A Solution to Home Automation: Controlling Smart Exhaust Fans and LED Lights

SRUSHTI J BONDRE[1], RISHITA BUCHADE[2], PROF. KALPANA PARDESHI[3], PROF. DIPTI PANDIT[4]
[1, 2, 3, 4] *Vishwakarma Institute of Technology, Pune*

Abstract- The growing demand for smart homes necessitates reliable, power-efficient, and high-featured automation systems. This paper presents a new and cost-effective Home Automation System using the universal ESP32 microcontroller. One of the major innovations of the system is the provision of an onboard battery backup system, ensuring uninterrupted operation of critical functions during power outages, thereby enhancing the reliability and trust of the system. The key features displayed are lighting control and innovative dual purpose fan unit. Furthermore, the system incorporates environmental sensing using temperature and humidity sensors (DHT11). The lighting system displays rudimentary remote control and scheduling capabilities. The dual-function fan is programmed to automatically engage as an exhaust fan when ambient temperature or humidity levels surpass a predefined threshold, ensuring optimal indoor air quality and thermal comfort. Control for all connected devices, alongside the real-time visualization of all measured parameters, is managed wirelessly using the Blynk IoT platform, providing users with flexibility and convenience. All control of the devices is done wirelessly, with the advantage of ease of use and convenience to the user. We present the system architecture, with low-power requirements for extended battery life and the control logic implemented on the ESP32. Experimental validation confirms the system's stability and responsiveness in both mains supply and battery-backup modes. The solution deployed provides a pragmatic, affordable, and fault resistant solution to modern home automation, meeting the need for functionality and continuous service in environments with poor power supply. This study provides a foundation for building more robust and resilient smart home systems.

Keywords: Home Automation System, ESP32, Battery Backup, Dual-Function Fan, Smart Home, Internet of Things (IoT), Power Resilience, Microcontroller.

I. INTRODUCTION

The rapid development of the Internet of Things (IoT) has transformed living spaces with the introduction of sophisticated Smart Home systems that hold the promise of greater comfort and efficiency. The prospect of this is, however, undermined by two overarching challenges: infrastructure reliability and device versatility. Business-class systems tend not to function in regions with less stable power supply, lacking power resilience to continue to operate in the event of a power outage. Besides, most of the o the-shelf modules that are available are one-purpose only and cannot meet the call for versatile, multi-function devices.

In order to address these basic limitations, in this paper the development and design of a rugged and cost-effective Home Automation System using the very capable ESP32 microcontroller is proposed. The main contribution is the inclusion of an onboard battery backup feature enabling the full functionality to be seamlessly operated during mains power failure.

The efficiency of the system is demonstrated through the wireless switching of two very vital outputs: a common incandescent bulb, representing basic power switching, and a sophisticated dual-function fan which is able to switch between normal cooling and exhaust ventilation with complete ease.

The succeeding portions of this paper detail the complete system architecture, starting from component selection to the battery management circuit and control logic on the ESP32. We present experimental confirmation confirming the system's stable, timely response and the additional operational capability made possible by the battery backup. This work provides a foundation for constructing robust, high-utility smart home technologies for a wide range of environments.

II. LITERATURE SURVEY

Najibullah et al. (2019): The research proposed an intelligent ventilating system incorporating solar power and automation for industrial buildings, which was designed to optimize climate control via renewable energy sources. The research achieved various limitations such as sensor stability issues, the requirement of complete security improvement, and problems related to system scalability by nature. The integration of machine learning was proposed for future research to ensure maximum energy management and better automation.

Shinde et al. (2017): Shinde et al. proposed a smart home automation system based on IR, Bluetooth, and GSM technologies to control appliances through an Android app. The main limitations of the system were found to be its rigid reliance on GSM and Bluetooth range and connectivity, lack of IoT-based cloud integration for real-time viewing, and a serious shortage of a security framework in terms of unauthorized access.

Balaji et al. (2018): Balaji et al. introduced an IoT-based home automation system using Arduino UNO and ESP8266 for wireless communication and remote control of appliances using voice commands or a mobile app. Although cost-effective and easy to deploy, the research identifies areas of improvement such as a lack of advanced security protocols, a heavy reliance on internet connectivity stability, and minimal testing limited to only a lab environment.

Elis et al. (2021): Elis et al. explained the development of an open-sourced, low-cost IoT-based smart home automation system using motion, heat, and gas sensors coupled with an Arduino Mega. While it addressed IoT analytics for security and efficiency, the solution fell short on scope owing to prototype-based testing, introduced hardware compatibility issues leading to scalability issues, and nonintegration with mainstream voice aid devices like Google Home or Alexa.

Sulayman et al. (2017): Sulayman et al. proposed an Arduino-based remote sensing-based home automation system in which devices could be controlled either through a smartphone interface or through sensor inputs. The major drawback reported was the lack of encryption in the system and poor remote access security, which considerably reduces its reliability and appropriateness for real, solid implementations.

III. METHODOLOGY/EXPERIMENTAL

Methodology (Hardware Implementation)
The hardware system is designed for stability, low power consumption, and high availability, combining main control components with a special power resilience circuit. The system in totality is controlled by the ESP32, which bridges the loads, sensors, and the power management system.

