RL78/G13

Smart Medicine Box with BLE

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Introduction

This document describes a Renesas microcontroller RL78/G13 application for a smart medicine box via RL78/G1D BLE module.

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
• Wireless Communication	BLE
• Alarm Sound	Over 80 dB
• Operating Temperature:	Ambient temperature

Specifications

• Function:	Connect to mobile app via RL78/G1D BLE 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.

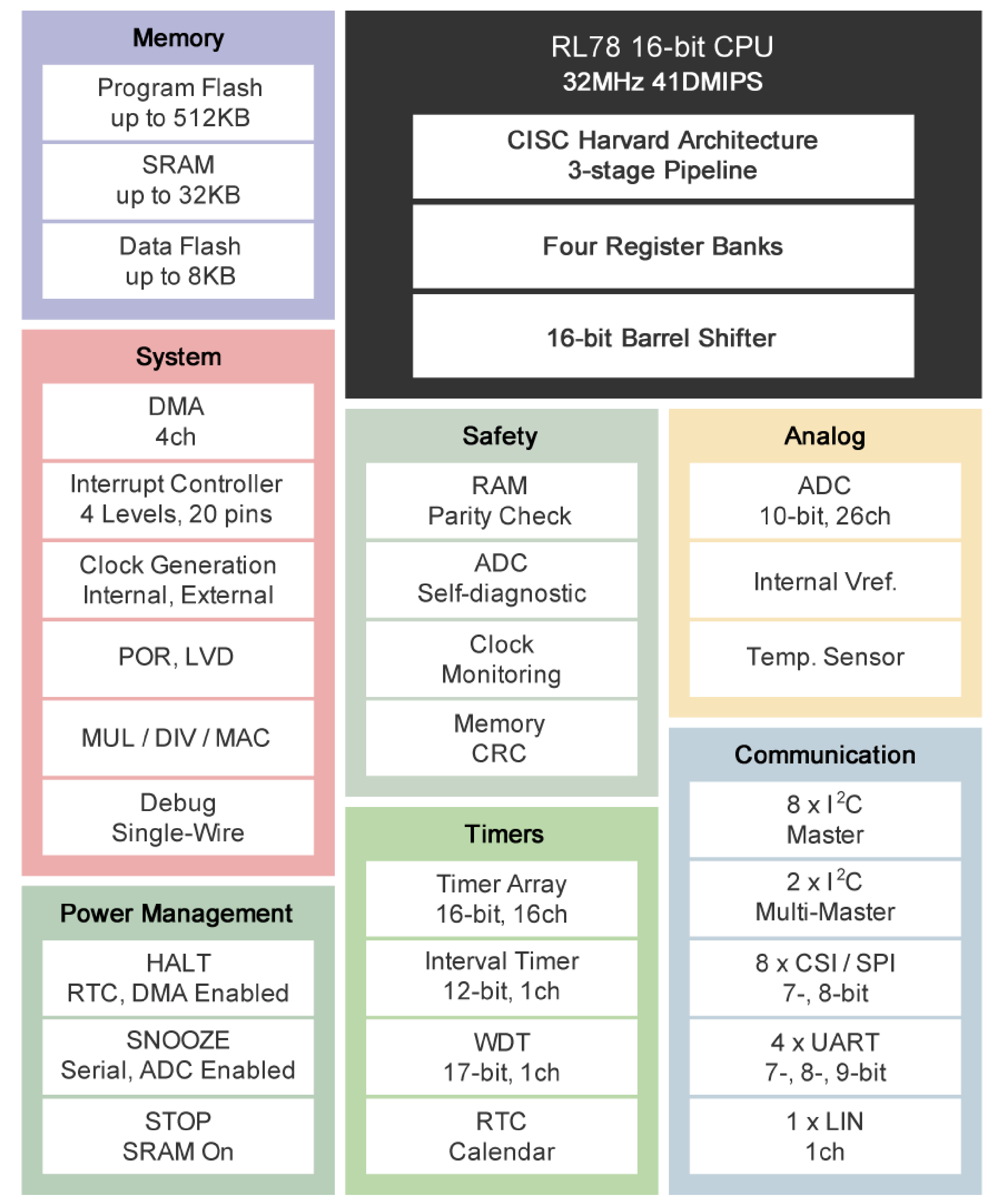

Figure 2.1 RL78/G13 Block Diagram

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)

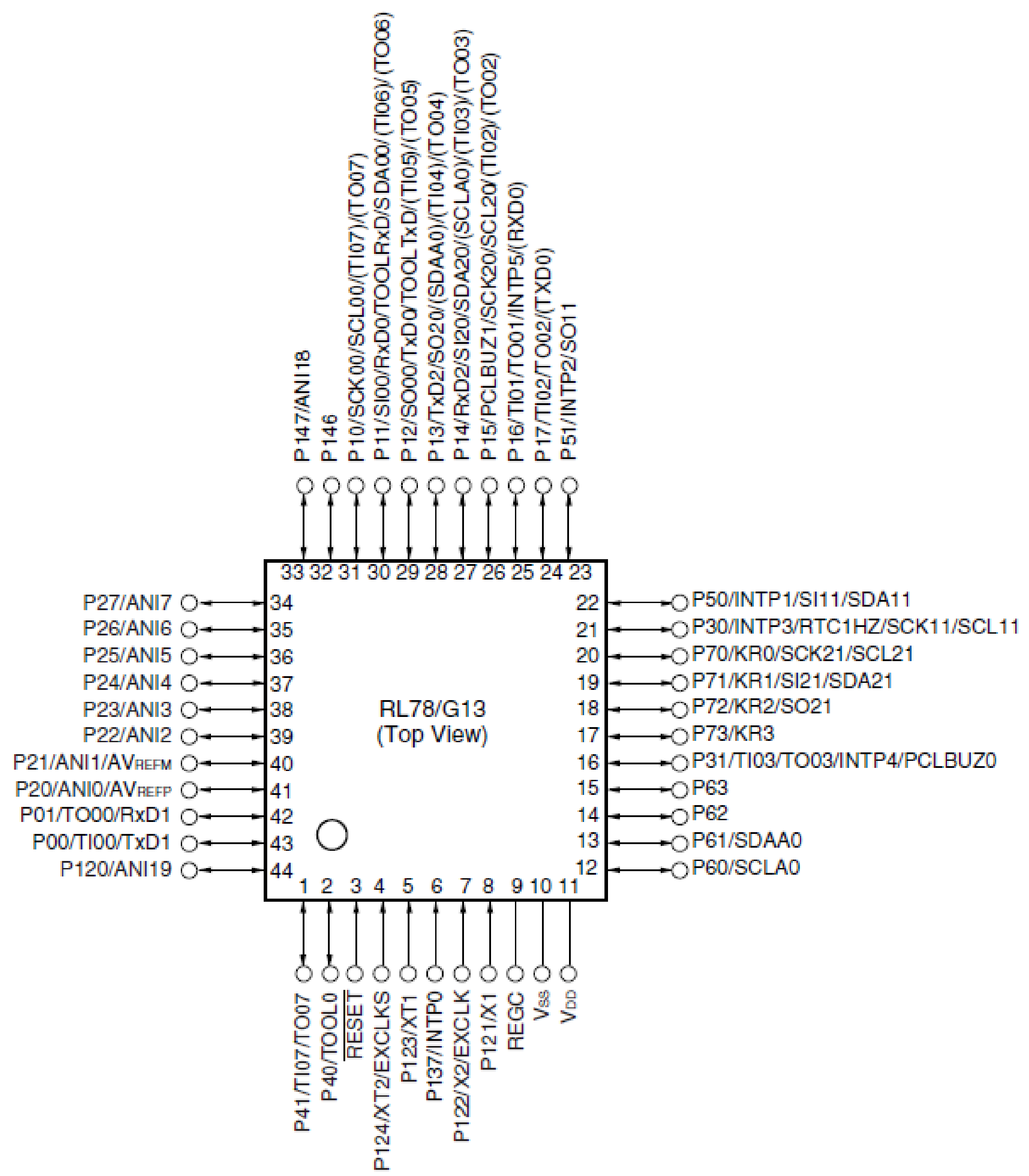

Figure 2.2 RL78/G13 (44-pin products) Pin Configuration

3. System Outline

3.1 Principle Introduction

The smart medicine box uses an RL78/G13 microcontroller and a RL78/G1D BLE module and a mobile app. Figure 3.1 shows the system connection and communication diagram.

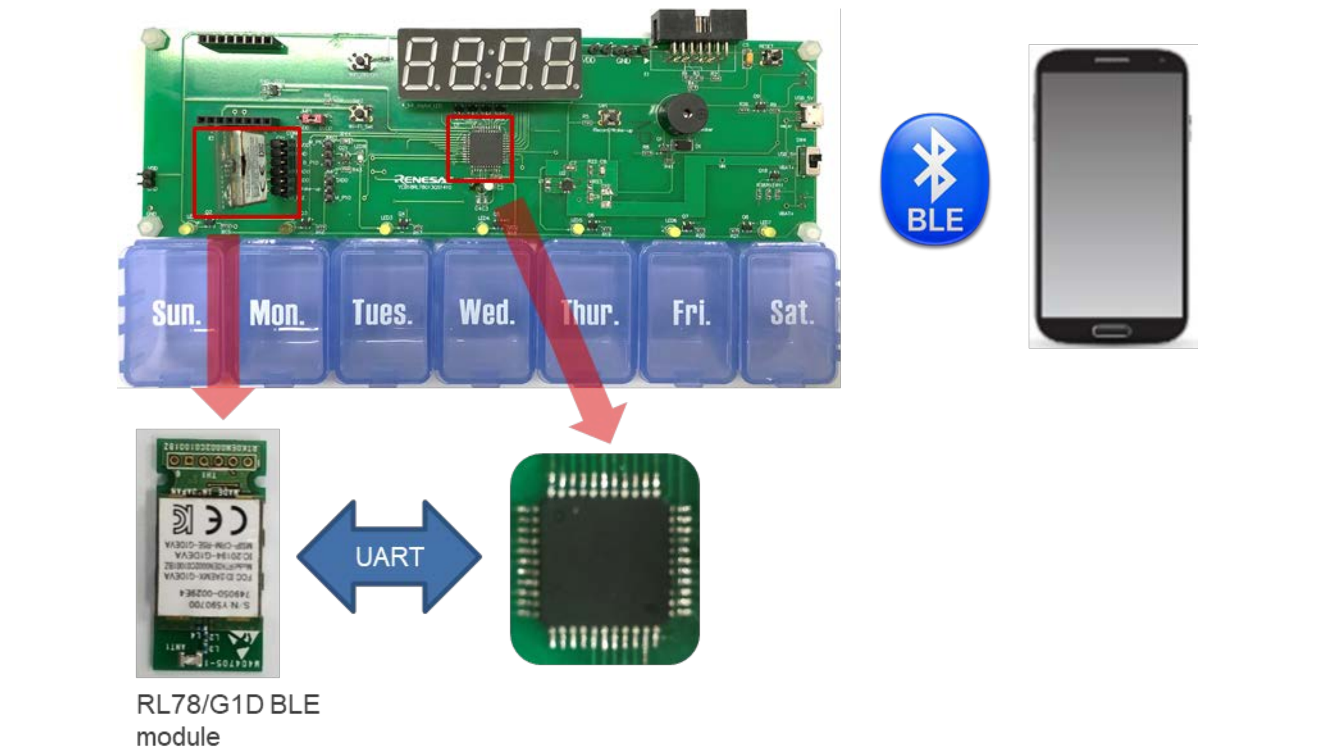

Figure 3.1 System Communication Block Diagram

The mobile app can program the notification time to the RL78/G13, and record pills taken remotely using BLE 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 BLE module when a recording key is pushed.

