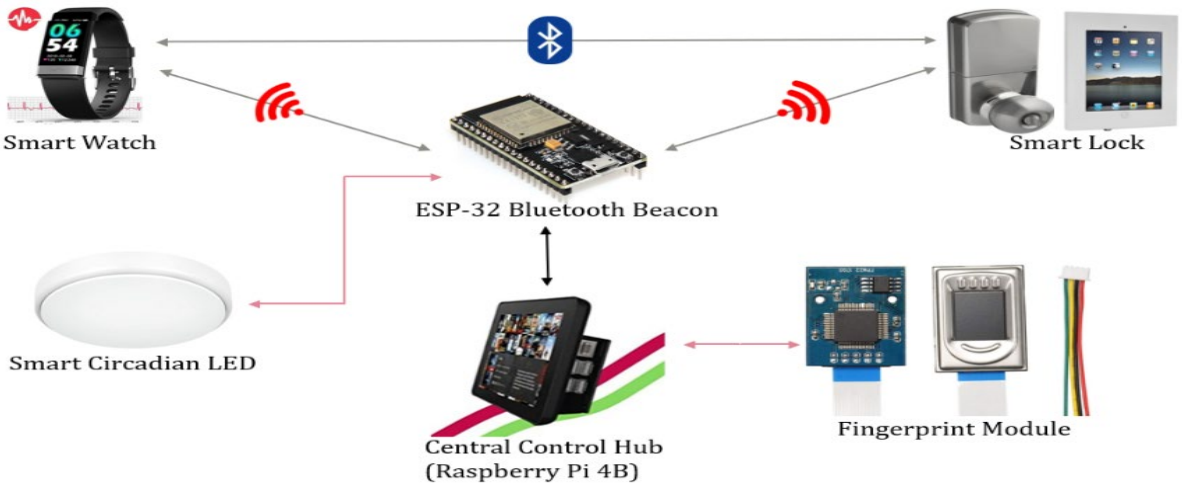


Figure 1. Elli Design Concept.

As illustrated in Figure 1, there are five major components of the system consisting of: a central control hub, Bluetooth beacon, smart lock, LED light source, and smart wearable watch. Each part plays a role in the system and features several subsystem hardware components. Understanding the purpose of these components or sub system's performance helped in material selection, system configuration, and software development.

Central Control Hub

The Central Control Hub is the system's main processor and functions as the brain that facilitates how different parts of the system are communicating. The CCH comprises of three pieces of hardware: A NeeGo 7-inch screen case with a daughterboard, a 2GB Raspberry Pi 4B with a 32GB SD card, and a StarTech capacitive fingerprint module.

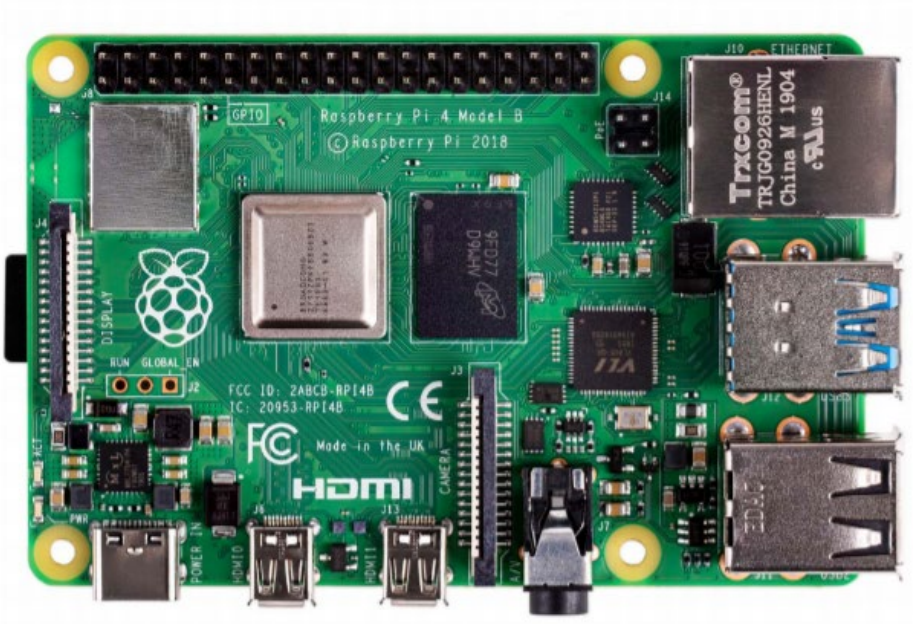


Figure 2. Raspberry Pi 4 Model B [9].

With dual display support, the Raspberry Pi 4B is the 4th generation microprocessor with a 64-bit quad-core processor. The Raspberry Pi 4B also holds up to 4GB of RAM, dual-band 2.4/5.0 GHz wireless LAN, Bluetooth 5.0, Gigabit Ethernet, USB 3.0, and PoE capability[10]. One of the key features is the modularity of the Bluetooth and LAN; this enables the controller to segment the connections to other wireless devices while improving the processors' compatibility.

The Raspberry Pi 4B features a 40-pin General Purpose Input/Output pins (GPIOs), demonstrated in Figure 3 below. The pin configuration, featuring eight ground pins, can deliver 5V or 3.3V. While some pin locations deal specifically with specific formats of data and signal,

the remaining pins are all GPIO pins [11]. GPIOs send and receive signals from external components.

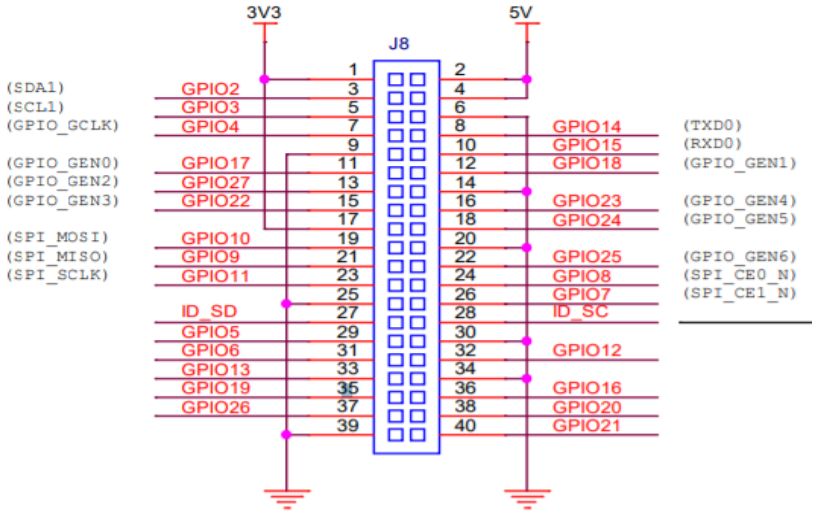


Figure 3. Raspberry Pi 4B Pin Layout [10].

Serving as the display for the CCH, the NeeGo 7-inch touch screen case has a full color 800 x 480 resolution. The touch screen allows the user to view and input relevant patient data. The NeeGo 7-inch touchscreen case manufactured for the Raspberry Pi 4B has built-in compartments for accessing the Raspberry Pi ports. The display makes the system more mobile, which improves system implementation.

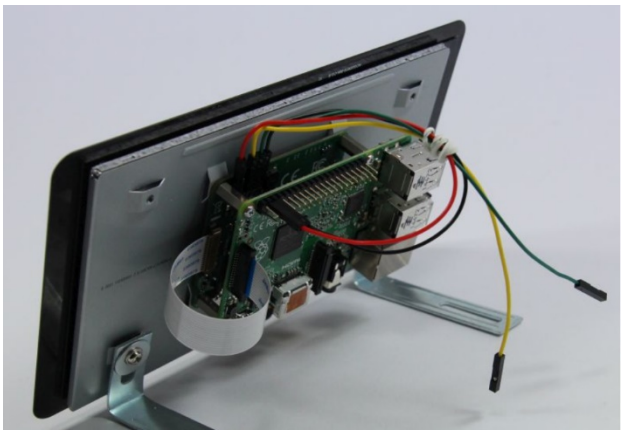


Figure 4. Elli Touch Screen Display.

The screen case will serve as a cover to improve the aesthetics of the control hub. Additionally, the case allows the placement of heat sinks to manage the system's operating temperature. The application of special adapters simplifies the screen configuration; this screen connection features a Raspberry Pi display daughterboard, which is a microprocessor that bridges the link of the screen to the Raspberry Pi motherboard. Bridging the connect improves the assembly process and allows for ease of maintenance. Accessing any patient information requires authentication. As stated in the project specification, it would require a biometrics collection mechanism. The system will utilize a capacitive fingerprint module for the implementation of an Electronic Visit Verification mechanism. The StarTech capacitive fingerprint secures over 1000 thousand prints and features a DSP chip that does rendering, calculation, feature-finding, and searching [12].

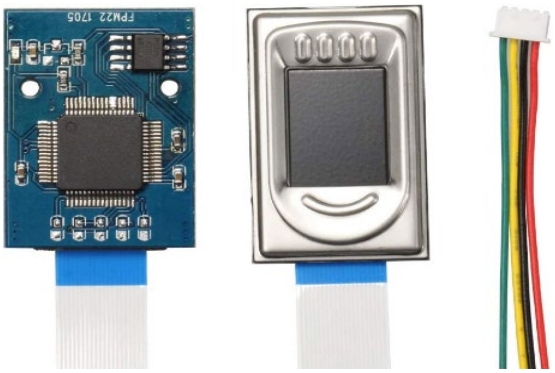


Figure 5. StarTech Capacitive Fingerprint Module [13].

Installing the fingerprint module requires a physical connection between the Raspberry Pi and the sensor. The fingerprint sensor can be connected using the wires from the fingerprint module directly on the GPIO pins; however, for simplicity, we will use a USB TTL series convertor. This converter changes the connection from the GPIO pins to the USB ports, and it improves the installation process. The figure below illustrates the fingerprint module connects via the USB TTL series converter to the Raspberry Pi along with an LED display.

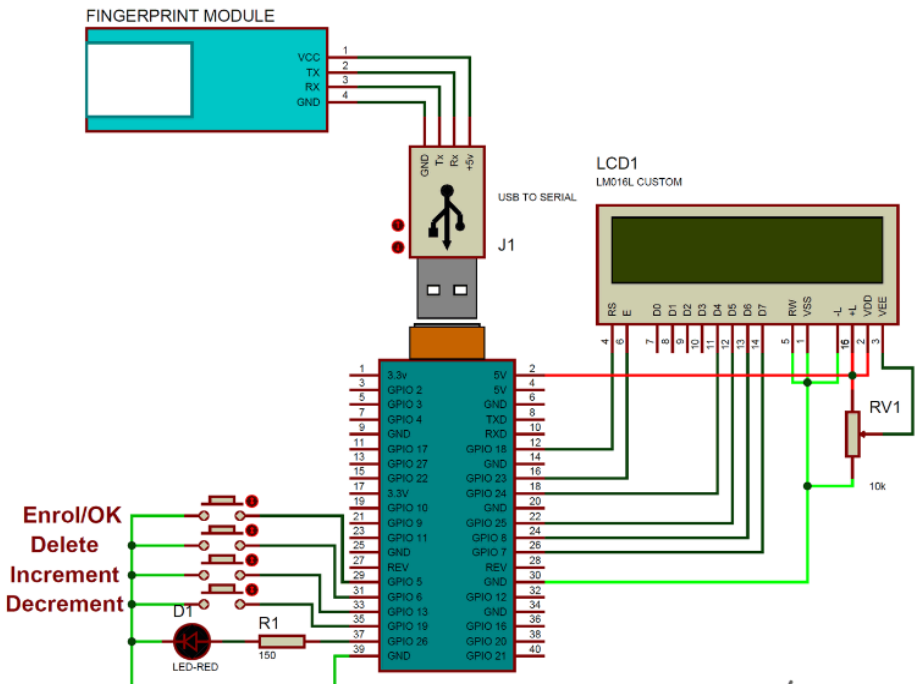


Figure 6. Fingerprint Module Testing Connection [14].

Connecting the fingerprint module does not ensure the module will work correctly, so testing the module is required. It was programmed to display access granted or denied. Four push buttons are featured in Figure 6, and it was also used in the testing process to enroll, delete and increment or decrement; the module even stores and authenticates the fingerprints. The buttons and LED displays are replaced by the user interface application. Storing the fingerprint data in multiple slots within the programming; this improves the accuracy and allows the system to recognize the fingerprint, further reducing delays [15].

Bluetooth Beacon

The Bluetooth beacons utilizing a NodeMCU ESP-32s development board. This board is ultra-low power, powered by a standard 5V-2A MicroUSB charging cable or a 1000mAh lithium battery, and works great with the Arduino IDE. They put out very little heat when functioning to the max capacity. The beacon case is explicitly designed to allow for heat dissipation. The boards can pick up a Bluetooth signal within a 10m range, so each one of the beacons can cover an area

of 314m^2. The placement of the beacons should maximize the coverage area of the beacon while allowing overlapping coverage circles. The beacons detect the proximity by sending out a predefined packet of data. This data is read by the smartwatch, which gives the location of the smartwatch. Several parameters can be adjusted to make the system run as desired.

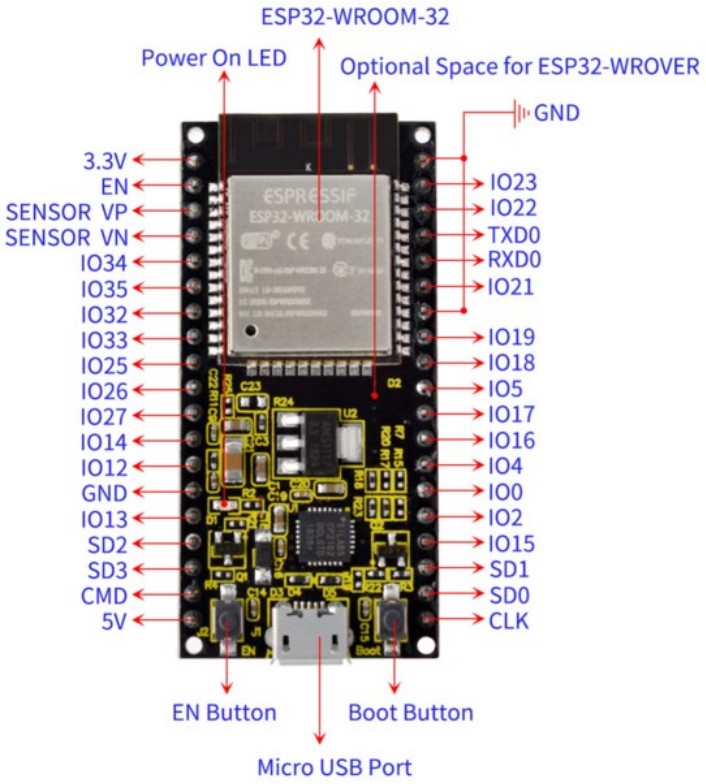


Figure 7. ESP-32 Development Board Pin Layout [13].

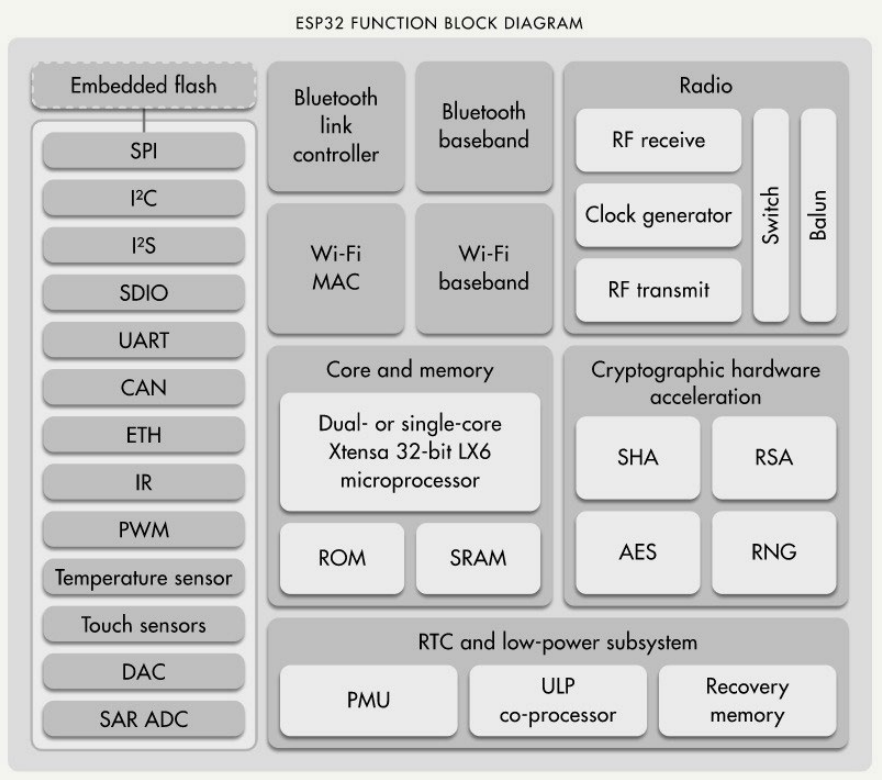


Figure 8. ESP-32 Block Diagram [16].

Smart Lock

A smart lock is arguably the most essential part of a smart system. In an Assisted Living Facility, this permits the patients to come and go freely without the need for a key to keeping their living area secured. There is no Bluetooth door lock available on the market that will grant access based on the Bluetooth MAC address of a smart device. The result is a uniquely designed door lock system that uses a capacitive touch screen to initiate the unlocking process. Once the correct Bluetooth MAC address is verified, the NodeMCU ESP-32S transmits a unique identifier to the door lock via 433 MHz radio frequency.

This system allocates the user to assign special privileges to the patient, caregiver, or maintenance staff with identifiable characteristics. The Bluetooth device gives an area of 10 meters to be in range but will only verify the device in closer proximity. The lock offers activity logs so the user can backlog to see who has entered or exited the room and the duration of the activities.

An auto-lock feature, also included, requires the lock to engage after a few seconds to maintain positive security automatically.

Led Lighting Source

These are the requirements that the lighting must be at to accommodate the Elderly. The illuminance level is the intensity of the light source per unit area and is measured in lux. The UGR rating is the rating of how much glare should affect one person. The Chromatic Rendering Index (Ra) is the rating in which how much a light source gives off the color of an object [17]. Table 1 below lists the lighting requirements for increased vision in the elderly.

Table 1. Lighting Elderly Requirements [17].

Application and activity	Average illuminance levels			Uniformity Avg/min	UGR max	R_a
	E_{floor}	$E_{work\text{-}plane}$	E_{eye}			
– *Bedroom*						
General	100 lx		60 lx	3:1	19	>80
Desk		800 lx	75 lx	3:1		
Reading in the bed		400 lx	100 lx	3:1	19	>80
Chairs		400 lx	50 lx	3:1		
TV watching	60 lx		30 lx	3:1		
Medical examination	300 lx	500 lx	150 lx	3:1	16	90
– *Dining room*						
General	100 lx		40 lx	5:1		
Formal		100 lx	40 lx	4:1	22	>80
Informal		200 lx	80 lx	4:1	22	>80
Breakfast		400 lx	100 lx	5:1	22	>80
Lunch		200 lx	40 lx	3:1	22	>80
Dinner		200 lx	40 lx	3:1	22	>80
– *Living room*						
General	60 lx		60 lx			>80
Table games		400 lx	150 lx			>80
Reading, studying		1,000 lx	400 lx			>80

Creating comfortable lighting without glare, making sure that the LED light source is not visible by adjusting the angles of the light beam.

The luminous intensity distribution shows the direction and intensity of light that emits from the light source. Figure 10 illustrates the direction and location of the rays of light coming out of the source, using a "direct-indirect" method of lighting for the patient room. The C-angle correlates to the coordinate of the light source such as north, south, east, and west. The gamma angle is the direction the light rays will be hitting a target such as upwards, downwards, or a combination of both.

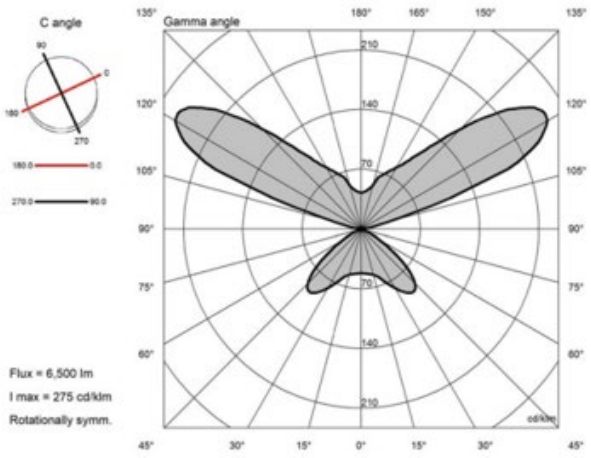


Figure 9. Luminous Intensity Distribution for Patient Room [17].

