Door Sure: The Garage Door Status Detector

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***Abstract* — DoorSure is a smart garage door monitoring and control system designed to enhance home security, improve user convenience, and provide peace of mind. DoorSure utilizes an IoT-based approach, integrating sensors, a servo motor, and microcontroller units to detect and control the garage door's position. Users interact with the system through an accompanying web-based application, which supports live camera feeds and real-time notifications. Safety is further enhanced through object detection, preventing door closure if an obstruction is detected. The system also utilizes AI-based object identification for common garage items that are causing an obstruction for ease of identification.**

***Index Terms* — artificial intelligence, cloud computing, internet of things, microcontrollers, object detection, remote monitoring, sensor networks.**

I. Introduction

Garage doors, when accidentally left open or unattended for long periods of time, can put a home owner's property and safety at risk. The FBI 2019 reported over 1.1 million burglaries, resulting in losses of an estimated $3 billion in stolen valuables and direct property damage. More recently, 2024 reports from Securiteam indicate that burglary remains a major concern, with approximately 2.5 million burglaries occurring in the United States, resulting in an estimated $3.4 billion in losses [1]. More recently, data from Securiteam indicates that burglary, although on a declining trend, remains a major concern, with approximately 2.5 million burglaries occurring in the United States and causing an estimated $3.4 billion in losses [2]. However, advancements in smart security technology and neighborhood surveillance systems have contributed to an overall declining trend in burglary rates over the years. Enhanced security measures such as smart home devices, motion-activated cameras, and automated alerts are making it harder for intruders to go undetected, reducing the likelihood of break-ins.

Beyond theft, however, an open door exposes your garage to the elements - rain, wind, or even wandering animals that could cause property damage. The longer one is absent, these risks only increase. In response to this problem, modern technology can be used to create smart home solutions that provide not only property security but also peace of mind. As engineers, solutions can be made by combining integration of sensors and real-time monitoring systems with software technology that will allow homeowners to remotely check the status of and receive alerts about their garage door, as well as giving said users the ability to interact with their garage door, ensuring their home remains secure even when they are miles away.

DoorSure addresses this gap by empowering users with real-time awareness and remote control over their garage door via Internet. DoorSure is designed with universal compatibility with garage doors and cost-efficiency in mind which stands apart from existing systems that are brand specific. DoorSure supports garage doors without requiring significant hardware modification, combining key features of status detection, object awareness, live streaming and remote operation into a unified affordable solution.

II. System components

The DoorSure system is an IoT of carefully researched hardware and software selections to prioritize user-friendliness, cost effectiveness.

A. Microcontroller (ESP32-WROOM, ESP32-S3)

Selecting the appropriate microcontrollers was a critical design consideration, as the system is responsible for managing multiple peripherals, uploading data to a cloud computing service, supporting live video streaming, and analyzing object identification using artificial intelligence. The ESP32-WROOM was chosen for the secondary device due to its low cost, integrated Wi-Fi module, 240 MHz clock speed, and 4MB of flash memory. In comparison to other microcontrollers reviewed such as the BCM2835 or the RP2040, the selected ESP32-WROOM has a lower operating voltage of 3.3V. Its energy-efficient architecture supports the project's goal of achieving a battery life of at least three months, with an estimated power consumption between 2W and 6W.

Due to the peripherals on the primary device, the ESP32-WROOM was insufficient in RAM. As such, it demanded a higher capacity microcontroller capable of handling real-time camera functions and AI workloads. The flash and PSRAM limitations of the WROOM variant rendered it unsuitable for these tasks. As a result, the

ESP32-S3 was selected, offering double the flash memory sitting at 8 MB, 8 MB of PSRAM, and additional GPIOs, making it well-suited for image processing and advanced peripheral control.

B. Door Position Sensor (Reed Switch MC-38)

Accurate detection of the garage door's position is a critical function of the DoorSure system. To ensure reliability, low power consumption, and high precision, the MC-38 reed switch was selected as the primary sensor for position detection. Unlike mechanical contact-based sensors, the reed switch operates via magnetic proximity, thereby improving durability and reducing the likelihood of mechanical failure. The sensor's installation process is straightforward: the magnet is mounted on the moving garage door, while the switch component is affixed to the stationary primary device. This configuration enhances system usability and supports the project's objective of maintaining a user-friendly and easily deployable design.

