



VIETNAM NATIONAL UNIVERSITY HO CHI MINH CITY
HO CHI MINH CITY UNIVERSITY OF TECHNOLOGY

CHRONOSYNC EMBEDDED DIGITAL CLOCK

Instructed by **MSc. Bui Quoc Bao**
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1. INTRODUCTION



Project Objectives



System Specifications

1A. Project Objectives

- Understand and integrate key hardware modules via I²C, SPI, and UART.
- Design an efficient and stable power supply for low-power operation.
- Develop schematic and PCB layout; fabricate and assemble the hardware.

1A. Project Objectives

- Build a protective enclosure to enhance usability and aesthetics.
- Integrate hardware and firmware into a complete functional system.
- Test and evaluate performance in accuracy, power, and responsiveness.
- Design a mobile app to control and configure the system via Bluetooth.

1B. System Specifications

Functional Requirements (FR)

FR-1: Time display functionality.

FR-1.1: Display the current time.

FR-1.2: Update the displayed time once every second.

FR-1.3: Include hour, minute, day of week (DoW), date of month (DoM), month, and year.

FR-1.4: Retain real-time data across power loss.

1B. System Specifications

Functional Requirements (FR)

FR-2: Store alarms.

FR-2.1: Allow configuring up to 10 alarms.

FR-2.2: Each alarm: hour, minute, second, DoW or DoM, alarm mode (DoW/DoM/unused), ON/OFF flag.

FR-2.3: Compare current time and stored alarms every second to detect matches.

FR-2.4: Upon matching, activate a buzzer.

FR-2.5: Alarm configurations retained across power cycles.

1B. System Specifications

Functional Requirements (FR)

FR-3: Allow time and alarm configuration via physical buttons.

FR-3.1: Support incrementing, decrementing, and navigating between configuration fields.

FR-3.2: Support both short press and long press detection to accelerate user input

1B. System Specifications

Functional Requirements (FR)

FR-4: Allow alarm review and editing.

FR-4.1: Allow browsing existing alarms by slot index.

FR-4.2: Allow toggling an alarm's ON/OFF state while reviewing.

FR-4.3: Support editing a selected alarm.

1B. System Specifications

Functional Requirements (FR)

FR-5: Allow time and alarm configuration wirelessly.

FR-5.1: Support a mobile application for wireless configuration.

FR-5.2: Communicate with the app via bluetooth.

FR-5.3: Support time synchronization and alarm setup from a smartphone.

1B. System Specifications

Functional Requirements (FR)

FR-6: System Options includes:

FR-6.1: Support a mobile application for wireless configuration.

FR-6.1.1: Clear all alarms.

FR-6.1.2: Perform factory reset.

FR-6.1.3: Run display test pattern.

FR-6.1.4: Show distributor information.

1B. System Specifications

Functional Requirements (FR)

FR-8: Support low power consumption and extended battery operation.

FR-8.1: Include an E-Ink display to minimize power consumption.

FR-8.2: Be powered by a rechargeable lithium-ion battery.

FR-8.3: Display the remaining battery level in percentage.

1B. System Specifications

Constraints (C)

C-1: Timing and Accuracy

C-1.1: Ensure time deviation is less than ± 3 ppm at room temperature.

C-1.2: Alarm matching logic shall be executed within 50 ms per main loop iteration.

C-1.3: Maintain accurate real time for at least 30 days on power loss.

1B. System Specifications

Constraints (C)

C-2: Alarm Storage

C-2.1: Retain all alarm data across power loss.

C-2.2: Total memory usage for alarm storage shall not exceed 50 bytes.

C-2.3: Storage read/write operations shall complete in less than 10 ms.

1B. System Specifications

Constraints (C)

C-3: Input Responsiveness

C-3.1: A short button press shall be detected with latency under 30 ms.

C-3.2: A long button press shall be registered after holding the button for 600 ms.

C-3.3: Button debouncing shall ensure fewer than 1 false trigger per 100 presses.

1B. System Specifications

Constraints (C)

C-4: Power and Energy Constraints

C-4.1: Operate on four 2000 mAh, 3V lithium-ion batteries.

C-4.2: Function for at least 90 days on a full charge in idle conditions.

C-4.3: consume less than 3 mW during typical operation.

C-4.3.1: Perform periodic operations once per second.

C-4.3.2: The display shall consume no more than 0.02 mW.

C-4.3.2.1: The display refresh rate shall be limited to 1 Hz when displaying real time, and shall only refresh on value changes in other modes.

1B. System Specifications

Constraints (C)

C-5: Physical Dimensions

C-5.1: The overall device dimensions shall not exceed $15 \times 15 \times 8$ cm.

C-5.2: The total weight of the device shall be less than 300 g.

2. MATERIALS & METHODS



A List of Components & Selection Justifications



B Development Tools



C Programming & Debugging Methodology

2A. List of Components & Selection Justifications

Microcontroller Unit (MCU)

STM32F103C8T6 Microcontroller

- Supports RTC, display, Bluetooth via I²C, SPI, UART.
- Low-power with sufficient processing for embedded tasks.
- Well-supported by STM32CubeIDE and HAL libraries.

2A. List of Components & Selection Justifications

Power Supply

**TPS54231 Buck Converter, AMS1117-3.3V Regulator,
SS54 Schottky Diode, CDRH127 Inductor,
100 μ F Electrolytic Capacitors, TAJC476K016RNJ 47 μ F Tantalum
Capacitors**

- Buck + LDO combo ensures 12V → 3.3V conversion.
- Schottky diode & inductor optimize efficiency.
- Capacitors smooth output and stabilize transient loads.

2A. List of Components & Selection Justifications

Oscillators

SMD HC49-S Crystal Oscillator 8MHz,

- Stable system clock for STM32.

FC-135 3215 Crystal 32.768kHz

- Precise, low-power RTC timebase.

Display System

2.9-inch Waveshare E-Ink Display

- Ultra-low power (refresh-only).
- High readability; SPI-driven for simplicity.

2A. List of Components & Selection Justifications

Timekeeping

DS3231SN RTC Module

- ± 2 ppm temperature-compensated accuracy.
- Backup battery supported; I²C interface.

Alarm Storage

AT24C64D EEPROM (64Kbit)

- Retains alarms across power loss.
- Fast I²C; enough space for 10+ alarms.

2A. List of Components & Selection Justifications

User Interface

**Tactile Push Buttons (12x12mm), SMD LED 0805 (Power Indicators),
100nF Capacitors, SMD 0805 Resistor 10kΩ**

- Short/long press control with debounce support.
- LEDs indicate power and system state.

Audio & Output Control

9x4.2mm 80dB Buzzer, MMBT2222A NPN Transistor

- Audible alarm alerts.
- Transistor drives buzzer safely from STM32.

2A. List of Components & Selection Justifications

Wireless Communication

HC-05 Bluetooth Module

- Enables app-based time/alarm control via UART.
- Easy mobile integration (MIT App Inventor).

Connectors & Wiring

XH2.54 Bus Cables (2-pin and 8-pin), XHB-2A Connectors

- Modular connections for easy debugging.
- 2.54mm pitch ensures PCB compatibility.

2B. Development Tools

Hardware Development Tools

- Altium Designer
- Soldering Station & Solderer
- Digital Multimeter & Oscilloscope

Firmware & Embedded Software Tools

- STM32CubeIDE
- STM32CubeMX
- ST-Link Utility/ OpenOCD

2B. Development Tools

Firmware & Embedded Software Tools

- STM32CubeIDE
- ST-Link Utility/ OpenOCD

Mobile Interface Tools

- MIT App Inventor

Version Control and Documentation

- GitHub
- Microsoft Word

2C. Programming & Debugging Methodology

Programming Structure

Application Layer: Handles system state logic and mode transitions.

Middleware Layer: Manages data encoding/decoding, EEPROM access, and RTC time parsing.

Driver Layer: Interfaces with external peripherals such as the RTC (DS3231), EEPROM (24C32), buttons, buzzer, and E-Ink display.

2C. Programming & Debugging Methodology

Naming Convention

camelCase: local variables,

lowercase_with_underscores: global variables and struct members,

Upper_Camel_Snake_Case: function names,

ALL_CAPS_WITH_UNDERSCORES: macros and constants.

2C. Programming & Debugging Methodology

Debugging Strategy

- Live Expressions Monitoring
- Breakpoints and Step Execution
- Hardware-in-the-Loop Testing
- Modular Testing