Local Device consists of RL78/G13 as a Host MCU and RL78/G1D as a BLE MCU which ware connected by UART. Remote Device is Smart Phone which is Android device.

Local Device behaves as a Slave and Remote Device behaves as a Master. RL78/G14 executes BLE communication with Smart Phone by controlling BLE protocol stack on RL78/G1D via interactive UART communication.

Figure 3.2 shows the MCU board block diagram.

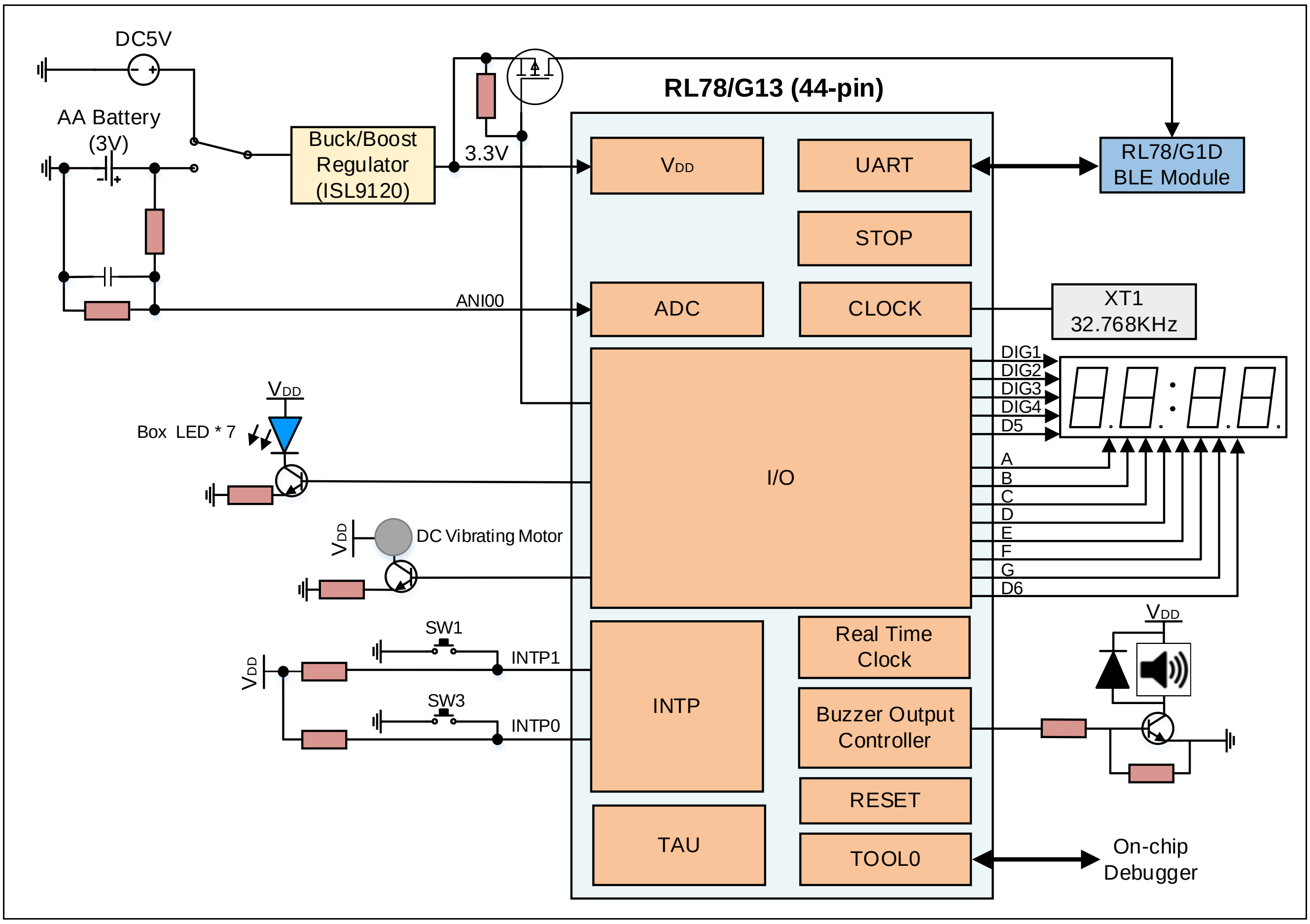

Figure 3.2 MCU Board Block Diagram

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 RL78/G1D BLE 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 control the BLE module power ON/OFF
INTP1	The switch input (SW1) to record taking pills action or wake up the system
Channel0 of TAU0	1 second interval timer for system timers of 10 seconds and 60 seconds.
Channel2 of TAU0	1 ms interval 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 P123/XT1	32.768 kHz crystal resonator connection
P11/RXD0, P12/TXD0	UART communication interface with the RL78/G1D BLE module
P41/TO07	Control DC vibration motor
P60	Control the BLE 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”
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
- RL78/G1D BLE module
- Windows PC
- 2x Micro USB data cable
- 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_ble.mot file (in the folder of “X:\..\Source Code\Program file”) according to the instruction of Renesas Flash Programmer.

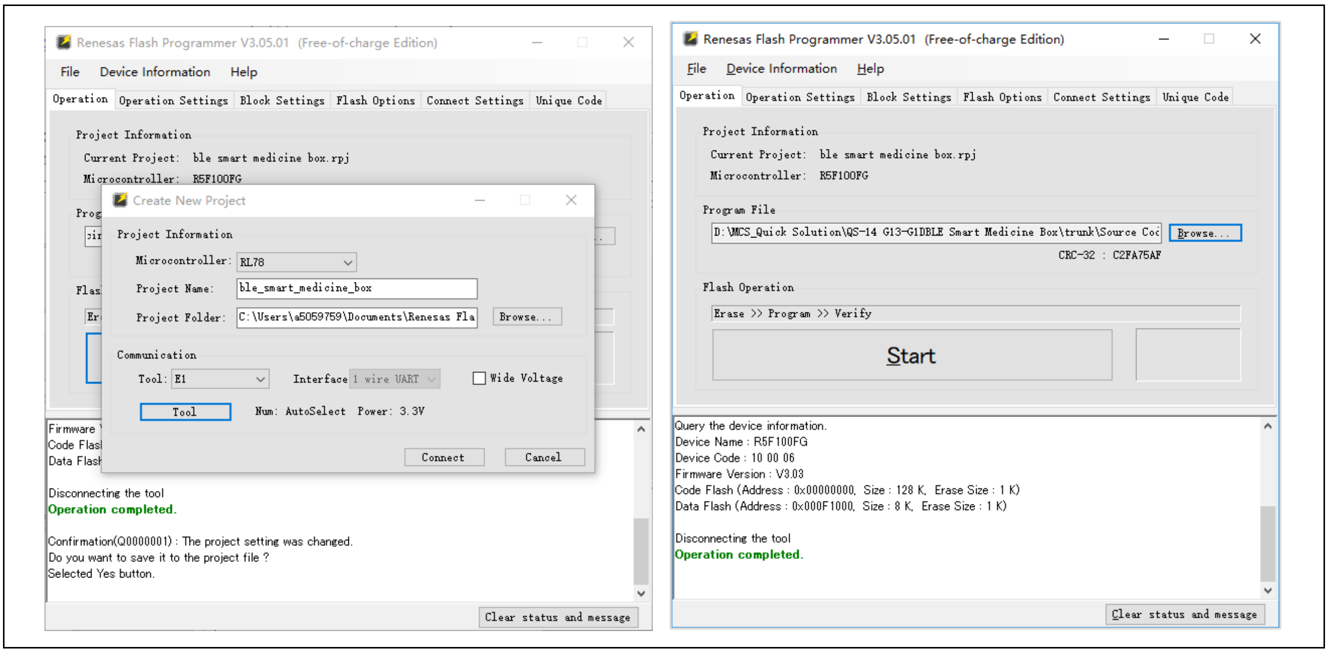

Figure 3.3 Program MCU mot file

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

STEP 2. Program firmware to RL78/G1D BLE module
For the procedure about preparing BLE MCU of RL78/G1D, please refer to the Renesas application note of Bluetooth® Low Energy Protocol Stack RL78/G14 Host Sample (R01AN2807EJ0121 Rev.1.21) chapter [3.1.2 BLE MCU].

It is possible to use “RL78_G1D_CM(SCP).hex” firmware included in the package of BLE protocol stack, which is (in the folder of “X:\..\Source Code\Program file\ble_mcu_firmware”).

If the flash is programmed with OK, RL78/G1D BLE module is ready.

STEP 3. Connect RL78/G13 smart medicine box demo board and the RL78/G1D BLE module.
Connect RL78/G13 board with the RL78/G1D BLE module. The pins connection is shown in Table 3.3.

Table 3.3 Pins connection between RL78/G13 and RL78/G1D

RL78/G13 Ports	RL78/G1D Ports	Function
P12/TXD0	P11/RXD0	UART (Host MCU → BLE MCU)
P11/RXD0	P12/TXD0	UART (BLE MCU → Host MCU)
Vss	Vss	Ground

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

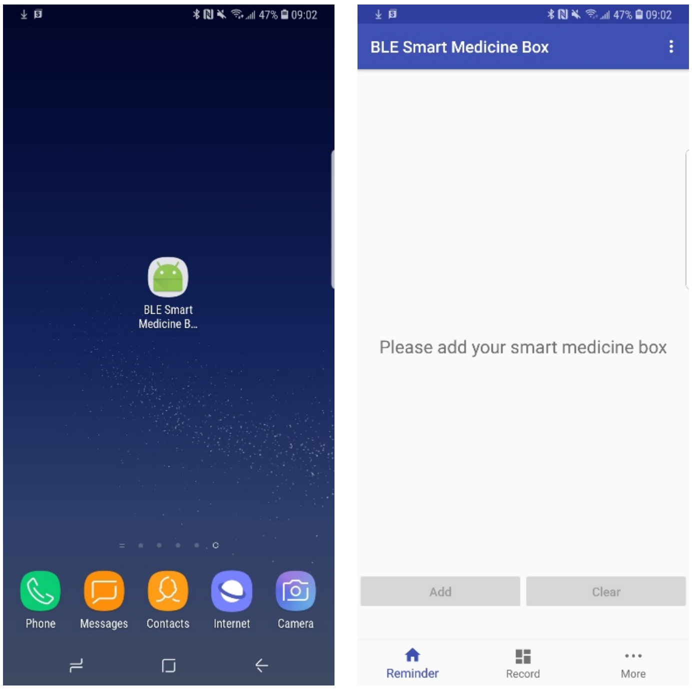

Figure 3.4 Installation of the Mobile App

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 RL78/G1D BLE 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) BLE protocol is used for communication within the smart medicine and mobile phone app.
Click “More” and “Add Box” button, the smart medicine box BLE device of “Renesas-SMB” will be found out. Select this device and the mobile app will connect to the medicine box via BLE automatically. This setting procedure is shown in Figure 3.5.
When the smart medicine box connects with the mobile app successfully, the real-time calibration message will be sent to the smart medicine box via BLE 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.

