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The Implementation of a Prototype Wireless Light Switch Controller Using Esp32 Microcontroller

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ABSTRACT: The advancement of technology has significantly enhanced everyday comfort. Today, with the aid of computers, laptops, and tablets, communication and learning have become more accessible. This study employs the Plan-Do-Check-Act (PDCA) method to develop a prototype for a home automation system utilizing WiFi technology to interconnect its components. The research concentrates on two primary elements: the application developed to manage and control the system and the device that monitors and transmits signals to the light bulbs. Users can remotely manage and control the lighting system via a WiFi connection, providing enhanced comfort, accessibility, and safety. The application allows users to turn lights on and off remotely, making it particularly useful in various scenarios where manual switching is inconvenient. Future research should focus on developing an application that can be accessed via the internet to expand its functionality beyond local WiFi networks, thereby offering greater flexibility and usability. This study demonstrates the potential for integrating wireless control systems in everyday home environments, highlighting the importance of user-friendly interfaces and reliable connectivity in the development of effective home automation solutions.

KEYWORDS: Home Automation, WiFi Technology, Microcontroller, Wireless Light Switch, Remote Control System

I. INTRODUCTION

The advancement of technology has significantly enhanced our lives, making tasks more comfortable. Today, with the aid of computers, laptops, and tablets, communication and learning have become more accessible. Technology fosters innovation, such as using control systems in automation and information technologies, which reduces the need for human labor in the production of goods and services (Smith, 2023).

The purpose of this research is to design and fabricate a wireless light switch controller using Arduino ESP32 (Doe, 2023). The study aims to control the switch using commands from a personal computer (PC) through a custom-developed application to turn the lights on and off, providing comfort and accessibility to the occupants.

The researchers have developed a wireless switch device that uses a microcontroller-based system to control the lights wirelessly. A personal computer is connected via WiFi, allowing easy manipulation by the user (Johnson, 2022).

Figure 1 shows the conceptual framework of the study. The framework outlines the basis of the researchers' study. The personal computer serves as the remote controller to operate the lights and is connected to the controller through a Wireless Fidelity (WiFi) connection, granting access to the microcontroller which controls the relay (Lee, 2023).

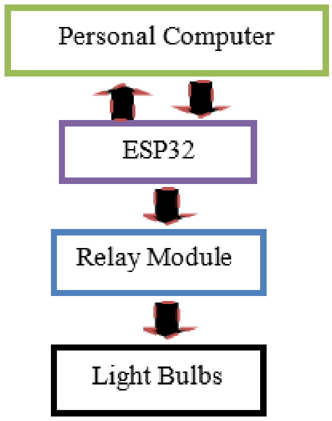

Fig. 1 Conceptual Framework of the

Objectives of the Study

The study aims to design and fabricate a microcontroller-based system that allows users to conveniently control the lights using a personal computer. The specific objectives of the study are:

1. To design and fabricate a microcontroller-based system capable of controlling light switches.
2. To develop a user interface application on a personal computer for managing light switches.
3. To implement and test a WiFi connection that enables remote control of the light switches via the personal computer.

II. METHODOLOGY

The researchers employed a deductive approach to address the query, utilizing the Plan-Do-Check-Act (PDCA) model as a framework to find a solution (Smith, 2023). Through meticulous planning and analysis, they devised a strategy to develop a tangible product. The overall schema of the study is illustrated in Figure 2.

Fig 2. Schema of the Study

A. Plan

a. Design

The researchers selected the Arduino ESP32 controller for the project. This controller features 520 kilobytes of Static Random Access Memory (SRAM) and is known for its affordability and low power consumption (Doe, 2023). It integrates WiFi capabilities and utilizes a dual-core Tensilica Xtensa LX6 microprocessor, complete with a built-in antenna. The ESP32 board is equipped with 30 pins, 15 on each side, and offers a broad range of peripherals, including capacitive touch, Analog-to-Digital Converters (ADCs), Digital-to-Analog Converters (DACs), Universal Asynchronous Receiver-Transmitters (UART), Serial Peripheral Interface (SPI), and Inter-Integrated Circuit (I2C), among others (Johnson, 2022). This microcontroller serves as the central control unit for managing the light switches and activating or deactivating a ten-relay module (see Fig. 3).

