

ELECTRICAL ENGINEERING INNOVATION COMPETITION & EXHIBITION 2026



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(UITMCTKD)



IN COLLABORATION
JABATAN KEJURUTERAAN ELEKTRIK
POLITEKNIK SULTAN MIZAN ZAINAL ABIDIN
(PSMZA)



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It is with great pride and immense pleasure that I commend the Electrical Engineering Innovation Competition and Exhibition 2026 on achieving another historic milestone. This success was made possible through a synergistic collaboration between Politeknik Sultan Mizan Zainal Abidin (PSMZA) and Universiti Teknologi MARA (UiTM). Our partnership exemplifies the spirit of unity and the shared vision required to bring this meaningful publication to fruition.

We stand at a remarkable juncture in human history, where electrical engineering continues to be the beating heart of global progress. From the expansion of smart grids and renewable energy to breakthroughs in artificial intelligence and advanced telecommunications, the work of electrical engineers is actively rewiring our world. The innovative prototypes and systems documented in this compilation serve as a testament to the rich pool of ideas cultivated within our two esteemed institutions.

Bringing an endeavor of this magnitude to life requires extraordinary dedication. I want to extend my deepest gratitude to the joint organizing committee from both UiTM and PSMZA, whose tireless efforts have transformed this shared vision into reality. To all our contributors and partners, thank you for your unwavering support and for investing in the next generation of engineering pioneers.

I wish all the participants the very best of luck in their future endeavors, and I hope everyone who engages with this body of work leaves inspired by the limitless possibilities of electrical engineering.

Thank you.

FOREWORD BY HAJI MOHD DASRI BIN CHE MOK @ ADNAN KJ JKE PSMZA

Assalamualaikum Warahmatullahi Wabarakatuh and Salam Sejahtera.

Alhamdulillah, praise be to Allah SWT for His blessings and guidance that have enabled the successful publication of the Electrical Engineering Innovation Competition & Exhibition 2026 (EEICE 2026) Extended Abstracts. This publication represents another significant milestone in the ongoing academic collaboration between the Department of Electrical Engineering, Politeknik Sultan Mizan Zainal Abidin (PSMZA) and the Faculty of Electrical Engineering, Universiti Teknologi MARA Cawangan Terengganu.

The rapid advancement of technology and the increasing demand for innovative engineering solutions continue to challenge and inspire future engineers. The collection of extended abstracts presented in this volume showcases the creativity, technical competence and problem-solving capabilities of our students. Through their final year projects (FYP), students have demonstrated their commitment to addressing contemporary issues in areas such as renewable energy, Internet of Things (IoT), automation, smart systems, sustainability and digital transformation.

I would like to express my sincere appreciation and gratitude to the editorial committee, academic staff and all contributors whose hard work and commitment have made this publication possible. My heartfelt congratulations also go to all participating students for their determination, creativity and achievements.

It is my hope that this collection of extended abstracts will serve as a useful reference and source of inspiration for future researchers and students. May the knowledge and innovations presented herein continue to foster a culture of continuous learning, research excellence and technological advancement in the field of Electrical Engineering.

Thank you.

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ARDUINO-BASED ELECTRONIC SAFEBOX WITH PIN AUTHENTICATION

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Abstract: This project presents the design and development of an electronic safebox using an Arduino Uno microcontroller for secure asset protection. The system employs a Personal Identification Number (PIN) authentication method through pushbuttons, ensuring only authorized users can access the safebox. An LCD display provides user feedback, while a buzzer and servo motor enhance security and locking functionality. The proposed system addresses limitations of conventional mechanical safes by offering easier access, customizable PIN settings, and improved usability. Experimental results demonstrate that the safebox operates effectively, providing a simple, reliable, and cost-effective security solution for personal use.

Keywords: Electronic safebox, Arduino Uno, PIN Authentication

INTRODUCTION

Security is an important aspect of daily life, particularly when protecting valuable items, confidential documents, and personal belongings. Conventional safeboxes commonly use mechanical locks that require physical keys or combination dials. However, these systems may be inconvenient, time-consuming to operate, and vulnerable to issues such as lost keys or forgotten combinations. With the advancement of embedded systems and microcontroller technology, electronic security solutions have become increasingly popular due to their improved functionality, reliability, and user convenience. Recent studies have demonstrated the effectiveness of Arduino-based security systems for access control applications. [1] developed an Arduino-based password-protected locking system incorporating a keypad, LCD, and servo motor. Their system also included a lockout mechanism after multiple incorrect password attempts, enhancing security. Authors in [2] proposed an Arduino-based automatic door lock using PIN authentication, which provided improved convenience and security compared to conventional locking methods. Furthermore, another study [3] presented a password-based security system utilizing an Arduino microcontroller, keypad, and servo motor, where the locking mechanism was controlled through password verification.

Inspired by these developments, this project focuses on the design and development of an Arduino-Based Electronic Safebox with PIN Authentication. The system utilizes pushbuttons for PIN entry, an LCD display for user feedback, a servo motor as the locking mechanism, and a buzzer for audio notifications. The proposed system aims to provide a simple, secure, and cost-effective alternative to traditional mechanical safeboxes. By allowing users to set and manage their own PINs, the safebox enhances accessibility while maintaining a high level of security. Furthermore, the integration of electronic components enables automated locking and unlocking operations, improving user experience. This project demonstrates the practical application of embedded systems in developing a reliable security solution suitable for personal and small-scale use.