3. SYSTEM DESIGN



A Hardware Design

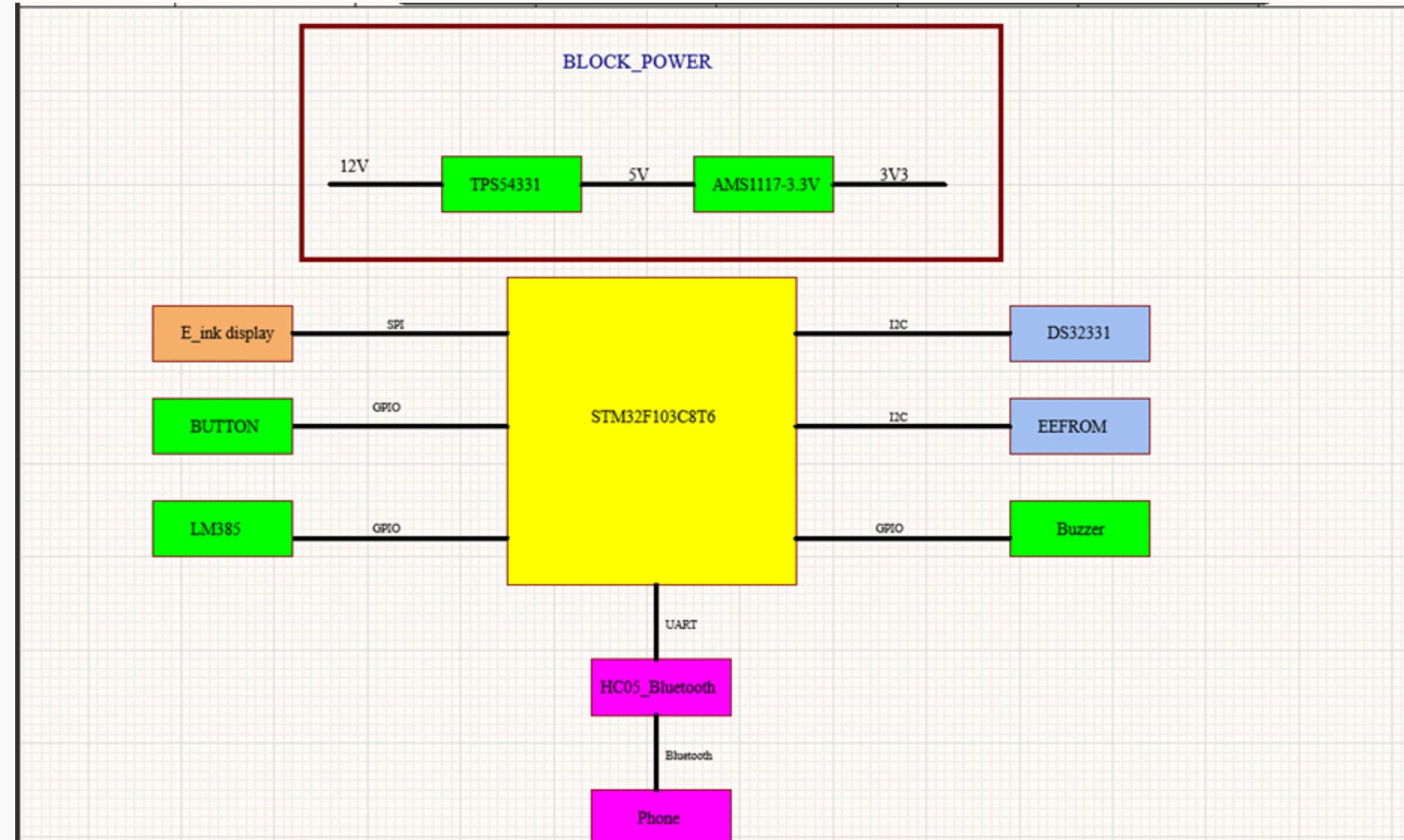


B Firmware Design

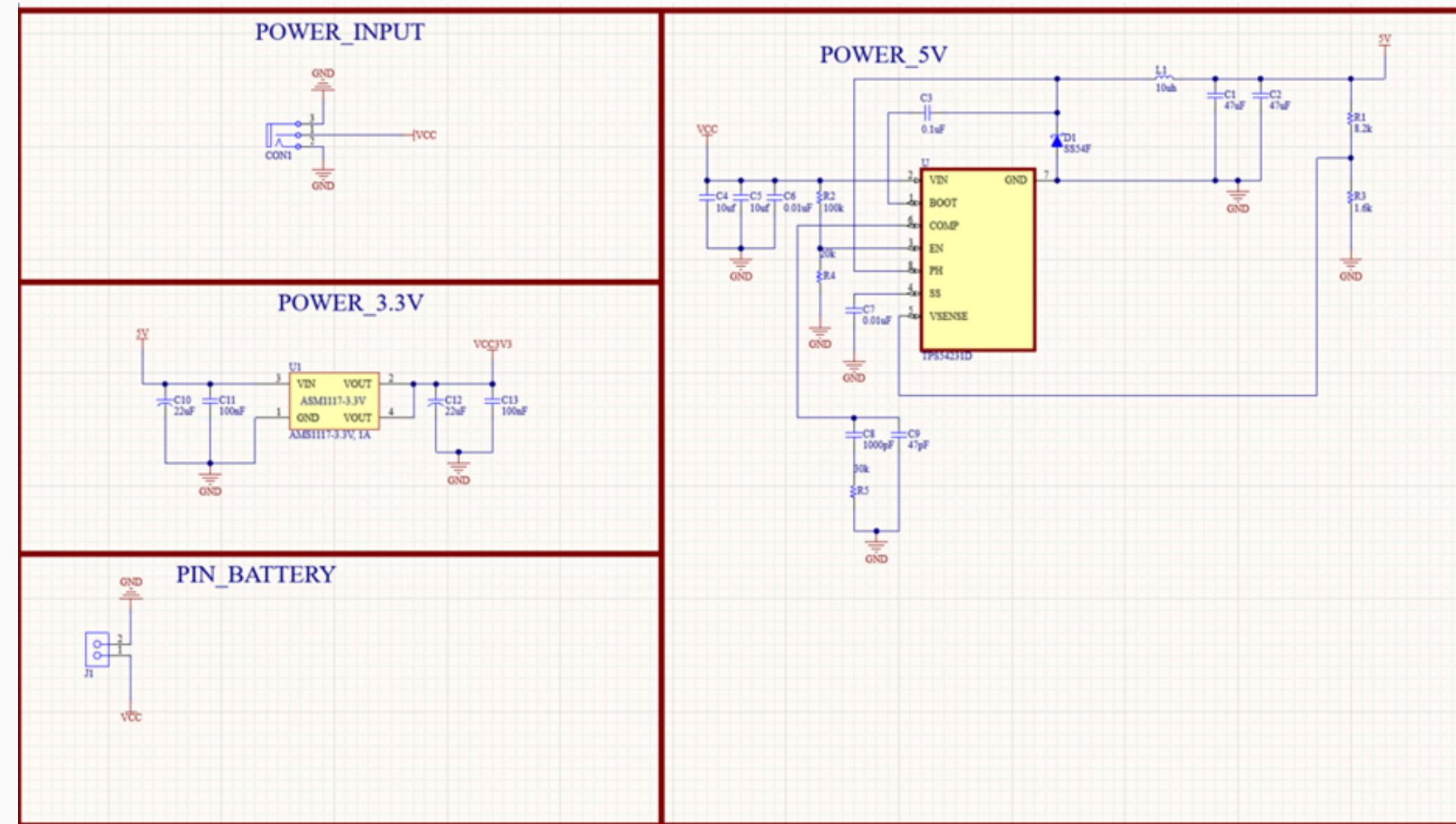


C Mobile Application Design

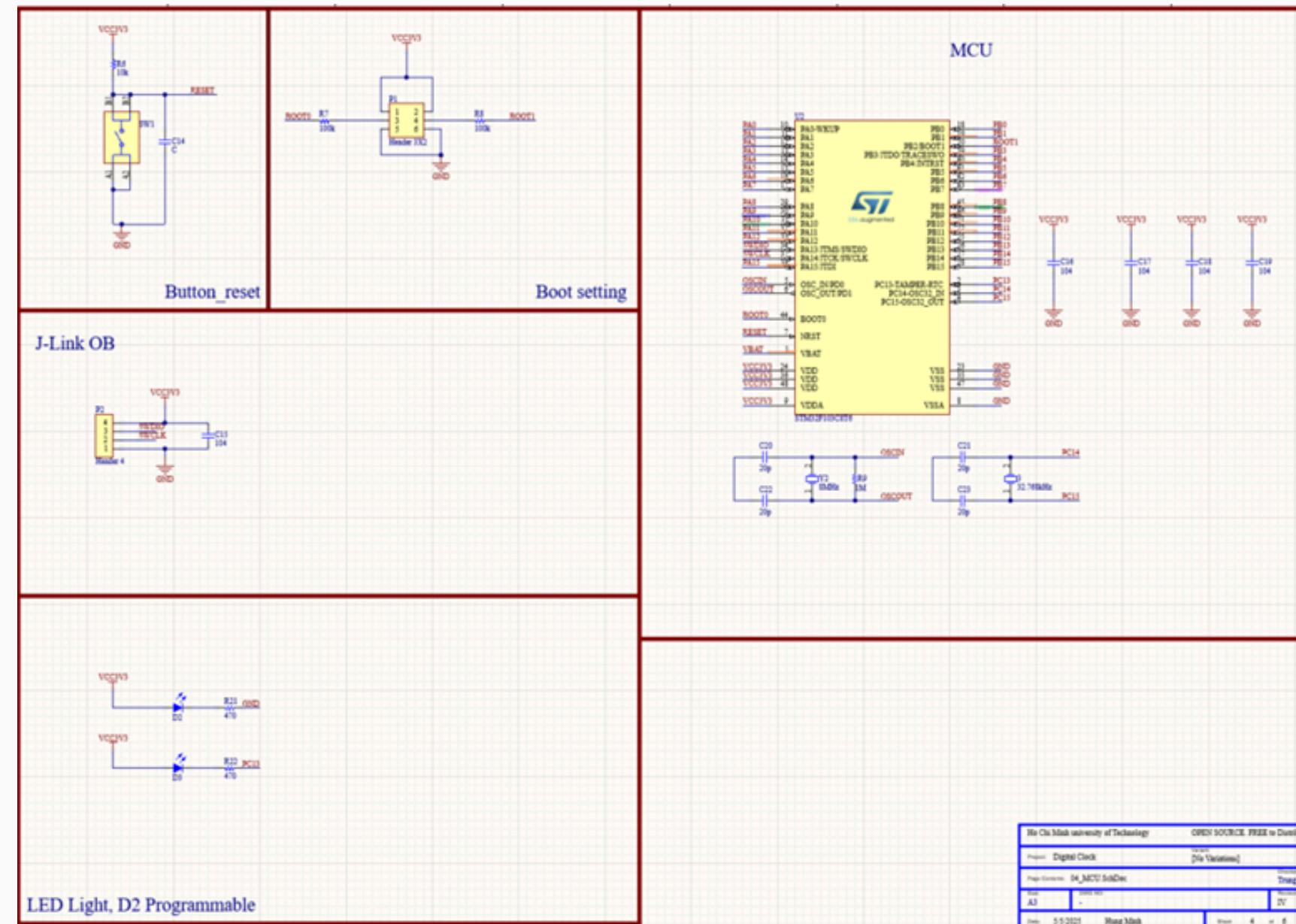
3A. Hardware Design