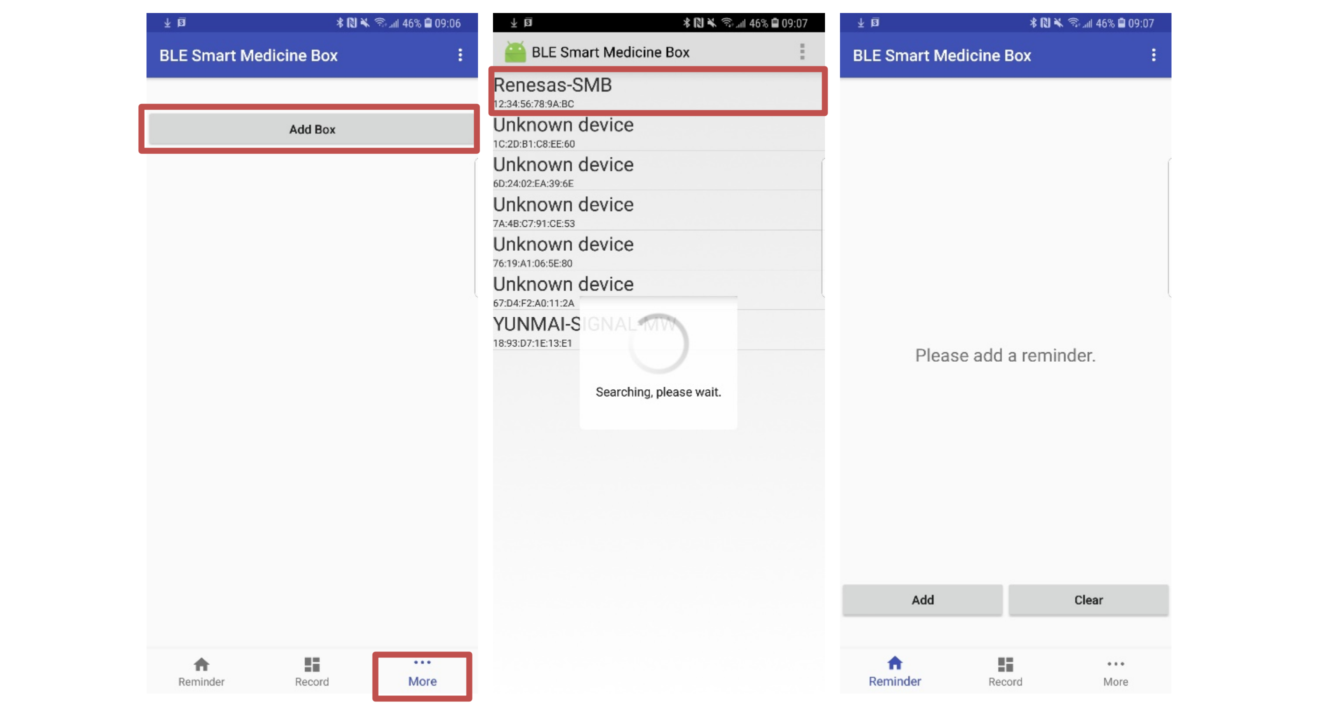

Figure 3.5 Connect the Smart Medicine Box to Mobile App via BLE

(3) 3 reminder times (maximum) can be set on the mobile app and the message will be sent to the smart medicine box via BLE to remind the patient to take the medicine. Each reminder time information will be also stored in Data Flash in the RL78/G13.

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 3.6.

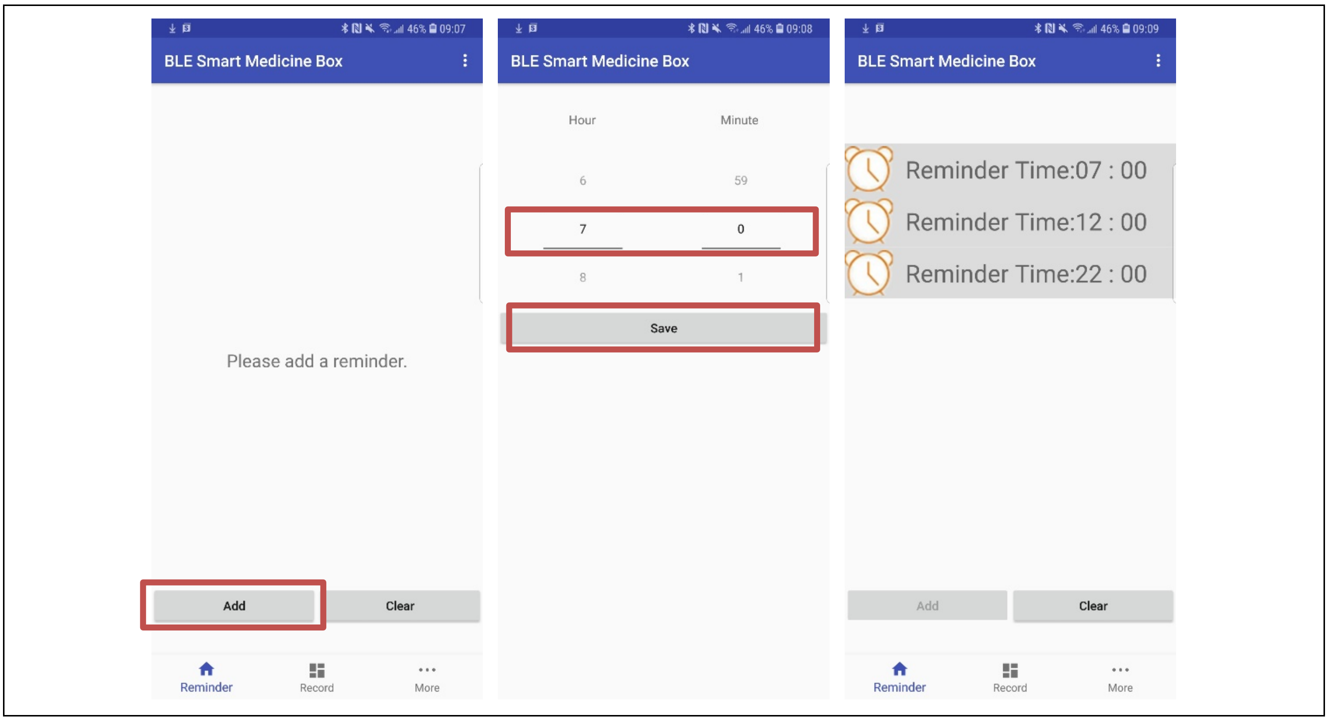

Figure 3.6 Adding Reminder time

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 BLE. This setting procedure is shown in Figure 3.7.

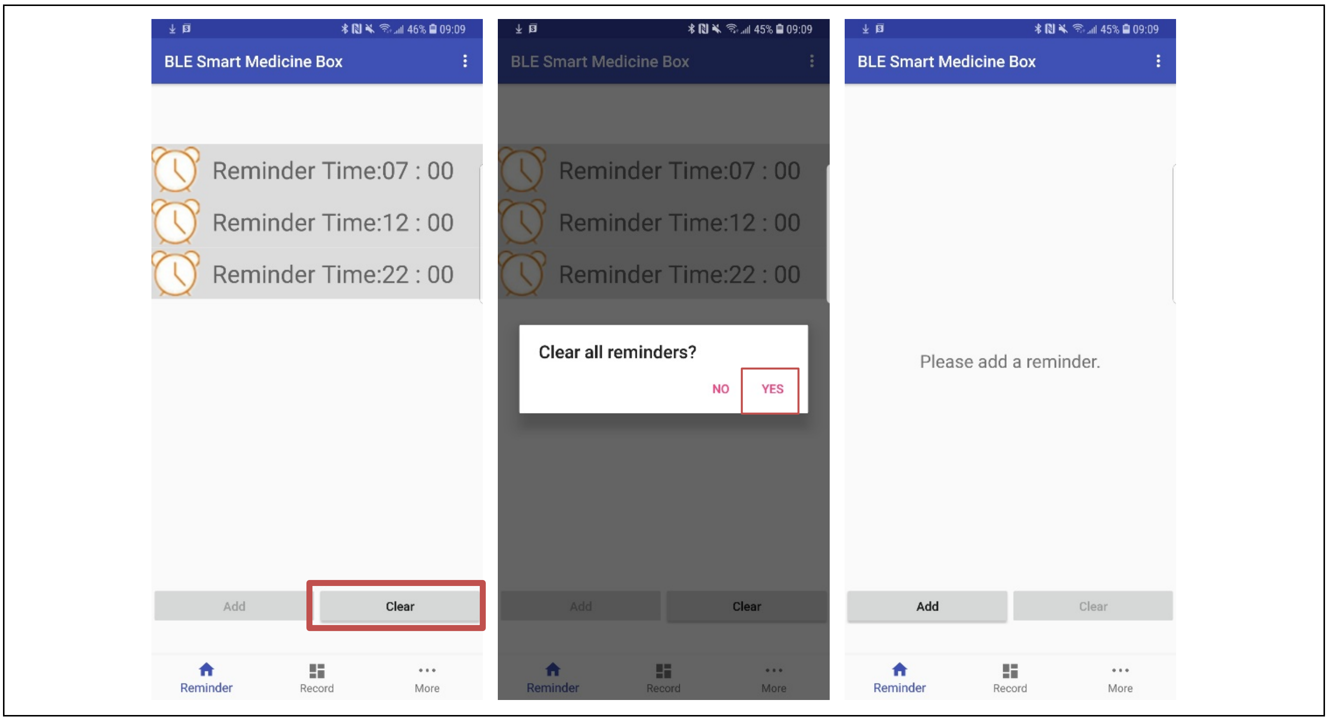

Figure 3.7 Deleting Reminder Time

(4) 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), all notification actions will stop and the medicine record will be stored in RL78/G13 MCU.

Click “Record” on the mobile app, the smart medicine box will upload the medicine record timeline to the mobile app via BLE module. And the taking medicine records can be viewed as shown in Figure 3.8.

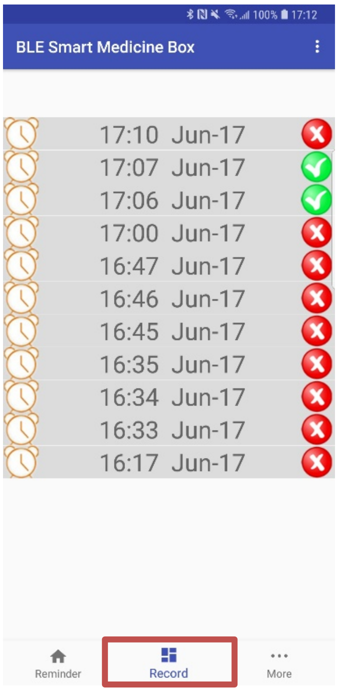

Figure 3.8 Taking Pill Records

(5) 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 voltage command is received, RL78/G13 MCU will send the battery voltage data to the mobile app via BLE module.

Click "More" and "Check the battery capacity" button, and 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 3.9.

