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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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SMART DRAIN OVERFLOW DETECTION SYSTEM

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Abstract: Flooding of public places due to clogged drainage channels is a significant concern when there is an increase in the amount of rain. This project was aimed at developing an Automated Drainage Water Level Detection and Alert System that incorporates an ESP32 module along with an ultrasonic sensor. The water level is constantly monitored by the system inside the drainage channels. Rising water levels can be detected accurately by using an ultrasonic sensor to sense changes in the distance of the sensor from the surface of the water. ESP32 processes all the information obtained and sends audio and visual alerts when it detects possible cases of flooding. This helps to make drainage management more effective and reduce flooding instances. It also integrates the system with Telegram notification services to enhance real-time alerts to users and maintenance teams in cases of detected drain overflow conditions for rapid responses and early interventions against flooding.

Keywords: ESP32, water level, ultrasonic sensor, drain overflow

INTRODUCTION

Flooding due to blocked drainage systems poses significant safety, hygiene, and infrastructure risks, particularly in urban and campus environments. Manual inspection methods are inefficient and often result in delayed maintenance responses. Therefore, an automated monitoring system is required to detect rising water levels in drainage channels at an early stage. This project proposes an ultrasonic sensor-based water level detection system integrated with an ESP32 to provide real-time monitoring and alerts. The system offers a cost-effective and reliable solution for early flood detection and prevention.

The urban drainage infrastructure is planned to correctly direct rainwater from public space. However, the collection of waste materials and improper maintenance pose a significant risk of blockages in the drains, causing flooding in a particular area. Recent studies have proven that the use of IoT technology for monitoring the drains improves the time taken to respond to the situation effectively [1], [2]. Various researchers have proposed smart drainage and sewer monitoring system designs using microcontrollers like ESP32 and wireless communication techniques. The system can identify an overflow situation and send an alert message via software like Telegram. It can be monitored remotely, thus faster maintenance can be initiated [1], [3].

This project aims to develop an automated drainage monitoring system using an ESP32 microcontroller to provide real-time water level detection. The system integrates ultrasonic sensors with a dual-alert mechanism: a local visual warning light for immediate on-site notification and a cloud-based Telegram alert system for remote monitoring by maintenance teams.

METHODOLOGY

The development of the Smart Drain Overflow Detection System involves both hardware integration and software logic control. Figure 1 illustrates the block diagram of the proposed Smart Drain Overflow Detection System. The hardware architecture integrates an ESP32 microcontroller with an ultrasonic sensor, an LCD screen, and a warning light module. The system continuously measures the distance between the sensor and the water surface to monitor real-time drainage levels.

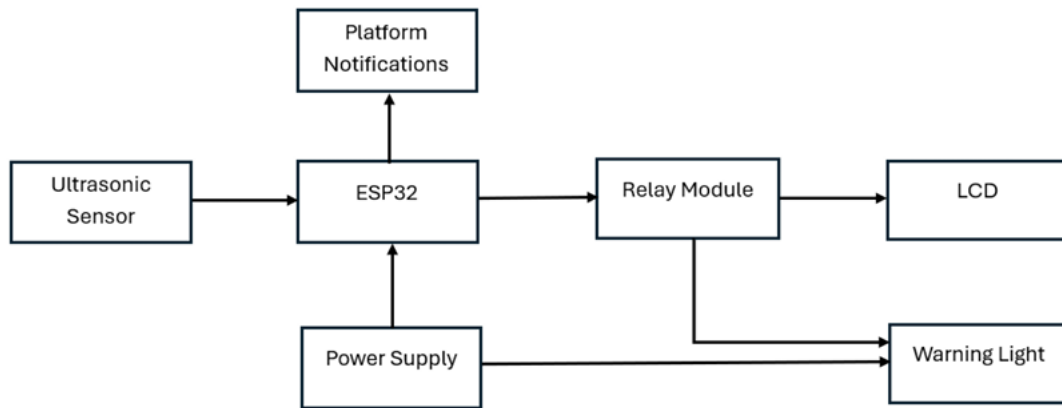


Figure 1. Block diagram of Smart Drain Overflow Detection System

System responses are automatically executed based on three operational thresholds:

- Safe Status (> 21 cm): The warning light remains off, and no alerts are sent.
- Warning Status (11 cm – 20 cm): The warning light activates for 2 seconds, and an alert notification is sent via Telegram.
- Danger Status (≤ 10 cm): The warning light activates for 5 seconds, and a high-priority danger notification is pushed to Telegram.

The current distance and status are displayed concurrently on the LCD screen, and the process repeats continuously to ensure real-time monitoring

RESULT AND DISCUSSION

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

Table 1. Sensor readings based on water level

INPUT	OUTPUT		
ULTRASONIC SENSOR	WARNING LIGHT	LCD	NOTIFICATION
≥ 21 CM	OFF	STATUS: SAFE	NO NOTIFICATION
≥ 11 CM to ≤ 20 CM	TRIGGER 2 SECONDS	STATUS: WARNING	WARNING: WATER IS INCREASING!!!
≤ 10 CM	TRIGGER 5 SECONDS	STATUS: DANGER	DANGER: WATER HAS REACHED DANGER LEVEL!!!

