Department of Electronic and Telecommunication Engineering
University of Moratuwa

EN1190 - Engineering Design Project

Final Project Report

IOT-Based Home Security System

Core Four

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Overview

Our project is a simple IOT based home security system that alerts users of the open/ closed state of doors & windows and if someone enters their residence. These can be monitored in real-time.

➢ Done by - Group of engineering undergraduates in Electronics and Telecommunication Department -University of Moratuwa.

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1. Problem Description, Motivation and Justification for selection

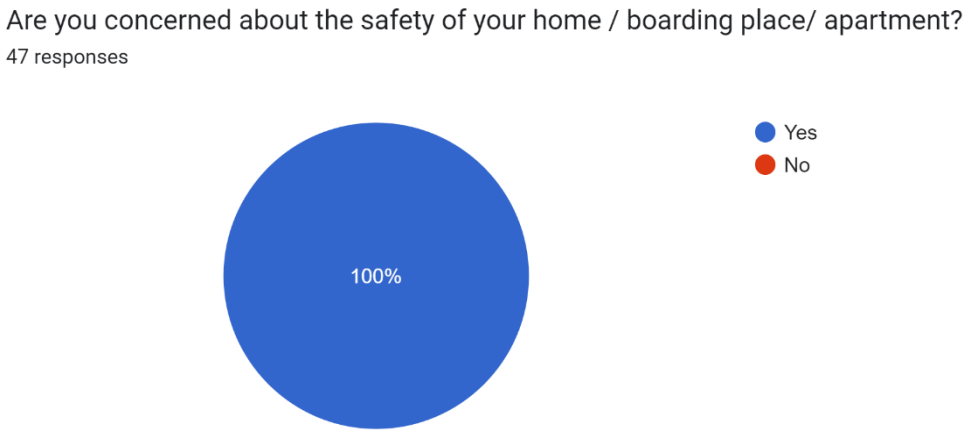
1.1. Problem

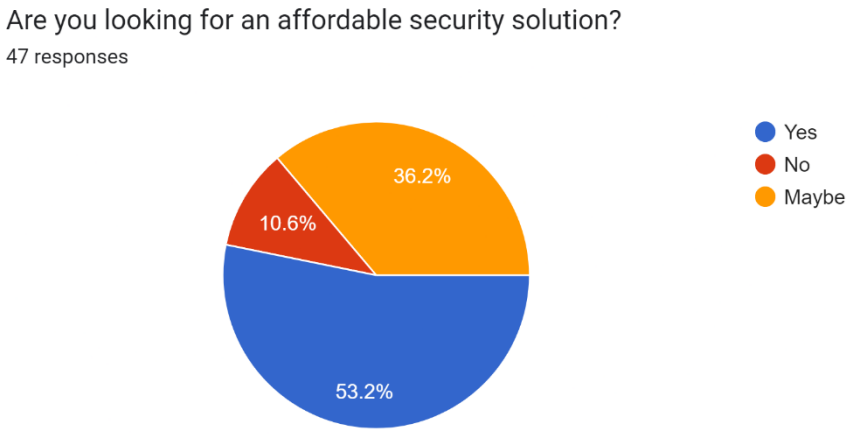
- Because of the economic crisis and the pandemic situation that prevailed in the country, thefts and home invasions are on the rise in Sri Lanka.
- We got this idea after hearing that so many houses were broken into, but due to a security system not being in place the homeowners were not alerted.

1.2. Is this an actual concern?

- Home invasions and breaking have always been a problem in Sri Lanka, and the current economic crisis has only worsened it. We have come to understand that this is a serious issue that has made people question the safety of their homes and boarding places.
- From our market analysis, a central hub could cost more than 12,000 LKR while a simple magnetic door reed sensor unit could cost around 5,000 - 8000 LKR. Such units come separately while they don't have the ability to relay data to an app as it does not come as a system.
- People must put their safety at risk due to the inability to afford such expensive security systems. Furthermore, most systems do not function when there are power cuts.
- As most systems are imported, there is no professional assistance for installation failure.
- Our system integrates many devices used for security purposes together. Both magnetic reed switches and PIR sensors are used while both add an extra layer of protection to one another. The ability to monitor the status of these in real-time while being able to be notified with an alarm is more convenient for the user.
- Such systems in the market are costly. A central hub alone costs more than 10,000 LKR while a sensor unit that only consists of a simple magnetic reed switch costs more than 8,000 LKR while cheaper ones imported from China cost about 6,000 LKR. Most of these sensors do not provide the ability for users to get real-time data.

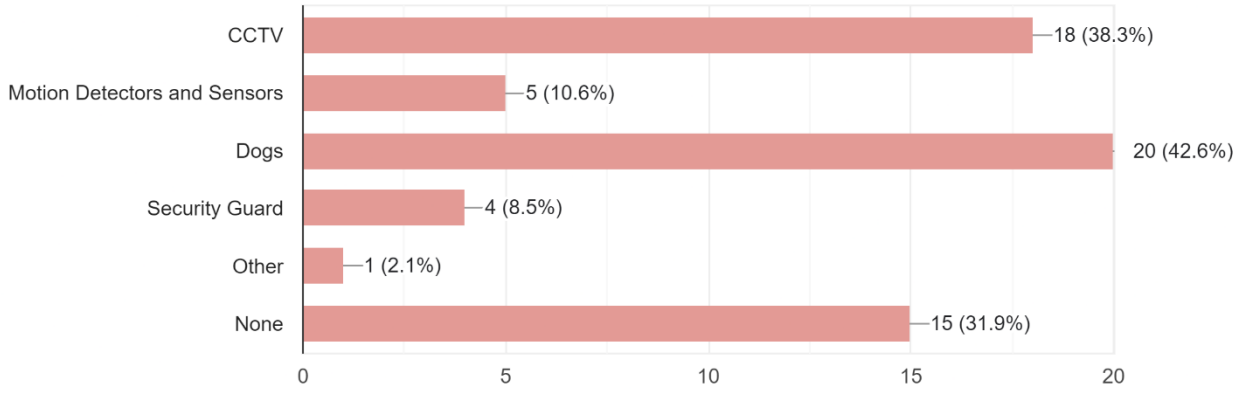
We conducted an initial survey asking if customers would opt for our product at a price of LKR 4,000 and LKR 4,500 to which it was a largely positive response but during our project, we incurred unseen costs which resulted in us having to increase the price of the hub and the sensor and conducted the survey again to see the responses and we understood that the responses still remained positive as see below.





