Multi-Purpose Digital Clock

with RTC and Stopwatch using STM32F446RE

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Project Abstract

This project presents a multi-purpose digital clock system using the STM32F446RE microcontroller, integrating real-time clock (RTC) and precision stopwatch capabilities with user-configurable settings.

Key Innovations

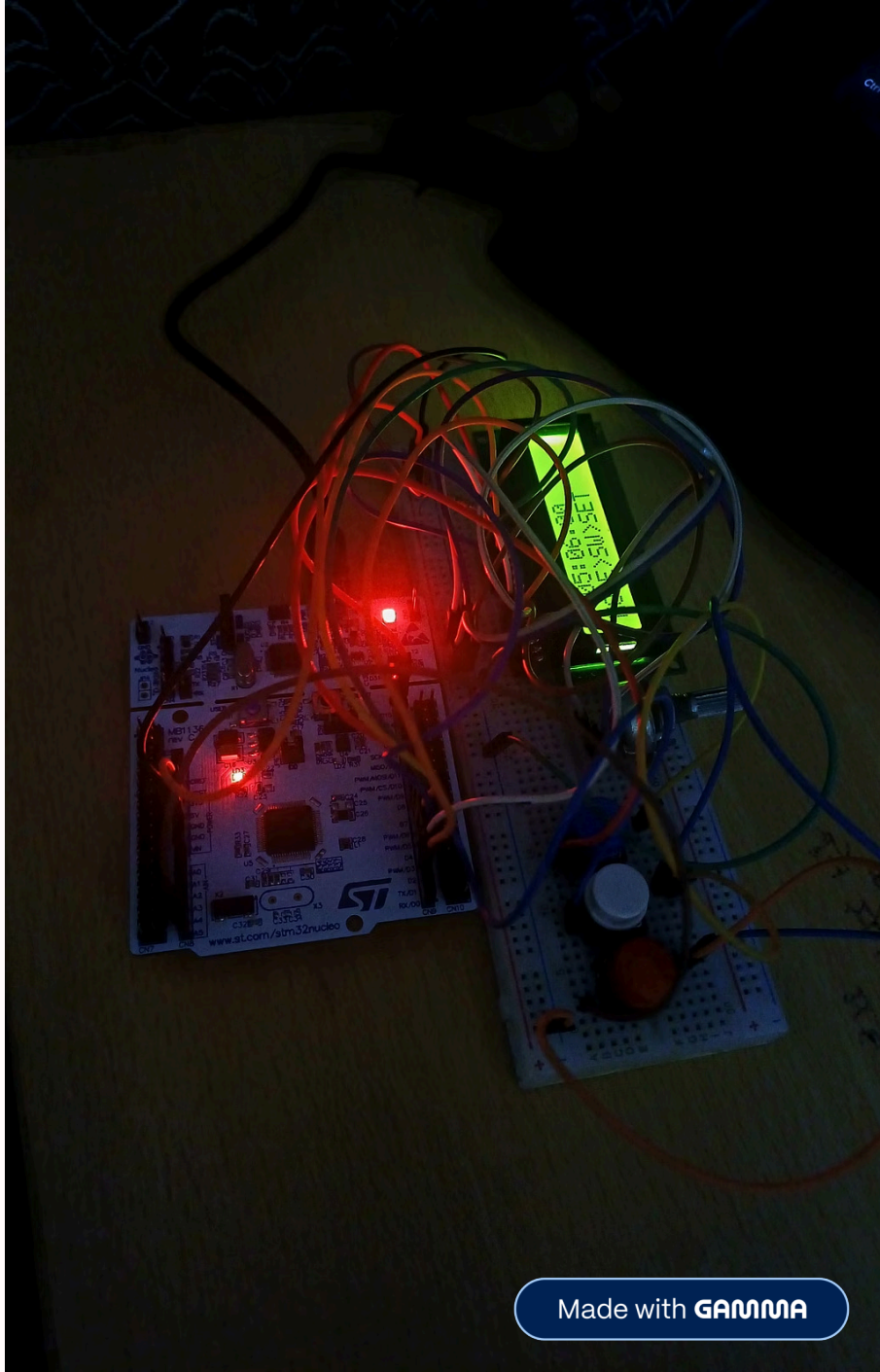
- Backup register for persistent timekeeping
- State-machine based mode management
- Space-optimized 16x2 LCD display

Achieved Accuracy

Accurate timekeeping with ±2 seconds/day precision.

