# RL78/G13

## Smart Medicine Box

R01AN4261EC0100
Rev.1.00
Nov. 30, 2018

## Introduction

This document describes a Renesas microcontroller RL78/G13 application for a smart medicine box.

## Target Device

RL78/G13

When applying the sample program covered in this document to another microcomputer, modify the program according to the specifications for the target microcomputer and conduct an extensive evaluation of the modified program.

## Contents

# 1. Description

## 1.1 Abstract

The smart medicine box, described in this document, is designed for those users who regularly take medicines and the prescription of their medicine is very long as it is hard to remember for patients and for their care giver. Also, old age patients suffer from the problem of forgetting to take pills on time which causes certain health issues like diabetes, blood pressure, heart problems, etc. The smart medicine box can solve these problems by setting up a time table of prescribed medicines through a mobile app as given in prescription. Present time will be saved in RTC module and notification time (RTC alarm) will be saved in Data Flash.

## 1.2 Specifications and Main Technical Parameters

### Technical Parameters

- Power Supply — USB power supply (5 V) or 3 V (2 AA batteries)
- Operating Voltage (MCU) — 3.3 V
- Alarm Sound — Over 80 dB
- Wi-Fi — 2.4 GHz
- Operating Temperature: — Ambient temperature
- Power Consumption (Whole System): — 71.6 μA (STOP mode, Wi-Fi module is powered off)

### Specifications

- Function:
  Connect to Renesas IoT Sandbox via WeMos ESP8266 module.
  Record pill taken activities.
  Set the notification time according to the message from the mobile app.
  Generates notification sound and display the bright light.
  Transmit record of pills taken back to the mobile app.
  Low battery voltage alert.
  Display real-time data on a 4-digit 7-segment LED.

# 2. RL78/G13 Microcontroller

## 2.1 RL78/G13 Block Diagram

Figure 2.1 shows the block diagram of RL78/G13.

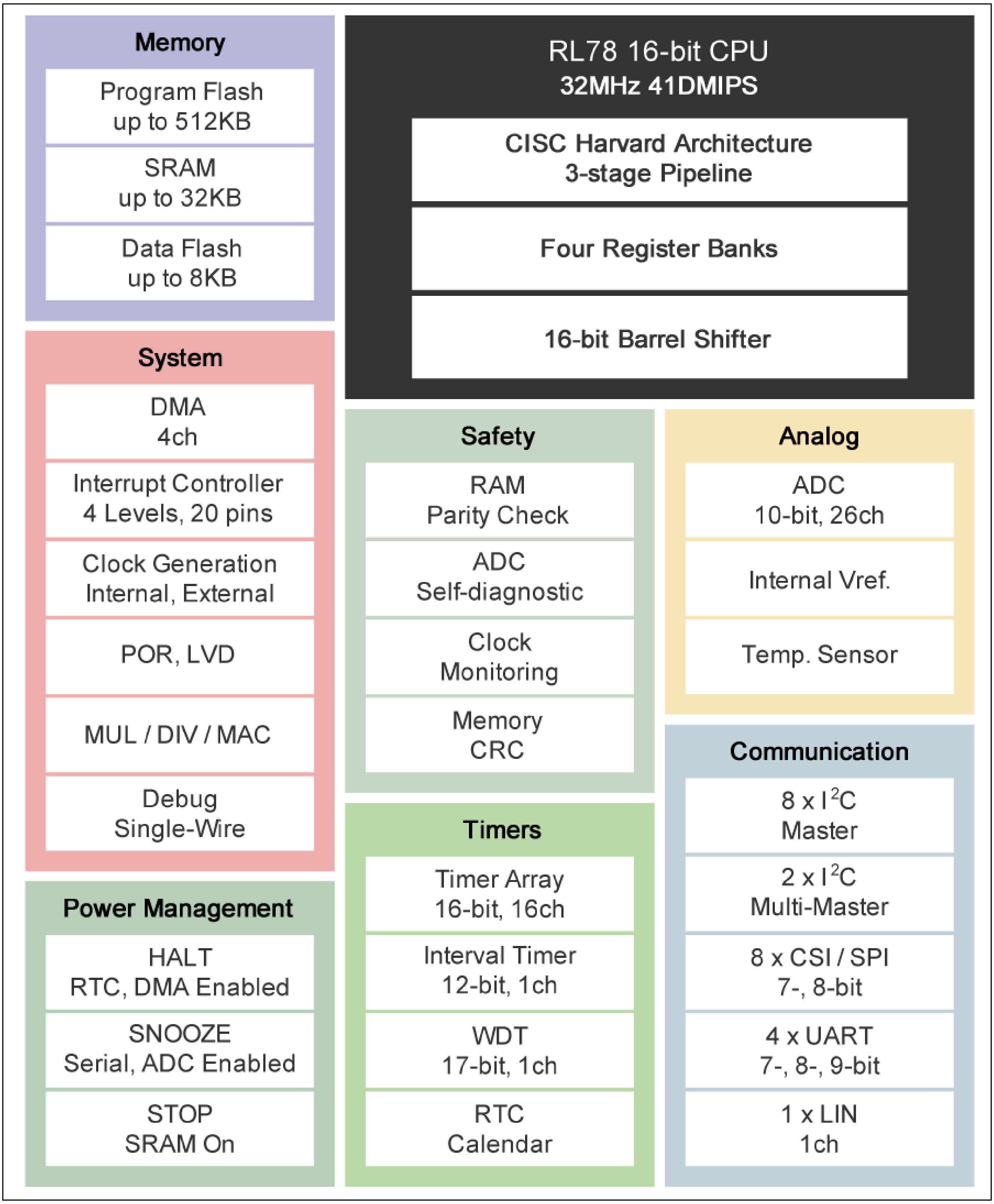


**Figure 2.1 RL78/G13 Block Diagram**

## 2.2 Key Features

- Minimum instruction execution time: Can be changed from high speed (0.03125 µs: @ 32 MHz operation with high-speed on-chip oscillator) to ultra-low speed (30.5 µs @ 32.768 kHz operation with subsystem clock)
- General-purpose registers: (8-bit register × 8) × 4 banks
- ROM: 16 KB to 512 KB, RAM: 2 KB to 32 KB, Data Flash: 4 KB to 8 KB
- Selectable high-speed on-chip oscillator clock: 32/24/16/12/8/6/4/3/2/1 MHz (TYP.)
- On-chip single power supply flash memory
- Power management and reset function
- On-chip power-on-reset (POR) circuit
- On-chip voltage detector (LVD) (Select interrupt and reset from 14 levels)
- On-chip debug function
- On-chip key interrupt function
- On-chip clock output/buzzer output controller
- I/O port: 16 to 120 (N-ch open drain I/O [withstand voltage of 6 V]: 0 to 4, N-ch open drain I/O [$V_{DD}$ withstand voltage $EV_{DD}$ withstand voltage]: 5 to 25)
- Timer
  16-bit timer: 8 to 16 channels
  12-bit interval timer: 1 channel
  Real-time clock: 1 channel (calendar for 99 years, alarm function, and clock correction function)
  Watchdog timer: 1 channel (operable with the dedicated low-speed on-chip oscillator)
- Serial interface
- CSI: 2 to 8 channels
- UART/UART (LIN-bus supported): 2 to 4 channels
- I2C/Simplified I2C communication: 2 to 8 channels
- 8/10-bit resolution A/D converter: 6 to 26 channels
- Internal reference voltage (1.45 V) and temperature sensor
- DMA (Direct Memory Access) controller: 2/4 channels
- Multiplier and divider/multiply-accumulator
- 16 bits × 16 bits = 32 bits (Unsigned or signed)
- 32 bits ÷ 32 bits = 32 bits (Unsigned)
- 16 bits × 16 bits + 32 bits = 32 bits (Unsigned or signed)
- Standby function: HALT mode, STOP mode, SNOOZE mode
- Power supply voltage: $V_{DD}$ = 1.6 to 5.5 V
- Operating ambient temperature: $T_A$ = -40 to +85°C

## 2.3 Pin Configuration

Figure 2.2 shows the pin configuration of RL78/G13 (44-pin products).

- 44-pin plastic LQFP (10 × 10 mm, 0.8 mm pitch)

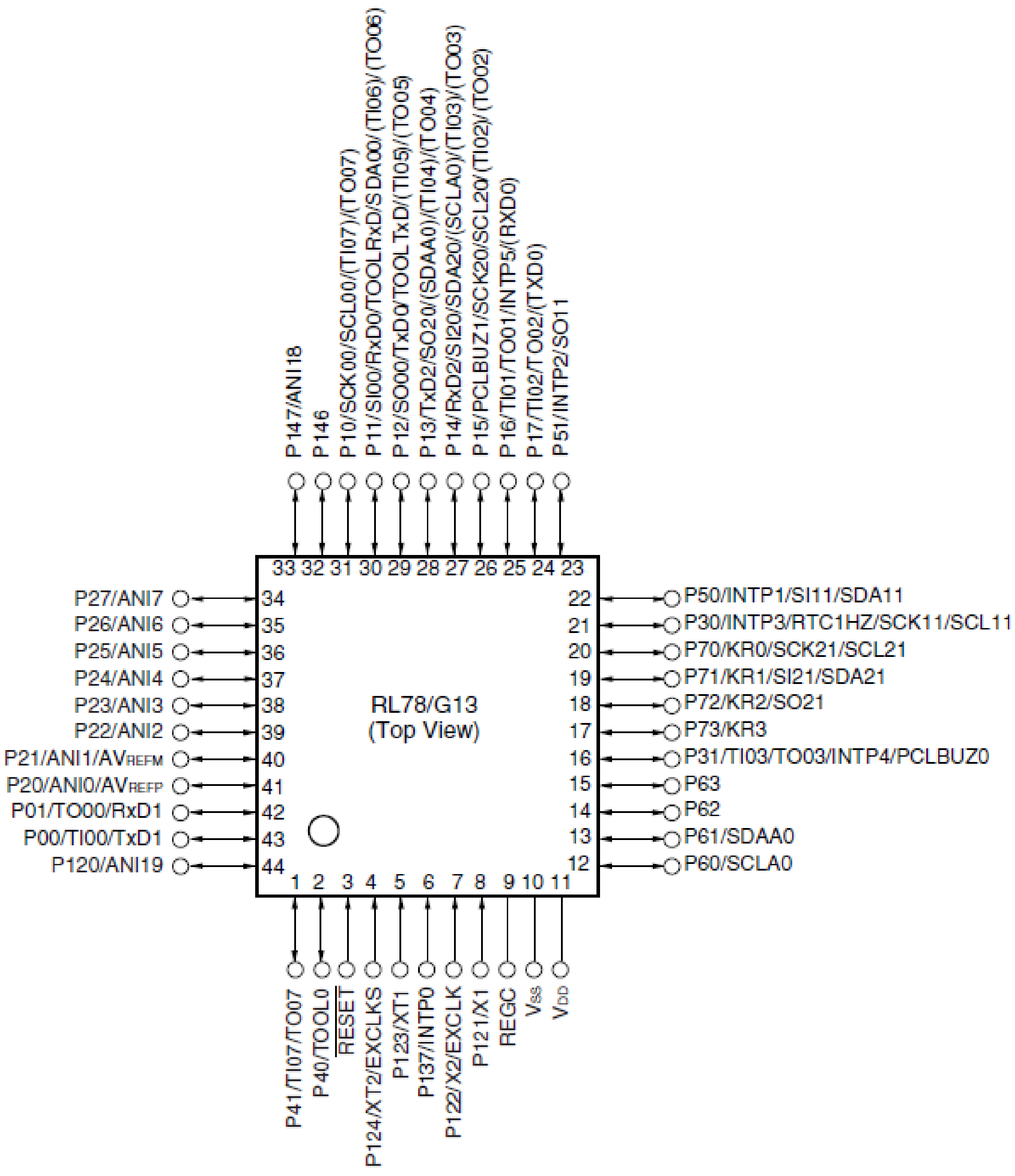


**Figure 2.2 RL78/G13 (44-pin products) Pin Configuration**

# 3. System Outline

## 3.1 Principle Introduction

The smart medicine box uses an RL78/G13 microcontroller and a WeMos ESP8266 module (Wi-Fi module[Note]) and a mobile app. Via a Wi-Fi module, it can link to the Renesas IoT Sandbox. Figure 3.1 shows the system connection and communication diagram.

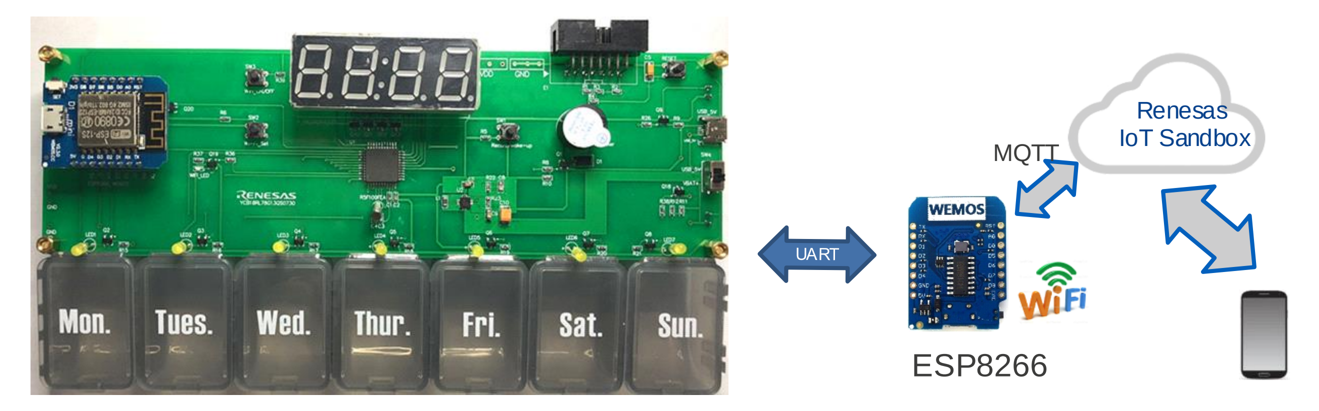


**Figure 3.1 System Communication Block Diagram**

The mobile app can program the notification time to the RL78/G13, and record pills taken remotely using MQTT protocol. At the time of taking medicine, the smart medicine box generates a notification sound and displays a bright light in certain pill boxes, so that the patient will know the specific number of boxes from which they should take out medicine. The smart medicine box can also determine if the patient has taken out pills from the box by checking recording key is pressed or not. The record can also be transmitted to the mobile app via the Wi-Fi link when a recording key is pushed.