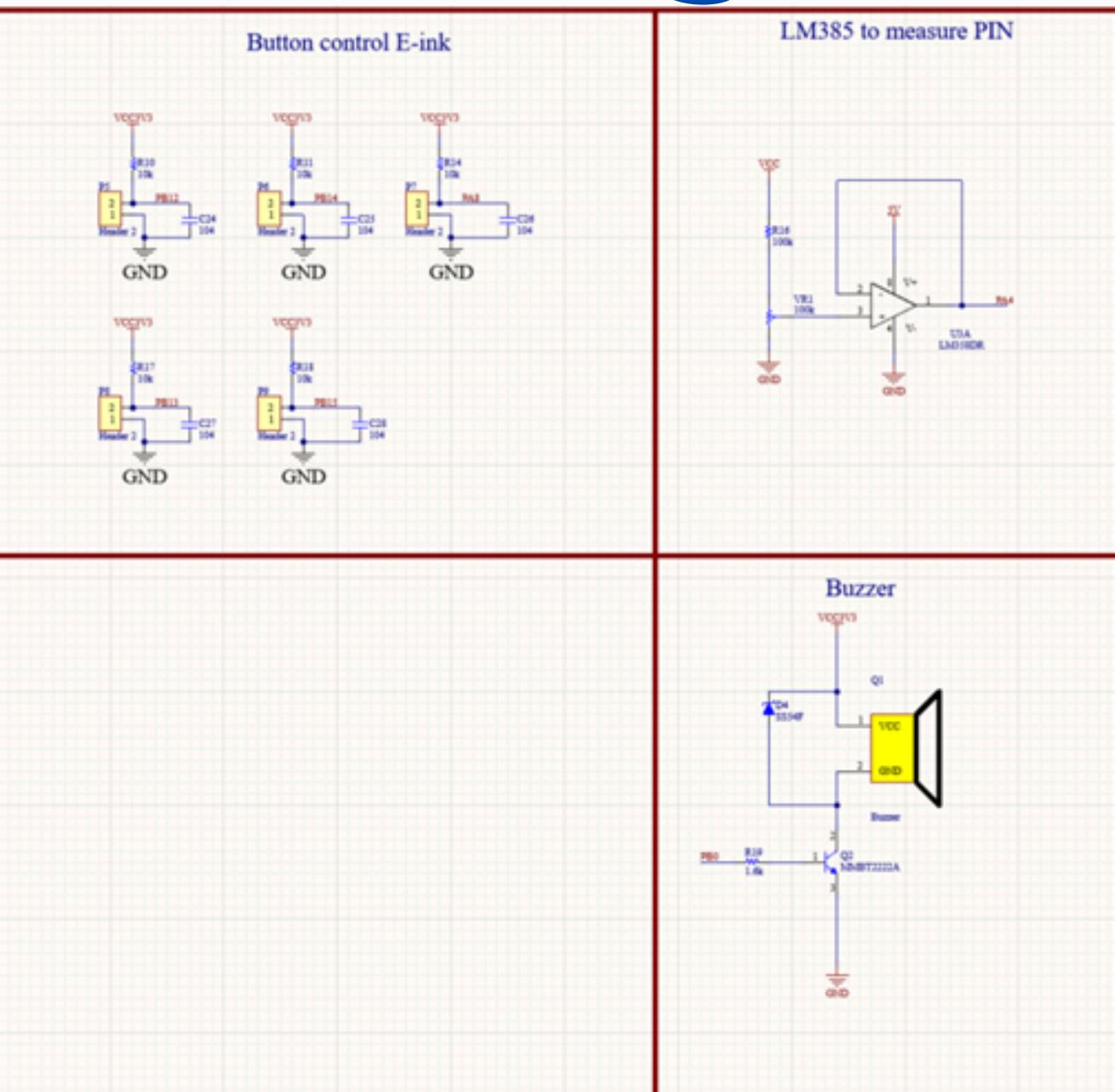
3A. Hardware Design



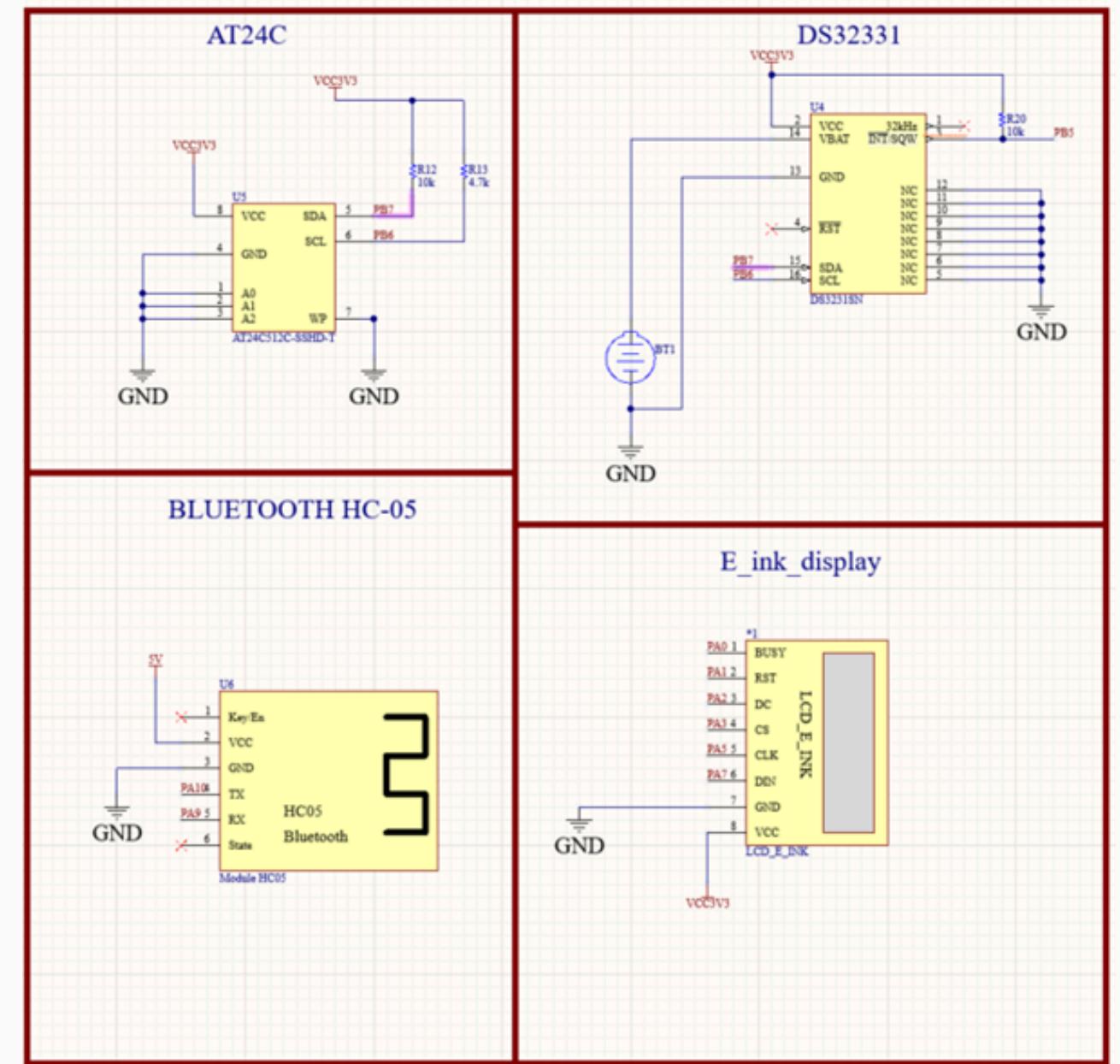
3A. Hardware Design



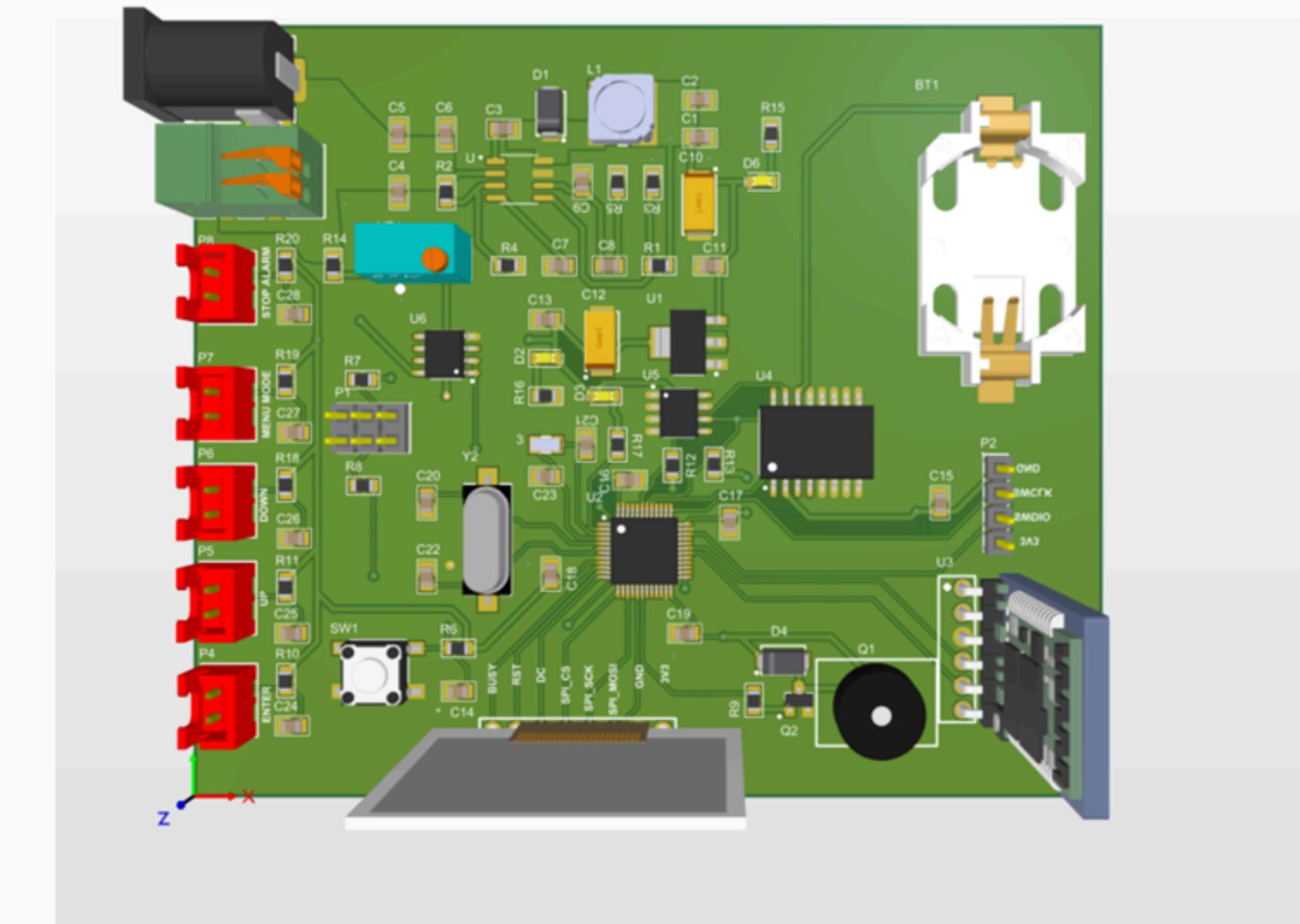
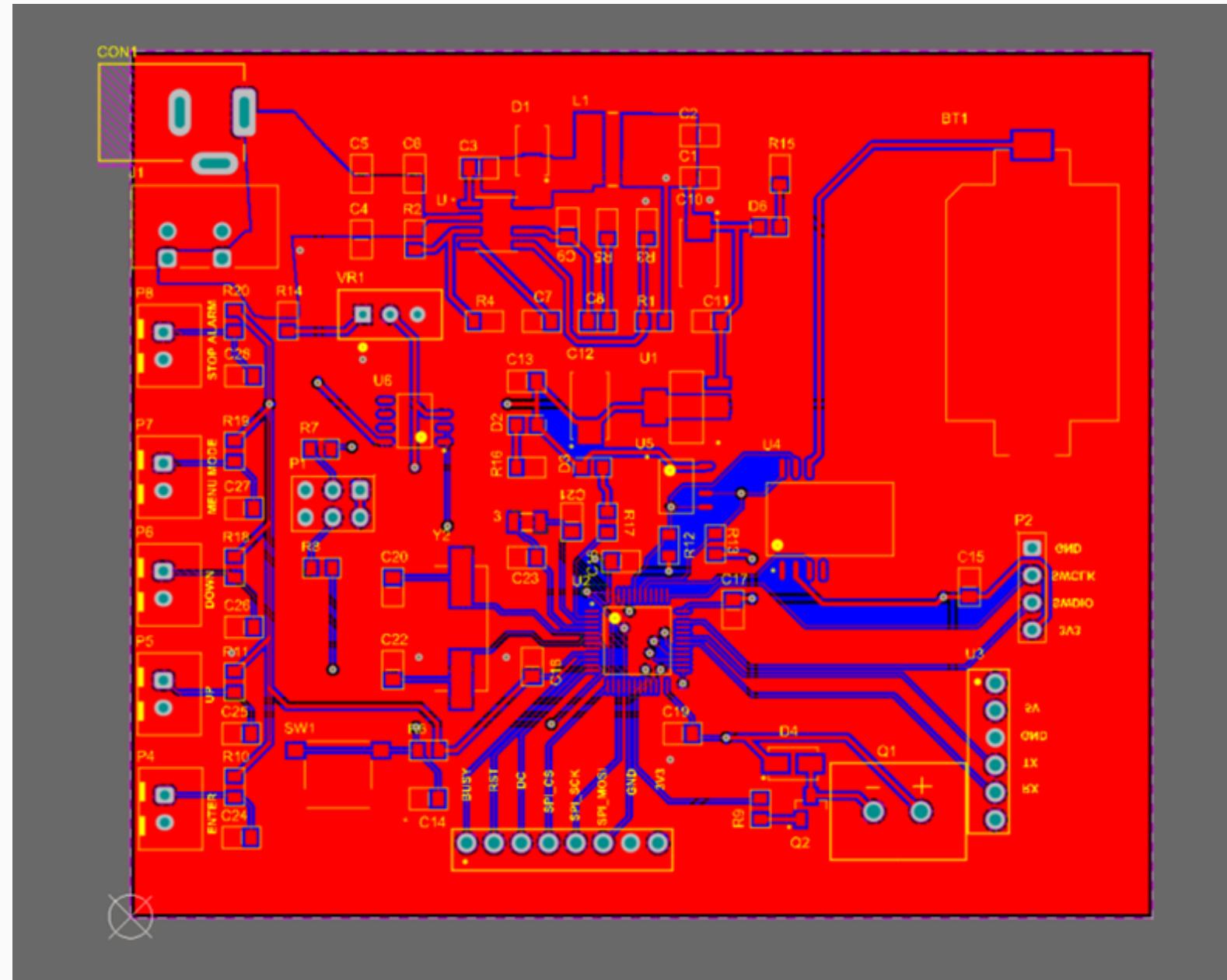
3A. Hardware Design