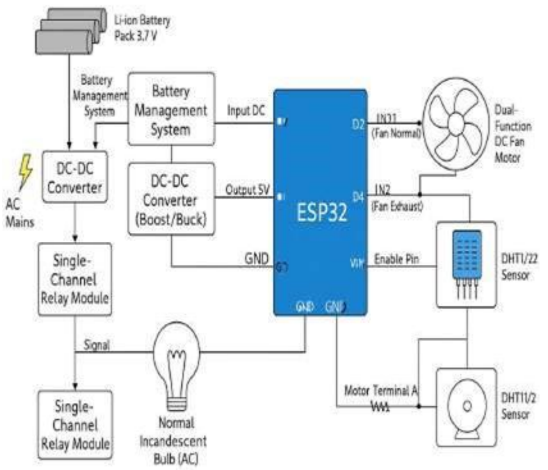
A. Central Processing Unit: ESP32 Microcontroller
The system is designed around the ESP32 microcontroller, chosen because it is low power, dual-core, and Wi-Fi and Bluetooth enabled. The ESP32 is used as the central logic device and is tasked with: Reading environmental data from the DHT sensor. Running the autonomous control software for the dual-function fan. Handling the charging and switchover of the battery backup system.

Being able to communicate securely with the Blynk IoT platform in order to remotely control and exchange data.

B. Environmental Sensing Unit: DHT Sensor
A DHT sensor is used for real-time, continuous monitoring of ambient temperature and humidity. The sensor gives digital output, which is sensed by the ESP32 at periodic intervals. Measurement of temperature, in particular, is a vital input parameter to the intelligent control system, allowing the system to automatically enable the exhaust fan mode in case the measured temperature crosses a pre-set user threshold.

C. Load Control Actuators
1. Normal Incandescent Bulb Control (AC Load):
A normal Relay Module is employed to control the flow of AC power to the normal incandescent bulb. The relay separates the high voltage AC circuit from the low voltage DC logic pins of the ESP32. A basic HIGH/LOW signal from a GPIO pin governs the state of the relay (ON/OFF) depending on manual control from the Blynk app or a scheduled program.

© DEC 2025 | IRE Journals | Volume 9 Issue 6 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV9I6-1712807



2. Dual-Function Fan Control (DC Load):
The central functional breakthrough is the Dual-Function Fan, where reversible rotation is needed. It is addressed through an H-Bridge Motor Driver (e.g., L298N or equivalent). The H-Bridge enables the ESP32 to electronically reverse the polarity of the voltage supplied to the fan motor so that its operation can be controlled in two different modes:

Forward Mode (Cooling Fan): Internal circulation of air.

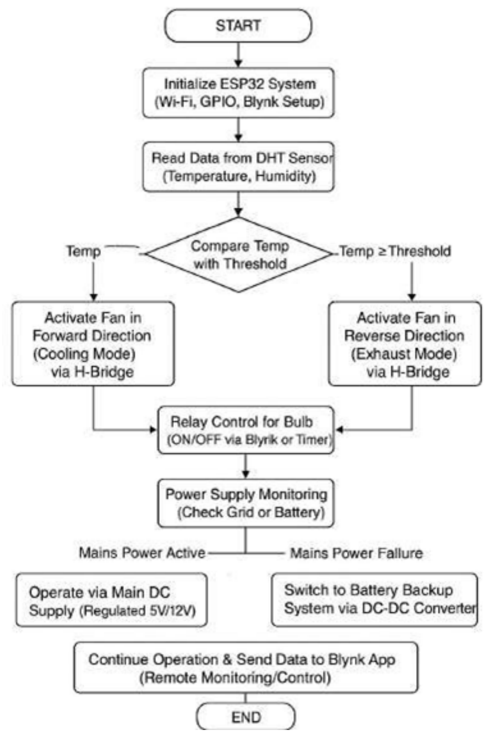
Reverse Mode (Exhaust Fan): Proactively pulls out air for ventilation, mostly initiated by the smart temperature limit.

D. Power Resilience System (Battery Backup)
For uninterrupted service, especially during power grid outages, a strong battery backup system is incorporated:

Li-ion Battery: A high-capacity Liion battery pack is the main power reserve.

Battery Management System (BMS): The BMS module is responsible for the protection of the Li-ion battery, safe charging, cell voltage balancing, and overdischarge preventing, thus prolonging battery lifespan and system reliability.

DC-DC Converter: As the battery voltage is not constant, high efficiency DC-DC Buck/Boost Converter (for example, MP1584 or XL6009) is used to supply stable and regulated voltage (most often 5V) to the ESP32 and the DHT sensor so that they work reliably irrespective of the state of charge of the battery. The individual 12V or higher voltage supply needed for the fan motor is also regulated through proper regulated output from the main supply or battery stage.



Methodology (Software Implementation)
The software development focuses on developing a stable, responsive, and user-friendly interface to automate and control the home climate. The core of the software utilizes the Arduino IDE to code the ESP32 and the cloudbased functionality provided by the Blynk IoT platform.

