

## Smart Building Management System Using ESP32

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### Abstract

*This paper presents a Smart Building Management System utilizing ESP32 to automate essential home functions, enhancing energy efficiency and convenience. In many homes and buildings, tasks like turning lights on or off, checking water levels, or opening doors are still done manually, leading to energy waste, inconvenience, and lack of monitoring. To solve this, our project introduces a Smart Building Management System using the ESP32 microcontroller. The system uses sensors such as the Light Dependent Resistor (LDR) for light detection, Passive Infrared (PIR) sensor for motion sensing, Infrared Obstacle Avoidance sensor (IR) for object detection, and HC-SR04 Ultrasonic Distance Sensor for water level monitoring. It also uses ThingSpeak to store and display sensor data in real-time graphs. This automation reduces manual effort, saves electricity, and adds safety to the environment. The uniqueness of the project lies in combining all these functions into a single system that is low-cost, easy to use, and can be controlled and monitored remotely.*

**Keywords:** ESP32, ThingSpeak, HC-SR04 sensor, PIR sensor, IR sensor, LDR sensor, IoT, Automation.

### 1. Introduction

In today's world, the demand for automation and energy-efficient systems in homes and buildings is growing rapidly. Manual control of lights, doors, and water management not only consumes more energy but also lacks real-time monitoring and convenience. This gap has led to the need for smart systems that can automate basic functions and provide users with remote control and live data tracking. Smart building systems play a vital role in reducing energy waste, enhancing security, and improving user comfort through intelligent sensing and control. These sensors work together to automate tasks such as streetlight control based on ambient light, indoor light activation based on motion detection, automatic door operation, and water level monitoring with alerts. This system reduces manual effort, optimizes energy usage, and offers a more sustainable way of managing daily building operations. At the heart of the system is the ESP32 microcontroller, a low-power, high-performance chip known for its built-in Wi-Fi and Bluetooth modules. These features allow seamless data transmission and remote access to the system. The ESP32 is widely used in IoT-based applications due to its scalability, power efficiency, and cost-

effectiveness. It enables the integration of multiple sensors and actuators while maintaining reliable performance, making it ideal for smart automation systems. To store and visualize the data collected from sensors, the system uses the ThingSpeak platform. ThingSpeak is an IoT cloud service that enables real-time data logging, analysis, and display in graphical formats. It helps users monitor trends, get alerts, and analyze system performance remotely using a simple web interface. This makes the system not only smart but also transparent and easy to manage. While many existing research papers have focused on individual automation systems, like only smart lighting or water level indicators, our system stands out by integrating multiple functionalities into a single unified system. Unlike previous works that often lack real-time data logging or remote access, this project uses ThingSpeak for live monitoring, making it more interactive and practical. The combination of multi-sensor automation, wireless control using ESP32, and cloud-based data logging makes this solution unique, efficient, and aligned with smart city and smart home development goals [1-3].

## 2. System Architecture

The smart building management system consists of sensors, actuators, a microcontroller, and a cloud-based monitoring platform. The sensors collect environmental data, while the actuators respond by performing specific actions, such as turning on lights or opening doors, shown in Figure 1 [4].

### 2.1. Workflow

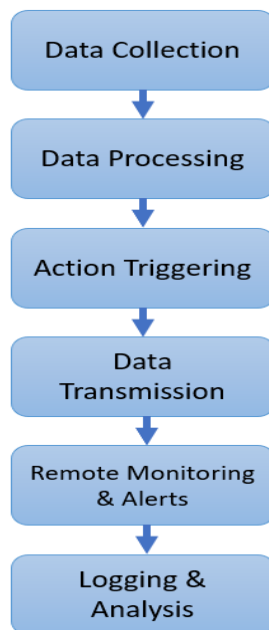


Figure 1 Workflow

## 3. Methodology

The Smart Building Management System is developed using various sensors, actuators, a microcontroller, and software platforms to enable automation and remote monitoring. The system collects real-time data from sensors, processes it using the ESP32 microcontroller, and performs automated actions through actuators.

### 3.1. Sensors

- **HC-SR04 Ultrasonic Sensor:** Measures water levels in a storage tank. When the water reaches a predefined threshold, a buzzer is activated to alert users.
- **LDR (Light Dependent Resistor):** Detects ambient light intensity. When it gets dark, the streetlight LED turns on, and when it's bright, the LED turns off automatically.
- **PIR (Passive Infrared) Motion Sensor:**

This sensor detects human movement and controls indoor lighting, reducing unnecessary power consumption.

- **IR Sensor:** Enables automatic door control by detecting nearby objects and triggering a servo motor to open or close the door, shown in Table 1 [5].

Table 1 Specifications of the Sensors

| Sensor Name | Range                   | Power Consumption        |
|-------------|-------------------------|--------------------------|
| LDR         | Depends on light source | Very low (<1 mW)         |
| PIR Motion  | 3–7 meters              | ~0.1 W                   |
| IR sensor   | 2–30 cm                 | ~5 mA @ 5V (~25 mW)      |
| HC-SR04     | 2–400 cm                | ~15 mA @ 5V (~75 mW)     |
| Servo Motor | 0–180° rotation         | ~10 mA idle, ~100–250 mA |

### 3.2. Actuators

Actuators perform actions based on sensor inputs, enhancing automation:

- **Buzzer:** Provides an alert when the water level reaches a critical point.
- **LED:** Turns on or off based on the LDR sensor's input.
- **Servo Motor:** Controls door movement based on IR sensor detection.

