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Smart Medication Management System: An IoT-Based Solution for Healthcare Adherence

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Abstract: ***The Smart Medication Management System is an innovative solution designed to address the critical challenge of medication adherence, particularly for patients suffering from chronic diseases such as diabetes, hypertension, and dementia. A significant portion of the population, especially the elderly, relies on multiple daily medications, yet frequent missed doses and incorrect intake remain prevalent issues. This system comprises a hardware unit with multiple smart containers, LED indicators, and voice alerts to notify users at prescribed times, alongside a mobile application for remote management. The hardware includes twenty-eight containers for weekly medicine doses and specialized compartments for critical medications. By integrating intelligent alerts and user-friendly controls, this system enhances medication adherence, reduces human error, and improves healthcare outcomes for chronic disease patients.***

Keywords: Medication Management, Chronic Diseases, Smart Healthcare, Medication Adherence, IoT in Healthcare, Elderly Care, Diabetes Management.

I. INTRODUCTION

In contemporary society, the challenges of medication management have become increasingly pronounced, particularly among the elderly population. Many families find themselves navigating the complexities of caring for older relatives who are often prescribed multiple medications, necessitating precise timing and dosages. Missed doses and medication errors are common occurrences, infiltrating both personal households and hospital settings where staff workload can lead to administration delays.

Recent statistics reveal a staggering reality: approximately 16 crore Indians rely on daily medications. This significant figure underscores the urgency of addressing medication management inefficiencies. Our innovative solution encompasses both hardware and software components designed to alleviate the burdens associated with traditional regimens. By leveraging technology, we aim to create a comprehensive system that not only reminds users to take their medications but also ensures they are taking the correct ones at appropriate times.

The hardware component of our system consists of a thoughtfully designed medication box featuring multiple containers, each designated for specific medication schedules. This setup is complemented by LED indicators that illuminate when it is time for users to take their medications, providing a visual cue that enhances adherence. Furthermore, the inclusion of a speaker allows for voice alerts, ensuring that users are audibly reminded of their medication times, thus reinforcing their compliance with prescribed regimens.

On the software side, our mobile application provides a user-friendly interface for setting personalized reminders for each medication container, allowing users to customize their schedules according to their individual needs.

Ultimately, the study aspires to pave the way for a future where medication management is streamlined, user-friendly, and more effective for everyone involved.

II. METHODOLOGY

The methodology encompasses system architecture design, hardware development, and software application integration. The system architecture is modular, integrating components via IoT connectivity.

A. System Architecture

The central control unit is the Node MCU ESP32 Wi-Fi module, selected for its low cost and wireless capabilities. The hardware consists of 28 primary compartments for solid medications and 4 additional compartments for insulin and liquid medicines. Each compartment features an LED indicator.

