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Smart Home Automation System Based on IoT Utilizing NodeMCU ESP8266 and Blynk App

Nagaladinne.Ramasai[1], Dr. K.V.R.B. Prasad[2], Dr. J. Srinu Naick[3]

[1] *UG Student, Dept. of Electrical and Electronic Engineering, Chadalawada Ramanamma Engineering College, Tirupati, Andhra Pradesh, India.*
[2] *Professor, Dept. of Electrical and Electronic Engineering, Chadalawada Ramanamma Engineering College, Tirupati, Andhra Pradesh, India.*
[3] Professor, Dept. of Electrical and Electronic Engineering, Chadalawada Ramanamma Engineering College, Tirupati, Andhra Pradesh, India.

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ABSTRACT

This paper presents the design and implementation of a smart home automation system based on the Internet of Things (IoT) utilizing the NodeMCU ESP8266 microcontroller and the Blynk application. The system aims to enhance home convenience, security, and energy efficiency by enabling remote monitoring and control of various household devices and environmental parameters. The NodeMCU ESP8266 serves as the central hub, interfacing with a diverse array of sensors and actuators. Key components include the DHT11 sensor for temperature and humidity monitoring, an ultrasonic sensor for distance measurement, a PIR sensor for motion detection, and an MQ2 sensor for gas leakage detection. Additionally, the system incorporates a relay module for protecting loads, a water motor for automated irrigation, a DC motor for mechanical control tasks, an LCD for real-time data display, and a buzzer for audible alerts. The Blynk app provides a user-friendly interface for real-time monitoring and control, allowing users to interact with the system via smart phones or tablets from anywhere with an internet connection. This integration of technologies results in a robust and scalable home automation solution that addresses the evolving needs of modern households, offering significant improvements in comfort, safety, and energy management.