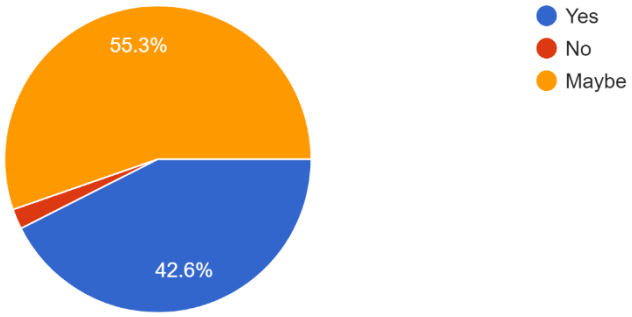
What security systems exist in your residence?

47 responses



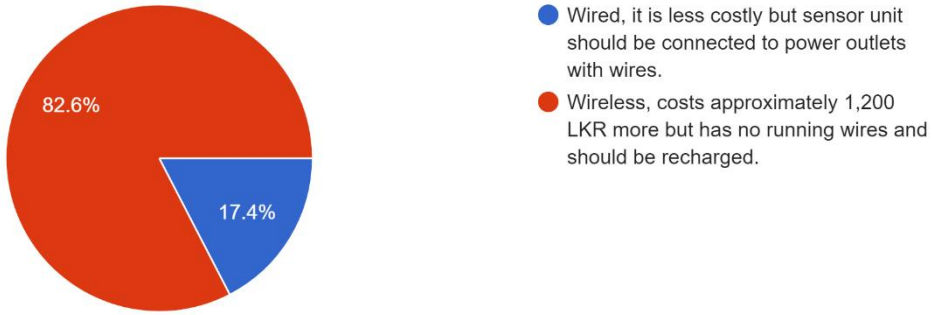
With a cost of 5,000 LKR for a central hub and approximately 6,000 LKR for a sensor unit for each door and window (with the ability to monitor them through an app too), will you buy such a product?

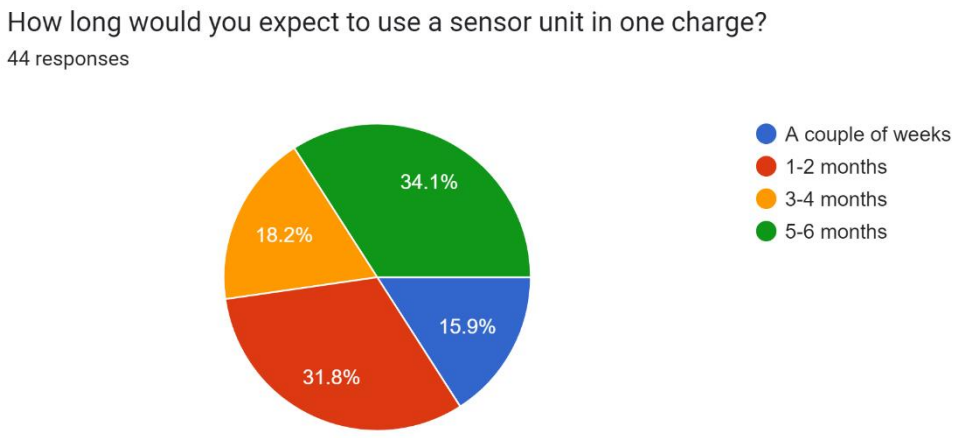
47 responses



Do you prefer wired or wireless?

46 responses





1.3. Justification

These results clearly indicate that people are interested in such a product. We can see through the survey that the most people expect to use the sensor unit wireless and therefore with the use of a rechargeable battery they expect to use the unit for more than 2 months in a single charge but we can manufacture this unit so that it has a life of about 5 months. We can produce a hub with a cost margin of about 2,200 LKR while producing a sensor unit with a cost margin of about 1,700 LKR. As users buy multiple sensor units this would satisfy the market. Most people have spent excess of 100,000 LKR on such security systems.

All the facts and survey results mentioned above indicate that a security system has become an essential piece of equipment in every house and residence. As a result, we can be confident that our product will be very valuable to clients and will be in high demand in the market, and we can plan for future advancements based on that need.

2. Technical Feasibility

2.1. Performance Targets

- Detect thieves and home invasions.
- Show real-time data of the Open /Closed state of doors and windows.
- Notify the user with an alarm sound.
- Operation of the sensor unit for about.

2.2. Availability of Hardware components

Needs of this design project include some Hardware and Software. Hardware that are used and their corresponding performance targets are mentioned below.

1) To detect motions, we need a sensor which triggers only in the case of motion of a human being. So, there is a sensor in the market which is called PIR (Passive infrared sensor). Its operation is based on infrared rays which emit from living beings. This has a range of up to 10 meters, a single detector placed near the entrance is all that is necessary for rooms with only a single entrance. A magnetic reed switch is used. This switch operated based on magnetic attraction and is attached to doors to indicate if they are opened or not.

