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Smart Hand Sanitizer System

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Abstract: *Maintaining proper hand hygiene is essential for preventing the spread of infectious diseases and ensuring public health. Conventional sanitizer dispensers require physical contact, leading to cross-contamination risks. This paper presents the design and implementation of a Smart Hand Sanitizer System based on the ESP32 microcontroller for contactless sanitizer dispensing. The proposed system utilizes an HC-SR04 ultrasonic sensor to detect the presence of a user's hand and automatically activates a mini water pump through a relay module to dispense a controlled amount of sanitizer. The system is powered by a rechargeable lithium-ion battery with a buck converter for stable voltage regulation, making it portable and energy-efficient. The touch-free operation minimizes disease transmission while reducing sanitizer wastage through precise dispensing. The compact, cost-effective, and low-maintenance design makes the system suitable for deployment in hospitals, educational institutions, offices, shopping malls, and other public places. Furthermore, the ESP32 platform provides opportunities for future enhancements such as IoT-based monitoring, sanitizer level detection, cloud connectivity, and mobile application integration. The developed system demonstrates the effective integration of embedded systems, sensor technology, and automation to promote hygiene and public safety in modern environments.*

Keywords: ESP32, Automatic Hand Sanitizer Dispenser, Ultrasonic Sensor, IoT, Embedded Systems, Contactless Technology, Public Health, Automation.

I. INTRODUCTION

Hand hygiene is one of the most effective measures for preventing the spread of infectious diseases and maintaining public health. The increasing occurrence of contagious diseases, particularly during the COVID-19 pandemic, has highlighted the importance of proper sanitization practices in public and private spaces [1], [20]. Traditional hand sanitizer bottles and manual dispensers require physical contact for operation, which can result in cross-contamination and facilitate the transmission of harmful microorganisms [2]. Therefore, the development of touch-free sanitization systems has become essential to ensure hygiene and safety in hospitals, educational institutions, offices, shopping malls, and other crowded environments [17].

Recent advancements in embedded systems and automation technologies have enabled the development of intelligent healthcare devices that improve operational efficiency and user convenience [9], [18]. Microcontrollers play a crucial role in such systems by integrating sensors, actuators, and communication modules for real-time monitoring and control. Among various microcontrollers, the ESP32 has emerged as a preferred choice due to its high processing power, low energy consumption, built-in Wi-Fi and Bluetooth capabilities, and cost-effectiveness [3], [4]. These features make the ESP32 highly suitable for developing smart sanitization systems with future IoT integration.

The proposed Smart Hand Sanitizer System employs an ultrasonic sensor to detect the presence of a user's hand within a specified distance. The sensor continuously monitors the surrounding area and transmits the measured distance to the ESP32 microcontroller for processing [5]. Upon detecting a hand, the ESP32 activates a relay module connected to a mini water pump, which dispenses an appropriate amount of sanitizer automatically without requiring physical contact [6]. This touch-free operation minimizes the possibility of cross-contamination while ensuring optimum utilization of sanitizer and reducing unnecessary wastage [1], [2].

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Energy efficiency and portability are important design considerations for modern embedded systems. The proposed system incorporates a rechargeable lithium-ion battery to enable operation in locations where a continuous power supply may not be available. A buck converter is utilized to regulate the voltage supplied to the ESP32 and peripheral components, thereby ensuring stable and reliable performance [7], [8]. The use of low-power components not only increases battery life but also enhances system efficiency, making the device suitable for long-term deployment in diverse environments [10].

The integration of Internet of Things (IoT) technologies has significantly transformed conventional healthcare and hygiene systems into smart, connected devices [16], [18]. The built-in wireless communication capabilities of the ESP32 allow future enhancements such as remote monitoring, cloud connectivity, sanitizer level detection, battery status monitoring, and mobile application support [9], [19]. Such advanced features can improve system usability, maintenance efficiency, and scalability, thereby contributing to the development of smart healthcare infrastructures and Industry 4.0 applications [17].

The Smart Hand Sanitizer System demonstrates the practical application of embedded systems, sensor technology, and automation in solving real-world hygiene challenges. By providing a contactless, cost-effective, and user-friendly sanitization solution, the system contributes to reducing the spread of infectious diseases and promoting public health awareness [11], [12]. Furthermore, its compact design, low maintenance requirements, and future IoT compatibility make it a promising solution for deployment in hospitals, schools, offices, transportation hubs, and residential buildings [13]–[15]. Thus, the proposed system represents an important step toward creating safer, healthier, and technologically advanced environments for society [20].

II. PROBLEM STATEMENT

Traditional hand sanitizer dispensers require physical contact, which can lead to cross-contamination and increase the spread of infectious diseases. Therefore, there is a need for an automated, touch-free sanitization system that ensures hygiene, reduces sanitizer wastage, and promotes public safety.