Figure 3.2 shows the MCU board block diagram.

Note: The WeMos D1 module may not be a certificated device for emitting the radio frequency in some regions. You need to do the certifications (like FCC / CE / TELEC) by yourself if it is necessary.

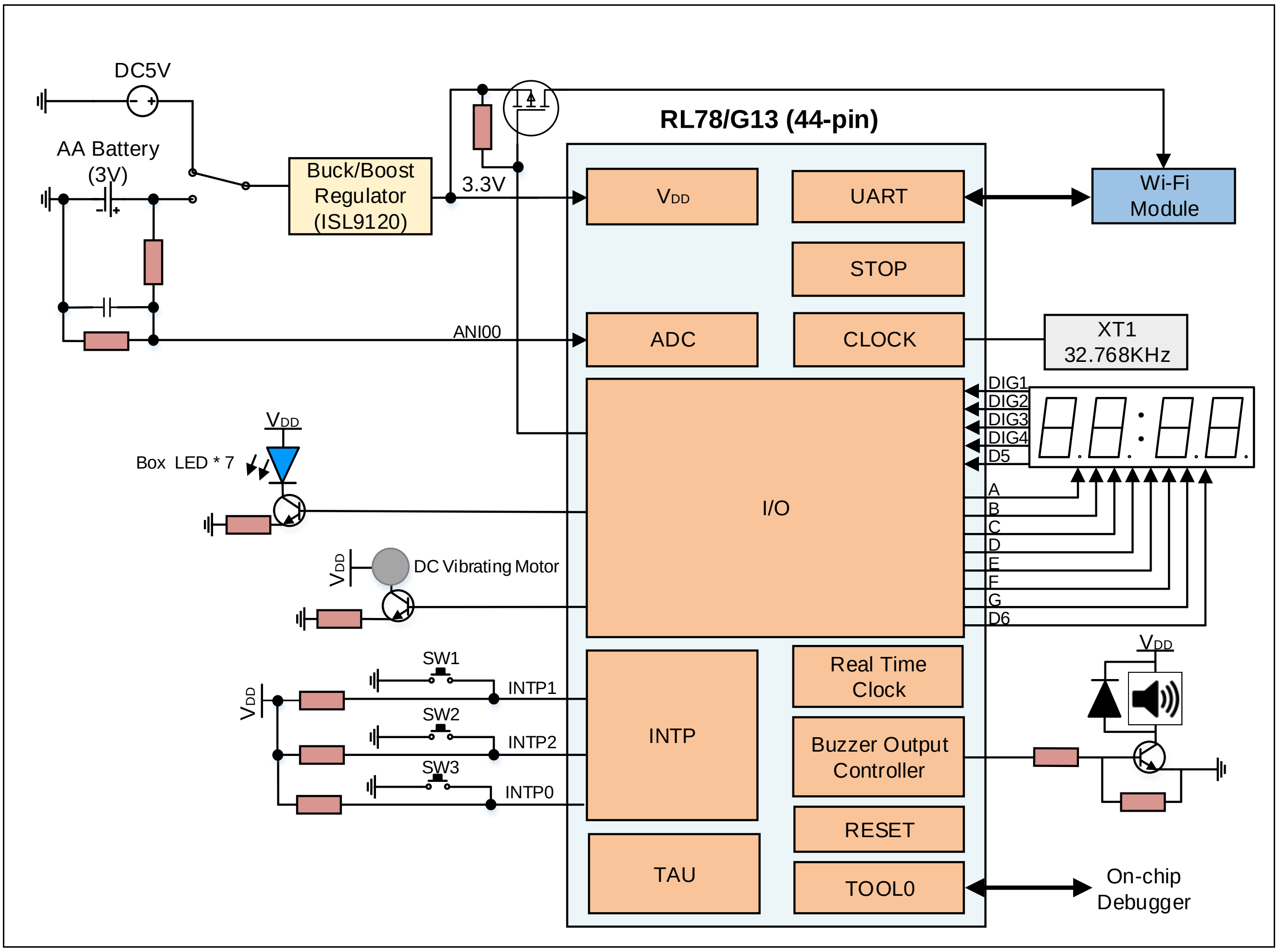


**Figure 3.2 MCU Board Block Diagram**

## 3.2 Peripheral Functions to be Used

Table 3.1 lists the peripheral functions to be used and their usage.

**Table 3.1 Peripheral Functions to be Used**

| Peripheral Function | Usage |
|---|---|
| UART0 of SAU0 | Communicate with the WeMos ESP8266 module. |
| Real-time Clock | Real-time clock counting and generate alarm time interrupt. |
| A/D converter | Detect the switch battery voltage. |
| PCLBUZ0 | Control the buzzer to sound. |
| INTP0 | The switch input (SW3) to receive the demand of power ON/off the Wi-Fi module |
| INTP1 | The switch input (SW1) to record taking pills action or wake up the system |
| INTP2 | The switch input (SW2) to send the demand of configure the Wi-Fi module |
| Channel0 of TAU0 | 1 second interval timer for system timers of 10 seconds and 60 seconds. |
| Channel1 of TAU0 | 20 ms interval timer as the timer for key dithering elimination. |
| Channel2 of TAU0 | 200 ms interval timer as the WeMos ESP8266 module reset timer |
| Channel3 of TAU0 | 5 ms interval timer as the refresh ratio for the 4-digit 7-segment LED |
| Data Flash | Store the values of the RTC alarm time. |

## 3.3 Pins to be Used

Table 3.2 lists the pins to be used and their function.

**Table 3.2 Pins to be Used**

| Pin Name | Description |
|---|---|
| P21~P27 | Control 7 LEDs which indicate the specific number of boxes from which the patient should take out medicine to follow the weekday information |
| P20/ANI0 | Analog input for battery voltage detection |
| P120 | Control the power switch for battery voltage detection circuit |
| P124/XT2/EXCLKS<br>P123/XT1 | 32.768 kHz crystal resonator connection |
| P11/RXD0, P12/TXD0 | UART communication interface with the WeMos ESP8266 module |
| P41/TO07 | Control DC vibration motor |
| P00 | Control the RESET pin of the WeMos ESP8266 module |
| P60 | Control the Wi-Fi module power on/off |
| P31/PCLBUZ0 | Control the buzzer |
| P10, P13~P17, P30, P70~P73, P146, P147 | Control 4-digit 7-segment LED |
| P137/INTP0 | Switch input of “SW3” |
| P50/INTP1 | Switch input of “SW1” |
| P51/INTP2 | Switch input of “SW2” |
| $V_{DD}$ | Power supply voltage |
| $V_{SS}$ | Ground |
| REGC | Connect this pin to $V_{SS}$ via a capacitor (0.47 to 1 µF) with good characteristics to stabilize internal voltage. |
| P40/TOOL0 | Data I/O for flash memory programmer/debugger |
| RESET | Reset pin |

## 3.4 What You Need to Get Started

- Renesas RL78/G13 smart medicine box demo board
- Wi-Fi Internet access (2.4 GHz only)
- ESP8266 WeMos D1 Mini board, v.2.3.0
  https://wiki.wemos.cc/products:d1:d1_mini
- Windows PC
- 2x Micro USB data cable
- WeMos ESP8266 module bin file: main_smb_iot_sandbox_no_tls.ino.d1_mini.bin
- esptool.exe flashing tool
  https://github.com/Medium-One/m1_cloud_io/blob/master/esptool.exe
- RL78/G13 mot file: rl78g13_smart_medicine_box.mot

STEP 1. Program RL78/G13 mot file
Connect the RL78 to the Windows PC via one Renesas emulator (e.g., E1 emulator) and open Renesas Flash Programmer (https://www2.renesas.cn/products/software-tools/tools/programmer/renesas-flash-programmer-programming-gui.html) .

Download rl78g13_smart_medicine_box.mot file (in the folder of "X:\..\Source Code\Program file") according to the instruction of Renesas Flash Programmer.

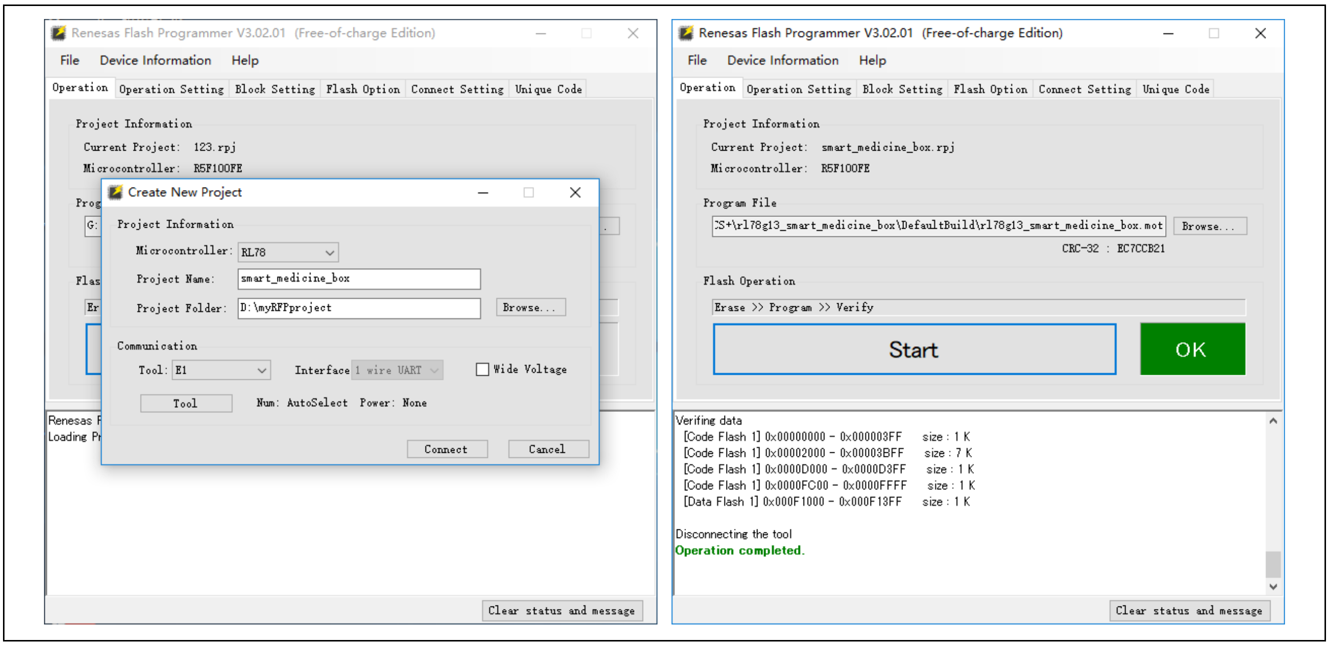


**Figure 3.3 Program MCU mot file**

If the flash is programmed with OK, the RL78/G13 demo board is ready.

STEP 2. Flash the WeMos ESP8266 module
Connect (via 2x Micro USB data cable) the ESP8266 board into Windows PC. Install Windows USB driver (https://wiki.wemos.cc/downloads) for WeMos board, which will allow the Windows PC to communicate with and flash the WeMos board.

Open the device manager. Under the 'Ports' dropdown, the USB Serial Port # (COM#) of WeMos ESP8266 Module can be got.

Open the Command Prompt and change directories into the folder ("X:\..\Source Code\WiFi Module\esptool flashing tool") where the files of main_smb_iot_sandbox.ino.d1.bin and esptool.exe tool are in.

In the command window, copy and paste the following command and replace COM8 with your COM# then press "Enter".

```
esptool.exe -vv -cd nodemcu -cb 921600 -cp COM8 -ca 0x00000 -cf
main_smb_iot_sandbox.ino.d1.bin
```

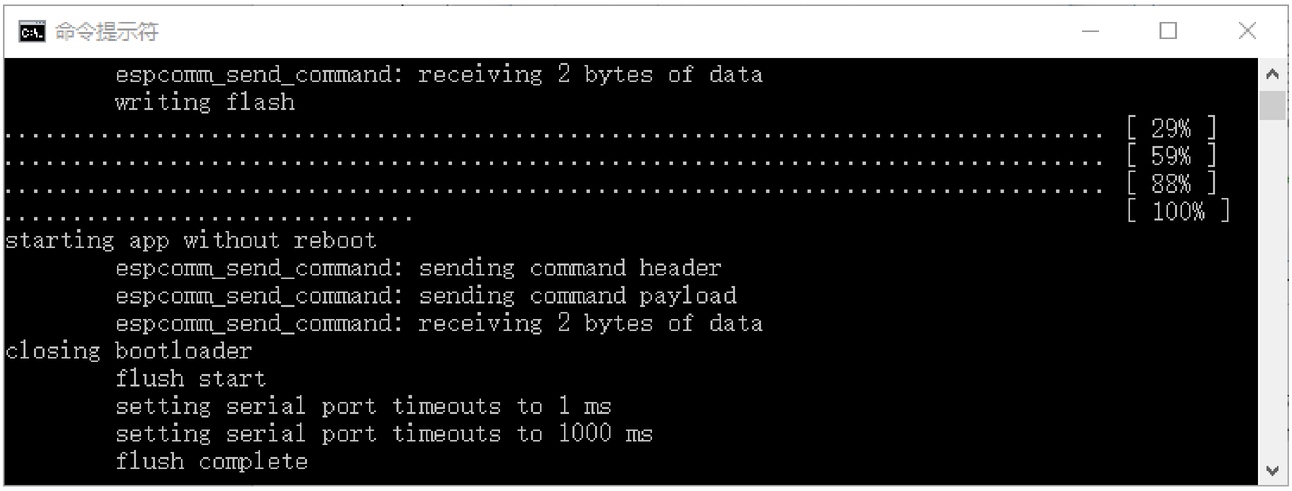


**Figure 3.4 Program WeMos ESP8266 Module**

If the flash is programmed 100%, the WeMos ESP8266 module is ready.