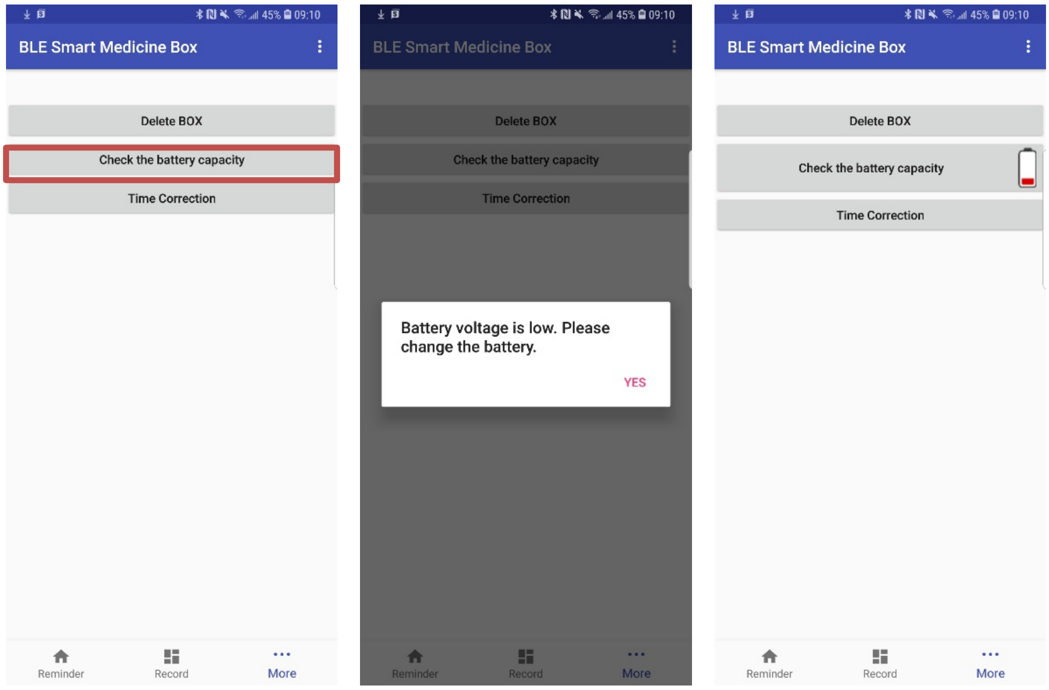

Figure 3.9 Checking Battery Voltage

(6) 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 BLE. 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 3.10.

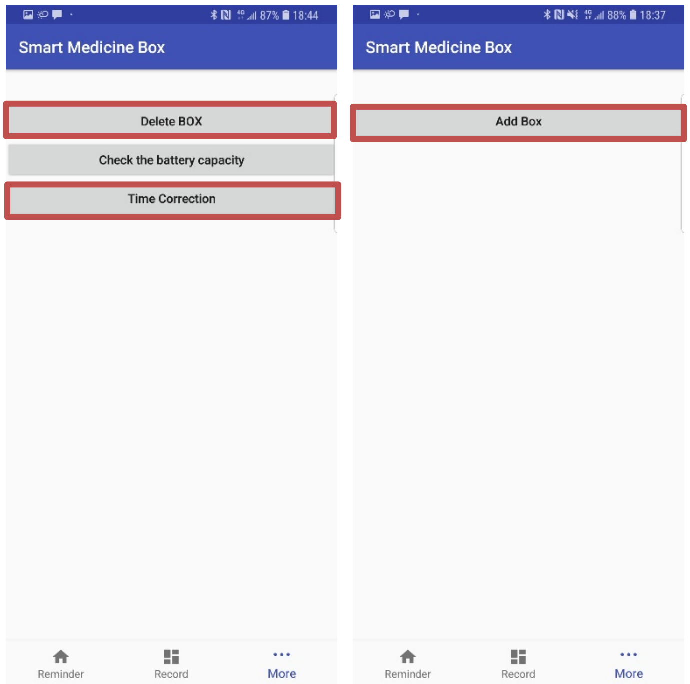

Figure 3.10 Time Correction and Delete Box

(7) When the system is powered via batteries, the RL78/G1D BLE module can be powered off by pressing SW3 to reduce the power consumption. 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 BLE 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 RL78/G1D BLE module power control circuit, the box LEDs control circuit and 4-digit 7-segment LED display circuit.

Figure 4.1 shows the board picture.

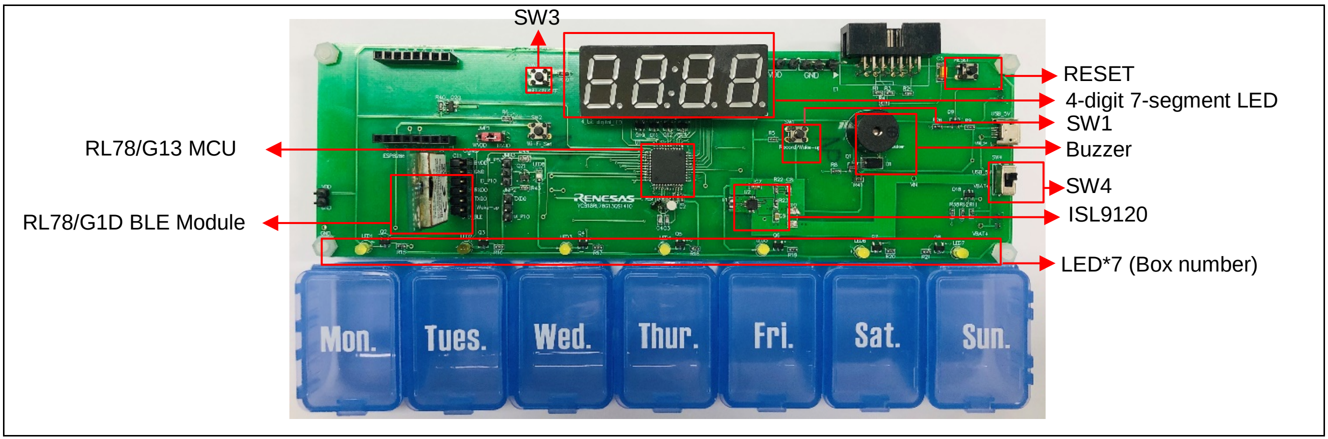

Figure 4.1 Board Picture

4.1 Power Supply Circuit

Figure 4.2 shows the schematics of the power supply circuit.

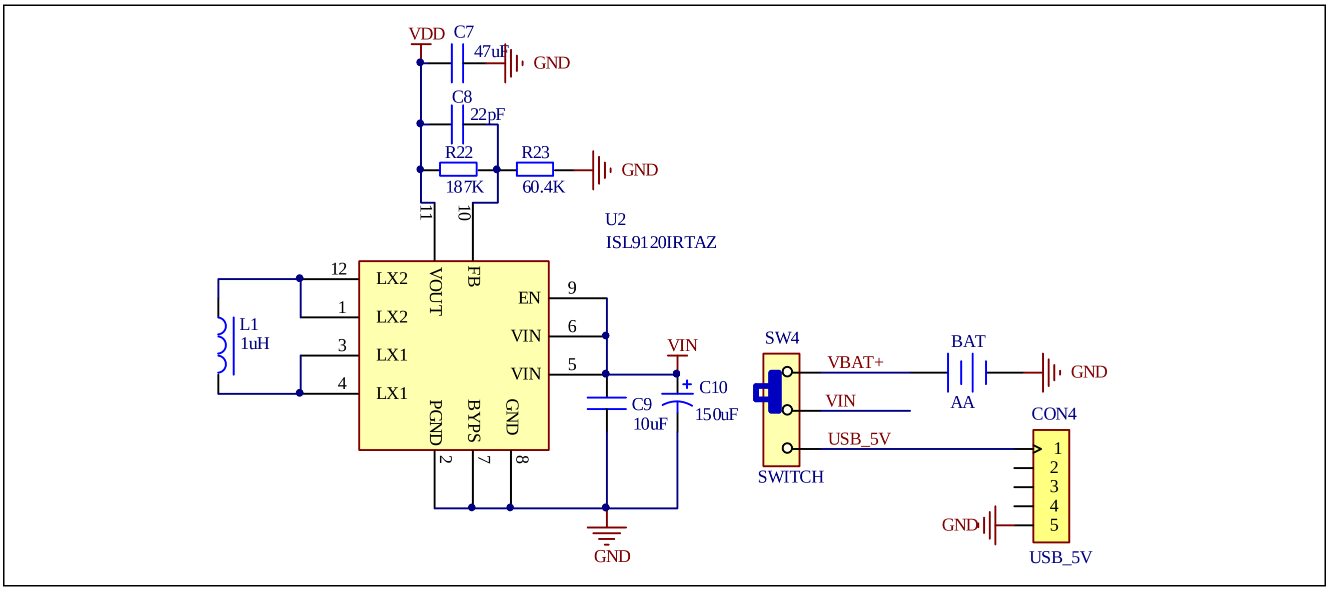

Figure 4.2 Power Supply Circuit

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 RL78/G1D BLE module, LED, etc.

4.2 Battery Voltage Detection Circuit

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

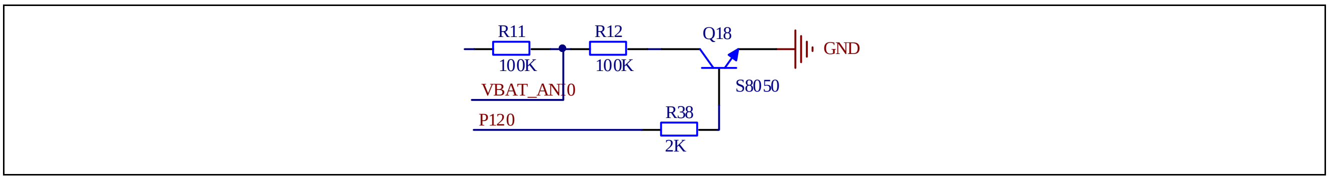

Figure 4.3 Battery Voltage Detection Circuit

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.

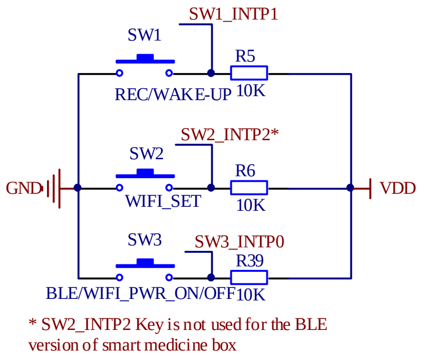

Figure 4.4 Function Key Detection Circuit

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 RL78/G1D BLE module.

The falling edge of the SW3 key is used to inform the MCU to power on/off the BLE 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.

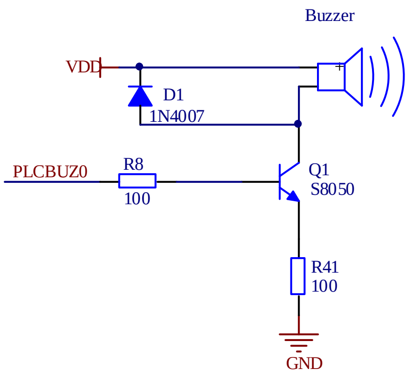

Figure 4.5 Buzzer Control Circuit

When the alarm interrupt occurs, the MCU outputs the square wave of 0.256 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.