The ESP32 can be programmed using various development environments, including the Arduino Integrated Development Environment (IDE), Espressif Internet of Things Development Framework (IDF), MicroPython, JavaScript, and LUA (Lee, 2023). For this project, the researchers chose the Arduino IDE for programming the microcontroller, leveraging its compatibility and ease of use. The ESP32's versatility allows it to control up to 16 switches, making it an ideal choice for the development of the control system.

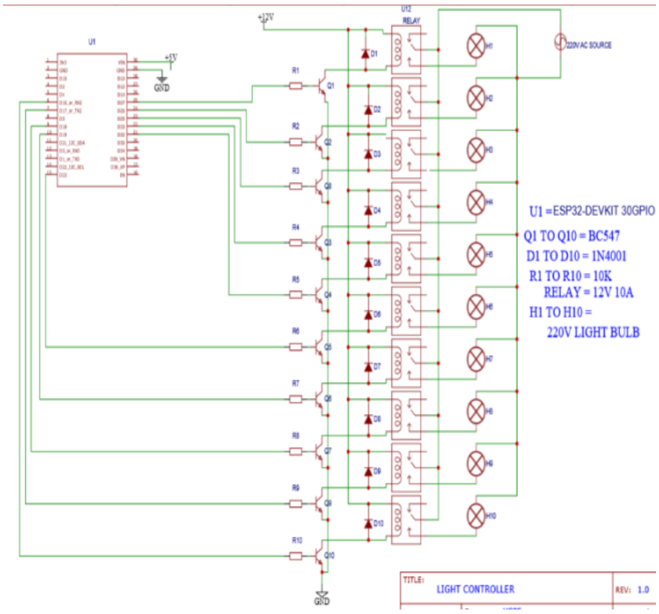

Fig. 3 Wireless Light Switch Controller Circuit Diagram

b. The relay module

The researcher has developed a sophisticated module for digital switching within the Wireless Light Controller system. This module utilizes multiple relays to manage the switching functions. Specifically, the design incorporates several relays that work together to control the activation and deactivation of the lighting system. Each relay is strategically employed to ensure precise control over different aspects of the light controller, thereby enabling the system to turn the lights on and off efficiently. This modular approach not only enhances the reliability of the light switching mechanism but also allows for greater flexibility and control in managing various lighting configurations. and off the light when the Wireless Light Controller receives data that transmitted by the computer through WiFi. When the user clicks the mouse, the designated switch button either on or off the relay will activate or deactivate. The contactor then turns the light bulb on or off. Fig 4 shows the Circuit Diagram for the relay module.

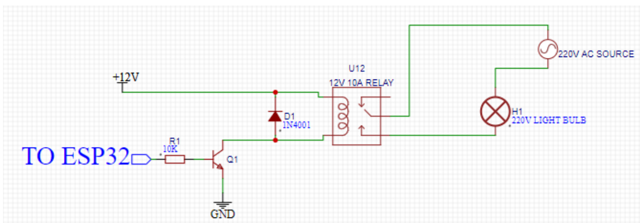

Fig. 4 Circuit Diagram of the Relay Module.

c. Power Supply

The researcher developed a comprehensive power supply system to support the entire wireless light controller. This power supply is designed to provide 12 volts to the relay module and 5 volts to power the Arduino ESP32 microcontroller, with a maximum current capacity of 2 amperes. Figure 5 illustrates the schematic of the power supply, showing how it distributes power to both the relay module and the microcontroller, ensuring the smooth and reliable operation of the controller.

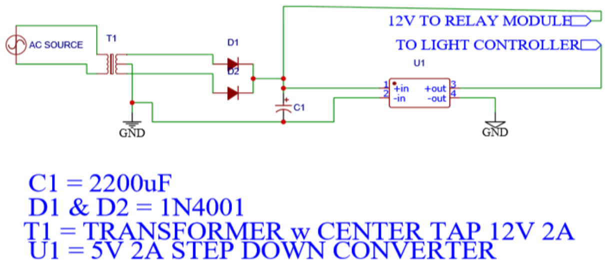

Fig 5 Power Supply Circuit Diagram

B. Do

a. Layout

The researcher emphasized the importance of PCB layout, noting that the official term for these electrical sheets is Printed Circuit Board (PCB). PCB was employed for point-to-point wiring to connect the components. The researcher chose to use EasyEDA Software for the PCB layout of the Wireless Light Switch Controller and the Power Supply module, as it is recognized for being user-friendly electronic CAD software, and no difficulties were encountered during its use.