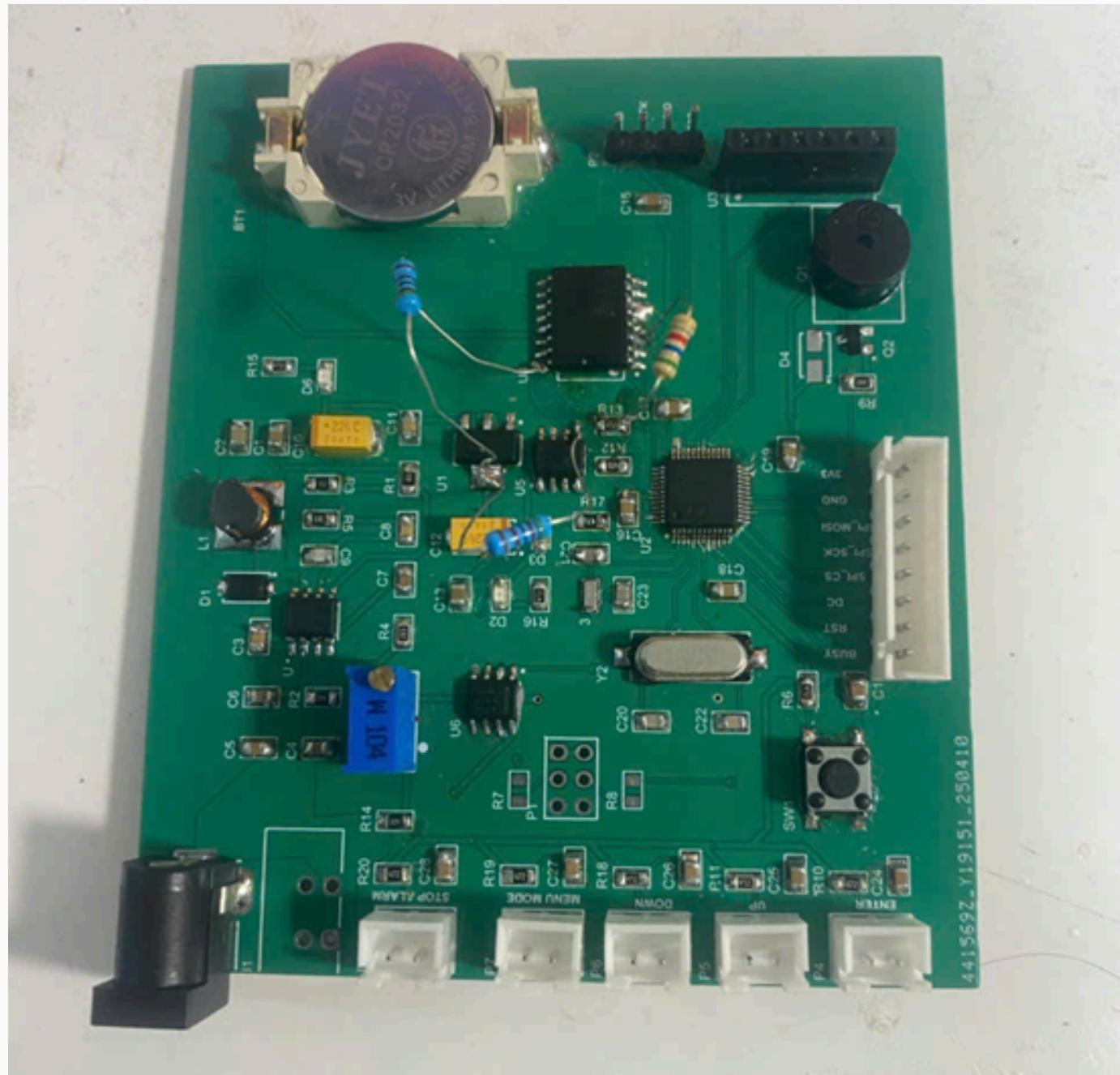
3A. Hardware Design



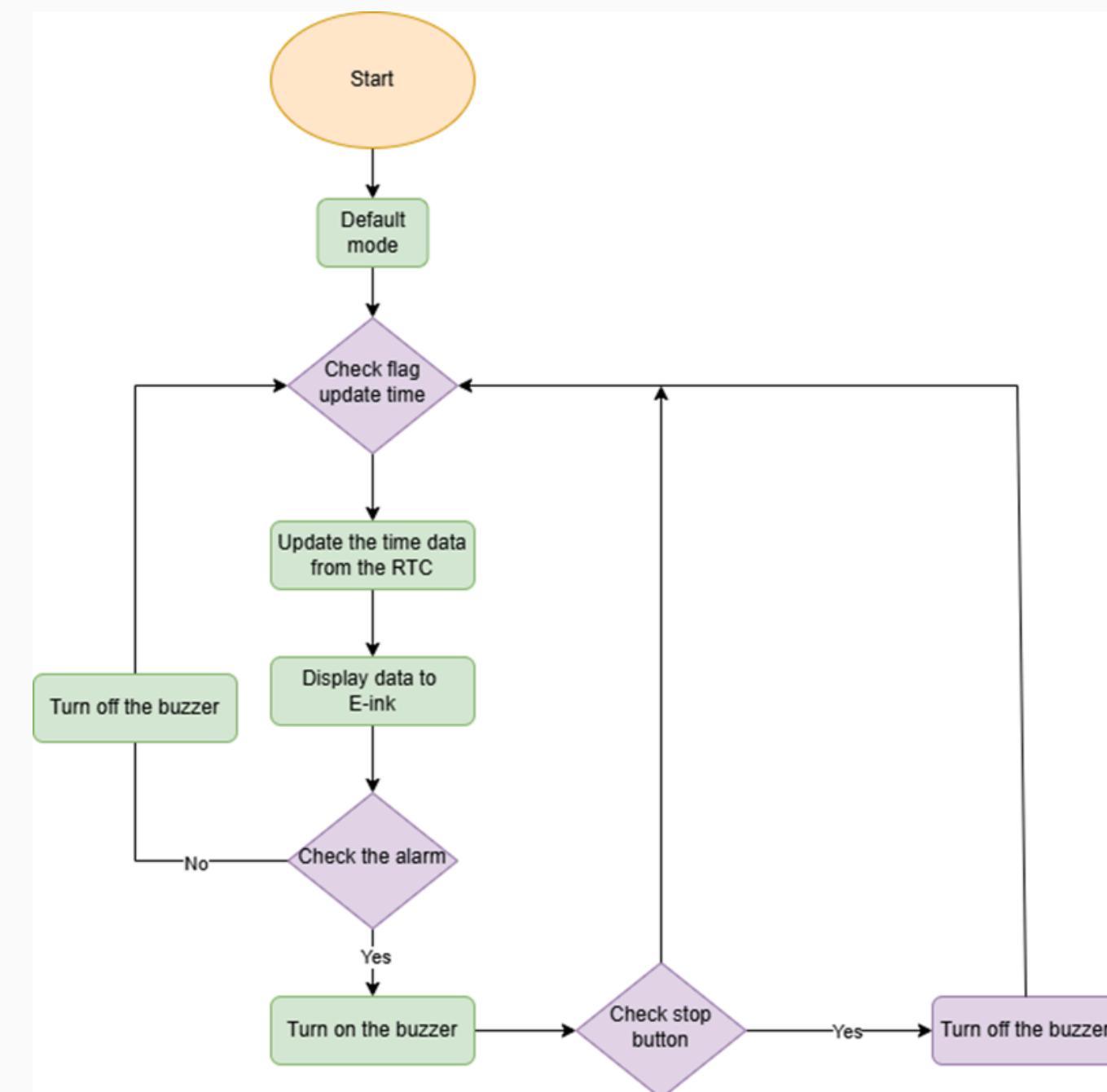
3A. Hardware Design



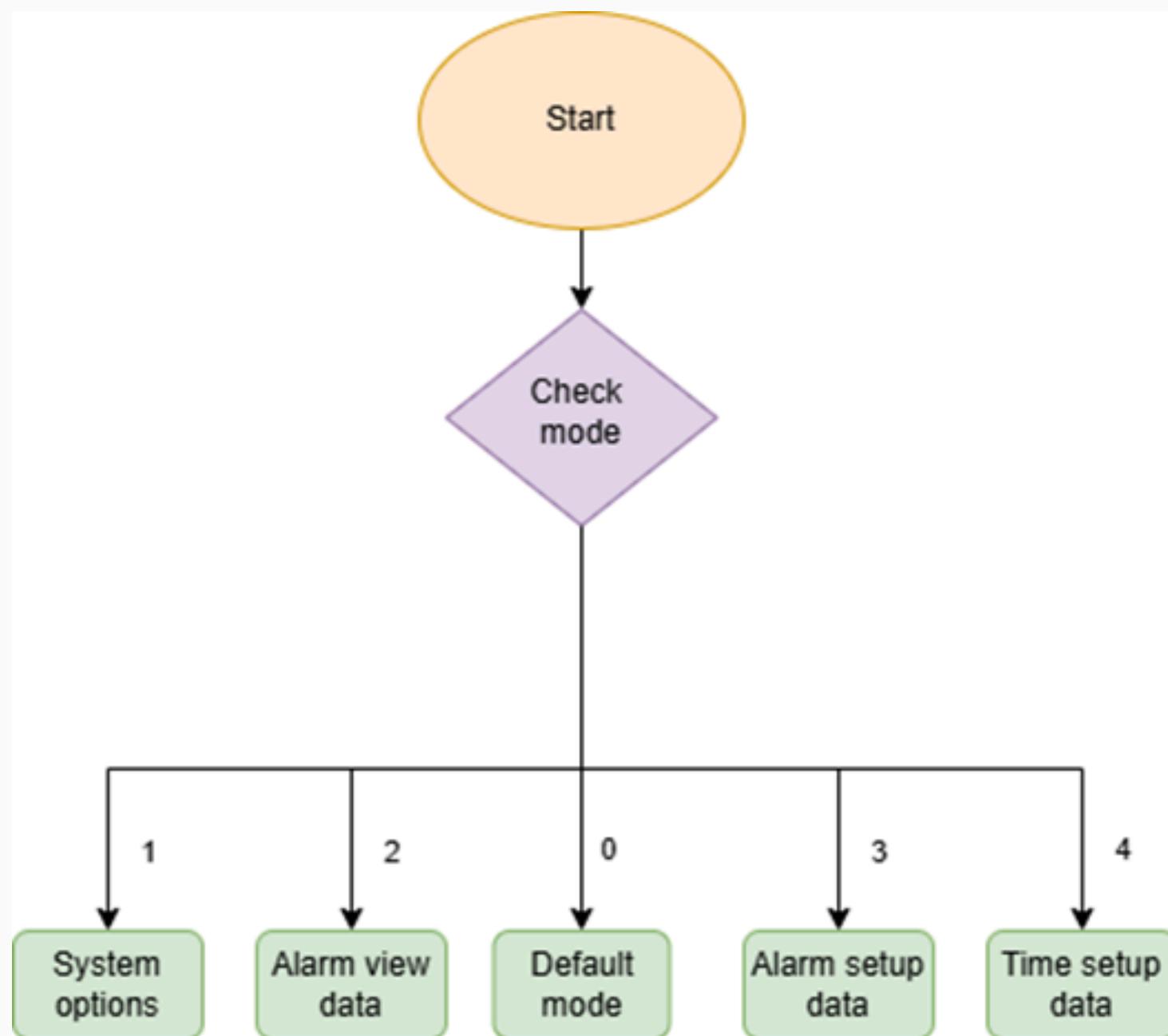
3A. Hardware Design



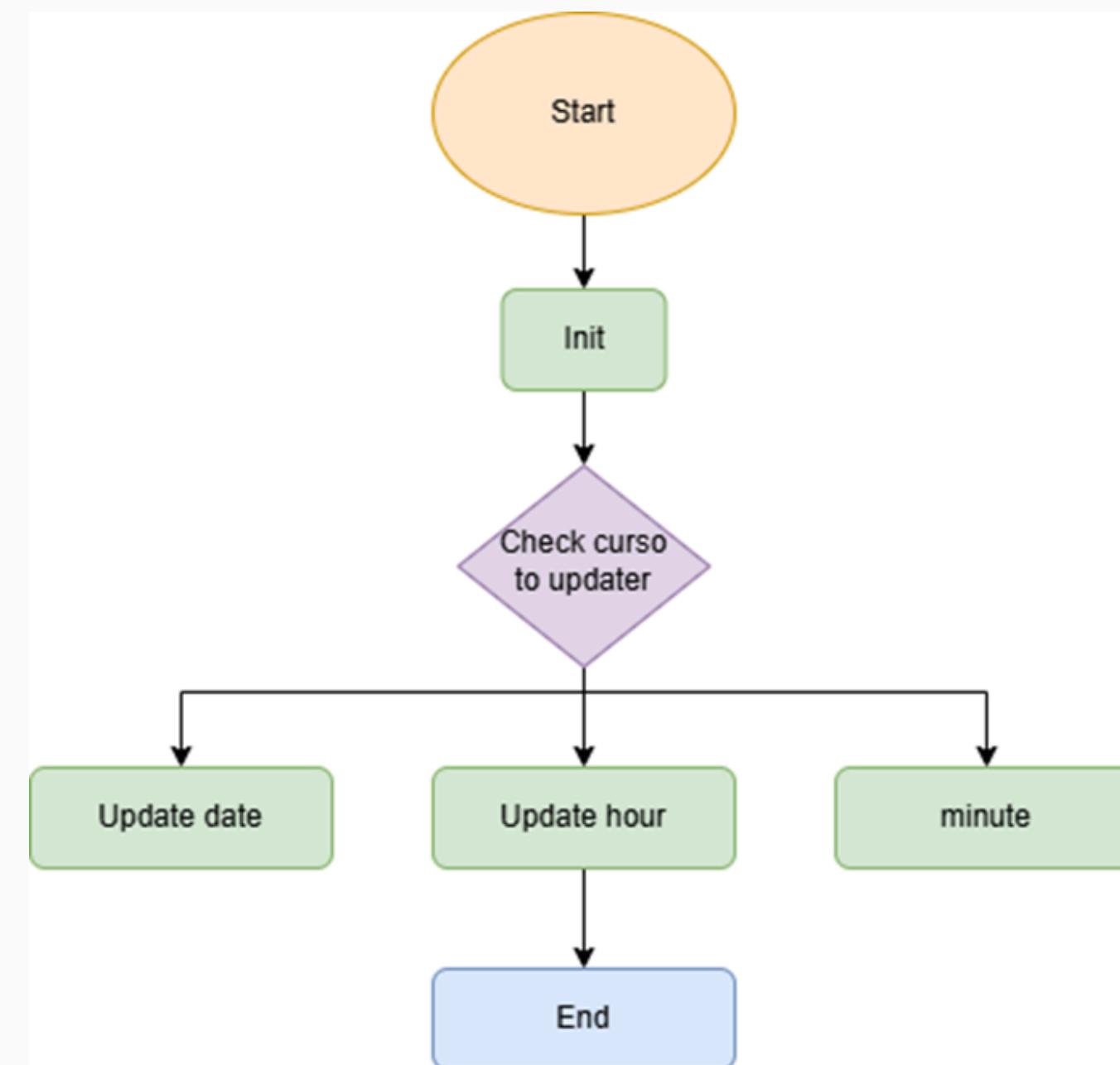
3B. Firmware Design



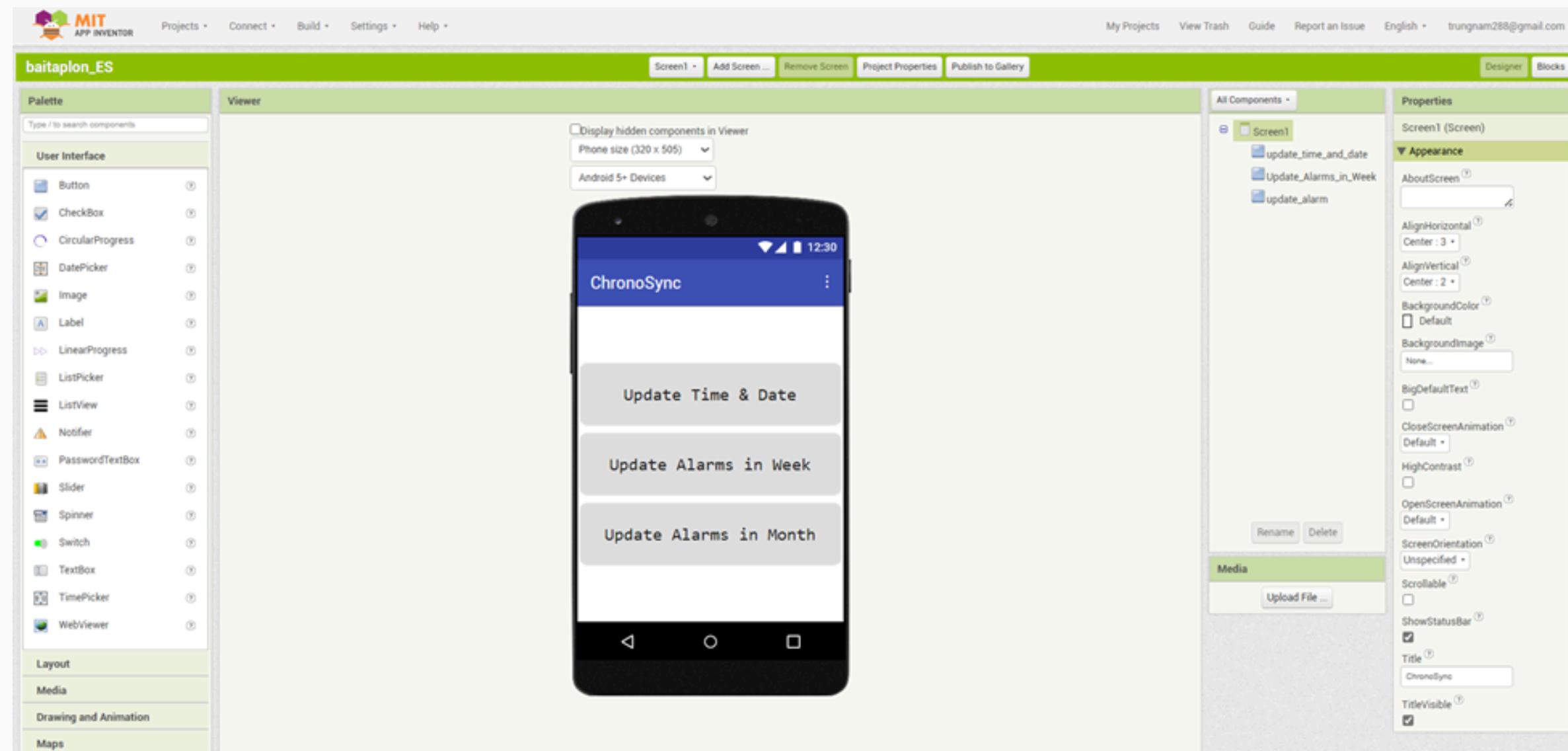
3B. Firmware Design



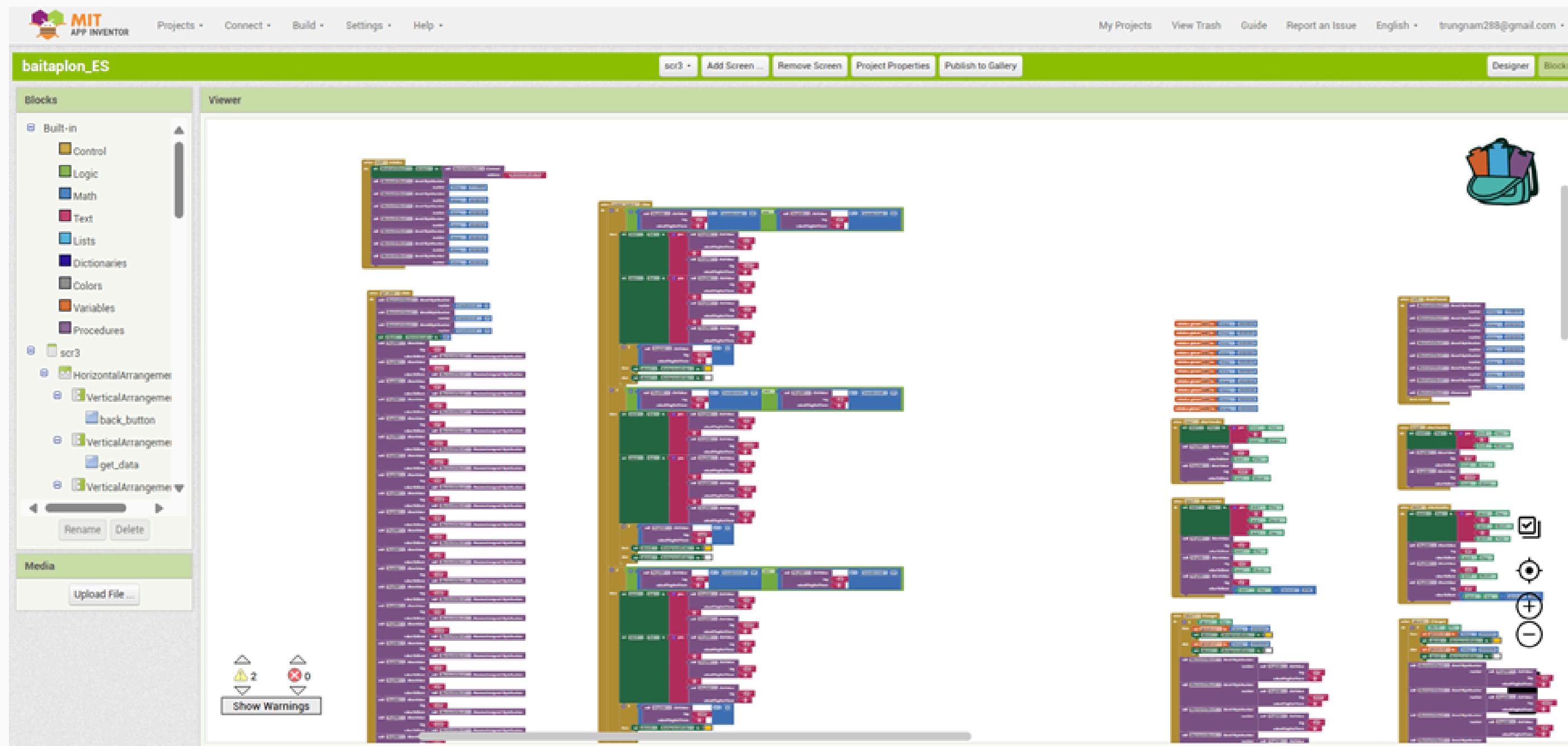
3B. Firmware Design



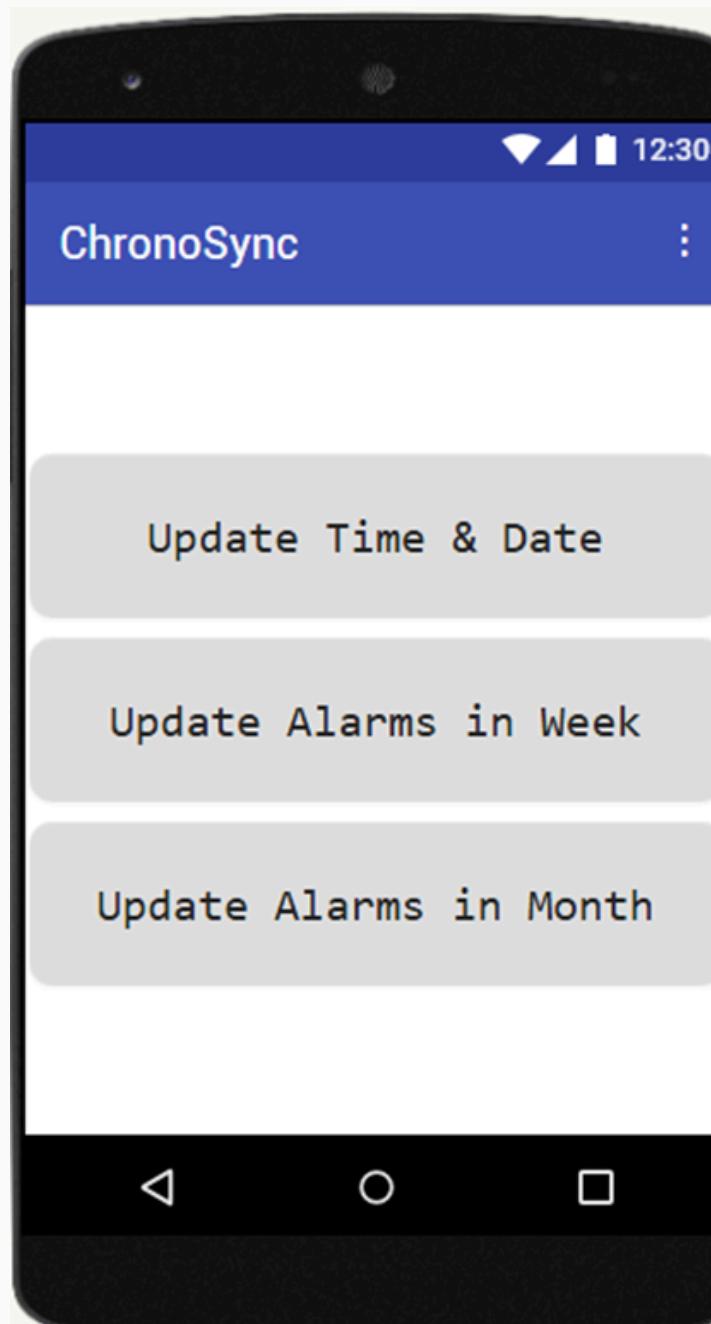
3C. Mobile Application Design



3C. Mobile Application Design



3C. Mobile Application Design

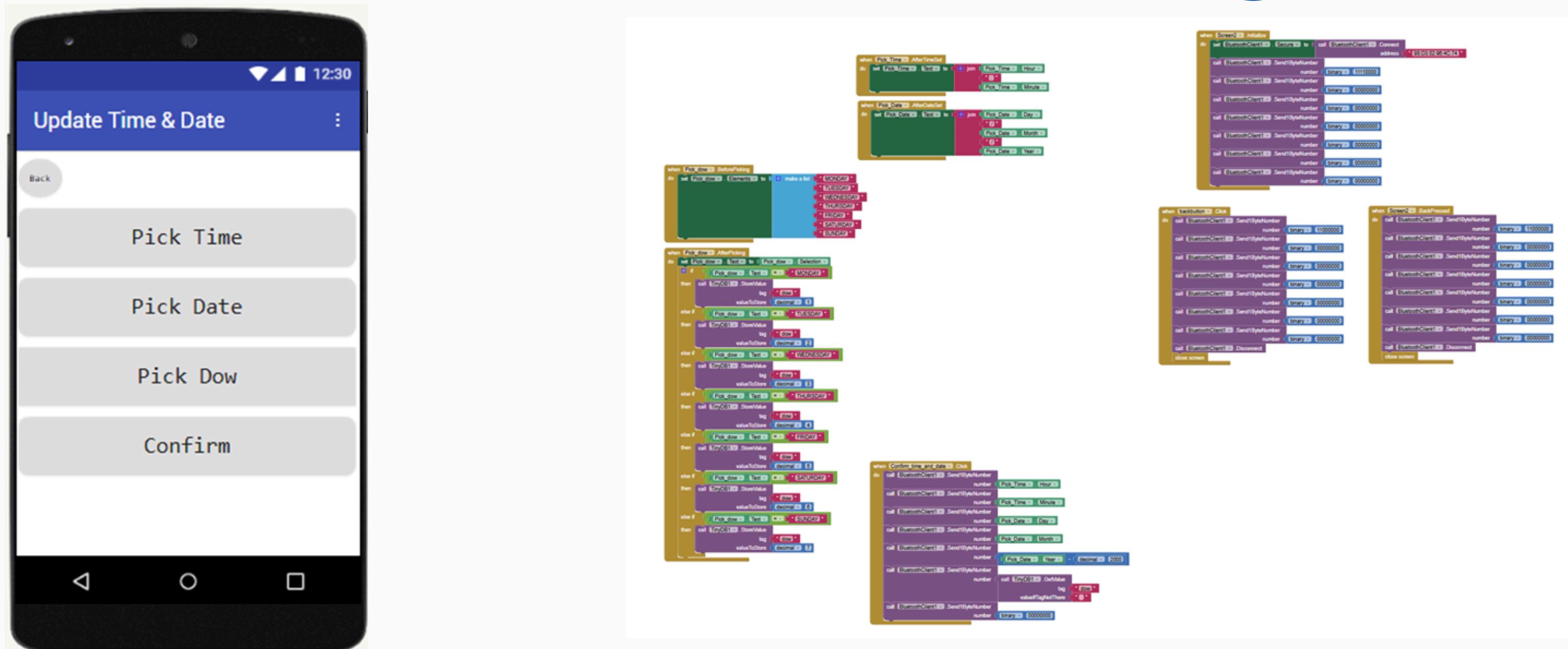


```
when update_time_and_date .Click
do open another screen screenName Screen2

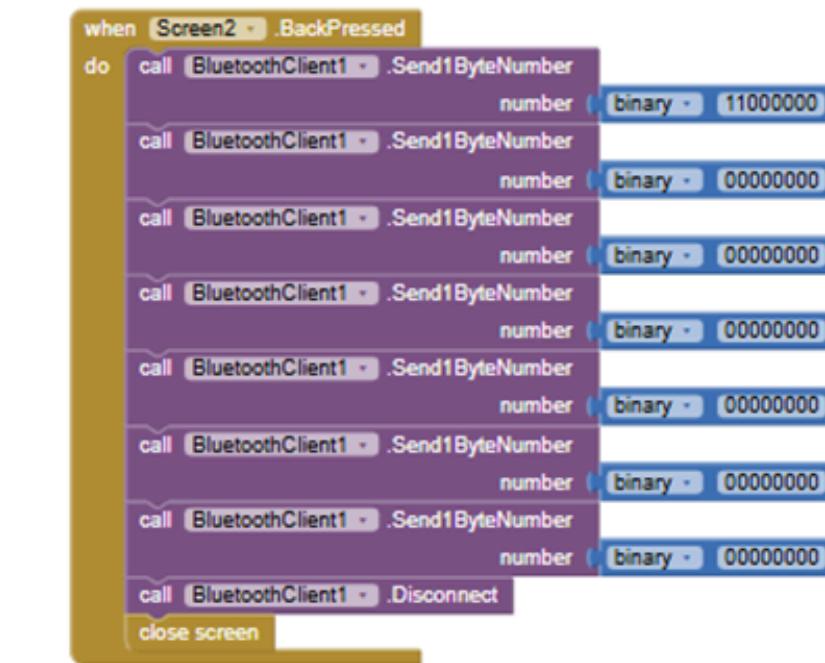
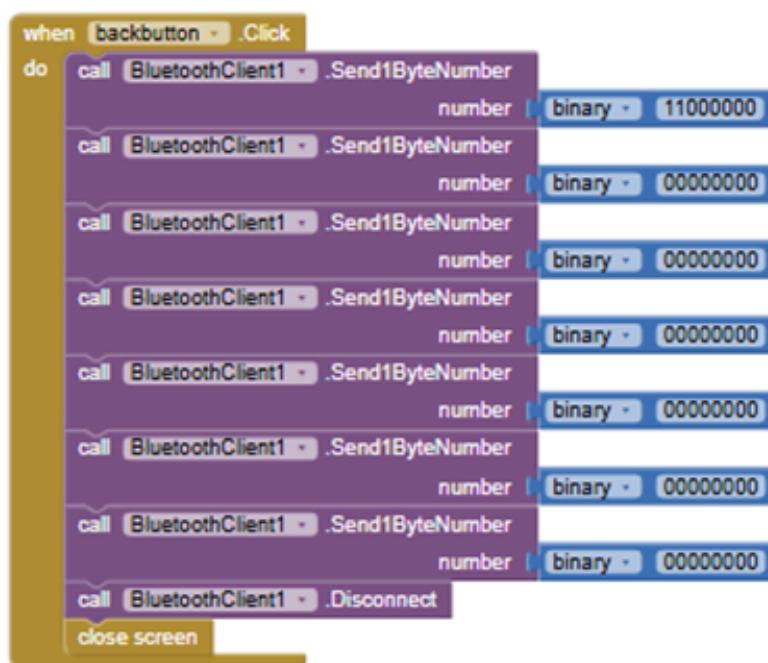
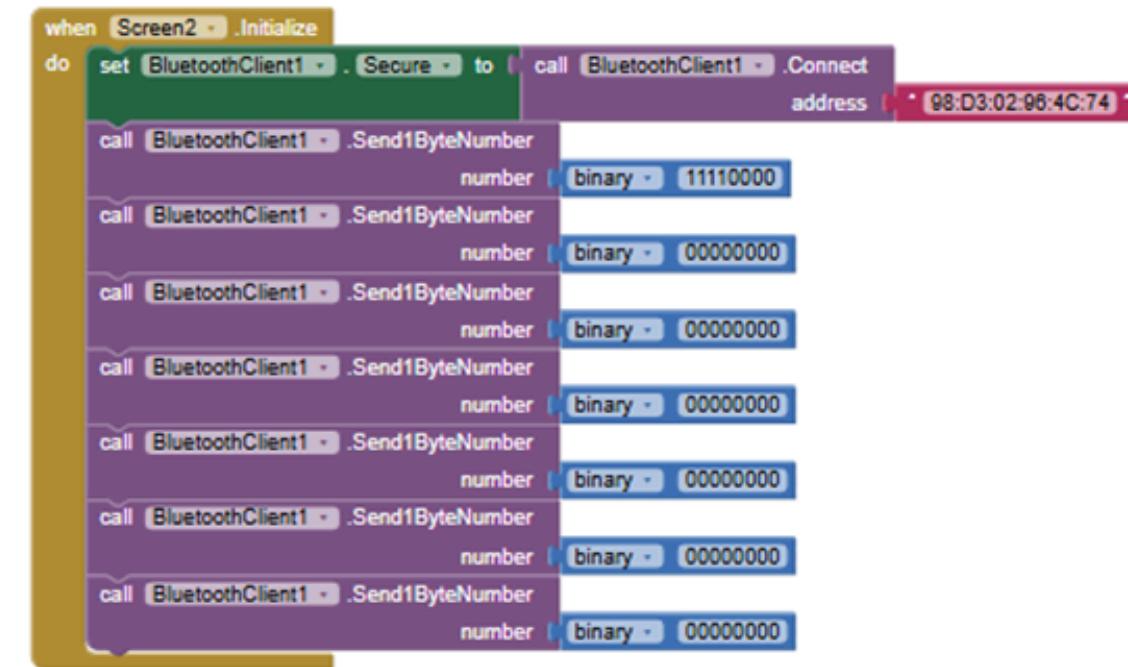
when update_alarm .Click
do open another screen screenName scr3

when Update_Alarms_in_Week .Click
do open another screen screenName Screen4
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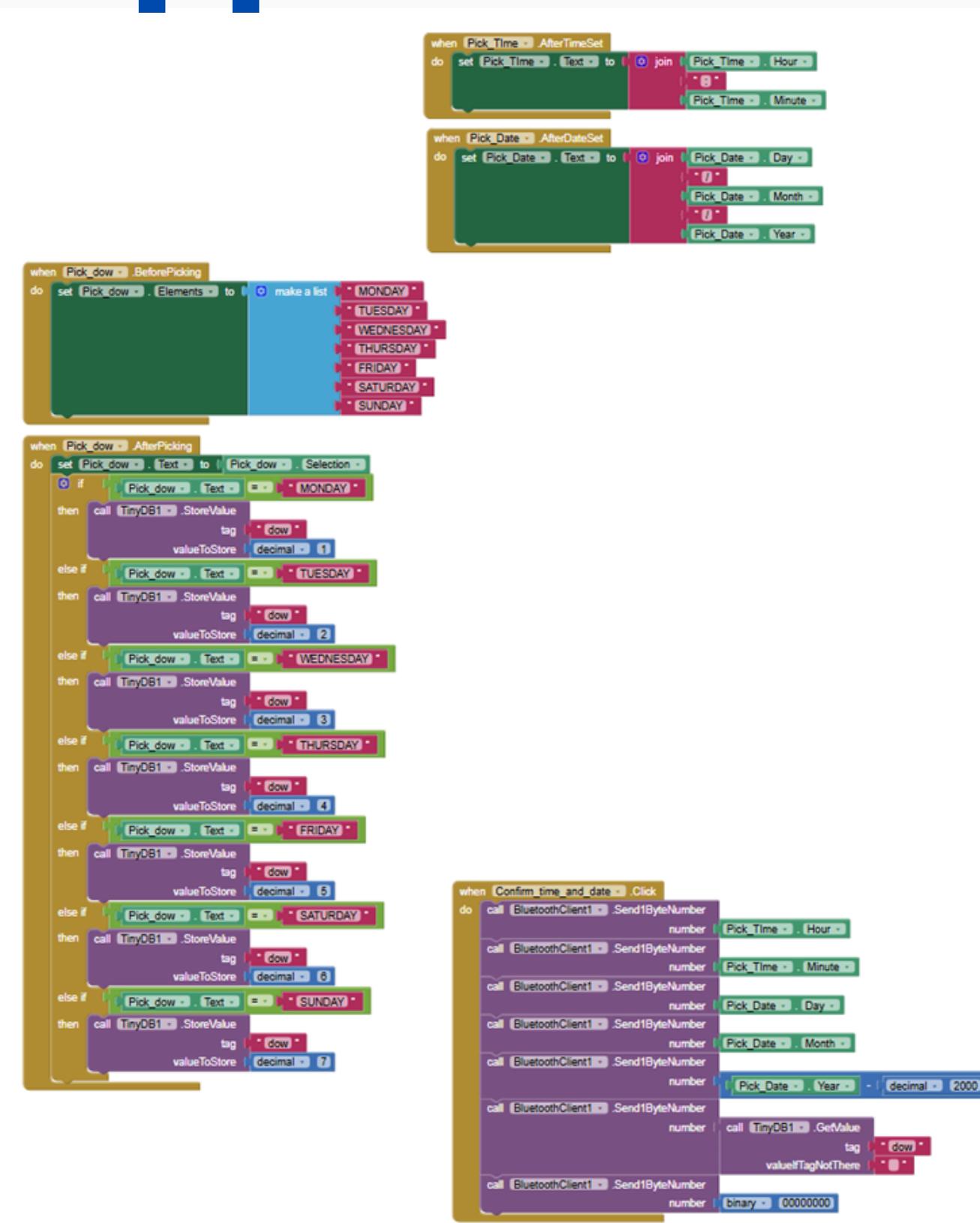
3C. Mobile Application Design



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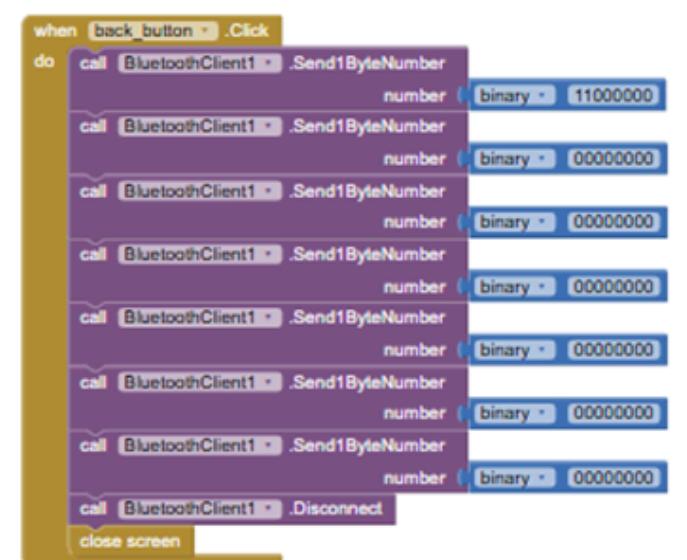
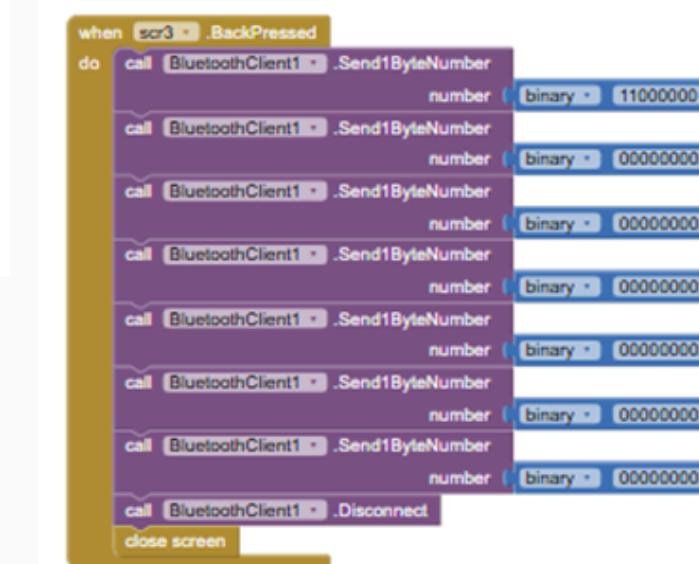
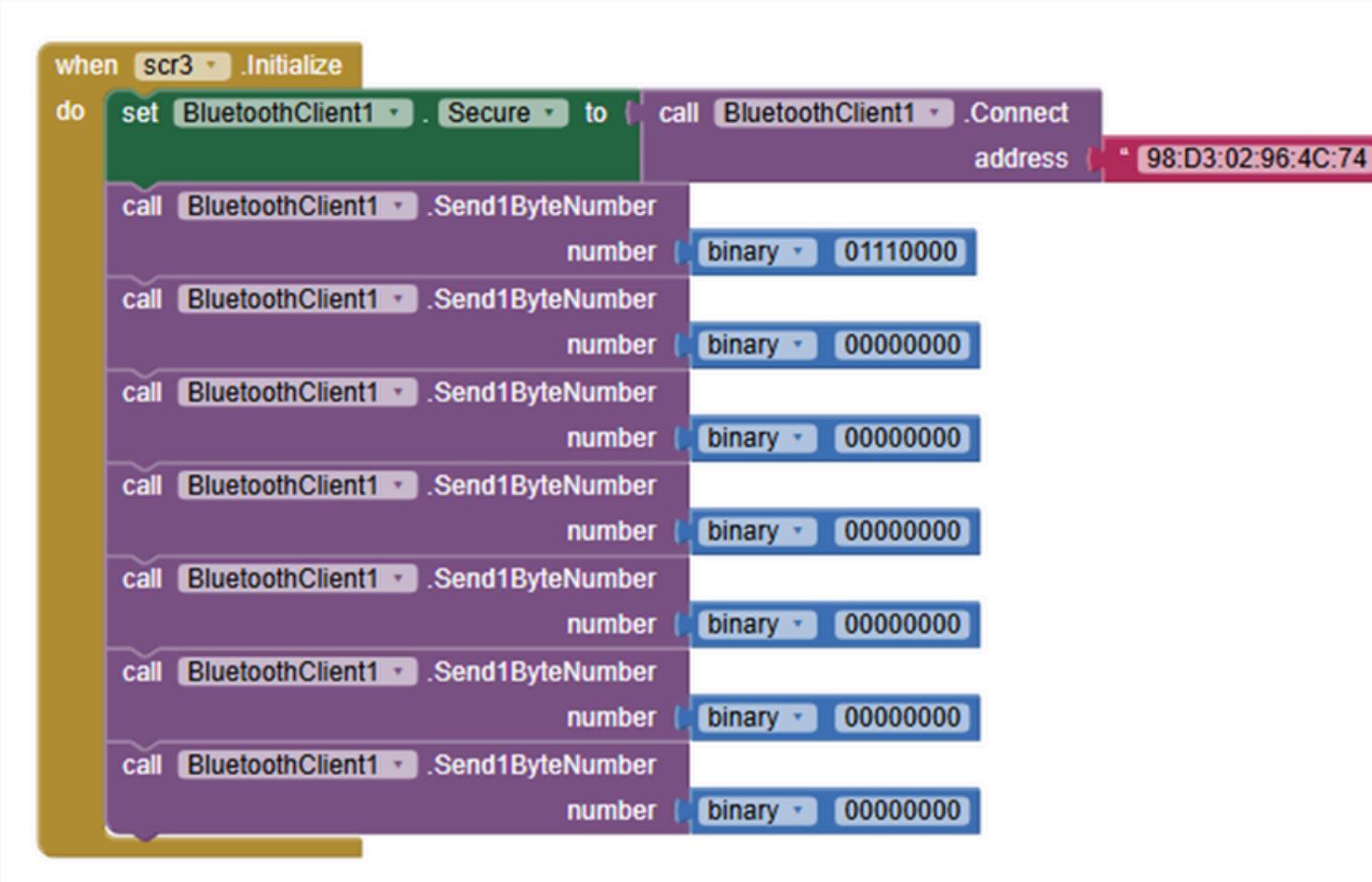
3C. Mobile Application Design



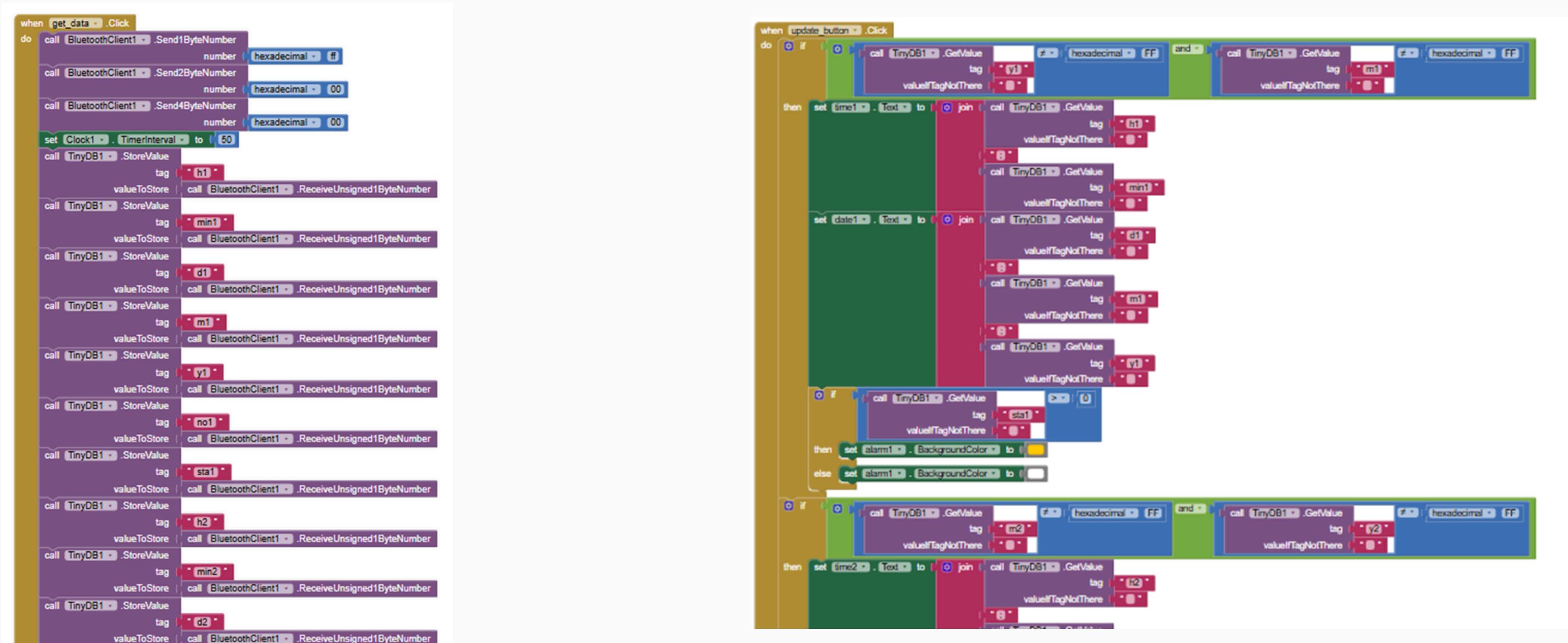
