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Mini Portable IoT Trainer Kit

Subramanian Sinnakanoo[a], Sivadev S. Nadarajah[b], Afizah Binti Abdoll Mutalib[c]

[a]*subram@puo.edu.my*
[a,b,c]*,Department of Electrical Engineering, Ungku Omar Polytechnic, 31400 Ipoh, Perak, Malaysia*

Abstract

The rapid advancement of Internet of Things (IoT) technologies has opened new opportunities for automating and optimizing home electrical systems. This innovation introduces a smart control system that overcomes the limitations of traditional one-gang two-way electrical switches, which depend solely on manual operation, by integrating IoT technologies. The primary objective is to merge domestic electrical wiring concepts with IoT coursework to create a more practical and engaging learning experience. The system improves accessibility and convenience by enabling remote control via mobile devices, utilizing microcontrollers, relay modules, and the Blynk platform. A mixed-methods research approach was employed, combining surveys and experimental implementation to assess the system's effectiveness. Data were gathered through student feedback and prototype testing, followed by descriptive and thematic analysis. The findings reveal significant advantages, including interactive and interesting by using Blynk and mobile applications to control the switch, interactive and interesting, exciting learning experience, encourage to explore, real-world application, motivated to develop and understand traditional system. Over 96.3% of participants reported improved motivation and a clearer understanding of IoT-enabled systems. The study also suggests future improvements such as better user interfaces, enhanced safety features, and the integration of data analytics. Despite challenges like occasional Wi-Fi disruptions, the research demonstrates the potential of IoT-based tools to bridge theory and practice while fostering a more innovative, technology-driven learning environment.

Keywords: Relay Module; ESP 32; IoT Platform; One Gang Two Way Switch

1. Introduction

The Internet of Things (IoT) is transforming conventional systems into intelligent, responsive platforms capable of real-time communication, control, and monitoring. By making use of Internet of Things, it is now possible to remotely manage lighting and appliances, schedule operations, and track energy consumption efficiently. Several studies have demonstrated the practical applications of Internet of Things in smart home and automation systems. (Atzori, L., Iera, A., & Morabito, G.; Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M.).

For instance, explored Zigbee-based smart switch systems that emphasize low power consumption; however, these systems often face limitations in communication range. implemented a Wi-Fi-based smart home system using Arduino and Blynk, achieving effective real-time control and monitoring. examined the use of MQTT protocols for scalable IoT applications, highlighting the significance of lightweight communication in resource-constrained environments. Meanwhile, developed a smart plug system capable of measuring and controlling power usage, integrating cloud-based analytics to enhance energy efficiency. (ZigBee Alliance.; Banks, A., & Gupta, R.)

In the context of technical education, the domestic electrical wiring course in the Electrical Engineering Department introduces first-semester students to the basics of circuit design and manual switch operation. The existing one-gang two-way switch panel in the Electrical Wiring Lab provides foundational knowledge but lacks relevance to modern smart technologies. (Floyd, T. L.; Grodzinsky, F. S., Miller, K. W., & Wolf, M. J.).

As global trends continue to shift toward automation and digitalization, it is crucial for educational institutions to incorporate up-to-date technologies into their curriculum. To bridge this gap, the Internet of things course was introduced in the fourth semester. This course equips students with skills in program coding, IoT communication, and automation system. (Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M.; Hussain, F., Hussain, R., Hassan, S. A., & Hossain, E.)

This research centred on the smart control of a one-gang two-way switch using IoT serves as a cross-course innovation. It reinforces theoretical knowledge through hands-on application and provides a practical understanding of real-world systems. The aim is to develop a smart switch system that is cost-effective, user-friendly, and compatible with existing electrical setups, allowing remote control via mobile applications or internet-connected devices. (Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M.; Alam, M. R., Reaz, M. B. I., & Ali, M. A. M.).

This paper outlines the system's hardware and software architecture, details the experimental setup, and evaluates key performance metrics including response time, reliability, and scalability. By integrating microcontrollers, Wi-Fi communication, and mobile platforms like Blynk, the system allows students to interact directly with IoT-enabled devices. The innovation not only enhances conventional teaching tools but also promotes student-centred, technology-driven learning in alignment with Industry 4.0 standards. (Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M.; Al-Fuqaha, A., Guizani, M., Mohammadi, M., Aledhari, M., & Ayyash, M.)