C. Obstacle Detection (Ultrasonic Sensor RCWL-1601)

The device responsible for detecting obstructions in the path of the garage door must be reliable, cost-effective, and capable of covering a sufficient range to accommodate various garage configurations. The RCWL-1601 ultrasonic sensor was selected for this purpose due to its affordability, ease of integration, and maximum detection range of approximately 13 feet. Unlike optical sensors, ultrasonic sensors operate independently of lighting conditions, making them suitable for both indoor and outdoor environments. Their non-contact nature also reduces mechanical wear over time, contributing to long-term reliability. Additionally, the RCWL-1601 is capable of detecting a wide range of surface types with relatively high accuracy. Despite its limitations involving minimum detection threshold, its overall performance and cost-effectiveness make it well-suited for this application.

D. Camera (OV5640)

The camera is mounted on the primary PCB and is responsible for providing a live video feed to the web application, as well as performing AI-based object classification to detect obstacles in the path of the garage door. The Waveshare OV5640 Model B was selected due to its cost efficiency and integrated fisheye lens, which offers a wider field of view suitable for garage environments. Furthermore, the camera connects directly to the ESP32-S3 via a dedicated interface, simplifying integration and making it an ideal choice for the system's requirements.

E. Servo Motor (MG90S)

The servo motor is responsible for initiating the mechanical action required to close the garage door by applying torque to the garage door button. Since this component is expected to operate repeatedly, a model with metal gears was selected to minimize wear and extend longevity. Durability and reliability under repeated use were prioritized during the part selection process. Additionally, the servo was chosen for its compact size, low power requirements, and compatibility with the 5V regulated supply used in the system. The selection of the MG90s supports a wide range of motion with a stall torque of 1.8kg/cm at 4.8V, making it suitable for the mechanical actuation required for the DoorSure system.

F. Temperature and Humidity (DHT11)

The temperature and humidity sensor is mounted on the secondary device's PCB, as this unit is positioned closer to the center of the garage environment than the primary device. Its purpose is to provide users with insight into the ambient conditions within the garage. The DHT11 sensor was selected due to its suitable operating temperature range of -20°C to 60°C, low power requirement of 3.3V, and cost-effectiveness. As this peripheral serves as a supplementary feature rather than a core system component, low cost and minimal power consumption were prioritized to allocate resources toward more demanding elements of the system.

G. Power Supply System

Reliable power delivery is essential for the effective operation of the DoorSure system. The power subsystem begins with a pair of 556065 3.7V Li-Po batteries (2500 mAh) connected in series, selected for their high capacity, long battery life, and rechargeability. This configuration provides the necessary system voltage while reducing long-term operational costs for users. Voltage regulation is achieved through two dedicated buck converter daughter boards: a 3.3V regulator utilizing the AP63203 and a 5V regulator based on the AP63205. These converters ensure consistent and stable voltage outputs required by various system components. Implementing the regulators on separate daughter boards improves modularity, simplifies system assembly, and facilitates maintenance.

H. Web-Based Application

The accompanying web application connects the hardware components to user interactions, proving an intuitive way to remotely control their garage door. Through the app, users can review real-time sensor data — such as current garage door position, object obstructions, and temperature and humidity values — alter the state of their garage door, view live camera feed, and adjust notification preferences. A web-based application was selected over native iOS or Android platforms due to its minimal development overhead, absence of publishing fees or app store restrictions, and streamlined maintenance through instant updates. Furthermore, the development team possessed prior experience with web technologies, making this approach both efficient and practical.

Google's Firebase platform was chosen as the backend service over alternatives such as AWS or Microsoft Azure, primarily due to its generous free-tier pricing, simplified integration with front-end technologies, and its Realtime Database (RTDB), which enabled low-latency synchronization of state changes—an essential feature for this system's real-time monitoring requirements.

III. System Concept

This section of the report will provide a more in depth description of the chosen hardware components, as well as show how the separated primary and secondary devices will communicate to form one system. This section also depicts the software flow of the DoorSure system to showcase how the software will be incorporated to bring the system to life.

A. System Hardware Concept

As discussed in the introduction to this section, the hardware block diagram shown in Figure 1, shows the two devices for the system, primary and secondary, and its interactions wirelessly and wired with the web server and the user's electronic device connected via the internet.