3C. Mobile Application Design



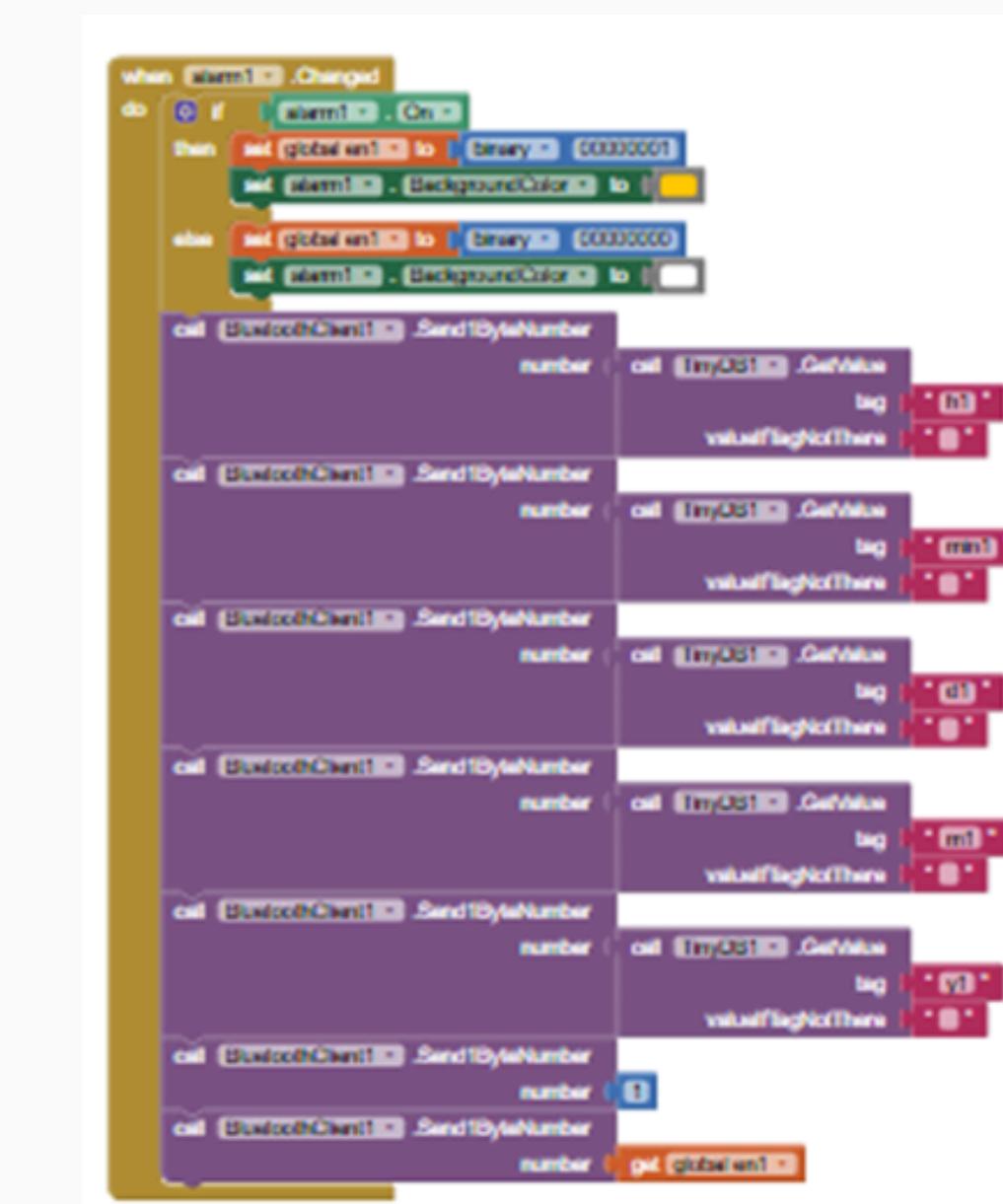
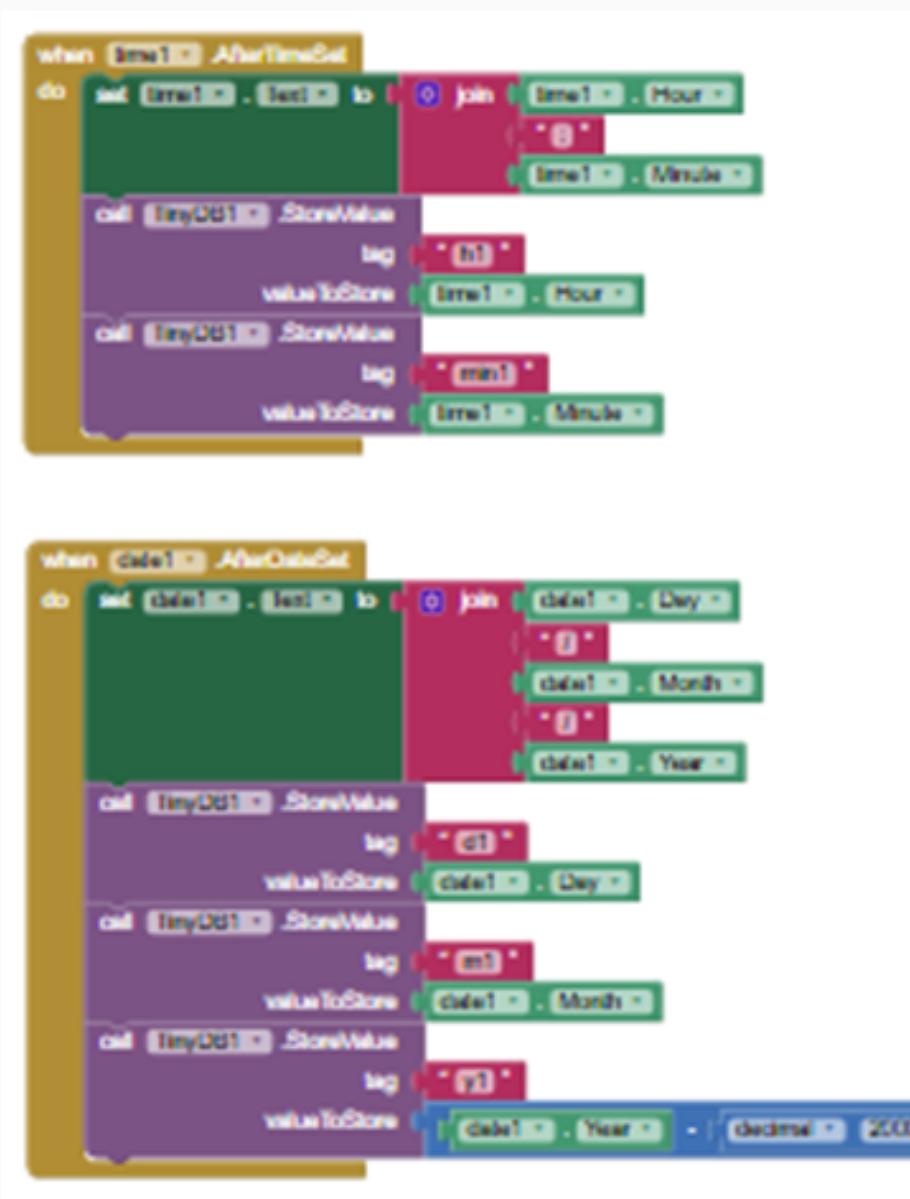
3C. Mobile Application Design



3C. Mobile Application Design



3C. Mobile Application Design



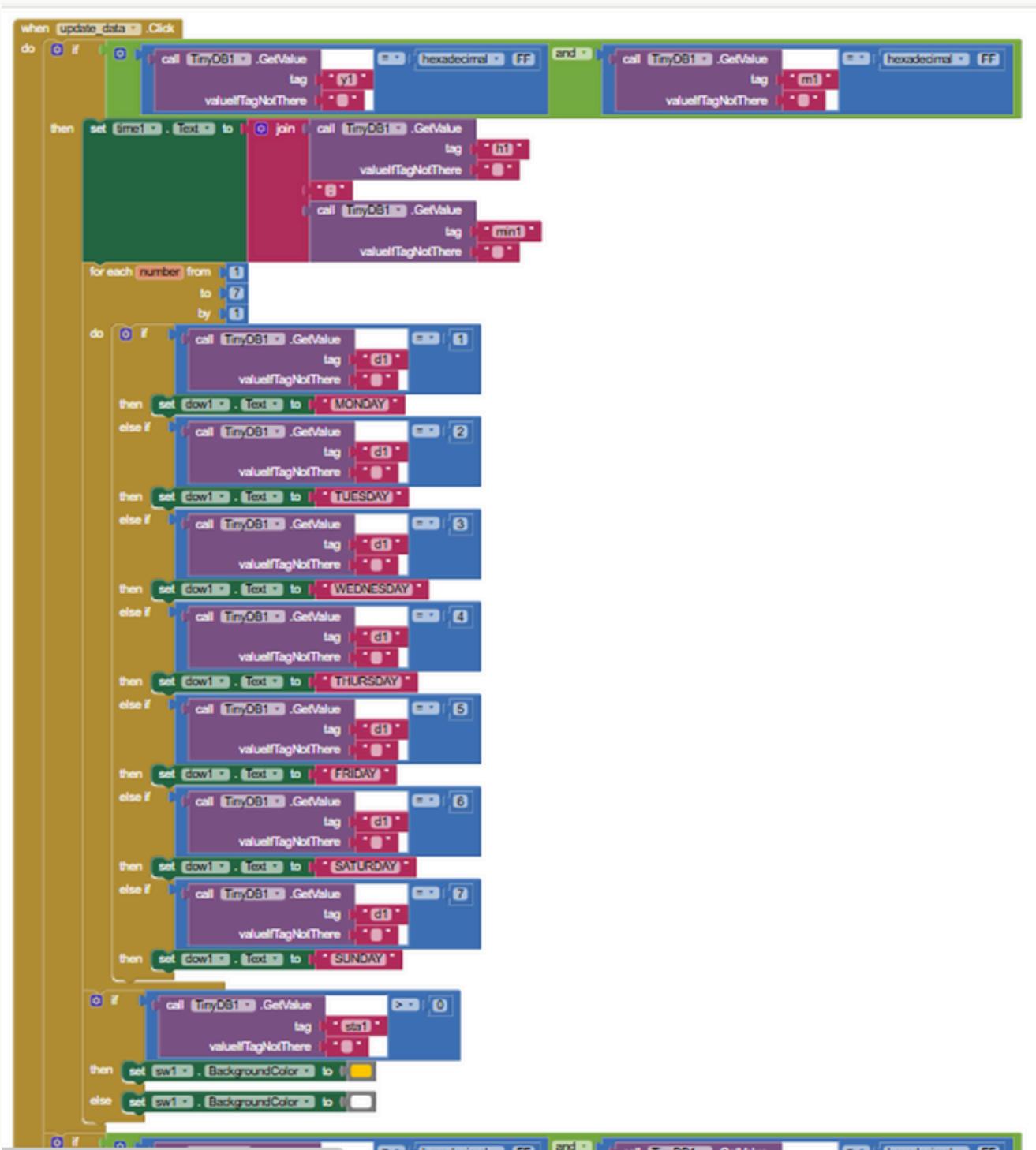
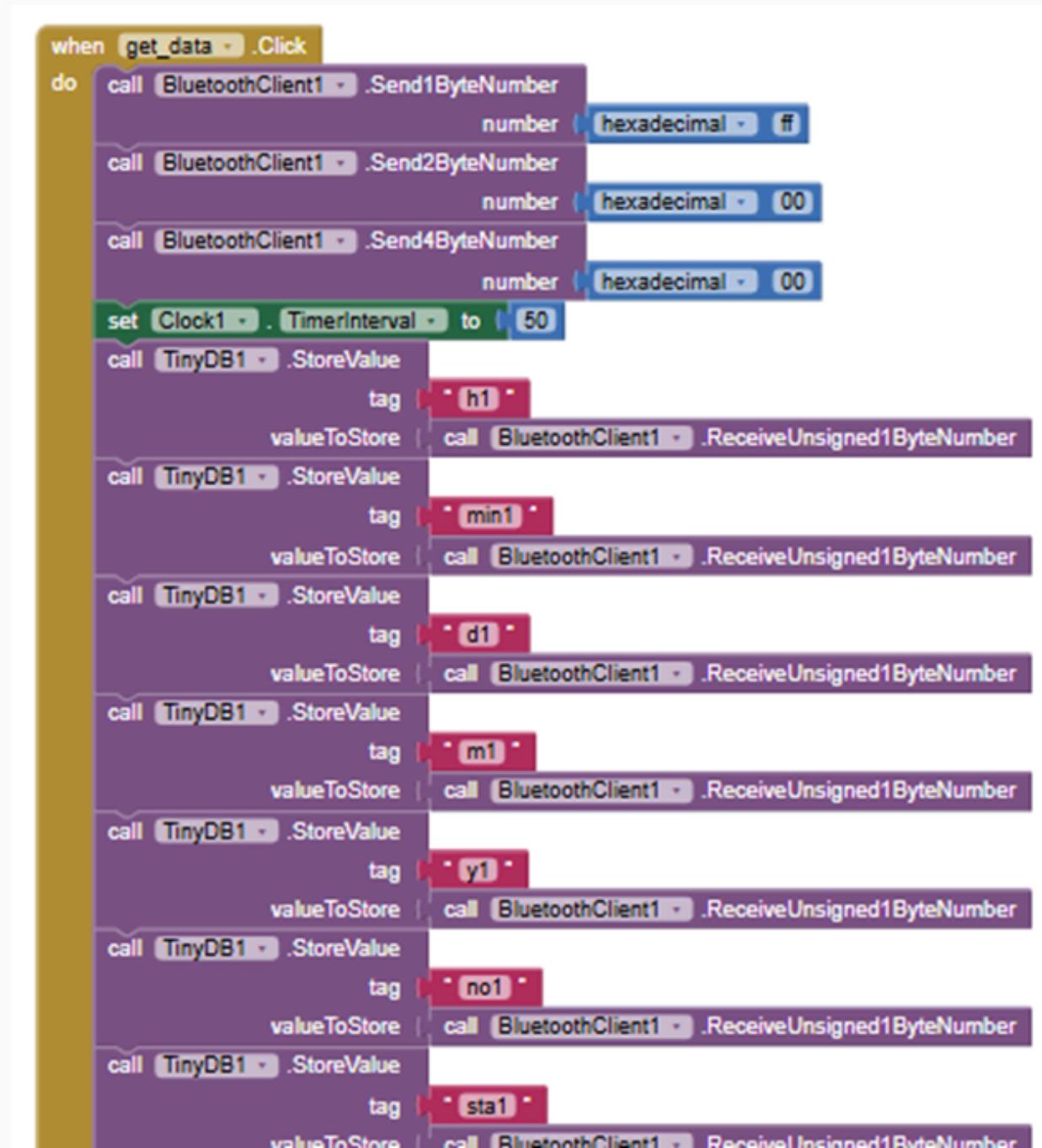
3C. Mobile Application Design



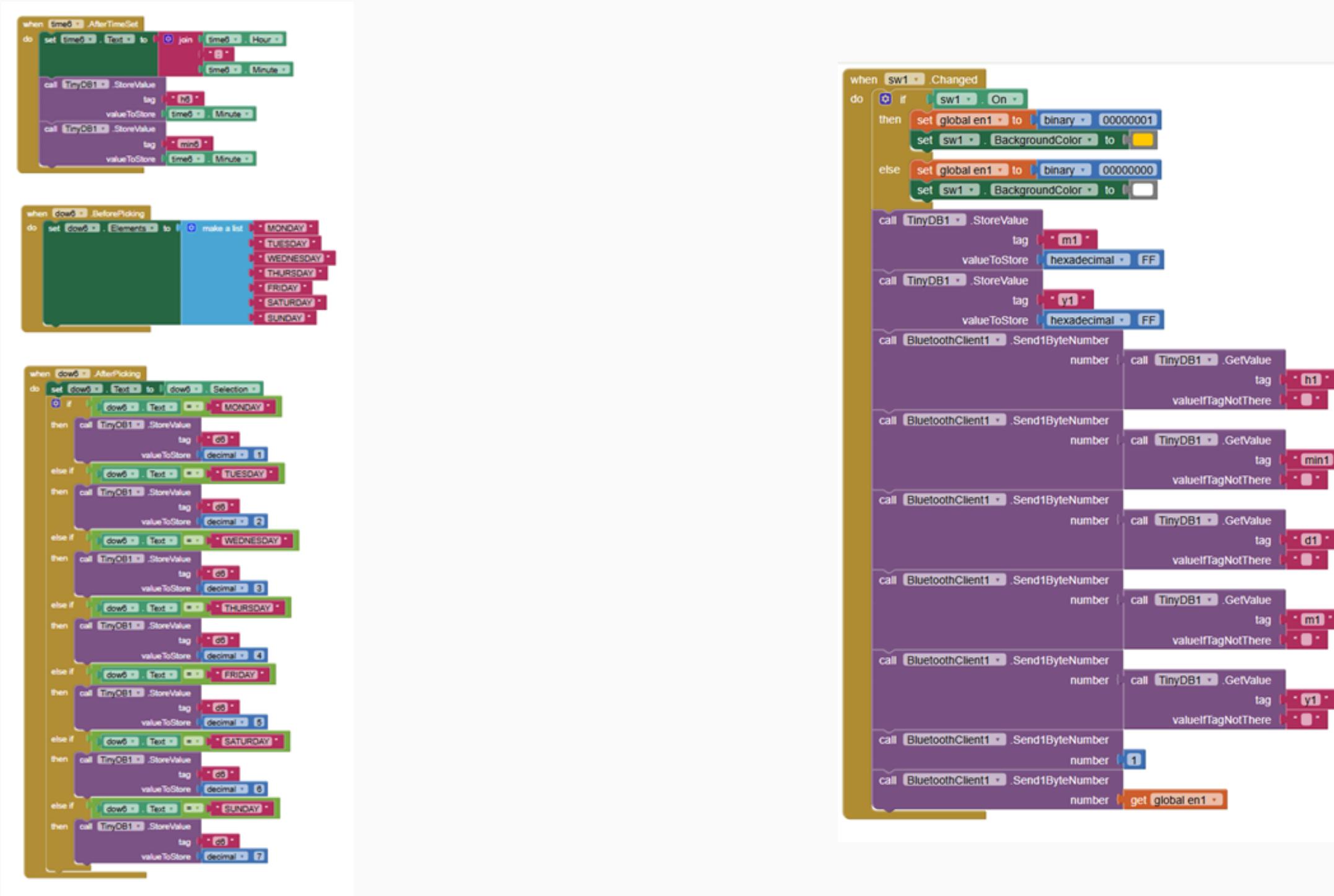
3C. Mobile Application Design



3C. Mobile Application Design



3C. Mobile Application Design



4. RESULTS & DISCUSSION



A Implemented Features



B Testing & Debugging Process



C Challenges & Solutions



D Performance Evaluation

4A. Implemented Features

FR-1: Time Display Functionality

FR-2: Alarm Management

FR-3: Time and Alarm Setting via Physical Buttons

FR-4: Alarm Review and Editing

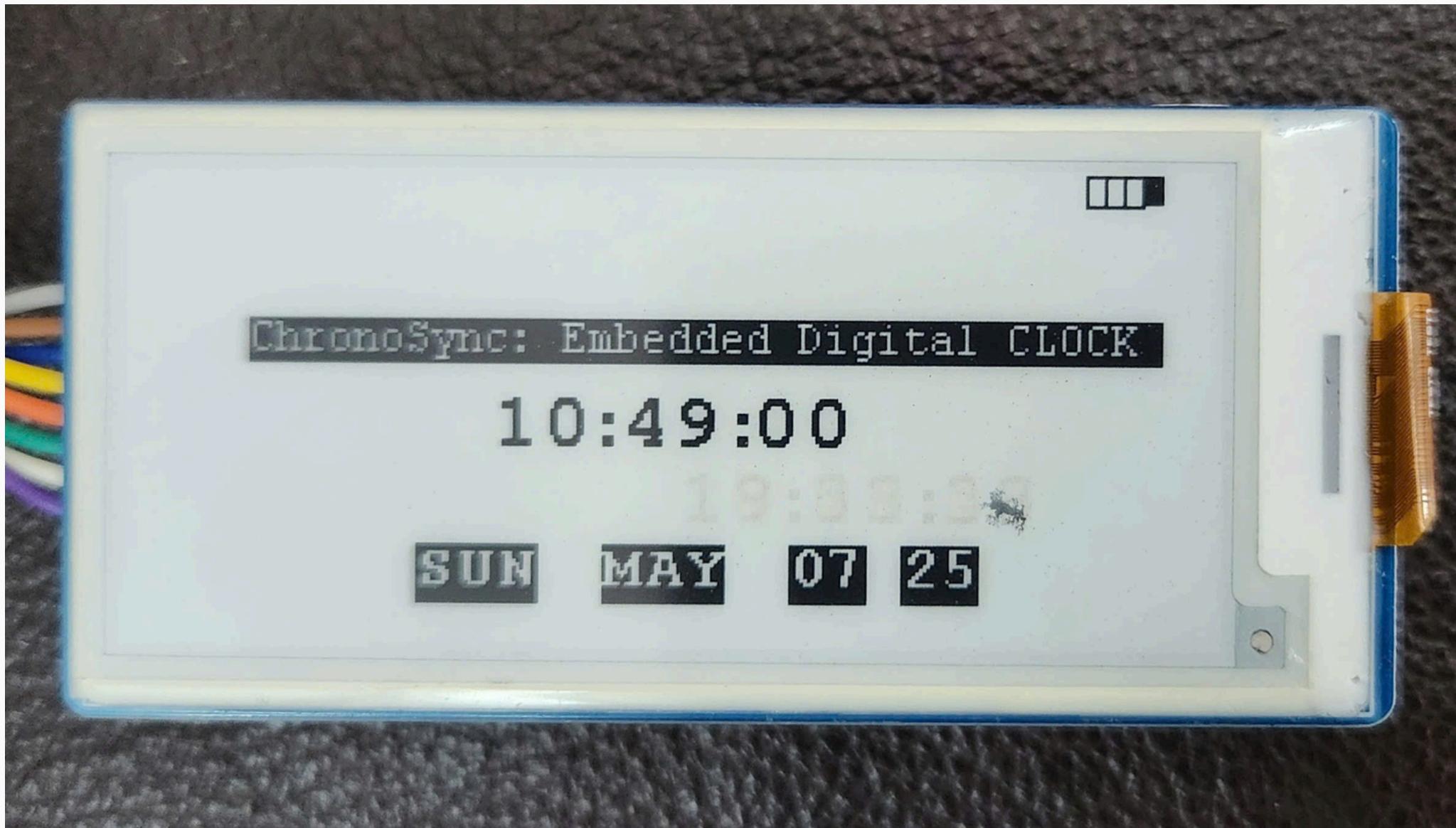
FR-5: Time and Alarm Configuration via Mobile Application

FR-6: System Utility Features

FR-7: Physical Device Requirements

FR-8: Power Efficiency and Display Technology

4A. Implemented Features



Default Mode

4A. Implemented Features



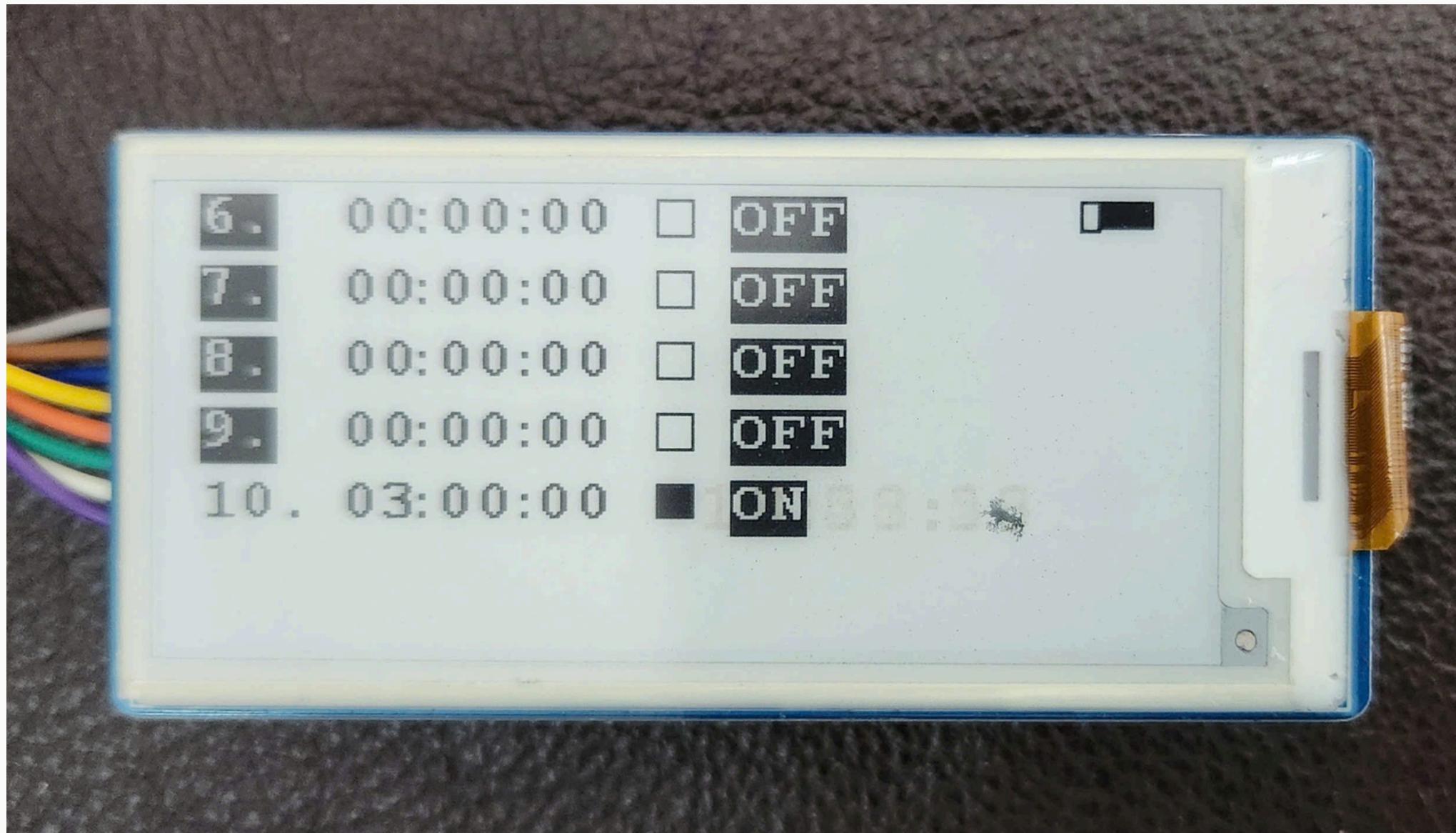
Time Setup Mode

4A. Implemented Features



Alarm Setup Mode

4A. Implemented Features



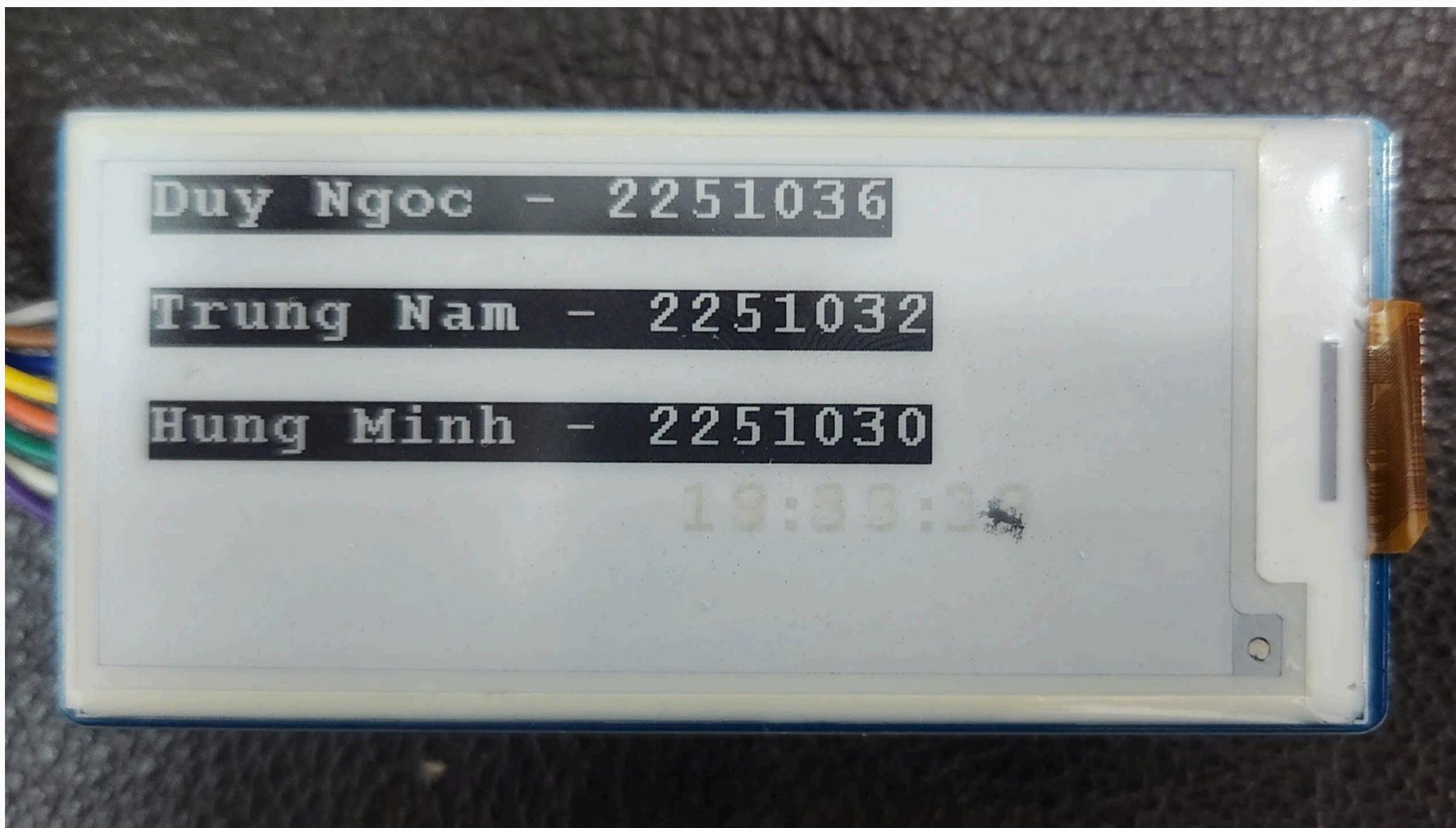
Alarm View Mode

