RL78/L1A

Smart Blood Pressure Monitor

R01AN3913EC0100
Rev.1.00
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Introduction

This user's manual describes a Renesas ultra-low-power consumption LCD microcontroller RL78/L1A and Renesas Bluetooth Low Energy (BLE) microcontroller RL78/G1D application for a smart blood pressure monitor (for Android). RL78/L1A controls the BLE microcontroller RL78/G1D device programmed with BLE protocol by serial communication. Please refer to the following documents for the program structure and usage information on the application.

Document		Document No.
Bluetooth® Low Energy Protocol Stack	User's Manual	R01UW0095E
	API Reference Manual: Basic	R01UW0088E
	Application Note: Sample Program	R01AN1375E
	rBLE Command Specification	R01AN1376E
	RL78/G1D Evaluation Board	R30UZ0048E
	RL78/G14 Host Sample	R01AN2807E

Target Device

RL78/L1A

Contents

1. Outline of System Function

1.1 Introduction of Smart Blood Pressure Monitor

The blood pressure is an important physiological parameter that reflects the state of the cardiovascular system. An appropriate blood pressure is a necessary condition to maintain normal metabolism. With the improvement of living, people pay more attention to their own health problems, while unhealthy lifestyles and unscientific eating habits lead to more and more human diseases. Hypertension has gradually risen in human disease charts, seriously harms to human health. Effective and convenient measurement instrument of the blood pressure can make people understand the physical condition in time, and prevent and cure hypertension effectively.

The electronic blood pressure monitor has the advantages of low cost, miniaturization, automation and so on. It is easy to operate and carry. It has gradually become an essential healthcare product for the family. With the development of smart phones and mobile internet technology, the smart blood pressure monitor can achieve wireless transmission of measurement data and record the value of blood pressure parameters. So, it is favored by more and more people. The smart blood pressure monitor introduced in this user's manual integrates the Bluetooth module on the general electronic blood pressure monitor and uses Bluetooth to realize the wireless transmission.

To demonstrate the application, the BLE protocol stack program and application program are required to be written into RL78/G1D module and RL78/L1A respectively. Then, install the appropriate APP on Android smartphone to achieve the communication between the smartphone APP and the smart blood pressure monitor through BLE function. The APP receives systolic pressure, diastolic pressure and pulse data from the smart blood pressure monitor. Then the APP displays and records the parameters. The demo board is composed of main MCU RL78/L1A, RL78/G1D module (RTK0EN0002C01001BZ) and peripheral board (LCD, blood pressure measurement circuit, air pressure control circuit, etc.)

The smart blood pressure monitor system is shown in Figure 1.1.

Figure 1.1 The Smart Blood Pressure Monitor System

The demo board of the smart blood pressure monitor is shown in figure 1.2.