A Unified Glare Rating (UGR) calculates glare from light through bright light sources such as an LED bulb[18]. The UGR rating grades, ranging from 5 to 40, and rates the likelihood that a luminaire will cause discomfort. The average UGR values are between 10 to 30. Below ten is shown to have no discomfort to the eyes, but anything above 30 will cause discomfort[18].

$$\mathbf{UGR} = 8 \log \left[\frac{0.25}{L_b} \sum \left(\frac{L^2 \omega}{p^2} \right) \right]$$

L= The luminance value of the luminaire
Lb= The value of the background luminance
ω= The solid angle of the luminaire that is seen by the viewer
p= The Guth Index. Based on the likelihood of glare, also known as Visual Comfort Probability
Σ= Shows that the equation (shown above) includes all the fittings located within the area.

Figure 10. The Unified Glare Rating Formula[19].

UGR is calculated at the line of sight. Figure 12 is the position and orientations chosen for the calculation of UGR. The positions and orientations chosen for the UGR calculations are based on typical patient positions.

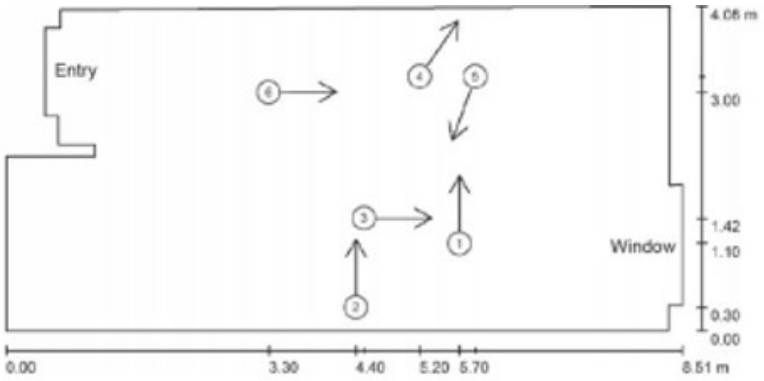


Figure 11. Position and Orientation for UGR Calculations [17].

Table 2 shows the values of the UGR at the position and orientation in Figure 11. The values indicate the UGR ratings are within the acceptable limits and is not likely to cause discomfort in the patient.

Table 2. Values of UGR Factors in Typical Patient Positions

Ref.	Position	Angle	UGR
1	Standing, between the two beds, facing the desk	90°	15
2	Lying on the bed, reading	90°	13
3	Sitting on the bed, oriented towards the window	0°	17
4	Sitting at the desk, facing the wall	55°	<10
5	Sitting at the desk, facing the beds	−110°	20
6	Standing, entering the room	0°	<10

These two vantage points demonstrate how the intensity and glare will influence the observer. Entering the room, as shown in Table 2, shows how low the glare is because the value

for UGR was less than ten so as the patient enters the room, he or she can see everything inside the room.

Historically humans have been living during daytime hours under the sun, which typically produces a broad spectrum 6500K environment [20]. Most lighting designers avoid the "bluish" color of 6500K sources, even though the blue/cyan portion of the spectrum helps to suppress melatonin in our bodies and keeps us awake. Figure 15 illustrates the effects of lightning intensity on melatonin suppression. While we need blue stimulus during the day, at night, we need to prepare our bodies for sleep with warmer CCTs such as 2700K, 2200K, or even 1800K [8].

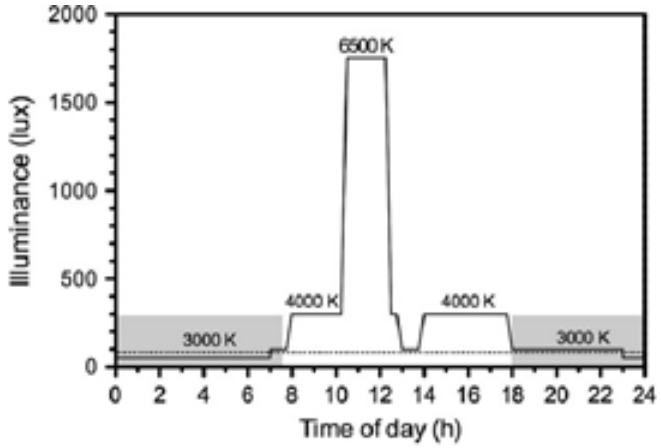


Figure 12. Average 24-Hour Circadian Rhythm Scenario [21].

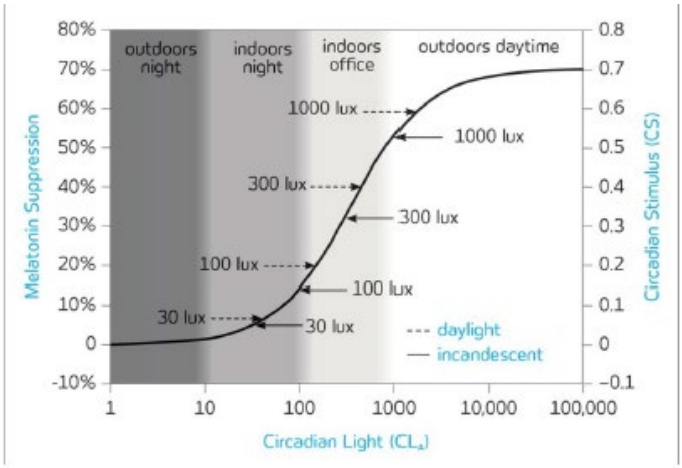


Figure 13. Light Intensity Vs. Hormones Suppression [20].

A significant component of the ELLI system, the lighting source, is comprised of the IESTARING Dimmable LED Flush Mount Ceiling Light - 12W (120W Equivalent) and the ESP-32 to facilitate communication between the light fixture and the wearable Bluetooth device. As a patient approaches the lighting fixture located in their rooms, the light will turn and adjust to their circadian rhythm by changing light intensity and wavelength to a more optimal value for the patient. The lighting fixture aids the Central Control Hub to maintain communication with other components of the system.

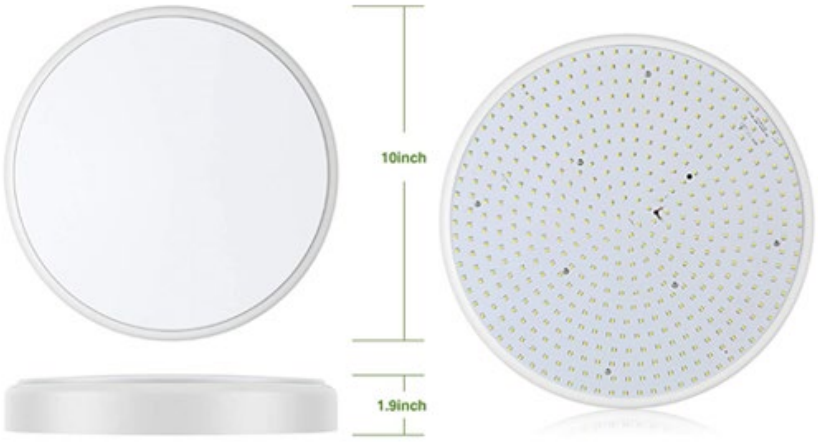


Figure 14. Flush Mount LED Light Source [22].

Table 3. Lighting Specifications

SPECIFICATIONS	
Light Technology	LED
Color Temperature	4000k
Maximum Wattage	12 watts
Light Output	1200 lumens
Incandescent	120 watts
Dimmable	APP Control Only
Input	100- 240V, AC
Average Life	50,000 hours

The chosen LED ceiling light offers brilliant lighting (1200 lumens) and high luminous efficiency, while the ceiling light provides adequate lighting to illuminate the room. These top-quality LEDs have an estimated lifespan of up to 50,000 hours per one lighting fixture. The facility supplies the standard 124.5VDC. The ESP-32 will need to operate under 5V/3A. In order to work, it is necessary to decrease the power; otherwise, the standard voltage and overall power output from the wall are too powerful for the small device. From the wall, we have the power transmitting directly to the light itself, but also, split and fed into the buck converter for conversion for the ESP32 device. A Buck converter is required as a measure to reduce the power and ensure the ESP32 functions without errors.

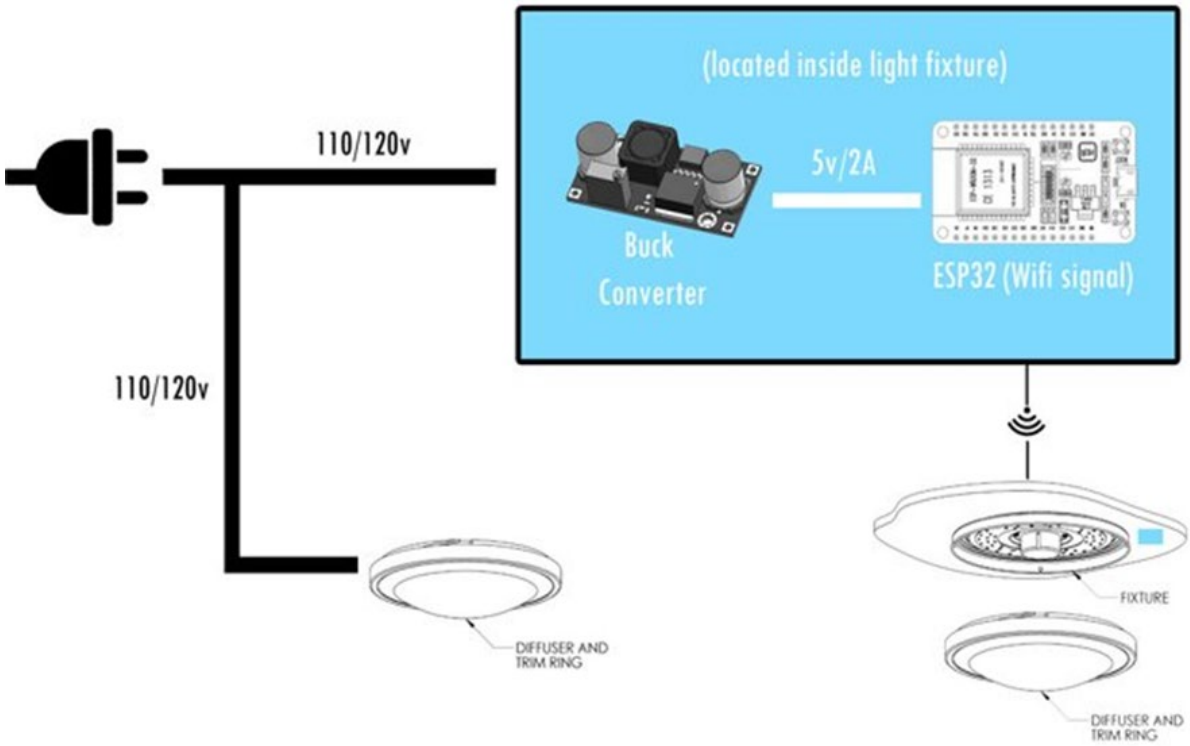


Figure 15. Flow chart displaying DC connection with a buck converter.

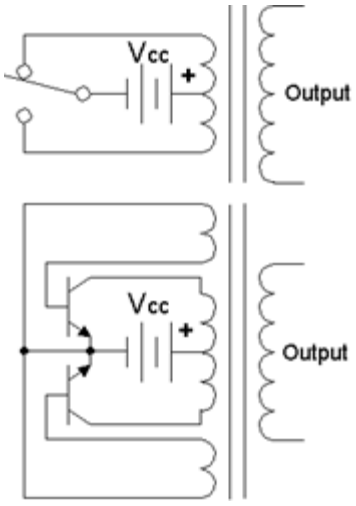


Figure 16. Simple inverter circuit [23].

The inverter circuit above is a micro-view of what allows the conversion of power to 5V/3A needed for the ESP32.

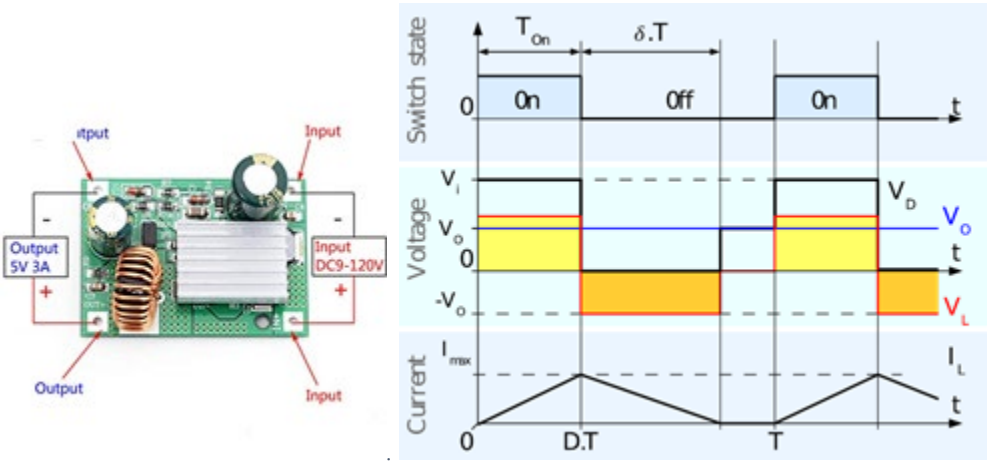


Figure 17. Buck Converter (DC Step Down Module) and accompanying switching chart [24],[25].

This chart displays the switching of power for adjustment needed in order to power the ESP32 device correctly.

Table 4. Functions of a buck converter.

STEP DOWN MODULE'S KEY CHARACTERISTICS
• High voltage input • Stable voltage output • Support over-temperature protection • Support overvoltage protection • Support short circuit protection • Low power consumption • Support constant voltage constant current output • Support charging function

The table above lists the functions of the buck converter. These are necessary for the support of the device while active, to prevent any potential issue.

Table 5. Calculation Data.

DATA DERIVED FOR CALCULATIONS	
Heat dissipation	
Working Voltage	DC 9.0V - 120V (Keep input is at least 4V higher than output)
Output Voltage	DC 5V
Output Current	3A
Output Power	15 W
Conversion efficiency	About 96% (The smaller the differential voltage, the higher the efficiency
Working frequency	140 kHz
Soft Starter	Yes
Over-temperature protection	Yes
Overvoltage protection	Yes
Short circuit protection	Yes
Working Temperature range	-40℃ ~ 85℃
Working Humidity range	0% - 95% RH

Fourier analysis is used to calculate the total harmonic distortion (THD), which is the square root of the sum of the squares of the harmonic voltages divided by the fundamental voltage. This sample EKG is an expansion on the Fourier analysis, basically a sine wave. This is like pulse width modulation (PWM); however, stepping is different. With all the elements placed together, it provides for the heart of the lighting system.

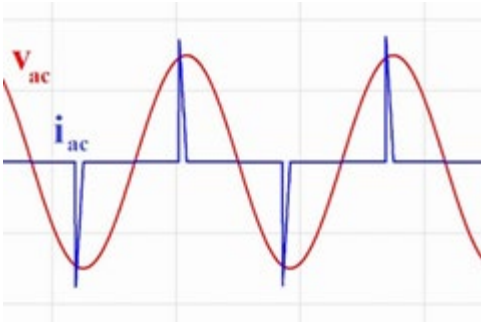


Figure 18. Sample EKG [26].

The fluctuations in the sample EKG are alternating frequencies that simulate the changes that can be made by the light when adjusting to the circadian rhythm of the patient. Where there are peaks, the lighting is at maximum power and output, and when lowest, it is off.

Smart Fitness Tracker

The selected wearable device is a MorePro V19 Fitness Tracker, a unique wearable E-C-G that provides the user with professional E-K-G analysis. Simply rest their fingers on the sensors for 30 seconds (no wires or gels required) and view the results on the App instantly. Track their rhythm and heart rate at any time, anywhere, while giving them peace of mind. An electrocardiogram video on the App displays how the heart rhythm performs.

The wearable device is detailed with a 1.14-inch IPS color screen. Although it has a less bulky design, it is equipped with a bigger and brighter HD screen to provide more visible readings even while in the sun with the brightness adjustment. With IP68 waterproof capacity, the device can be worn while washing hands, taking a shower, or even partaking in some water sports. It also provides a 24/7 health monitor with updated sleep monitoring, and it works for not only general night detecting but also daytime naps with detailed sleeping data like deep sleep/light sleep. The green light plus infrared dual detect heart rate and blood pressure with personalized in-app reports.

It continuously tracks steps, walking distance, calories burnt, activity times. No technology is required to sync the device to a phone, and easily access health reports for generally 30 days.

Download the free Morepro App and pair it to a device. With cordless USB charging style, it has a long battery life with up to 5 days fully charged for daily progress. It is universally compatible with Android 4.4 or higher, iOS 8.0, or higher smartphones.

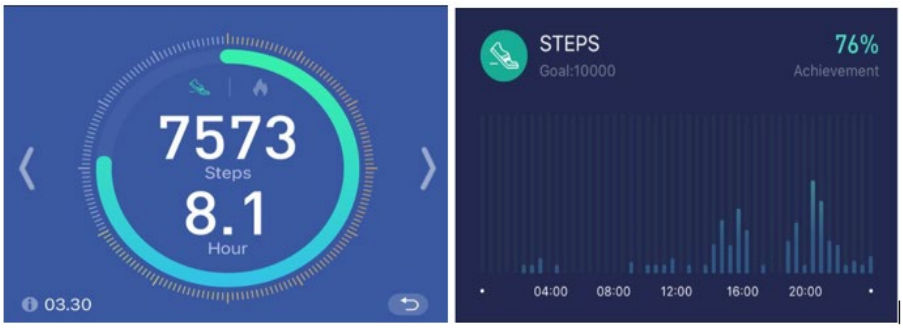


Figure 19. Steps Data from MorePro App



Figure 20. Biometric Data from MorePro App

Black Box

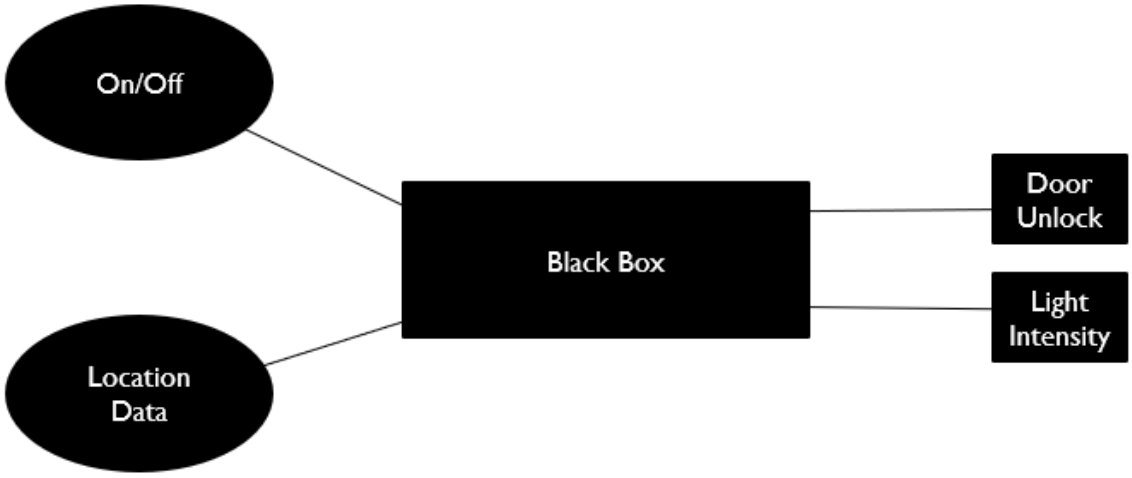


Figure 21. Black Box.

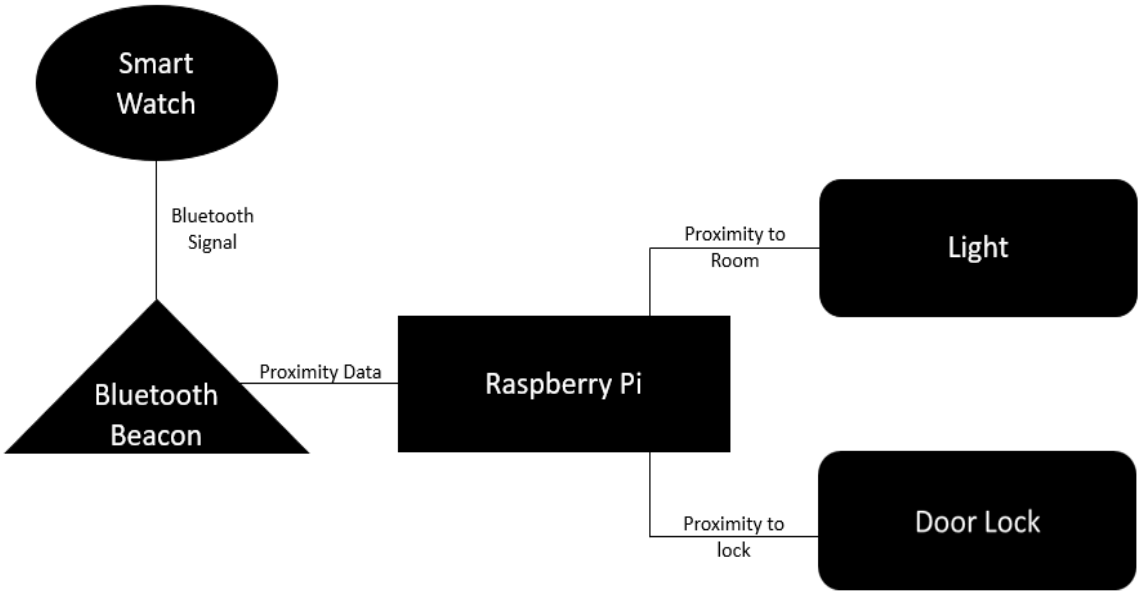


Figure 22. Grey Box

DESIGN ANALYSIS

The objective of this analysis is to identify critical aspects that will impact the performance of the system and risk factors that are associated with the concept designs. The analysis focuses on the following areas: safety, reliability, feasibility, cost, and time. The intelligent lighting system consists of four main components: a Raspberry Pi 4B, an LED light source, a microcontroller processor, and a smart device. In order to effectively analyze the system, it is essential to isolate each component and analyze its performance. A failure mode analysis also ensures an examination of the safety performance of each element.