4A. Implemented Features



System Options Mode

4A. Implemented Features



System Options Mode

4B. Testing & Debugging Process

- Button Debounce and Press Type Detection
- System Mode Handling vs. E-Ink Display Timing
- RTC and EEPROM I2C Communication
- RTC Square Wave Output to STM32 Interrupt
- Time and Alarm Data Encoding/ Decoding
- Efficient Alarm Matching Algorithm
- Alarm Ring Melody Management
- System State Management Across Modes
- Context-Aware Button Handling

4C. Challenges & Solutions

Functional Limitations

Button long press: continuous increment/decrement

Long press detected, but no continuous value change due to E-Ink delay.

→ Use timer/interrupt for async input; delay display refresh.

Debounce vs. E-Ink

Debounce delay conflicts with slow display updates.

→ Make display refresh conditional/non-blocking.

4C. Challenges & Solutions

Functional Limitations

Incomplete app features

App lacks real-time sync, alarm editing, battery display.

→ **Add BLE UUIDs and callbacks for time, alarm, battery sync.**

Basic display UI

Display shows raw data without user-friendly layout.

→ **Redesign UI with icons, fonts, and screen partitions.**

4C. Challenges & Solutions

Functional Limitations

Missing system options

Factory reset and test pattern not implemented.

→ **Add system reset and screen test handlers.**

No proper enclosure

Cardboard case; lacks durability.

→ **Design 3D-printable Mica/ABS case with accurate cutouts.**

4C. Challenges & Solutions

Functional Limitations

Battery not connected

No battery installed; ADC block unused.

→ **Solder battery holder, enable ADC voltage reading for percentage.**

4C. Challenges & Solutions

Constraints & Testing Limitations

C-1.2: Alarm match < 50 ms

Alarm match logic unmeasured; early exits implemented.

→ **Use HAL_GetTick() or cycle counters to measure and tune.**

C-2.3: EEPROM access < 10 ms

EEPROM is fast, but timing not verified.

→ **Benchmark with GPIO toggle or live expression, avoid repeated access.**

4C. Challenges & Solutions

Constraints & Testing Limitations

C-4.3: Power < 3 mW

Designed for low power, but no real measurement yet.

→ **Use power meter to test idle/active current, optimize ADC/UART idle.**

4D. Performance Evaluation

C-1: Timing and Accuracy

- C-1.1: Time accuracy within ± 3 ppm at room temperature
- C-1.2: Alarm matching executed < 50 ms per loop
- C-1.3: RTC retains time for ≥ 30 days without power

C-2: Alarm Storage

- C-2.1: Alarm data persistent after power loss
