REAL-TIME MEDICINE REMINDER USING FREERTOS

24EE61 - REAL-TIME SYSTEMS LABORATORY

PROJECT REPORT

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(24MU01)

Dissertation submitted in partial fulfilment of the requirements for the degree of

MASTER OF ENGINEERING

Branch: ELECTRICAL & ELECTRONICS ENGINEERING

Specialization: EMBEDDED AND REAL-TIME SYSTEMS

of Anna University

MAY 2025

DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

PSG COLLEGE OF TECHNOLOGY

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SYNOPSIS

In modern healthcare applications, especially for elderly individuals and patients with chronic illnesses, real-time medicine reminders have become essential for improving treatment adherence, health outcomes, and quality of life. Missing doses or taking medication at incorrect times can lead to severe health risks, especially for individuals managing multiple prescriptions. To address this, the proposed system presents a real-time medicine reminder system built using the ESP32 microcontroller and FreeRTOS.

The system integrates key components such as the DS3231 RTC module (for accurate timekeeping), a buzzer (for auditory alerts), an OLED display (for visual notifications), and push-buttons (for user acknowledgment and interaction). FreeRTOS is used to manage concurrent tasks including time tracking, alert generation, display updates, and user input handling, ensuring deterministic scheduling and responsive system behavior. Each scheduled dose triggers a visual and audible reminder, and the user can acknowledge it through a button press, which reinforces medication adherence.

This modular and low-cost design ensures high reliability and is well-suited for home use without the need for continuous supervision. It is particularly beneficial for elderly users who require a simple, standalone solution to manage their medication routines effectively. The use of FreeRTOS enables scalability and flexibility for integrating more complex features in the future, such as dose history tracking or multi-dose reminders.

Though implemented using affordable components, the system demonstrates strong potential for practical deployment in real-world healthcare environments. Future enhancements could include IoT-based cloud integration for caregiver monitoring, mobile app interfaces for remote configuration, and smart scheduling algorithms to personalize medication routines. This solution lays a solid foundation for intelligent healthcare support systems focused on user-friendly, real-time interaction.

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND AND MOTIVATION

Medication non-adherence has become one of the critical challenges in the healthcare sector. Patients, particularly those suffering from chronic illnesses or undergoing complex treatment regimens, often find it difficult to keep track of multiple medications throughout the day. As a result, skipped doses or incorrect timings can lead to serious medical complications, increased hospitalization rates, and reduced quality of life.

To address this growing concern, the integration of embedded systems into personal healthcare offers an innovative solution. This project introduces a real-time medicine reminder system designed using FreeRTOS. Real-Time Operating Systems (RTOS) provide deterministic responses, allowing precise scheduling and execution of tasks based on urgency. In this context, FreeRTOS serves as the software backbone that coordinates timing, alert generation, and user interaction effectively.

By combining FreeRTOS with the ESP32 microcontroller and a real-time clock (RTC) module, this project ensures that medicine alerts are not only timely but also fail-safe. This initiative aligns with the increasing demand for intelligent health monitoring systems that are both autonomous and user-centric, minimizing human intervention while maximizing health safety and compliance.

Furthermore, the proposed system not only generates alerts but also facilitates user acknowledgment and logging mechanisms, ensuring a complete loop of notification and response. This feedback loop is essential in medical systems as it verifies that the patient has received and acted on the reminder, thereby reducing ambiguity in dosage compliance. In contrast to generic alarm-based solutions, this system provides both structure and traceability to medication management.

With the increasing availability of affordable microcontrollers and open-source real-time operating systems, it has become feasible to create highly responsive and customizable healthcare devices. This project stands as a proof-of-concept that merges medical utility with embedded intelligence. The architecture also allows for future enhancements, such as remote monitoring and AI-assisted scheduling, making it a scalable and forward-compatible solution for modern digital healthcare ecosystems.

1.2 PROBLEM STATEMENT

One of the most persistent and under-addressed challenges in patient healthcare is medication non-adherence—the failure to take medications at the prescribed times or dosages. This is particularly problematic for elderly patients, individuals with cognitive decline, and those managing multiple prescriptions simultaneously (polypharmacy). In such cases, even a minor lapse in memory can result in skipped doses, double dosing, or incorrect timing, leading to adverse drug reactions, prolonged recovery periods, and in severe cases, hospitalization or life-threatening complications.