Table 1 presents the evaluation of the system's output responses across varying water level thresholds. The empirical results demonstrate that the ESP32 successfully processes data from the ultrasonic sensor and executes the predefined control logic without latency.

CONCLUSIONS

The project successfully developed an automated, low-cost Smart Drain Overflow Detection System using the ESP32 microcontroller. Empirical testing validated that the integration of ultrasonic sensing with a dual-alert mechanism provides reliable, real-time drainage monitoring. By automatically escalating alerts from safe to dangerous thresholds and broadcasting instant Telegram notifications, the system minimizes human intervention and accelerates critical response times. This automated solution offers a highly scalable and practical framework for localized flash flood mitigation on campus.

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SMART SOLAR-POWERED PARKING AND PATHWAY LIGHTS

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Abstract: Effective outdoor lighting is essential for streets and residential areas. It not only improves public safety but also plays a critical role in preventing accidents during the night. Recognizing the importance of safety, this project provides an automated lighting solution for the paths and parking zones at Kolej Gemia, UiTM Dungun. The proposed project utilizes solar power stored in a battery for energy supply. Two sensors—LDR and PIR—are integrated to create an autonomous control system. The LDR activates the system at dusk, while the PIR sensor triggers the lamps upon detecting motion, providing reliable lighting for the targeted areas. This approach effectively reduces power waste while ensuring consistent illumination throughout the night.

Keywords: safety, solar power, autonomous control system.

INTRODUCTION

Safety in public spaces, particularly along walkways and in parking areas, is essential for community confidence and well-being. Inadequate lighting poses a significant hazard at night; when illumination is insufficient, the risk of accidents—such as trips or falls—increases considerably. Furthermore, poorly lit areas can compromise personal security, making individuals more vulnerable to criminal activity.

The East Coast of Malaysia, particularly Kelantan and Terengganu, receives high levels of solar irradiance, offering significant potential for solar energy utilization[1]. Capitalizing on this natural resource, the Terengganu government, in partnership with TNB, has expanded large-scale solar initiatives at Tasik Kenyir. These investments underscore the state's commitment to transitioning toward a sustainable, renewable energy-driven economy [2].

Taking advantage of the high solar potential in the region, this project was developed with the primary goal of utilizing solar energy as the main power source. The energy generated is stored in a battery system for later use. To achieve automation, the system incorporates two specific sensors: a PIR sensor and an LDR. The PIR sensor is installed at the parking area to trigger lighting when motion is detected, serving as a security measure to prevent theft. Meanwhile, the LDR is positioned along the walkway to manage lighting based on ambient light levels. An Arduino Uno serves as the central controller; when it receives a signal from these sensors, it activates the relays to switch the lamps on automatically.

METHODOLOGY

This section explains the operation of The Smart Solar-Powered Parking and Pathway Lights. The project block diagram is shown in Figure 1.

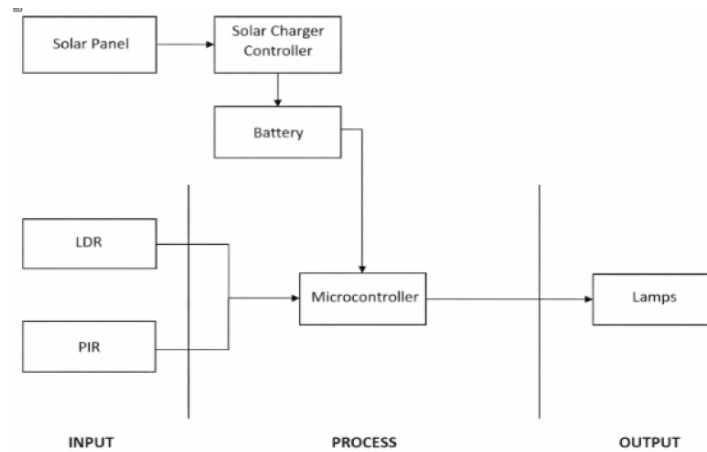


Figure 1: Block diagram of Smart Solar-Powered Parking and Pathway Lights

The Arduino microcontroller processes inputs from the sensors using independent logic. The lamps are programmed to trigger if either the PIR sensor detects motion (signal '1') or the LDR sensor identifies low light levels (value below 61).

RESULT AND DISCUSSION

The experimental results for the system are summarized in the table below:

Table 1. Sensor readings and output status

Sensor Type	Input Value / Condition	Detection Status	Lamp Status
PIR (Motion)	1 (High)	Motion Detected	ON
PIR (Motion)	0 (Low)	No Motion	OFF
LDR (Light)	< 61	Dark / Low Light	ON
LDR (Light)	> 61	Bright / Daylight	OFF

Table 1 records observations of sensor input logic and the lamp output status.