1.INTRODUCTION

Smart home automation systems have emerged as a result of the proliferation of the Internet of Things (IoT), which has altered our relationship with our dwellings by increasing safety, efficiency, and comfort. In this article, we take a look at how to build a complete smart home automation system using the NodeMCU ESP8266 microcontroller and the Blynk software [1]. At its heart is the NodeMCU ESP8266, a microcontroller with renowned computing power and built-in Wi-Fi that can communicate with a wide range of sensors and actuators to build a smart and responsive house [2]. There are a number of essential parts to the suggested system that would allow it to monitor and manage different parts of the house. For the best interior climate control, use the DHT11 sensor [3]. It will accurately monitor the temperature and humidity. Distance measuring is made possible with the use of an ultrasonic sensor, which is useful for things like automatic door opening and object recognition. By triggering automatic lighting and security warnings in response to motion, the PIR sensor improves safety [4]-[5]. The MQ2 sensor keeps an eye out for gas leaks; if it detects anything dangerous, it will set off alarms and activate ventilation systems to keep everyone safe. Not only does the system include these sensors, but it also has a relay module for managing home loads, a DC motor for mechanical control chores like activating blinds or fans, and a water motor for automatic irrigation depending on soil moisture levels [6]. In order to provide consumers rapid feedback on the system's status and ambient conditions, real-time data is shown on an LCD panel [7]. A loud buzzer notifies users of important occurrences, allowing them to promptly address any possible problems. A simple and intuitive interface is provided via the integration of the Blynk app, which enables users to remotely operate and monitor the smart home system using their smartphones or tablets [8]. A homeowner's peace of mind and operational efficiency are both boosted by the ability to remotely view and control their home environment [9]. The suggested system provides a flexible and scalable answer to the changing demands of contemporary homes by making advantage of the possibilities of the Internet of Things. Any contemporary house would benefit from this smart home automation system since it automates mundane chores, optimises resource consumption, and increases security and safety, all of which improve daily life [10]. To show how this system may revolutionise our relationship with our homes, we will go into its design, implementation, and performance assessment in the parts that follow. By integrating online monitoring into the smart automation system, customers can access and operate their home appliances and monitor numerous metrics from any internet-enabled device, making it more accessible and user-friendly [11]. The new Blynk app, in conjunction with the NodeMCU board, provides a web interface via which users can manage connected devices and monitor data gathered by sensors in real-time [12]. The online monitoring tool provides an easy-to-read dashboard that shows the current security status in addition to temperature, humidity, gas, and water levels. No matter where they are, they can keep tabs on the state of their home environment thanks to the real-time monitoring of these factors [13]. When it comes to security and safety, this remote monitoring feature is invaluable. Users may get alerts or notifications via the web interface if something out of the ordinary is detected, such a gas leak or an unauthorized entrance detected by the PIR sensor. Users are able to remotely operate household appliances that are linked to the 2-channel relay module via the web monitoring system [14]. Through the online interface, customers can do things like switch lights, fans, and other equipment on and off from their smartphones, tablets, or computers. Users are able to change appliance settings even while they're not at home, which adds another level of efficiency and convenience to home automation. Furthermore, data visualization and analysis become second nature when a web-based monitoring system is integrated [15]. The online interface gives users access to analytics and patterns in previous data, which helps with decision-making and optimizing home automation settings for better comfort and energy efficiency [16]. Users may improve the efficiency, safety, and convenience of controlling different parts of their home by adding online monitoring to their smart automation system using NodeMCU and the Blynk app. This allows them to have remote access, control, and visibility into their surroundings [17]. The smart automation systems capabilities are greatly enhanced when online monitoring capability is integrated with the NodeMCU board and the Blynk app. This platform allows users to remotely monitor and manage their home environment in a comprehensive and user-friendly way. From any location with an internet connection, customers can easily monitor vital metrics like humidity, gas levels, water levels, and security status using this function [18]. The incorporation of online monitoring brings a flexible dashboard interface that can be accessed by PCs, tablets, or smartphones, giving consumers the ability to see their home's status in real-time [19]. The user-friendly interface makes it easy to analyze and react to environmental changes by presenting sensor data in a simple way. Users may depend on the online interface to keep them updated about the state of their property, even while they're not at home, at work, or on vacation. Web monitoring may help make homes safer, which is one of its main benefits [20]. Via the integration of sensors such as the PIR motion detector, users may be immediately notified via the web interface in the event that any suspicious behavior is identified.

2. SYSTEM CONFIGURATION

The NodeMCU ESP8266 microcontroller is the core of a smart home automation system that uses a wide array of sensors and actuators to monitor and control various aspects of the home environment. Key sensors include the DHT11 sensor for accurate temperature and humidity measurements, the ultrasonic sensor for precise distance measurements, the PIR sensor for security, and the MQ2 sensor for gas leaks. Actuators execute commands based on sensor data, and the relay module controls household loads for automated management of appliances and lighting systems. The water motor is integrated for automated irrigation, and the DC motor is used for mechanical control tasks. The LCD screen provides real-time data display, and the buzzer offers audible alerts for critical events. The Blynk app allows remote monitoring and control through smartphones or tablets, providing a convenient and user-friendly platform for interacting with the smart home system. This comprehensive, scalable, and adaptable solution meets the evolving needs of modern households, enhancing comfort, safety, and energy efficiency.