### 3.3. Software Platforms

The system is developed using:

- **Arduino IDE:** Used for programming and uploading code to the ESP32 microcontroller.
- **ThingSpeak:** A cloud-based IoT analytics platform that stores sensor data and visualizes

it in graph format, allowing users to monitor

#### 4. Implementation

Integrating all four sensors and ensuring they function correctly with their respective actions was challenging. The following section presents the successful implementation of the project.

##### 4.1. Hardware Setup

- The HC-SR04 ultrasonic sensor measures the water level inside the tank. An alarm is triggered when the water reaches 1 cm from the sensor.
- The LDR sensor is installed in an outdoor location to detect ambient light levels. It turns the streetlight LED on when it is dark and off when it is bright.
- The PIR motion sensor is positioned in rooms to detect human movement. When motion is detected, the light turns on and automatically switches off after 30 seconds if no movement is detected.
- The IR sensor is placed near the door to detect a person's presence. When triggered, it activates a servo motor to open the door automatically.
- All sensors and actuators are connected to the ESP32 microcontroller, which processes the inputs and controls outputs accordingly.

##### 4.2. Software Configuration

- The code that defines sensor inputs, actuator responses, and communication protocols is written and uploaded to the ESP32 using the Arduino IDE.
- Users can remotely monitor system performance thanks to the integration of the ThingSpeak platform, which gathers, stores, and displays real-time sensor data in graph style.

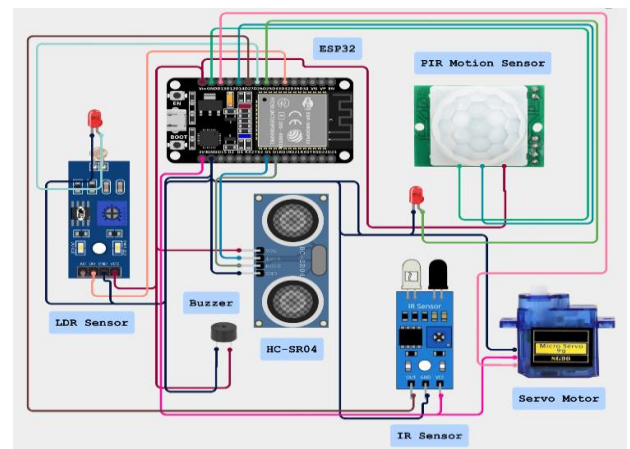
##### 4.3. System Testing

- To guarantee accurate data collection, every sensor is examined separately.
- Based on sensor inputs, actuators (servo motor, LED, and buzzer) are tested to ensure they respond appropriately, Figure 2.

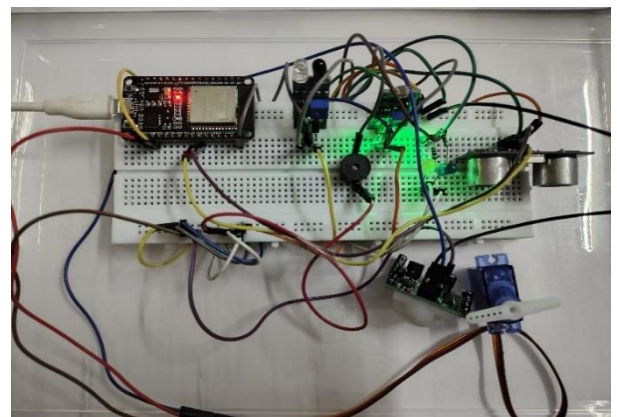
The ESP32 microcontroller, which includes 30+ GPIO pins, serves as the central controller for this prototype. It connects to an LDR sensor (using AO

trends over time [6-10].

and DO pins), a PIR motion sensor (with OUT pin to GPIO), an IR sensor (connected via GND, VCC, and OUT), and the HC-SR04 ultrasonic sensor (using Trig and Echo pins for distance measurement). A micro servo motor is controlled via a PWM-enabled GPIO pin. Additional components like LEDs and a buzzer are linked to digital pins for output indication, shown in Figure 3.



**Figure 2 Circuit Diagram**



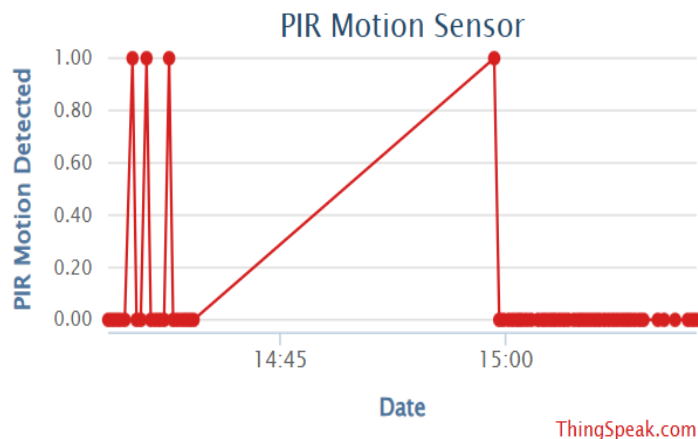
**Figure 3 Sensor Integration Test Setup**

#### 5. Results and Discussion

The Smart Building Management System works efficiently by automating different tasks and reducing manual effort. Overall, the integration of smart sensing and control in this system resulted in estimated energy savings of 25–40%, while also improving the responsiveness and automation of everyday building operations.