CONCLUSIONS

The proposed project has successfully utilized renewable energy to enhance safety in public areas. By integrating PIR and LDR sensors, the system responds effectively to motion and light levels. Future enhancements could include wireless connectivity for remote monitoring, further optimizing energy efficiency and large-scale urban management.

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NUTRIENT MONITORING FOR FERTIGATION SYSTEM

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Abstract: Fertigation is an efficient agricultural technique that delivers nutrients directly to plant roots through irrigation water; however, its effectiveness depends on maintaining optimal nutrient concentration, pH level, and temperature. This project presents the development of a monitoring system that is capable of measuring Total Dissolved Solids (TDS), pH value, and temperature of fertigation solutions. The system used ESP32 microcontroller integrated with a TDS Meter V1.0, pH module kit, and DS18B20 temperature sensor. Sensor data are processed by the ESP32 and displayed locally on an I2C LCD, while visual and audible alerts are provided through LED indicators when abnormal conditions are detected. Future enhancements may include additional sensors and wireless connectivity for expanded functionality.

Keywords: ESP32, IoT, PH, EC, fertigation system

INTRODUCTION

Fertigation is an agricultural technique that supplies nutrients to plants through irrigation water, allowing for efficient and precise nutrient delivery [1][3]. The effectiveness of a fertigation system highly depends on maintaining an appropriate nutrient concentration and solution temperature. Total Dissolved Solids (TDS) is a critical parameter used to indicate the concentration of dissolved nutrients in liquid fertilizer, while temperature plays an important role in nutrient solubility and plant nutrient absorption [2][4].

In conventional fertigation practices, nutrient concentration and solution temperature are often monitored manually. This approach is time-consuming, prone to human error, and does not provide continuous real-time data [2]. Inaccurate monitoring may result in over-fertilization or under-fertilization, which can negatively affect crop growth, increase operational costs, and reduce overall agricultural efficiency [1][3].

To overcome these limitations, this project presents a nutrient monitoring system using an ESP32 DevBoard. The system integrates EC, DS18B20 temperature, and pH sensors, displaying data locally on an LCD screen. LED indicators provide immediate visual alerts when solution parameters exceed safe thresholds.

METHODOLOGY

This section explains the operation of the Nutrient Monitoring for Fertigation System. The project's block diagram is shown in **Figure 1**.

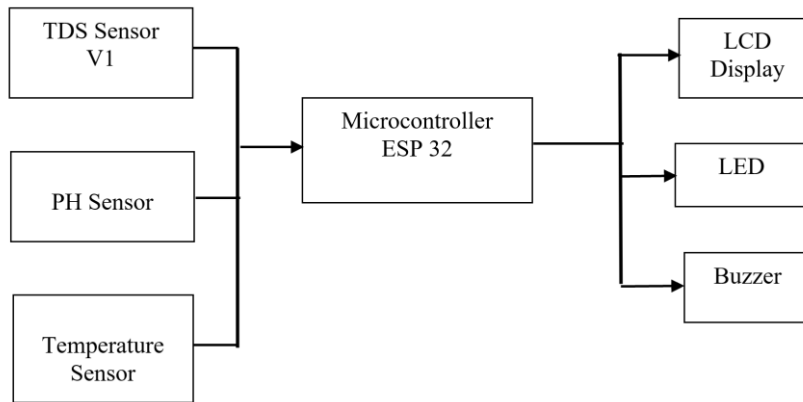


Figure 1. Block diagram of the nutrient monitoring for fertigation system

The block diagram represents the functional structure of the Nutrient Monitoring System. The TDS Sensor V1.0 measures the Total Dissolved Solids of the nutrient solution to indicate nutrient concentration, while the pH sensor monitors the acidity or alkalinity, and the temperature sensor measures the solution temperature. These sensors continuously collect data and transmit the measured signals to the ESP32 microcontroller, which acts as the main processing unit of the system by converting sensor data into readable values and determining whether the parameters are within predefined safe ranges.

Based on the processed data, the ESP32 controls several output components, including displaying real-time readings on an LCD, activating LED indicators as visual alerts, and a buzzer as noise alerts when parameters exceed acceptable limits. Overall, the block diagram demonstrates an integrated system that combines sensing, processing, and communication to provide an efficient and reliable fertigation monitoring solution.

RESULT AND DISCUSSION

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

Table 1. System status of Nutrient Monitoring for Fertigation System

TDS (ppm)	pH	Temperature (°C)	LED	Buzzer	Status Display
< 300	< 5.5	< 25	RED	ON	Acidic
300 - 600	5.5 - 7.5	25 - 33	GREEN	OFF	Normal
Above 600	> 7.5	> 33	RED	ON	Alkaline

The results in **Table 1** illustrate the monitoring of water quality parameters such as TDS, pH, and temperature in real time. When the TDS value is below 300 ppm, the nutrient concentration is considered too low, indicating insufficient nutrients in the solution. In this condition, the red LED and buzzer are activated to warn the user, and the status display shows “Acidic.”