The DoorSure system consists of two distinct embedded devices, referred to as the primary and secondary units, each equipped with specific peripherals. The primary board includes a reed switch, ultrasonic sensor, and a camera module. It is positioned near the bottom of the garage door to monitor obstructions along the door's path. The secondary board, mounted near the wall-mounted garage door button, integrates a servo motor, temperature and humidity sensor, and a buzzer. Both devices connect to the user's home Wi-Fi network and communicate with a web application via the Firebase cloud platform, enabling real-time monitoring and control.

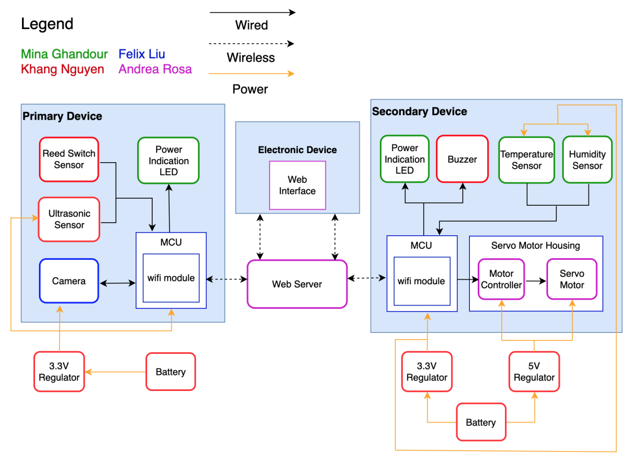


Fig. 1. Hardware block diagram of system

B. System Software Concept

After discussing the hardware components in more detail, this section will detail how the software will interact with the hardware to create the overall system.

The first half of the system operational flowchart is seen below in Figure 1. The decision flow and peripheral interactions within the secondary system shows that upon receiving a user-initiated door control request, either to open or to close, the system will check the current state of the garage. If the garage door is currently in the closed state, it will automatically signal for the servo motor to move, therefore opening the garage door. Alternatively, if the garage is open, the system will inquire the Firebase object obstruction flag (1:obstruction detected, 0: all clear). If an object is detected, the request will be aborted and a corresponding error will be displayed to the user on the web interface. If there was no obstruction detected, the request is then forwarded to the secondary device same as if the door was shifting from close to open. The secondary device also features a buzzer peripheral that will produce a simple pattern whenever the servo motor is activated. This is done for audible alerts. Additionally, a temperature and humidity sensor is featured on this device that periodically updates the web interface with the environmental values of the garage room. Finally, the battery powering the system will send the user a notification once the voltage reading has decreased past a certain point.