METHODOLOGY

This section explains the methodology used to develop the automatic lighting system, focusing on the hardware integration and circuit design. As illustrated in Fig. 1, the ESP32 acts as the central controller, receiving input signals from the PIR sensor, LDR circuit, and RTC module. The ESP32 uses the input data to control the lamp brightness and operation automatically based on motion, ambient light, and preset time schedules.

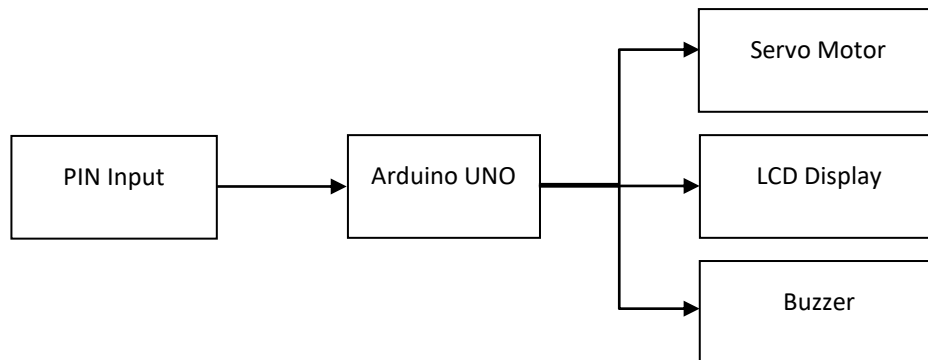


Figure 1. Block diagram of the Arduino-based Electronic Safebox with PIN Authentication

The Arduino-based Electronic Safebox operates by receiving a PIN entered through the pushbutton input. The Arduino Uno processes the entered PIN and compares it with the stored password. If the PIN is correct, the Arduino activates the servo motor to unlock the safebox and displays a successful access message on the LCD screen. Simultaneously, the buzzer produces a sound to indicate successful authentication. If an incorrect PIN is entered, the LCD displays an access denied message and the buzzer sounds as an alert. This system ensures secure and efficient access control for the safebox.

RESULT AND DICUSSION

Table 1 shows the relationship between the input conditions and the corresponding system responses of the electronic safebox. The results demonstrate that the system was able to accurately process user inputs and generate the expected outputs. Correct PIN entry resulted in the display of “Access Granted” and “Unlocked” messages, accompanied by a +90° servo motor rotation, while incorrect PIN entry produced an “Access Denied” message without activating the locking mechanism.

In addition, the lock function operated as intended by displaying “Locked” and rotating the servo motor by −90°. The buzzer consistently provided audible feedback for each button press, confirming proper interaction between the input and output components. These findings verify the functionality and reliability of the developed system.

Table 1. Input Conditions and Corresponding System Responses

Input Condition	LCD	Servomotor	Buzzer
Numeric button (0–6) pressed	Display entered digit	-	Beep
Enter button (E) pressed	Display "E" and verify PIN	-	Beep
Clear button pressed	Clear entered PIN	-	Beep
Enter correct PIN and press Enter	Display "Access Granted" and "Unlocked"	Rotate +90°	Beep
Enter incorrect PIN and press Enter	Display "Access Denied"	No movement	Beep
Lock button pressed	Display "Locked"	Rotate −90°	Beep

CONCLUSIONS

The Arduino-based electronic safebox with PIN Authentication was successfully developed and tested. The system was able to verify PIN entries accurately and perform the intended locking and unlocking functions through the servo motor. The LCD display and buzzer provided effective user feedback during operation. Overall, the project achieved its objectives and demonstrated a simple, reliable, and cost-effective security solution for personal asset protection.

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AUTOMATED MULTI LIQUID DISPENSER WITH IOT

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Abstract: This project presents the design and implementation of an automatic hand hygiene station capable of dispensing water, soap, and hand sanitizer without physical contact. The system integrates three types of sensors, an ultrasonic sensor for water dispensing, an infrared (IR) sensor for soap, and an obstacle sensor for hand sanitizer to detect hand presence and activate the corresponding pumps. A 2-channel relay module controls the dispensers based on signals from an ESP-32 microcontroller. To promote environmental sustainability, the system is powered by 9V battery with a voltage regulator circuit. Each dispensing unit includes an LED indicator to provide visual feedback during operation and also to initialize the Internet of Things (IoT) function. The touchless design improves hygiene and reduces the risk of cross-contamination, making it ideal for our campus. The project demonstrates the effectiveness of combining renewable energy with sensor-based automation for smart hygiene solutions.

Keywords: Arduino, dispenser, IoT

INTRODUCTION

The Automated Multi-Liquid Dispenser with IoT utilizes an ESP32 microcontroller to develop a touchless dispensing system with two independent sensing stations for water and soap dispensing. Two HC-SR04 ultrasonic sensors are used to detect hand movement within a range of 20 cm, automatically activating the corresponding 5V water pumps through a 2-channel relay module, while LEDs provide output status indication [1]. The system is integrated with the Blynk IoT platform, enabling real-time monitoring and remote control via smartphone applications. Users can select either automatic sensor operation or manual control mode, while real-time pump and sensor status data are transmitted through IoT connectivity. The developed system demonstrates an efficient, hygienic, and smart liquid dispensing solution suitable for modern automation applications [2].