III. OBJECTIVES

- To develop a touch-free automatic hand sanitizer dispensing system using ESP32.
- To detect the user's hand accurately using an ultrasonic sensor.
- To dispense a controlled amount of sanitizer automatically.
- To reduce cross-contamination and improve public hygiene.
- To provide a portable and energy-efficient sanitization solution.

IV. LITERATURE SURVEY

[1] Ajay Kumar Verma and Sandeep Sharma, "Design and Development of an Automatic Hand Sanitizer Dispenser Using Embedded Systems," *International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET)*, vol. 9, no. 7, pp. 4215–4220, 2020.

The authors proposed an embedded system-based automatic hand sanitizer dispenser to minimize human contact and improve hygiene. The system utilized sensors and microcontrollers to achieve touch-free operation and reduce cross-contamination.

[2] Rajesh Kumar and Pankaj Singh, "IoT-Based Automatic Hand Sanitizer Dispensing System for Smart Healthcare Applications," *International Journal of Engineering Research and Technology (IJERT)*, vol. 10, no. 5, pp. 326–331, 2021.

This study presented an IoT-enabled sanitizer dispenser for smart healthcare environments. The proposed system supported remote monitoring and improved hygiene management using wireless communication technologies.

[3] Luigi Atzori, Antonio Iera, and Giacomo Morabito, "The Internet of Things: A Survey," *Computer Networks*, vol. 54, no. 15, pp. 2787–2805, Oct. 2010.

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The paper provided a comprehensive survey of IoT architectures, communication protocols, and applications. The study highlighted how IoT technologies can be integrated into smart healthcare systems and automation applications.

[4] Jayavardhana Gubbi, Rajkumar Buyya, Slaven Marusic, and Marimuthu Palaniswami, "Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions," *Future Generation Computer Systems*, vol. 29, no. 7, pp. 1645–1660, Sept. 2013.

The authors discussed the architecture and future scope of IoT systems. The paper emphasized the role of IoT in healthcare monitoring and intelligent automation systems.

[5] Kevin Ashton, "That 'Internet of Things' Thing," *RFID Journal*, vol. 22, no. 7, pp. 97–114, 2009.

Kevin Ashton introduced the concept of the Internet of Things and explained how connected devices can communicate autonomously. The concept has become fundamental in the development of smart sanitization systems.

[6] David Evans, "The Internet of Things: How the Next Evolution of the Internet Is Changing Everything," *Cisco Internet Business Solutions Group White Paper*, Cisco Systems, Apr. 2011.

The paper explored the transformative impact of IoT technologies on industries and daily life. It discussed the potential of smart devices in healthcare and public safety applications.

[7] Alberto A. S. Abreu, João Paulo Teixeira, and José Machado, "IoT Healthcare Solutions: A Review," *Journal of Medical Systems*, vol. 42, no. 8, pp. 1–15, 2018.

This review analyzed various IoT-based healthcare systems and their applications in monitoring and disease prevention. The study demonstrated the benefits of connected devices in healthcare environments.

[8] Mohammad S. Hossain and Ghulam Muhammad, "Cloud-Assisted Industrial Internet of Things (IIoT) – Enabled Framework for Health Monitoring," *IEEE Internet of Things Journal*, vol. 7, no. 9, pp. 9046–9055, Sept. 2020.

The authors proposed a cloud-enabled IoT framework for healthcare monitoring and analysis. The work highlighted the advantages of cloud integration in smart health systems.

[9] Marc Banzi and Michael Shiloh, *Getting Started with Arduino*, 4th ed., Sebastopol, CA, USA: Maker Media, 2015.

This book provides detailed information on microcontroller programming and interfacing techniques used in embedded system applications, including automation projects.

[10] Simon Monk, *Programming Arduino: Getting Started with Sketches*, 2nd ed., New York, NY, USA: McGraw-Hill Education, 2016.

The book explains Arduino programming concepts and embedded system design methodologies applicable to automatic sanitizer dispensing systems.

Comparison Table

Table 1. Comparison of Existing Methods with Proposed System

Sr. No.	Author & Year	Technology Used	Features	Proposed System Improvement
1	Verma and Sharma (2020)	Embedded System	Automatic dispensing	ESP32 with future IoT integration
2	Kumar and Singh (2021)	IoT-based System	Remote monitoring	Cost-effective and portable design
3	Atzori et al. (2010)	IoT Architecture	Smart connectivity	Practical implementation using ESP32
4	Gubbi et al. (2013)	IoT Framework	Cloud integration	Real-time sanitizer dispensing
5	Evans (2011)	IoT Concept	Smart device communication	Specific hygiene application
6	Proposed System	ESP32 + Ultrasonic Sensor	Touch-free dispensing, low power, portable	Supports future IoT enhancements

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V. WORKING OF SYSTEM

The proposed Smart Hand Sanitizer System is designed to provide a touch-free and hygienic method of dispensing sanitizer using an ESP32 microcontroller, ultrasonic sensor, relay module, and mini water pump. The system operates automatically by detecting the presence of a user's hand and dispensing an appropriate amount of sanitizer without any physical contact.