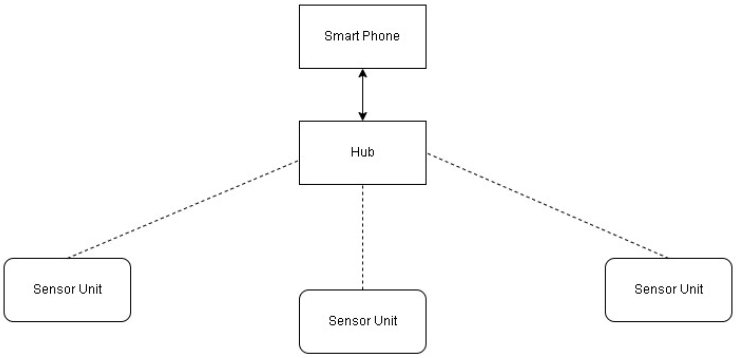
2) Alert the user through the network, we need a device that has the functionality of providing connection between our device and a specific mobile phone of a user. The ESP32 IC has an inbuilt Wi-Fi module to communicate with other ESP32 ICs Module which can be easily found in the market provides that necessity.

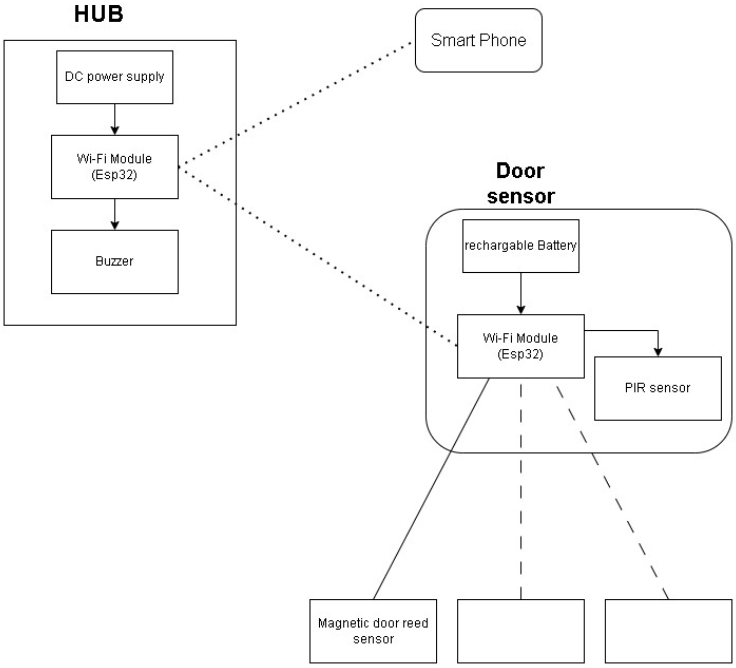
3) Making the time we can use a sensor unit long enough to not be inconvenient. Through the ESP NOW function we can lengthen this to about 5 months for a user to use a sensor unit in a single charge.

4) Making an alarm sound is very straightforward, there are several methods and components, but in our device, we continue with a simple small buzzer.

5) We designed our enclosure for the product in a smart shape which provides much convenience to users.

3. Product Architecture





3.1.1 HUB

The hub is the device that connects to a smartphone and connects one or more sensor units that are attached to doors and windows. It is powered by a 230V power line. The hub contains three components.

1. DC power supply- To step down 230V to 5V and power the other components in hub.

2. 2 Esp32 chips -One chip to communicate with each sensor unit and the other chip to receive the data that the first chip receives from sensor units and upload that data to the smartphone app.

3. Buzzer- To produce an audible alert to notify occupants or authorities of a potential security breach or unauthorized access.

3.2. SENSOR UNIT

This sensor unit is the device that identifies unauthorized entry and it communicates with the hub. sensor unit contains four components.

1. Rechargeable battery- 3.7V 3200mAh rechargeable battery that powers PIR sensor, magnetic door reed and Wi-Fi module

2. Magnetic door reed sensor- A magnetic door reed sensor is a device that detects the opening and closing of a door or window using a magnet and a reed switch.

3. PIR sensor- To detect movement inside the house.

4. Esp32 chip- To send state of window or door and output of PIR sensor to the hub.

3.3. SMART PHONE

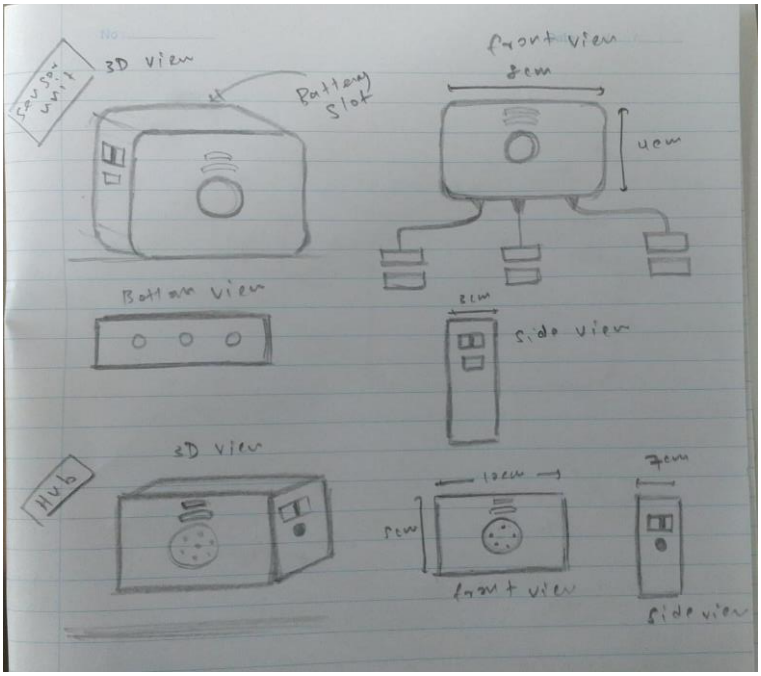
The app that is installed into the smart phone allows the user to monitor real time data such as the open / close state of door and windows and alerting users when an intrusion occurs. Furthermore, it allows the user to turn on and off the security system. We tested this by using the Blynk app. This app has a cloud to which the one of the Esp32 chips upload data that is then seen in the application.