METHODOLOGY

This section explains the operation of Automated multi liquid dispenser with IoT. The project's block diagram is shown in Figure 1.

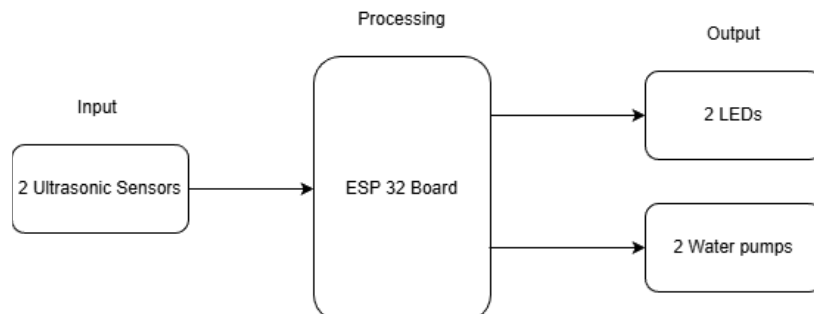


Figure 1. Block diagram of the project

The block diagram in Figure 1 illustrates the overall flow of information and control within the automated dispenser system, organized into three distinct stages: Input, Processing, and Output. The

process begins at the Input stage, where two ultrasonic sensors are utilized to detect the presence of a user's hand. This detection data is sent directly to the Processing stage, which consists of the ESP 32 Board. The ESP32 acts as the central control unit; it interprets the signals from the sensors to determine if an object is within the required range. Once the logic is confirmed, the system moves to the output stage. Here, the microcontroller sends signals to activate the two water pumps to dispense the liquid, while simultaneously powering the two LEDs to provide visual confirmation that the system is operating.

RESULT AND DISCUSSION

The prototype is tested as shown in the results below:

Table 1. Sensor sensitivity and stability test result

Test Distance (cm)	Detection Success Rate (out of 10)	Observation
20 cm	10/10	Detected hand successfully, but also triggered falsely when objects passed nearby
15 cm	10/10	High sensitivity; occasional false triggers from reflective surfaces.
10 cm	10/10	Good detection but still activated too easily during unintentional movements.
5 cm	10/10	Only activated when the hand was deliberately placed under the nozzle. Zero false triggers.

The system was tested at different distances to find the best sensor range. Although the sensor could detect objects at 20 cm, it often caused unwanted liquid dispensing. After testing, 5 cm was found to be the best distance because it gave accurate detection and prevented liquid waste. The system also showed a fast response time of about 0.5 seconds between hand detection and pump activation. This proves that the ESP32 can process the system quickly and provide a smooth user experience.

CONCLUSIONS

This project successfully achieved its main objective of developing an Automated Multi-Liquid Dispenser with IoT technology. The system uses an ESP32 microcontroller and HC-SR04 ultrasonic sensors to provide touchless liquid dispensing, which improves hygiene and user convenience. Testing showed that a 5 cm detection range works more accurately than 20 cm by reducing false triggers and preventing liquid waste. In addition, the integration with the Blynk platform enables real-time remote monitoring of the dispenser system. Overall, the prototype works effectively as a smart, efficient, and user-friendly hygiene solution.

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AUTOMATIC LIGHTING SYSTEM FOR DORMITORY APPLICATIONS

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Abstract: This project presents the design and development of an Automatic Lighting System for dormitory applications using an ESP32 microcontroller, a Passive Infrared (PIR) sensor, a Light Dependent Resistor (LDR) circuit, and a Real-Time Clock (RTC) module. The system aims to improve energy efficiency by controlling lighting based on ambient light conditions, motion detection, and scheduled operating times. Pulse Width Modulation (PWM) dimming is implemented to reduce power consumption during low-activity periods. A prototype was developed and tested to evaluate system functionality. Although integration challenges affected performance, the project demonstrated the potential of intelligent lighting control.

Keywords: ESP32, PIR sensor, RTC, smart lighting, energy efficiency

INTRODUCTION

Lighting systems play an important role in ensuring safety, visibility, and comfort in dormitory environments, particularly during nighttime. However, conventional lighting systems often operate continuously at full brightness regardless of occupancy or environmental conditions. This practice results in unnecessary electricity consumption, increased operational costs, and reduced energy efficiency. With the growing demand for sustainable energy management, intelligent lighting systems have become an effective solution for optimizing electricity usage while maintaining adequate illumination.

Recent advancements in embedded systems and sensor technologies have enabled the development of automated lighting systems capable of responding to real-time environmental changes. By integrating sensors and programmable controllers, lighting systems can be controlled automatically based on ambient light levels, human presence, and predefined operating schedules. Such systems not only reduce energy wastage but also improve user convenience and safety.

Several studies have demonstrated the effectiveness of intelligent lighting systems. In [1], an ESP32-based system integrated with PIR and LDR sensors was developed for automatic lighting control and energy monitoring. Similarly, [2] implemented an ESP32, an LDR sensor, and a dimming control mechanism to reduce electricity consumption by automatically adjusting light intensity according to ambient lighting conditions. These studies highlight the potential of sensor-based automation in improving lighting efficiency.