Safety design is a process of identifying hazards and then evaluating each hazard in terms of two basic parameters: the occurrence probability of each hazard and the magnitude of possible consequences. Establishing these parameters allows us to quantify the safety performance of the system. The tables below describe the classification of failures and the anticipated outcomes and the probability of occurrence.

Table 6. Hazard Consequence Classification

DESCRIPTION		EQUIPMENT	PERSONEL
Catastrophic	C	• Damages > $50 Million • Production Losses > 1 week	• Prompt Fatalities • Life-Threatening Injuries • Permanent Disability
High	H	• $100,000 < Damage ≤ $50 million • Equipment Destroyed • Critical Equipment Damaged • Production Loss Less Than 1 Week	• Serious Injuries • Non-Permanent Disability • Hospitalization Required
Marginal	M	• Damage ≤ $100,000 • Repairable Damage to Equipment • Significant Operational Downtime • Minor Impact on Surroundings	• Minor Injuries • No Hospitalization
Negligible	N	• Minor Repairs to Equipment Required • Minimal Operational Downtime • No Impact on Surroundings	• Negligible Injuries

Table 7. Probability of Occurrence

DESCRIPTION		FREQUENCY LEVEL
Anticipated, Expected	A	Frequency > 10^{-2}/yr.
Possible	P	10^{-4}/yr. < Frequency ≤ 10^{-2}/yr.
Unlikely	U	10^{-6}/yr. < Frequency ≤ 10^{-4}/yr.
Remote Possibility	RP	Frequency ≤ 10^{-6}/yr.

The combination of Table 5 and Table 6 produces a risk assessment matrix that rates the safety performance of the system. The table below illustrates the risk assessment matrix based on quantitative analysis.

Table 8. Risk Assessment Matrix

			Frequency			
			Remote Possibility	Unlikely	Possible	Anticipated, Expected
			RP	U	P	A
Consequence	Catastrophic	C	5	2	1	1
	High	H	5	3	3	2
	Marginal	M	5	4	4	3
	Negligible	N	5	5	5	5

This approach isolates components of the design and assesses failure rates, repair rates, human error, mission time, and system logic. Each concept design will be evaluated and rated based on the safety performance of its components. To prevent a compromise in the system and not put the operator at risk, the impact of safety failures will likely govern the corrective action plan that will enable the team to focus on developing corrective action for failures.

Figure 26 illustrates the subsystems of the Raspberry Pi 4B; understanding the roles of each of these subsystems will enable us to identify parts of the subsystem that is essential to the functionality of the CCH.

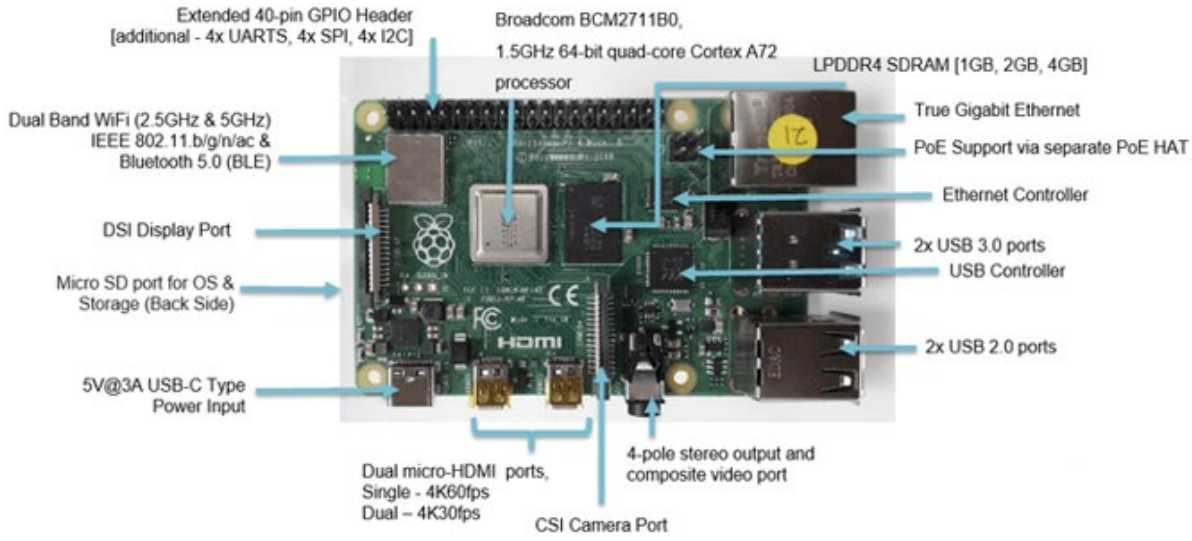


Figure 23. Raspberry Pi Subsystem [27].

Table 8 is a safety and failure analysis of the Raspberry Pi 4B. The actual life span of a raspberry pi can range between 25 to 30 years; the application of the device in the design concept will require the device to run 24 hours a day, which could significantly reduce the life span. The frequency of occurrence is based on a system life span of 15 years, but for a factor of safety, the system is assumed to have a life span of approximately ten years. The table has a mitigation plan that would help in the event of a system failure.

Table 9. Raspberry Pi 4B Subsystem Analysis

FAILURE	PROBABILITY	IMPACT	CATEGORY OF IMPACT	CORRECTIVE ACTION PLAN
SD Card Failure	Occasional	A corrupt system control mechanism	Marginal	Move highly moved files away from SD card and back up regularly
Bluetooth Card	Remote	Disrupts system connection	Marginal	Replace Raspberry PI
Processor Failure	Remote	System damage	Critical	Replace Raspberry PI
HDMI Port	Remote	Disrupt video feed to platform	Negligible	Reassign HDMI port
Exceed Operating Temperature	Remote	System damage	Critical	Thermal management casing (fan)
Ethernet Port	Remote	Disrupt physical connection	Negligible	Wireless Access Point
USB Ports	Occasional	Disrupt system communication	Negligible	Reassign USB port
Input/output Ports	Occasional	Disruption system communication	Marginal	Reassign input/output ports
Wi-Fi Card	Remote	Disruption system communication	Marginal	Switch to Ethernet connection

Failures, as a result of remote occurrence and negligible impact, usually will not require additional design changes. The following table illustrates the design considerations for failures causing significant disruptions to the system.

Table 10. Raspberry Pi 4B Design Considerations

COMPONENTS	DESIGN CONSIDERATIONS
SD Card	• Card Class (at least 10MB/s) • Wear Leveling algorithms • Manage files / Analyze I/O • Unexpected Power Disruption • Ingrate External Storage device
HDMI Port	• Probability of occurrence 3% • Reduce Frequent changes in connection
Processor/memory	• Operating Temperature • Set Temperature Limits • Initiate Throttling • Thermal Pad on Heat Sink

Recommended design considerations increase the material cost; nevertheless, this cost is justified because it impacts the performance of this component and extends the life span. The thermal regulation of the Raspberry Pi is necessary to maintain the durability and performance of the Processor. Applying additional thermal pads on the heat sink along with a fan casing improves the heat dissipation.

Evaluation of the LED cell focuses on components that changes lighting output variables such as intensity and wavelength. Figure 23illustrates the autonomy of a single LED cell. The LED light analysis is in Table 11, listed below.

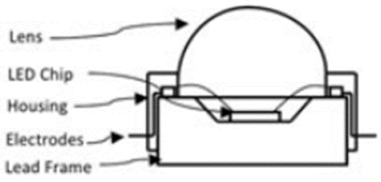


Figure 24. Anatomy of an LED cell

Table 11. LED Cell Considerations

FAILURE	PROBABILITY	IMPACT	CATEGORY OF IMPACT	CORRECTIVE ACTION PLAN
Light Degradation	Frequent	Reduce Light Output	Negligible	Compensate with other LED cells
Thermal Runaway	Remote	Increase Resistance and Operating Temperature	Critical	Heat sinks in the fixture
Electrical Open/Short	Remote	Loss of Light	Critical	Compensate until further investigation can be carried out
Threading Dislocation	Remote	Leakage of current with increase resistance	Negligible	Select UL approved bulbs
Exceed Operating Temperature	Remote	Bulb Explosion	Critical	Heat Sink in the fixture and modular design will isolate the problem
Glass Passivation	Remote	Can cause a short in the LED	Negligible	Select UL approved LED/Compensate

Table 12. LED Light Source Design Considerations

COMPONENTS	DESIGN CONSIDERATIONS
Light Degradation	• Type of lens • Size of the LED chip • Power Supply • LED driver
Thermal Runaway	• Inadequate/poor materials • Type of material for heat sink • Wire connections • UL certified source
Electrical Open/Short	• Current Leakage • Cross-connection in circuit • Bulb position • Fail to Open
Operating Temperature	• Low thermal protection • The thermal pad inside the fixture

The quality of the LED cell impacts functionality; often, better-quality LED cells are more expensive and typically more cumbersome. The size of the LED chip is proportional to light output, and the weight of heat sinks material impacts how much heat is absorbed. Selecting the most optimal LED light cell is essential to maintaining system integrity.

The flexibility of a wearable smart device allows future iterations of the design, and the data collected from the device supports health providers in achieving care plan decisions for the patient. Also, a smart device can also be used to access other systems such as a patient's medical records that useful in emergencies. The following table illustrates the analysis of the wearable smart device.

Table 13. Wearable Smart Device

FAILURE	PROBABILITY	IMPACT	CATEGORY OF IMPACT	CORRECTIVE ACTION PLAN
Screen Damage	Occasional	Screen Display and Functionality	Marginal	Reduce Screen Surface area
Power On/Off Button	Remote	Disrupts Device Power Supply	Critical	Keep Device Charged
Connectivity Card	Remote	Interrupt external device connections	Critical	Replace the device
Rapid Battery Drainage	Remote	Leakage of current with increase resistance	Negligible	Select UL approved bulbs
Exceed Operating Temperature	Remote	System failure	Critical	Heat Absorbing sinks

Alleviating the risk factors facing the wearable device depends on how well the user maintains it. Keeping the device charged will reduce the strains on the power supply and ensure consistent connectivity with the Central Control Hub and ESP-32. Limiting excessive heat exposure reduces the likelihood that the device will exceed operating temperature.

The other components in the system are the Raspberry Pi display and ESP-32, which are microprocessors used in various applications. The performance of this device is impacted by two key factors: operating and ambient temperature. These electronic device temperatures rapidly increase if there is poor thermal management in the housing fixtures. The key is to absorb the heat and dissipate it to the surrounding. In addition to thermal management, the current going to these devices must be regulated to avoid any leakage or electrical short.

BILL OF MATERIALS

Table 14. Project Bill of Materials (BOM)

PART NAME	UNIT COST	QTY REQUIRED	QTY ON HAND	TOTAL COST	PART TOTAL
CENTRAL HUB					
NeeGo Raspberry Pi 4 Screen Case for Raspberry Pi Monitor Touchscreen Display 7-inch	$24.99	1	1	$24.99	$206.45
KEXIN 3 Pack 32GB Micro SD Card Memory Card MicroSDHC UHS-I Memory Cards Class 10 High Speed Card, C10, U1, 32 GB 3 Pack	$16.99	1	1	$16.99	
Raspberry Pi 7" Touch Screen Display	$49.99	1	1	$49.99	
Easycargo Raspberry Pi 4 Heatsink Kit Aluminum + Copper + 3M 8810 Thermal Conductive Adhesive Tape for Cooling Cooler Raspberry Pi 4 B, 3 B+, Pi 3 B, Pi 2, Pi Model B+ (4pcs)	$4.99	1	1	$4.99	
Raspberry Pi 4 Model B 2019 Quad Core 64 Bit Wi-Fi Bluetooth (2GB)	$48.01	1	1	$48.01	
StarTech.com Raspberry Pi Board - USB 2.0 480Mbps - USB to M.2 SATA Converter - USB to SATA Raspberry Pi SSD (PIB2M21)	$21.49	1	1	$21.49	
FlashTree TCS2SS FPM22 Capacitive Fingerprint Module Sensor for Arduino Raspberry pi	$39.99	1	1	$39.99	

Table 15. Project Bill of Materials (BOM) Continued

PART NAME	UNIT COST	QTY REQUIRED	QTY ON HAND	TOTAL COST	PART TOTAL
BLUETOOTH BEACON					
HiLetgo ESP-WROOM-32 ESP32 ESP-32S Development Board 2.4GHz Dual-Mode WiFi + Bluetooth Dual Cores Microcontroller Processor Integrated with Antenna RF AMP Filter AP STA for Arduino IDE	$10.99	5	4	$54.95	$54.95
PROXIMITY LIGHTING					
IESTARING Dimmable LED Flush Mount Ceiling Light - 12W (120W Equivalent) WiFi Smart 10" Round Surface Mount Light Fixture for Bathroom/Bedroom/Dining Room, Compatible with Amazon Alexa (10" 12W)	$39.99	2	1	$79.98	$127.94
HiLetgo ESP-WROOM-32 ESP32 ESP-32S Development Board 2.4GHz Dual-Mode WiFi + Bluetooth Dual Cores Microcontroller Processor Integrated with Antenna RF AMP Filter AP STA for Arduino IDE	$10.99	2	1	$21.98	
18 AWG 3 Conductor 3-Prong Power Cord with Open Wiring, 10 Amp Max, 10 ft Replacement Power Cord with Open End, Pigtail Open Cable	$12.99	2	1	$25.98	

Table 16. Project Bill of Materials (BOM) Continued

PART NAME	UNIT COST	QTY REQUIRED	QTY ON HAND	TOTAL COST	PART TOTAL
SMARTWATCH					
MorePro Monitor Watch, Waterproof Fitness Tracker with Heart Rate Blood Pressure Monitor, Activity Tracker with Enhanced Sleep Monitor for Android iOS, Pedometer Calorie Step Counter for Women Men	$49.97	2	1	$99.94	$99.94
DOOR LOCK					
MiLocks WKK-02SN Digital Doorknob Lock with Keyless Entry via Remote Control for Interior Doors, Satin Nickel	$66.67	2	1	$133.34	$220.26
MakerFocus 4pcs 3.7V Lithium Rechargeable Battery JST1.25 Connector 2pin, 852540 3.7V 1000mAh Battery with Protection Board and Insulated Rubber Tape Compatible with ESP32 Development Board WiFi Kit	$21.99	1	0	$21.99	
MakerFocus 10pcs TP4056 Charging Module with Battery Protection 18650 BMS 5V Micro USB 1A 186 50 Lithium Battery Charging Board	$10.99	1	0	$10.99	
Magnetic Charging Configuration***		2	0	$0.00	
LANDZO 3.5 Inch Touch Screen 320480 for Raspberry Pi 3 Model B and Pi 2 Pi Zero Pi 1 with Touch Pen … (3.5 inch)	$18.88	2	1	$37.76	
MORNING INDUSTRY INC RM-RF Extra Remote	$16.18	1	1	$16.18	

***Magnetic Charging was not fully designed due to COVID-19.

Table 17. Project Bill of Materials (BOM) Continued

PART NAME	UNIT COST	QTY REQUIRED	QTY ON HAND	TOTAL COST	PART TOTAL
ACCESSORIES					
HATCHBOX PLA 3D Printer Filament, Dimensional Accuracy +/- 0.03 mm, 1 kg Spool, 1.75 mm, White	$39.99	2	2	$79.98	
Freenove Ultimate Starter Kit for Raspberry Pi 4 B 3 B+, 434 Pages Detailed Tutorials, Python C Java, 223 Items, 57 Projects, Learn Electronics and Programming, Solderless Breadboard	$49.95	1	1	$49.95	
USB Wall Charger, Hootek 5-Pack 1A/5V USB Power Adapter Wall Charger Plug Box Charging Block Cube Brick Compatible with iPhone XS X 8 7 6S Plus, iPad, Samsung S20, HTC, LG, Moto, Android Phone Charger	$10.79	2	0	$21.58	$179.28
USB Type C Cable OULUOQI USB C Cable 3 Pack(6ft) Nylon Braided Fast Charger Cord(USB 2.0) Compatible with Samsung Galaxy S10 S9 Note 9 8 S8 Plus,LG V30 V20 G6 G5,Google Pixel(Grey)	$9.99	1	0	$9.99	
Micro USB Cable 10ft 3Pack by Ailun High Speed 2.0 USB A Male to Micro USB Sync Charging Nylon Braided Cable for Android Phone Charger Cable Tablets Wall and Car Charger Connection Silver&Blackwhite	$8.89	2	0	$17.78	
			Total		$888.82

Remaining Cost	$292.81

FINAL ACCEPTANCE CRITERIA

Table 18. Mechanical Specifications.

SPECIFICATION	DESCRIPTION	DEVICE/INSTRUMENT TO MEASURE, UNIT	ACCEPTANCE CRITERIA
Lighting Fixture	Circadian Rhythm	Schedule/Time Based	On-Time (<5 min delay) Scheduled Changes
Lighting Fixture	Bluetooth Proximity	Location Accuracy	Within 1 meter
Bluetooth Locks	Touch-To-Activate Bluetooth Locks	Touch-To-Activate	Capacitive Touch Screen Touch Activation
Location Monitoring	Bluetooth Beacons	Locate within 1 meter	Radial Measurement
Customizable Off-Limits Area	Identify if a patient goes outside a set parameter.	Setup Constrained Area	Alarm
Smart Wearable Device	Monitor patient vital signs	Vitals on central Hub	Display Available
Fall Detection	Fall detection using three axis accelerometer, rate of movement, and abruptness of impact.	Experimental Testing	95% successful identification
Wireless Communication Network	Design a wireless Communication network for the entire system architecture.	Closed Wireless Connection for System Architecture	Network Available

Table 19. Electrical Specifications.

SPECIFICATION	DESCRIPTION	DEVICE/INSTRUMENT TO MEASURE, UNIT	ACCEPTANCE CRITERIA
Lighting Fixture	AC Outlet Power	3-Prong Outlet Cable	Correct Cable Available
Bluetooth Locks	Built-In Power	Battery Powered	Battery Powered w/ recharge system designed
Bluetooth Beacons	AC Outlet Power	Micro USB Outlet Cable	Correct Cable Available

DISCUSSION

This project proved to be quite challenging as it is focused on software engineering to create smart devices for elderly care. The well-being of our elderly citizens is paramount. Often elderly patients are neglected or mistreated because of their vulnerable state. Elderly patient care is riddled with laws to help prevent such things from happening. This project has so many aspects that can be entailed. There simply was not enough time to complete all the design components that were discussed, coupled with the rise of Covid-19. The system that has been designed is made to aid elderly patients and help maintain their safety by allowing access to only their rooms. The smart light will provide the environment for a well-maintained circadian rhythm. Ideally, the system would include a visit verification tool with a fingerprint scanner. A big issue that is faced by the elderly care services is the healthcare providers showing up to take care of a patient and then leaving before their paid time is up so they can make more money by going and seeing other patients. The electronic visit verification would guarantee the health care provider is at the older adult's home for the entire duration that they are required to be there. The fingerprint module was added in for that purpose. However, we were limited by time constraints, so it ultimately is designed for access to the central Hub by the healthcare provider to access patient information. A big obstacle that the team ran into was trying to find a Bluetooth lock that would be compatible with what we were trying to accomplish. Unfortunately, the Bluetooth locks on the market do not fit all our design criteria for a smart lock. The lock uses a signal transmitted over the 433 MHz frequency. The ESP-32 is applied to in front of the locking mechanism to detect Bluetooth proximity. When the proximity requirements are met, it sends the specific frequency fluctuation code to the unlock signal. This project has potential for future development, and future iteration can improve the functionality of the system.

RECOMMENDATIONS

This system is designed to be built upon so that the following design groups can add what the client desires. The current state of the design is incomplete. The customer wants many different functions listed below. These add-ons were beyond the time constraints presented by a single semester. Several of the items listed below could be an entire project.