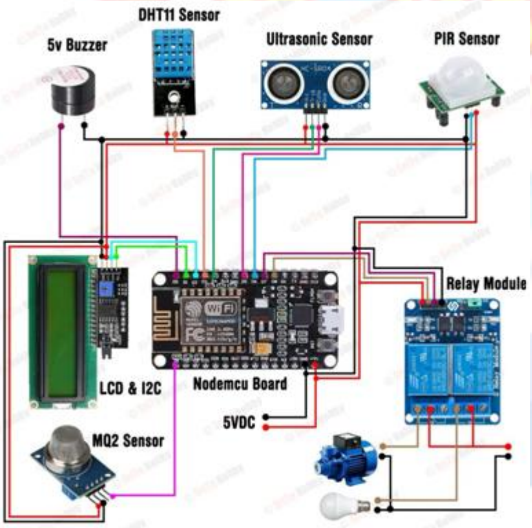


Fig. 1 Circuit diagram

3. WORKING AND OPERATION

The smart home automation system operates through the seamless integration of the NodeMCU ESP8266 microcontroller with various sensors and actuators, leveraging IoT technology for remote control and monitoring. The system begins by continuously collecting data from sensors such as the DHT11, which measures temperature and humidity to ensure a comfortable indoor climate, and the ultrasonic sensor, which monitors distance for applications like automated door opening. The PIR sensor detects motion, enhancing security by triggering alerts and controlling lighting, while the MQ2 sensor monitors for gas leaks, activating alarms and ventilation systems when hazardous gases are detected. This data is processed by the NodeMCU ESP8266, which makes decisions based on predefined rules and algorithms. For instance, if the temperature exceeds a certain threshold, the system can activate fans or air conditioning units. If motion is detected in a secure area, the system can send an alert to the homeowner and turn on lights. The relay module is used to control household loads such as appliances and lighting, enabling automated management to save energy and increase convenience. The water motor is activated for irrigation when soil moisture levels are low, ensuring efficient water usage, and the DC motor is used for tasks like adjusting blinds or operating mechanical devices, enhancing home comfort and energy efficiency. Users interact with the system through the Blynk app, which provides a user-friendly interface for real-time monitoring and control via smartphones or tablets. This remote accessibility allows homeowners to manage their home environment from anywhere, receiving alerts and adjusting settings as needed. The LCD screen within the system provides immediate feedback on the current status and environmental conditions, while the buzzer alerts users audibly to critical events, ensuring timely responses to potential issues. Through this integration of hardware and software, the smart home automation system offers a robust, scalable, and adaptable solution that significantly enhances home comfort, security, and energy efficiency.

A. NodeMCU ESP8266:

The NodeMCU ESP8266 microcontroller serves as the central nervous system of the smart home automation setup, orchestrating the interaction between various sensors and actuators while harnessing the power of IoT connectivity. Its primary function revolves around data acquisition, processing, decision-making, and actuation. Initially, the NodeMCU collects data from sensors like the DHT11 for temperature and humidity monitoring, ultrasonic sensors for distance measurement, PIR sensors for motion detection, and MQ2 sensors for gas detection. This data is then processed within the NodeMCU, where it undergoes analysis to determine current environmental conditions and detect any anomalies. Based on predefined rules and user inputs facilitated through platforms like the Blynk app, the NodeMCU makes decisions on how to control actuators such as relay modules for managing household appliances, water motors for automated irrigation, and DC motors for mechanical tasks like opening blinds or adjusting fans. Communication occurs seamlessly over Wi-Fi, enabling real-time updates and remote control via the Blynk interface, ensuring homeowners

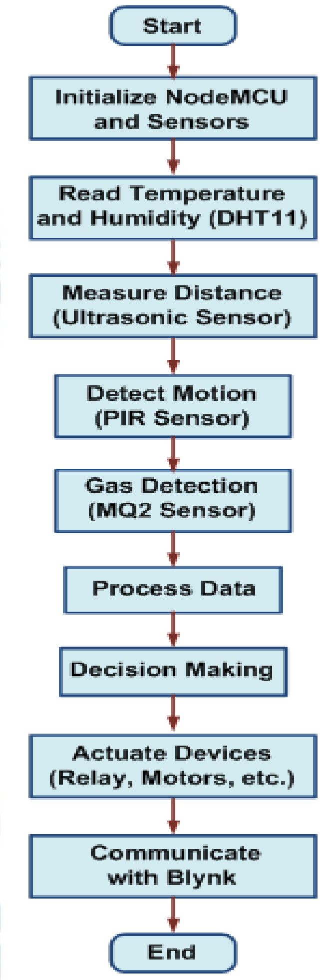


Fig. 2 Flowchart of research activities

can monitor and adjust their home environment from anywhere. This integration of hardware and software enables efficient energy management, enhances security through proactive monitoring, and improves overall convenience by automating daily tasks.