When the TDS value is between 300 and 600 ppm, the nutrient concentration is within the normal and suitable range for plant growth. At the same time, the pH value between 5.5 and 7.5 and the temperature range of 25°C to 33°C indicate optimal fertigation conditions. Under these conditions, the green LED

lights up, the buzzer remains off, and the status display shows “Normal.”

However, when the TDS value exceeds 600 ppm, the nutrient concentration becomes too high and may negatively affect plant growth. Similarly, a pH value above 7.5 indicates alkaline conditions, while temperatures above 33°C may stress the plants and reduce nutrient absorption efficiency. In these situations, the system activates the red LED and buzzer as warning indicators, and the display shows “Alkaline.”

CONCLUSIONS

This project successfully designed and developed a Nutrient Monitoring for Fertigation System that measures Total Dissolved Solids (TDS), temperature, and pH of nutrient solutions in real time using an ESP32 DevBoard integrated with TDS, DS18B20, and pH sensors. The system displays data locally on an LCD display and provides immediate alerts by using a buzzer and LED indicators if parameters exceed safe thresholds. The project demonstrates that real-time monitoring improves nutrient management, reduces human error, and optimizes crop growth. Overall, the project fulfils its objectives by providing a practical, low-cost, and user-friendly solution for modern fertigation management.

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OVERCURRENT DETECTOR AND MONITORING SYSTEM

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Abstract: The excessive usage of electrical equipment and lack of supervision when using them are among the main causes of fatal incidents involving their use. Overcurrent, which is strongly linked to overload and can lead to electrical incidents, is one of the electrical hazards that can be produced. In order to avoid this from happening, an overcurrent detector and monitoring system are created. This system uses an ESP32 microcontroller along with two sensors, a current sensor and a voltage sensor. These sensors will measure the AC current and AC voltage values in real-time. When an overcurrent condition is detected, it triggers immediate alerts by activating the buzzer and sending a notification through the Blynk application and email.

Keywords: Overcurrent, detector, ESP32, monitoring

INTRODUCTION

Life and property are seriously at risk due to electrical fire hazards in residential areas. One of the main causes of these incidents is overcurrent issues. Two methods have been used to prevent such incidents from happening: the first one is the traditional method, where fuses and circuit breakers are used. The second method is the modern method, which is used by incorporating cutting-edge technologies, such as advanced sensors, microcontrollers, and communication modules. Therefore, an overcurrent detector system is chosen because of their advanced technologies, such as real-time monitoring, IoT integration, and smart sensors that can provide a robust layer of protection against potential risk [1].

[2] focuses on creating an automatic system that will enhance electrical safety in homes and small businesses, which can avoid damage to electronic devices. Its specific goal is to create a system that can monitor and regulate electrical current in real time and automatically cut off power when overcurrent is detected. This project used a NodeMCU ESP 8266 microcontroller as the main processor of the project system. The sensor that is used in this project is a PZEM-004T module, which is different from the sensor I used in my project. For this project, it also includes the control module, which is a relay module that is used to serve as an automatic switch that will disconnect the power when limits are exceeded.

Another similar project improves the reliability of the distribution transformer and the electrical infrastructure by monitoring and controlling overloaded conditions. Its main objective is to improve electrical safety by offering real-time monitoring and quick power supply disconnections in the event of fault occurrence, such as an overcurrent. The NodeMCU ESP8266 and Arduino UNO microcontroller are used in this project as the main processor. The Arduino UNO is used to process sensor data and carry out commands, and the NodeMCU ESP8266 is utilised to integrate with the Wi-Fi module. In contrast to the current sensor SCT-013 utilised in my project, the current sensor used in this project is ACS712. To monitor and receive fault notifications, this system establishes a connection with the Blynk mobile application. To provide a path for current and trip the circuit automatically when an overload is detected, the relay module is attached between the controller and the load [3].

Meanwhile, [4] reduces electricity waste in the residential sector by implementing an IoT-Based smart energy monitoring system and demand response system. According to the study, households generate about 41% of electrical waste, and putting such a system in place can result in energy savings of 7.8% up to 16.7%. The Arduino UNO and NodeMCU ESP8266 microcontroller were implemented in the system hardware. The NodeMCU ESP8266 was utilized to connect to the internet using a Wi-Fi module, specifically the ESP8266, to receive messages from any location and monitor using a mobile application or on an LCD. The ACS712 current sensor module and a voltage sensor were used in this project to

measure the current and voltage values.

This project aims to develop an overcurrent detector and monitoring system designed to detect current values in high-power appliances. This prototype can track the current usage, detect overcurrent value, and display the safety status. An IoT notification is also issued.