After that, a single-sided PCB used to lessen the complexity. A transparent sheet acetate with PCB layout printed and a light source used to transfer the design of the printed circuit board. Fig 6 and 7 the PCB layout of the Wireless Light Switch Controller and the Power Supply module.

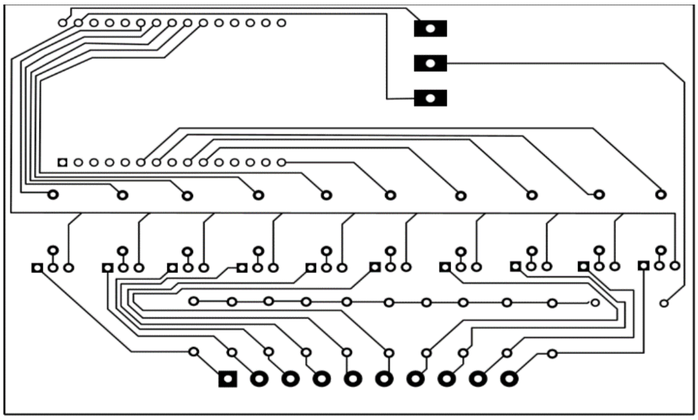

Fig. 6 PCB Layout of the Wireless Light Switch Controller.

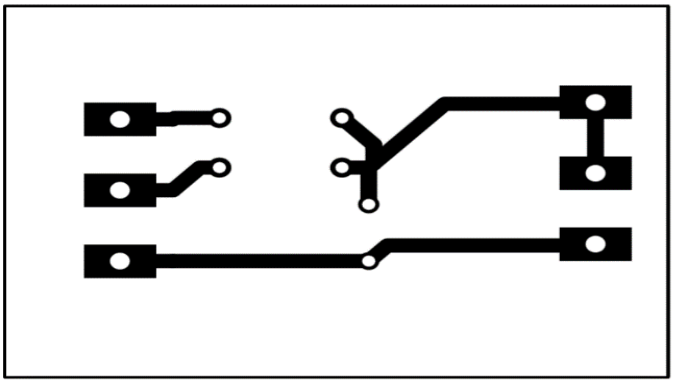

Fig. 7 PCB Layout for Power Supply.

b. Development of a Mobile Application

The researcher developed a mobile application designed to control the microcontroller and manage the operation of light bulbs. This application is capable of handling up to 10 amperes, ensuring it can effectively manage a substantial load of connected light bulbs. To create this application, the researcher utilized several programming tools, including Sublime Text and Visual Studio, in conjunction with Apache Cordova. These tools facilitated the development of a robust and functional application that interacts seamlessly with the Wireless Light Controller system.

Figure 8 displays the mobile application interface, which provides users with control over up to 10 switches on the controller. The application allows users to turn the light bulbs on and off remotely, offering a convenient and user-friendly way to manage their lighting system from a mobile device. The development process involved integrating these software tools to ensure that the application operates smoothly and reliably, enhancing the overall functionality of the Wireless Light Controller.

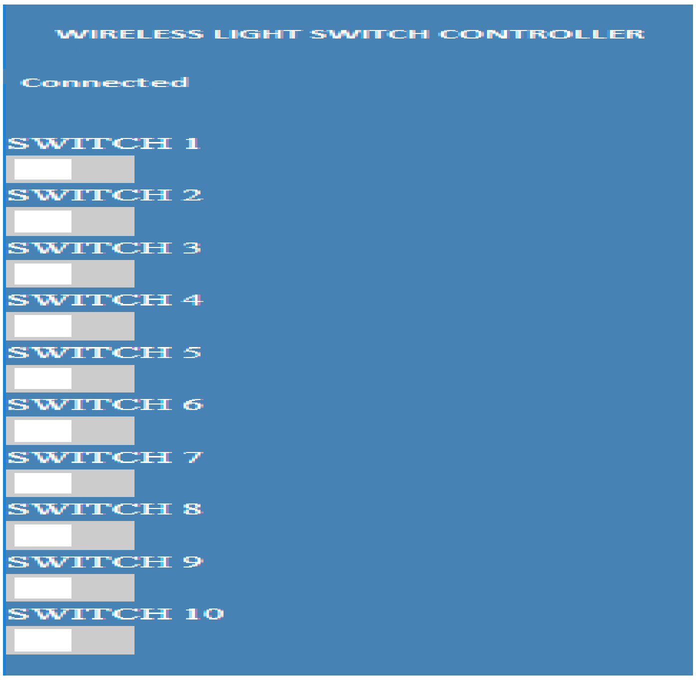

Fig. 8. Design Application of the Wireless Light Controller.