Motivated by these developments, this project focuses on the design and development of an Automatic Lighting System for Dormitory Applications using an ESP32 microcontroller. The system incorporates a LDR circuit to distinguish between day and night conditions, a PIR sensor to detect human movement, and time-based control to regulate lighting operation according to scheduled periods. In addition, PWM is utilized to adjust light intensity during low-activity hours, further enhancing energy efficiency.

The proposed system aims to provide an intelligent and cost-effective lighting solution that minimizes electricity consumption while ensuring sufficient illumination and user safety within dormitory facilities.

METHODOLOGY

This section explains the methodology used to develop the automatic lighting system, focusing on the hardware integration and circuit design. As illustrated in Fig. 1, the ESP32 acts as the central controller, receiving input signals from the PIR sensor, LDR circuit, and RTC module. The ESP32 uses the input data to control the lamp brightness and operation automatically based on motion, ambient light, and preset time schedules.

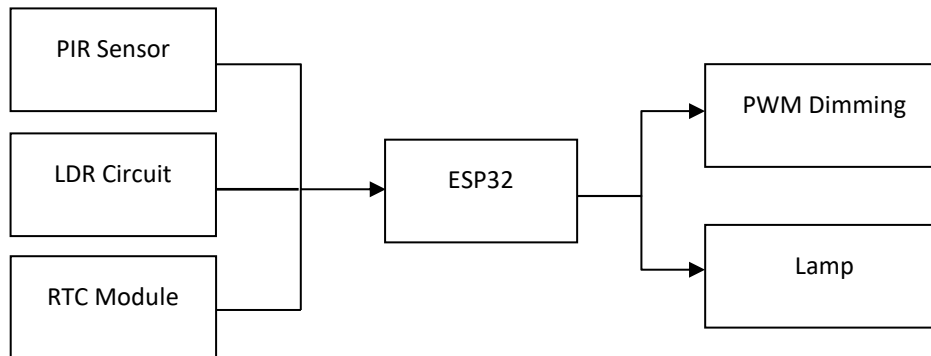


Figure 1. Block diagram of the Automatic Lighting System

The proposed system operates by combining ambient light detection, motion sensing, and time-based control to manage dormitory lighting automatically. The LDR circuit activates the lighting system during nighttime, while the PIR sensor detects human movement and switches on the toilet light when occupancy is detected. Additionally, time-based control and PWM dimming are implemented to adjust light brightness during late-night hours, reducing electricity consumption while maintaining adequate illumination.

RESULT AND DISCUSSION

The proposed Automatic Lighting System provides autonomous control of dormitory lighting based on ambient light conditions, motion detection, and predefined operating schedules. Lamp 2 operates only during nighttime, providing full illumination between 7:00 p.m. and 11:00 p.m. and reduced brightness through PWM dimming from 11:00 p.m. to 7:00 a.m. to improve energy efficiency. Meanwhile, Lamp 1 activates automatically upon detecting human movement in the designated area. Overall, the system is designed to reduce unnecessary electricity consumption while ensuring adequate illumination, safety, and user convenience within the dormitory environment.

Table 1. Summary of the System Performance

Paramter	Result
LDR Circuit	Detects day and night conditions correctly; Lamp 2 turns ON only at night.
PIR Sensor	Detects human motion and turns Lamp 1 ON when movement is present.
RTC Control	Controls Lamp 2 according to the programmed schedule (7:00 p.m.–11:00 p.m. and 11:00 p.m.–7:00 a.m.)
PWM Dimming	Reduces Lamp 2 brightness during late-night hours to save energy.
Overall System	Operates automatically and reduces unnecessary electricity consumption while maintaining adequate lighting and safety.

Table 1 presents the results of the Automatic Lighting System, highlighting the intended operation of each system function to achieve energy-efficient and automated lighting control.

CONCLUSIONS

In conclusion, the Automatic Lighting System successfully demonstrates the integration of ambient light detection, motion sensing, and time-based control for dormitory lighting applications. The system is designed to enhance energy efficiency by automating lighting operation while maintaining adequate illumination, safety, and user convenience within the dormitory environment.

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DESIGN AND DEVELOPMENT OF AN IOT-BASED SOLAR-POWERED ADVANCED IRRIGATION SYSTEM WITH REAL-TIME MONITORING

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Abstract: This project presents the design and development of an IoT-based solar-powered advanced irrigation system with real-time monitoring for Anthurium plants. The system aims to optimize water usage and maintain suitable soil moisture levels to support healthy plant growth. It integrates a soil moisture sensor, ESP32 microcontroller, automated water pump, LCD display, LEDs, and the Blynk IoT platform for continuous monitoring and control. Real-time soil data are processed to determine irrigation requirements, activating the water pump automatically when the soil is dry. Notifications are also sent through the Blynk application. The developed system demonstrates efficient irrigation management, water conservation, and improved plant care using IoT technology.

Keywords: IoT, solar-powered irrigation, real-time monitoring, soil moisture sensor, ESP32.