STEP 3. Connect RL78/G13 smart medicine box demo board and the WeMos D1 mini board.
Connect RL78/G13 board with the WeMos ESP8266 module. The pins connection is shown in Table 3.3.

**Table 3.3 Pins to be Used**

| Pins on RL78/G13 MCU Board (CON5) | | Pins on WeMos D1 Mini Board | |
|---|---|---|---|
| **Pin No. in CON5** | **RL78/G13 pin** | **ESP8266 pin** | **Function** |
| 1 | $V_{DD}$ | 3V3 | 3.3V |
| 2 | P11/RXD0 | D7 | GPIO13 (software TXD) |
| 3 | P12/TXD0 | D6 | GPIO12 (software RXD) |
| 4 | P60 | RST | Module Reset |
| 5 | $V_{SS}$ | G | GND |

STEP 4. Install mobile app
Open the installation file of "Smart Medicine Box.apk" and install the app in the android mobile.

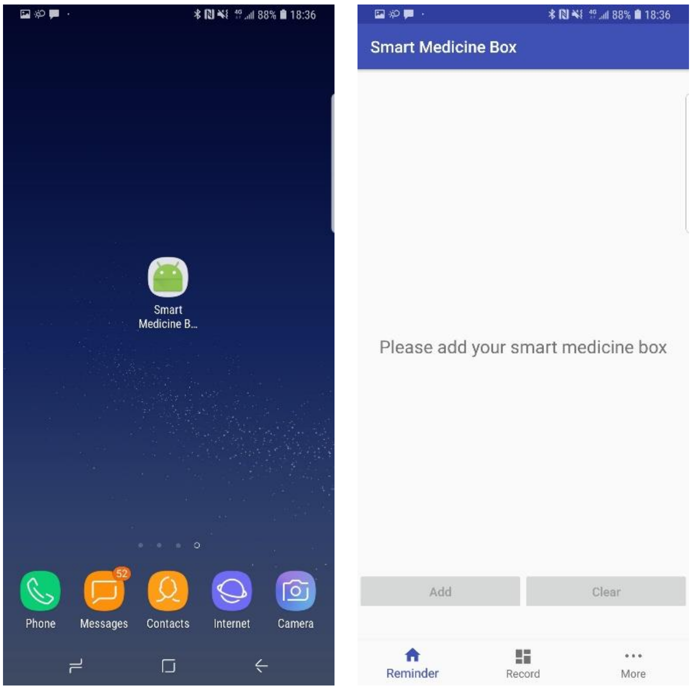


**Figure 3.5 Installation of the Mobile App**

About the MQTT information for each demo
In the sample program, some medicine boxes ID and MQTT ID and password have been registered. Please choose one number by the selection in the smbinfo.h file, which is shown in Figure 3.6.

If users want to change the smart medicine box ID, please rebuild the project in CS+ or e$^2$studio to generate the mot file again. Then implement step 1 and step 2 again to program the MCU flash and WeMos module flash again.

```
/*******************************************************************************************
* File Name     : smbinfo.h
* Version       : V1.00.00
* Device(s)     : R5F100FE
* Tool-Chain    : CCRL
* Description   : This file declares smart medicine box device ID and MQTT information.
* Creation Date: 2018/6/6
*******************************************************************************************

//#define SMB001
//#define SMB002
//#define SMB003
//#define SMB004
//#define SMB005
//#define SMB006
#define SMB007
//#define SMB008
//#define SMB009
//#define SMB010
```

**Figure 3.6 Smart Medicine Box ID and MQTT Information Selection**

## 3.5 Operating Instructions

(1) The smart medicine box can be powered on via micro USB or batteries. Switch the SW4 to choose the power source (USB or $V_{BAT}$). Power on the smart medicine box, it will enter the initialization operation. The WeMos ESP8266 module will be reset, and the 4-digit 7-segment LED will be ON. After 10 seconds, the smart medicine box enters STOP mode.

(2) The WeMos ESP8266 module should be configured first. The LED on the Wi-Fi module will blink at different timer intervals to indicate the different working status, which is shown in Table 3.4.

**Table 3.4 Wi-Fi Module Working Status Indication**

| Wi-Fi module LED blinking interval | Wi-Fi module working status description |
|---|---|
| 4 s | Wi-Fi connection is failed. |
| 1 s | Wi-Fi connection is successful.<br>MQTT connection is successful. |
| 500 ms | Wi-Fi connection is successful.<br>MQTT connection is failed. |
| 100 ms | In Wi-Fi ssid and password setting processing |

When SW2 is pressed for over 1 second, the RL78/G13 will send the Wi-Fi set command to the WeMos module, then the WeMos module enters the Wi-Fi setting mode. The Wi-Fi ssid and password can be set through the mobile app. The smart medicine box device ID and MQTT connecting user name and password will be sent to mobile app as well.

Press the switch of P51/INTP2 (SW2) on the smart medicine box for over 1 second to let the WeMos module enter the Wi-Fi setting mode. Open the mobile app and click the “More” and “Add Box” buttons. Enter the local Wi-Fi ssid and password, with which the WeMos ESP8266 module can connect to the router. This setting procedure is shown in Figure 3.7.

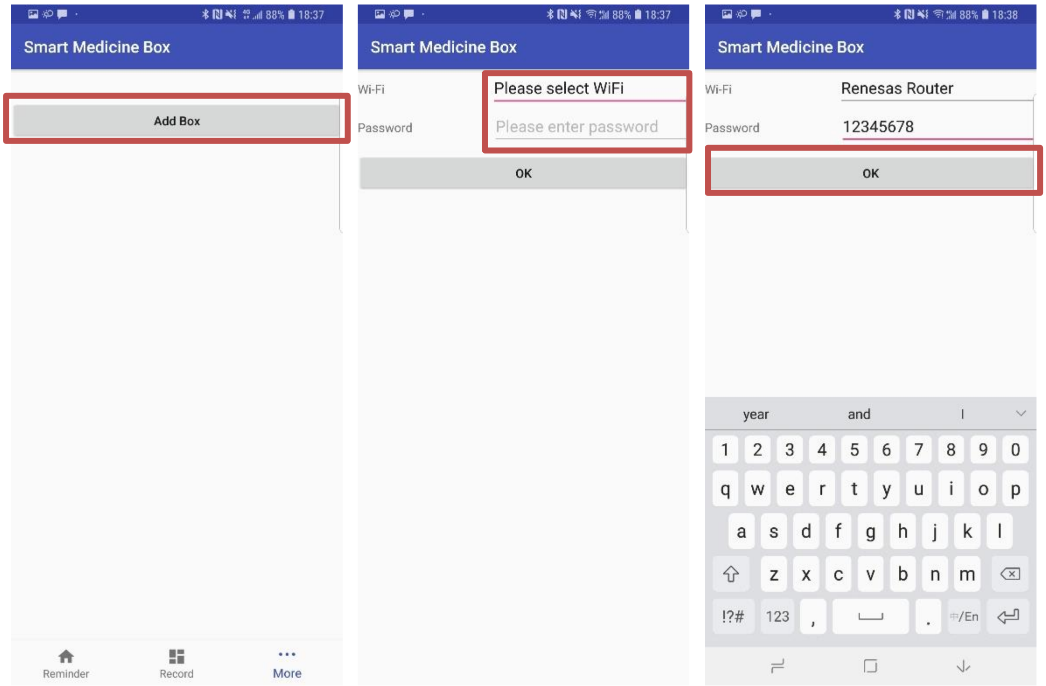


**Figure 3.7 Config the Smart Medicine Box Wi-Fi**

When the WeMos module is connected to the broker (Renesas IoT Sandbox) successfully, the LED on the Wi-Fi module will blink at 1 second interval when the network connection is successful. If not, please delete the medicine box and add it again according to the step 2.

(3) MQTT protocol is used for communication within the smart medicine and mobile phone app. When the smart medicine box is added successfully, the real-time calibration message will be sent to the smart medicine box via MQTT automatically. The RL78/G13 MCU will update the real-time clock to the current time and display the HH:MM on the 4-digit 7-segment LED. At the same time, RL78/G13 will send the response through MQTT to the mobile app to indicate that the smart medicine box is on-line.

The smart medicine box's on-line or off-line status will be checked automatically. If the smart medicine box is on-line, the "Add" and "Clear" button will be enabled. If the smart medicine box is off-line, check the LED blinking status on the Wi-Fi Module. Check the Wi-Fi and network connection and wait until the LED blinks at 1 second interval, click the "Reconnect" button again. Or go back to (2) to add the smart medicine box again. This setting procedure is shown in Figure 3.8.

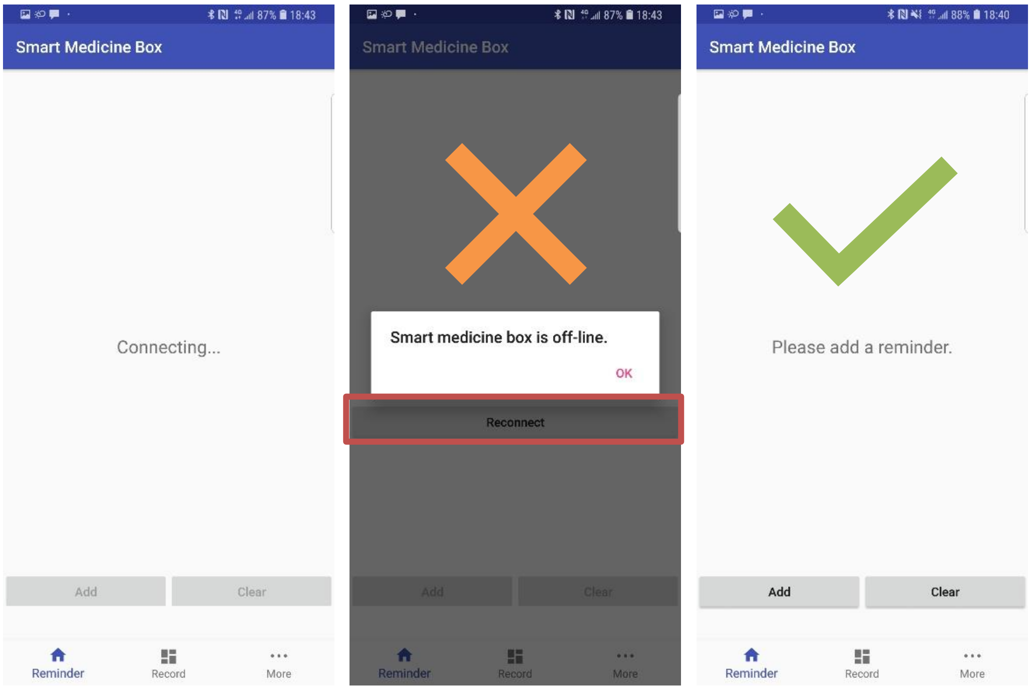


**Figure 3.8 Smart Medicine Box On-line Checking**

(4) 3 reminder times (maximum) can be set on the mobile app and the message will be sent to the smart medicine box via MQTT to remind the patient to take the medicine. Each reminder time information will be also stored in Data Flash.

Click "Add" button and select "Hour" and "Minute" on the reminder time setting page. When "Save" button is clicked, one reminder time will be set. This setting procedure is shown in Figure 3.9.

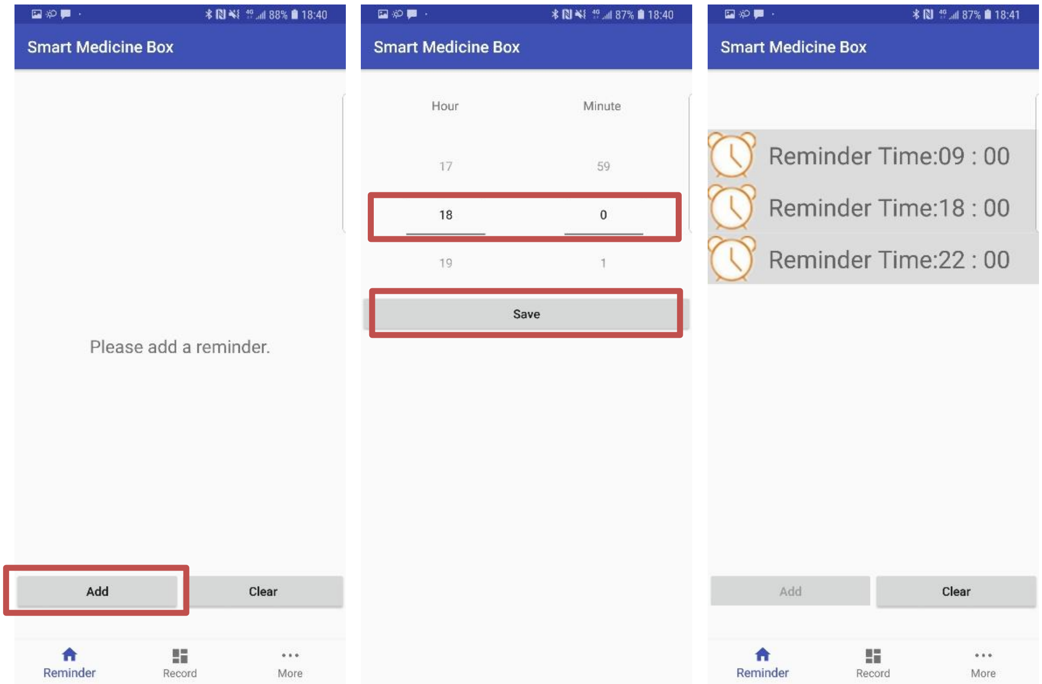


**Figure 3.9 Setting Reminder time**

When "Clear" button is clicked, all 3 reminder times will be deleted. Meanwhile, the corresponding message will be sent to the smart medicine box via MQTT. This setting procedure is shown in Figure 3.10.