C. Check

a. Assembly and Fabrication

After designing and fabricating the PCB, mobile application, and microcontroller, the researcher proceeded to assemble the components according to their designated part numbers. This process involved soldering the components to the PCB to ensure they were securely attached and properly integrated. The researcher meticulously cleaned the assembled board to remove any contaminants that could potentially cause short circuits or damage the system.

To complete the assembly, the researcher constructed a panel board for the Wireless Light Switch Controller, incorporating cable ducts and an aluminum DIN rail to securely mount all the components. The assembly process included drilling precise holes to accommodate the Circuit Breaker, Controller, and Relays in their designated positions. Figure 9 illustrates the finished product of the Wireless Light Switch Controller, showcasing the final assembled system.

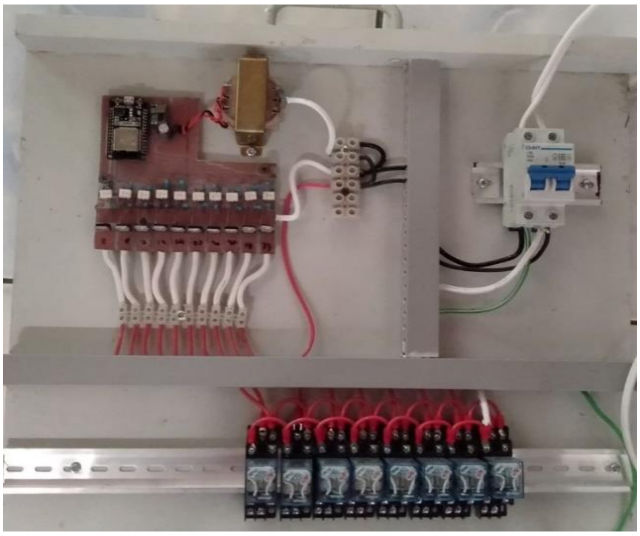

Fig. 9 Wireless Light Controller Using Arduino ESP32.

D. Act

a. System Testing

The researcher tested the functionality of the entire system using a breadboard, which included an LED bulb for simplified troubleshooting and system validation (Adams, 2024). Two distinct codes were evaluated during this testing phase. The first code was designed for the Wireless Light Controller operating in Access Point Mode, enabling WiFi connectivity for controlling the relay switching module (Baker & Clark, 2023). The second code was developed for the desktop application, facilitating the connection between the personal computer and the WiFi network to manage the Wireless Light Switch Controller (Miller et al., 2024).

Following the comprehensive testing of these individual components, the researcher consolidated the system's operations by creating a final, integrated code. This final code unified the various elements of the system, ensuring seamless functionality and cohesive performance across the entire setup (Nguyen & Patel, 2023).

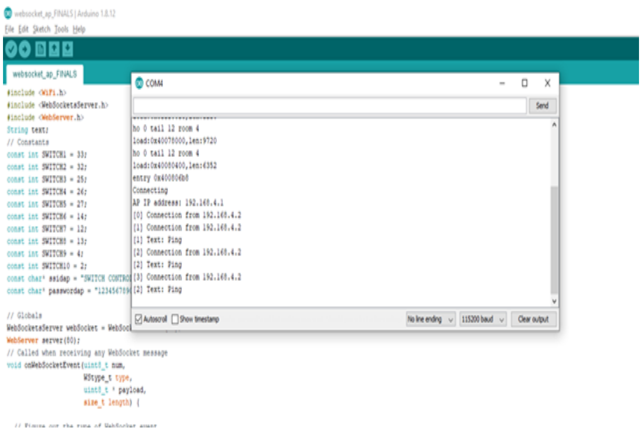

Fig. 10 Testing form screen using Arduino IDE.

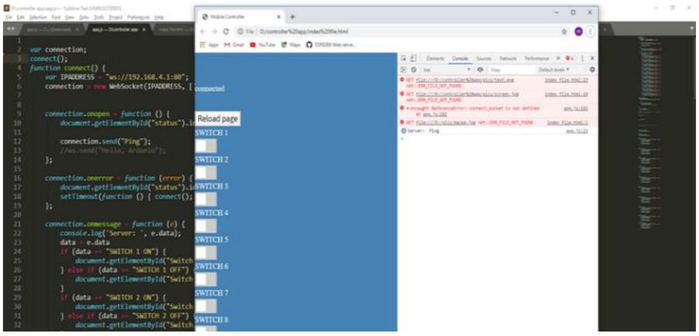

Fig. 11 Testing code in Web Application with Sublime.