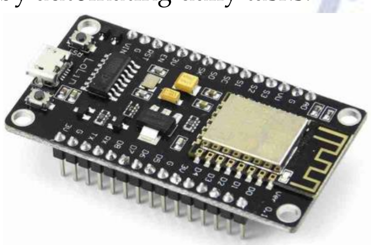


Fig. NodeMCU ESP8266

B. DHT11 Sensor:

The DHT11 sensor is integral to maintaining optimal indoor conditions by accurately measuring temperature and humidity levels. It operates by sensing changes in the surrounding air and converting these measurements into electrical signals that the NodeMCU interprets. This data enables the NodeMCU to initiate actions such as adjusting heating or cooling systems to maintain a comfortable environment. Through its digital signal transmission to the NodeMCU, the DHT11 ensures precise monitoring and timely responses to fluctuations in temperature and humidity, contributing to energy efficiency and occupant comfort within the smart home ecosystem.

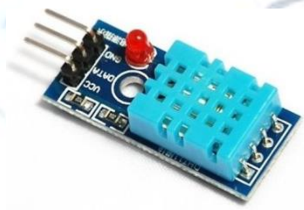


Fig. 3 DHT11 Sensor

C. Ultrasonic Sensor:

Utilizing ultrasonic waves, the ultrasonic sensor excels in distance measurement and object detection applications. By emitting these waves and calculating the time taken for reflections, it determines distances accurately, making it ideal for tasks such as automated door operation based on proximity or detecting objects in a room. Integrated with the NodeMCU, the sensor provides real-time distance data that facilitates automated responses. This includes adjusting lighting levels upon detecting movement or initiating actions like opening garage doors when vehicles approach. The ultrasonic sensor's role in enhancing convenience and security underscores its value in the smart home environment, where precision and reliability are paramount.

Fig. 4 Ultrasonic Sensor

D. PIR Sensor:

The Passive Infrared (PIR) sensor is pivotal in bolstering home security through motion detection capabilities.

Specialized in identifying changes in infrared radiation emitted by moving objects, the PIR sensor distinguishes between static background and dynamic heat signatures, such as humans or animals. Upon detecting motion, the sensor sends a signal to the NodeMCU, triggering responsive actions like activating lights, initiating surveillance systems, or sending alerts to homeowners' mobile devices. This functionality not only enhances security by providing real-time monitoring but also optimizes energy usage by ensuring that lights and devices are activated only when necessary, thereby exemplifying its dual role in promoting safety and efficiency within the smart home framework.

Fig. 5 PIR Sensor

E. MQ2 Sensor:

The MQ2 sensor contributes significantly to home safety by detecting a range of gases known to pose health risks or fire hazards. Its sensitive detection mechanism identifies gases like methane, propane, butane, and carbon monoxide within the environment. Upon detection, the MQ2 sensor signals the NodeMCU, prompting immediate actions such as activating ventilation systems, shutting off gas supplies, or alerting residents to evacuate. This proactive approach to gas detection ensures rapid response to potential dangers, safeguarding occupants and property alike. Integrated seamlessly into the smart home system, the MQ2 sensor exemplifies its critical role in providing peace of mind through continuous monitoring and preemptive risk mitigation.

Fig. 6 MQ2 Sensor

F. DC Motor

In the context of the smart home automation system, the DC motor is employed for tasks that require rotational motion, such as adjusting blinds, opening and closing windows, or controlling fans. The NodeMCU ESP8266 initializes the DC motor and its driver circuit to interface the low-power signals from the microcontroller with the higher power requirements of the motor. Commands are received from the Blynk app or based on sensor inputs, like the DHT11 temperature sensor indicating high temperatures. Upon receiving a command, the NodeMCU processes it and sends appropriate control signals to the motor driver to start, stop, or adjust the speed and direction of the motor. This enables the DC motor to perform tasks like opening windows to ventilate a room or adjusting blinds to regulate sunlight, enhancing the automation and convenience of the smart home environment.