Despite the availability of smartphones and digital alarm systems, these tools often fall short in meeting the dynamic and personalized needs of patients. Standard alarms do not adapt to changing schedules, cannot confirm whether medication was actually taken, and offer no logging or feedback mechanism. Moreover, they lack integration with physical medication storage or user acknowledgment features, making them ineffective for critical healthcare use.

Additionally, in environments where caregivers are not always present, such as with elderly individuals living alone or in rural areas, reliance on manual systems introduces significant risks. Without an automated and intelligent reminder system, patients are left vulnerable to human error and forgetfulness, both of which have measurable impacts on health outcomes and healthcare costs.

The lack of a low-cost, embedded, and real-time solution that can not only remind but also log and prioritize medication alerts is a significant gap in current healthcare technology. The goal of this project is to address this gap by developing a real-time medicine reminder system that provides timely, audible, and visual alerts, prioritizes reminder tasks, and allows for simple user acknowledgment, ensuring better medication adherence and patient safety.

1.3 OBJECTIVE OF THE PROJECT

The primary objective of this project is to design and implement a real-time, automated medicine reminder system that leverages the multitasking capabilities of FreeRTOS on an ESP32 microcontroller platform. The system is aimed at enhancing medication adherence by generating timely alerts based on predefined medicine schedules, thereby supporting patients in taking the right medicine at the right time.

A core goal is to ensure that critical operations, such as alert generation and real-time clock tracking, are handled with high priority using FreeRTOS's task scheduling mechanism. This allows the system to function with deterministic behavior, ensuring that alerts are never delayed or missed, even when multiple tasks are running concurrently.

Another objective is to integrate user interaction by incorporating simple hardware components like push buttons, enabling patients to acknowledge reminders directly. The system should then log this acknowledgment, effectively closing the loop and confirming that the medicine was taken. This creates a feedback mechanism vital for monitoring and auditing patient compliance.

The project also aims to make the system cost-effective, scalable, and user-friendly, with clear visual indicators via an OLED/LCD display and audio alerts using a buzzer. These design choices are intended to make the system accessible for elderly users and those without technical backgrounds.

In addition, the system is designed with modularity in mind, allowing future enhancements such as cloud connectivity, smartphone integration, and AI-based dynamic scheduling. Ultimately, this project seeks to provide a practical and reliable healthcare tool that can reduce medication errors, improve patient independence, and contribute positively to the broader goal of digital health transformation.

1.4 ORGANIZATION OF THE REPORT

The report is organized as follows:

- Chapter 2 discusses the review papers on previous work on Real-Time Medicine Reminder using FreeRTOS in past years.
- Chapter 3 describes the system development approaches.
- Chapter 4 discusses the hardware setup and results of the project work.
- Chapter 5 brief about the summary of work done ad future enhancements of the project work.

CHAPTER 2

LITREATURE SURVEY

Liu et al. (2025) developed a smart medicine box reminder system using the STM32F103C8T6 microcontroller. The system integrates an OLED display, infrared detection, servo motors, and Wi-Fi connectivity to manage medication schedules. Users can set reminder times and dosages, with voice alerts and automatic box opening at designated times. Infrared sensors monitor medication intake, and the system sends real-time data to a mobile application for monitoring and management. This design aims to assist users in adhering to medication schedules and improving their quality of life.[1]

Behera et al. (2022) introduced a self-health monitoring and medicine reminder system utilizing IoT technology. The system monitors vital health parameters such as body temperature, pulse rate, blood glucose level, and ECG. It provides timely medication reminders via LCD display and buzzer alerts. In case of abnormal readings, the system sends emergency messages to caregivers or medical professionals, facilitating prompt intervention. This approach enhances healthcare accessibility, especially in rural or resource-limited settings.[2]

Malvi et al. (2024) proposed an IoT-based medicine reminder system tailored for self-sufficient senior citizens. The system employs cloud connectivity to store and manage medication schedules, providing reminders through various interfaces. It aims to support elderly individuals in maintaining their medication routines independently, thereby promoting better health outcomes.[3]

Sree et al. (2020) designed a smart medicine pillbox reminder system featuring voice prompts and display notifications. The system targets emergency patients, ensuring they receive timely medication through audible and visual cues. This user-friendly design enhances medication adherence and reduces the risk of missed doses.[4]