Future Design Add-ons:

- Fully integrate all reporting and record systems into a single unified interface.
- Scheduling integration
    - Alert caregivers to administer medications (barcode scanning to approve proper medications)
    - Alert caregivers to take patients to doctor visit
    - Alert caregivers to complete their daily notes
- Implement NFC verification connecting visit verification with the patient's wearable device
- Integrate Shift verification by requiring fingerprint to assess patient records on the system
- Ability to specify a customizable area as off-limits
    - Identify if a patient goes outside a set parameter
    - ALARM (GUI/DEVICE) – if the patient goes outside a set parameter
- The wearable device must be able to detect and alert the caregiver if the patient falls
    - ALARM (GUI/DEVICE)
    - Fall detection using a three-axis accelerometer, rate of movement, and abruptness of impact.
    - Record fall in Patient Record
    - SQL Database of patient data stored on centralized Hub

CONCLUSION

Designing ELLI required a different approach to solving problems facing home-based health care. A system that prioritizes patients' safety and quality of care while complying with all federal and state regulations. ELLI's central control hub was designed to be mobile to give the caregiver more flexibility. The Central Control Hub features a full color LED screen and a fingerprint module for authentication. Additionally, the fingerprint module would allow for Healthcare Agencies to employ an Electronic Visit Verification process to remain in compliance with the state mandates. The patient's wearable device is another vital piece to ELLI. The wearable device will track the patient's vital signs and help control access via smart Bluetooth locks. The patient's vital signs are useful for the healthcare provider administering care and help other healthcare professionals make more effective care plans. The Bluetooth smart locks will control accessibility, which will improve the patient's safety and help prevent medication abuse. The smart LED circadian lighting will aid in improving patients' sleep patterns. The lighting fixture will maintain the patient's circadian rhythm will have a significant impact on the patient's overall health. The effectiveness of this system depends on the system able to adapt to different space configurations. ELLI uses a NodeMCU ESP-32S circuit board hosting an ESP-WROOM-32D microprocessor as a Bluetooth beacon, which significantly extends signals strength and distance; this allows ELLI to be implemented in more extensive homes/facilities. Although there are smart home systems currently in the market, ELLI is specifically designed with the patient in mind. Leveraging commercially available products makes the system more scalable. ELLI's modular design makes future design considerations easier to implement.

RELEVANT STANDARDS

ISO/AWI TS 23536	Health informatics — Digital elderly home care system (DECS)
ISO 8995:1989	Principles of Visual Ergonomics-The Lighting of Indoor Work Systems
ISO/IEEE 11073-20701:2020	Health informatics — Device Interoperability — Part 20701: Point-of-care medical device communication

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APPENDIX A - POSTER

The University of Texas at TYLER

HEC-16 Elderly Location and Logistics Interface

Rasheed Oduro[2], Amaobi Onyejiaka[1], Austin Parker[1], Trang Pham[1], Benjamin Stilwell[1]

[1]Department of Mechanical Engineering, University of Texas at Tyler – Houston Engineering Center, Houston, TX
[2]Department of Electrical Engineering, University of Texas at Tyler – Houston Engineering Center, Houston, TX

Background

Home/Facility based health care aid can be complicated when managing patients with chronic illness and disabilities. The challenges facing these facilities is balancing effective safety measures while abiding to the HIPAA laws that protect patients' privacy. Healthcare agencies would like to have more oversight on their staff to ensure that they are providing various services in order to meet all government regulations.

Objective

1. Develop, produce, and present a proof of concept for an intelligent control system that integrates different smart devices
2. Effectively and efficiently improve the quality of care and safety of patients receiving in home care.
3. The facility lighting source would need to maintain patient's circadian rhythm.

Specifications

Primary Requirement

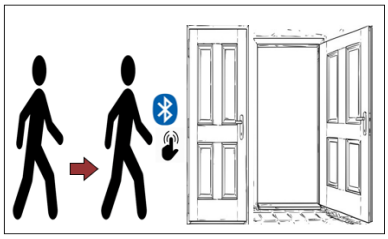
- Touch-to-Activate Bluetooth locks to prevent access to restricted areas
- Design a set of Bluetooth Beacons to track the location and movements of patients
- Ability to specify a customizable area as off-limits.
- Design a wireless Communication network for the entire system architecture
- Integrate a smart wearable device to monitor patient vital signs

Secondary Requirement

- The system will feature a graphical user interface
- Adding an emergency/panic button for patients.
- Integrate an electronic visit verification mechanism for caregivers.

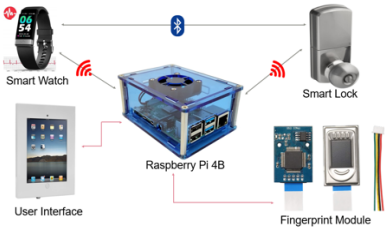
Process

Proximity Key with Touch to Unlock

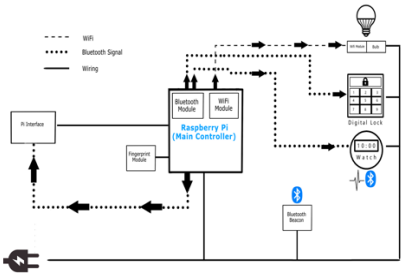


Abstract

The idea is to develop a system that integrates a smart wearable device that tracks patient movement and biometrics. Bluetooth locks will also be implemented and will allow controlled access through the smart watch. The system will feature a user interface that the care provider can use to make necessary adjustment.



Design Flow Diagram



Conclusion

The motion tracking used will increase the ability to customize the system for each patient. Without the touch activation of the lock, the door opens when the patient walks by the door even if they are not attempting to access their room. The Bluetooth allows for the patient not to worry about having another item such as a key to keep track of and to increase the ease of use.

Key Decisions

- Use of smart watch to track patient's all-day activity.
- Deciding on usage of a Raspberry PI or Android Tablet.
- Android or IOS based smart watch.
- Switching from battery operated to direct power.
- Make an easily upgradable system for future modifications.
- No longer focused on motion tracking lighting.

Future plans

The system will feature a graphical user interface	Fully integrate all reporting and record systems into a single unified interface	Scheduling interface.	Implement NFC verification connecting visit verifications	Integrate Shift verification by requiring fingerprint to assess patient records.

Acknowledgements

- **Sam Ogletree** - Faculty Advisor
- **Dr. Andres Garcia** – Director of HEC
- **Dr. Mohammad Biswas** - Faculty
- **Chrisavnetcare Homecare Services** - Sponsor

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Figure A. 1. Elli Design Poster.

APPENDIX B – SIGN OFF SHEET

The University of Texas at TYLER
COLLEGE OF ENGINEERING

Department of Mechanical Engineering
Phone: +1.903.566.7003
Fax: +1.903.566.7148
Uttyler.edu/engineering

SENIOR DESIGN II – FINAL STATUS SHEET

TEAM: HEC 16 **Date:** 04/22/2020

Project final status:
COMPLETED: _____ **NOT COMPLETED:** X
ESTIMATED % Completion 65 %

Location on OneDrive where team project folder can be downloaded - See instructions after this table: https://livepatriotsuttyler-my.sharepoint.com/:f:/g/personal/aparker23_patriots_uttyler_edu/Eiw8WbE8WGtAr3et7z7h4FgBq7APTNNb-qZMUGnUqXzyOw

PENDING ITEMS:
Full Assembly of System Components
Installation and system testing
Install ESP-32 Bluetooth beacon into Lighting Fixture
Assemble and test coding for Central Control Hub
Test System connectivity range

OUTSTANDING ITEMS ORDERED (BUT NOT RECEIVED)
USB TTL Adapter

OUTSTANDING ITEMS NOT ORDERED
Additional Lighting Fixture
Additional Smart locks
Additional Bluetooth Beacon

FINAL COMMENTS:
The system components were tested to ensure performance and validate design, however we were not able to fully assemble all the components and test the system extensively. Assembling the system would allowed the team to test different scenarios and make any neccesary adjustments in the system configuration.

SIGNATURE:

1.- Name: Rasheed Oduro	**Signature:**
2.- Name: Austin Parker	**Signature:**
3.- Name: Trang Pham	**Signature:**
4.- Name: Amaobi Onyejiaka	**Signature:**
5.- Name: Ben Stilwell	**Signature:**
6.- Name: Samuel Ogletree	**Signature:**
7.- Name: Chris Okeke	**Signature:** chrisokeke

Page 1 of 2

Figure B. 1. Final Status Sheet.

APPENDIX C – ECONOMIC FEASIBILITY

Cost of each component of the system (not including tax)

- Base Cost of Hub: $207
- +$170/smart door lock
- +$50/person for watch
- +$128/smart light
- +$18/314m^2 Bluetooth beacons for main areas not utilizing smart lights

Single bedroom for a facility (11'x13'8")

- Total Cost = $555 ($683 w/ optional extra light)
- Base Hub + 1 door lock + 1 smart light + 1 watch (+ optional extra light)

4 Bedroom with a living area for an apartment-style housing facility

- Total Cost = $1855 ($1617 for no smart lights in living room)
- Base Hub + 4 door locks + 4 smart lights + 4 watches (Base Hub + 4 door locks + 6 smart lights + 4 watches)

The system is not limited by the hardware, but it is limited by the patient to caregiver ratio

- Five patients/caregiver during the day
- Ten patient/caregiver at night

APPENDIX D – TIMELINES AND MILESTONES

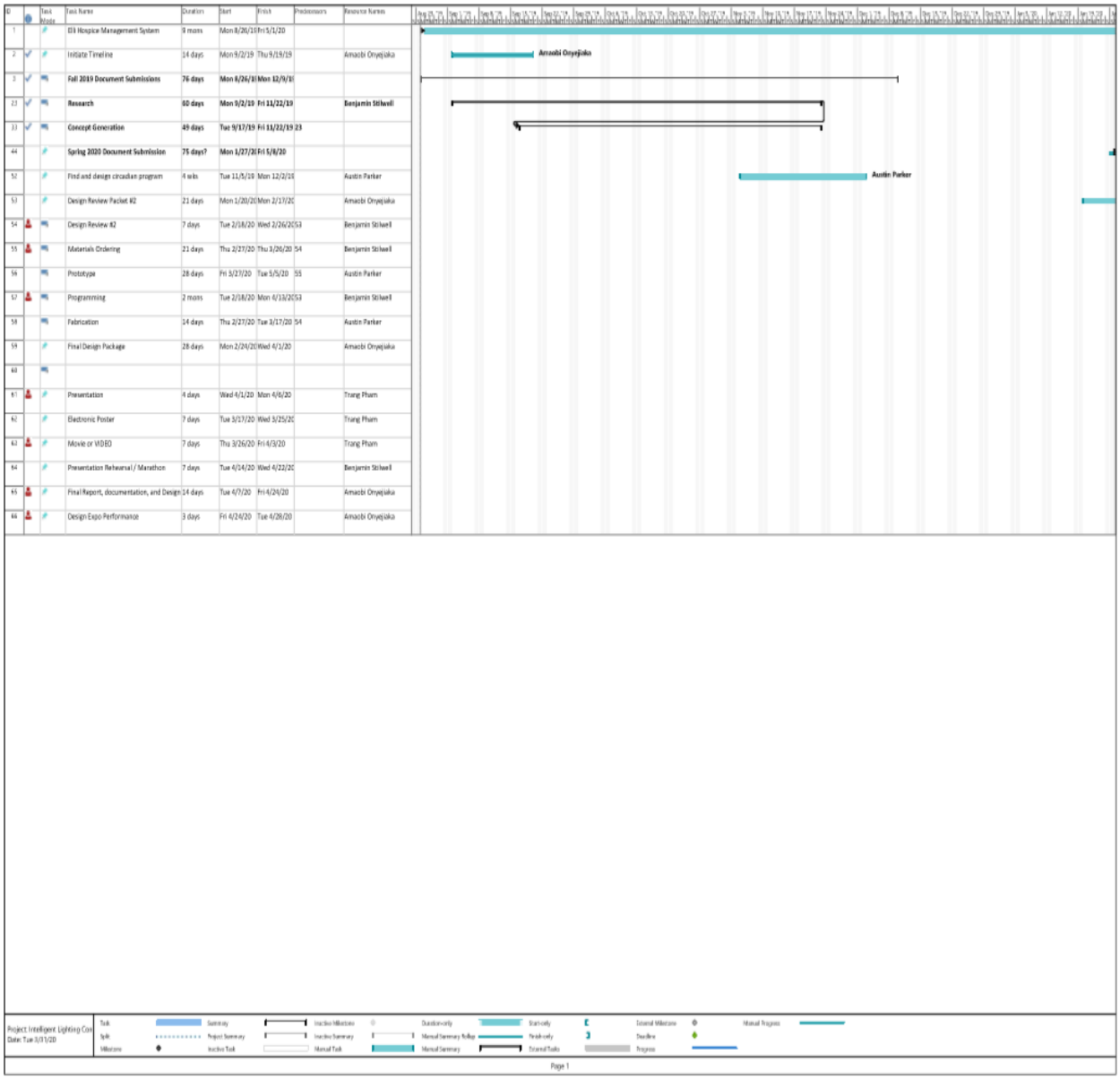


Figure D. 1. Gantt Chart Part A.

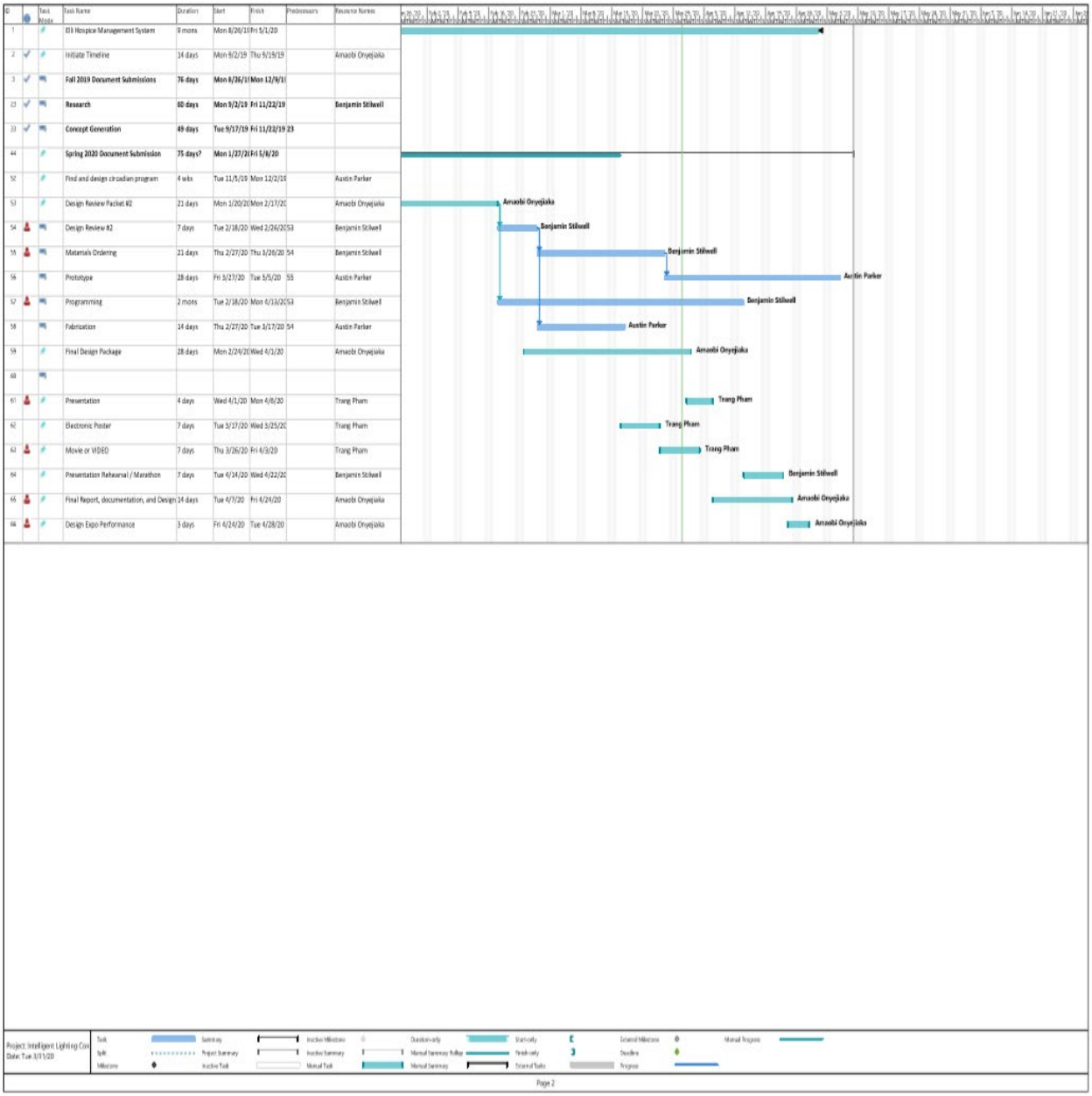


Figure D. 2. Gantt Chart Part B.

APPENDIX E – ARCI CHART

REPORT DISTRIBUTION				
NO.	**ITEM / PART**	**ASSIGNED TO**	**REVIEWED BY**	**IMPORTANT NOTES**
1	Cover Page	B. Stilwell	R. Oduro	
2	Acknowledgements	T. Pham	A. Parker	**Acknowledgments**: List individuals and/or companies that provided support in the way of equipment, advice, money, samples, etc.
3	Executive Summary	A. Parker	T. Pham	• The purpose of the executive summary is to provide key information up-front, such that while reading the report, a reader has expectations that are fulfilled on a continuous basis. Key to a good Summary is the first sentence, which must contain the most essential information that you wish to convey. • The summary is to be written as if the reader is totally uninformed about your project and is not necessarily going to read the report itself. • It must include a short description of the project, the process and the results. • The Executive Summary is to be one page or less with one figure maximum.
4	Table of contents	B. Stilwell	R. Oduro	
5	Introduction / Background	T. Pham	A. Parker	Include appropriate background on the project for the reader to be able to put the information provided in context.

REPORT DISTRIBUTION				
NO.	**ITEM / PART**	**ASSIGNED TO**	**REVIEWED BY**	**IMPORTANT NOTES**
6	Concept Statement	A. Parker	T. Pham	
7	Requirements and Specifications (tables)	A. Onyejiaka	R. Oduro	Table made up of requirements directly from NASA Document.
8	Constraints (table)	R. Oduro	A. Onyejiaka	Table made up of requirements directly from NASA Document.
9	System and subsystem level black box and functional diagram	R. Oduro	B. Stilwell	
10	Design Concepts / Alternatives	A. Parker	T. Pham	
11	Comparison table / Decision making process	A. Onyejiaka	A. Parker	**Feasibility Study**: include any assumptions made and all factors that were considered
12	Selected design details / analysis / decisions' bases	A. Onyejiaka	A. Parker	
13	Design calculations and selection reasoning for each component, subsystem, and system	R. Oduro	B. Stilwell	
14	List of risks involved / Failure mode analysis	A. Onyejiaka	A. Parker	Pugh Analysis

REPORT DISTRIBUTION				
NO.	**ITEM / PART**	**ASSIGNED TO**	**REVIEWED BY**	**IMPORTANT NOTES**
15	Testing plans and Design of experiments for outcomes	T. Pham	A. Parker	**A Testing/Verification Plan**: Write a narrative description of test plans. Use tables, graphs, and wherever possible to show how you will record and quantify your results. Also, include a description of how you plan to test the final system, and any features you will include in the design to facilitate this testing. This section forms the written record of the performance of your design against specifications.
16	BOM and detailed Budget	T. Pham	A. Onyejiaka	**Bill of materials**: Parts costs include only those items included in the final design. A detailed bill of materials includes (if possible) manufacturer, part number, part description, supplier, quantity, and cost.
17	Flow charts of software	B. Stilwell	R. Oduro	
18	Mechanical drawings	T. Pham	A. Onyejiaka	Include fixtures, central hub box, Vegetation Lighting, etc.
19	Electric circuits diagrams	R. Oduro	B. Stilwell	
20	Acceptance criteria and success-metrics (related to 7 and 8 above)	A. Parker	T. Pham	

REPORT DISTRIBUTION				
NO.	**ITEM / PART**	**ASSIGNED TO**	**REVIEWED BY**	**IMPORTANT NOTES**
21	Timelines and milestones with dates	A. Parker	T. Pham	**Gantt chart**: Show a complete listing of the major tasks to be performed, a time schedule for completing them, and which team member has the primary responsibility (and who will be held accountable) for each task.
22	ARCI chart	B. Stilwell	R. Oduro	The RACI/**ARCI** Matrix is a responsibility assignment matrix system that brings structure and clarity to assigning the roles people play within a team.
23	Discussion	T. Pham	A. Onyejiaka	
24	Safety	A. Onyejiaka	T. Pham	
25	Recommendations	R. Oduro	B. Stilwell	
26	Conclusion	T. Pham	A. Onyejiaka	**Conclusion**: Provide a reasoned listing of only the most significant results.
27	References	B. Stilwell	R. Oduro	
28	Appendices	**ALL**	B. Stilwell	

Final Formatting	B. Stilwell

	Assigned to	**Reviewed by**
B. Stilwell	5	5
R. Oduro	5	6
A. Onyejiaka	5	5
T. Pham	7	6
A. Parker	5	6

APPENDIX F - MECHANICAL DRAWINGS

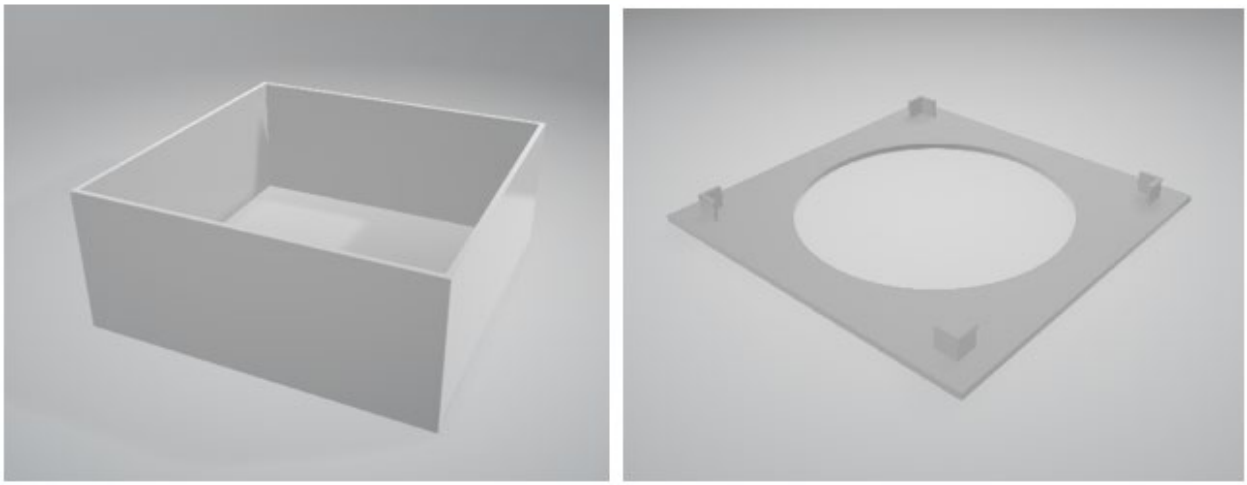


Figure F. 1. Initial Light Fixture Design.