These studies demonstrate both the feasibility and benefits of IoT in smart electrical control, though most lack focus on low-cost, user-friendly deployment models for widespread adoption. This research aims to bridge that gap with a practical, scalable implementation. (Kagermann, H., Wahlster, W., & Helbig, J.; Hermann, M., Pentek, T., & Otto, B.)

2. Methodology

2.1. Research design

This study employed a mixed-method approach, integrating both experimental and survey-based research designs. The experimental component focused on the development, implementation, and testing of the IoT-enabled smart control electrical switch system. This was complemented by a survey method aimed at evaluating students' perceptions and learning outcomes following their engagement with the system. (Creswell, J. W., & Plano Clark, V. L.; Dede, C., Ketelhut, D. J., Whitehouse, P., Breit, L., & McCloskey, E. M.).

2.2. Data collection methods

The smart switch system was tested in the Electrical Wiring Lab and Internet Based Controller Lab to assess its performance, reliability, and compatibility with existing infrastructure. Questionnaires were structured and administered to students who participated in practical sessions using smart switch-based systems to gather feedback on their experiences. (Creswell, J. W., & Creswell, J. D.; Dörnyei, Z.)

2.3. Analysis techniques

2.3.1. Descriptive statistical analysis:
Quantitative data from the questionnaires were examined using descriptive statistics to highlight key trends and patterns in students' feedback.

2.3.2. Thematic analysis:
Qualitative feedback from open-ended responses was analyzed using thematic analysis to uncover recurring hemes concerning usability, learning effectiveness, and suggestions for improvement.

2.4. System design

The system is composed of three primary components where the microcontroller handles Wi-Fi connectivity and processes control commands. Relay Module functions as a switch to control the on/off state of connected electrical appliances where else mobile Interface built using the IoT platform, allows users to control the system remotely via the internet. Figure 1 shows the actual connectivity of the research.

Figure 1. Product description

Table 1 list the numbered input-output devices labelled on Figure 1

Table 1: Name of the devices on the trainer

No.	Input devices	No.	Output devices
1	Trainer Kit	6	
2	6-Channel Relay Module	7	Main Switch, ELCB & MCB
3	Microcontroller ESP32	8	240V 13A Socket Outlet & Socket Tester
4	240V AC Bulbs – 3 Different Colored	9	Microcontroller ESP32
5	Two-way switch labelled 1, 2, 3 & 4	10	240V AC Bulbs

Figure 2 shows the block diagram of the research design. (Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M.; Alam, M. R., Reaz, M. B. I., & Ali, M. A. M.).

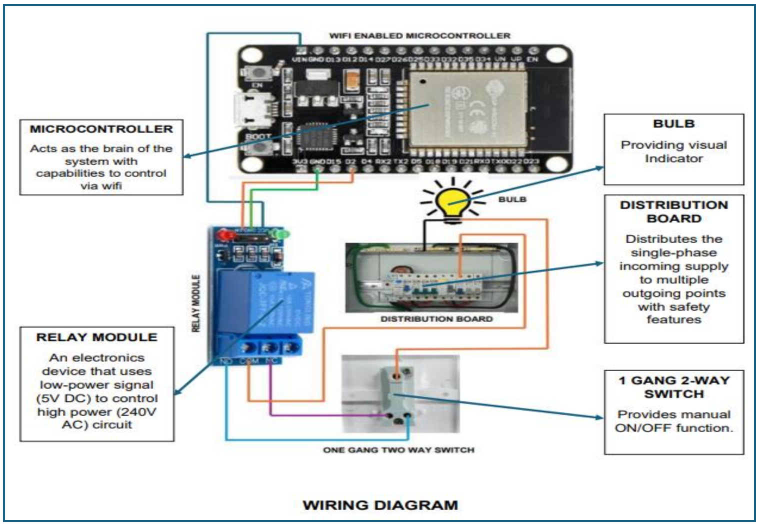

Figure 2. Product Block Diagram

The sample of the trainer operations is shown in Figure 3

Figure 3. Product operation

2.5. Working principle

The microcontroller is connected to a relay module and programmed to receive HTTP or MQTT-based commands. The relay module serves as an electronic switch between the power supply and the connected appliance. Control commands are sent from the Blynk mobile app over Wi-Fi to the microcontroller. Based on the received command, the microcontroller activates or deactivates the relay to switch the appliance on or off.