Al-Haider et al. (2020) developed a smart medicine planner specifically for visually impaired individuals. The system incorporates tactile feedback and audio alerts to guide users in managing their medication schedules effectively. By addressing accessibility challenges, this planner promotes independence and health management among visually impaired users.[5]

Miao et al. (2021) introduced a home-style smart medicine box designed for the elderly. The device features user-friendly interfaces and automated dispensing mechanisms to assist seniors in adhering to their medication regimens. It emphasizes comfort and ease of use, aiming to improve the quality of healthcare for aging populations.[6]

Ahmad et al. (2020) presented an IoT-based pill reminder and monitoring system. The system tracks medication intake and provides real-time reminders to users. It also offers monitoring capabilities for caregivers, ensuring adherence to prescribed medication schedules and enabling timely interventions when necessary.[7]

Mathina et al. (2023) developed an enhanced medication reminder and alert system using IoT. The system provides timely alerts for medication intake and monitors adherence, aiming to reduce the incidence of missed doses. Its integration with IoT technologies allows for remote monitoring and data analysis, facilitating improved healthcare management.[8]

Velasco et al. (2020) created an intelligent pillbox that is automatic and programmable. The device assists users in managing complex medication schedules by providing automated dispensing and reminders. Its programmable features allow customization to individual needs, enhancing medication adherence and reducing errors.[9]

Ray (2014) proposed the Home Health Hub Internet of Things (H3IoT) framework for monitoring the health of elderly individuals. The architecture includes medication reminder functionalities, integrating various health monitoring devices to provide comprehensive care. This system aims to support aging populations in maintaining their health and independence through technology-driven solutions.[10]

CHAPTER 3

REAL-TIME MEDICINE REMINDER USING FREERTOS

The working of the real-time medicine reminder system is centered around an ESP32 microcontroller running FreeRTOS, which allows multiple tasks to operate concurrently while being scheduled based on priority. The system integrates several components including a DS3231 Real-Time Clock (RTC) module, an OLED or LCD display, a buzzer, and user input buttons. These components work together under the control of FreeRTOS to create a reliable and timely reminder mechanism.

Upon powering up, the system initializes all the hardware peripherals. The RTC module provides accurate timekeeping, which is critical for generating medicine alerts at the scheduled times. A dedicated high-priority FreeRTOS task continuously reads the current time from the RTC and compares it against the stored medicine schedule. This ensures that no medicine alert is missed due to delays or system load.