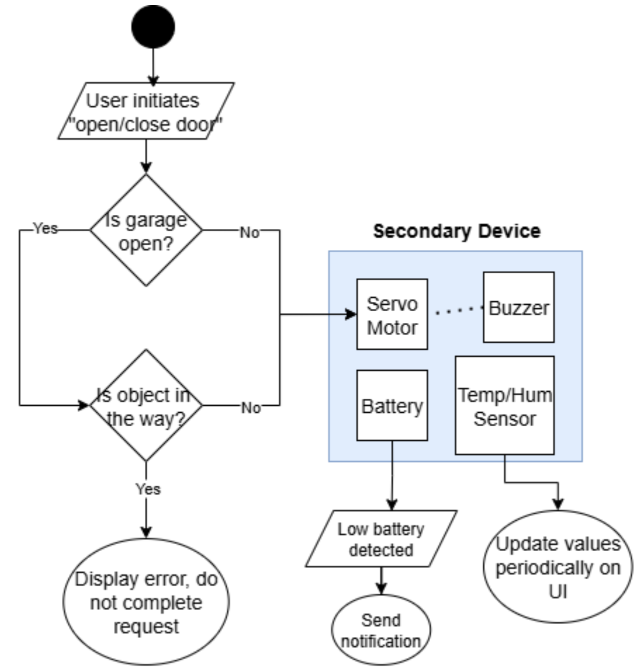


Fig. 2. Secondary system operational flowchart

The second half of the system's operational flowchart is seen in Figure 3. Dissimilar to the secondary device, the primary device is typically not initiated with user control. The reed switch component is attached to the garage door, which updates the door status on the Firebase cloud system with the corresponding values (1: open, 0: closed) depending on magnetization. The ultrasonic peripheral is activated by the system only when the garage status is 'open'. This is done primarily to save power consumption since there is no need to search for obstructions if the door is already in the closed state. When the garage door is in the open state, the ultrasonic actively searches for object obstructions, setting a flag accordingly. Additionally, if the user has the notification preferences on, the system will send an alert to the web application stating there is an obstruction. Similar to the previous device, once the voltage levels are a certain reading, the user will receive a notification. Finally, the camera component streaming live feed can be accessed at any time by the user on the web interface. Furthermore, if there is an object obstruction identified, the web interface will have a button to display a description of the object powered by AI Google Gemini. A press of a button activation was used for this action to save power consumption and storage for the MCU.

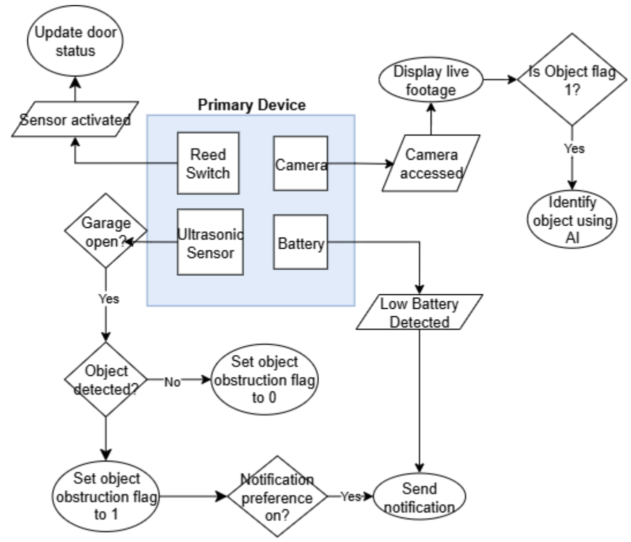


Fig. 3. Primary system operational flowchart

IV. Hardware Detail

The DoorSure system consists of two devices: The primary device, which is responsible for detecting the status of the garage door's position, any obstacles within the device's path, and providing a live camera feed of the garage room, and the secondary device, which is responsible for opening and closing the garage door, along with recording the temperature of the garage room. Both devices utilize the same battery system, being two 556065 3.7V li-po batteries running in series, with a 3.3V and a 5V regulator powering each component respectively.

A. *Power Requirements*

On the primary device, the ESP-32S3 microcontroller, the OV5640 camera, and the RCWL-1601 ultrasonic sensor require 3.3V to operate. The remaining items, the reed switch and the power indication LED can be supplied through the ESP-32S3. On the secondary device, the ESP-32 WROOM microcontroller and the DHT11 require 3.3V of power while the servo motor needs 5V of power to operate. The indication LED and the buzzer can be supplied from the ESP-32 WROOM.

To verify that the power source is sufficient in supplying system demands in the primary and second devices, this requires the use of a few formulas. The 556065 battery's capacity is 2500mAh, as the battery is a 1C system, this makes the current draw 2.5A. This means that the current draw for each respective device must be below 2.5A.

For the primary device, the current draw for the components are provided here:

TABLE I

VOLTAGE AND CURRENT DRAWS FOR PRIMARY DEVICE COMPONENTS

Component	Voltage	Current
ESP32-S3	3.3V	500mA
OV5640	3.3V	140mA
RCWL-1601	3.3V	2.2mA

Based on the current and voltage values provided in Table I, the total power consumption of the primary device was calculated using the standard power equation,

$$P = V \times I \quad (1)$$

$$P = 3.3 \times (500mA + 140mA + 2.2mA) = 2.11W \quad (2)$$

Accounting for inefficiencies and power losses, the total power consumption is conservatively rounded to 3 W. Given a supply voltage of 7.4 V from the two series-connected Li-Po batteries, the resulting current draw is calculated as:

$$I = \frac{P}{V} = \frac{3\,W}{7.4\,V} = .41\,A \quad (3)$$

The calculated current draw using the value found in equation 3 is .41A, which is well sufficient for the power source.