INTRODUCTION

Previous studies on irrigation systems have shown that traditional irrigation methods are often inefficient due to excessive water usage, manual monitoring, and poor irrigation scheduling. Many farmers still rely on conventional watering techniques that distribute water uniformly without considering the actual moisture condition of the soil [1]. As a result, overwatering and underwatering frequently occur, affecting plant health, reducing crop productivity, and increasing operational costs. Researchers have introduced automated irrigation systems to overcome these issues; however, several existing systems still face limitations such as high-power consumption, lack of real-time monitoring, and limited remote accessibility [2].

Recent developments in Internet of Things (IoT) technology have improved the efficiency of irrigation systems by enabling real-time data collection and automated control [3]. Previous studies demonstrated that soil moisture sensors combined with microcontrollers can effectively monitor soil conditions and activate irrigation only when required. Despite these improvements, many IoT-based irrigation systems depend heavily on conventional electricity sources, making them less suitable for rural or remote agricultural areas with unstable power supply. In addition, some systems lack user-friendly interfaces for remote monitoring and control [4][5].

To address these challenges, this project proposes the *Design and Development of an IoT-Based Solar-Powered Advanced Irrigation System with Real-Time Monitoring*. The system integrates soil moisture sensors, an ESP32 microcontroller, solar energy supply, and the Blynk IoT platform to provide efficient irrigation management. The use of solar power reduces energy dependency and operational costs, while IoT integration enables continuous monitoring and remote access through a mobile application. This approach supports sustainable agriculture by improving water management, reducing labour requirements, and maintaining optimal soil moisture conditions for healthier plant growth.

METHODOLOGY

Referring to Fig. 1, soil moisture is sensed and sent to the ESP32. The ESP32 also receives user commands and threshold settings from the Blynk app through the Blynk IoT cloud. Based on sensor data and user input, ESP32 controls the water pump via a driver/relay, updates LCD/LED status, triggers buzzer alerts, and uploads readings and pump status to Blynk.

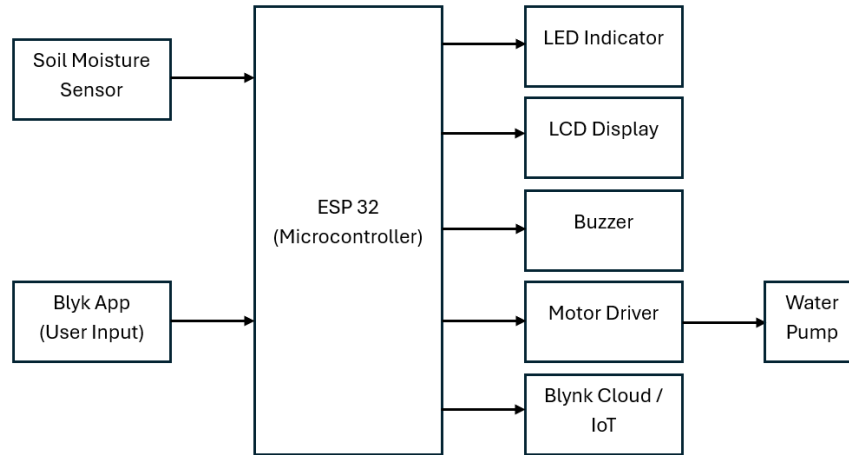


Figure 1. Block diagram of Advanced Irrigation System

RESULT AND DISCUSSION

The prototype is tested in various scenarios as shown in the results below:

Table 1. Soil Moisture Sensor readings and system responsive

Soil Moisture Sensor Volumetric Water Content, VWC (%)	LED	LCD Display	Buzzer	Motor Driver	IoT Notification
0 – 10 (Very Dry)	RED	DRY	ON	ON	VERY DRY
10 – 20 (Dry)	RED	DRY	ON	ON	DRY
20 – 35 (Moderate/Optimal)	YELLOW	DRY	ON	ON	MODERATE
35 – 45 (Wet)	GREEN	WET	OFF	OFF	WET
45 – 60+ (Very Wet)	GREEN	WER	OFF	OFF	VERY WET

Based on the results in Table 1, the system was successfully functioning to detect, monitor, and control the soil moisture precisely.

CONCLUSIONS

In conclusion, the design and development of the IoT-based solar-powered advanced irrigation system with real-time monitoring for anthurium plants has successfully demonstrated an efficient and sustainable approach to modern agriculture. The system is capable of monitoring soil moisture, temperature, and humidity in real time, ensuring that anthurium plants receive the appropriate amount of water according to their growth requirements. By utilizing IoT technology, farmers can monitor and control the irrigation process remotely, reducing manual labour and improving water management efficiency. In addition, the integration of solar power provides a renewable energy source that lowers electricity consumption and operational costs. This project also helps maintain suitable environmental conditions for healthy anthurium growth, improving plant quality and productivity. Overall, the

developed system offers a reliable, cost-effective, and environmentally friendly solution for smart irrigation applications in ornamental plant cultivation.

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DEVELOPMENT OF A SOLAR-POWERED IOT ADVANCED DOORBELL WITH MOTION DETECTION

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Abstract: This project presents the development of a solar-powered IoT advanced doorbell with motion detection for enhanced home security. The system uses a Passive Infrared (PIR) sensor to detect movement near the entrance and sends real-time notifications to homeowners through Telegram Web. Simultaneously, an audible doorbell alerts occupants inside the house. The integration of IoT technology enables remote monitoring and faster response to visitor activity or security concerns. In addition, the use of solar energy promotes sustainable and energy-efficient operation. Overall, the proposed system provides a practical, reliable, and user-friendly advanced security solution for modern residential applications.