Future Expansion

Modular design supports alarms, sensing, and wireless connectivity.

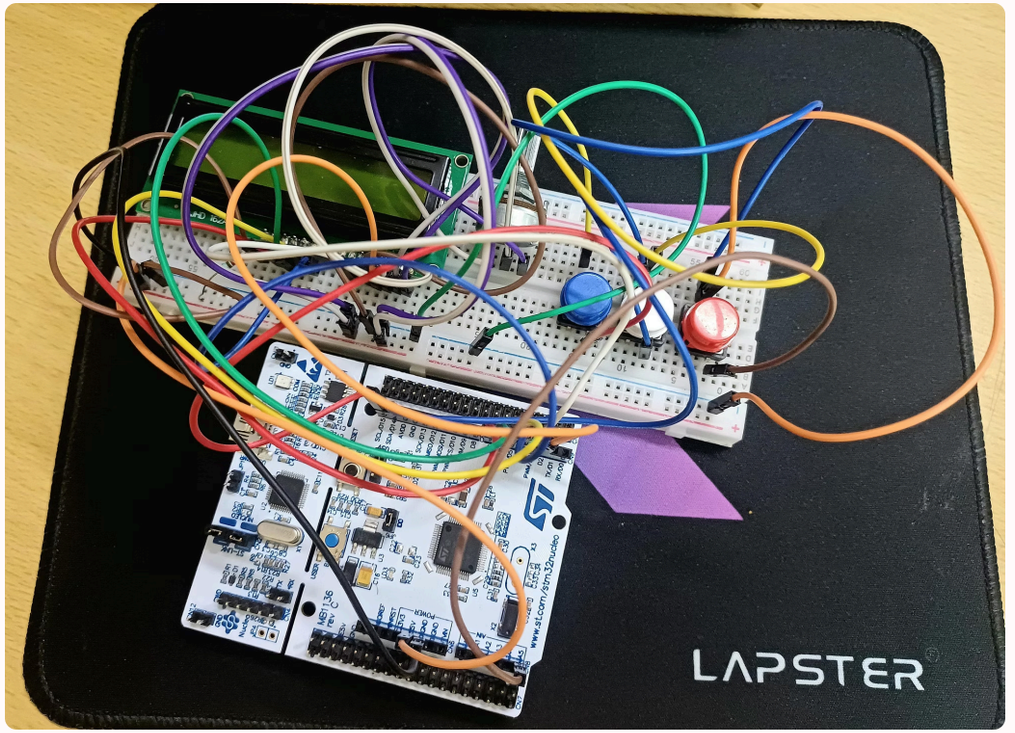


Introduction & Motivation

In today's interconnected world, digital clocks transcend basic time display, evolving into sophisticated multi-functional embedded systems. This project harnesses the power of the STM32F446RE microcontroller, utilizing its integrated Real-Time Clock (RTC) for precise, energy-efficient timekeeping.

Why STM32F446RE?

- Leveraging an existing development board, the project aimed to create a comprehensive embedded solution.
- Capitalizing on prior experience with the RTC peripheral and 16x2 LCD, streamlining development.
- Seizing the opportunity to develop a versatile, full-featured digital clock system.



Initially conceived as a basic time display, the project rapidly expanded its scope, integrating advanced features such as a precision stopwatch, user-configurable settings, and engaging visual animations.

Problem & Objectives

Commercial clocks offer limited configurability. This project addresses the need for a transparent, programmable timekeeping system for practical use and educational reference.

1

Accurate Timekeeping

RTC-based with battery backup, ±2 sec/day accuracy.

2

Multi-modal Operation

Clock, stopwatch, and configuration modes with seamless transitions.

3

Intuitive UI

Space-optimized 16x2 LCD display for time, date, and mode.

4

Expandable Architecture

Modular software for future features like alarms and sensing.

5

Educational Framework

Demonstrates peripheral integration and state machine design.

Novelty & Contributions

This project introduces several hardware and software innovations beyond standard digital clock implementations.

State-Machine Driven

Cleanly manages transitions between Clock, Stopwatch, and Settings modes.

Custom LCD Animation

Rocket-launch startup animation using CGRAM custom characters.

Enhanced Time-Setting

Blinking fields, field-selection logic, debounced input, "Save & Exit" interface.