In our initial product architecture design, we only used one Esp32 chip in the Hub. This was to be used to receive Sensor unit data and simultaneously send it to the mobile app through the internet. I was doable using one Esp32 chip but there were some drawbacks such as the chip taking more time to send data and consuming a lot of power. Furthermore, the ESP-Now and Wi-Fi channels need to share the same channel. Since the Wi-Fi channel changes the Esp32 chip in the sensor unit should scan before sending data to make sure of the channel. This consumes a lot of power from the battery that this Esp32 is powered from and the battery power is a constraint in our project so we needed optimizing the battery usage.

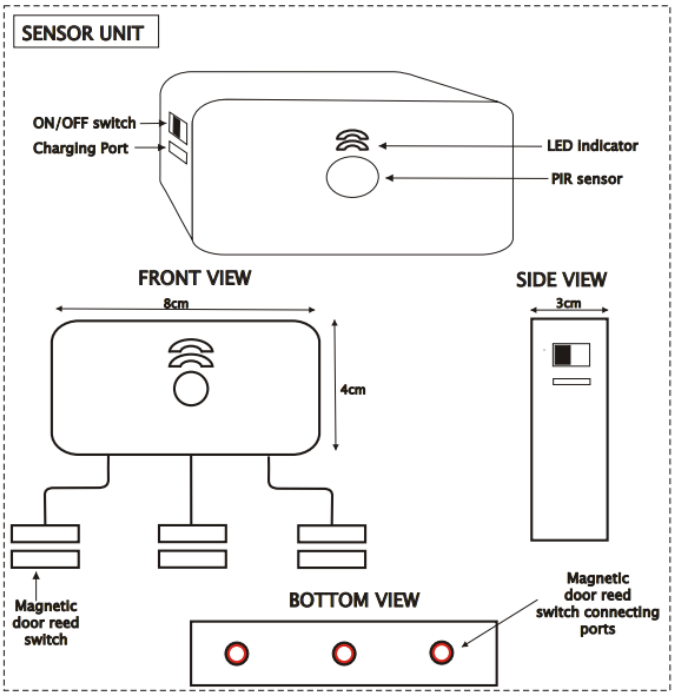
Using two Esp32 chips in the Hub, one chip to communicate with each sensor unit and the other chip to receive the data that the first chip receives from sensor units and upload that data to the smartphone app we can solve the issue of communication.

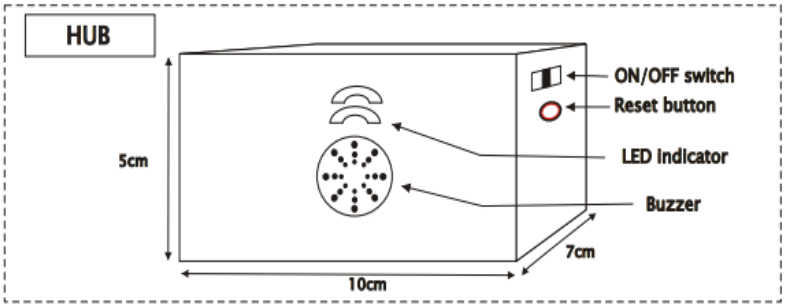
4. Initial and Final Sketches of the Enclosure