Keywords: IoT, doorbell, passive infrared (PIR), Telegram, energy.

INTRODUCTION

The development of advanced home technology has increased the demand for advanced security systems that provide convenience, safety, and real-time monitoring. One of the commonly used security devices in residential buildings is the doorbell system [1]. Traditional doorbell systems are designed mainly to notify homeowners of a visitor's arrival through a simple ringing sound activated by pressing a button outside the house. Although these systems have been widely used for many years due to their simplicity and affordability, they offer limited functionality and lack modern security features [2].

Conventional doorbell systems have several limitations. Most systems require wired installation, which can increase installation costs and maintenance difficulties. In addition, traditional doorbells only provide audio notifications without allowing homeowners to identify visitors or monitor activity near the entrance remotely [3]. They also lack integration with advanced technologies such as motion detection, internet connectivity, and mobile notifications. Over time, mechanical components may experience wear and tear, resulting in reduced performance and reliability.

To overcome these limitations, this project focuses on the development of a solar-powered IoT advanced doorbell with motion detection. The proposed system integrates a Passive Infrared (PIR) sensor to detect movement near the entrance and sends real-time notifications to homeowners through Telegram Web [4]. The system also activates an audible bell to alert occupants inside the house. Furthermore, the use of solar energy promotes sustainable and energy-efficient operation. This project demonstrates how IoT technology can enhance home security by providing advanced, safer, and more efficient monitoring solutions for modern residential applications [5].

METHODOLOGY

Referring to Fig. 1 and Fig. 2, the system operates using a PIR sensor to detect motion near the entrance. The sensor sends signals to the microcontroller, which activates the doorbell and transmits notifications through Telegram Web via IoT connectivity. The system is powered by solar energy, ensuring continuous, energy-efficient, and sustainable operation.

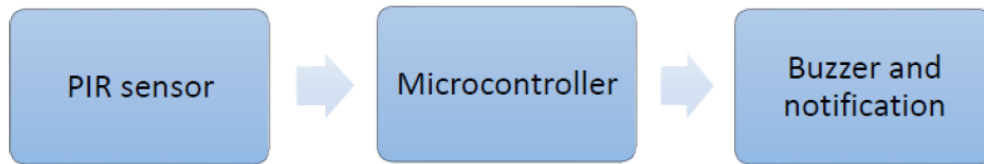


Figure 1. Block diagram of Advanced Doorbell System

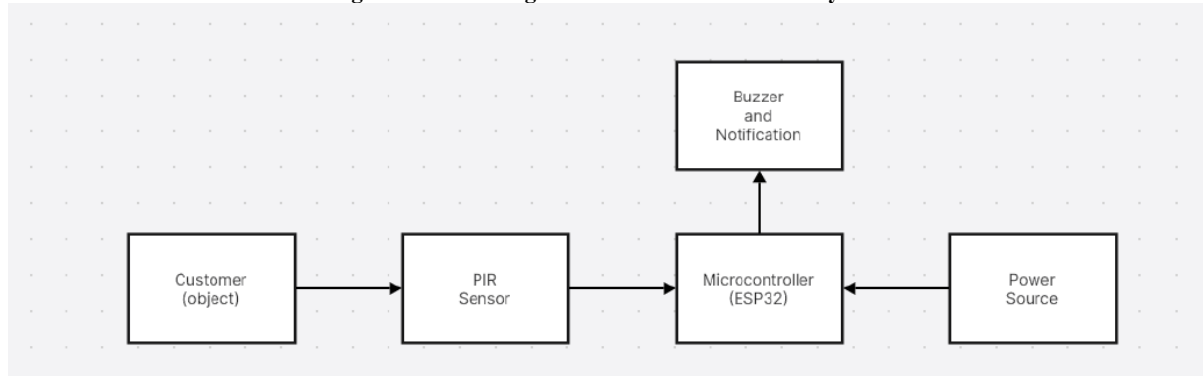


Figure 2. System Diagram of Advanced Doorbell System

RESULT AND DISCUSSION

The prototype is tested in various scenarios as shown in the results below:

Table 1. Sensor readings based on PIR Sensor Input

PIR Sensor	Buzzer	Notification	Solar-Charging
Control	Off	Off	On
No-Detection	Off	Off	On
Detection	On	On	On

Based on the results in Table 1, the system was successfully functioning to detect guests and notify the homeowner via Telegram notifications.

CONCLUSIONS

In conclusion, this project successfully developed an advanced solar-powered IoT doorbell system with motion detection to enhance home security and monitoring efficiency. The system integrates a Passive Infrared (PIR) sensor, IoT communication, and Telegram Web notifications to provide real-time alerts whenever motion is detected near the entrance. At the same time, the ringing bell notifies occupants inside the house, ensuring effective dual communication for both indoor and remote users. The implementation of solar energy also improves the system's sustainability and energy efficiency by reducing dependence on conventional electrical power. In addition, the integration of IoT technology enables homeowners to monitor activities near their entrance remotely through mobile devices, increasing convenience and response speed during security situations.