LDR-Based Auto-Brightness (Proposed)

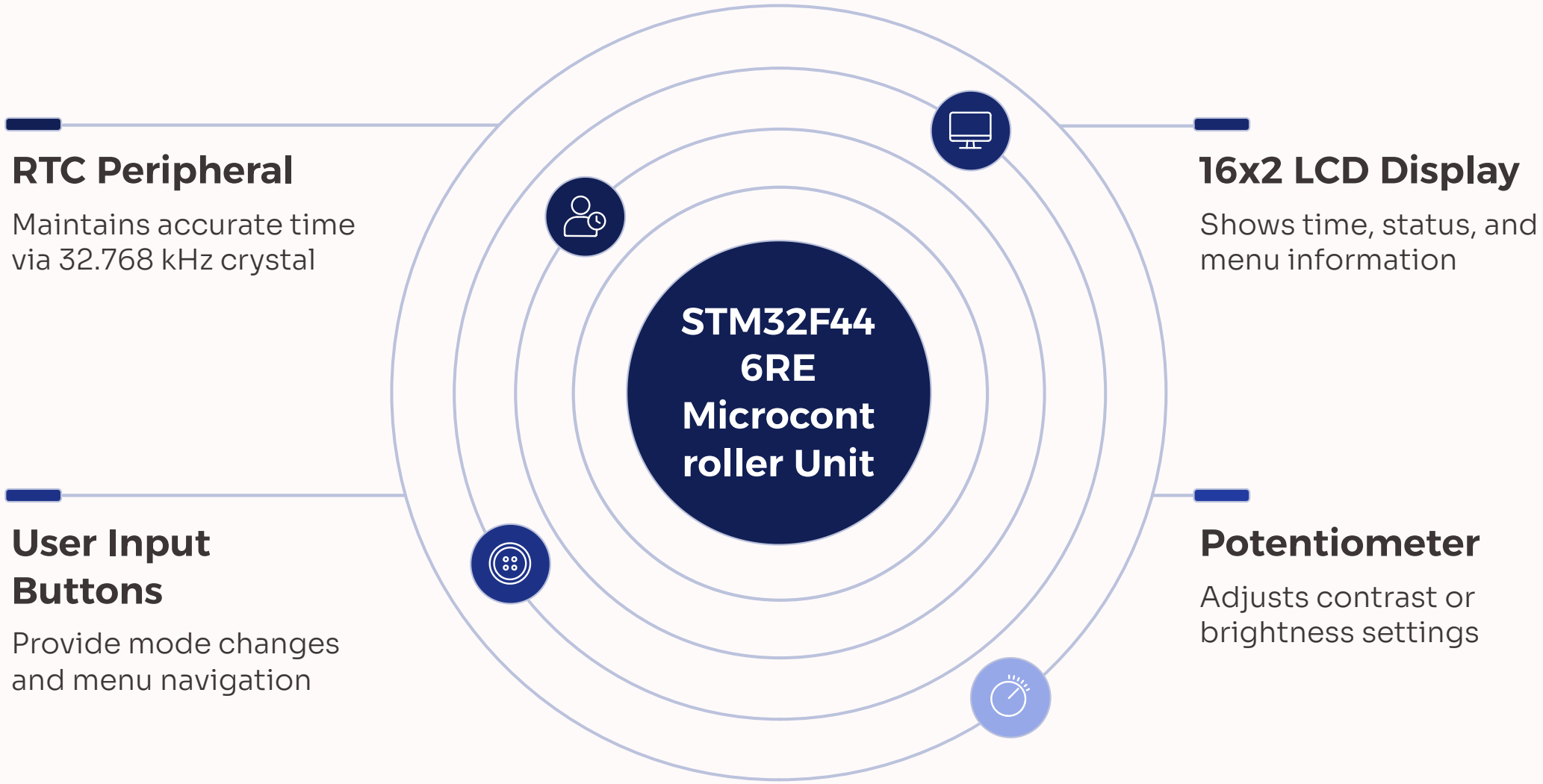
Automatic LCD contrast/backlight adjustment based on ambient light.

LED/Buzzer Feedback (Proposed)

Additional user feedback for mode changes and operations.

System Architecture

The overall approach for designing, implementing, and validating the multi-purpose clock system.



Microcontroller Unit

STM32F446RE: Executes program logic and manages modes.

RTC Peripheral

With 32.768 kHz crystal: Maintains accurate time.

16x2 LCD Display

Displays time, stopwatch values, and settings.

User Input Buttons

Three tactile switches for Mode, Start/Stop, and Reset.