Figure F. 2. Initial Central Hub Casing.

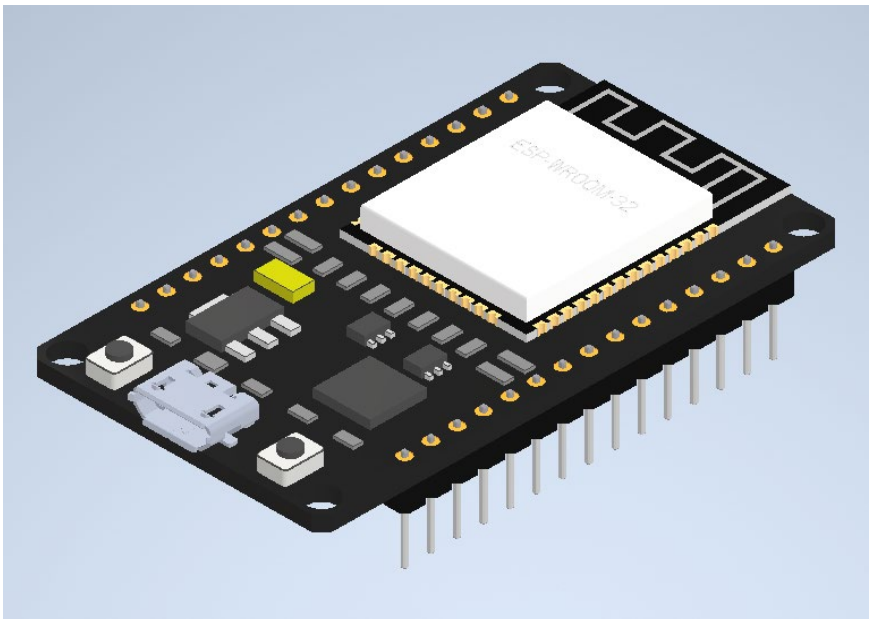


Figure F. 3. NodeMCU ESP-32S.

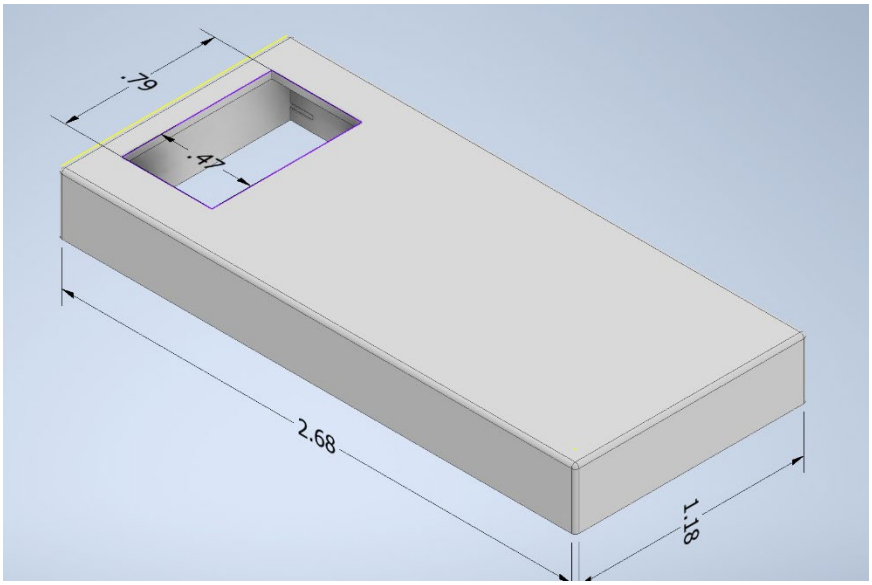


Figure F. 4. Beacon Casing.

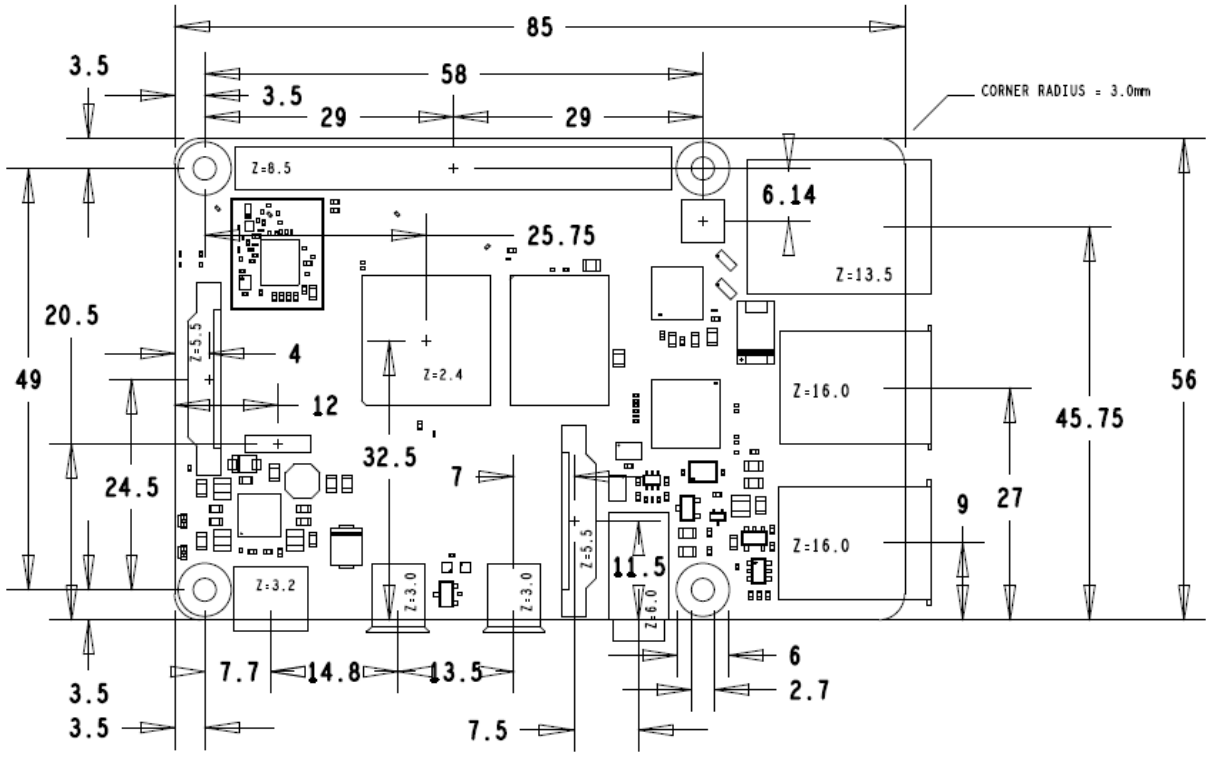


Figure F. 5. Mechanical Drawings for Raspberry Pi 4B [10].

APPENDIX G – ELECTRIC SCHEMATICS

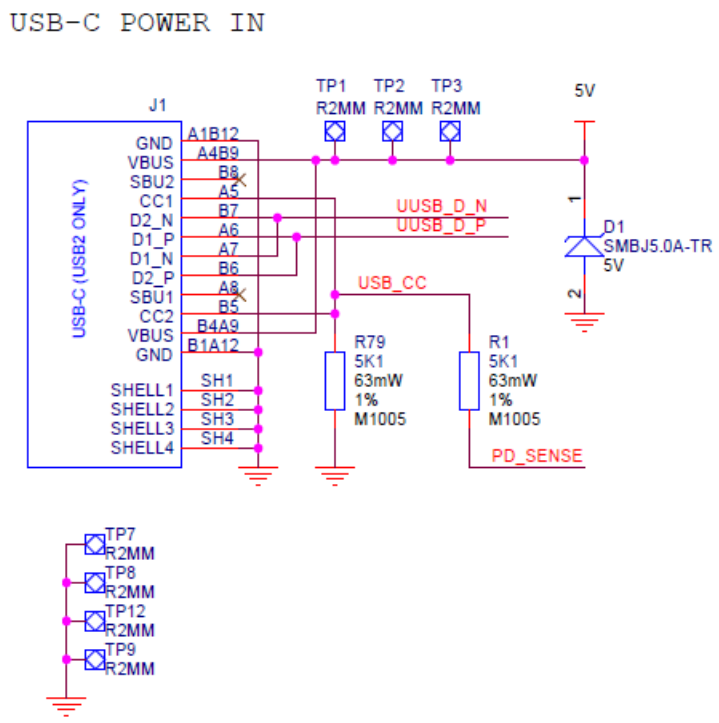


Figure G. 1. Raspberry Pi 4B USB-C Power Design [10].

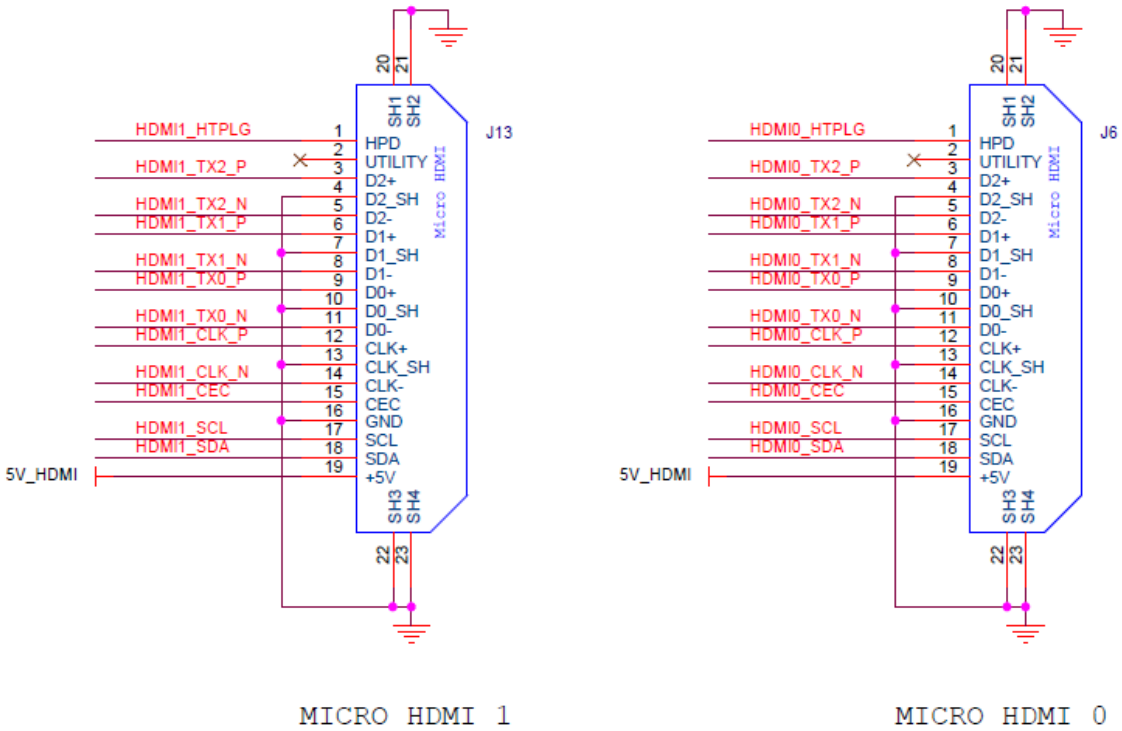


Figure G. 2. Raspberry Pi 4B HDMI Electrical Design [10].

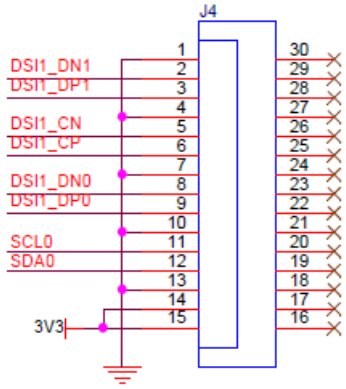


Figure G. 3. Raspberry Pi 4B Display Output Connection [10].

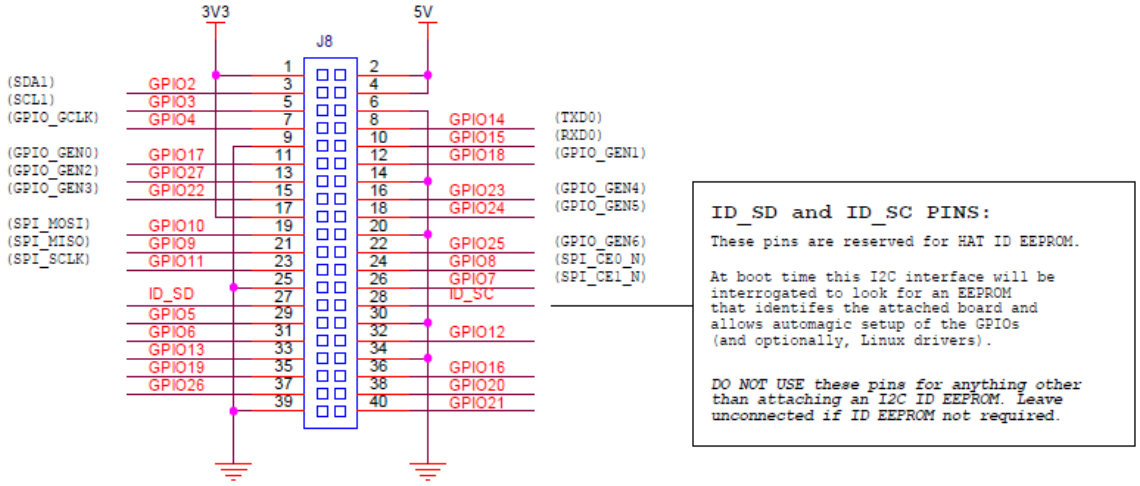


Figure G. 4. Raspberry Pi 4B GPIO Expansion Pin Identification [10].

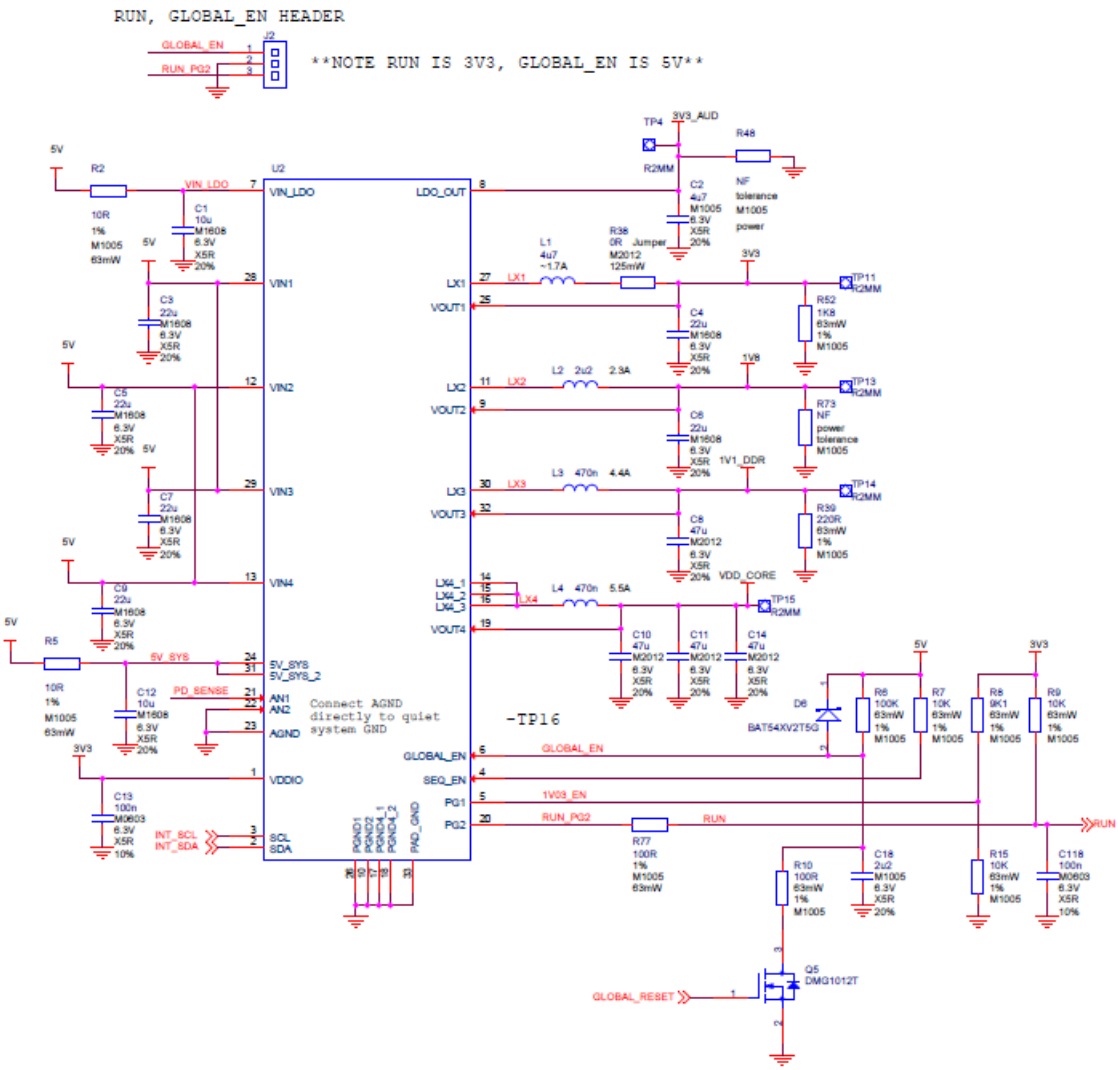


Figure G. 5. Raspberry Pi 4B Electrical Power Design Specifications [10].

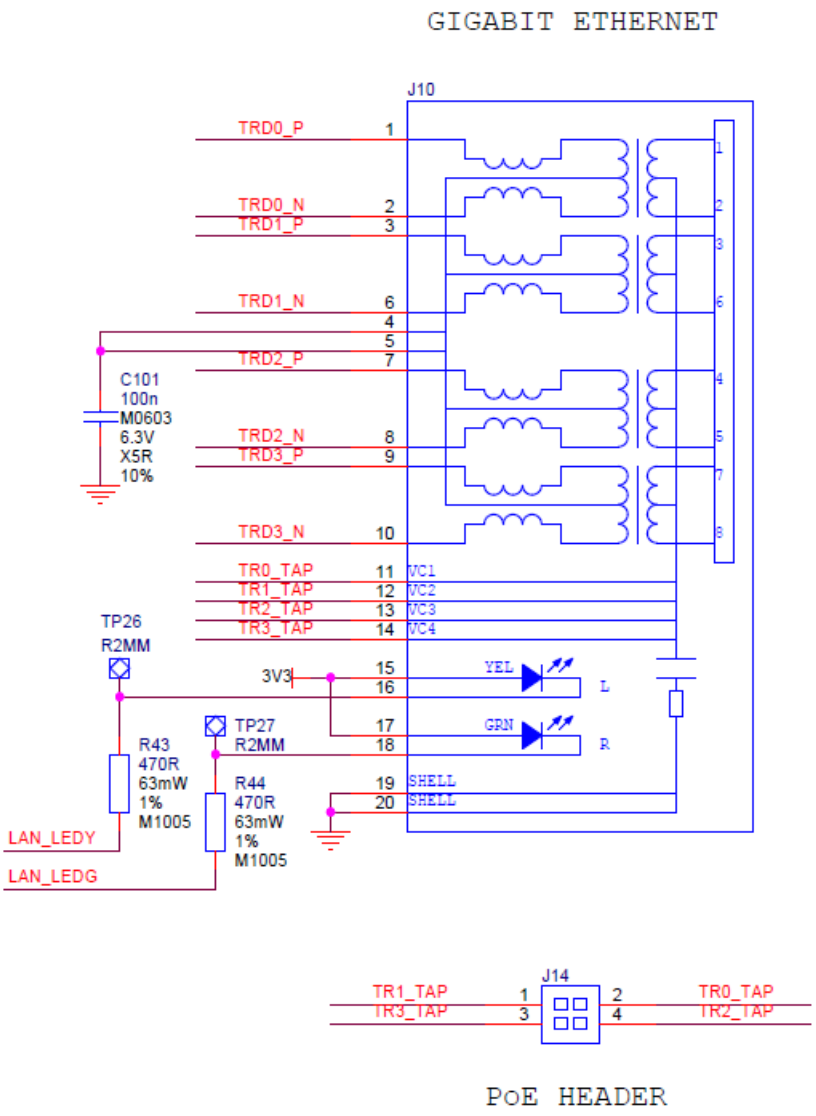


Figure G. 6. Raspberry Pi 4B Gigabit Ethernet Connection Design [10].