The developed system demonstrates that combining motion detection, internet connectivity, and renewable energy technology can create a more reliable and efficient home security solution. Overall, this project achieves its objective of providing an advanced, user-friendly, and cost-effective security system suitable for modern residential applications. Future improvements may include integrating a camera module, facial recognition system, and cloud storage for enhanced security and monitoring capabilities.

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IOT AUTOMATED AQUAPONIC MONITORING SYSTEM

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Abstract: Traditional farming is quite wasteful because the ground absorbs water in a 'one-way system.' Consequently, this method is hard to sustain in regions facing frequent water shortages. To overcome this challenge, aquaponics offers an ideal solution because its recycling loop maximizes water efficiency. To achieve this, our project uses two inputs: a pH sensor to measure acidity or alkalinity levels, and a water temperature sensor to check the water's thermal condition. These sensors are connected to an ESP32, which acts as the brain of the system. For the outputs, a water pump is installed to regulate water flow, and LED grow lights are used to provide artificial sunlight so plants can grow through photosynthesis, regardless of the weather outside. Additionally, an IoT feature using a Telegram bot provides real-time alerts if abnormal conditions or hardware faults are detected. Overall, this suggested system improves operational efficiency, reduces manual intervention, and promotes sustainable and intelligent aquaponic farming, making it suitable for small-scale, educational, and home-based applications.

Keywords: Aquaponics, ESP32 microcontroller, Telegram bot.

INTRODUCTION

Traditional agriculture needs a large area of land and a lot of maintenance. Farmers have to prepare the soil, water the plants, remove weeds, and control pests regularly. This makes farming difficult, especially in places where land is limited. Because of this, a new method called aquaponics was introduced as a better and more efficient way to grow food without needing a lot of space or hard work. Aquaponics, is an integrated system combining aquaculture (fish farming) and hydroponics (soilless plant cultivation), is increasingly recognized as a sustainable and innovative solution to address global challenges in food production, resource scarcity, and environmental sustainability [1].

An aquaponics system is a soil-less system that does not require large agricultural land and can even be set up on a rooftop or in small spaces. However, this system is not cheap, especially during the initial setup, because of the running and maintenance costs involved. But in the long run, with good management, this system can be cost-effective over time [2]-[3].

One of the advantages of this aquaponic system is that it is worth considering for people living in towns and for vulnerable groups such as widows, single parents, and low-income families. This is because the system is space-saving, low-effort, and cost-effective in the long run. Through this system, it is hoped that people can save money on food while also gaining a sense of independence and productivity.

Therefore, this project aims to develop an IoT-based smart aquaponic monitoring system using the ESP32 microcontroller. The system is designed to monitor important water conditions such as pH level and water temperature in real time and will automatically control the water pump and LED grow lights based on the recorded readings, without the need for manual operation. All sensor data and system alerts will be sent directly to the user through a Telegram bot, allowing the system to be monitored remotely and enabling a quick response whenever needed. It is hoped that through the development of this system, aquaponic farming can become more efficient, require less manual work, and support more sustainable farming practices in the long run.

METHODOLOGY

This section explains the operation of the IoT Automated Aquaponic Monitoring Systems project. The project's block diagram is shown in Figure 1.

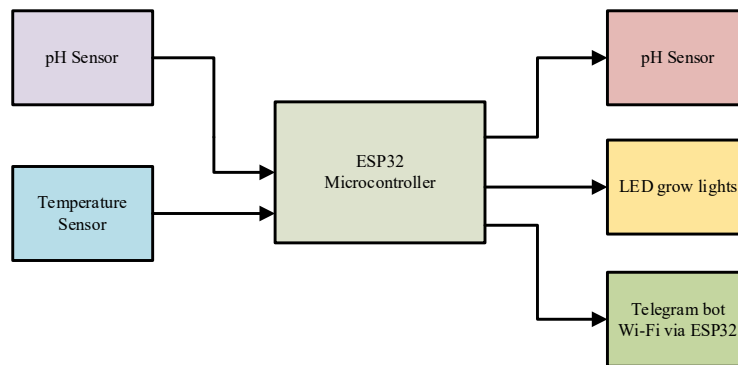


Figure 1. Block diagram of IoT Automated Aquaponic Monitoring Systems

The system consists of two input sensors, a microcontroller, and two output devices. The pH sensor and the DHT11 temperature sensor act as the inputs by collecting real-time water condition data and sending it to the ESP32 microcontroller. The ESP32 then processes the data and automatically controls the two outputs, which are the water pump and the LED grow lights, based on the predefined conditions. Any sensor data and alerts are also sent to the user through a Telegram bot, enabling remote monitoring at any time.

RESULT AND DISCUSSION

The input operation for the project is shown in table below:

Table 1. pH Sensor Reading Range and Water Condition

pH reading Range	Water Condition
1-6	Not normal
6.5 -7.5	Normal
7.5-14	Not normal

Table 1. records the range of pH sensor levels and the required water condition for the aquaponic system

Table 2. Water Temperature Range and Pump Operation Schedule

Temperature	Pump On	Pump Off
25-27	2 minutes	15 minutes
28-30	3 minutes	10 minutes
>30	5 minutes	10 minutes

Table 2. shows the pump operating time based on the increase in water temperature level.