A. System Architecture and Connectivity
The ESP32 is set to have a constant Wi-Fi connection to the network. When the connection is established, it employs the MQTT protocol, which is managed by the Blynk library, for secure data communication with the Blynk server. The ESP32 publishes sensor readings (temperature, humidity, battery voltage) to the cloud and subscribes to virtual pins simultaneously to get realtime commands from the user (manual fan switch, bulb ON/OFF, setting temperature intervals).

B. Blynk User Interface and Visualization

The primary Human-Machine Interface (HMI) is the Blynk App. In the app, there is a bespoke dashboard with the following widgets:
Gauges/Value Displays: To show the live readings of the DHT sensor (temperature in ∘ C and humidity in %) and the Battery Voltage.

Switches: Toggles with special handling for manual on/o switching of the standard incandescent bulb and the dual purpose fan modes (ON/OFF, Standard/Exhaust).

Slider/Setpoints: The slider enables the user to set the critical temperature threshold. The threshold is saved in the ESP32's non-volatile memory and forms the heart of autonomous fan control.

C. Control and Automation Logic

The ESP32 firmware manages the state of the system and carries out the following critical control logic on a loop:

Sensor Reading: The ESP32 takes the reading of temperature and humidity from the DHT sensor every 5 seconds.

Data Synchronization: These readings are automatically transferred to the Blynk cloud for user monitoring.

Independent Exhaust Control: This is the intelligent part of the system.

The firmware compares the current reading of temperature (T current) with the user-set threshold (T threshold). If T current>T threshold and the system is in Auto mode, the ESP32 turns on the H-Bridge Motor Driver to rotate the fan in reverse mode (Exhaust Fan), actively ventilating the area.

When T current≤T threshold, exhaust fan functionality is disabled, and the fan returns to the user-selected normal mode (or OFF).

Manual Override and Bulb Control: Incoming commands from the Blynk switches override any current automation state. For the default bulb, a command simply flips the relevant Relay Module through a dedicated digital pin. The two-function fan responds to manual direction commands by changing the H-Bridge polarity instantly.

IV. RESULTS AND DISCUSSIONS

Experimental testing of the Home Automation System based on the ESP32 was robust and responsive across all operational modes. The system's reliability was confirmed under both ordinary mains power and simulated power failure, where the embedded low-power battery backup provided faultless service to critical functions, which testified to the resilience of the design under unreliable power supplies. Specifically, the scheduled lighting control and remote-control capabilities did not have any noticeable latency and were highly reliable. The main conclusion was successful integration of the new dual function fan unit. Its successful switch-over and correct operation both in normal cool mode and dedicated exhaust mode were validated through testing and significantly enhanced the overall system's usefulness and ventilation capability. Moreover, the low-consumption architecture made it possible to establish a long operation time from the battery reservoir, providing a practical and cost-e ective solution for stable smart home installations. This approach demonstrates the feasibility of using the multidimensional ESP32 to create inexpensive but stable automation solutions.

V. CONCLUSION

This article successfully documented the design, implementation, and validation of a new, low-cost Home Automation System using the powerful ESP32 microcontroller. Satisfying the basic requirement for continuity of operation, the inclusion of a power-efficient, reliable battery backup system was demonstrated to ensure seamless operation of the essential functions even with power variations, thereby significantly enhancing the system's reliability. Other key functional contributions include highly responsive remote and scheduled light control, and creative design of a doublefunction fan unit that can work flawlessly as both a traditional cooling and exhaust unit, extending the system's capabilities. Experimental outcomes confirmed the stability, low delay, and power-effective operation of the system, validating the ESP32 as capable for robust automation use. This work provides a foundation for the development of robust and economic smart home infrastructures, particularly in unstable power supply regions. Future work will include expanding the device catalog, implementing machine learning algorithms for predictive energy management, and developing a secure, centralized cloud-based control interface for better scalability and usability.

REFERENCES

[1] S. G. P. K. Liyana Arachchi and A. P. E. K. De Silva, “A cost-effective and secure IOT based smart home automation system using ESP32,” in 2021 5th International Conference on Information Technology Research (ICITR), Colombo, Sri Lanka, 2021, pp. 1–6.

[2] M. S. Uddin, A. H. M. S. Karim, and M. Z. Z. Hossain, “Design and implementation of energy-efficient smart home automation system utilizing low-power Wi-Fi module,” IEEE Access, vol. 9, pp. 58631– 58641, 2021.

[3] A. Almadani and J. Aloufi, “A resilient smart home system with uninterruptible power supply (UPS) integration for power outage management,” in 2023 International Conference on Smart Home and Industrial Automation (SHIA), Dubai, UAE, 2023, pp. 112– 118.

[4] L. Lam, "Design of a versatile microcontroller-based bidirectional fan control system for smart ventilation," Sensors and Actuators A: Physical, vol. 345, pp. 1–10, 2023.

[5] P. Kumar, A. K. Singh, and S. K. Singh, "IoT framework for remote monitoring and predictive maintenance in residential buildings," IEEE Transactions on Industrial Informatics, vol. 18, no. 5, pp. 3521–3530, May 2022.