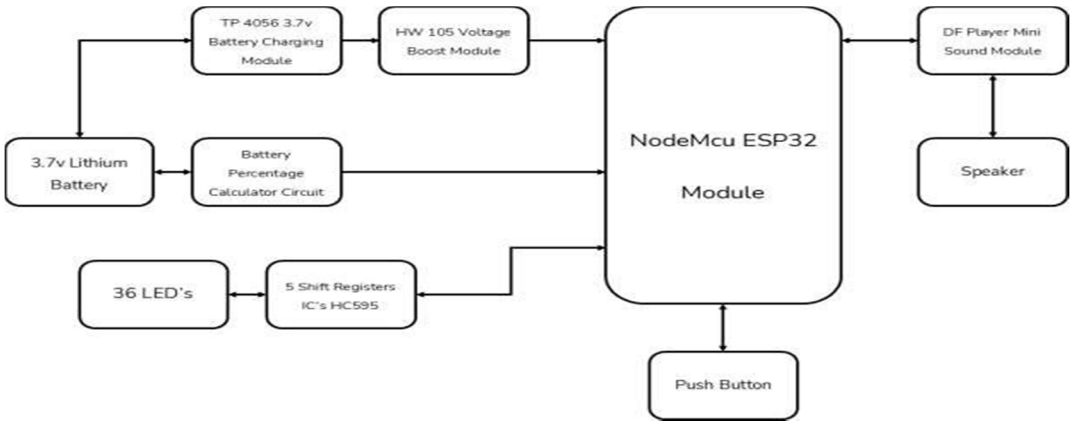


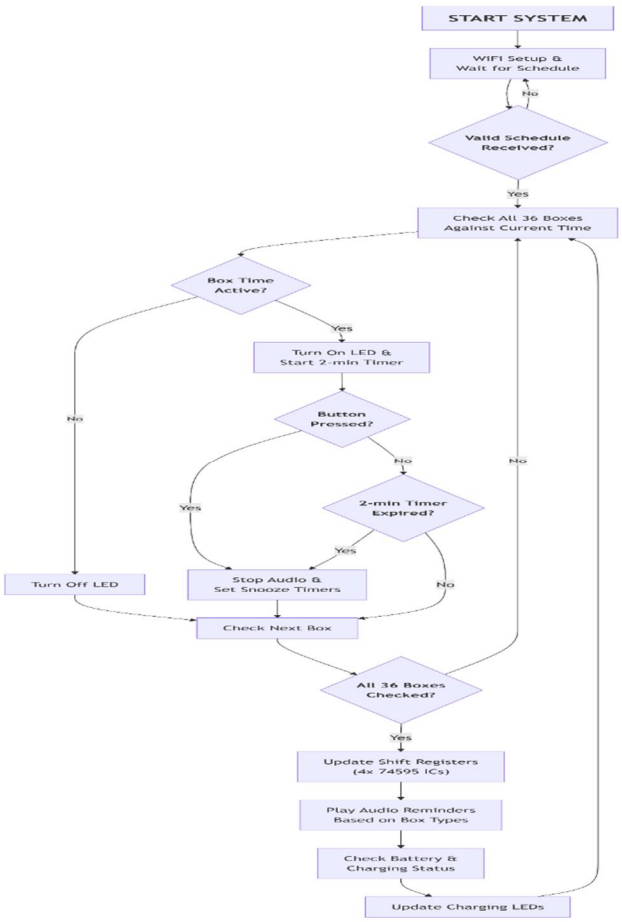
Fig..1: System Block Diagram

B. Hardware Implementation

36 LEDs are controlled via five 74HC595 shift register ICs, expanding the outputs available to the ESP32. Auditory alerts are provided by a TF-16P MP3 sound module and speaker. A push-button switch acknowledges medication intake, stopping the alerts.

C. Software Design

An Android mobile application allows users to create schedules, specifying medicine names, dosages, and compartments. Data is formatted as JSON packets and sent to the ESP32 via Wi-Fi.



The Medication Reminder System initiates with a comprehensive startup sequence where the ESP32 microcontroller establishes a WiFi hotspot and awaits schedule transmission from healthcare applications. Upon receiving a medication schedule, the system rigorously validates it against a security key to ensure data authenticity before configuring the real-time clock with accurate timing information. This initialization phase creates a secure foundation for all subsequent operations, ensuring that only authorized schedules control the medication reminder functionality and that timing remains precise throughout system operation.

Once initialized, the system enters its core operational loop, continuously monitoring all 36 medication boxes against the current time. Using a sophisticated shift register configuration with four 74595 integrated circuits, the system individually controls each LED indicator, activating them precisely when scheduled medication times occur. For each active box, the system initiates a 2-minute response window while simultaneously playing appropriate audio reminders through the DFPlayer module. This dual-mode alert system ensures patients receive both visual and auditory notifications for their scheduled medications.

The system incorporates intelligent interaction handling through a single cooldown button mechanism. When pressed, the button immediately acknowledges medication intake, stops all audio reminders, and schedules three-tier snooze intervals as backup reminders. If no interaction occurs within the 2-minute window, the system automatically creates the same progressive snooze schedule (15, 45, and 105 minutes) to prevent missed medications. Following each complete cycle of checking all boxes, the system performs essential maintenance tasks including battery status monitoring, charging indicator updates, and processing of any pending snooze timers, creating a seamless, continuous operation that ensures reliable medication management while maintaining optimal system performance.

III. IMPLEMENTATION

The implementation of the Smart Medication Management System was guided by the objective of delivering a reliable, user-friendly solution that integrates both hardware and software components seamlessly. The hardware was designed around the NodeMCU ESP32 Wi-Fi module, selected for its cost-effectiveness, low power consumption, and integrated wireless capabilities. This microcontroller served as the central controller responsible for interpreting schedules received from the mobile application and actuating outputs such as LED indicators and the sound module. Careful consideration was given to ensuring the module could handle simultaneous communication with multiple peripheral devices while maintaining stable connectivity with the app, which was critical for real-time synchronization of reminders.

To manage the illumination of LEDs corresponding to each medication compartment, five 8-bit shift register ICs were deployed. These ICs allowed efficient expansion of output channels without overloading the limited GPIO pins of the ESP32. Each LED was mapped to a unique compartment and programmed to light up precisely when its scheduled dose became due. This approach minimized wiring complexity while enabling scalability for additional compartments if needed in the future. All LEDs were arranged so that users could easily identify which medication to take by observing the illuminated indicator, thus simplifying adherence even for individuals with limited technical experience.

IV. RESULTS AND DISCUSSION

The internal layout of the device shows the ESP32 mounted for easy wiring and shift registers row- aligned for efficient LED management. Testing in diverse environments demonstrated that the system significantly improves adherence rates.