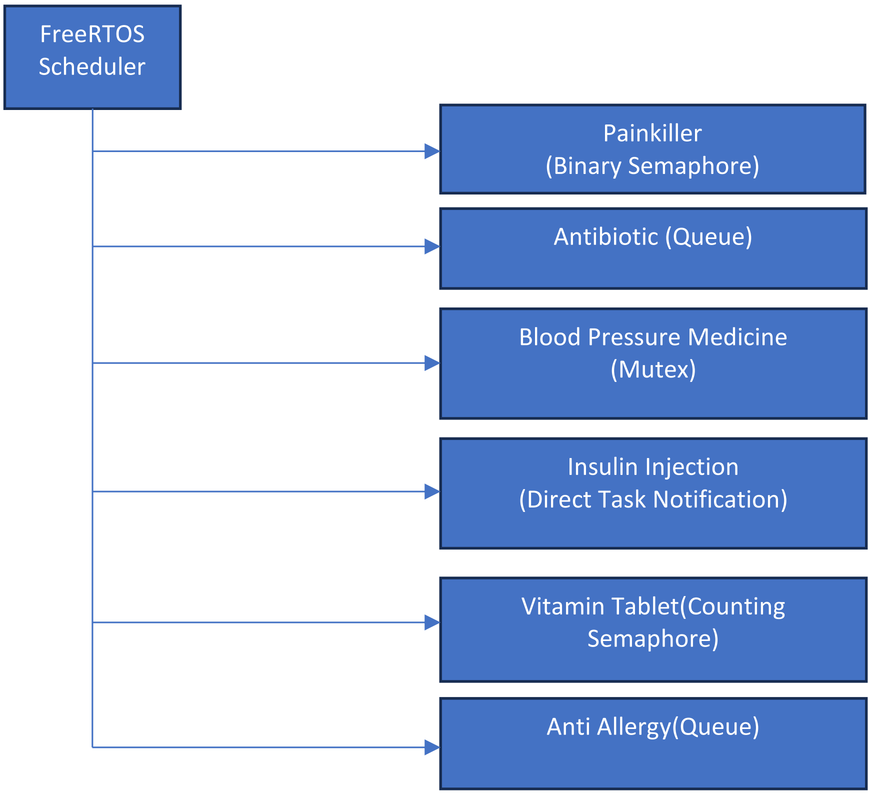

Figure 3.1: Block Diagram of working of the FreeRTOS Scheduler

Once the current time matches any of the predefined reminder times, another task is triggered to activate the alert mechanism. This involves turning on the buzzer to produce an audible sound and updating the OLED display to show a visual message indicating it is time to take the medication. The buzzer continues until the user acknowledges the alert, ensuring that the reminder is not ignored.

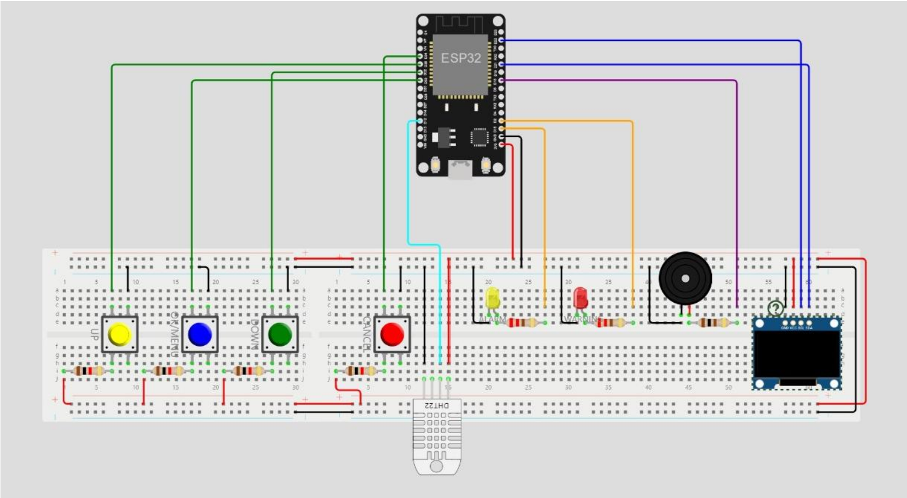

Figure 3.2: Circuit Diagram of the Real-Time Medicine Remainder System

For user acknowledgment, a push button is connected to the ESP32. A separate FreeRTOS task constantly monitors this button. When pressed, it indicates that the user has taken the medicine. The system then logs the acknowledgment, disables the buzzer, and clears the message from the display. This acknowledgment can also be stored in flash memory or displayed on-screen for audit and tracking purposes.

FreeRTOS features such as queues and semaphores are used for safe inter-task communication and synchronization. This ensures that the system remains responsive, and tasks like time tracking, display updates, and alert handling do not interfere with each other. Lower-priority tasks, such as updating logs or managing non-critical display elements, are executed without affecting the real-time performance of the system.

This modular design not only makes the system highly reliable and fault-tolerant, but also allows it to be expanded in the future. Features like remote monitoring via Wi-Fi, app integration, or multiple medication schedule tracking can be added with minimal modification to the core system architecture.

3.1 ESP32 Microcontroller

The ESP32 is a powerful, dual-core microcontroller with integrated Wi-Fi and Bluetooth capabilities. It is highly efficient for real-time applications, especially those requiring multitasking and low-latency execution. In this project, the ESP32 acts as the brain of the system, managing task scheduling, sensor communication, user interaction, and alert generation.

Figure 3.3: ESP32 Microcontroller

Working Principle:

The ESP32 uses its dual-core architecture to run multiple tasks concurrently. It is fully compatible with FreeRTOS, enabling the developer to create and manage tasks with defined priorities. The microcontroller communicates with peripherals like the RTC module, buzzer, display, and input buttons through its digital I/O, I2C, and SPI interfaces.

Key Features:

- Operating Voltage: 3.3V
- Clock Speed: Up to 240 MHz
- Dual-core processor
- Built-in Wi-Fi and Bluetooth
- GPIOs: Over 30 configurable pins
- FreeRTOS Support: Pre-installed with ESP-IDF, compatible with Arduino IDE

Applications:

- IoT Devices
- Smart Home Systems
- Wearables and Health Devices
- Industrial Automation

Usage in the Project:
The ESP32 is responsible for executing all core functionalities—reading time from the RTC, comparing it with scheduled reminders, generating audio-visual alerts, and handling user acknowledgment. It also runs the FreeRTOS kernel to ensure each task is executed with proper timing and priority.