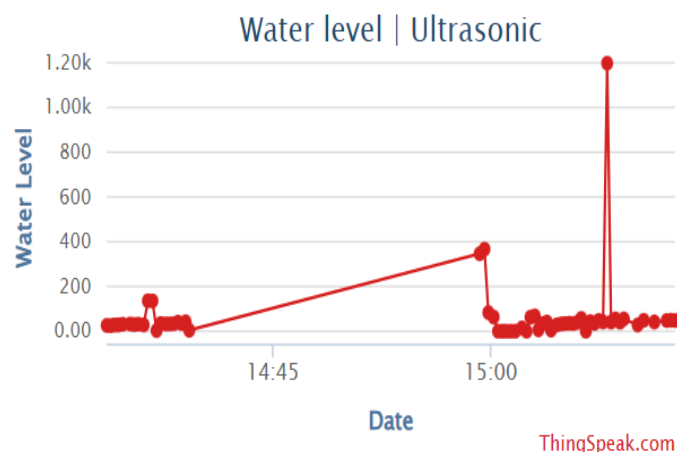
Let's discuss the graphs representing the sensor data.

- **Motion-Activated Lighting:** The PIR sensor detects movement and turns on the light when a person is present. If no motion is detected for 30 seconds, the light turns off automatically, saving electricity.



**Figure 4** Data Logging Graph of PIR motion Sensor

- **Water Level Monitoring:** The ultrasonic sensor checks the water level in the tank. When the water reaches 1 cm from the sensor, it triggers an alarm to alert the user, preventing overflow, shown in Figure 4.

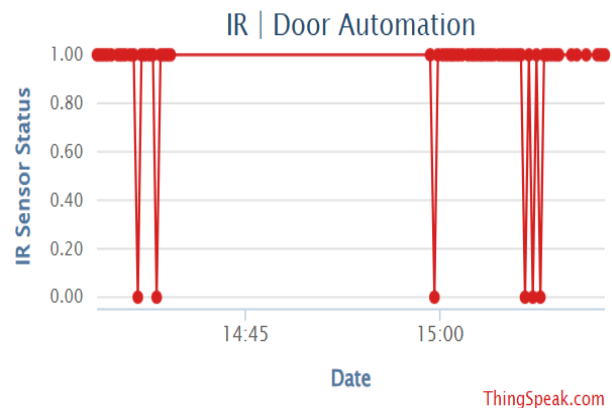


**Figure 5** Data Logging Graph of Ultrasonic Sensor

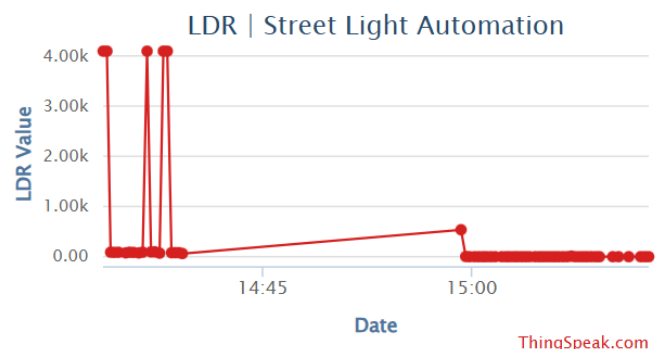
- **Automatic Door Control:** The IR sensor detects when someone is near the door and

signals the servo motor to open it automatically, making entry easier.

- **Street Light Automation:** The LDR sensor checks the brightness of the surroundings. If it is dark, the streetlight turns on, and if it is bright, the light turns off automatically, reducing power wastage, shown in Figure 5.



**Figure 6** Data Logging Graph of IR Sensor



**Figure 7** Data Logging Graph of LDR Sensor

## Conclusion

Most similar projects focus on just one feature, but this system brings several together cost-effectively and efficiently. The project successfully implements an IoT-based Smart Building Management System to improve automation and efficiency with low power consumption. Integrating sensors like PIR, IR, LDR, and ultrasonic modules enhances security, optimizes energy usage, and ensures effective water management. Real-time monitoring reduces manual effort and prevents resource wastage. This smart approach improves convenience and promotes sustainability, making it a reliable solution for

modern infrastructure. Additionally, the project promotes energy efficiency and resource conservation, aligning with the United Nations Sustainable Development Goals (SDGs), particularly Goal 7: Affordable and Clean Energy and Goal 11: Sustainable Cities and Communities, shown in Figure 6 & Figure 7 [11].

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