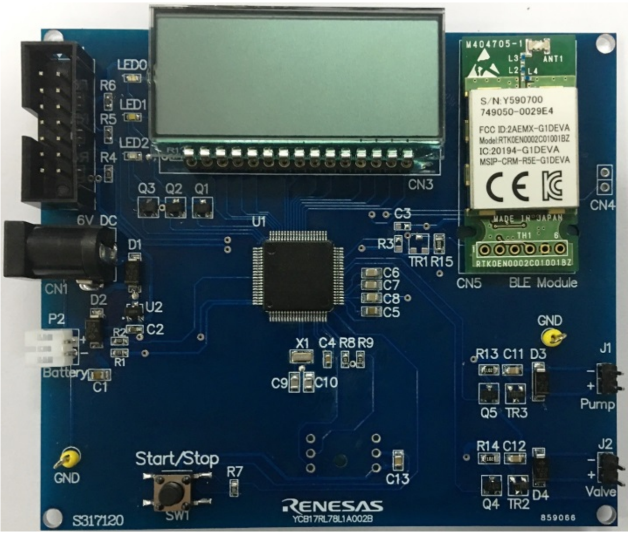

Figure 1.2 The Smart Blood Pressure Monitor Demo Board

1.2 Introduction of Blood Pressure Measurement Theory

The blood pressure measurement method is based on Korotkoff sounds or oscillometric method generally. But the Korotkoff sounds method has some inherent shortcomings. So, the electronic blood pressure monitor mostly uses the oscillometric method for measurement. In the measurement process of the oscillometric method, the arm cuff is used to block the upper arm artery blood flow. Because of the hemodynamic effect of the heartbeat, the pressure fluctuations in the arm cuff pressure overlap with the heartbeat, i.e. the pulse wave. When the arm cuff pressure is much higher than the systolic pressure, the pulse wave disappears. As the arm cuff pressure drops, pulse waves begin to appear. The pulse wave suddenly increases when the arm cuff pressure drops from above the systolic pressure to below the systolic pressure. When the pressure drops to the average pressure, the pulse wave reaches maximum. Then the pulse wave decays with the arm cuff pressure drops. Oscillometric method measurement estimates the blood pressure based on the relationship between the pulse wave amplitude and the arm cuff pressure. Corresponding to the maximum amplitude of the pulse wave amplitude is the average pressure, and the systolic and diastolic pressure is determined by the ratio of the maximum amplitude of the pulse wave.

The block diagram of the blood pressure measurement is shown in Figure 1.3. P_m is average pressure, P_s is systolic pressure, and P_d is diastolic pressure. U_m is the maximum amplitude of pulse wave. Ks and K_d are the ratio coefficients of the pulse amplitude corresponding to systolic pressure and diastolic pressure corresponding to average pressure. K_s and K_d are selected by the blood pressure monitor manufacturers based on experience.