METHODOLOGY

This section explains the operation of the project. The project's block diagram is shown in Figure 1.

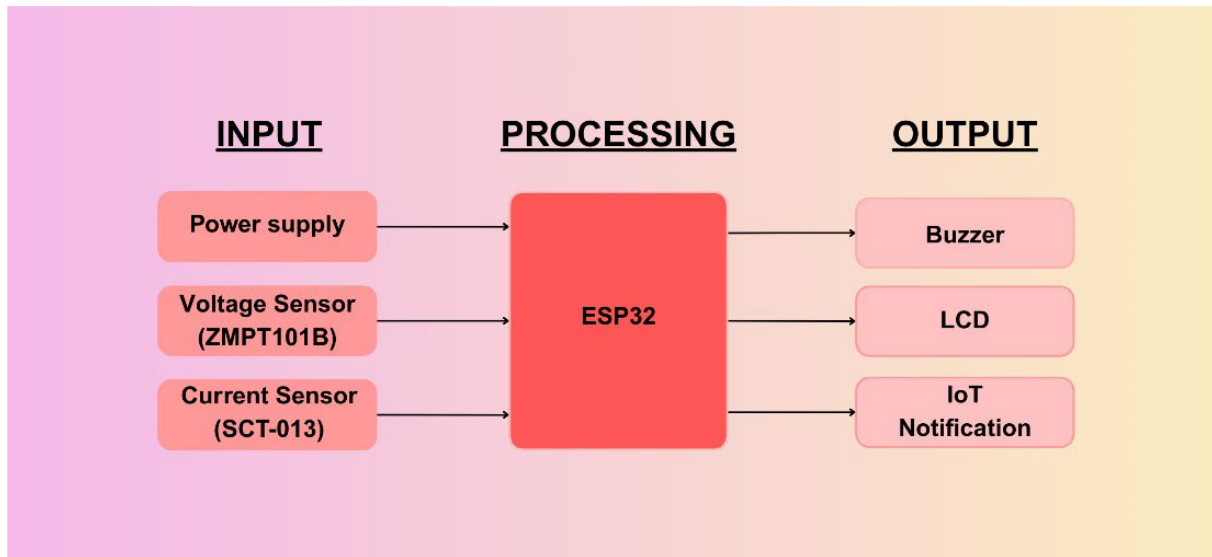


Figure 1. Block diagram of Overcurrent Detector and Monitoring System

Figure 1 shows a block diagram of the proposed system. This system can be implemented using an ESP32 microcontroller, a current sensor, a voltage sensor, an LCD, and LEDs. The power source supplies power to the load. The current sensor SCT-013 will measure the current load and send the data to the ESP32 microcontroller. Based on the input, the ESP32 will notify the user using the IoT. The LCD will display the value of the current and voltage, and also include the condition of the device.

RESULT AND DISCUSSION

The project has been tested as shown in the results below:

Table 1 Comparison between Breadboard and PCB

Comparison	
Breadboard	PCB
The LCD turns on and shows the parameter and status	The LCD turns on, but no parameter and status are shown
The buzzer turns on according to the threshold set	The buzzer always turns on, even if it does not exceed the threshold value

Calibration Formula:

$$\text{New calibration} = \text{Old Calibration} \times \frac{\text{MULTIMETER VALUE}}{\text{SERIAL MONITOR VALUE}}$$

Table 2 Calibration

Appliance	Multimeter	Serial Monitor	
		Before calibration	After calibration
Steam Iron	6.16 A	3.77 A	6.20 A
Dry Iron	3.70 A	6.27 A	3.70 A

CONCLUSIONS

The project successfully validated the fundamental idea of overcurrent monitoring and provided practical experience in PCB design and assembly, system development, and troubleshooting. The challenges encountered highlight critical concerns for future improvement in PCB design, soldering techniques, and quality.

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A ROBOTIC SOLUTION FOR AUTOMATED PING PONG BALL RETRIEVAL

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Abstract: This project details the design, implementation, and performance evaluation of an autonomous ping pong ball collector robot developed to assist in the efficient retrieval of scattered balls in indoor sports and recreational facilities. The system is built around an ESP32 microcontroller, which processes environmental data and manages peripheral systems. For physical operation, the robot utilizes DC motors driven by an L298N dual H-bridge motor driver for locomotion, alongside a secondary DC motor-driven suction mechanism controlled via a relay module to securely collect the balls. An HC-SR04 ultrasonic sensor provides continuous distance mapping to ensure successful obstacle detection and collision avoidance. Power distribution is managed through a 7.4V lithium-ion battery system coupled with an LM2596 buck converter for precise voltage regulation. Hardware evaluation confirms that the prototype navigates indoor environments autonomously, performs swift avoidance maneuvers, and safely activates its collection systems.