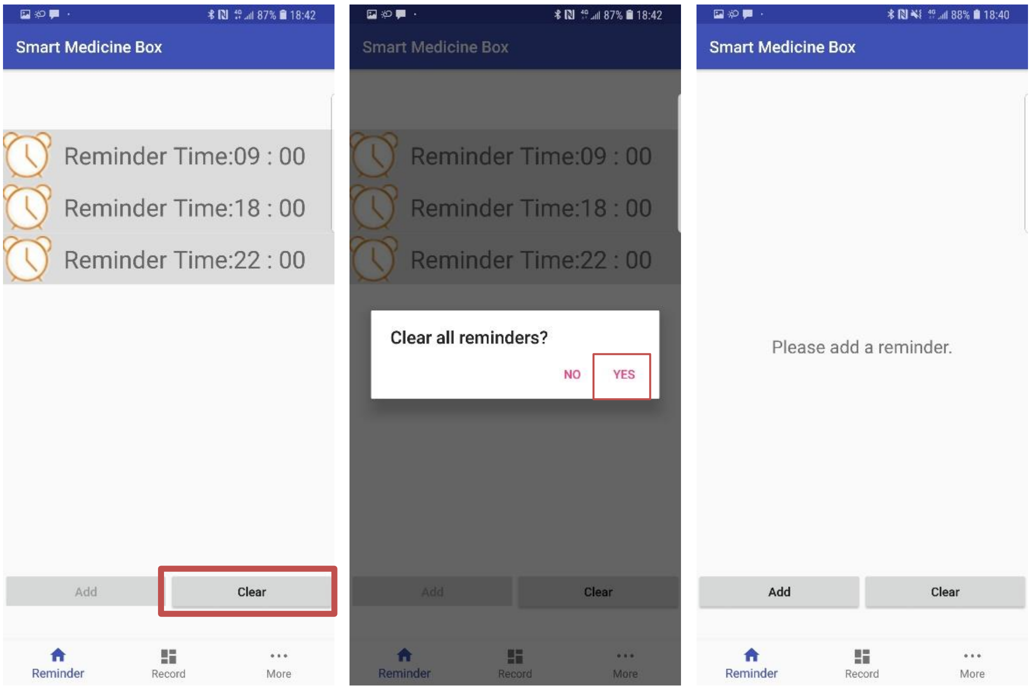


**Figure 3.10 Deleting Reminder Time**

(5) If one of the reminder time is up, the RTC alarm interrupt of the RL78/G13 will occur, and the system will generate the notification sound with the buzzer and display the bright light in the corresponding number of pill boxes. If the user presses the taking pill record switch (SW1), the smart medicine box will upload the medicine record timeline to the mobile app via MQTT through WeMos module.

Click “Record” on the mobile app, the taking medicine records can be viewed as shown in Figure 3.11.

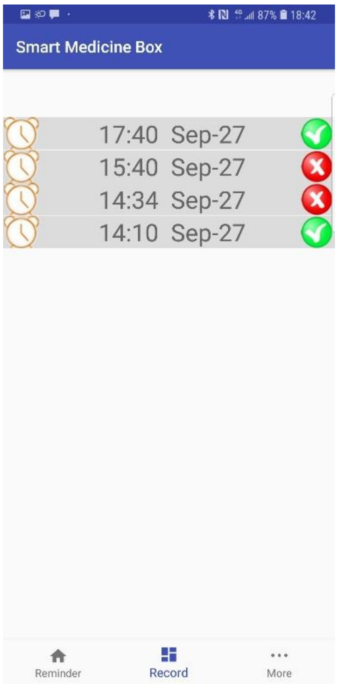


**Figure 3.11 Taking Pill Records**

(6) 4-digit 7-segment LED is used to display the real-time data. Each time the switch of SW1 is pressed or any interrupt occurs, the 4-digit 7-segment LED will be ON for 10 seconds.

(7) The battery voltage can be checked timely if the system is powered via batteries. When the RTC 1-hour interrupt occurs, the battery voltage will be checked by the A/D converter of the RL78/G13 MCU. If the battery voltage is lower than 2.5 V, the buzzer on the smart medicine box will sound every 60 seconds to notify the user to change the battery immediately. If the check battery command is received, RL78/G13 MCU will send the battery voltage data to the mobile app via MQTT through WeMos module.

Click “More” and “Check the battery capacity” button. The corresponding warning message will be displayed on the mobile screen if the battery voltage is lower than 2.5 V, as shown in Figure 3.12.

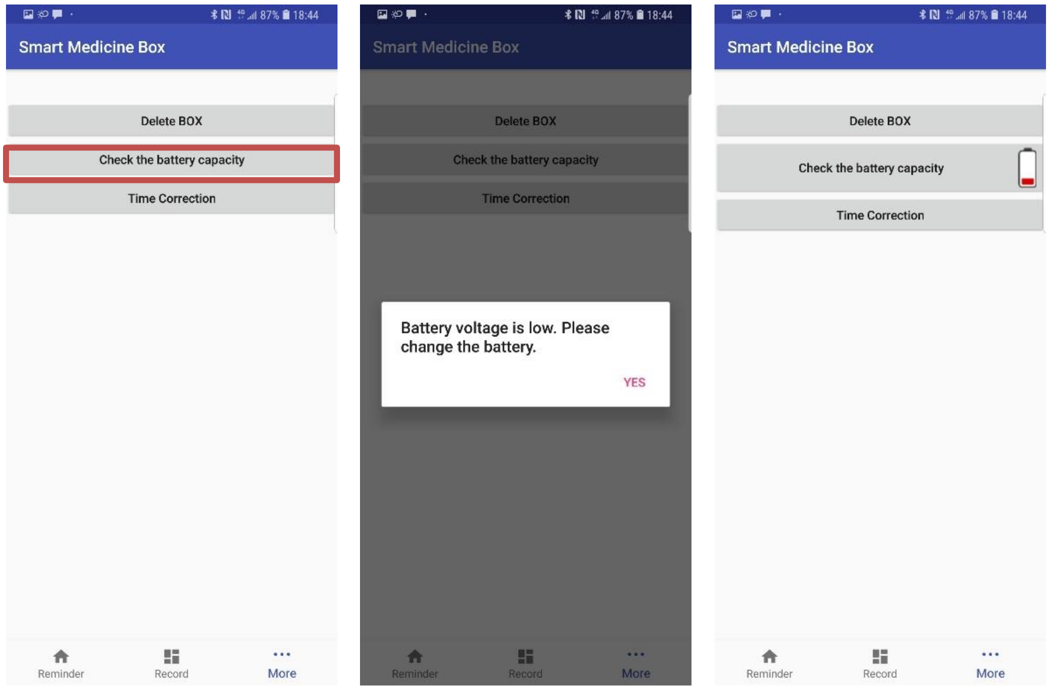


**Figure 3.12 Checking Battery Voltage**

(8) When the RTC time of the MCU is not consistent with the time of the mobile phone, click “More” and “Time Correction” button on the app, the real-time calibration message will be sent to the smart medicine box via MQTT automatically. The RL78/G13 MCU will update the real-time clock to the current time.

Click “More” and “Delete box” button on the app, the smart medicine box information will be deleted in the app. Click “Add box” button to add a smart medicine box again, as shown in Figure 3.13.

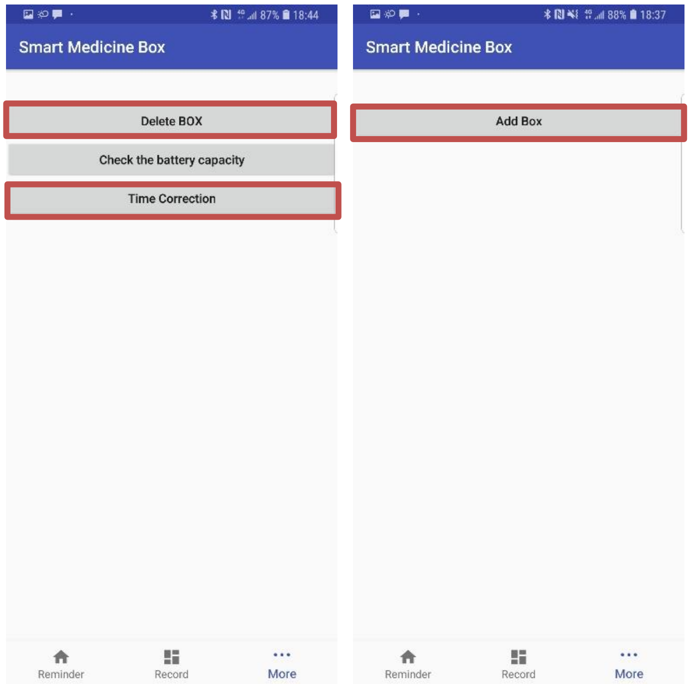


**Figure 3.13 Time Correction and Delete Box**

(9) When the system is powered via batteries, in order to reduce the power consumption, the WeMos ESP8266 module can be powered off by pressing SW3. However, the reminder times cannot be set as the smart medicine box is off-line. The taking pills record cannot be sent to mobile app, too. Press SW3 again, the WeMos module will be powered on again.

## 4. Hardware

This section describes the main circuits of the smart medicine box, including the power supply circuit, the battery voltage detection circuit, the function key detection circuit, the buzzer control circuit, the DC vibrating motor control circuit, the WeMos ESP8266 module power control circuit, the box LEDs control circuit and 4-digit 7-segment LED display circuit.

Figure 4.1 shows the board picture.

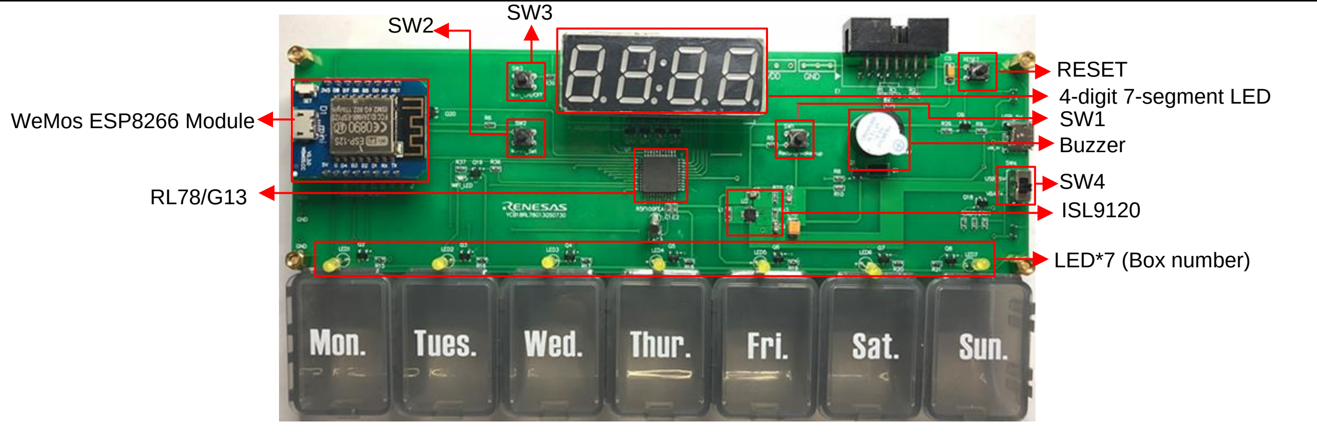


**Figure 4.1 Board Picture**

## 4.1 Power Supply Circuit

Figure 4.2 shows the schematics of the power supply circuit.

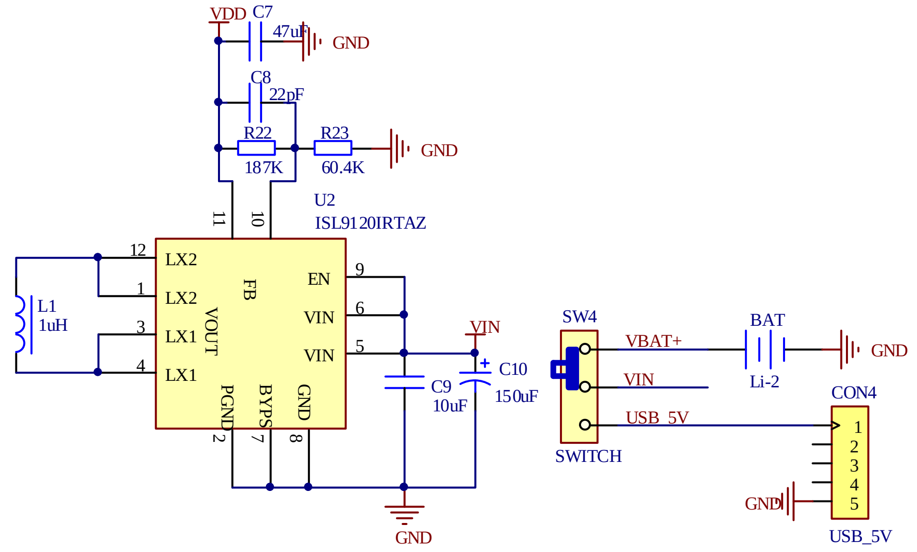


**Figure 4.2 Power Supply Circuit**

ISL9120 buck-boost regulator enables efficient power management of system power supplies and peripherals such as Wi-Fi, Bluetooth®, memory cards or LCD modules. This device can deliver up to 800mA of output current (VIN = 2.5 V, VOUT = 3.3 V) and provides excellent efficiency due to its adaptive current limit Pulse Frequency Modulation (PFM) control architecture.

The 3 V battery voltage is boosted to 3.3 V by ISL9120, which provides the power supply for the entire system circuit: MCU, the WeMos ESP8266 module, LED, etc.

## 4.2 Battery Voltage Detection Circuit

Figure 4.3 shows the schematics of the battery voltage energy metering IC control circuit.

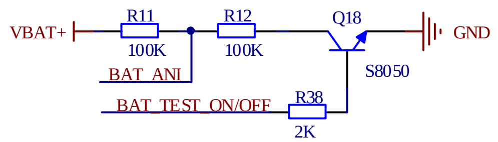


**Figure 4.3 Battery Voltage Detection Circuit**

The system is a battery-powered system. It can inform users to replace the battery when its voltage is lower than a certain level (e.g. 2.5 V). It uses two divider resistors and A/D converter to monitor the battery voltage divider. An I/O port is used to control the power ON/OFF the battery voltage detection circuit for the low power consumption.