CONCLUSIONS

The proposed IoT Automated Aquaponic Monitoring System has achieved the objectives of monitoring the pH level and water temperature of the aquaponic tank in real time. The water pump and LED grow lights are also able to operate automatically based on the sensor readings to ensure the water conditions remain suitable for both fish and plant growth. Additionally, the Telegram bot feature allows the user to receive real-time alerts and monitor the system remotely through a mobile phone, reducing the need for manual intervention. This project can be further enhanced by introducing a water level sensor to prevent the pump from running dry, a turbidity sensor to detect excess waste or algae growth, and a Total Dissolved Solids (TDS) sensor to measure the concentration of nutrients dissolved in the water, ensuring more comprehensive monitoring in the future.

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IMPLEMENTATION OF A PUMP WATERING SYSTEM FOR CAMPUS PLANT HEALTH MONITORING

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Abstract: This project focuses on the development and implementation of a mobile robot-based Pump Watering System designed for Campus Plant Health Monitoring. The system is developed to address inconsistent plant care across campus areas, where manual watering is often time-consuming and requires continuous supervision. To improve efficiency, a robot capable of operating in manual and autonomous modes was constructed. In manual mode, the user can control the robot to navigate to selected plant locations, while in autonomous mode, it follows a programmed path to monitor soil conditions. A soil moisture sensor is used to detect the moisture level of the soil, and when the reading falls below the threshold value, the robot automatically activates a water pump to irrigate the plant. Once the soil reaches an optimum moisture level, the pump is turned off, and the robot proceeds to the next location for further monitoring. The methodology of this project involves hardware integration such as DC motors for movement, soil moisture sensors, a microcontroller as the main controller, and a water pump for irrigation. Testing results show that the robot can identify dryness levels accurately and perform watering only, when necessary, thus reducing water wastage. The implementation of mobility allows the system to service multiple plants within a single operation. This study demonstrates that a controller watering robot can enhance maintenance efficiency, support sustainable irrigation practices, and potentially reduce manpower requirements on campus. The system presents significant potential for future improvement, such as real-time monitoring data, solar-powered operation, and larger navigation coverage.

Keywords: Arduino, plant, humidity, temperature, water

INTRODUCTION

Significant advancements in robotics, microcontrollers, and sensing technologies have paved the way for smart agriculture, offering higher precision and better resource management compared to traditional methods. In environments like university campuses, manual watering often leads to inconsistencies such as overwatering or neglect due to human error. To solve this, the project introduces an autonomous plant-watering robot that integrates mobility and humidity sensing to ensure plants receive precise irrigation, thereby maintaining a balanced and healthy ecosystem.

The proposed robotic system functions by tracking plant positions and using soil moisture sensors to trigger irrigation only when necessary, moving to the next area once optimal levels are reached. This automation not only minimizes water waste and reduces reliance on manual labor but also aligns with long-term sustainability and green campus initiatives. Furthermore, the potential integration of renewable energy sources, such as solar power, enhances the system's efficiency and environmental friendliness in line with global energy standards [1], [2].

METHODOLOGY

This section explains the operation of a pump watering system for campus plant health monitoring. The project's block diagram is shown in Figure 1.

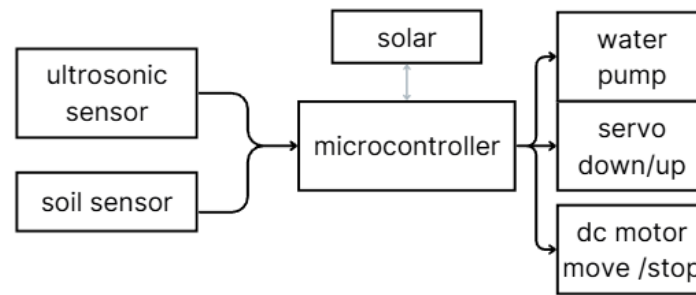


Figure 1. Block diagram of the project

Figure 1 illustrates the main control algorithm programmed into the ESP32 microcontroller. The flowchart describes the autonomous operating logic of the robot, starting from navigation and obstacle detection until the execution of the watering process.

RESULT AND DISCUSSION

The prototype is tested in various scenarios as shown in the results below:

Table 1. Soil Moisture Sensor

Soil Condition	Raw Reading (Analog)	Estimated Percentage (%)	Water Pump Status
Air (Very Dry)	~3500 - 4095	0% - 15%	ON
Dry Soil	~2500 - 3499	16% - 49%	ON
Moist Soil (Ideal)	~1200 - 2499	50% - 80%	OFF
Water (Very Wet)	0 - 1199	81% - 100%	OFF

The soil moisture sensor readings were converted into a percentage value from 0% to 100%, with a 50% threshold set for watering activation. In dry soil conditions, the sensor detected about 15% moisture, causing the water pump to turn on successfully. In wet soil conditions, the sensor detected about 85% moisture, so the water pump remained off. Both tests passed and confirmed that the moisture control system operated correctly.

CONCLUSIONS

In conclusion, the Solar-Powered Automated Plant Watering Robot successfully achieved the project objectives by integrating renewable energy and autonomous irrigation technology. The system was able to monitor soil moisture levels and perform automatic watering efficiently using the ESP32 microcontroller and sensors. The implementation of a solar-powered system also improved battery operation and promoted sustainable energy usage. Overall, the project demonstrates a practical solution for reducing water wastage and labor dependency in agriculture applications, although improvements can still be made in solar efficiency and navigation performance.

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