2.6. Software tools

Arduino IDE is used to write, compile, and upload code to the Microcontroller. Blynk App provides the user interface for remote control and monitoring of the system

3. Results

3.1. Components

Table 2 displays the components that were used in this research with its specifications.

Table 2. The list of components

No.	Component	Specification / Usage
1	Microcontroller ESP32	Wi-Fi module, 2.4GHz
2	Relay Module 6-Channel	5V, 10A
3	Bulb 5W, 240V	Testing Load
4	Breadboard & Wire	Circuit Testing
5	Blynk application (IoT Platform)	Web-based
6	Wi-Fi Router	Internet Connection

3.2 Testing procedure

- The system is connected to the designed circuit.
- The coding is uploaded to ESP 32 via Arduino IDE Software.
- The connection between the ESP32 and the Blynk application is tested.
- The control command (ON/OFF) is sent from the Smartphone application.
- The two-way switch action and the lamp status are observed and recorded.
- The test is performed 5 times to verify consistency.

Figure 4 shows the Web Server from a web browser and Table 2 displays the relay module function test results.

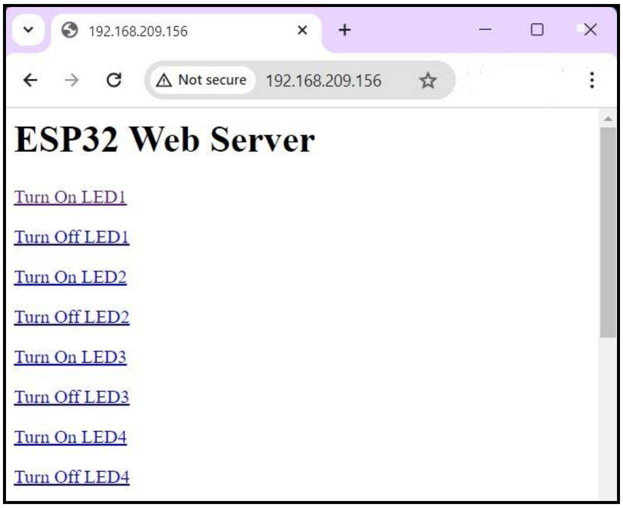

Figure 4. ESP32 web server connection

Table 3. Results of the relay module function

Switch number	Switch instruction	Relay module response	Lighting response	Time response (seconds)
1	On	Normally open	On	0.4
	Off	Normally closed	Off	0.5
2	On	Normally open	On	0.4
	Off	Normally closed	Off	0.4
3	On	Normally open	On	0.5
	Off	Normally closed	Off	0.4
4	On	Normally open	On	0.4
	Off	Normally closed	Off	0.5

3.3. Analysis and observation

- The tests result show that the system works steadily and accurately.
- The average response time was less than 1 second, indicating instant response.
- A stable Wi-Fi connection is essential for smooth operation.
- There were no delays or failures during the tests.

To obtain data from all respondents, the question in this questionnaire is set by using google form link. The questions are made using the Likert scale where it is most appropriate for respondents to choose the answers. Each question requires respondents to give their opinion on whether they strongly agree or strongly disagree based on the Likert rating scale at five different levels shown in Table 4.

Table 4. Five levels of scale rating

Likert scale	Scale rating
Strongly disagree	1
Disagree	2
Not sure	3
Agree	4
Strongly agree	5

3.4. Data collection procedures

All the respondents were briefed on the purpose of this study before they were given the questionnaire by google form link. After the respondent's finished answering, the researcher can use google form format to download and analyse the data towards achieving the study objectives. One set of questionnaires in google form link contained 6 questions. To facilitate data analysis, this scale will be graded into 3 levels as shown in Table 5.