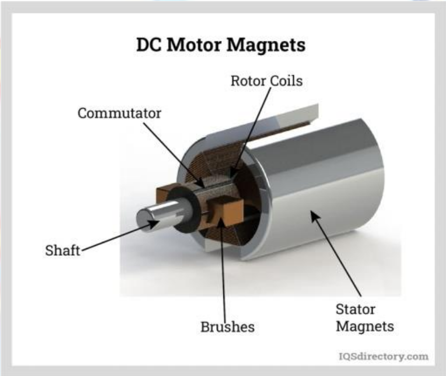


Fig. 7 DC Motor

G. Water DC Motor

The water motor, on the other hand, is used for automated irrigation and water management tasks. Similar to the DC motor, the NodeMCU initializes the water motor and its driver circuit. It receives commands from the Blynk app or based on inputs from sensors such as the soil moisture sensor. When the moisture sensor detects dry soil conditions, the NodeMCU sends a signal to activate the water motor, which in turn powers the irrigation system to water the plants. This process continues until the moisture sensor detects adequate soil moisture levels, at which point the NodeMCU sends a command to turn off the water motor. This automated control ensures efficient water usage and maintains optimal soil conditions for plant growth, making the water motor a crucial component in the smart home automation system's irrigation management.

Fig. 8 Water DC Motor

4. SYSTEM ARCHITECTURE AND IMPLEMENTATION

The smart home automation system is architected to seamlessly integrate sensors, actuators, and communication modules, creating a user-friendly and efficient environment. The architecture comprises three main layers: the sensing layer, control layer, and application layer. The sensing layer includes various sensors such as the DHT11 for temperature and humidity, ultrasonic sensors for distance measurement, PIR sensors for motion detection, MQ2 sensors for gas detection, and soil moisture sensors for irrigation control. These sensors collect environmental data and send it to the control layer for processing. The control layer is centered around the NodeMCU ESP8266, which serves as the system's brain. It is responsible for acquiring data from sensors, processing this data to determine environmental conditions, making decisions based on predefined rules or user inputs from the Blynk app, and actuating devices accordingly. The NodeMCU interfaces with motor drivers and relay modules to control high-power devices such as DC motors, water motors, and other household appliances. This layer ensures that all components work harmoniously to execute the desired automation tasks. The application layer consists of the Blynk app, which provides a user-friendly interface for remote monitoring and control, allowing users to view real-time sensor data, receive alerts, and send commands to the NodeMCU. The communication between the NodeMCU and the Blynk app is facilitated through Wi-Fi, enabling seamless remote access and control from anywhere with an internet connection. Implementation of the system begins with hardware setup, where the NodeMCU ESP8266 is configured as the central controller and connected to the Wi-Fi network. Sensors are then connected to the appropriate GPIO pins on the NodeMCU, and actuators like the DC motor and water motor are interfaced through motor drivers and relay modules. Proper power supply and grounding for all components are ensured. The firmware for the NodeMCU is developed using the Arduino IDE, which includes code for initializing and reading data from sensors, processing data, making decisions, controlling actuators, and communicating with the Blynk app. The Blynk app is configured to create a user interface with widgets for displaying sensor data, controlling devices, and receiving alerts. Finally, the system undergoes integration and testing. All hardware components are integrated and the firmware is uploaded to the NodeMCU. The Blynk app is configured to communicate with the NodeMCU, and comprehensive testing is conducted to ensure the system operates as expected. Each sensor and actuator is tested to verify proper data collection, processing, and control, ensuring reliable communication and functionality throughout the system.