- C-2.2: Max 50 bytes used for all alarm storage
- C-2.3: EEPROM read/write time < 10 ms

4D. Performance Evaluation

C-3: Input Responsiveness

- C-3.1: Short press latency < 30 ms
- C-3.2: Long press registered after 600 ms
- C-3.3: <1 false trigger per 100 presses

4D. Performance Evaluation

C-4: Power and Energy

- C-4.1: Operates on $4 \times 3V$ 2000 mAh batteries
- C-4.2: ≥ 90 days idle runtime per full charge
- C-4.3: Typical power consumption < 3 mW
 - C-4.3.1: Periodic tasks run once per second
 - C-4.3.2: Display draws < 0.02 mW in any mode
 - C-4.3.2.1: Display refresh max 1 Hz

4D. Performance Evaluation

C-5: Physical Dimensions

- C-5.1: Size \leq 15 cm \times 15 cm \times 8 cm
- C-5.2: Weight $<$ 300 g

5. CONCLUSION

- **Core functions achieved:** timekeeping, alarm, button/Bluetooth control, low-power E-Ink
- **Modular hardware & firmware design**
- **Incomplete features:** app sync, utility modes, battery integration
- **Stable performance, responsive interaction**
- **Future work:** UI refinement, power optimization, full feature coverage
- **Gained experience:** embedded design, real-time coding, HW/SW integration



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Q & A



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Thank You