3.2 DS3231 Real-Time Clock (RTC) Module

The DS3231 is a high-precision RTC module used to maintain accurate date and time, even in power-off conditions. It is essential for applications where precise timekeeping is required.

Figure 3.4: DS3231 RTC Module

Working Principle:
The module uses a temperature-compensated crystal oscillator (TCXO) to maintain time. It communicates with the ESP32 via the I2C protocol, delivering real-time clock data. A built-in battery ensures that the clock runs even when the main system is turned off.

Key Features:

- Operating Voltage: 3.3V
- Communication Protocol: I2C
- Accuracy: ±2ppm from 0°C to +40°C
- Battery Backup: Yes
- Registers: Seconds, Minutes, Hours, Day, Date, Month, Year

Applications:

- Time-based Automation
- Event Scheduling
- Clock-based Data Logging
- Wearable Health Devices

Usage in the Project:
The DS3231 module ensures accurate time tracking for the medicine reminder. The ESP32 reads the time at regular intervals to check if it matches any scheduled medication alert time.

3.3 Buzzer

The buzzer is used as an audible output device to alert the user when it's time to take their medicine.

Figure 3.5: Piezoelectric Buzzer

Working Principle:
The piezoelectric buzzer generates sound when an oscillating electric signal is applied. Controlled by a GPIO pin from the ESP32, it can be turned on or off based on the schedule.

Key Features:

- Voltage: 3.3V – 5V
- Sound Output: ~85 dB
- Control: Digital On/Off
- Low Power Consumption

Applications:

- Alarm Systems
- Notification Systems
- Health Devices
- Embedded Feedback Systems

Usage in the Project:

When the scheduled time is reached, the buzzer produces a tone to alert the user. It continues until the user acknowledges the reminder via a button press.

3.4 OLED Display

An OLED display is used to provide clear visual output of time, scheduled alerts, and user interaction feedback.

Figure 3.6: OLED Display Module

Working Principle:

The OLED module communicates with the ESP32 using I2C or SPI protocol. It displays alphanumeric characters and simple graphics using an embedded controller.

Key Features:

- Resolution: 128x64 pixels
- Interface: I2C
- Operating Voltage: 3.3V
- High contrast and visibility
- Compact and energy-efficient

Applications:

- Wearable Displays
- IoT Device Screens
- Environmental Monitors
- Embedded Dashboards

Usage in the Project:
The display shows current time, next reminder, and acknowledgment messages. It enhances the user experience and ensures the user is aware of system status at all times.

3.5 Push Button

The push button allows the user to acknowledge alerts. It is a simple but crucial input interface for the system.

Figure 3.7: Push Button

Working Principle:
The button completes or breaks a circuit when pressed, sending a digital signal (HIGH or LOW) to the ESP32. A FreeRTOS task monitors this input continuously.

Key Features:

- Operating Voltage: 3.3V
- Debounce Time: ~5ms (handled in software)
- Simple and reliable
- Easy to integrate with microcontrollers

Applications:

- User Input Panels
- Reset/Acknowledge Functions
- Industrial Controls
- Smart Home Buttons

Usage in the Project:

The user presses the button to acknowledge a medicine reminder. This disables the buzzer and updates the internal log to mark the medicine as taken.

3.6 FreeRTOS Library (Arduino IDE)

FreeRTOS is an open-source real-time operating system designed for embedded devices. It is integrated into this project to handle concurrent task execution and timing precision.

Figure 3.8: FreeRTOS Library Integration

Working Principle:

FreeRTOS enables the microcontroller to run multiple tasks in parallel by allocating time slices and setting task priorities. Tasks such as time checking, alert generation, and button polling are all managed independently without blocking one another.

Key Features:

1. Preemptive and Cooperative Task Scheduling
2. Inter-task Communication (Queues, Semaphores)
3. Low Memory Footprint
4. High Accuracy Timers and Delays
5. Compatible with Arduino IDE and ESP32

Applications:

- Industrial Controllers
- IoT and Automation Projects
- Wearables and Health Devices
- Robotics and Drones

Usage in the Project:

In the Arduino IDE, the Arduino_FreeRTOS.h library is included to define multiple tasks. FreeRTOS handles real-time execution of high-priority tasks (like time monitoring and alerts) while enabling background tasks (like logging or display updates) to run concurrently without delays.