Process Description

The clock system operates through Initialization and Main Operation phases.

1

Initialization Phase

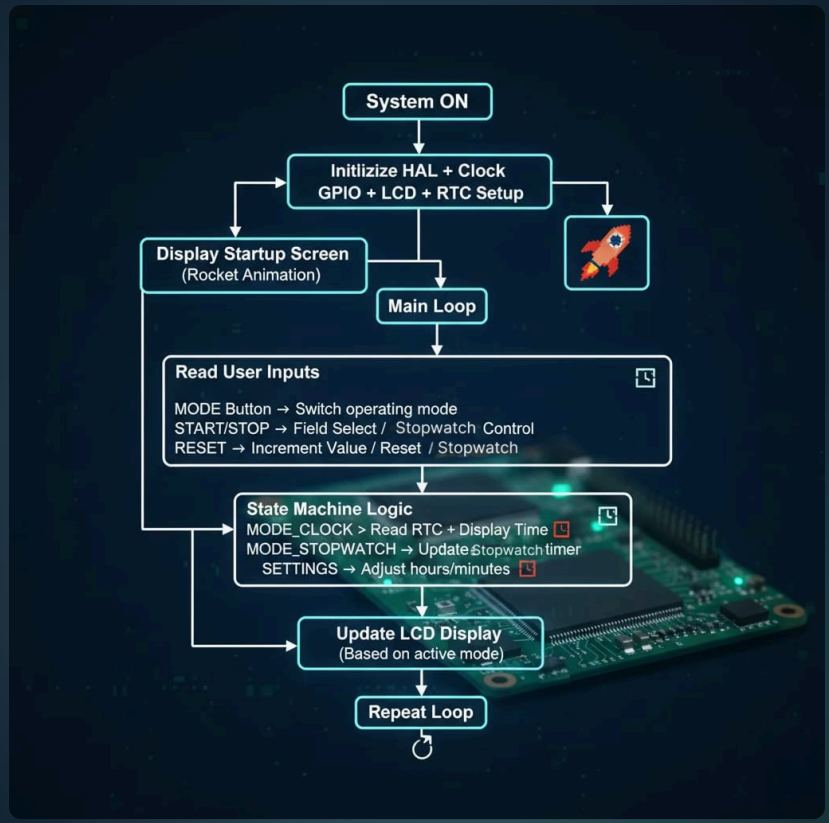
- HAL & Clock Setup
- GPIO Configuration
- RTC Initialization
- LCD Driver Initialization
- Startup Animation

2

Main Operation Phase

- Button Input Scanning
- Mode Manager (State Machine)
- Data Handling (Stopwatch, RTC)
- LCD Update System

Settings procedure involves incrementing hours/minutes, blinking fields, and saving to RTC, similar to digital wristwatches.



Component List & Implementation

Key components and the steps taken to build the multi-purpose digital clock.

Components

STM32F446RE	RTC Peripheral	1	Main Controller
16x2 LCD		1	Display
Buttons	Tactile	3	Mode inputs
Potentiometer	10kΩ	1	LCD Contrast
Resistor	220Ω	1	LCD backlight
Mini B cable	Data cable	1	Power, Flashing

Future Upgrades

- LDR for Auto Brightness
- Buzzer for Sound Feedback

Implementation Steps

Hardware Setup

Connect LCD, buttons, and power.

Software Setup

Configure peripherals, develop drivers, implement stopwatch, add UI effects.

Testing & Validation

Test RTC accuracy, button inputs, stopwatch precision, settings, and stability.

Results & Performance

The Multi-Purpose Digital Clock system was successfully implemented and tested, meeting all objectives.

RTC Drift

Better than expected (typical ±3-5 sec/day).

Stopwatch Reset

Fast response, <100 ms expected.

Mode Button Accuracy

Consistent transitions over 50 cycles.

User interface features like blinking fields, debounced inputs, and custom animations performed reliably, providing a user experience comparable to commercial digital watches.

Conclusion

The project successfully integrates RTC, stopwatch, and user-configurable settings on the STM32F446RE, demonstrating robust embedded system design.

Key Achievements

- Accurate RTC operation (±2 sec/day)
- Reliable millisecond-resolution stopwatch
- Intuitive time-setting interface
- Stable and responsive UI with custom animations

Impact

Exceeds typical academic projects with advanced RTC usage, custom UI, and robustness. Provides a strong educational example of peripheral interfacing and real-time programming.