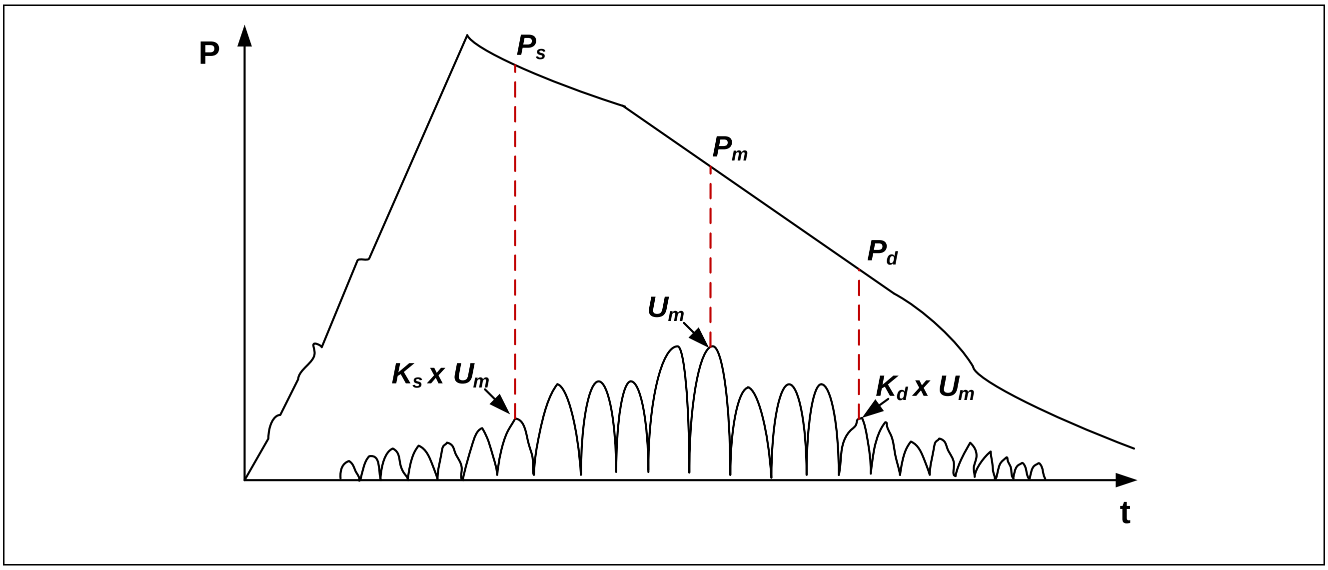

Figure 1.3 The Block Diagram of Blood Pressure Measurement

1.3 Introduction of Operation

1.3.1 Device Connection

Install the smart blood pressure monitor APP into Android smartphone. Run it and start to scan the device named "Renesas Blood Pressure", and then click for connection if the device is available.

The connection interface of the smart blood pressure monitor APP is shown in Figure 1.4.

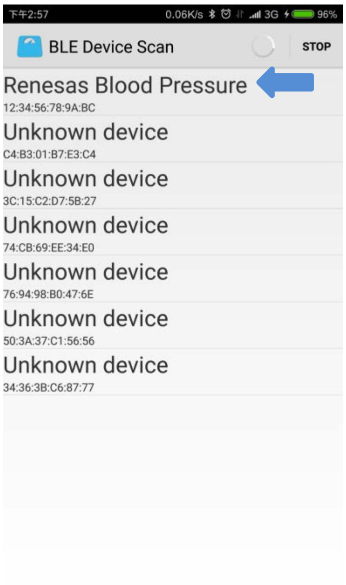

Figure 1.4 The Connection Interface of the Smart Blood Pressure Monitor APP

1.3.2 Blood Pressure Measurement

The smart blood pressure monitor starts the automatic measurement process by pressing the "Start/Stop" key or the "Start measurement" button of the smart blood pressure monitor APP (invalid during the measurement process). Firstly, press on the arm cuff, the solenoid valve is closed during the pressurization process. PWM control air pump is used for pressurizing the arm cuff. After the pressure reaches the setting value (this application is 160mmHg), the pressurization process is stopped and a linear deflation process is started. In the process of the linear deflation, the smart blood pressure monitor is used for sampling data and calculation. After the calculation, systolic pressure, diastolic pressure and pulse data are repeatedly shown on the LCD in this order. At the same time, the smart blood monitor APP also shows the same data. In the measurement process, if you want to terminate the measurement, press the "Start/Stop" button again. The quick release solenoid valve is open, releases the air in the arm cuff.

The LCD display of systolic pressure is shown in Figure 1.5. LED0 (red) light, which represents systolic pressure display.

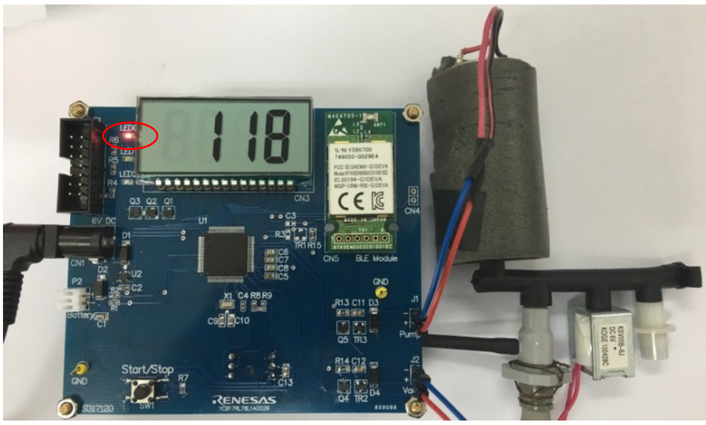

Figure 1.5 The Blood Measurement Results (Systolic Pressure)

The LCD display of diastolic pressure is shown in Figure 1.6. LED1 (yellow) light, which represents diastolic pressure display.