CHAPTER 4

RESULTS AND DISCUSSIONS

The Real-Time Medicine Reminder system was successfully designed, implemented, and tested using the ESP32 microcontroller, FreeRTOS, and supporting hardware components including the DS3231 RTC, OLED display, buzzer, and user input buttons. The system's functionality was evaluated under multiple conditions to validate its reliability, responsiveness, and usability.

During testing, the system accurately tracked time using the DS3231 RTC module. Reminders were triggered at the correct time, as defined in the internal schedule. The buzzer generated audible alerts without delay, and the OLED display showed the correct time and reminder messages with clarity. The real-time execution of alert tasks was consistent, even when other lower-priority tasks were running in the background. This confirms that FreeRTOS's priority-based task scheduling was functioning as intended, with high-priority tasks such as alert generation taking precedence over less time-critical operations like display updates or button polling.

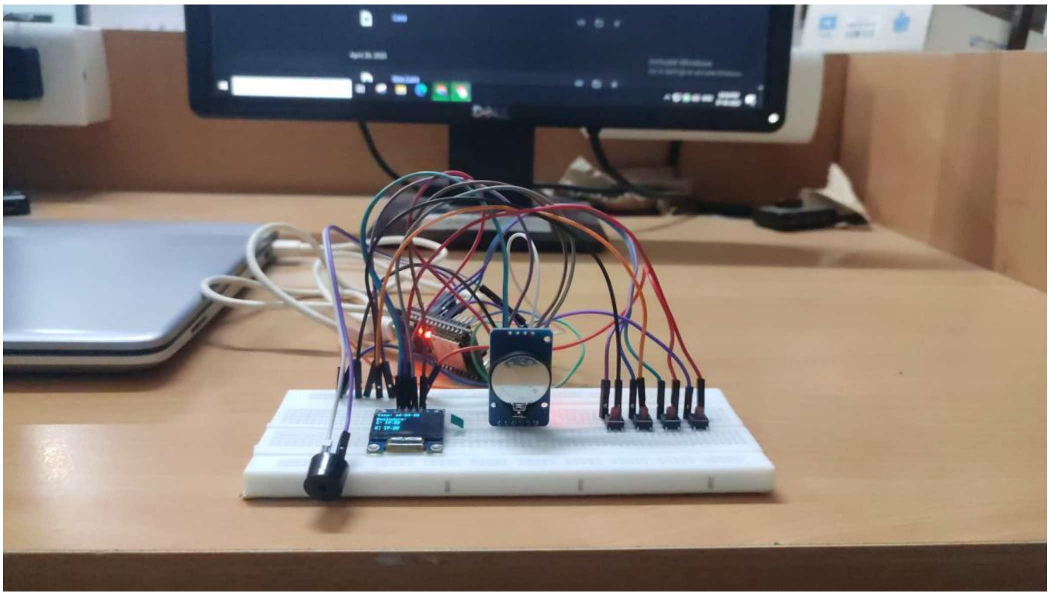

Figure 4.1: Full Hardware Setup

The integration of FreeRTOS significantly improved system responsiveness. Multiple tasks—such as time monitoring, display refresh, buzzer control, and button detection—were able to operate concurrently without interfering with each other. For instance, while the display was updating, the system could still detect the user’s button press instantly and respond by turning off the buzzer and logging the action. This real-time multitasking proved essential for creating a smooth and interactive user experience.