TABLE II

VOLTAGE AND CURRENT DRAWS FOR SECONDARY DEVICE COMPONENTS

Component	Voltage	Current
ESP-32WROOM	3.3V	500mA
DHT11	3.3V	0.3mA
MG90	5V	250mA

When applying the same for the secondary device using Table 2 values,

$$P = (3.3V \times (5mA + .3mA)) + (5 \times 250mA) = 2.9W \quad (4)$$

Considering losses, this can be rounded to 3.2W.

$$I = \frac{P}{V} = \frac{3.2\,W}{7.4\,V} = .43\,A \quad (5)$$

The calculated current draw using the value found in equation 3 is .43A, which is also well sufficient for the power source.

B. Wireless Communication

In regards to the wireless connectivity, communication to the web server via WiFi was used. After testing, it was found that lower latency and faster response times occurred if both devices were connected independently through WiFi to the Firebase server as supposed to the primary solely connected and communicating through ESP-NOW to move the servo on the secondary device.

C. System Device Flashing

Due to the nature of the programming and flashing for both primary and secondary devices, it will be through a dedicated CP2102N USB to UART custom PCB, with a USB-A connection connecting to the computer and three wires connecting RX, TX, and ground to the three respective ports on each of the devices. This was a thoughtfully processed choice in design as incorporating the CP2102 chip onto the primary and secondary PCBs can lead to major complications should the chip experience a malfunction; having an external connection will make troubleshooting the UART PCB less time consuming and easy to diagnose any problems.

V. SOFTWARE DETAIL

The Doorsure project is focused on detecting obstacles, monitoring door status, and providing real-time alerts, and visual feedback through Firebase. To achieve this, the software architecture consists of embedded firmware running on multiple ESP32-based microcontrollers and a web-based dashboard for remote monitoring. The key responsibilities of the software include object detection powered by Google Gemini, live streaming by uploading images to Firebase, ultrasonic distance sensing, servo-controlled garage door actuation, environmental sensing, and a responsive dashboard interface built using HTML, CSS, and JavaScript.

A. System Firmware and Tools

The firmware is primarily written in C++ using the Arduino framework for the ESP32. Arduino IDE was selected for firmware development due to its native support for the ESP32 and the availability of an active community and compatible libraries. The libraries used for this project are as follows:

- Wi-Fi Library (<WiFi.h>)

This library provides Wi-Fi connectivity for the ESP32. It was used to connect the devices to the local network and retrieve their IP addresses, enabling communication with the web application and Firebase via WebSocket.

- Firebase Arduino Client Library (<Firebase_ESP_Client.h>)

Developed by Mobizt, this library was used to configure the Firebase connection and manage authentication. It enables secure reading and writing of data to the Firebase Realtime Database.

- ESP32Servo (<ESP32Servo.h>)

This library was used to control the servo motor connected to the secondary device. It allows angle-based movement by defining a servo object and setting its position programmatically.

- DHT Sensor Library (<DHT.h>)

Provided by Adafruit, this library was used to interface with the DHT11 temperature and humidity sensor. The readings were displayed on the web application and written to Firebase for real-time updates.

These are deployed across two individual units to add functionality to the hardware.

1. Primary unit (ESP32-S3 N8R8)

This unit performs real-time sensing and image analysis. It includes:

- A camera (OV5640)
- An ultrasonic distance sensor (HC-SR04)
- EEPROM for Wi-Fi provisioning
- Wi-Fi + HTTPS communication to Firebase and Google Gemini

```
void loop() {
  measureUltrasonicDistance();
  if (triggerConditionMet()) {
    captureImage();
    uploadToFirebase();
    sendToGemini();
    receiveAndParseGeminiResult();
    logDetectionToFirebase();
    updateWarningStatus();
  }
}
```

Fig. 4. Main loop operational

2. Secondary Unit (ESP32-WROOM)

This unit controls:

- A servo motor to open/close the garage
- A DHT11 for temperature and humidity
- Realtime status reporting via Firebase

```
void loop() {
  readTemperatureHumidity();
  writeToFirebaseStatus();
  if (checkForDoorCommand()) {
    controlServo(openOrClose);
  }
}
```

Fig. 5. Secondary unit loop

Both units authenticate with Firebase using email/password and share a synchronized command/state protocol via Realtime Database.