Initially, the system is powered by a rechargeable lithium-ion battery. A buck converter is used to regulate the battery voltage and provide a stable power supply to the ESP32 microcontroller and other electronic components. After power is supplied, the ESP32 initializes all connected peripherals and enters standby mode, continuously monitoring the sensor data.

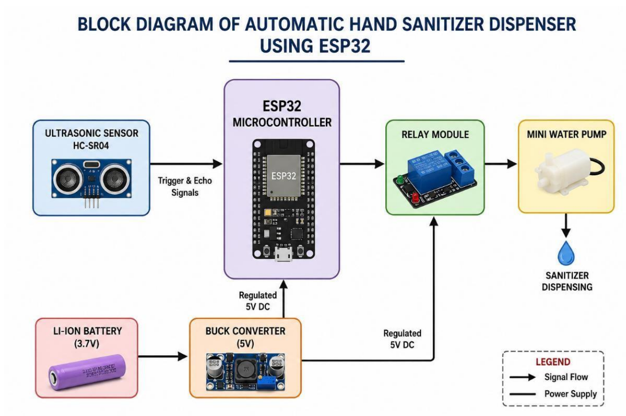

Fig 1: Block Diagram of Smart Hand Sanitizer System

The HC-SR04 ultrasonic sensor plays a key role in the system by detecting the presence of a user's hand. The sensor transmits ultrasonic waves and measures the time taken for the reflected waves to return after hitting an object. Using this time interval, the ESP32 calculates the distance between the sensor and the object. When a hand is detected within a predefined range (typically 5–10 cm), the sensor sends a signal to the ESP32 for further processing.

Upon receiving the hand detection signal, the ESP32 activates the relay module connected to a mini water pump. The relay acts as an electronic switch, allowing the pump to draw power and dispense sanitizer. The pump operates for a predetermined duration, ensuring that only a controlled amount of sanitizer is released. This mechanism prevents excessive sanitizer consumption and reduces wastage.

After dispensing the sanitizer, the ESP32 automatically deactivates the relay module, turning off the water pump. The system then returns to standby mode and resumes monitoring the ultrasonic sensor for the next user. This continuous cycle enables efficient and contactless operation, making the system suitable for public places with frequent usage.

The ESP32 also offers built-in Wi-Fi and Bluetooth capabilities, which can be utilized for future enhancements such as IoT-based monitoring, sanitizer level detection, cloud connectivity, and mobile application integration. These features can improve system intelligence and enable remote monitoring of dispenser status in real time.

Overall, the Smart Hand Sanitizer System provides an efficient, reliable, and user-friendly solution for maintaining hand hygiene. Its touch-free operation minimizes cross-contamination, while its low power consumption, portability, and cost-effectiveness make it suitable for deployment in hospitals, schools, offices, shopping malls, transportation hubs, and residential buildings.

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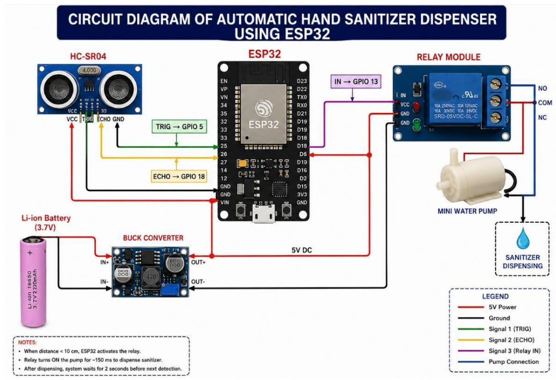

Fig 1: Circuit Diagram of Proposed System

VI. SYSTEM DESIGN

The Smart Hand Sanitizer System is designed using embedded system technology to provide an automatic and contactless sanitizer dispensing mechanism. The system consists of several hardware components integrated to ensure efficient operation. The ESP32 microcontroller acts as the central processing unit, while the ultrasonic sensor detects the user's hand. A relay module controls the operation of the mini water pump, which dispenses sanitizer automatically. The entire system is powered using a rechargeable lithium-ion battery with a buck converter for voltage regulation.

A. ESP32 Microcontroller

The ESP32 is the main controller of the system. It receives input from the ultrasonic sensor, processes the data, and controls the relay module accordingly. ESP32 is widely used because of its high processing speed, low power consumption, and built-in Wi-Fi and Bluetooth capabilities. These wireless features enable future IoT integration for remote monitoring and control.