4.1. Initial Sketch



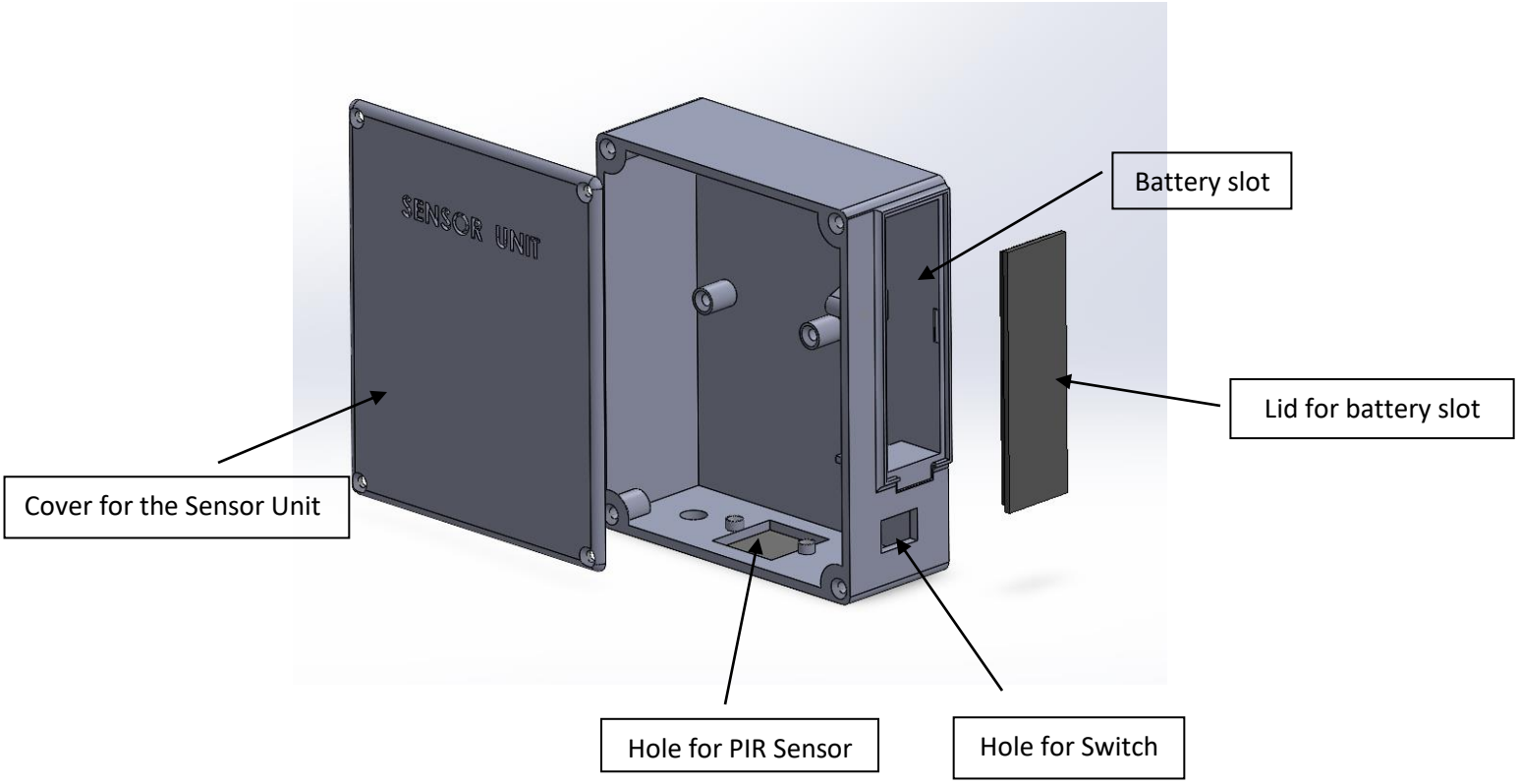
4.2. Final Sketch





5. Final SolidWorks Designs

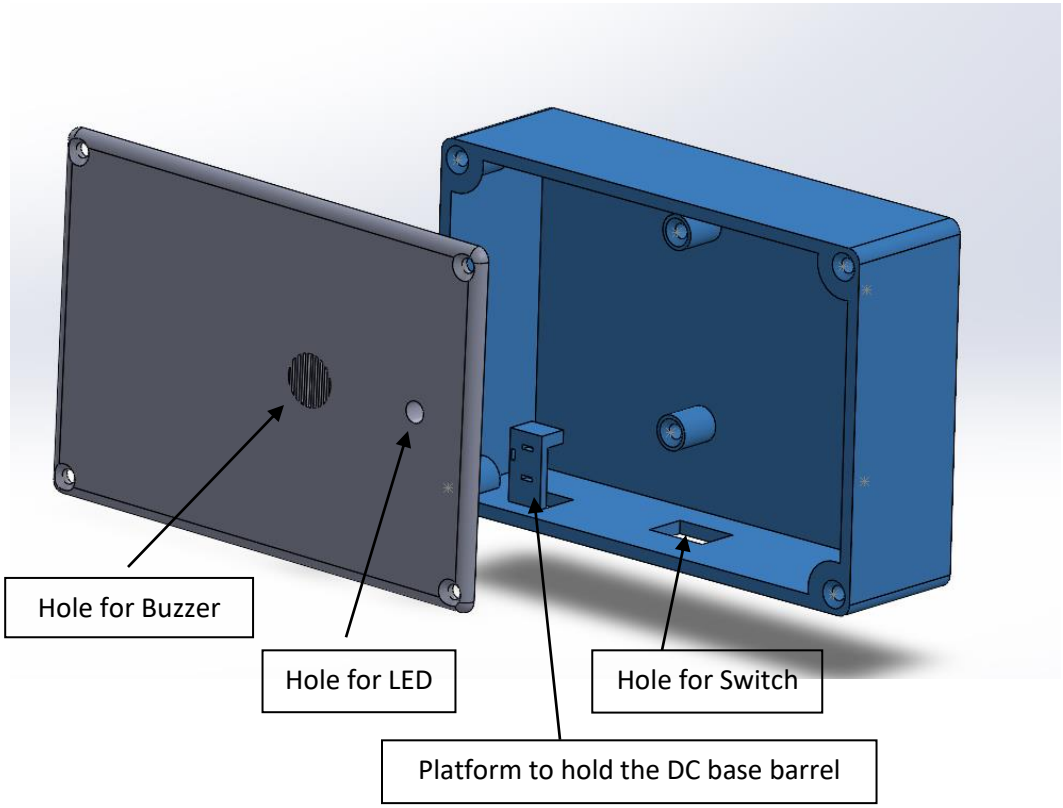
5.1 Sensor Unit



Dimensions of Sensor Unit

Height = 12.1 cm Width = 10.1 cm Thickness = 4.1 cm
Total volume = 501.05 cm^3
Weight - 150g

5.2 The Hub



Dimensions of Hub

Height = 11.9 cm Width = 8.25 cm Thickness = 3.3 cm
Total volume = 323.98 cm^3
Weight - 150g