B. Object Detection with Google Gemini

Instead of local AI (e.g., Edge Impulse), Doorsure sends images to the Google Gemini API for object recognition. The workflow is described as below:

(1) Capture the image as a JPEG
(2) Upload to Firebase Storage
(3) Send a prompt such as “What’s in the frame?”
(4) Gemini returns a natural language description of the scene (e.g., “*There is a ball on the ground near the garage door*” or “*No objects detected in the frame.*”)

This language-based inference provides a flexible, bias-free, and powerful alternative to fixed-label ML models.

C. Data Structures and Logic

ESP32 memory is used efficiently through well-defined data structures:

```
struct DetectionResult {
  String description;
  bool obstacleDetected;
  long timestamp;
};

struct EnvData {
  float temperature;
  float humidity;
};
```

Fig.6. Data structures and logic code

D. Timing and Edge Case Handling

All critical operations in the firmware use non-blocking timing loops based on millis() to ensure responsiveness. For example, ultrasonic updates happen every 2 seconds, trigger checks every 3 seconds, and streaming uploads every 200 milliseconds. If Firebase connectivity fails, the ESP32 logs errors via Serial and retries on the next cycle. If Gemini fails to respond or Firebase upload fails, the system gracefully reports the failure but continues to operate.

Resetting the EEPROM clears all stored Wi-Fi credentials and reboots the system into AP configuration mode. This ensures configurability without flashing new firmware. All Firebase reads include error handling to improve robustness during Wi-Fi fluctuations.

E. Web Application UI Design and Framework

The web application serves as the primary user interface for interacting with the DoorSure system. It was developed using HTML, CSS, and JavaScript, with Visual Studio Code as the primary coding environment. The application allows users to remotely monitor the garage door status, view live camera feeds, control door operation, and receive alerts regarding obstructions or low battery conditions.

To prototype and iterate on interface designs, the team utilized Figma, an online UI/UX design tool. Early wireframes and interactive prototypes were developed to streamline layout decisions, improve usability, and gather peer feedback before front-end implementation.The web application is hosted via Firebase Hosting, enabling low-latency content delivery and integration with other Firebase services such as Authentication and the Realtime Database. For collaborative development and version control, GitHub was used extensively to manage source code changes, track feature additions, and ensure codebase stability.

Figure 7 displays a UML sequence diagram that outlines the interaction between the user interface, Firebase, and the embedded hardware systems. It details both open and close request workflows and the conditions under which object obstruction is handled.

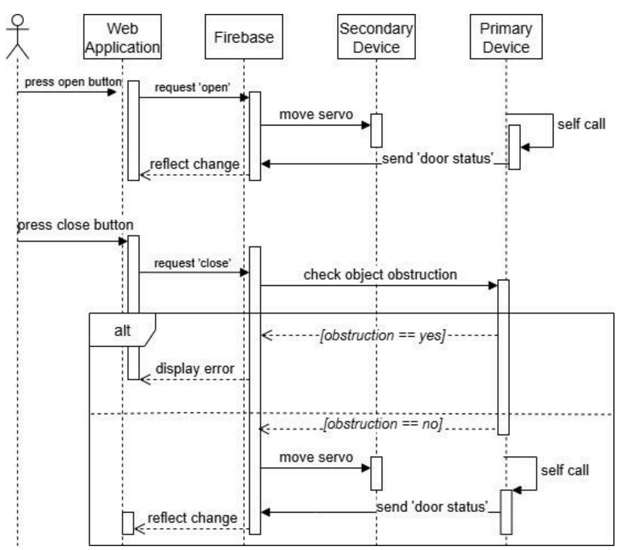


Fig. 7. Sequence diagram

VI. Board Design

The PCB design was executed with careful attention to signal integrity, electrical isolation, and manufacturability. All design practices conformed to the standards set by the Department of Electrical and Computer Engineering at the University of Central Florida, as well as the specifications provided by the selected PCB fabrication vendor to minimize the risk of production delays. Each PCB was designed using a two-layer configuration, with components placed on the top layer and routing traces distributed across both layers to simplify signal management and reduce electromagnetic interference. Fusion 360 was utilized as the primary design tool, selected due to the engineering team's prior experience and its compatibility with the project's workflow.

Six custom PCB boards were developed for the DoorSure system. They are the Primary device, Secondary Device, Temperature and Humidity Sensor, USB to UART, 3.3V regulator, and 5V regulator.