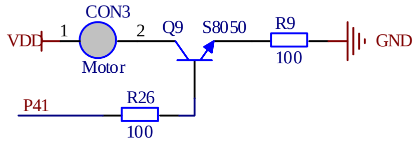

Figure 4.6 DC Vibrating Motor Circuit

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

4.6 BLE Module PMOD interface and Power Control Circuit

Figure 4.7 shows the schematics of BLE module PMOD interface and power control circuit.

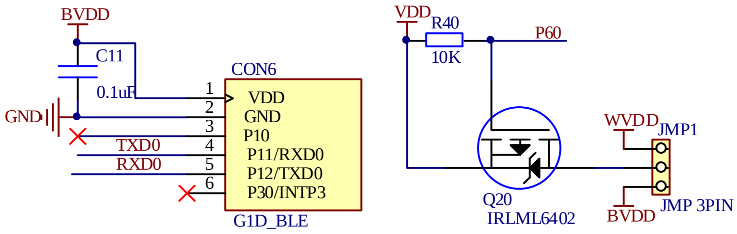

Figure 4.7 BLE Module PMOD Interface and Power Control Circuit

P60 is used to control the power supply ON/OFF to the RL78/G1D BLE module. UART0 is used to communicate with RL78/G1D BLE module.

4.7 Box LEDs Control Circuit

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

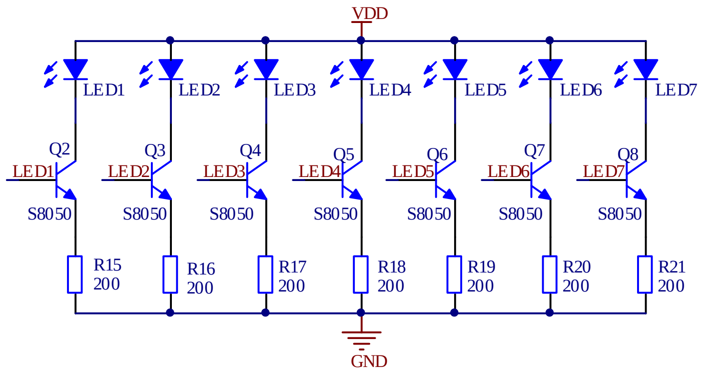

Figure 4.8 Box LED Control Circuit

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.

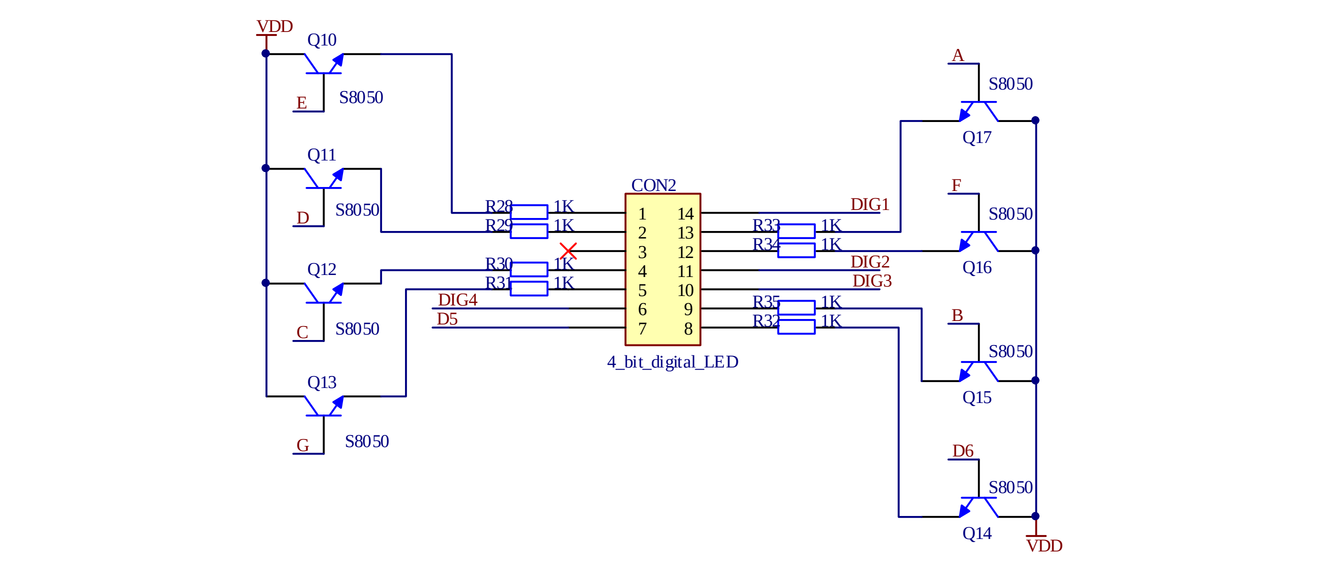

Figure 4.9 4-Digit 7-Segment LED Display Circuit

The system uses a 4-digit 7-segment LED to display the real-time clock information. When an alarm occurs, or a SW1 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 (R5F100FG)
Operating frequency	High-speed on-chip oscillator (HOCO) clock: 24 MHz CPU/peripheral hardware clock: 24 MHz 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) LVD: reset mode, 2.45 V
Integrated development environment (CS+)	CS+ V8.01.00 from Renesas Electronics Corp.
C compiler (e^2 studio)	CC-RL V1.08.00 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 (counting stopped after reset)
000C1H/010C1H	01011111B	LVD reset mode which uses 2.45 V (2.40 V to 2.50 V)
000C2H/010C2H	11111000B	HS mode, f_{HOCO}: 24 MHz CPU clock f_{CLK}: 24 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.

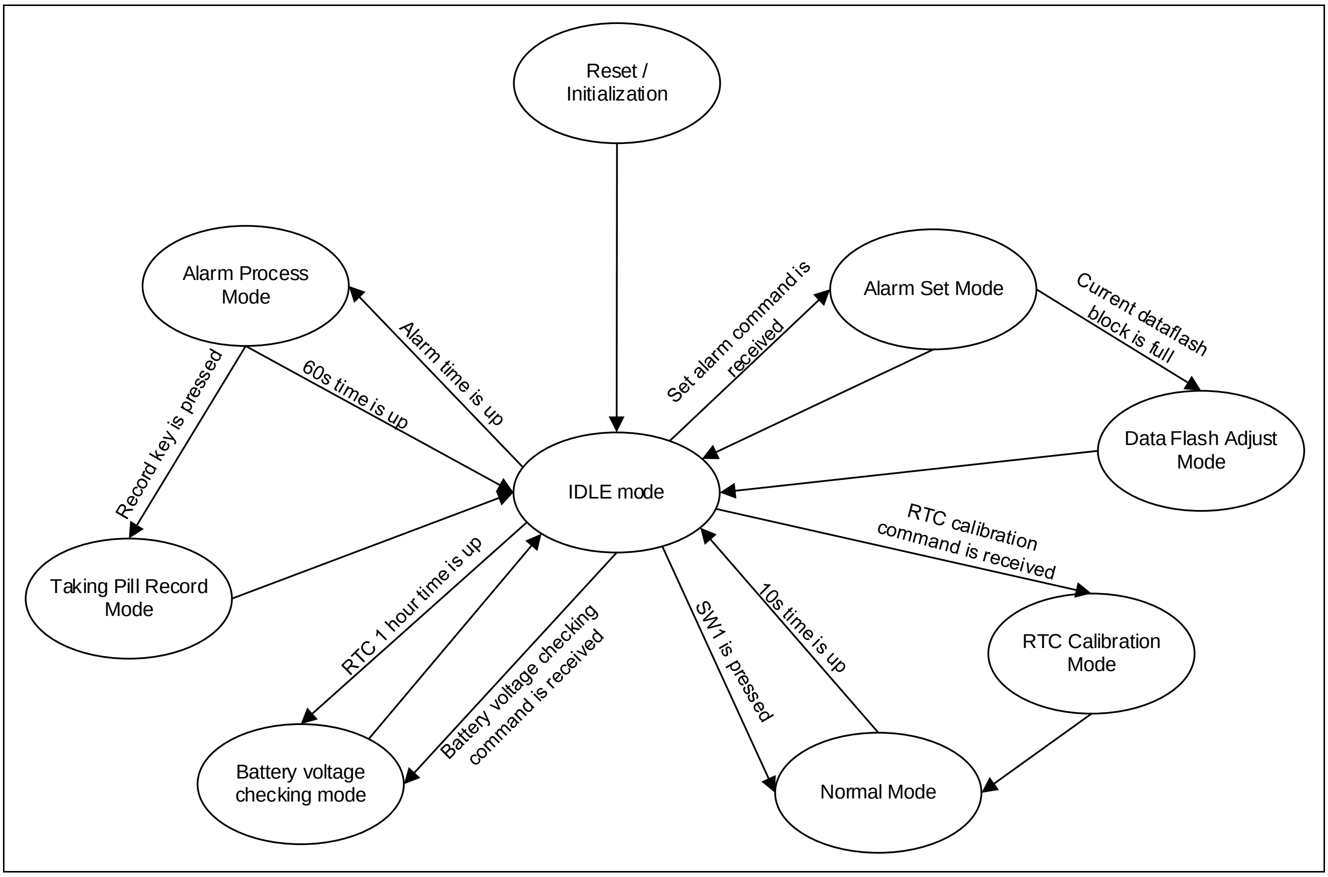

Figure 5.1 Tasks Transition Block Diagram

(1) Reset / Initialization

When the smart medicine box is powered on, it will enter the initialization operation. The UART module, RTC, INTP0~1, ADC modules and I/O pins will be initialized. The RL78/G1D BLE 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. The system will transfer to other modes according to the interrupt request source. If no other interrupt occurs, the system will remain the IDLE mode.

(3) Normal mode

In normal mode, the 4-digit 7-segment LED is ON for 10 seconds. 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 RL78/G1D BLE 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 IDLE 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 RL78/G1D BLE 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 enter 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 IDLE 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. At the same time, the vibration motor starts vibrating.

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 IDLE mode.

(8) Take pill record mode

In this mode, the smart medicine box records the taking medicine status for the current reminding time. Then, the system will return to the IDLE 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 high/low status will be sent to the mobile app via BLE through RL78/G1D BLE module. If the battery voltage is lower than 2.5 V, the buzzer will sound for 400ms 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.