Keywords: ESP32, ping pong, Blynk, ultrasonic sensor

INTRODUCTION

In table tennis training facilities, multi-ball drilling and high-intensity practice routines continuously result in huge volumes of ping pong balls being scattered across the floor. The conventional method of cleaning the playing space requires players or coaching staff to manually bend over and gather the balls. This repetitive task is time-consuming, physically exhausting, disrupts training momentum, and poses an immediate slipping safety hazard to individuals on the court. While commercial solutions exist, they typically depend on expensive, bulky machinery that remains unaffordable for small local clubs, schools, or home users [1-3].

In order to bridge this technology gap, this project establishes a fully automated, cost-effective robotic framework. The target design is guided by two core objectives: to design and develop an autonomous mobile platform capable of clearing scattered balls with minimal human intervention using a specialized suction mechanism and to integrate a sensor-driven navigation logic using an onboard microcontroller to perform active obstacle mapping and ensure fluid collision avoidance [4-6].

METHODOLOGY

The execution of the project follows a systematic methodology spanning hardware architecture, custom printed circuit board (PCB) engineering, and embedded firmware development.

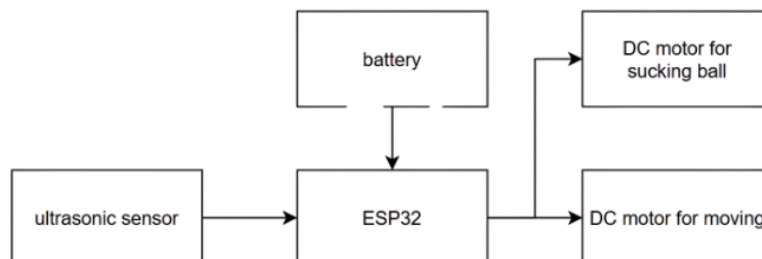


Figure 1. Block diagram of Ping Pong Ball Collector

Figure 1 shows the block diagram of ping pong ball collector. A battery powers the ESP32, while an ultrasonic sensor provides distance data for obstacle detection. Based on this input, the ESP32 controls a DC motor for movement and another DC motor for sucking and collecting the ball.

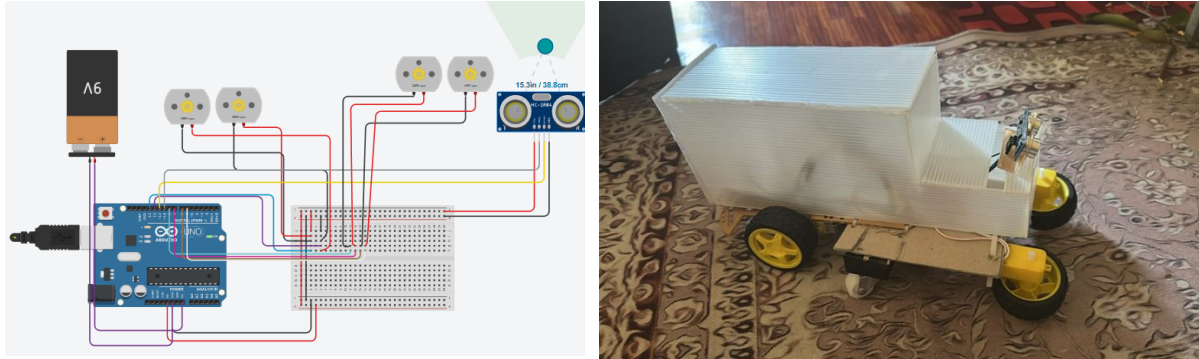


Figure 2. a) Simulation Circuit Configuration b) Prototype of Automated Ping Pong Ball Retrieval

Figure 2a) shows the simulation circuit configuration of the ping pong ball collector, while Figure 2b) shows the ping pong ball collector prototype designed as a small mobile vehicle. A 7.4 V battery provides power to the system, with all components sharing common ground. An ultrasonic sensor is connected to the ESP32, which triggers the sensor and reads the echo signal to measure distance. Based on this data, the ESP32 decides how the robot should move. The DC motors are driven through an L298N motor driver. The ESP32 sends control and PWM signals to the L298N, which safely supplies the higher current needed by the motors from the battery. Overall, the ESP32 handles sensing and logic, while the L298N handles motor power and direction control.

As the robot moves, ping pong balls can be guided into the front opening and stored inside the box compartment. The internal electronics, including the controller and battery, are mounted on the lower platform to keep the center of gravity low and improve stability. Overall, this prototype demonstrates a simple and effective design for automatically collecting ping pong balls, combining mobility, distance sensing, and a storage compartment in a compact structure.

RESULT AND DISCUSSION

System electrical performance in idle and running scenarios is shown in Table 1. In idle, the system consumes 18.5 W with 7.4 V and 2.5 A input voltage and current. The output voltage stays at 7.4 V, and the output current is 2.5 A, suggesting that the system is powered but not moving the motors or load. During operation, the input voltage drops to 7.2 V and the current declines to 2.24 A. The output voltage is regulated to 5.4 V, and the current is 1 A, producing 5.4 W. Power is used by the controller and motors when the system is running, and voltage regulation causes power loss.