Table 5. Likert scale and score value

Likert scale	Scale rating	Score
Strongly disagree	1	1 (disagree)
Disagree	2	
Not sure	3	2 (not sure)
Agree	4	3 (agree)
Strongly agree	5	

For answers that strongly disagree or disagree, a score of 1 is given. While answers that agree or strongly agree will be given a score of 3. Not sure, answers will be given a score of 2. Respondent's responses to the statements are classified in the form of percentage. This is to ensure that respondents really read the questions carefully before answering. The total percentage analyzed will be classified into five levels of achievement. The achievement level classification table is stated in Table 6.

Table 6. Achievement level classification table

Achievement level	Percentage (%)
Excellent	80 – 100
Good	65 – 79
Everage	50 – 64
Poor	40 – 49
Very poor	0 – 39

The achievement score range has been modified, namely the percentage of achievement at each level has been changed to be more appropriate and in line with the objectives of the study, as shown in Table 5. However, this classification is only used for this study, not subject to other studies.

4. Data analysis and discussion of results.

4.1. Introduction

This chapter discusses the analysis of data obtained from the questionnaires that were given to respondent's using google form link. A total of 45 respondents answered the questionnaires through google form link. The respondents involved were respondents of semester 1, Electrical Wiring Course, for the Diploma in Electronic Engineering (Computer) - DTK Program. The responses given by the respondents will be analyzed and the findings from the analysis were shown in the form of distribution tables in percentages. The achievement level will be based on Table 7 and displayed in a graph form in Figure 5.

4.2. Data analysis

The data collected from all respondents from google form link will be processed using tables in word software. Data analysis will be used to get the percentage and to obtain the classification of achievement levels according to the Study Design. The results of the questionnaire were divided into two sections, namely Section A and Section B. Section A will analyse respondents' knowledge background of the respondents while Section B will analyse the findings from the questionnaire to answer the research questions recorded. The smart switch successfully responded to control inputs in under one second, with consistent performance across different devices. The setup was also tested for reliability over 7 days of continuous use, with no malfunctions observed.

Table 7. Total overall achievement in percentage

No.	Question keywords	Response (%)			Achievement level
		Disagree	Not sure	Agree	
Q1	Interactive & interesting	0	4.4	95.6	Excellent
Q2	Exciting learning experience	2.2	2.2	95.6	Excellent
Q3	Encourage to explore	0	2.2	97.8	Excellent
Q4	Real-world application	0	4.4	95.6	Excellent
Q5	Motivated to develop	0	2.2	97.8	Excellent
Q6	Traditional system understanding	0	4.4	95.6	Excellent
	Overall average %	0.4	3.3	96.3	Excellent

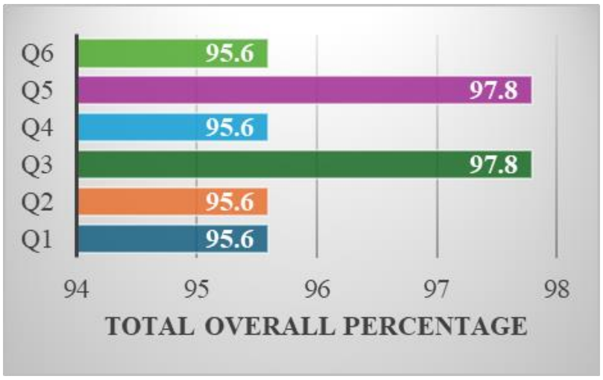

Figure 5. Total overall percentage

5. Conclusion

This study presents a functional and cost-effective solution for smart control of electrical switches using IoT. The system demonstrates fast, reliable, and user-friendly operation, making it suitable for real-world applications. As IoT technology continues to mature, such systems will play an increasingly important role in creating energy-efficient, intelligent homes.

The implementation confirms that IoT-based smart switches are not only feasible but also highly practical for modern smart homes. The system is scalable, allowing for multiple switches to be controlled via a centralized application. Moreover, integrating cloud services enables features like scheduling, energy logging, and AI-driven automation.

Challenges included Wi-Fi dependency, which may be mitigated through hybrid solutions (e.g., Bluetooth or Zigbee failover). Security remains a critical concern; incorporating encrypted communication protocols like HTTPS or secure MQTT can address this. Future improvements could include Voice assistant integration, Real-time energy analytics and Enhanced mobile UI with feedback mechanisms.

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