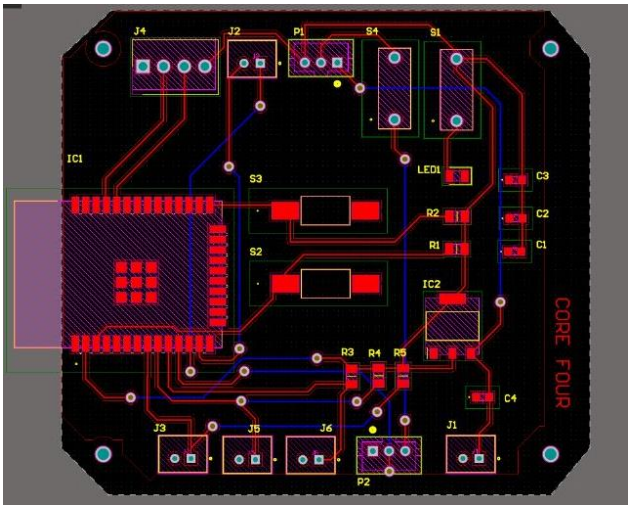
Enclosure of Sensor Unit

Enclosure of Hub

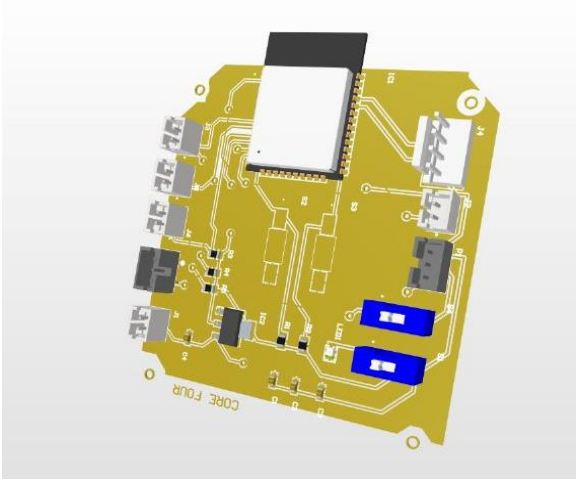
6. PCB Designs

Below are the PCB designs and schematic diagrams of the Sensor unit and the Hub.

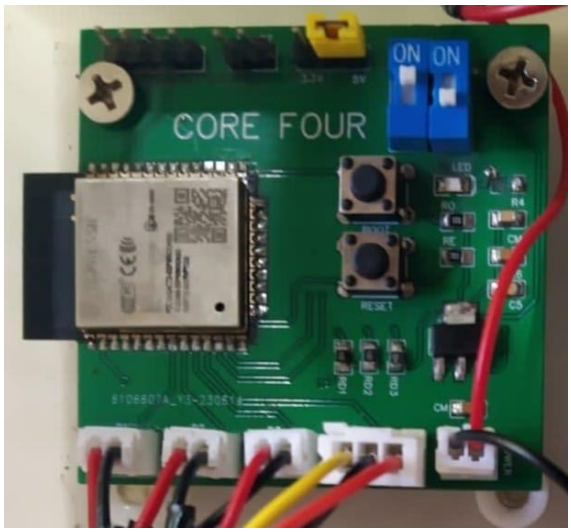
6.1 Design for the PCB of the Sensor Unit



PCB design for Sensor Unit



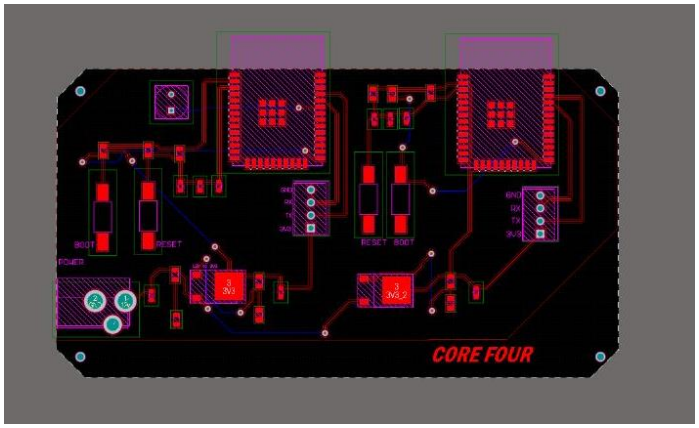
3D view of the PCB design



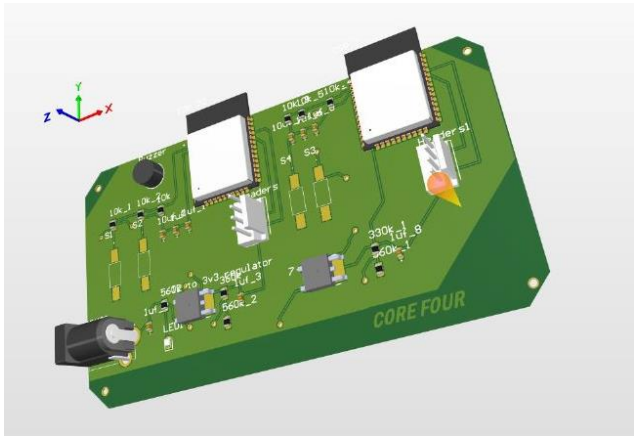
Printed PCB of Sensor Unit in the enclosure

6.2 Design for the PCB of the Hub

This was our first design for the PCB of the Hub using one Esp32 chip but the problems discussed previously made us switch to two Esp32 chips instead of one with a newer PCB design.