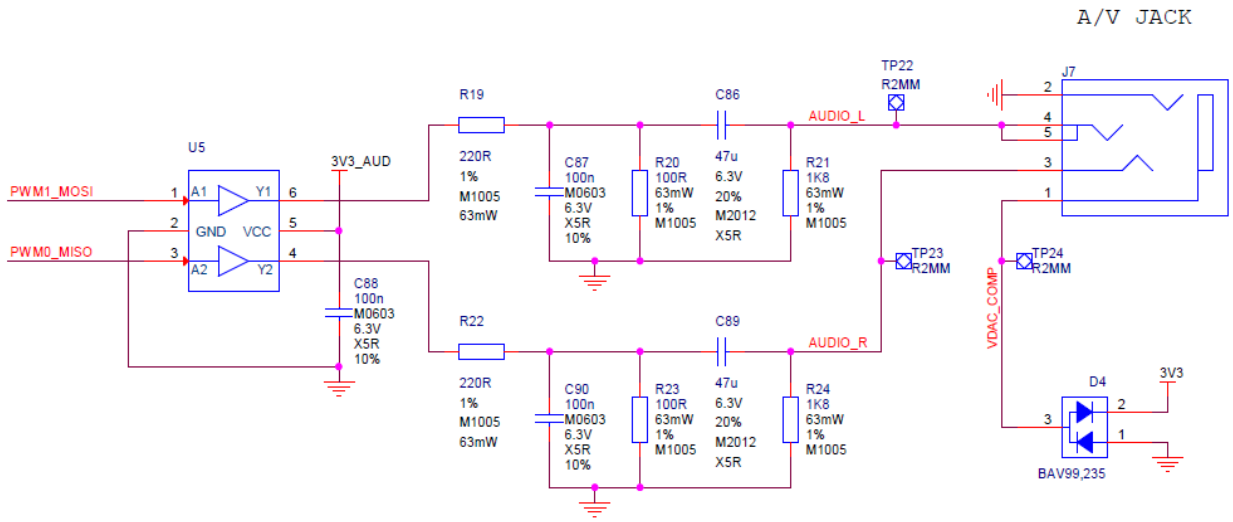


Figure J- 1. Raspberry Pi 4B A/V Jack Design [10].

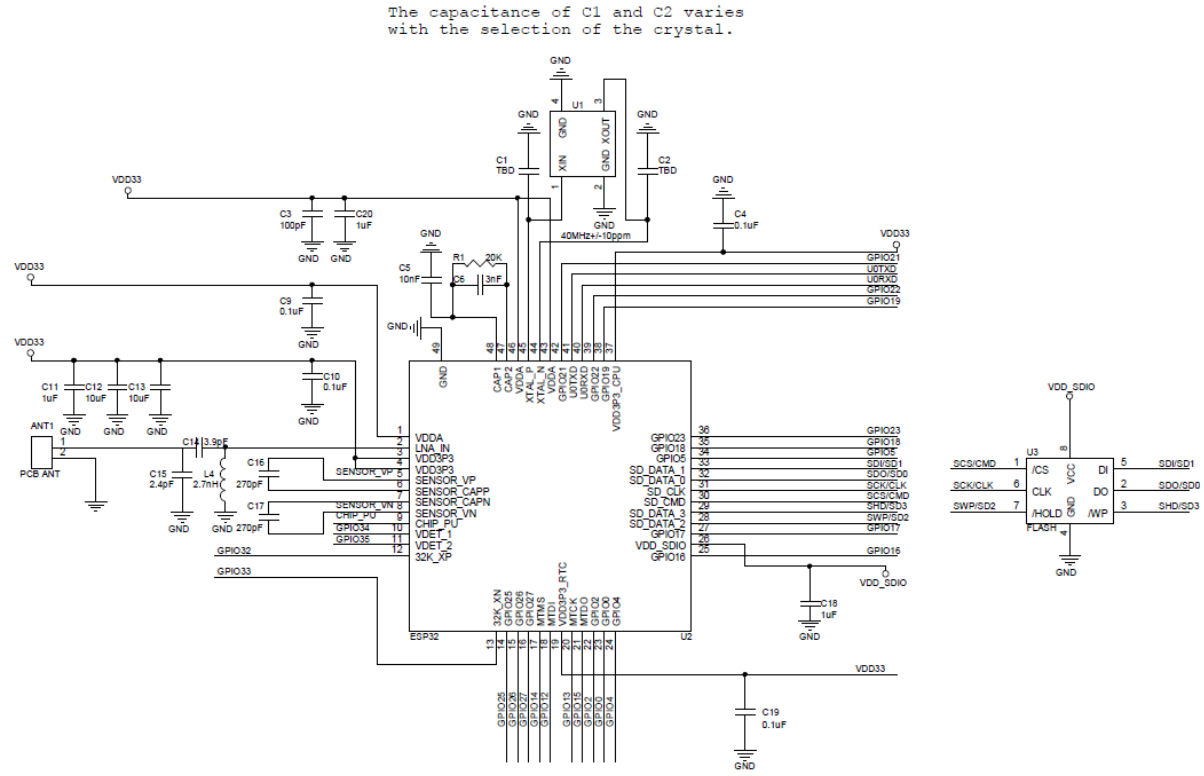


Figure J- 2. ESP 32S WROOM Electrical Specifications [28].

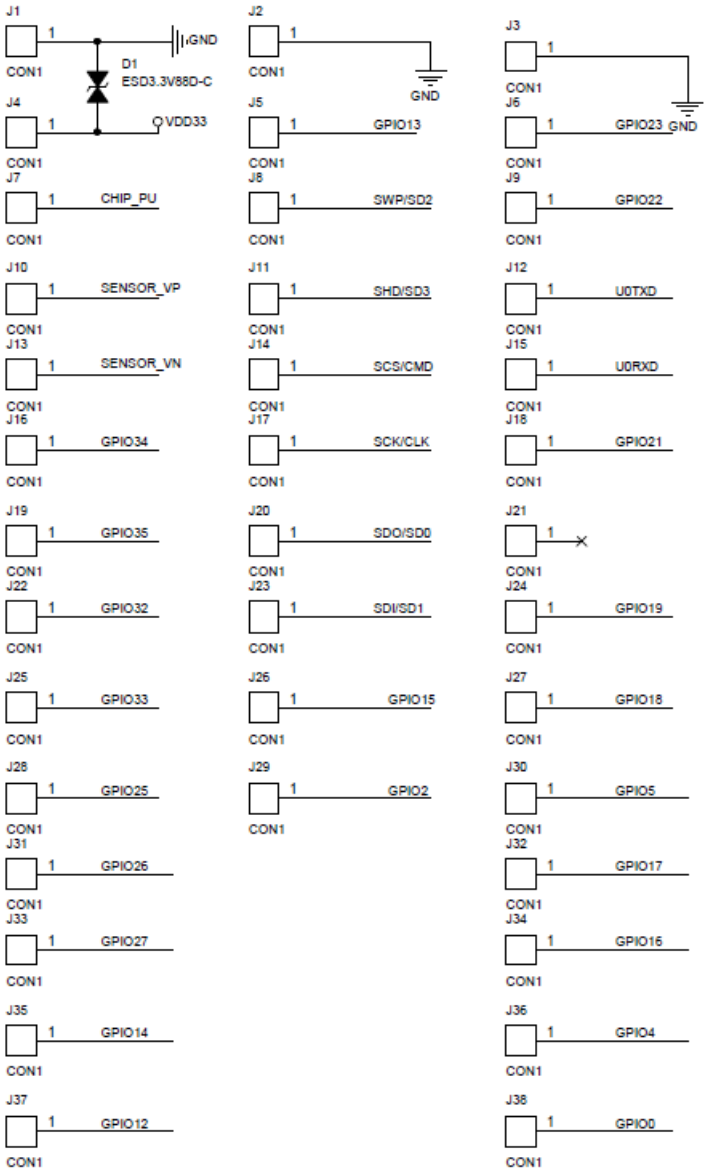


Figure J- 3. ESP 32S WROOM GPIO Expansion Pin Identification [28].

APPENDIX H – CODING

Below is the code of the simple testing of the Bluetooth proximity detection on an ESP-32 board. The purpose of it is to test to see if Bluetooth proximity can be used to unlock a door with close proximity detection. Since all the parts were split up, the way to test the proximity was by turning on an onboard LED on the ESP-32 device. It demonstrated that the proximity of Bluetooth could be used as an activation of and LED which could be modified to the activation of other items such as a lock.

Bluetooth Beacon Test

```
int PIN = 2;
int Contador =0;

static BLEAddress *pServerAddress;
BLEScan* pBLEScan;
BLEClient*  pClient;
bool deviceFound = false;
bool Encendida = false;
bool BotonOff = false;

String knownAddresses[] = { "00:16:a4:44:3d:3e"};
unsigned long entry;

static void notifyCallback(
  BLERemoteCharacteristic* pBLERemoteCharacteristic,
  uint8_t* pData,
  size_t length,
  bool isNotify) {
  Serial.print("Notify callback for characteristic ");
  Serial.print(pBLERemoteCharacteristic->getUUID().toString().c_str());
  Serial.print(" of data length ");
  Serial.println(length);
}

class MyAdvertisedDeviceCallbacks: public BLEAdvertisedDeviceCallbacks {
    void onResult(BLEAdvertisedDevice Device){
      //Serial.print("BLE Advertised Device found: ");
      //Serial.println(Device.toString().c_str());
      pServerAddress = new BLEAddress(Device.getAddress());
      bool known = false;
      bool Master = false;
      for (int i = 0; i < (sizeof(knownAddresses) / sizeof(knownAddresses[0])); i++) {
        if (strcmp(pServerAddress->toString().c_str(), knownAddresses[i].c_str()) == 0)
          known = true;
      }
      if (known) {
        Serial.print("Device found: ");
        Serial.println(Device.getRSSI());
        if (Device.getRSSI() > -50) {
          deviceFound = true;
        }
        else {
          deviceFound = false;
        }
        Device.getScan()->stop();
        delay(100);
      }
    }
};
```

```
void setup() {
  Serial.begin(115200);
  pinMode(2,OUTPUT);
  digitalWrite(2,LOW);
  BLEDevice::init("");
  pClient  = BLEDevice::createClient();
  pBLEScan = BLEDevice::getScan();
  pBLEScan->setAdvertisedDeviceCallbacks(new MyAdvertisedDeviceCallbacks());
  pBLEScan->setActiveScan(true);
  Serial.println("Done");
  }
void Bluetooth() {
  Serial.println();
  Serial.println("BLE Scan restarted.....");
  deviceFound = false;
  BLEScanResults scanResults = pBLEScan->start(5);
  if (deviceFound) {
    Serial.println("Light ON");
    Encendida = true;
    digitalWrite(2,HIGH);
    Contador = 0;
    delay(1000);
  }
  else{
    digitalWrite(2,LOW);
    delay(1000);
  }
}

void loop() {
  Bluetooth();
}
```

Fingerprint Module Code

The code was used for testing the functionality of the fingerprint module. As shown in FIGURE, the fingerprint module is connected to the Raspberry Pi via a USB TTL converter through a 4-pin connection (GND, VCC, TX, RX) with two pins dedicated for input and output signal. The code tests the connectivity to ensure that hardware is properly connected. Once the connection is established, the options to selection print storage location will be displayed. The storage is arranged in a set of index pages number 0-3, with each capable of holding up to 250 signatures. Assigning a location to the fingerprint allows the code to assign access to the desire location [29].

Library Installation in Python [29]

1. sudo bash
2. wget -O - http://apt.pm-codeworks.de/pm-codeworks.de.gpg | apt-key add -
3. wget http://apt.pm-codeworks.de/pm-codeworks.list -P /etc/apt/sources.list.d/
4. apt-get update
5. apt-get install python-fingerprint –yes
6. apt-get -f install

Test Code Scenario 1 Fingerprint Ports [29]

7. python2 /usr/share/doc/python-fingerprint/examples/example_index.py

Display Message

Currently stored templates: 0

Please enter the index page (0, 1, 2, 3) you want to see:

Test Code Scenario 2 Enroll/Delete and Search Fingerprint

8. python2 /usr/share/doc/python-fingerprint/examples/example_enroll.py
9. ~$ python /usr/share/doc/python-fingerprint/examples/example_search.py
10. ~$ python /usr/share/doc/python-fingerprint/examples/example_delete.py

The following code is used for attendance verification via fingerprint data this code expands the application of the fingerprint module to a more practical use. The code is designed to facilitate the login process by identifying the user fingerprint, validating the authenticity and time stamp all system logins. Testing the functionality of the code was not plausible because we were unable to connect all the hardware together, the disruptions caused by the COVID-19 pandemic impacted the hardware shipment.

```
#!/usr/bin/env python
# -*- coding: utf-8 -*-
from time import time, gmtime, strftime, sleep
from guizero import App, Picture, Waffle, Text,TextBox, Window, warn, info, PushButton,
from pyfingerprint.pyfingerprint import PyFingerprint
import multiprocessing
import csv

# initialise fingerprint module
f = PyFingerprint('/dev/ttyUSB0', 57600, 0xFFFFFFFF, 0x00000000)

#search for ID in a file when user logins
#this is to avoid duplicate login
def searchID(IDD):
    stat = False # flag to check the search status
    print(IDD)
    remFile = open('remdata.csv', 'r') # open the file in read mode
    csvReader = csv.reader(remFile) # pass file to csv reader
    #print(csvReader)
    data = list(csvReader) # convert the contents to a list
    print(data)
    for i in data: #iterate through the list
        # update attendance text with the number of logins in the file
        attendance_text.value = str(len(i)) +' out of ' + str(f.getTemplateCount())
        for j in range(len(i)):
            if i[j] == IDD: # if user ID is found, stat is true
                stat = True

    # close the file
    remFile.close()
    return stat
```

```
32
33  # write password
34  def updatePassword(pwd): #updates password in the file
35      print(pwd)
36      with open("pwdData.txt", "w") as log: #open file in write mode
37                      log.write("{0}".format(pwd))
38
39
40  #read password
41  def readPwd(): #reads password from file during authenication
42      pwd = "" # create an empty variable to hold retrieved password
43      f = open("pwdData.txt") #open file with default read mode
44
45      # read file content line by line
46      # but this file should have only one line
47      pwd = f.readline()
48      f.close() #make sure you close the file
49
50      return pwd
51
52
53  # this file is written to when a user logs in
54  # this stops the user from login in more than once
55  def writeRemToCSV(IDD):
56      print(IDD)
57      with open("remdata.csv", "a") as log:
58                      log.write("{0},".format(IDD))
59
60  # this file saves timestamp of logins in csv format with user ID
61  def writeLoginData(IDD):
62      print(IDD)
63      with open("login.csv", "a") as log:
64                      log.write("{0},{1},{2}\n".format(strftime("%Y-%m-%d %H:%M:%S"),
```

```
65
66  # this file saves timestamp of logouts in csv format with user ID
67  def writeLogoutData(IDD):
68      with open("logout.csv", "a") as log:
69                      log.write("{0},{1},{2}\n".format(strftime("%Y-%m-%d %H:%M:%S"), IDD,
70
71
72  # this method performs two functions
73  # 1 - updates the dashboard time
74  # 2 - holds code for login, it repeats every 100ms
75  # just like a loop
76  def update_time():
77      main_window_time.value = strftime("%H:%M:%S", gmtime()) #updates time
78      ## Tries to search the finger
79      try:
80              print('Waiting for finger...')
81
82              ## Wait that finger is read
83              if( f.readImage() == True ):
84                  ## Converts read image to characteristics and stores it in charbuffer 1
85                  f.convertImage(0x01)
86                  ## Searchs template
87                  result = f.searchTemplate()
88
89                  positionNumber = result[0]
90                  accuracyScore = result[1]
91
92                  if ( positionNumber == -1 ):
93                      print('No match found!')
94                      return
95                  #exit(0)
96                  else:
97                      #add to remember_data array for welcome and goodbye
98                      if searchID(str(positionNumber)): #search if user have logged in bef
99                          print('bye')
```

```
100                         msg_text.value = 'bye' # if true, log user out with bye
101                         writeLogoutData(str(positionNumber)) # update file with user log
102                         sleep(2) #delay for 2 seconds so user can remove his/her finger
103                         msg_text.value = '' #empty message text
104                     else:
105                         print('welcome')
106                         msg_text.value = 'welcome' #if false, log user in with welcome
107                         writeRemToCSV(str(positionNumber)) #enter user ID into file to a
108                         writeLoginData(str(positionNumber)) # update file with user log
109                         sleep(2) #delay for 2 seconds so user can remove his/her finger
110                         msg_text.value = ''  #empty message text
111
112                     print('Found template at position #' + str(positionNumber))
113                     print('The accuracy score is: ' + str(accuracyScore))
114                     sleep(2)
115
116             else:
117                  return
118
119     except Exception as e:
120             print('Operation failed!')
121             print('Exception message: ' + str(e))
122     return
123         #exit(1)
124
125 # function to update date on the dashboard
126 def update_date():
127     main_window_date.value = strftime("%d,%b,%Y", gmtime())
128
129 def update_attendance():
130     pass
131
132 # function to initalise the fingerprint module
133 def module_init():
```

```
    try:

        if ( f.verifyPassword() == False ):
            module_test.value =  'The given fingerprint sensor password is wrong!'
            raise ValueError('The given fingerprint sensor password is wrong!')
        else:
            module_test.value =  'Module successfully loaded'


    except Exception as e:
        print('The fingerprint sensor could not be initialized!')
        print('Exception message: ' + str(e))
        module_test.append('Exception message: ' + str(e));
        exit(1)


# function notifies user if attempting to enter restricted areas
def admin_warn():
    warn("NOTE!!", "You will need to provide authenications from here!")
    admin_menu_window.show(wait=True) # if user continues, show new window in modal m
    app.hide() # hide app or main window

# function notifies user if attempting to enter restricted areas
def admin_mainmenu_warn():
    info("INFO!!", "Please provide authenication!")

# switches windows on button click
def change_password_auth():
    change_pass_password_window.show(wait=True)
    admin_menu_window.hide()

# returns back to app or main window
def admin_back():
    app.show()
```

```
168         admin_menu_window.hide()
169
170     # switches windows on button click
171     def check_admin_pass():
172         admin_mainmenu_pass_window.show(wait=True)
173         admin_menu_window.hide()
174
175     def update_msg():
176         msg_text.value = ''
177
178
179     #windows starts
180     # all the windows are created here and are hidden immediately
181     app = App(title="Biometeric System", width=210, height=210,layout="grid")
182
183     admin_menu_window = Window(app, title="Admin Menu", width=210, height=210,layout="grid"
184     admin_menu_window.hide()
185
186     admin_mainmenu_pass_window = Window(app, title="Authenication yourself", width=210, hei
187     admin_mainmenu_pass_window.hide()
188
189     mainmenu_window = Window(app, title="Main Menu", width=210, height=210)
190     mainmenu_window.hide()
191
192     enroll_window = Window(app, title="Enroll", width=210, height=210)
193     enroll_window.hide()
194
195     change_pass_password_window = Window(app, title="Provide authenication", width=210, hei
196     change_pass_password_window.hide()
197
198     change_password_window = Window(app, title="Change Password", width=210, height=210)
199     change_password_window.hide()
200
201     delete_menu_window = Window(app, title="Delete Menu", width=210, height=210)
```

```
delete_menu_window.hide()
#windows ends

#main window starts
# user can login or logout on this window
# admin menu can be accessed from here

main_window_time = Text(app, text=strftime("%H:%M:%S", gmtime()), grid=[0,0])
main_window_time.repeat(100, update_time)  # Schedule call to update time

main_window_date = Text (app, text=strftime("%d,%b,%Y", gmtime()), grid=[0,1])
main_window_date.repeat(10800000, update_date)  #repeat every 3hrs

module_test = Text(app, text="checking modules...", grid=[0,2])


admin_menu_btn = PushButton(app, text="ADMIN MENU" ,command=admin_warn, grid=[0,4])
admin_menu_btn.bg = "blue"

msg_text = Text(app, text="####", grid=[0,5])
#msg_text.repeat(5000, update_msg)

attendance_text = Text(app, text="####", grid=[0,6])
picture1 = Picture(app, image="28.jpg", grid=[1,0,3,6])
module_init() #initialize module
#main window ends

#admin menu window starts
admin_main_menu_btn = PushButton(admin_menu_window, text="Main Menu" ,command=check_admi
admin_main_menu_btn.bg = "blue"

back_btn = PushButton(admin_menu_window, text="Back" ,command=admin_back, grid=[1,0])
back_btn.bg = "blue"

chgPassword_btn = PushButton(admin_menu_window, text="change Password", command=change_p
```

```
237 chgPassword_btn .bg = "blue"
238 #admin menu window ends
239
240 #admin menu password window starts
241 def chk_password():
242     global admin_password
243
244     if len(password_box.value) == 8:
245         if password_box.value == readPwd():#admin_password:
246             password_chk_text.value = "correct"
247             sleep(.2)
248             mainmenu_window.show(wait=True)
249             admin_mainmenu_pass_window.hide()
250             password_box.value = ""
251         else:
252             password_chk_text.value = "incorrect"
253             password_box.value = ""
254
255     elif not password_box.value == admin_password:
256          password_chk_text.value = "incomplete and incorrect"
257
258
259
260 password_box = TextBox(admin_mainmenu_pass_window,  grid=[0,0])
261 password_box.height=30
262 password_box.width=20
263 password_box.update_command(chk_password)
264 password_chk_text = Text (admin_mainmenu_pass_window, text="", grid=[1,0])
265 #admin menu password window ends
266
267 #change admin password password window starts
268 def chk_chg_password():
269     passw = readPwd()
270     if len(pass_box.value) == 8:
271         if pass_box.value == passw:#admin_password:
```

```
            pass_chk_text.value = "correct"
            sleep(.2)
            change_password_window.show(wait=True)
            change_pass_password_window.hide()
        else:
            pass_chk_text.value = "incorrect"

    elif not pass_box.value == passw:
         pass_chk_text.value = "incomplete and incorrect"

pass_box = TextBox(change_pass_password_window)
pass_box.update_command(chk_chg_password)
check_btn = PushButton(change_pass_password_window, text="check" ,command=chk_chg_passv
pass_chk_text = Text (change_pass_password_window, text="")
#change admin password password window ends

#change admin password window starts
def pass_operation():
    passw = readPwd()
    if not pass1_box.value ==  passw:
       passw_chk_text.value =  "this is not the current password"
    elif not pass2_box.value == vpass2_box.value:
       passw_chk_text.value =  "new password doesnt match verify password"
    elif not len(vpass2_box.value) <= 8:
        passw_chk_text.value =  "password length is less than 8 characters"
    else:
        updatePassword(vpass2_box.value)
        passw_chk_text.value =  "Operation was successful"

def back_to_main():
    passw_chk_text.value =  "Going back..."
    sleep(2)
    app.show()
    change_password_window.hide()
```

```
307
308 pass1_box = TextBox(change_password_window)
309 pass2_box = TextBox(change_password_window)
310 vpass2_box = TextBox(change_password_window)
311 vpass2_box.update_command(pass_operation)
312 passw_chk_text = Text (change_password_window, text="")
313 back_main_btn = PushButton(change_password_window, text="BACK" ,command=back_to_main)
314 #change admin password window ends
315
316 #main menu starts
317 def enroll_PF():
318     enroll_window.show(wait=True)
319     admin_mainmenu_pass_window.hide()
320     mainmenu_window.hide()
321
322 def _back():
323     mainmenu_window.hide()
324     enroll_window.show()
325
326 def delete_menu():
327     delete_menu_window.show(wait=True)
328     mainmenu_window.hide()
329
330 enroll_btn = PushButton(mainmenu_window, text="Start Enrolling", command=enroll_PF)
331 b_btn = PushButton(mainmenu_window, text="Back", command=_back)
332 delete_menu_btn = PushButton(mainmenu_window, text="Delete Menu", command=delete_menu
333 #main menu ends
334
335 #delete menu window starts
336 def clear():
337     ## Tries to delete the template of the finger
338     try:
339         for i in range(f.getStorageCapacity()):
340             f.deleteTemplate(i)
```

```
341
342         except Exception as e:
343             clearDB_text.value = "Operation failed! " + 'Exception message: ' + str(e)
344             print('Operation failed!')
345             print('Exception message: ' + str(e))
346         return
347
348     def clear_FDB():
349         clearDB = yesno("HEY!!!", "Are you sure?")
350         if clearDB == True:
351             clear()
352             info("HEY!!", "Operation was successful")
353         else:
354             info("NOTE!!", "Going back to main window ")
355             delete_menu_window.hide()
356             app.show()
357
358     clear_FDB_btn = PushButton(delete_menu_window, text="Clear FDB", command=clear_FDB)
359     clearDB_text = Text (delete_menu_window, text='Currently used templates: ' + str(f.getTe
360     #delete menu window ends
361
362     #enroll window starts
363     def enroll():
364         ## Gets some sensor information
365         print('Currently used templates: ' + str(f.getTemplateCount()) +'/'+ str(f.getStorag
366         enroll_status_text1.value =  'Currently used templates: ' + str(f.getTemplateCount(
367         ## Tries to enroll new finger
368         try:
369             print('Waiting for finger...')
370             enroll_status_text2.value = 'Waiting for finger...'
371             ## Wait that finger is read
372             while ( f.readImage() == False ):
373                 pass
374
375             ## Converts read image to characteristics and stores it in charbuffer 1
376             f.convertImage(0x01)
377
378             ## Checks if finger is already enrolled
379             result = f.searchTemplate()
380             positionNumber = result[0]
```