Table 1. Data Measurement

Condition	Vin (V)	Iin (A)	Vout (V)	Iout (A)	Pout (W)
Idle	7.4	2.5	7.4	2.5	18.5
Run	7.2	2.24	5.4	1.0	5.4

Table 2. Battery consumption

Time (min)	Voltage (V)	Current (A)
5	7.40	0.56
10	7.19	0.53
15	7.01	0.49
20	6.83	0.47
25	6.69	0.44

Table 2 shows the 7.4 V Li-ion battery consumption of the ping pong ball collection robot for 25 minutes.

CONCLUSIONS

The development of this autonomous ball collector validates the integration of low-cost embedded hardware to handle repetitive indoor sports maintenance tasks. By pairing an ESP32 processor with isolated motor driver networks and targeted ultrasonic distance monitoring, the platform successfully maneuvers around obstacles while managing a constant suction mechanism. Empirically logged battery discharge profiles confirm over 25 minutes of continuous runtime coverage. Future revisions will look to refine efficiency further by exploring ultra-lightweight carbon chassis layups, multi-sensor navigation arrays, and advanced path-planning algorithms to track dispersed objects across larger gym spaces. The proposed Plant Care System has achieved the objectives of reading temperature, humidity, and moisture values. The water pump is also able to act accordingly to ensure the soil's conditions are suitable. This project can be enhanced by introducing wireless connectivity options for remote monitoring and control.

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SMART AQUAPONIC SYSTEM

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Abstract: Aquaponics is an integrated system that combines aquaculture and hydroponics, where both subsystems share the same water resources to support mutual productivity. This project is designed specifically for urban residents who have limited space for conventional agriculture, such as those living in condominiums or flats. The proposed system aims to maximize the efficient use of small spaces while enabling sustainable vegetable cultivation and fish farming. The developed aquaponic system incorporates automated monitoring and control features to maintain suitable environmental conditions. A water level monitoring mechanism is implemented using sensors and indicator LEDs. When the water level falls below the normal threshold, a solenoid valve is activated to allow water to enter the aquarium until the desired level is restored. Conversely, when the water level exceeds the normal range, a water pump inside the aquarium is activated to discharge excess water until the level returns to normal. In addition, the system monitors water temperature to ensure an appropriate environment for aquatic life and plant growth. If the water temperature falls outside the optimal range of 27°C to 32°C, the water pump is activated to regulate the water condition. The system also includes a Light Dependent Resistor (LDR) sensor to detect low-light conditions during nighttime or cloudy weather. Under these conditions, LED grow lights are automatically switched on to provide sufficient lighting for the plants. Overall, this project demonstrates an automated and space-efficient aquaponic system suitable for urban applications, promoting sustainable food production and smart agricultural practices.

Keywords: Arduino UNO, aquaponic, LDR, LED

INTRODUCTION

Aquaponics is an integrated food production system that combines aquaculture (fish farming) and hydroponics (soilless plant cultivation) in a symbiotic environment. In this system, fish waste is converted into nutrients for plants, while plants help filter and clean the water for fish, creating a sustainable and closed-loop system. This method is increasingly recognized as an efficient solution for food production due to its low water consumption and reduced need for chemical fertilizers [1].

In recent years, aquaponics has gained attention as a suitable approach for urban agriculture, especially in areas with limited land availability. Studies show that aquaponic systems can be implemented in small-scale environments such as homes and apartments, making them ideal for urban residents [2]. However, maintaining stable conditions such as water level, temperature, and lighting is essential for ensuring system productivity and biological balance.

To improve system efficiency, this project is equipped with automatic water level control using a solenoid valve and water pump, as well as temperature monitoring to maintain suitable water conditions between 27°C and 32°C. Furthermore, the integration of LED lighting and LDR sensors enhances plant growth efficiency during dark conditions. These technologies allow real-time control of environmental parameters such as water level, temperature, and lighting conditions, reducing manual intervention and improving system reliability [3]. As a result, smart aquaponic systems provide a practical and sustainable solution for urban farming applications.

METHODOLOGY

This section explains the operation of the Smart Aquaponic System. The project's block diagram is shown in **Figure 1**.