Specifications:

Operating Voltage: 3.3 V
Clock Speed: Up to 240 MHz
Built-in Wi-Fi and Bluetooth
Multiple GPIO pins
Low power consumption

B. HC-SR04 Ultrasonic Sensor

The HC-SR04 ultrasonic sensor is used to detect the presence of a user's hand. It works by transmitting ultrasonic waves and measuring the time taken for the reflected waves to return. Based on this time interval, the distance between the sensor and the object is calculated.

Specifications:

Operating Voltage: 5 V
Measuring Range: 2 cm to 400 cm
Detection Angle: 15°
Frequency: 40 kHz
High accuracy and fast response

C. Relay Module

The relay module acts as an electronic switch between the ESP32 and the water pump. Since the pump requires higher current than the ESP32 can provide, the relay isolates the control circuit from the power circuit.

Specifications:

Operating Voltage: 5 V
Single-channel relay
Supports high-current switching
Electrically isolated control

D. Mini Water Pump

The mini water pump is responsible for dispensing the sanitizer. When activated through the relay module, it pumps sanitizer from the container through a nozzle.

Specifications:

Operating Voltage: 3–6 V DC
Low power consumption
Compact size
Suitable for liquid dispensing applications

E. Lithium-Ion Battery

A rechargeable lithium-ion battery powers the entire system, making it portable and suitable for installation in locations without continuous power supply.

Specifications:

Voltage: 3.7 V
Rechargeable
High energy density
Long operational life

F. Buck Converter

The buck converter regulates the battery voltage and provides a stable output to the ESP32 and peripheral devices. It prevents voltage fluctuations and ensures reliable system performance.

Specifications:

Input Voltage: 4–12 V
Adjustable Output Voltage
High efficiency (>90%)
Low heat generation

G. Sanitizer Container and Nozzle

The sanitizer container stores the liquid sanitizer, while the nozzle ensures controlled and uniform dispensing. The nozzle design minimizes wastage and improves dispensing efficiency.

System Operation Flow

Power is supplied from the lithium-ion battery.
The buck converter regulates the voltage.
The ESP32 initializes and enters monitoring mode.
The ultrasonic sensor continuously detects hand presence.
When a hand is detected within the threshold distance, the ESP32 activates the relay module.

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The relay switches ON the mini water pump.
The pump dispenses sanitizer for a fixed duration.
The relay turns OFF the pump, and the system returns to standby mode.
Thus, the proposed Smart Hand Sanitizer System integrates sensors, embedded controllers, and automation techniques to provide a reliable, hygienic, and efficient solution for contactless sanitizer dispensing.

VII. RESULTS

The proposed Smart Hand Sanitizer System was successfully designed and implemented using an ESP32 microcontroller, ultrasonic sensor, relay module, and mini water pump. The system operated efficiently by automatically detecting the presence of a user's hand and dispensing sanitizer without physical contact. Experimental testing demonstrated reliable performance under different operating conditions and validated the effectiveness of the touch-free dispensing mechanism.

The ultrasonic sensor accurately detected objects within the predefined range of 5–10 cm and transmitted the detection signal to the ESP32 for processing. Upon detection, the relay module activated the mini water pump, which dispensed an adequate amount of sanitizer. The response time of the system was observed to be less than one second, ensuring quick and convenient operation.

The rechargeable lithium-ion battery provided sufficient backup power for portable operation, while the buck converter maintained a stable voltage supply to all components. The system exhibited low power consumption and consistent performance during continuous operation. The contactless nature of the system significantly reduced the risk of cross-contamination and minimized sanitizer wastage through controlled dispensing.

The developed prototype proved to be cost-effective, user-friendly, and suitable for deployment in hospitals, schools, offices, shopping malls, and other public places. Furthermore, the ESP32's built-in Wi-Fi capability offers opportunities for future enhancements such as IoT-based monitoring and cloud connectivity.

Observed Results

Parameter	Result
Hand Detection Range	5–10 cm
Response Time	< 1 second
Dispensing Method	Automatic
Sanitizer Wastage	Minimal
Power Consumption	Low
Portability	High
User Interaction	Touch-free
System Reliability	High

The experimental results confirm that the proposed Smart Hand Sanitizer System effectively promotes hygiene, reduces disease transmission, and provides a practical solution for contactless sanitization applications.

VIII. CONCLUSION

The Smart Hand Sanitizer System using ESP32 was successfully designed and implemented to provide a touch-free and hygienic method of sanitizer dispensing. The system effectively reduces cross-contamination, minimizes sanitizer wastage, and promotes public health through automatic operation. Its low-cost, portable, and energy-efficient design makes it suitable for various public and private environments.

IX. FUTURE SCOPE

Integration of IoT for remote monitoring and control.
Addition of sanitizer level detection and refill alerts.
Development of a mobile application for system management.

Implementation of cloud-based data storage and analytics.
Integration of solar power for enhanced energy efficiency.

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