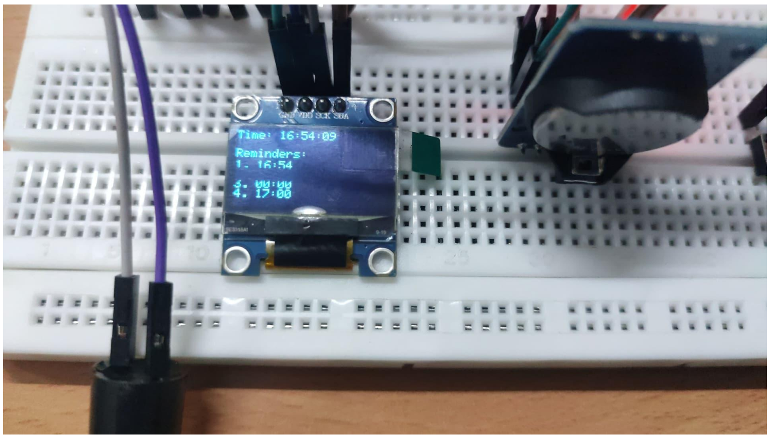

Figure 4.2: Medicine remainder time Queued in the OLED Display

The push button used for acknowledgment worked effectively. Upon pressing, the system silenced the buzzer and updated the reminder status. In real-life use cases, this feature simulates user feedback and ensures a closed loop where not only is the reminder sent, but it is also marked as received and acted upon. This creates opportunities for future enhancements such as digital logs or transmission of data to caregivers.

The system was tested over extended periods and proved to be stable with no system crashes, missed alerts, or freezes. FreeRTOS's built-in memory management and stack overflow checking helped maintain stable execution, even under multiple task loads. The RTC maintained precise timing throughout, and power interruptions were handled effectively using the RTC's onboard battery backup.

CHAPTER 5

CONCLUSION

5.1 SUMMARY OF THE WORKDONE

The project successfully implements a Real-Time Medicine Reminder System using the ESP32 microcontroller and the FreeRTOS operating system. The system addresses a crucial healthcare challenge—medication non-adherence—by delivering timely and automated alerts to ensure patients take their medications consistently and punctually. It integrates key hardware components including the DS3231 RTC for accurate timekeeping, an OLED display for visual reminders, a buzzer for audio alerts, and push buttons for user interaction and dose acknowledgment.

By leveraging FreeRTOS, the system efficiently manages multiple concurrent tasks such as real-time clock synchronization, alert generation, display updates, and button handling. The task-based design ensures responsive and deterministic system behavior, even under continuous operation. Each component is handled in an isolated FreeRTOS task, enabling modular code organization and easier debugging, while the use of queues and semaphores supports robust inter-task communication and synchronization.

A key feature of the system is its interactive feedback mechanism, where the user acknowledges medication intake via a push button, completing the alert cycle and enhancing user accountability. The integration of real-time scheduling ensures that each medication reminder is triggered precisely at the scheduled time, improving reliability and user trust. The system's low power consumption, standalone operation, and intuitive interface make it especially suitable for elderly users and those with complex medication regimens.

In conclusion, this project demonstrates a reliable, real-time healthcare reminder system with precise timing, multi-modal alerts, and user interaction. It highlights the potential of embedded systems and real-time operating systems in healthcare applications, offering a scalable and cost-effective solution for enhancing patient compliance, safety, and well-being. Additionally, the use of FreeRTOS for real-time task scheduling ensures that all periodic operations meet their deadlines, maintaining system responsiveness and operational stability even under concurrent task execution.

5.2 FUTURE WORK

Future enhancements to this Real-Time Medicine Reminder System could focus on integrating IoT capabilities for remote health monitoring and caregiver notifications. By leveraging the ESP32’s built-in Wi-Fi, scheduled medicine reminders and user acknowledgment data could be uploaded to cloud platforms such as Firebase or ThingSpeak, allowing caregivers or family members to remotely track patient adherence and receive real-time alerts.

Additional improvements could include the development of a mobile application or web dashboard for real-time visualization of medicine schedules, missed doses, and alert logs. This interface could provide push notifications, allowing users or caregivers to take immediate action in case of non-compliance. Integration with voice assistants such as Google Assistant or Amazon Alexa could further enhance accessibility for elderly or visually impaired patients.

The system could also be extended to support multiple medication schedules per day with dynamic rescheduling capabilities, adapting to changes in a patient's prescription or routine. RFID or NFC modules could be added to track which medicine has been taken, providing an additional layer of verification.

Moreover, incorporating biometric sensors such as heart rate or temperature monitors would allow the system to deliver personalized alerts based on the user's real-time health condition. Using machine learning algorithms, the system could analyze user interaction patterns and medication history to optimize reminder timings or detect signs of deteriorating adherence behavior.

Overall, these advancements would evolve the current system into a comprehensive and intelligent healthcare assistant, capable of supporting personalized care, enhancing patient safety, and reducing the burden on caregivers through data-driven, remote, and automated health management.

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