## 4.3 Function Key Detection Circuit

Figure 4.4 shows the schematics of the function key detection circuit.

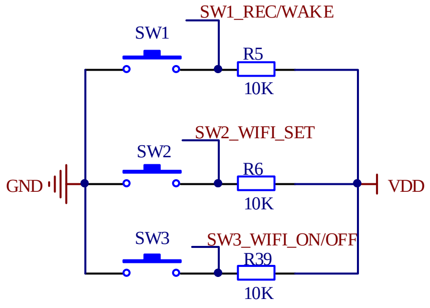


**Figure 4.4 Function Key Detection Circuit**

In IDLE mode, the falling edge of the SW1 key is used to wake up the system back to normal mode and the 4-digit 7-segment LED lights up and displays the current RTC time. When the RTC alarm interrupt occurs, the falling edge of SW1 will inform MCU to stop alarming and send the taking pill record to the WeMos ESP8266 module.

The falling edge of the SW2 key is used to inform the MCU to send the Wi-Fi module configuration command to the WeMos ESP8266 module.

The falling edge of the SW3 key is used to inform the MCU to power off the Wi-Fi module to reduce the power consumption when the system is powered by the batteries.

## 4.4 Buzzer Control Circuit

Figure 4.5 shows the schematics of the buzzer control circuit.

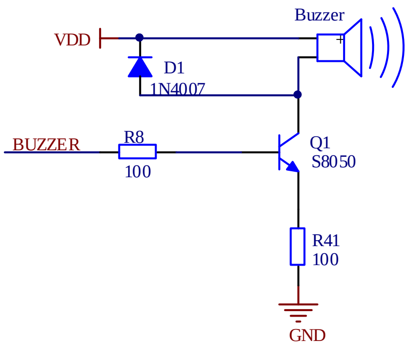


**Figure 4.5 Buzzer Control Circuit**

When the alarm interrupt occurs, the MCU outputs the square wave of 0.512 kHz from PCLBUZ0 to the buzzer control circuit to make the buzzer sound.

## 4.5 DC Vibrating Motor Control Circuit

Figure 4.6 shows the schematics of the DC vibrating motor control circuit.

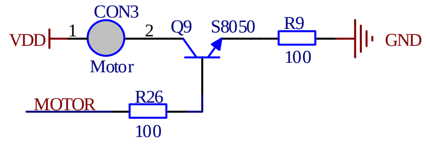


**Figure 4.6 DC Vibrating Motor Circuit**

When the alarm is generated, one I/O pin output a high level to drive the motor to produce a strong vibration.

## 4.6 Wi-Fi Module Power Control Circuit

Figure 4.7 shows the schematics of Wi-Fi module power control circuit.

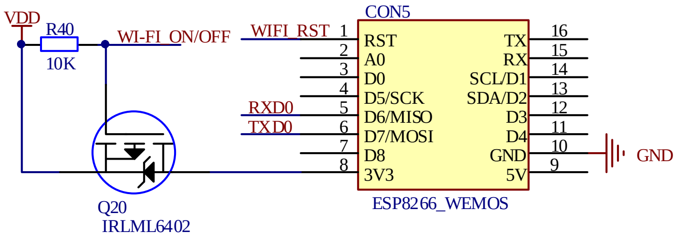


**Figure 4.7 Wi-Fi Module Status Control Circuit**

P60 is used to control the power supply ON/OFF to the WeMos ESP8266 module.

## 4.7 Box LEDs Control Circuit

Figure 4.8 shows the schematics of the box LEDs control circuit.

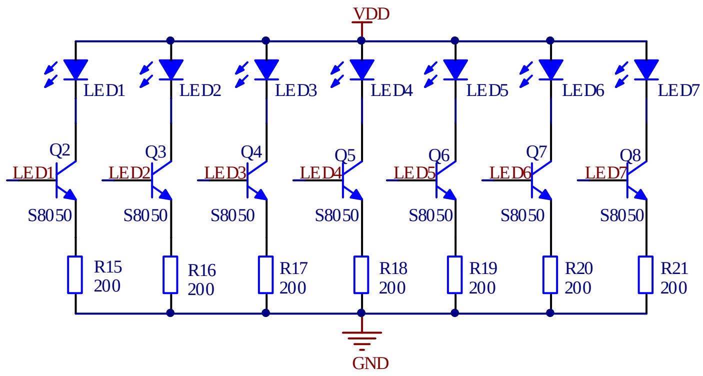


**Figure 4.8 Box LED Control Circuit**

Seven lights correspond to seven cells. When the RTC alarm interrupt occurs, the corresponding LED of weekday will be ON. For example, LED1 will light up on Monday and LED7 will light up on Sunday.

## 4.8 4-Digit 7-Segment LED Display Circuit

Figure 4.9 shows the schematics of the 4-digit 7-segment LED display circuit.

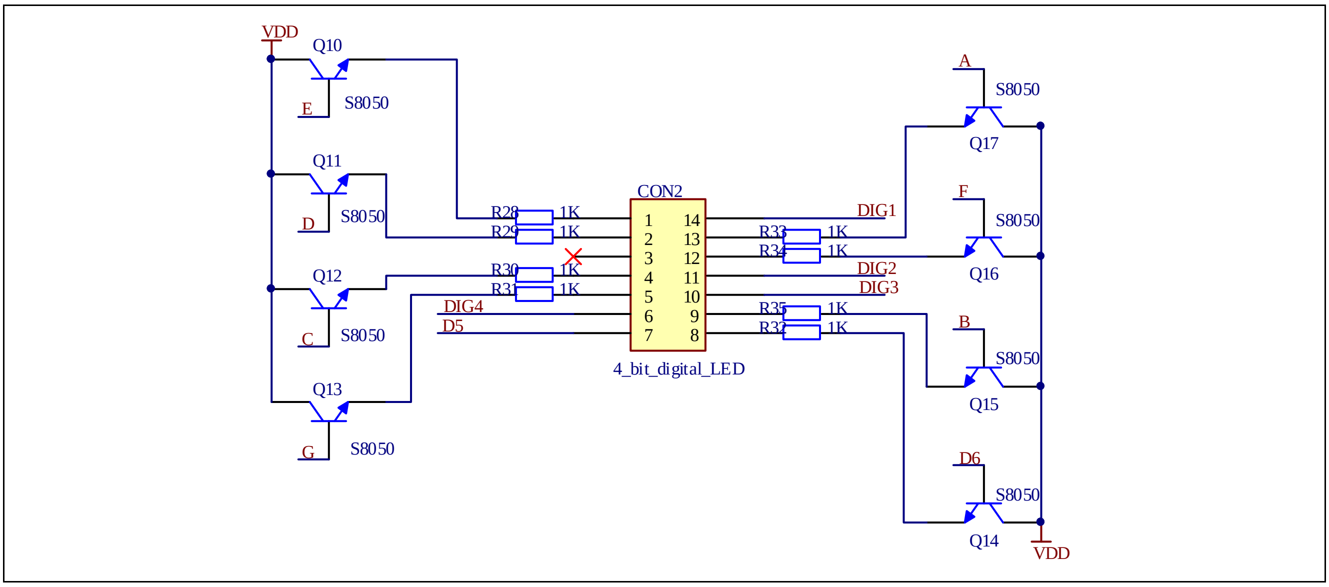


**Figure 4.9 4-Digit 7-Segment LED Display Circuit**

The system uses a 4-digit 7-segment LED to display the real-time clock information. When an alarm occurs, or a switch is pressed, the current time is displayed.

# 5. Software

## 5.1 Integrated Development Environment

The sample code described in this chapter has been checked under the conditions listed in the table below.

**Table 5.1 Operation Check Conditions**

| Item | Description |
|---|---|
| Microcontroller used | RL78/G13 (R5F100FE) |
| Operating frequency | High-speed on-chip oscillator (HOCO) clock: 16 MHz<br>CPU/peripheral hardware clock: 16 MHz<br>Subsystem clock oscillator clock: 32.768 kHz |
| Operating voltage | 3.3 V (can run on a voltage range of 2.7 V to 5.5 V)<br>LVD: reset mode, 2.45 V |
| Integrated development environment (CS+) | CS+ V6.01.00 from Renesas Electronics Corp. |
| C compiler (CS+) | CC-RL V1.06.00 from Renesas Electronics Corp. |
| Integrated development environment ($e^2$ studio) | $e^2$ studio V6.1.0 from Renesas Electronics Corp. |
| C compiler ($e^2$ studio) | CC-RL V1.06.00 from Renesas Electronics Corp. |

## 5.2 Option Byte

Table 5.2 summarizes the settings of the option bytes.

**Table 5.2 Option Byte Settings**

| Address | Value | Description |
|---|---|---|
| 000C0H/010C0H | 11101111B | Watchdog timer counter operation disabled<br>(counting stopped after reset) |
| 000C1H/010C1H | 01011111B | LVD reset mode which uses 2.45 V (2.40 V to 2.50 V) |
| 000C2H/010C2H | 11111001B | HS mode, $f_{HOCO}$: 16 MHz<br>CPU clock $f_{CLK}$: 16 MHz |
| 000C3H/010C3H | 10000100B | Enables on-chip debugging |

## 5.3 Operation Outline

The tasks of the entire system are listed as below: Reset/initialization, IDLE mode, normal mode, alarm set mode, RTC calibration mode, alarm process mode, take pill record mode, battery voltage checking mode, and Data Flash adjust mode.

Figure 5.1 shows the block diagram for the tasks transition.

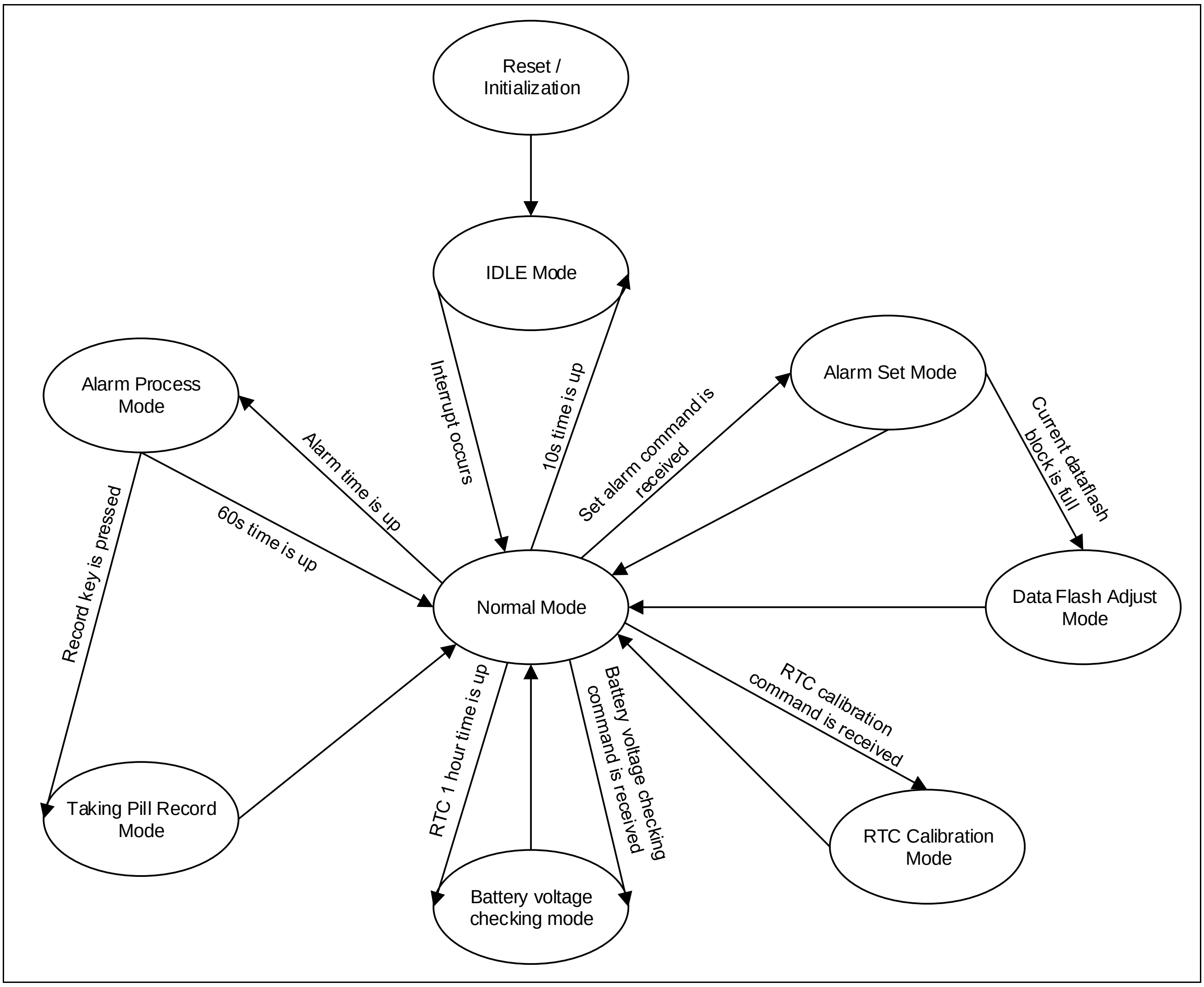


**Figure 5.1 Tasks Transition Block Diagram**

(1) Reset / Initialization

When the smart medicine box is powered on, it will enter the initialization operation. The UART module, RTC, INTP0~2, ADC modules and I/O pins will be initialized. The WeMos ESP8266 module will be reset and the 4-digit 7-segment LED will be ON. After that, the smart medicine box enters the battery voltage checking mode firstly.

(2) IDLE mode

When the system finishes all operation (transferring data via UART, turning off LED, etc.), it will enter IDLE mode. In this mode, the STOP command will be implemented. Any interrupt (UART receive with SNOOZE mode, RTC interrupt, INTP interrupt) can make the system exit from STOP mode. Then, the system will enter the normal mode.