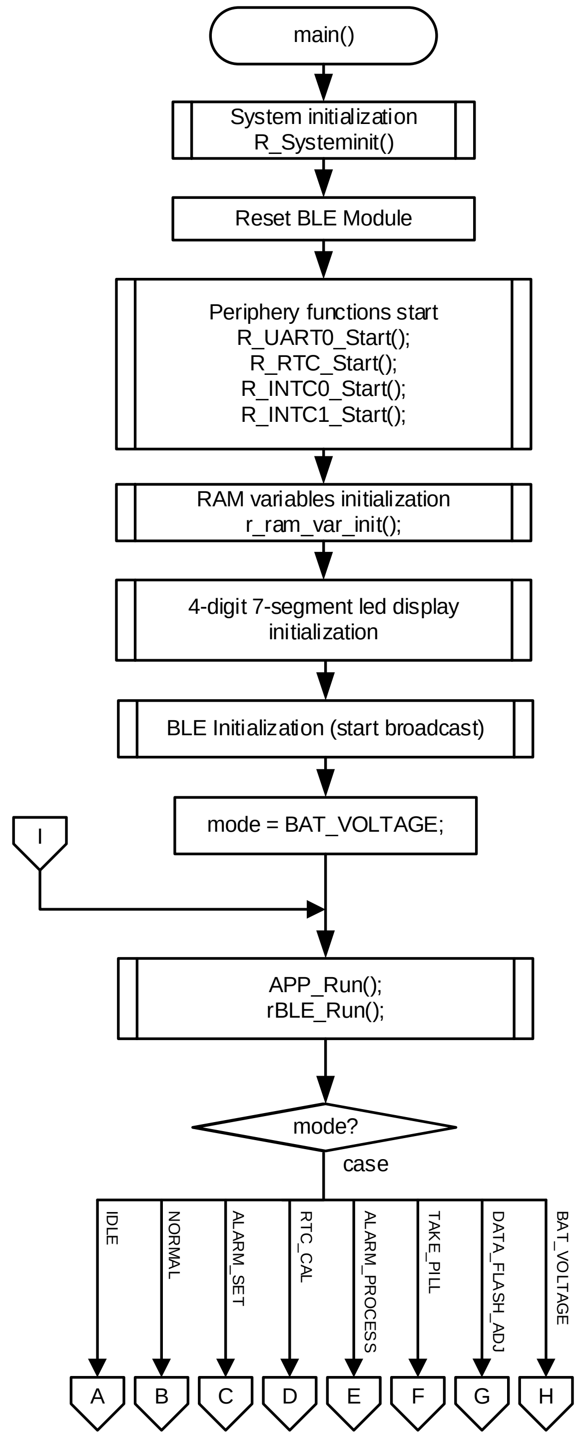

Figure 5.2 Main Processing (1)

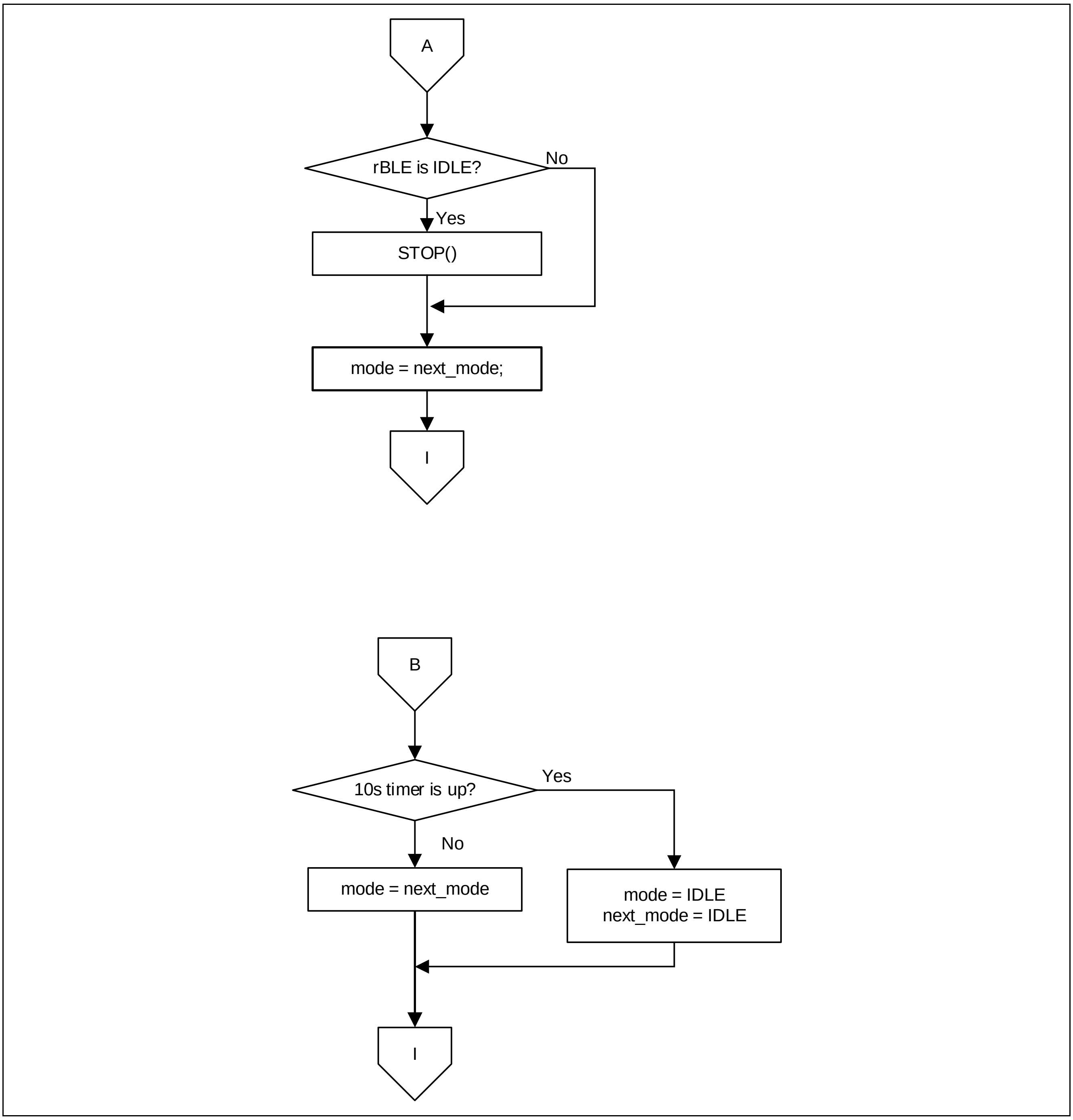

Figure 5.3 Main Processing (2)

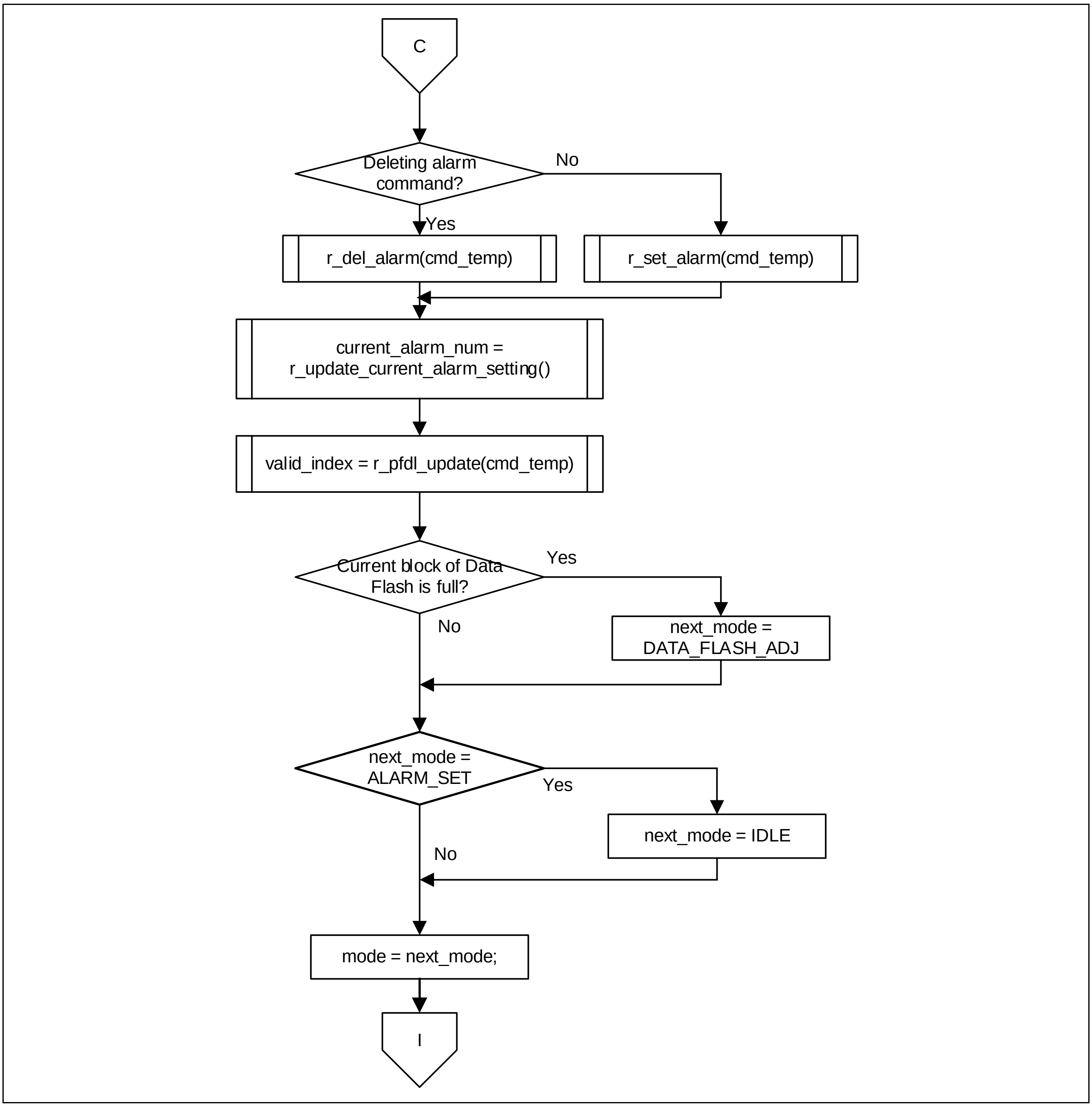

Figure 5.4 Main Processing (3)