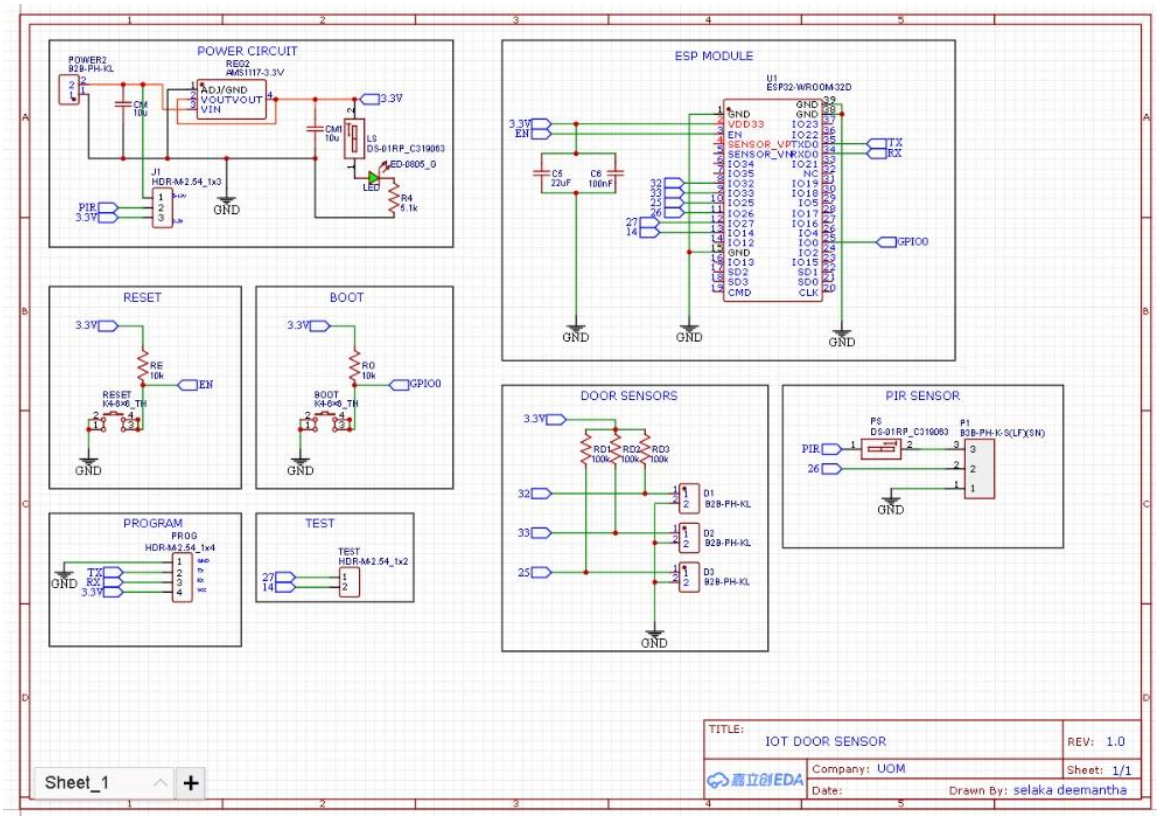


PCB design for Hub

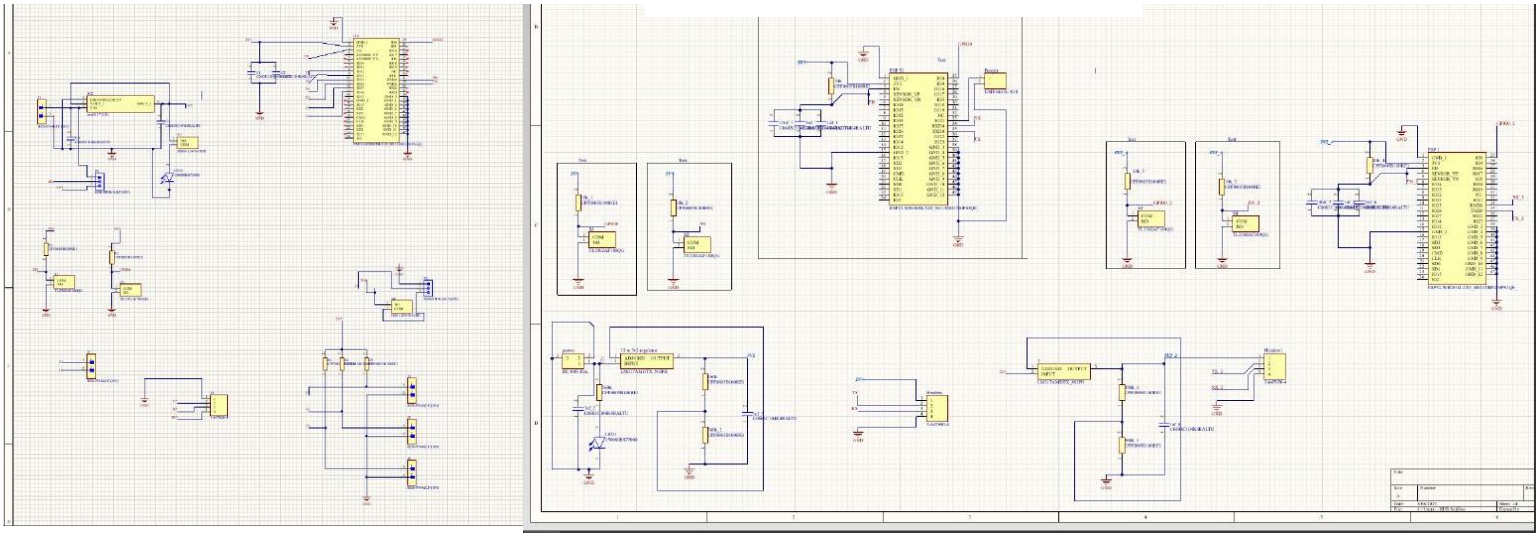


3D view of design for Hub

6.3 Schematic Diagrams



Sensor Unit



The Hub

7. A Basic Overview of the System

As mentioned previously the system has three main components: the Sensor Units for data collection, the Hub, and the mobile application.

The system has two modes: safe mode and buzzer mode. Our intentions were to make it able for the user to monitor the opened/ closed state of the doors or windows that the sensor units are mounted to when the safe mode is turned on through the app. We put a switch to the PIR sensor which can be turned on/ off manually. This allows the user to decide when they need to detect motion. The Hub too has a switch which enables the user to turn the buzzer on. An LED is used to indicate if the buzzer is on or off.