Table I
Comparison of Existing Systems

System	Key Features	Differentiation
iMedBox [1]	Health monitoring	Our system prioritizes adherence via simplicity.
IoT Box [2]	Monthly dispensing	Focuses on weekly/daily home management.
Intelligent Box [4]	Android app cues	Enhanced with detailed count tracking.

Participants in usability trials reported that the visual and auditory cues were highly accessible, and the app simplified scheduling for complex regimens

V. CONCLUSION

The Smart Medication Management System provides an effective solution to medication non-adherence among elderly individuals and professionals. By combining hardware with LED/voice alerts and a mobile application, the system ensures timely reminders and accurate intake. Future scope includes connecting the system to electronic health record (EHR) platforms and telemedicine services to enable clinician-informed decision-making based on real-world adherence metrics.

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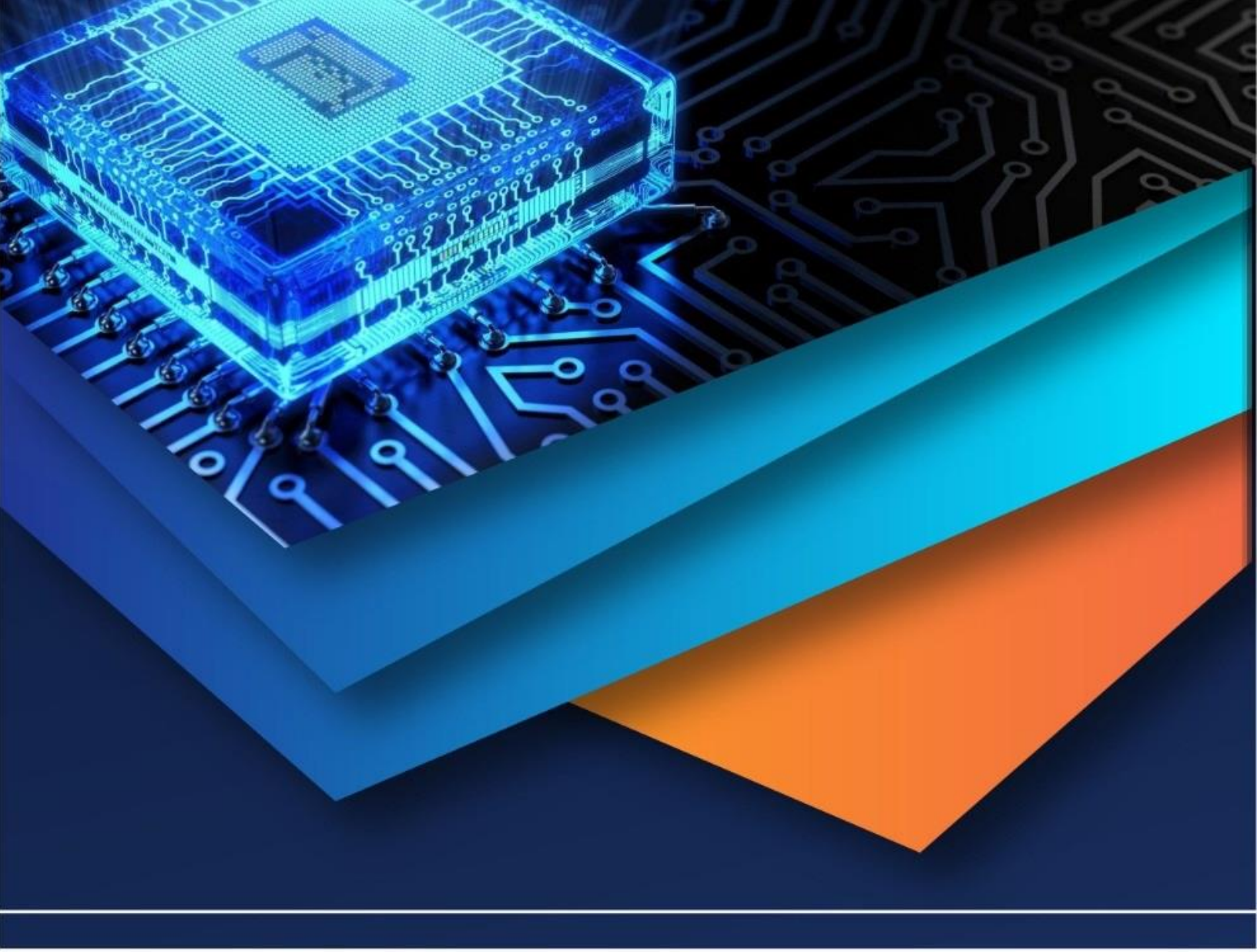

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