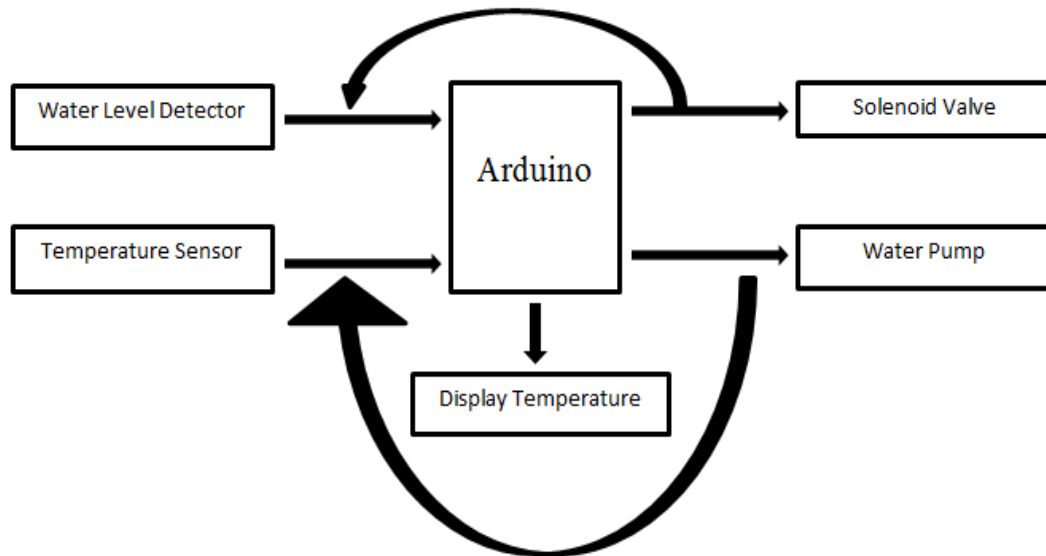


Figure 1. Block diagram of the Smart Aquaponic System

The block diagram in **Figure 1** outlines an automated water control system that uses an Arduino as its central brain. This setup is designed to monitor and manage water conditions without human intervention. The process starts with the inputs on the left: a water level detector and a temperature sensor. These devices act as the system's "eyes and ears," constantly gathering data and sending it to the Arduino for analysis.

Once the Arduino receives this information, it processes it based on pre-set rules. This is where the feedback loops (the curved arrows) come into play. For example, if the water level is too low, the Arduino senses this and tells the system to act. It also manages a Display Temperature module, which serves as a simple interface so a user can see exactly what the current thermal status is at any given moment.

Finally, the Arduino triggers the outputs on the right: the Solenoid Valve and the Water Pump. These are the mechanical parts that do the physical work, such as opening a valve to let water in or turning on a pump to move water through the system. By linking the sensors directly to these actuators through the Arduino, the system creates a continuous cycle that keeps the water level and temperature at the correct levels automatically.

RESULT AND DISCUSSION

Table 1. Experimental result and system response analysis for a day

Time	Temp (°C)	Environmental Condition	System Analysis and Response
5.30 AM	26.5	Low ambient	Pump activated for drainage; Solenoid valve engaged for freshwater replenishment.
1.00 PM	33.0	High ambient	Thermal threshold exceeded; Pump and Solenoid valve triggered for water exchange.
2.00 PM	31.5	High solar radiation	Evaporation detected; Solenoid valve activated to compensate for water loss.
3.30 PM	31.0	Precipitation (rain)	Level sensors detected a rise; Pump activated to restore nominal water level.
9.00 PM	28.5	Night time	Parameters within nominal range; Photo-resistor triggered automatic lighting.

An experimental result detailed in **Table 1** illustrates the system's capacity for autonomous environmental regulation through a series of reactive measures. During the early morning and midday periods, the system demonstrated precise thermal homeostasis; when temperatures deviated from the ideal range, dropping to 26.5°C at 5:30 AM then climbing to 33.0°C at 1:00 PM. The Arduino initiated a water exchange process. By coordinating the drainage via the water pump and replenishment through the solenoid valve, the system effectively utilized freshwater as a heat transfer medium to stabilize the aquarium's internal climate.

Beyond temperature control, the system successfully managed the physical water volume in response to fluctuating weather conditions. At 2:00 PM, the logic accounted for high solar radiation by activating the solenoid valve to compensate for volume lost to evaporation. Conversely, when precipitation caused a rise in water levels at 3:30 PM, the system switched to a drainage mode. This dual-action capability ensures that the aquarium maintains a constant hydrological state, protecting the hardware from overflow and the aquatic environment from desiccation.

Finally, the transition to nighttime conditions at 9:00 PM confirmed the reliability of the system's peripheral automation. As ambient light levels decreased, the photo-resistor triggered the lighting system, while the water parameters were recorded as being within the nominal range (28.5°C). This indicates that the control logic is sophisticated enough to prioritize different sensor inputs based on environmental necessity. Overall, the data confirms that the integration of sensors and actuators creates a robust closed-loop system capable of maintaining a stable, life-sustaining environment despite unpredictable external variables.

CONCLUSIONS

The development and testing of this project demonstrate the effectiveness of using a microcontroller-based architecture to maintain environmental stability. Smart Aquaponic System met all the objectives by integrating an Arduino with a suite of sensors and actuators; the project successfully transitioned from a theoretical design to a functional closed-loop control system. The experimental results confirm that the system can operate autonomously without the need for manual intervention.

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