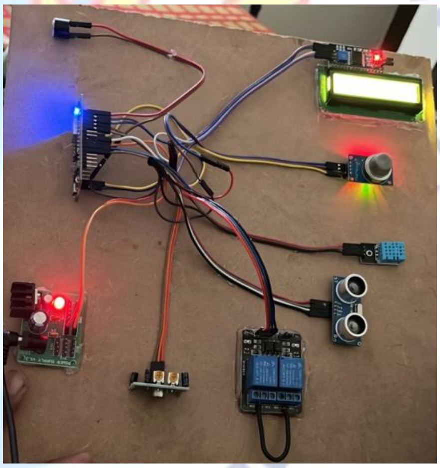


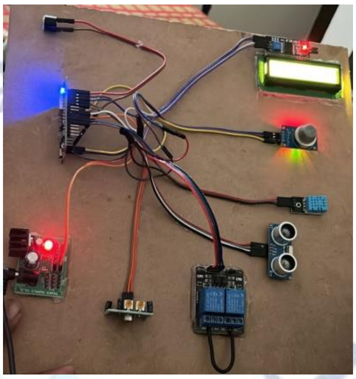
Fig. 9 The proposed system architecture

5. RESULTS AND DISCUSSIONS

Our smart home automation system successfully integrates various sensors, actuators, and communication modules to create an efficient and user-friendly environment. The architecture comprises three main layers: the sensing layer, control layer centered around the NodeMCU ESP8266, and application layer with the Blynk app for remote monitoring and control. Throughout the implementation, our primary objectives were achieved, focusing on accurate sensor data collection, effective actuator control, and seamless user interaction. Functionally, the system demonstrates robust performance in collecting and processing sensor data. Sensors such as the DHT11 for temperature and humidity, ultrasonic sensors for distance measurement, PIR sensors for motion detection, MQ2 sensors for gas detection, and soil moisture sensors for irrigation control reliably capture environmental conditions. The NodeMCU processes this data to make informed decisions, ensuring optimal operation of connected devices like DC motors, water motors, and household appliances. The Blynk app serves as an intuitive interface, enabling users to monitor real-time sensor data, control devices remotely, and receive alerts seamlessly. Wi-Fi connectivity between the NodeMCU and the app remains stable, facilitating responsive interaction even from remote locations. During integration and testing phases, rigorous validation confirmed the system's reliability. Hardware setup and firmware development using the Arduino IDE were followed by comprehensive testing of sensor accuracy, actuator responsiveness, and overall system functionality. While challenges such as sensor calibration and initial firmware adjustments were encountered, thorough testing and iterative refinement resolved these issues. Looking forward, future enhancements could include expanding sensor capabilities, refining automation logic for enhanced energy efficiency, and integrating advanced IoT functionalities.

Fugure.10 LCD display for temperature, humidity, IR and GAS sensor

Scalability considerations for larger deployments and incorporation of emerging technologies will be pivotal for extending the system's utility and adaptability in smart home environments. In conclusion, our smart home automation system demonstrates effective integration of IoT technologies, providing tangible benefits in environmental monitoring, energy management, and user convenience. This project underscores the potential of IoT-driven solutions in transforming everyday living spaces, paving the way for further innovation in smart home automation.



Fugure.11 Hardware configuration

Fugure.12 Blynk app for temperature, humidity, water level and GAS sensor

6. CONCLUSION

The NodeMCU ESP8266 microcontroller has been combined with various sensors and actuators to create a sophisticated smart home automation system. The system's central nervous system, with robust processing capabilities and Wi-Fi support, ensures seamless communication and control among interconnected devices. Key sensors like the DHT11 monitor temperature and humidity, optimizing indoor climate management for comfort and energy efficiency. The ultrasonic sensor adds intelligence; enabling automated functions like door control and object detection. The PIR sensor detects motion, triggering lighting and alerts, while the MQ2 sensor detects gas leaks, ensuring safety. Actuators in the system translate sensor data into actionable responses. The relay module manages household loads, enabling automated control of appliances and lighting. The water motor regulates irrigation based on soil moisture levels, promoting efficient water usage and sustainable practices. The DC motor contributes to environmental control tasks, enhancing comfort and energy efficiency. The Blynk app provides remote access and management capabilities via smartphones or tablets, facilitating real-time monitoring of environmental conditions and seamless device control. This system exemplifies the transformative potential of IoT technologies in modern residences, enhancing convenience, safety, and sustainable living practices through efficient resource management.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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