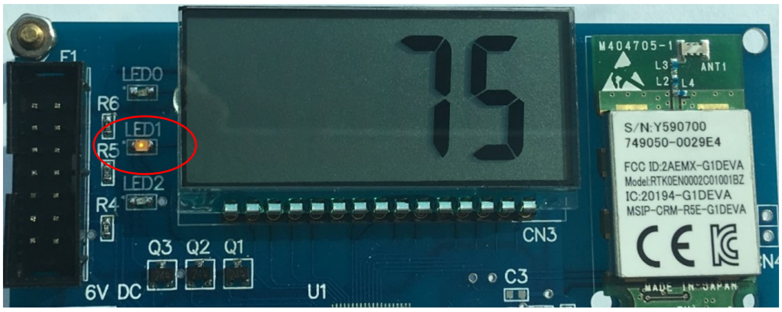

Figure 1.6 The Blood Measurement Results (Diastolic Pressure)

The LCD display of pulse is shown in Figure 1.7. LED2 (blue) light, which represents pulse display.

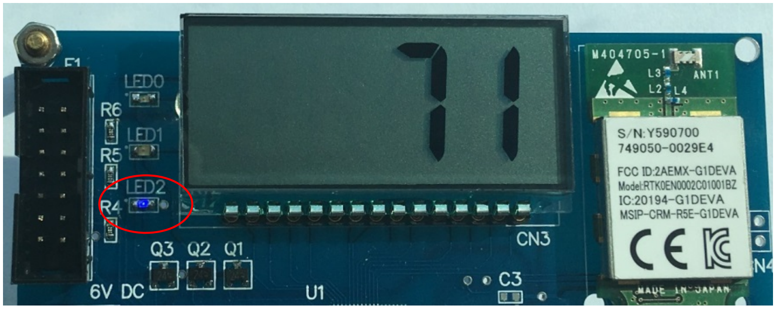

Figure 1.7 The Blood Measurement Results (Pulse)

The display of measurement results on the smart blood pressure monitor APP is shown in Figure 1.8.

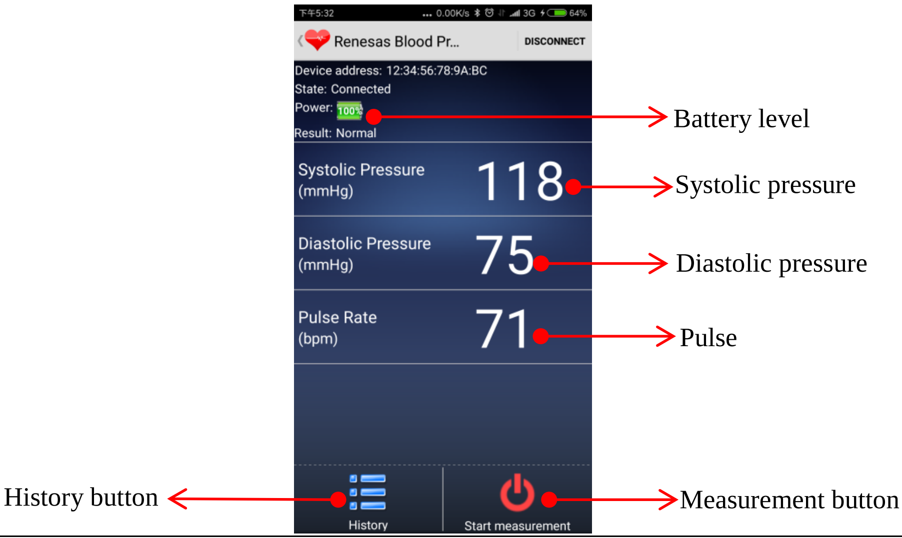

Figure 1.8 The Blood Measurement Results in Android APP

Press the "History" button on the smart blood pressure monitor APP, the historical measurement records are shown in Figure 1.9.