APPENDIX I – CALCULATIONS

Room Dimension

28’ x 14’ x 9’

Calculating illumination (lux)

Equation 1. Illumination Equation (lux)

$$E = \frac{\Phi_l C_u L_{lf}}{A_l} \quad (1)$$

E = illumination (lux, lumen/m^2)

Φ_l = luminance per lamp (lumen)

C_u = coefficient of utilization

L_{lf} = light loss factor

A_l = area per lamp (m^2)

Calculating C_U (coefficient of utilization)

$$RCR = \frac{5h_{RC}(L+W)}{LW} \quad (2)$$

RCR (Room-cavity ratio)

$$CCR = \frac{5h_{CC}(L+W)}{LW} \quad (3)$$

CCR (Ceiling-cavity ratio)

$$FCR = \frac{5h_{FC}\,(L+W)}{LW} \qquad (4)$$

FCR (Floor-cavity ratio)

L (Length of room)

W (Width of room)

h_{RC} (Room cavity height)

h_{CC} Ceiling cavity height

h_{FC} = Floor cavity height

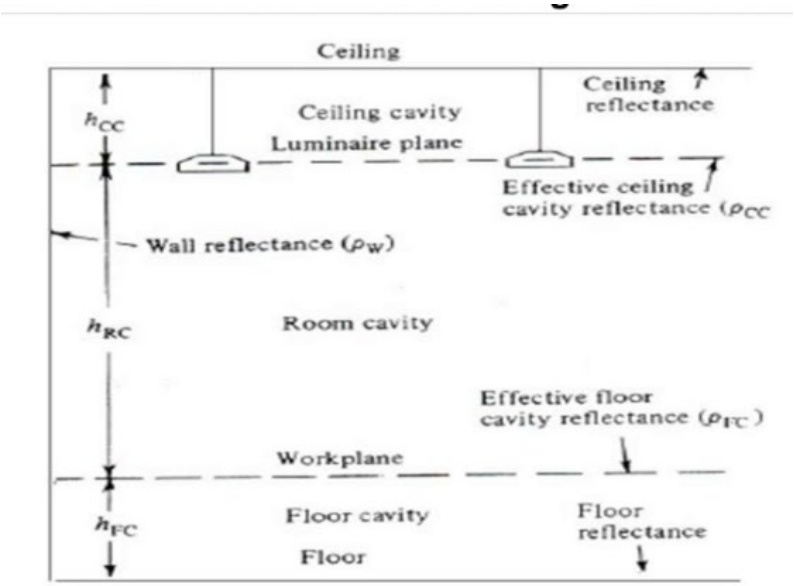


Figure I. 1. Cross-section of a Room Cavities [17].

Assumed Values

ρ_{CC}(Effective ceiling cavity reflectance) = 80%

ρ_{FC}(Effective floor cavity reflectance) = 50%

ρ_W(Wall reflectance) = 20%

L_{lf} (light loss factor) = 1

Assume New LED lights

No burnouts or lumen depreciation

Cleanroom surface

Voltage to luminaire negligible

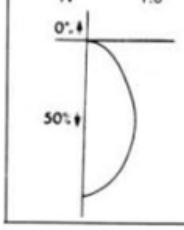
Typical Distribution and Percent Lamp Lumens	ρ_{CC}: →	80			70			50			0
	ρ_w: →	50	30	10	50	30	10	50	30	10	0
Maintenance Category: IV; Maximum S/MH: 1.0	RCR	Coefficients of Utilization for 20% Effective Floor Cavity Reflectance (ρ_{FC} = 20)									
	0	.60	.60	.60	.58	.58	.58	.56	.56	.56	.50
	1	.54	.52	.50	.52	.51	.49	.50	.49	.48	.44
	2	.48	.45	.43	.47	.44	.42	.45	.43	.41	.39
	3	.43	.40	.37	.42	.39	.37	.41	.38	.36	.34
	4	.39	.35	.32	.38	.35	.32	.37	.34	.32	.30
	5	.35	.31	.28	.35	.31	.28	.34	.30	.28	.26
	6	.32	.28	.25	.32	.28	.25	.31	.27	.25	.23
	7	.29	.25	.22	.29	.25	.22	.28	.25	.22	.21
	8	.26	.22	.20	.26	.22	.20	.25	.22	.20	.18
	9	.24	.20	.17	.24	.20	.17	.23	.20	.17	.16

Figure I. 2. Distribution Table [17].

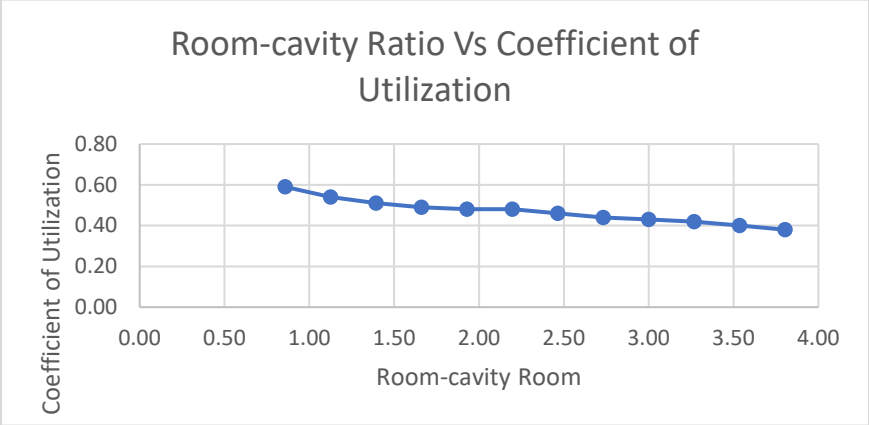


Figure I. 3. Room-cavity Ratio Vs. Coefficient of Utilization as HFC increase.

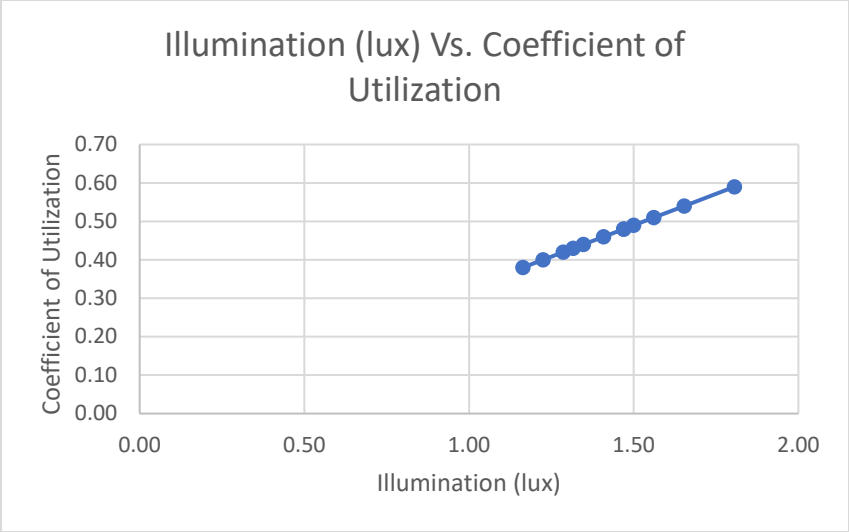


Figure I. 4. Illumination Vs. Coefficient of Utilization as HFC increase.

Table I. 1. Light Utilization Calculations.

RCR	HRC (ft)	HCC (ft)	HFC (ft)	L (ft)	W (ft)	H (ft)	Coefficient of Utilization
3.80	7.10	1.90	0.00	28.00	14.00	9.00	0.38
3.54	6.60	1.90	0.50	28.00	14.00	9.00	0.40
3.27	6.10	1.90	1.00	28.00	14.00	9.00	0.42
3.00	5.60	1.90	1.50	28.00	14.00	9.00	0.43
2.73	5.10	1.90	2.00	28.00	14.00	9.00	0.44
2.46	4.60	1.90	2.50	28.00	14.00	9.00	0.46
2.20	4.10	1.90	3.00	28.00	14.00	9.00	0.48
1.93	3.60	1.90	3.50	28.00	14.00	9.00	0.48
1.66	3.10	1.90	4.00	28.00	14.00	9.00	0.49
1.39	2.60	1.90	4.50	28.00	14.00	9.00	0.51
1.13	2.10	1.90	5.00	28.00	14.00	9.00	0.54
0.86	1.60	1.90	5.50	28.00	14.00	9.00	0.59

Table I. 2. Illuminance Factors.

Illumination	Luminance	Coefficient of Utilization	Light Loss Factor	Area (ft^2)
1.16	1200	0.38	1	392
1.22	1200	0.40	1	392
1.29	1200	0.42	1	392
1.32	1200	0.43	1	392
1.35	1200	0.44	1	392
1.41	1200	0.46	1	392
1.47	1200	0.48	1	392
1.47	1200	0.48	1	392
1.50	1200	0.49	1	392
1.56	1200	0.51	1	392
1.65	1200	0.54	1	392
1.81	1200	0.59	1	392

$$UGR = 8log\left[\left[\frac{0.25}{L_b} * \Sigma\frac{L^2\omega}{\rho^2}\right]\right] \quad \textit{(I.1)}$$

UGR (Unified Glare Rating)

L_b (Background luminance (cd/m2)

L (Luminance parts of each luminaire in the direction of the observer's eye (

ω (solid angle of the luminous part of each luminaire are observers' eye

ρ (Guth position index for each luminaire (displacement from the line of sight)

APPENDIX J – USER MANUAL

Place in an easy to access zone. The hub can also be wall-mounted for convenience. Be sure to select an area close to an outlet because the hub is powered through a MicroUSB.

The hub is Wi-Fi capable but does have the option for ethernet. Should you desire, the hub also can connect to a larger display. However, a mouse and keyboard will be required to utilize a second screen.

This control hub is meant to be accessed by the caregiver only. It is not to be used by any patients within the facility.

WEARABLE SMART WATCH



MorePro APP

Download on the App Store

For iOS 9.0 & above

MorePro APP

ANDROID APP ON Google Play

For Android4.4 & above

2. Connection Steps

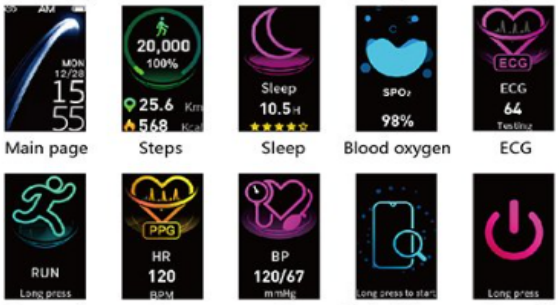
1、Turn on Bluetooth and don' t connect the device with phone's Bluetooth setting directly.

2、Go to morePro app---> setting--->device-->search the device--->find 'V19' model to connect.

Warm tips: If you are using android phones, please go to phone setting to turn on GPS while connection.

3. Basic Operation

1. 1. Simply click the touch button to switch among function pages.

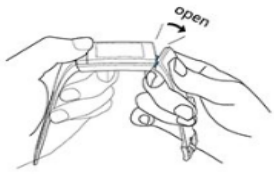


Main page | Steps | Sleep | Blood oxygen | ECG

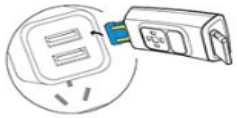
Run mode | HR | BP | Find cellphone | Turn off

I. Outlook

1. Charging method



Instruction for removing the strap



Charging method

Power on: Long press touch button
Power off: Switch to power off page, and long press touch button.

2. Packaging:

Wristband X 1 Packing box X 1 User manual X 1

II. Instruction before using

1. Download APP

A: For IOS phone, search "MorePro"(hereinafter called APP) on APP store to download.
B: For Android phone, search and download "MorePro' on some application markets,
such as Google play, application of treasure, wandoujia etc.

2. ECG function could be realized by switching to ECG page, and putting your finger on touch button till finishing detection.
Note: 1) Manually tested data on the device will not be recorded in the app.
2) The data from ECG detection can be recorded in the app while doing ECG detection in the app.

III. Main functions

A. **Sports mode**
The device supports Run mode, click the touch button and switch to run page, long press to the touch button to start.

B. **In-coming call reminder**
While call is coming, the device will vibrate to remind you. Short click to mute, long press to hang up calling.

C. **Message reminder**
While receiving new message on phone, the device will vibrate to remind you of clicking the device to check the message content.
Notes:
1) For message reminder function, you need to turn on notification function on phone, and turn on "message remind" on APP; Go to morePro app-->setting-->device--->message notification, turn it on.
2) While showing message remind on display, please click the screen to check the details.

D. **Other reminder**
Sedentary reminder
Reaching goal reminder
Alarm clock
Event reminder
More reminders, welcome to check on MorePro APP.

E. **ECG detection**
User could do ECG detection on the wristband and APP both, keep the finger touch well the touch button, and work with APP to monitor, to check the ECG data in details.
Notes:
1) Manually tested data on the device will not be recorded in the app.
2) The data from ECG detection can be recorded in the app while doing ECG detection in the app. We may recommend you to test ECG through app.

F. **Heart rate monitoring**
Switching to the heart rate interface device will automatically detect and the device monitoring will display the real-time heart rate data.
Note :
Tips for turning on Heart Rate Remind :Go to morePro app--->setting--->device--->heart rate scope--->set your heart rate limit and maximum, turn it on.

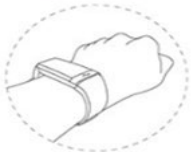
G. **Blood oxygen detection**
Switch to blood oxygen page to detect automatically, the real-time SPO2 data will show on the display.
Go the app-->Setting -->Device--> Switch setting-->Turn on "Blood oxygen detection in the evening" , the device will detect the blood oxygen data from 00:00 to 07:00 automatically, and detailed data can be checked on the APP.
Note :
When testing blood oxygen, please check if the wearing posture is correct and the device sensor is close to the skin. The signal on the wrist is weak, If the device shows no result, please remove the the bracelet, and cling your fingertip to the bottom of the sensor.



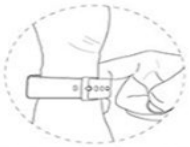
Fingers are pressed against
the bottom sensor for testing

H. **Blood pressure detection**
Switch to BP test page on the device manually to start detecting automatically, the test time depends on users physical status. It is normal to take long time to show the result, please be patient to wait.

I. **Sleep monitor**
Device could monitor sleep data in the evening automatically , switch to sleep page by clicking the touch button to check the sleep quality. If turn on "Scientific Sleep" function on the app, the noon nap and abnormal resting(such as night-shift work, rest at daylight) and more sleeping data in the evening can be detected and shown in details.
Note :
Please go to morePro app-->Setting -->Device--> Switch setting-->Turn on "Scientific Sleep" , then it will detect your nap sleep.



Touch fully between wristband and skin



Just allows to put one finger in tightly

J. **Find cellphone**
Switch to find cellphone page, long press the touch button, cellphone will ring to remind you.
Note : Please go to morePro app-->Setting -->Device--> Switch setting-->Turn on "Find cell phone" feature.

K. **Time setting**
Device's time is synchronized with the time on your cellphone. Setting time mode as 24/12 hours format on your cellphone time setting, then reconnecting device with the APP.

IV. Waterproof

It can be used to wash hands, do some water activities in the shallow water area. Stop using it while taking hot shower, diving, surfing etc.

V. Parameters

CPU: NRF52832
Battery capacity: 130 mAh
Screen type: TFT
Waterproof: IP68 life waterproof
Life time: 4 days
Working temperature: -5～45℃
Operate way: Touch, lift up wrist to display
Charging method: USB direct charge
Battery type: Polymer lithium battery
Data transfer: Low-power Bluetooth 4.0 sync
Device Requirement :
Android 4.4/above; Bluetooth 4.0; iPhone 4S/above, iOS 9.0/above;

VI. Security information:

1) Security information: To ensure operate properly, please read and follow by the quick guide before using the device.

2) Privacy protection: To protect your data, please check our privacy policy on APP.

3) Data security: If connect to the non-appointing 3rd software to connect or upgrade the device, it might cause device unworkable or leak out your private info.

4) Electronic device: On the places where is banned to use wireless device, such as petrol station, plane on aboard, medical occasion with wireless forbidden, please stop using the device, to avoid interruption with other electronic device or get in danger.

5) Traffic security: Keep your mind that safe driving is most important, please don't operate the device while driving. Don't place the device on the airbag or the area where airbag could get, to avoid the strong push strength to device cause people in the car get serious hurt.