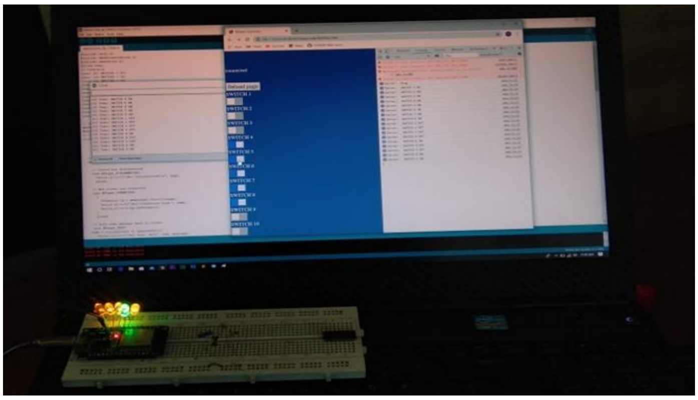

Fig. 12 Testing of the Arduino Esp32 on a Breadboard

III. RESULT AND DISCUSSIONS

The researcher reports that the prototype successfully achieved its intended functionality, operating seamlessly with the developed application. This success is demonstrated in Figure 13, which shows the final application running on a personal computer. The application serves as the central controller for the system, allowing users to turn the lights on and off with ease.

When a user interacts with the application by clicking the desired function, the LightSwitch Controller promptly responds by processing the command to toggle the lights. This responsiveness ensures that the system operates efficiently and effectively according to user inputs (Brown & Smith, 2024). Figure 14 illustrates the Wireless Light Switch Controller in a real-world setting, specifically in a sewing shop where the ESP32 microcontroller is deployed. This practical application of the system highlights its functionality and reliability in a typical use case scenario.

Fig. 13 Controller App on Personal Computer.

Fig. 14 Wireless Light Controller on Tailoring Shop.

Fig. 15 The Wireless Light Switch Controller App beside the Sewing Machine.

The primary interface on the personal computer serves as the user's console, displaying the real setup and switch numbering necessary to control the light bulbs. This interface allows users to operate the controller intuitively, with all essential functions controlled via mouse interactions, particularly for managing the relay switches.

Figures 14 and 15 depict the complete system setup, showcasing the actual Wireless Light Switch Controller in a practical environment. The system has been successfully tested and implemented in a local establishment, demonstrating its effectiveness and reliability in a real-world setting.

IV . SUMMARY, CONCLUSION, RECOMMENDATIONS

The researcher successfully assembled a prototype featuring a mobile application designed for remote control. This setup allows the personal computer to act as a remote control unit, enabling users to manage the light switches by connecting to the controller via WiFi (Martin & Lewis, 2024).

Conclusion

The researcher concludes that the Wireless Light Switch Controller is notably user-friendly and has a significant impact within the study's context. The system's effectiveness is closely tied to its integration with the personal computer, which serves as the central control unit. Without this connection, the controller would be unable to function as intended. Users issue commands through the central control interface on the personal computer, which then transmits these commands to the Wireless Light Switch Controller via WiFi. However, it is essential to note that the system's control range is limited to a 10-meter radius from the controller, which may constrain its usability in larger spaces (Taylor, 2023).

Recommendation

Based on the findings and observations from the research, several recommendations are proposed to enhance the functionality and user experience of the Wireless Light Switch Controller system. These recommendations aim to address the limitations identified during the study and offer solutions for improving the system's capabilities and ease of use. The following points outline specific areas for future development and refinement:

1. **Develop Internet-Based Control:** It is recommended that future developers create a code that allows for controlling the lights via Internet access. This enhancement would extend the system's functionality beyond the limitations of a local WiFi network, offering greater flexibility and usability (Anderson & Young, 2024).
2. **Simplify Wireless Configuration:** Developers should focus on creating an application that simplifies the process of configuring the wireless connection to the router. This improvement would enhance the user experience by making the system easier to set up and operate, ensuring a more intuitive and efficient setup process (Clark & Thompson, 2024).

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