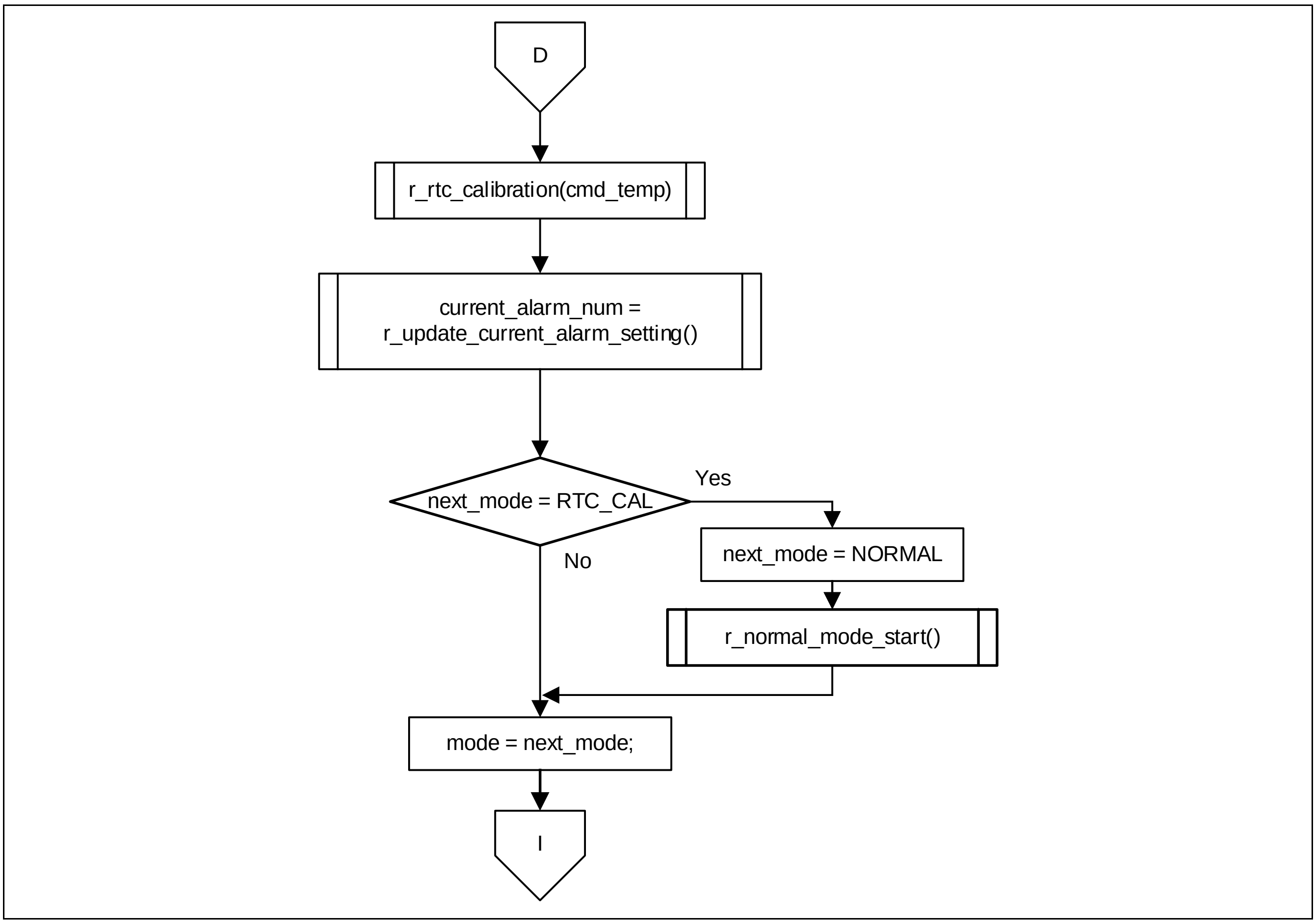

Figure 5.5 Main Processing (4)

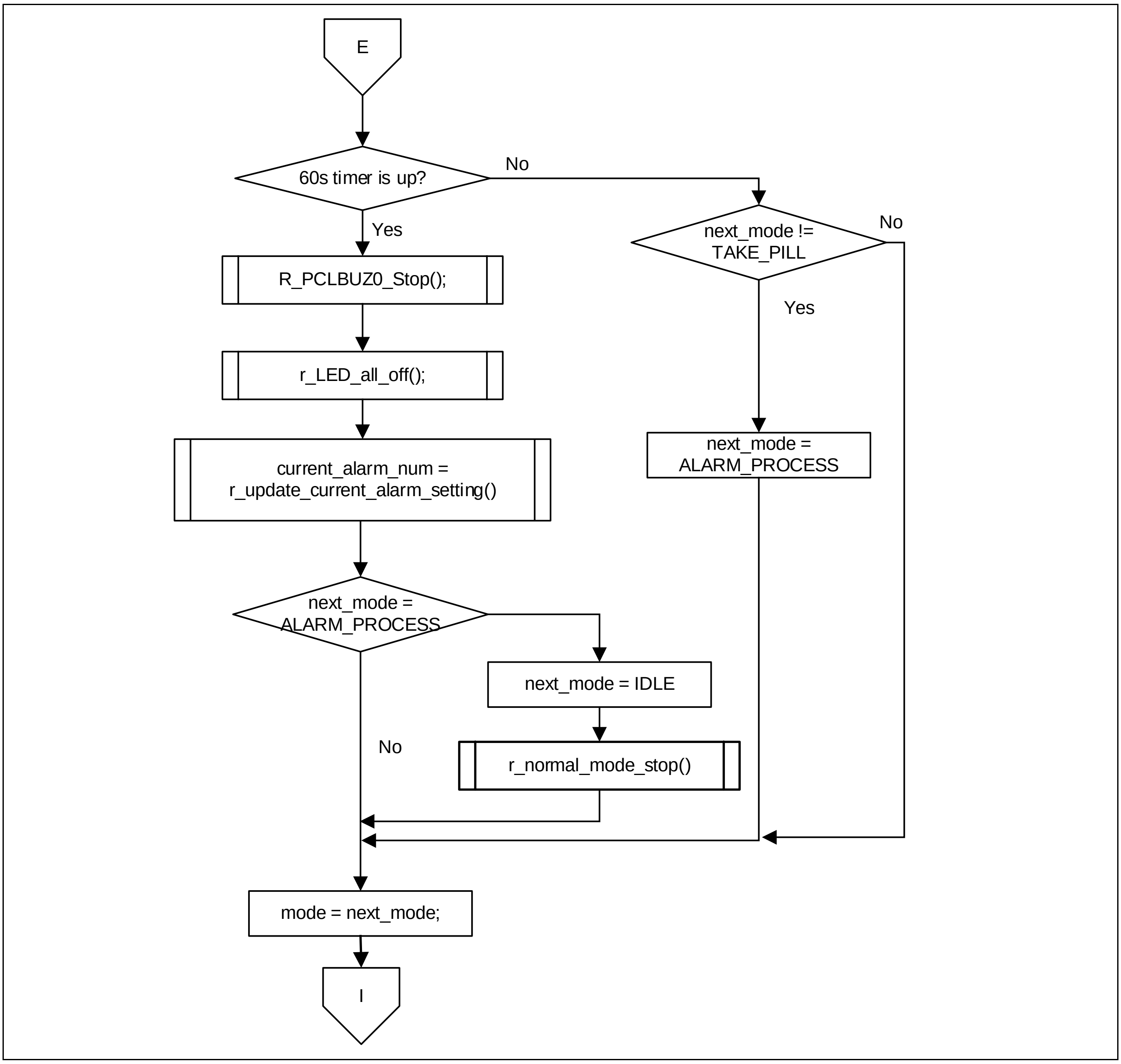

Figure 5.6 Main Processing (5)

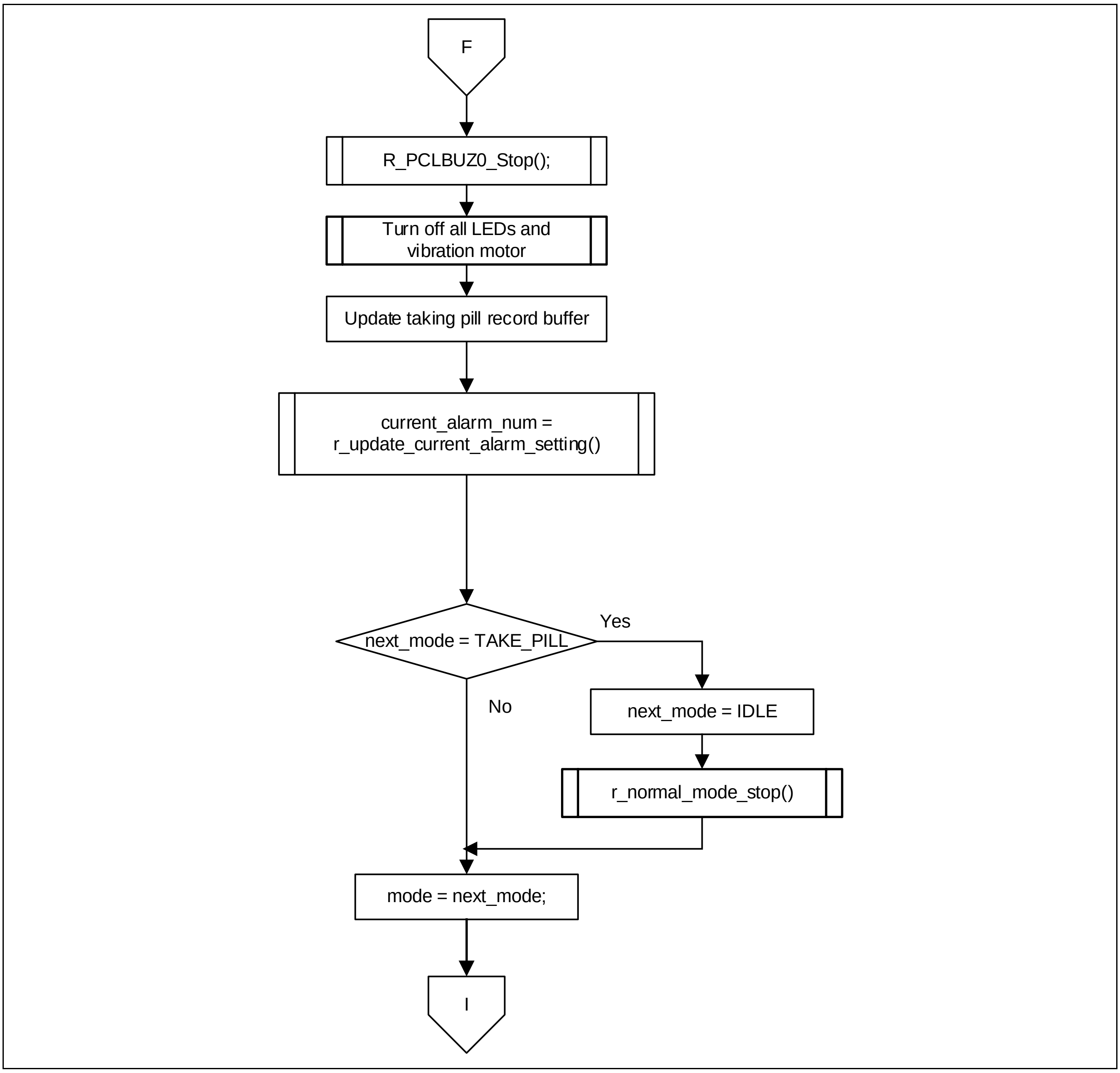

Figure 5.7 Main Processing (6)