A. Primary device

The ESP32-S3 WROOM-1 N8R8 microcontroller on the primary board was placed along the PCB edge to optimize antenna performance and minimize RF interference. High-frequency components, such as capacitors, were kept away from the antenna area. Peripheral modules—including the ultrasonic sensor, camera, reed switch, and power regulation circuits—connect via header pins to facilitate debugging and modular replacement. All GPIO pins are routed to external headers, enabling flexible I/O reassignment and easier rework without PCB modifications. The board layout emphasizes modularity, maintainability, and reliable wireless performance.

B. Secondary device

The secondary device will be utilizing an ESP32 WROOM chip since this device will need less RAM and flash memory compared to the primary device. This device will be responsible for managing the buzzer, a custom temperature and humidity sensor and a servo motor for the physical door control. Like the primary device the ESP32 chip is placed on the edge of the board to minimize the interference of other components with the wireless connectivity of the chip. The servo motor will be essential on this board since it will be responsible for physically pressing the button that will alter the garage door status, similar to the primary device, the unused pins on the ESP32 chip to ease the rerouting of pins in case of any damages to the dedicated pins, all peripherals are plug in to minimize any damages to the board and ease debugging and maintenance process.

C. Temperature and Humidity Sensor

The custom temperature and humidity sensor that was developed for this project will be responsible for making sure that the environment of the garage won't compromise the overall system, this custom board is minimal with only two components. It will be a plug in to the secondary device.

D. USB to UART

The USB to UART will be implemented on a daughter board. This decision was carefully chosen in consideration of time for soldering, installing and debugging the CP2102 chip on the board, as having the chip directly on the primary and secondary devices would increase complexity of sorting out problems on the main PCBs.

E. Voltage Regulators

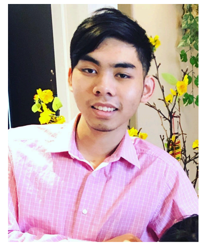
The DoorSure system employs two custom buck regulators, providing 3.3 V and 5 V outputs as daughter boards on the primary and secondary devices. The 3.3 V regulator powers the ESP32 microcontrollers and most peripherals, while the 5 V regulator supplies the servo motor on the secondary device and the ultrasonic sensor on the primary device. The 3.3 V regulator is based on the AP6303, and the 5 V regulator utilizes the AP63205, both selected for their high efficiency and reliable performance.

VII. Conclusion

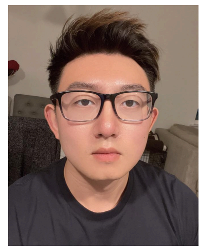
DoorSure builds upon existing smart home monitoring concepts to create an innovative, all-in-one IoT solution. Real-time sensing using ultrasonic and reed switches enables users to consistently and accurately monitor their garage door through a user-friendly, web-based application. The system allows for remote control over the garage door via the Internet, giving users peace of mind and reinforcing the priority of home security. Furthermore, the integration of object obstruction detection through the ultrasonic sensor, along with an AI-based object identification system, enhances safety and intelligence in garage door operation. Overall, Doorsure provides a universal and cost-effective solution to users for ease of remote access and controllability of their garage door.

VII.The Engineers

Mina Ghandour is a 24 year-old senior at the University of Central Florida. He is graduating with a Bachelor of Science in Electrical engineering, specializing in the communication and signal processing track. He is exploring different career opportunities in PCB design, embedded systems and other related fields.



Khang Nguyen is a 22 year-old senior at the University of Central Florida. He is graduating with a Bachelor's in Science in Electrical Engineering, along with obtaining a minor in Mathematics and Computer science. He is aspiring to pursue a career in power energy systems.



Felix Liu is currently a senior at the University of Central Florida. He is graduating with a Bachelor of Science in Computer Engineering in August 2025. He is passionate about hardware-software integration and aims to pursue a career in embedded or software engineering.

Andrea Rosa is a 22 year-old senior at the University of Central Florida. She plans to graduate with her Bachelor of Science in Computer Engineering in August of 2025. Her academic interests include embedded systems, IoT, and sustainable technologies. She aspires to pursue a Master's degree abroad, with a focus on applying embedded systems to environmental monitoring and conservation efforts.

Acknowledgements

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