(3) Normal mode

In normal mode, the 4-digit 7-segment LED is ON for 10 seconds. The system will transfer to other modes according to the interrupt request source. If no other interrupt occurs, the system will return to the IDLE mode after 10 seconds.

(4) Alarm set mode

The system receives the command of setting alarm from the WeMos ESP8266 module and updates the alarm minute register (ALARMWM), the alarm hour register (ALARMWH) and the alarm week register (ALARMWW) according to the current time and other alarms' time information which have been set already. After that, the latest alarm time data will be stored in Data Flash as a new record. Then, the system will return to the normal mode.

However, there are 4 blocks of Data Flash area (1 KB * 4 blocks). Reducing the erasing time can help extend the usage life cycle of the Data Flash. So, if one block is full after adding the new record of alarm time, the system will enter the Data Flash adjust mode.

(5) RTC calibration mode

The system receives the command of RTC calibration from the WeMos ESP8266 module and updates the registers of second count register (SEC), minute count register (MIN), hour count register (HOUR), day count register (DAY), week count register (WEEK), month count register (MONTH), year count register (YEAR) according to the calibration information sent by mobile app in real-time. Then, the system will return to the normal mode.

(6) Data Flash adjust mode

When the current Data Flash block is full, the system will search the latest records of 3 alarms and copy the records to the next block. After that, it will erase the current block. Then, the system will return to the normal mode.

(7) Alarm process mode

When the RTC alarm interrupt occurs, the system generates notification sound with buzzer and displays the bright light in corresponding number of pill boxes according to the week day information.

If the user presses the taking pill record key (SW1) within 60 seconds, the system will enter the taking pill record mode.

If the user doesn't press the key within 60 seconds, the system will return to the normal mode.

(8) Take pill record mode

The smart medicine box will publish a message, which means the user has taken the pill on time, to the mobile app via MQTT through WeMos ESP8266 module. Then, the system will return to the normal mode.

(9) Battery voltage checking mode

When the RTC constant-period interrupt (period: 1 hour) occurs, the system checks the battery voltage by A/D converter. If the battery voltage checking command is received, the battery voltage data will be published to the mobile app via MQTT through WeMos ESP8266 module. If the battery voltage is lower than 2.5 V, the buzzer will sound every 1 minute.

## 5.4 Flow Chart

### 5.4.1 Main Processing

Figure 5.2 to 5.9 shows the flowchart for main processing routine.