When the PIR and Hub switches are on and the safe mode is already turned on, turning the buzzer mode on allows the buzzer to turn on when a motion is detected or a door or window is opened and alerts the user. When the buzzer mode is turned on and one of the above or both occurs the user gets a notification alerting the occurrence and an alarm will ring on the user's phone.

7.1 Power Consumption

Our main concern was the battery life of the sensor unit for a single charge since the Esp32 chip should be powered by it. To overcome this, we made use of the Esp32 chip's Deep Sleep mode where it only wakes up when a door or window is opened or closed and is awake till the is close or opened or when a motion is detected from the PIR sensor. Simply put, the Esp32 chip in the wakes up to replay the information of a changed state in door or window of the sensor unit. We made the sensor unit in such a way that it can monitor up to a total of 3 doors/ windows since it has three magnetic reed switches.

- While active the Esp32 chip draws a current of 50mA and while in deep sleep mode it draws 100µA.
- If the doors/windows connected to one sensor unit are opened for a total of 2 hours collectively, daily then a user can use a sensor unit for 32 days with this 3200mAh battery.

8. Further Developments and Improvements

- Optimizing the power consumption of the battery during the brief wake-up time to extend the charge of a single battery charge.

  Currently a sensor unit can only be used for approximately a month from a single charge. But we can improve our code in such a way that the Esp32 chip is woken up when a magnetic reed switch or a PIR sensor is triggered and goes back to sleep right after it relays the message to the Esp32 chip in the Hub. We can limit this brief wake up to about 10s. Therefore, once a trigger happens the Esp32 is only active for 10s before going to sleep again.

  This way, if the reed switches and the PIR sensor are triggered a total of 50 times a day, then the Sensor unit will have a power consumption per day will be,

  Power consumption per trigger = 50mA*10/ (60*60) = 0.1389mAh

  Power consumption per day (50 triggers in total) = 50*0.1389mAh = 6.944mAh

  Since we use a 3200mAh battery,

  Lifetime of a single charge = 3200mAh / 6.944mAh = 461 days = 1.2 years

  If we consider the fact that the charge of rechargeable batteries reduces with time, we can expect a battery life of about 8 months to one year.

- Addition of a battery level indicator in the sensor unit.
- Smaller and better-looking designs for the Sensor unit and the Hub.
- Creation of an application using MQTT protocol for optimized user experience and real-time updates.

9. Marketing, Sales & Beyond

People are concerned about security these days because the number of robberies is on the rise. As a result, electronic security systems are in high demand. When it comes to recommending the best product packaging for an IoT-based security system, several factors should be considered, including the product's features, target market, brand identity, and overall customer experience.

There are numerous types of security equipment on the market, such as CCTV and burglar alarms. We have now discovered the substitutes and compared them to our product as the first stage. Higher electricity usage and hefty price tag are such goods' key drawbacks. We chose our tagline for our marketing campaign based on that.

“Secure your home, save energy and money.”

Initially, we will market these products regionally. We will improve our product by introducing additional features once we have captured the local market. We will also enter global markets because of this. Our marketing strategy is consistent with the four Ps of the marketing mix. The pricing of the product is an extremely crucial part of its market success. According to Google, the typical cost of installing a CCTV camera is between USD 150 - USD 450. We intended to sell at a modest markup to catch the early market. Initially, we will offer our product through various e-commerce platforms and tiny local businesses. Once we get public recognition, we will launch our own website to eliminate excessive commission charges. Furthermore, economies of scale can reduce our indirect costs such as shipping. We will begin marketing our product in international nations via ecommerce websites once we have revised our product based on feedback from local users.

Marketing Strategies: The marketing strategies for promoting the IoT-based security system will focus on maximizing reach, targeting the right audience, and showcasing the system's unique features and benefits. The following strategies will be employed:

1. Content Marketing

2. Search Engine Optimization (SEO)

3. Social Media Marketing

4. Pay-Per-Click (PPC) Advertising

5. Strategic Partnerships

Demonstrations and events by implementing these marketing strategies, the IoT-based security system will gain maximum visibility, effectively target the right audience, and showcase its unique features and benefits to drive customer adoption and sales.

Some after sales we can provide are free repairs and the maintenance of the app.

10. Project Budget with BOQ

10.1. Budget for a Sensor Unit

component	Number of components	Unit price (Rs)	Total prize (Rs)
ESP32 chip	2	1100	2200
DC power connector (5v)	1	780	780
Buzzer	1	60	60
Other (Resistors, capacitors, LEDs, switches, DC base barrel)			620
Total			3,660

10.2. Budget for the Hub

component	Number of components	Unit price (Rs)	Total prize (Rs)
ESP32 chip	1	1100	1100
Magnetic Reed Switch	3	180	540
Rechargeable battery	1	700	700
PIR sensor	1	350	350
Other (Resistors, capacitors, switches, battery casing)			500
Total			3,290

10.3. Manufacturing Process

- PCB printing- Rs 3,500 + Rs 4,200 = Rs 7,700
- Enclosure 3D printing - Rs 2,075 + Rs 2,075 = Rs 4,150
- Soldering wires – Rs 100

Total Budget = 1 x Central Hub + 2 x Sensor Units + Manufacturing Cost

Total Budget = Rs 18,900/=

11. Task Allocation

- Javin – Overseeing the project budget and deadlines, market research and marketing, product architecture and enclosure design using solid works.
- Shenal – PCB designing using Altium Designer and researching and analyzing the technical feasibility of the project.
- Selaka – Product testing, Circuit designing and Coding.

. 12. More Information

All our files such as the Altium files, SolidWorks files and video demonstrations have been uploaded to the following GitHub repository.

https://github.com/javin-5/IOT-based_home_security_system.git