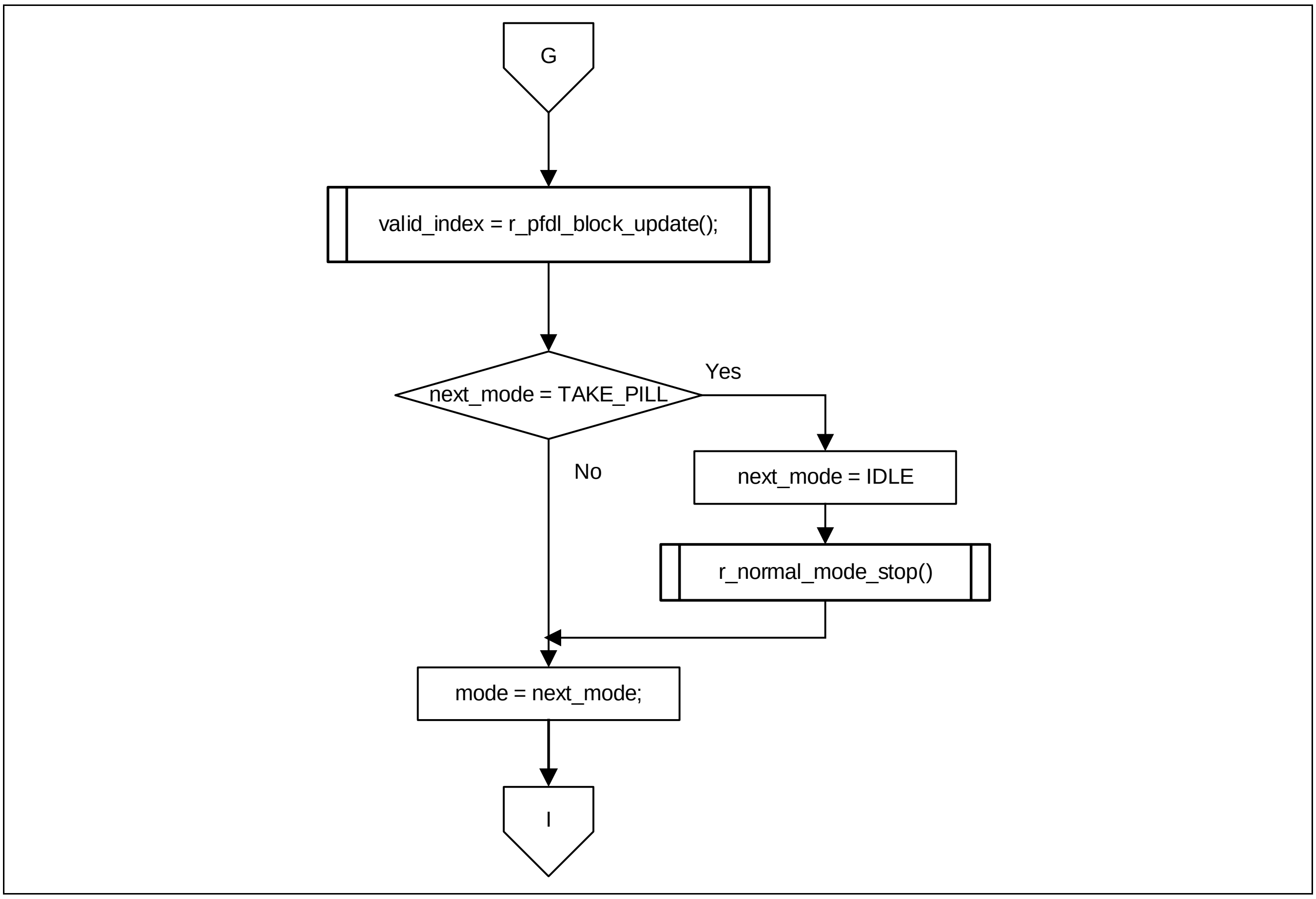

Figure 5.8 Main Processing (7)

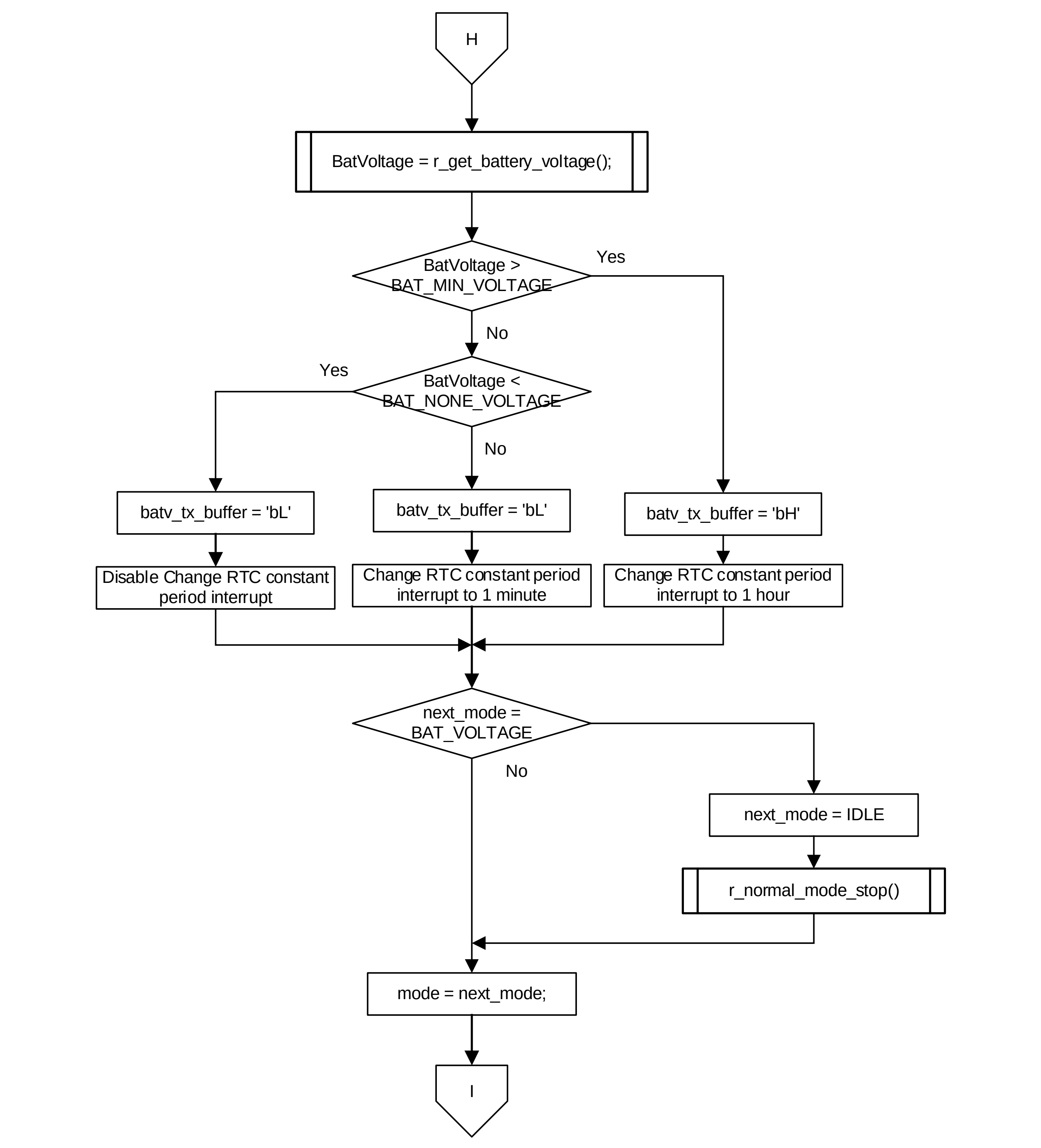

Figure 5.9 Main Processing (8)

5.4.2 BLE Main Sequence Chart

The main sequence chart is shown in Figure 5.10.

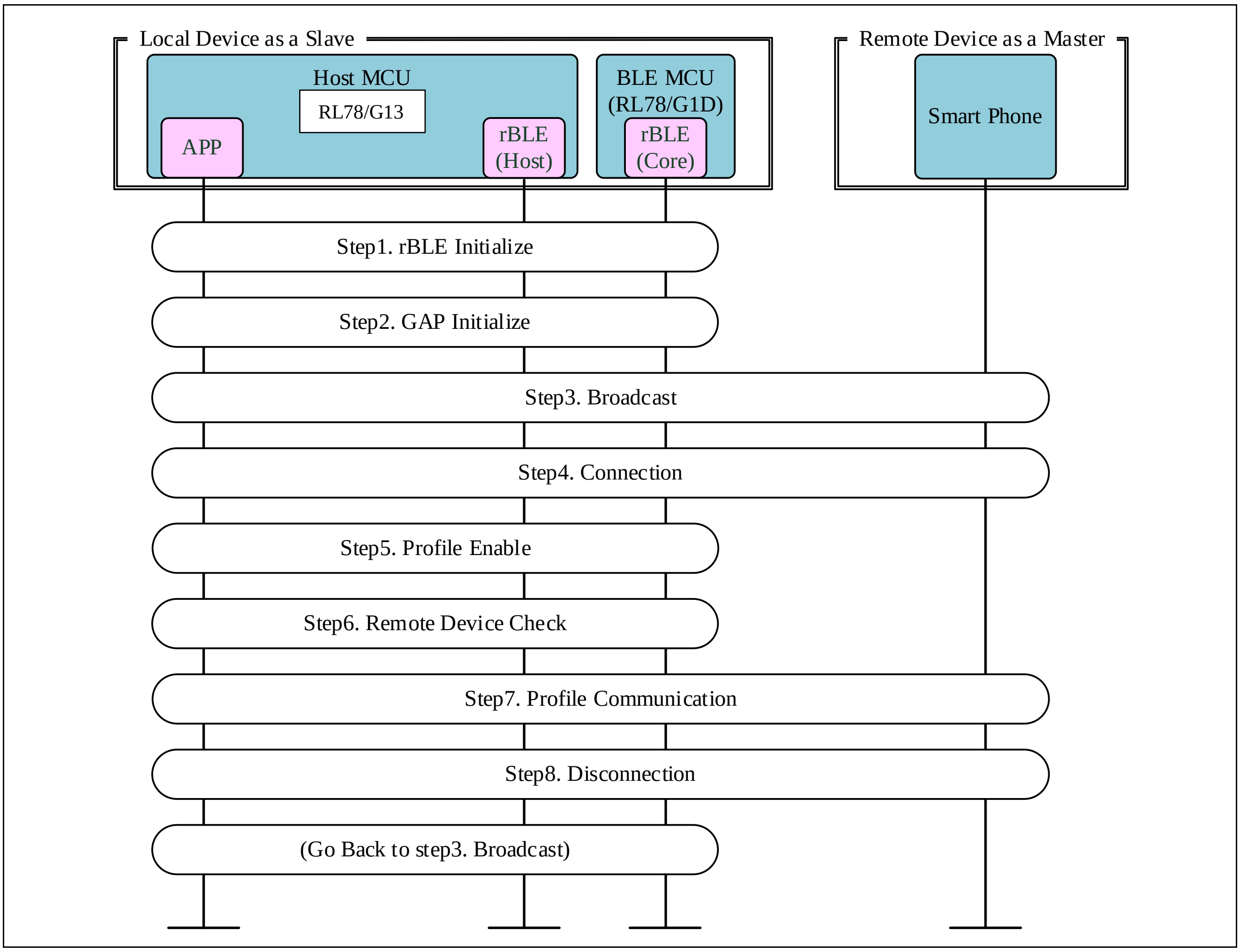

Figure 5.10 The BLE Main Sequence Chart

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)

Bluetooth® Low Energy Protocol Stack RL78/G14 Host Sample (R01AN2807EJ0121 Rev.1.21)

(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.)

Website and Support

Renesas Electronics Website
http://www.renesas.com/

Inquiries
http://www.renesas.com/contact/

Revision History

		Description	
Rev.	**Date**	**Page**	**Summary**
1.00	Jun. 30, 2019	—	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. Precaution against Electrostatic Discharge (ESD)

   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.

2. Processing at power-on

   The state of the product is undefined at the time 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 time 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 time 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 time when power is supplied until the power reaches the level at which resetting is specified.

3. Input of signal during power-off state

   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.

4. 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 the 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.

5. Clock signals

   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is 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. Additionally, 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.

6. Voltage application waveform at input pin

   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).

7. Prohibition of access to reserved addresses

   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.

8. Differences between products

   Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of 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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