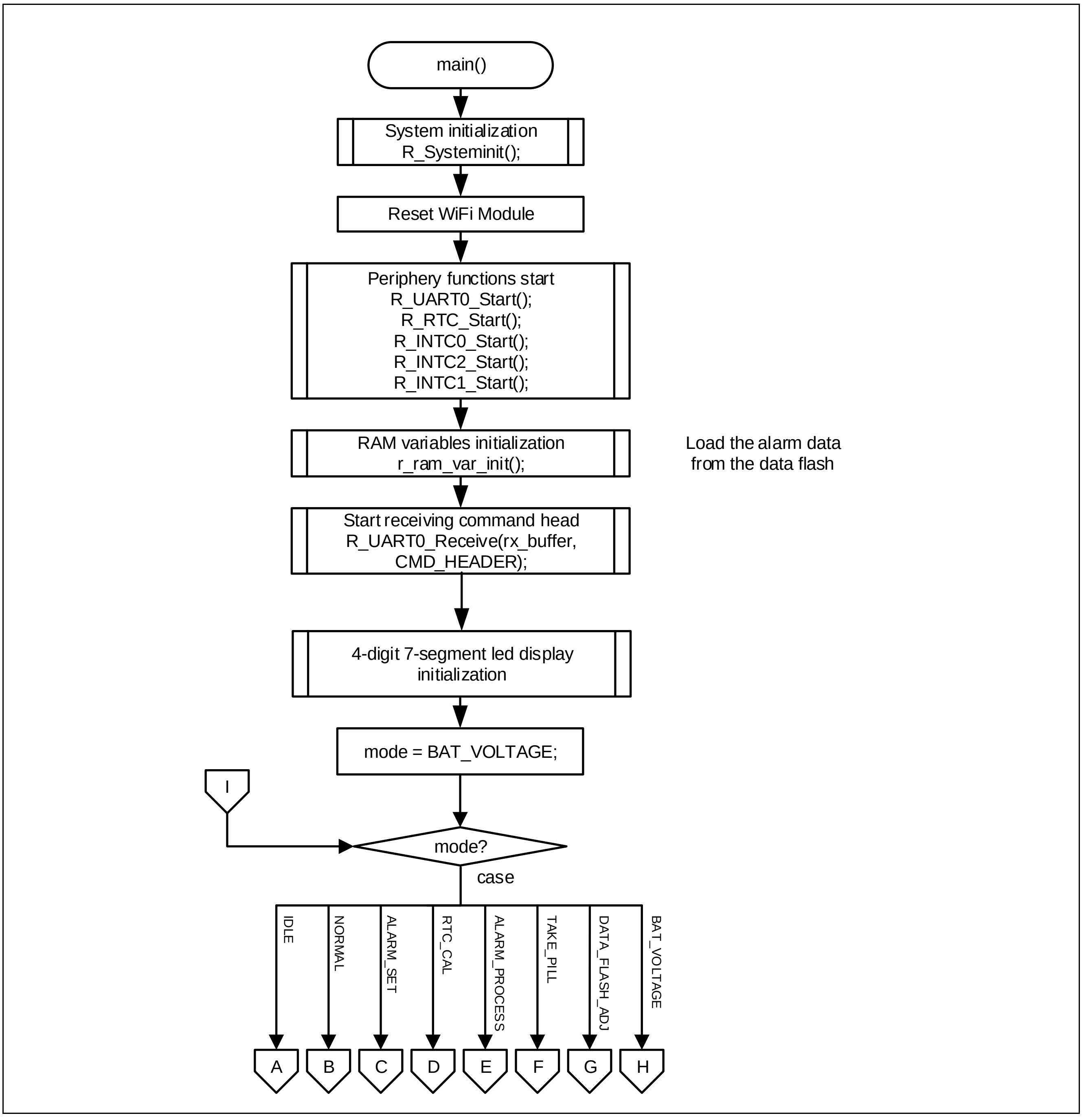


**Figure 5.2 Main Processing (1)**

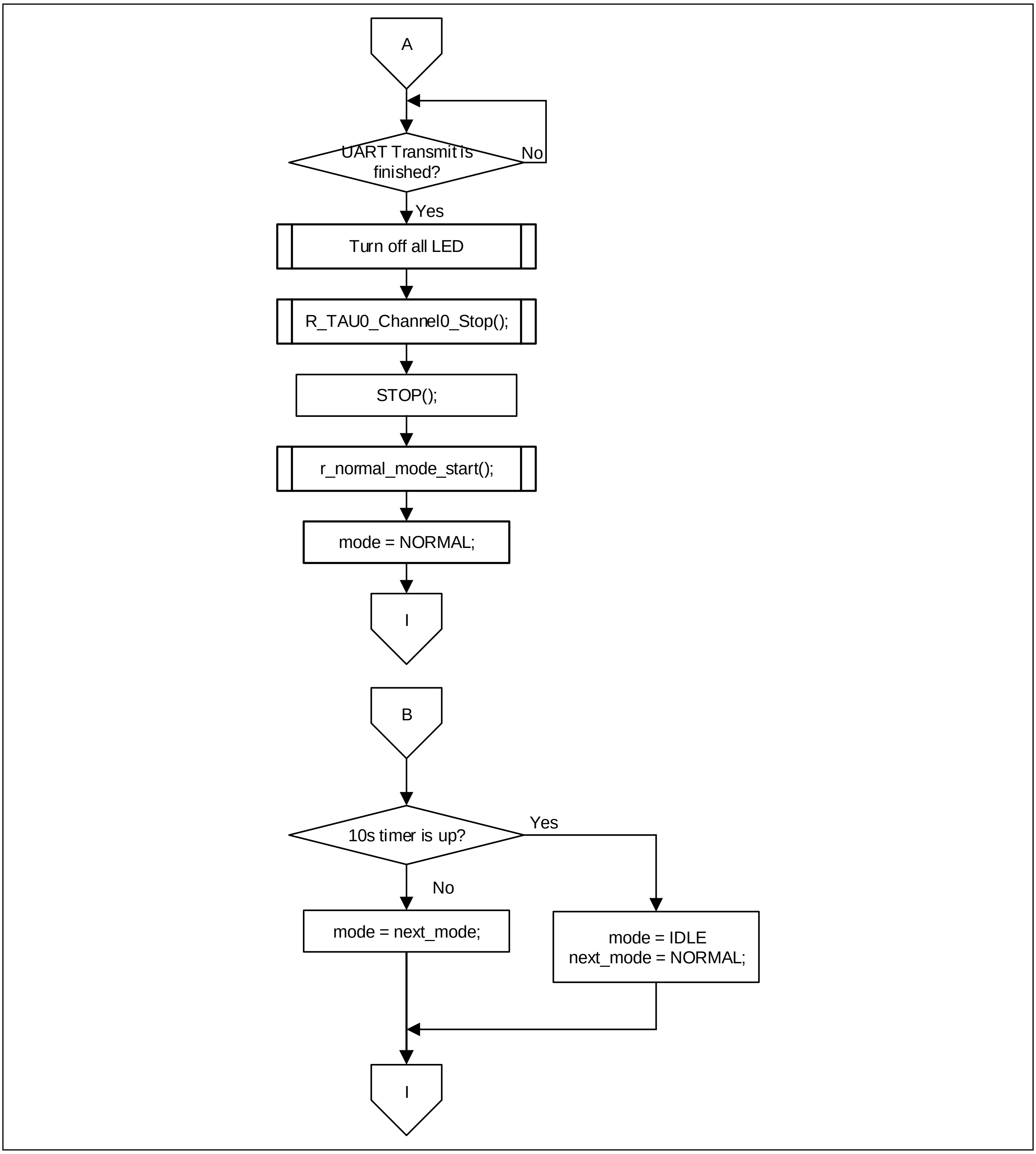


**Figure 5.3 Main Processing (2)**

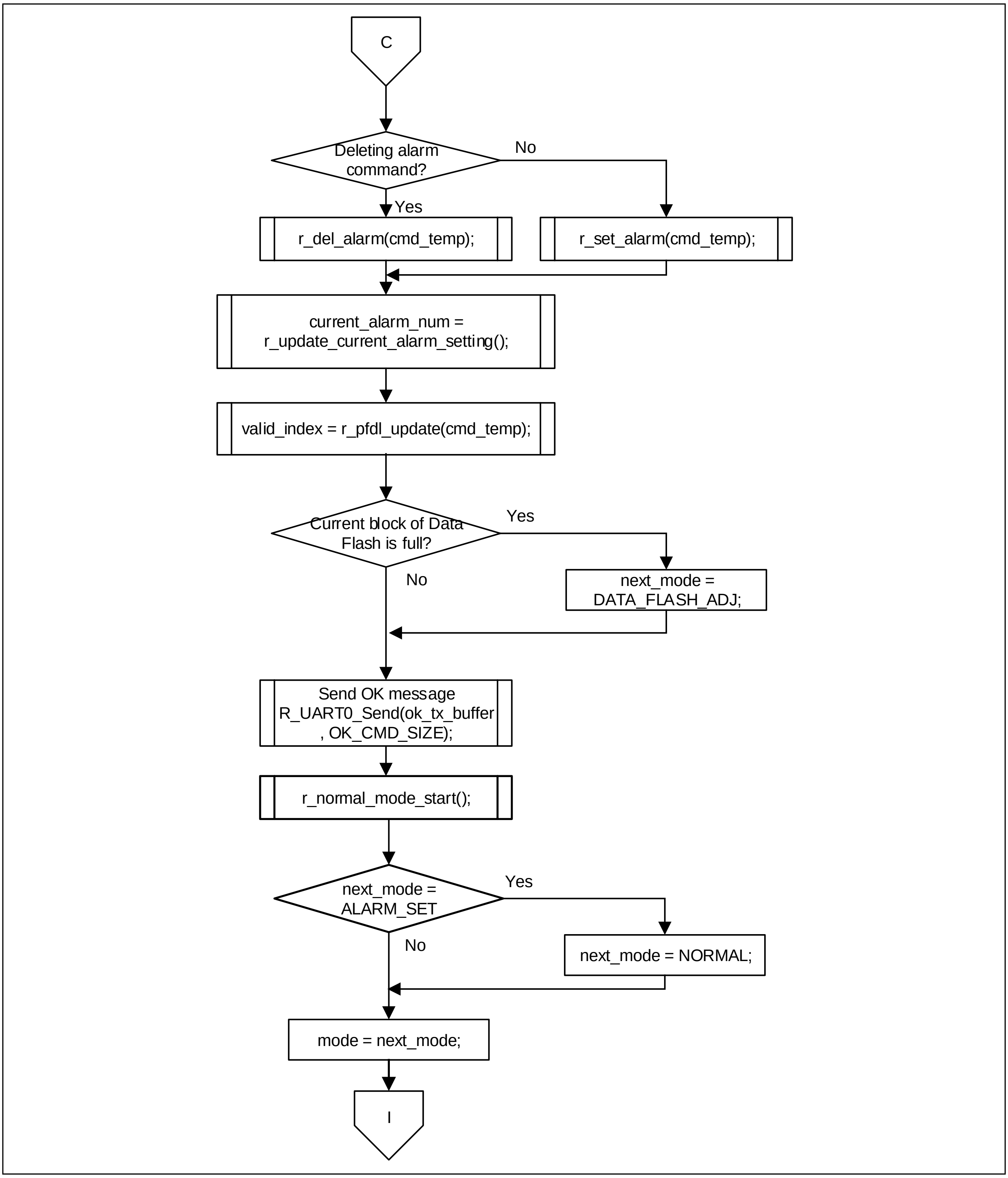


**Figure 5.4 Main Processing (3)**

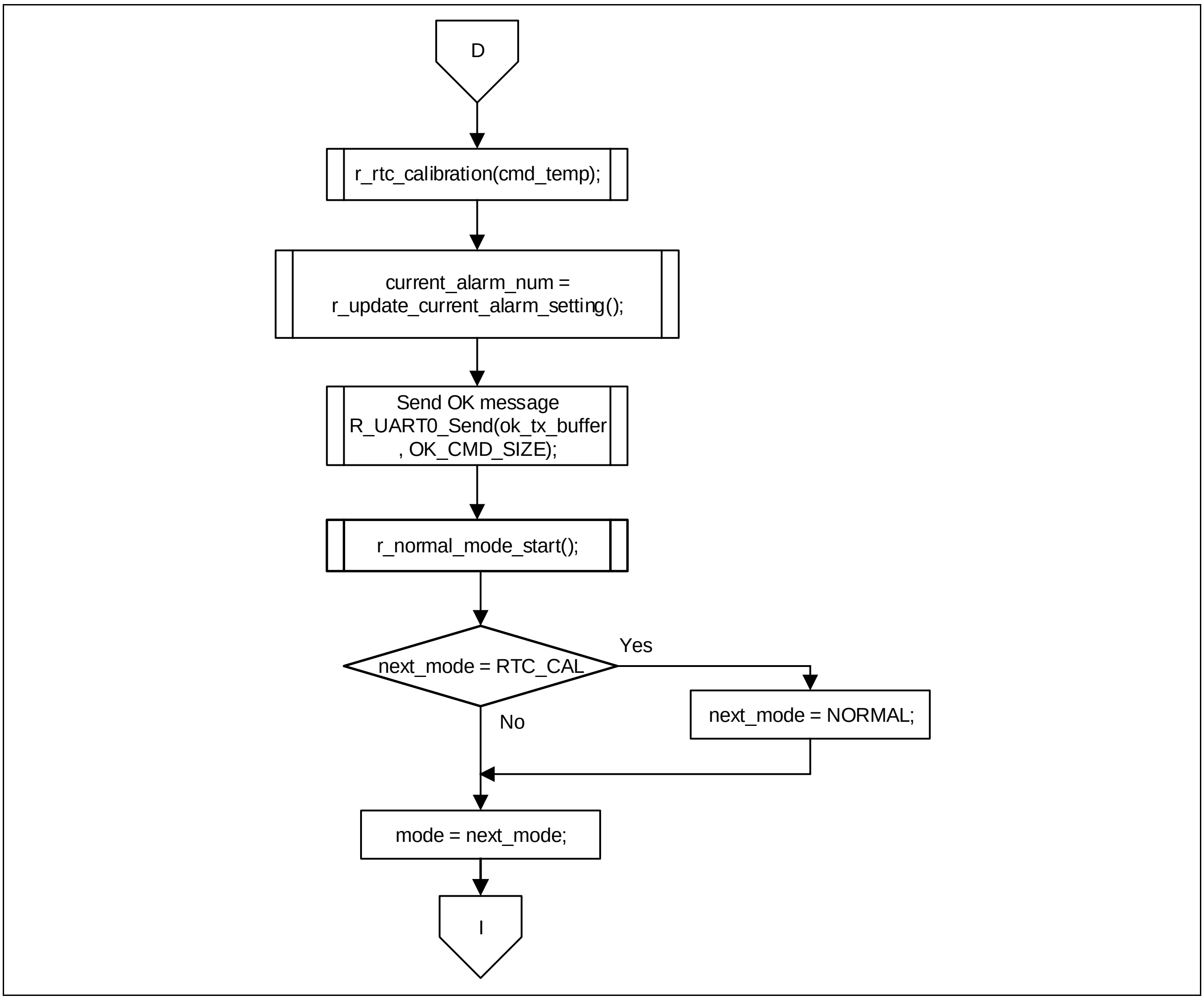


**Figure 5.5 Main Processing (4)**

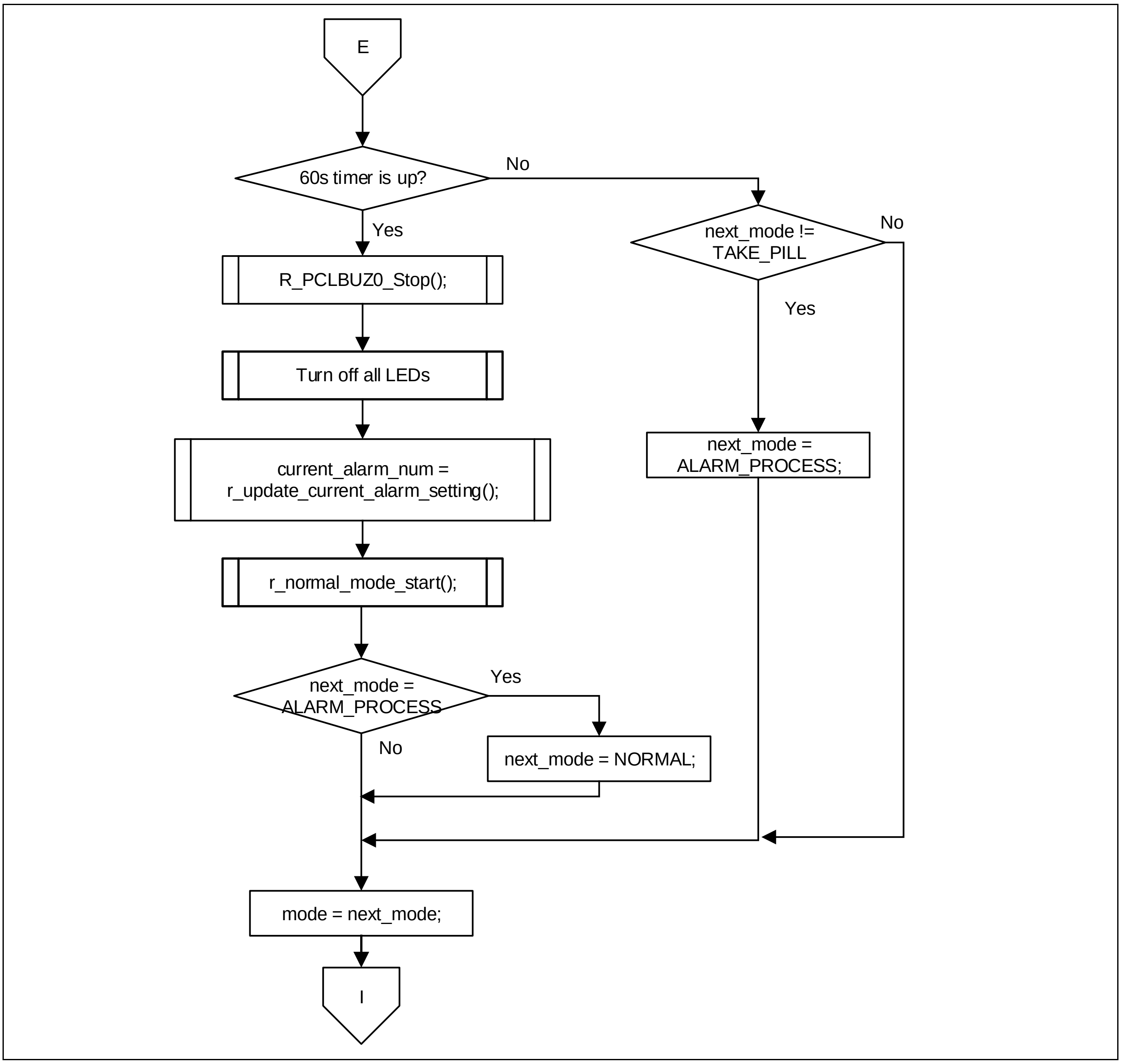


**Figure 5.6 Main Processing (5)**

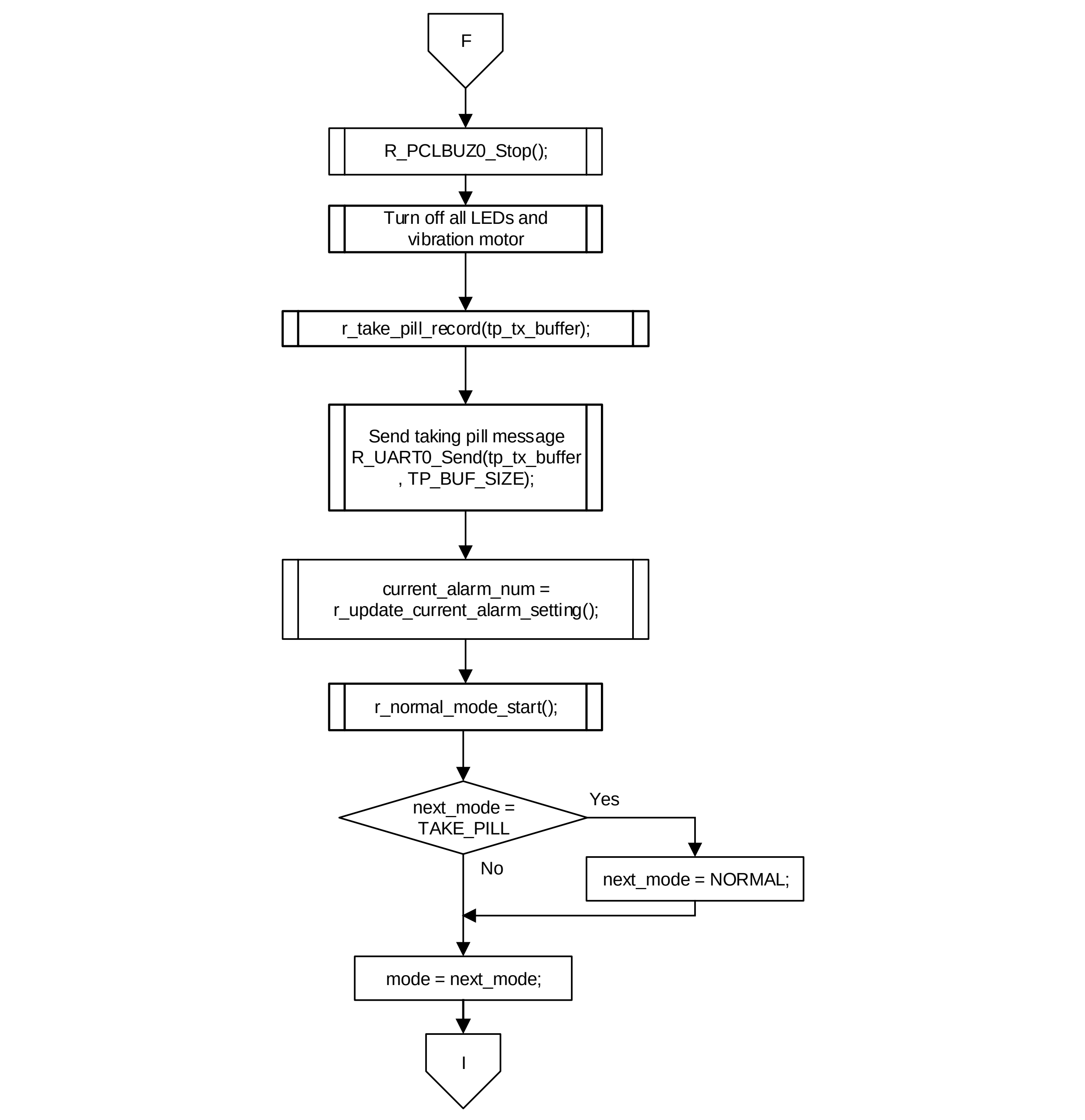


**Figure 5.7 Main Processing (6)**

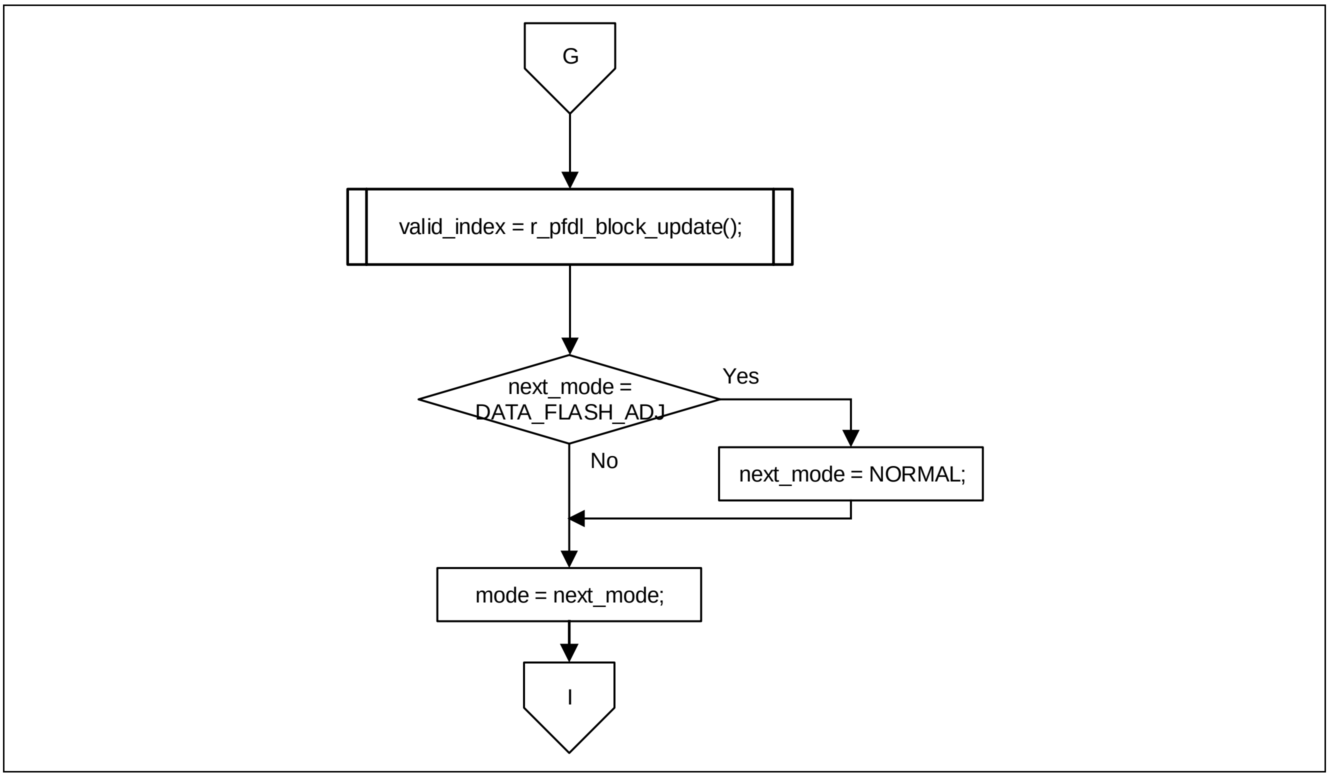


**Figure 5.8 Main Processing (7)**

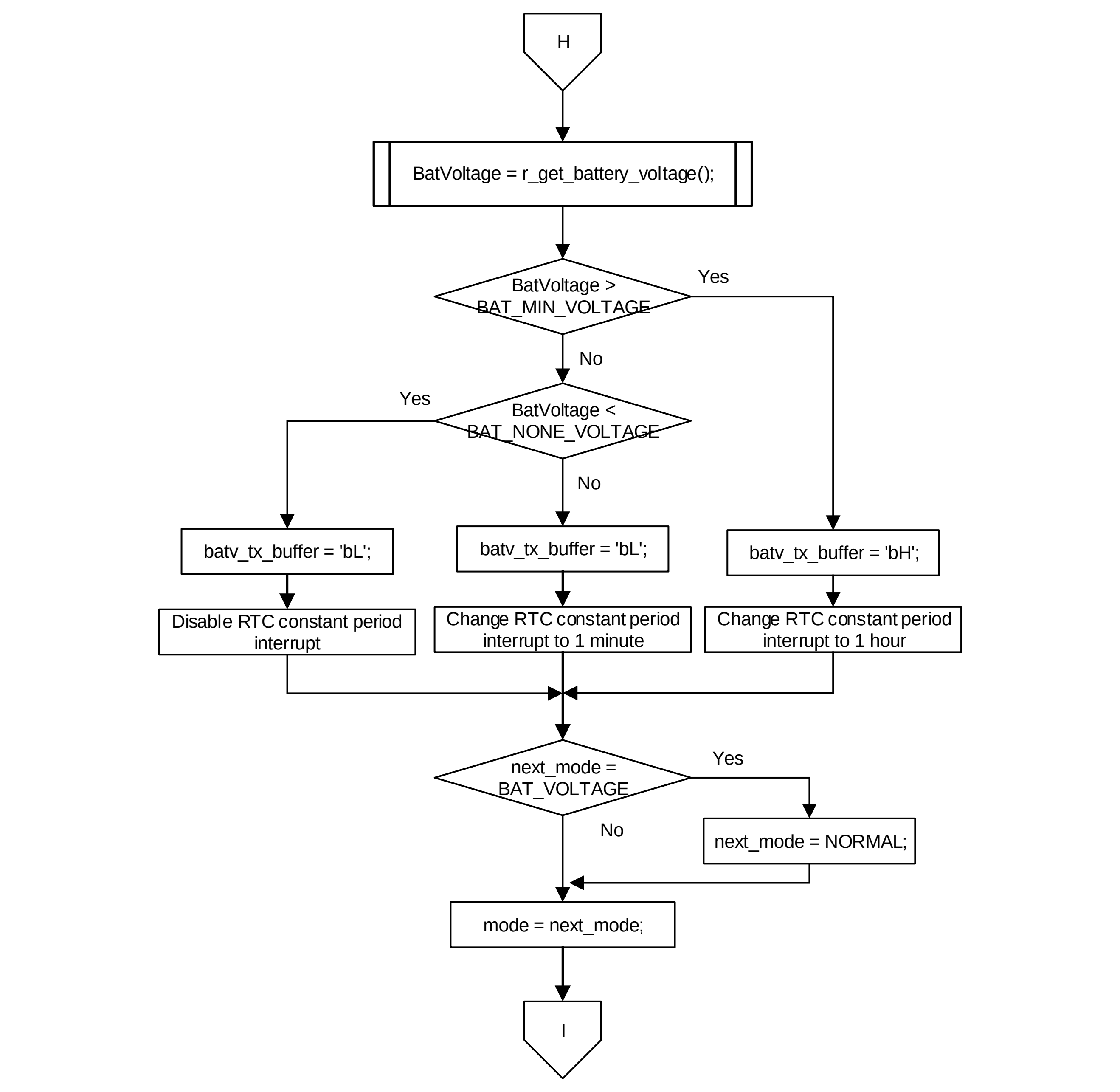


**Figure 5.9 Main Processing (8)**

### 5.4.2 UART Receive Interrupt Sub-Routine

Figure 5.10, 5.11 show the flowchart for UART receive interrupt sub-routine.

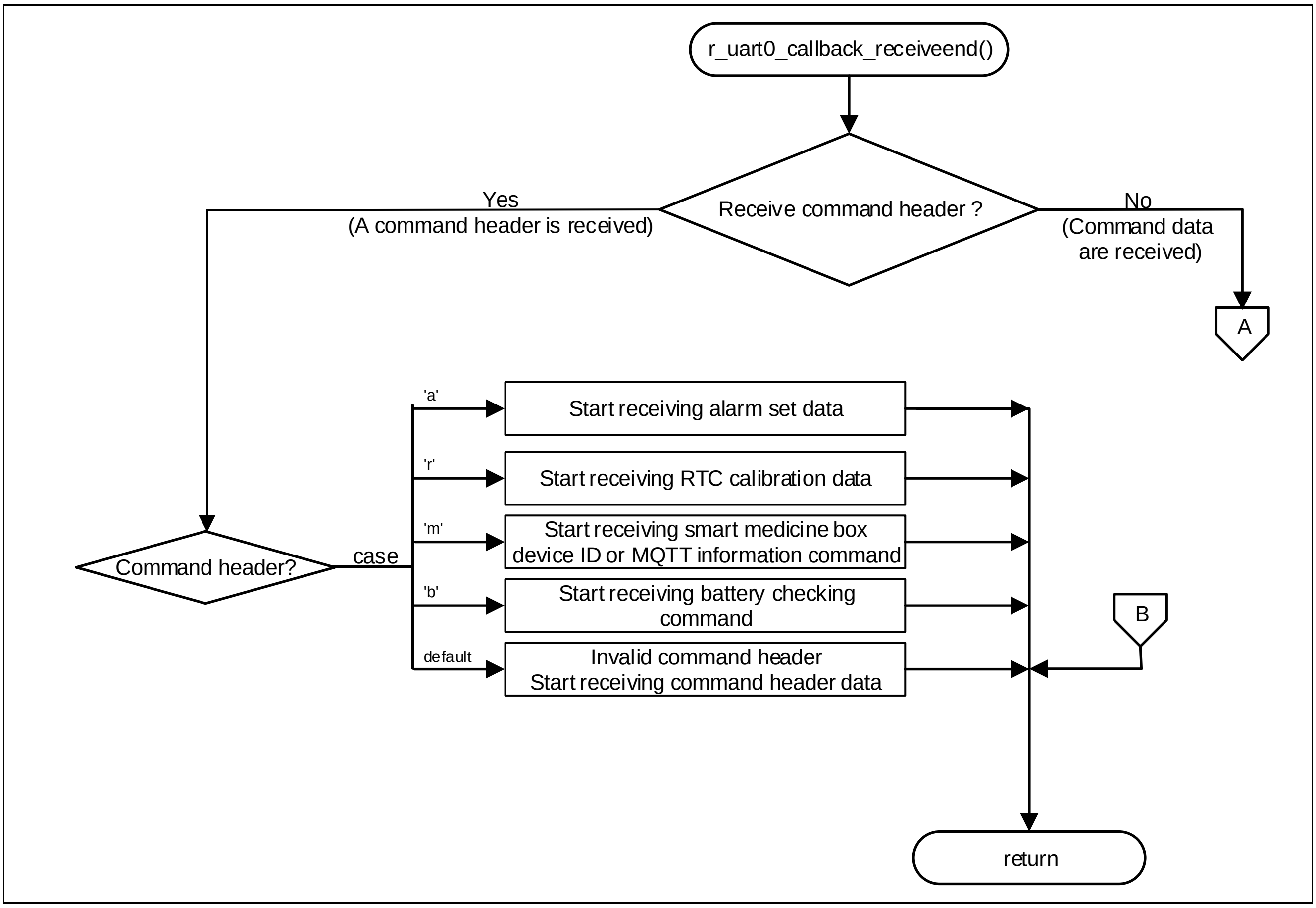


**Figure 5.10 UART Receive Interrupt Sub-Routine (1)**

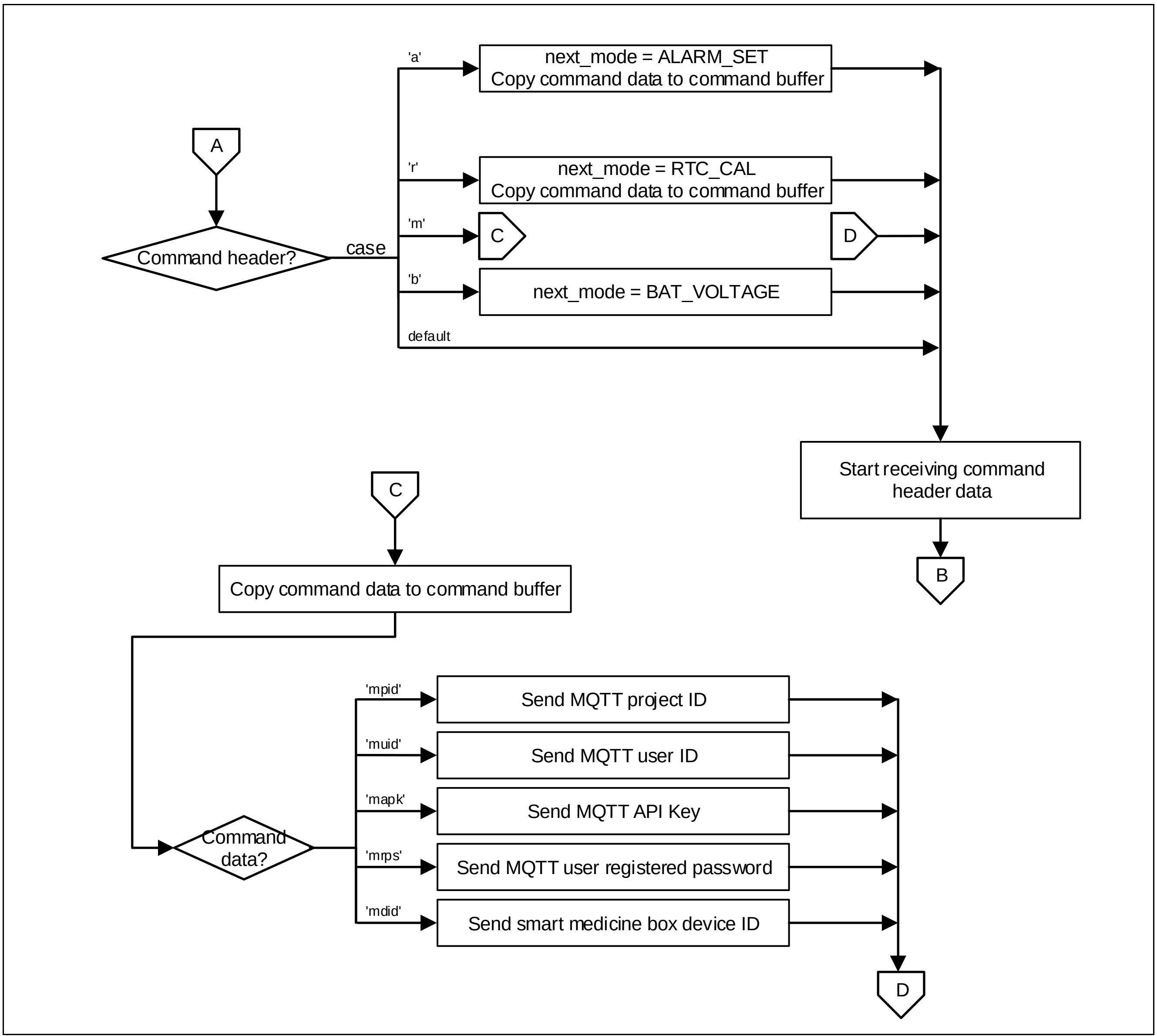


**Figure 5.11 UART Receive Interrupt Sub-Routine (2)**

## 6. Sample Code

The sample code is available on the Renesas Electronics Website.

## 7. Reference Documents

RL78/G13 User's Manual: Hardware (R01UH0146)

RL78 Family User's Manual: Software (R01US0015)

(The latest versions of the documents are available on the Renesas Electronics Website.)

Technical Updates/Technical News

(The latest information can be downloaded from the Renesas Electronics Website.)

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## Revision History

| Rev. | Date | Description | |
|---|---|---|---|
| | | Page | Summary |
| 1.00 | Nov. 30, 2018 | — | First edition issued |

## General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Handling of Unused Pins

   Handle unused pins in accordance with the directions given under Handling of Unused Pins in the manual.

   — The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible. Unused pins should be handled as described under Handling of Unused Pins in the manual.
2. Processing at Power-on

   The state of the product is undefined at the moment when power is supplied.

   — The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the moment when power is supplied.
   In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the moment when power is supplied until the reset process is completed.
   In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the moment when power is supplied until the power reaches the level at which resetting has been specified.
3. Prohibition of Access to Reserved Addresses

   Access to reserved addresses is prohibited.

   — The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.
4. Clock Signals

   After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has stabilized.

   — When the clock signal is generated with an external resonator (or from an external oscillator) during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Moreover, when switching to a clock signal produced with an external resonator (or by an external oscillator) while program execution is in progress, wait until the target clock signal is stable.
5. Differences between Products

   Before changing from one product to another, i.e. to a product with a different part number, confirm that the change will not lead to problems.

   — The characteristics of Microprocessing unit or Microcontroller unit products in the same group but having a different part number may differ in terms of the internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

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