6) Children health: the device with accessories attaches some small parts, please keep the device out of the place the children can get at. Children might break the device or accessories, or the children get in trouble for swallowing small parts or other dangerous action.

7) Responsibility limit: Following by law, under any circumstances, device supplier takes the largest responsibility limit of your loss for using the device(except for the bodily harm and the excluding harm in law instruction) , which is referring to the paid cost of the device.

8) Accessories request: Use unconfirmed or incompatible power, charger or battery, causes fire, explosion or other danger.

9) Battery security: The device is with built-in battery, please don' t change battery yourself, to avoid damage the battery or device. Don' t connect any metal conduct with battery's 2 poles to prevent from battery short circuit and injure body for battery too hot. Don't detach or change battery, insert other thing or dip into the water or any liquid, to prevent from battery liquid out, too hot or explosion.

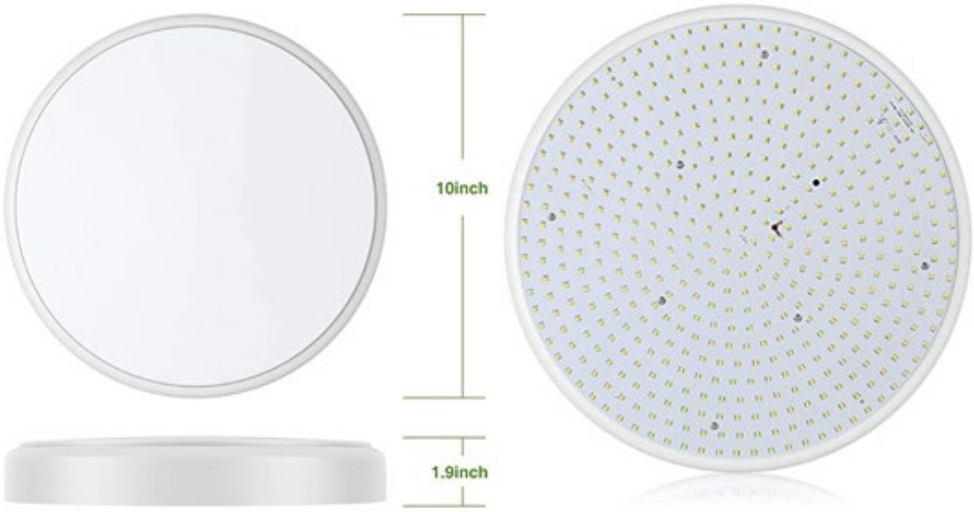
10) Operate occasion: Don't use the device at the place in high temperature/moisture or magnetic area, to avoid interior circuit issue in the device. Please use it in temperature -5 C~45 C, when the temperature around is too high or too low, it possibly cause device issue. Don't place the device under the direct sunlight, such as the car dashboard or window. Don't take the device close to the heat source or straight fire source, such as micro-wave stove, oven, stove fire or other thing which make the heat, and hot battery possibly cause explosion. Don't allow the children or pet swallow or bite the device or accessories, to prevent from the harm or bringing damage or explosion.

MorePro

Device Requirement: Android 4.4/above; Bluetooth 4.0;
iPhone 4S/above, iOS 8.0/above;

www.more-pro.com

LED LIGHT SOURCE



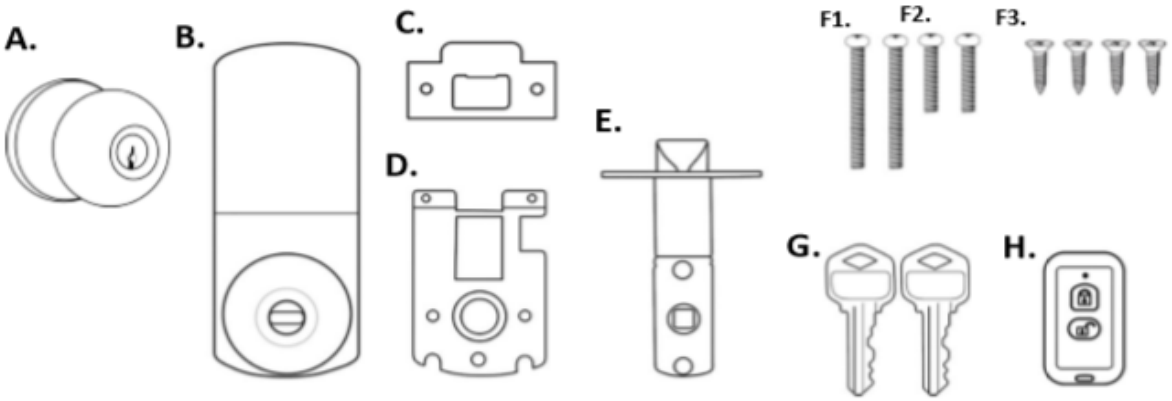
- **WIRELESS INSTALLATION**
  - Easily install the IESTARING Led ceiling light anywhere light is needed. Its weatherproof housing allows it to be used as a wireless shed light or automatic closet light. The ceiling light installs in less than 10 minutes with the included screws – no wires or electrician needed.
-
- **EASY INSTALLATION**
  - 1. Loosen the screws on both sides and remove the ceiling bracket and accessories
  - 2. Align the holes of mounting bracket and J-box, tighten them.
  - 3. Connect the black wire to the L terminal and white wire to the N terminal.

    4. Align the luminaire with the bracket, tighten the screw, then push the side plug into the two side holes to finish the installation

SMART LOCK SYSTEM

www.milocks.com®
MiLOCKS
The Keyless Entry Specialist

Model WKK



GENERAL WARNINGS & CAUTIONS:

1. The back module (Part B.) needs to be protected from the weather
2. Remote works up to 30' without obstructions

Tools Required *(not included):*



X1 Phillips Screwdriver



X4 AA Batteries

Auto-Lock Switch on Part B.:

On the back module (part B), there is a switch labeled "On-Off" which controls the auto-lock function.
On = Automatic lock after 10 seconds. (shortens battery life up to 50%)
Off = Does not automatically lock.

For assistance with assembly or installation, parts and customer service, call:
1-800-355-0157 (English & Spanish)
9am – 5pm PST Mon. – Fri.
North America

Battery Precautions

- Do not mix old with new batteries.
- Do not use rechargeable batteries.
- Remove batteries from product when storing for extended periods of time.
- Do not dispose of batteries in fire as they may explode. Please follow your local battery disposal procedure.
- Do not puncture batteries. Electrolyte leakage from the batteries is corrosive and can cause serious harm to the eyes or skin. If swallowed, the electrolyte can be toxic.
- Do not allow conductive materials such as jewelry or metal tools to make contact with the batteries which may cause a short circuit. With a short circuit, the batteries and conductive material can become extremely hot and cause burns.

Register Your Product

- Although we hope you never have to deal with a warranty claim during the use of our product, you should submit a product registration to validate the warranty. This keeps it on record with us so you don't have to save a receipt or record of any kind. Just give us a call and we will take care of you.
- Register at www.milocks.com

TROUBLESHOOTING

Low Batteries (Most Common Issue): To avoid any difficulties during set up, make sure you are using brand new AA alkaline batteries.

RF Remote Control Programming: Make sure the red light turns on when the buttons on the remote are pressed. If the red light does not turn on your issue may be battery related. If batteries are ok and the red light turns on but the remote still does not operate the door lock, give us a call during business hours to troubleshoot.

Remote Control Range: RF remote control works 10ft - 30ft away without obstructions. If the range is lower than this, it may be due to interference from an outside source. Give us a call during business hours to troubleshoot.

INSTEON Programming: If you are having issues operating the lock via INSTEON, please call INSTEON technical support at 1-866-243-8022

If you are unable to get your lock to work
please give us a call during business hours.

US Live Tech Support: 1-800-355-0157 M-F 9am - 5pm PST (English & Spanish)

Warranty shipments are always shipped promptly.

WARRANTY

MiProducts Corporation warrants to the original residential user of this product that it will be free from defects in materials and workmanship, under normal use, for 1 year from the date of purchase. User must provide a copy of original purchase receipt. This warranty does not cover abuse or misused products or products used in commercial applications. All mechanical components carry a limited warranty, for a period of 25 years from the date of purchase. The finish of the exterior of this lock carries a limited warranty of the lifetime of the unit against deterioration due to normal weather conditions. This warranty does not apply to locks that have been improperly installed, modified, put to a use other than designed, or subjected to acts of God (such as floods, lightning, earthquakes, etc.) This warranty is limited to repairing or replacing of this lock only at MiProducts Corporation's sole discretion. MiProducts Corporation will NOT be liable for the cost of installing, removing, nor reinstalling this product, nor direct, indirect, or consequential damages to persons or property resulting from the use of this product. This warranty only covers the cost of replacement parts, it does not cover shipping & handling fees.

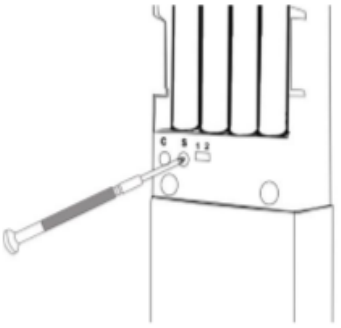
To implement this warranty please give us a call during business hours at 1-800-355-0157, or visit www.milocks.com.

MiProducts Corp. La Puente, CA 91746 1-800-355-0157 MADE IN TAIWAN

RF REMOTE CONTROL PROGRAMMING

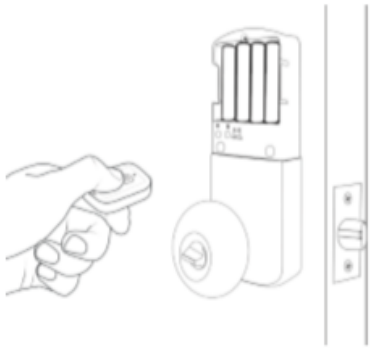
Program a Remote

Press the **S button** once



Within 5 sec.

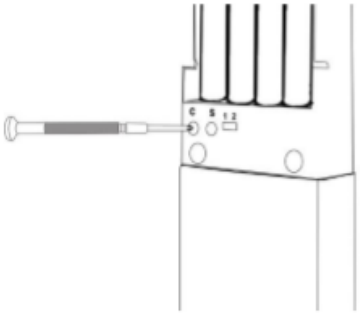
Press and hold either button on the remote you wish to program



2 Beeps = Success
0 Beeps = Go to Troubleshooting

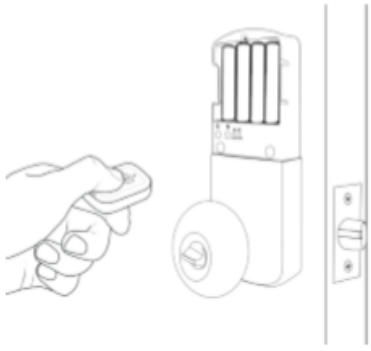
To clear all remotes

Press the **C button** once



Within 5 sec.

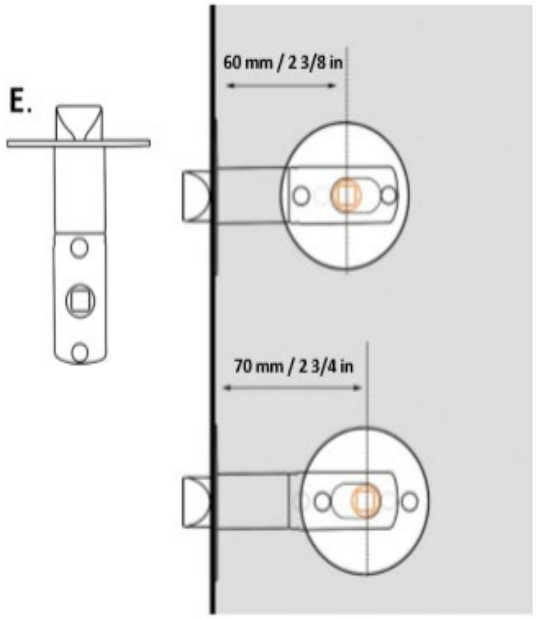
Press and hold either button on the remote you wish to delete



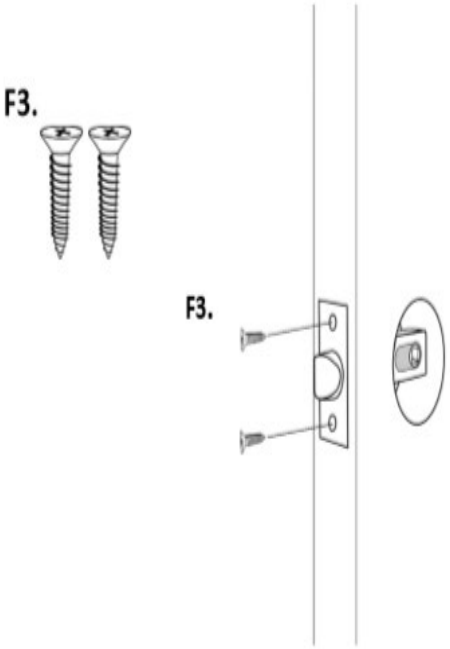
2 Beeps = Success
0 Beeps = Go to Troubleshooting

NOTE: This will delete all remotes stored in the memory and will program the remote you are using at that moment.

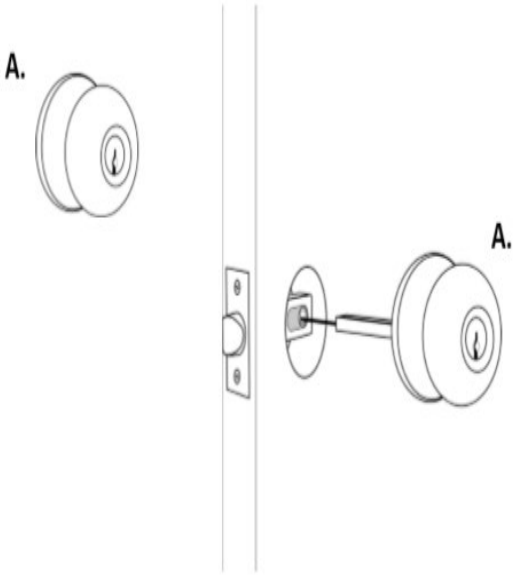
1. Adjust Latch Backset



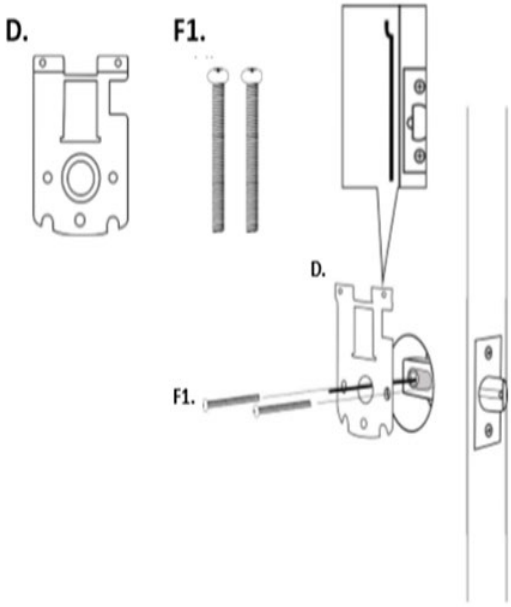
2. Install Door Latch



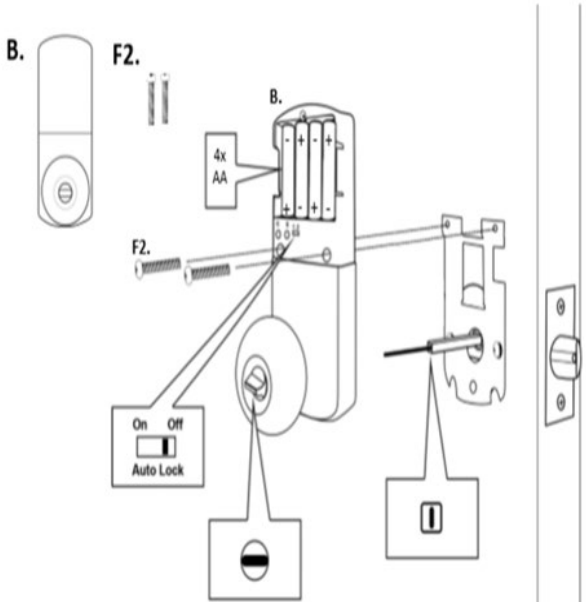
3. Mount Front Module



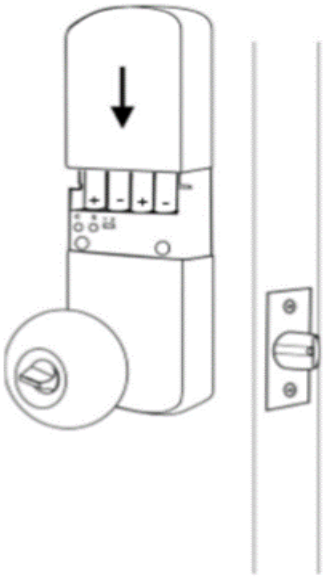
4. Fasten Back Mounting Plate



5. Mount & Fasten Back Module



6. Install Battery Cover



RASPBERRY PI



HOW TO USE[1]

The RPi LCD can be driven in two ways: Method 1. install driver to your Raspbian OS. Method 2. use the Ready-to-use image file of which LCD driver was pre-installed.

METHORD 1 DRIVER INSTALLING

1. Download OS image file from Raspberry Pi Website (Raspbian/Ubuntu Mate/Kali/Retropie)
2. Download image and extract to get .img file

[1] The instruction is based on Raspbian OS.

DRIVER CONFIGURATION

3. Insert SD card to your PC, format it and write .img file to SD card by Win32 Disk Imager software.
4. Insert SD card to your Raspberry Pi and power on. Access Raspberry Pi via SSH or you can connect HDMI screen and keyboard to it directly. Open Terminal
5. Download driver, don't forget connect network

```
git clone https://github.com/waveshare/LCD-show.git
cd LCD-show/
```

5.1. For 2.8inch RPi LCD (A)

```
sudo ./LCD28-show
#or (for Raspbian-Stretch-Lite)
sudo ./LCD28-show lite
```

5.2. For 3.2inch RPi LCD (B)

```
sudo ./LCD32-show
#or (for Raspbian-Stretch-Lite)
sudo ./LCD32-show lite
```

5.3. For 3.5inch RPi LCD (A)

```
sudo ./LCD35-show
#or (for Raspbian-Stretch-Lite)
sudo ./LCD35-show lite
```

5.4. For 3.5inch RPi LCD (B) old version

```
sudo ./LCD35B-show
#or (for Raspbian-Stretch-Lite)
```

After installing driver, you can change screen' s orientation by executing commands as below:

```
cd LCD-show/
```

1. For 2.8inch RPi LCD (A)

```
sudo ./LCD28-show X

#X should be 0, 90, 180 or 270
```

2. For 3.2inch RPi LCD (B)

```
sudo ./LCD32-show X

#X should be 0, 90, 180 or 270
```

3. For 3.5inch RPi LCD (A)

```
sudo ./LCD35-show X

#X should be 0, 90, 180 or 270
```

4. For 3.5inch RPi LCD (B)

```
sudo ./LCD35-show X

#X should be 0, 90, 180 or 270
```

5. For 35inch RPi LCD (B) V2

```
sudo ./LCD32B-show-V2 X

#X should be 0, 90, 180 or 270
```

This module uses high-precision components, while collecting fingerprint:

You only need to touch the collecting window gently, not need to press it hard, fingerprint could be identified quickly.

- **Correct Fingerprint**



- **Wrong Fingerprint**



APPENDIX K – TESTING

Due to the Covid-19 circumstances, we were only able to do a minimum of testing since many of the components of the project were divided amongst the team member. The Bluetooth beacon was tested with a spare android device (not the actual Wearable Smart Watch we have intended for our project) to provide a Bluetooth address. To test the proximity detection, the blue LED light on the board was programmed to switch on when the android device got within a range defined by the signal strength of the Bluetooth signal. A Bluetooth scanner app was used to determine the signal strength of devices in the room. From across the room, the signal strength of the Bluetooth devices was in the range of -80dB to -100dB. As the android device moved closer, the signal strength became exponentially larger. It was determined that when the devices were right next to each other, the signal strength was average -40dB. The proximity detection in the code was then set at -40dB and tested, but that appeared to be too sensitive; consequently, if there was any fluctuation in signal strength, the light cut off. The signal strength at which the light turns on was adjusted to -50dB. This seems to be an acceptable signal strength to activate the light within a 6in to 1ft range and was ideally the distance for the door lock activation.

Testing the fingerprint module was also limited, as it only confirms hardware functionality. The testing connections isolate the figure print module from the rest of the Central Control Hub. The coding used was designed to test the capacitive module capabilities along with its ability to recognize stored fingerprints. When testing the module for capacitive, the device scans ten prints and documents their capacitive score. The capacitive score measures the accuracy of the device in capturing fingerprints; for this testing process, the acceptable score is 75%. The fingerprint module exceeds the acceptable capacitive score in all ten prints. Storing the fingerprints was tested using buttons that initial the enroll/delete and increment/decrement, which changes the fingerprint

storage location, as illustrated in FIGURE. While this confirms the functionality of the device, integrating it into the Central Control Hub would require more extensive testing because different libraries and protocols would be used to manage input and output signals go to and from the fingerprint module.