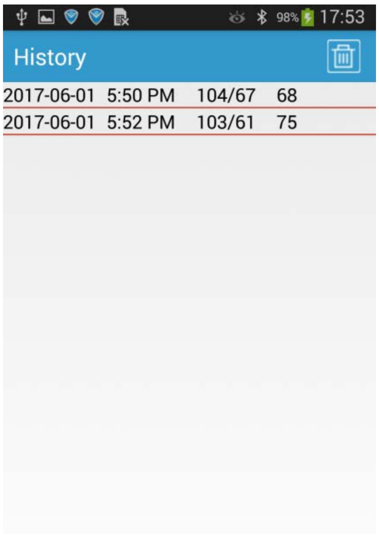

Figure 1.9 The Historical Measurement Record in Android APP

2. Introduction of Hardware

2.1 Introduction of PCB

The top view of the smart blood pressure monitor demo board is shown in Figure 2.1.

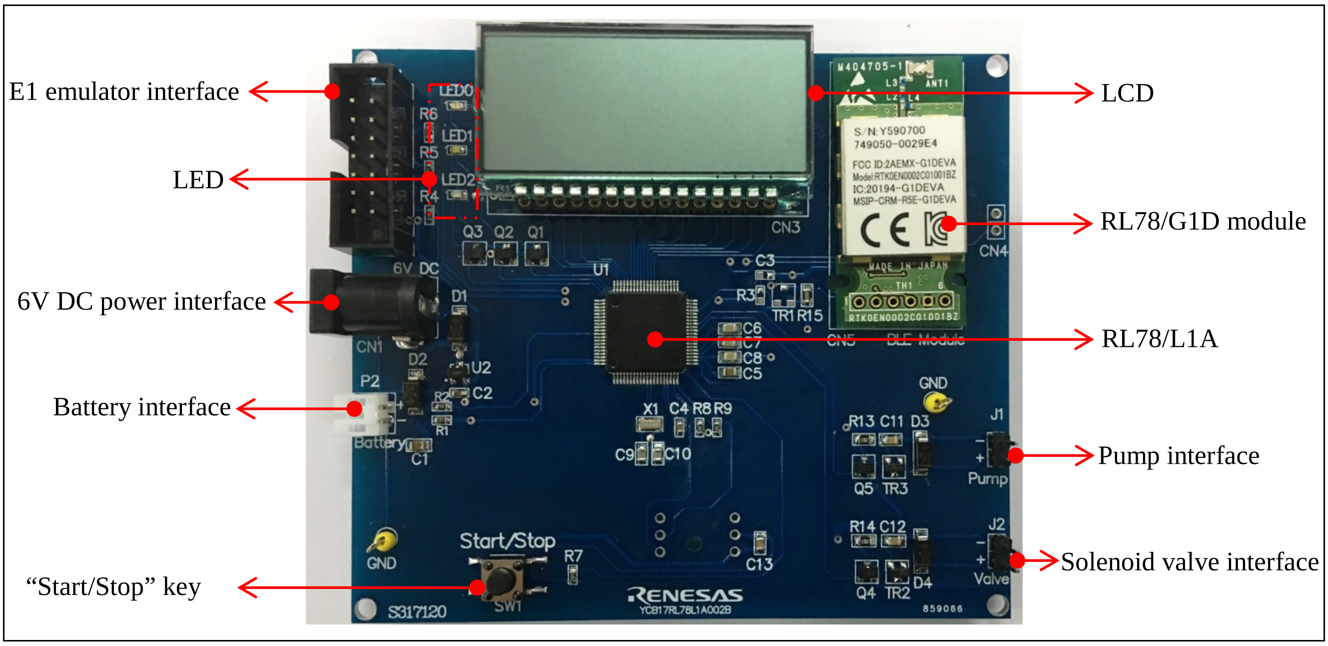

Figure 2.1 The Top View of Smart Blood Pressure Monitor Demo Board

The bottom view of the smart blood pressure monitor demo board is shown in Figure 2.2.

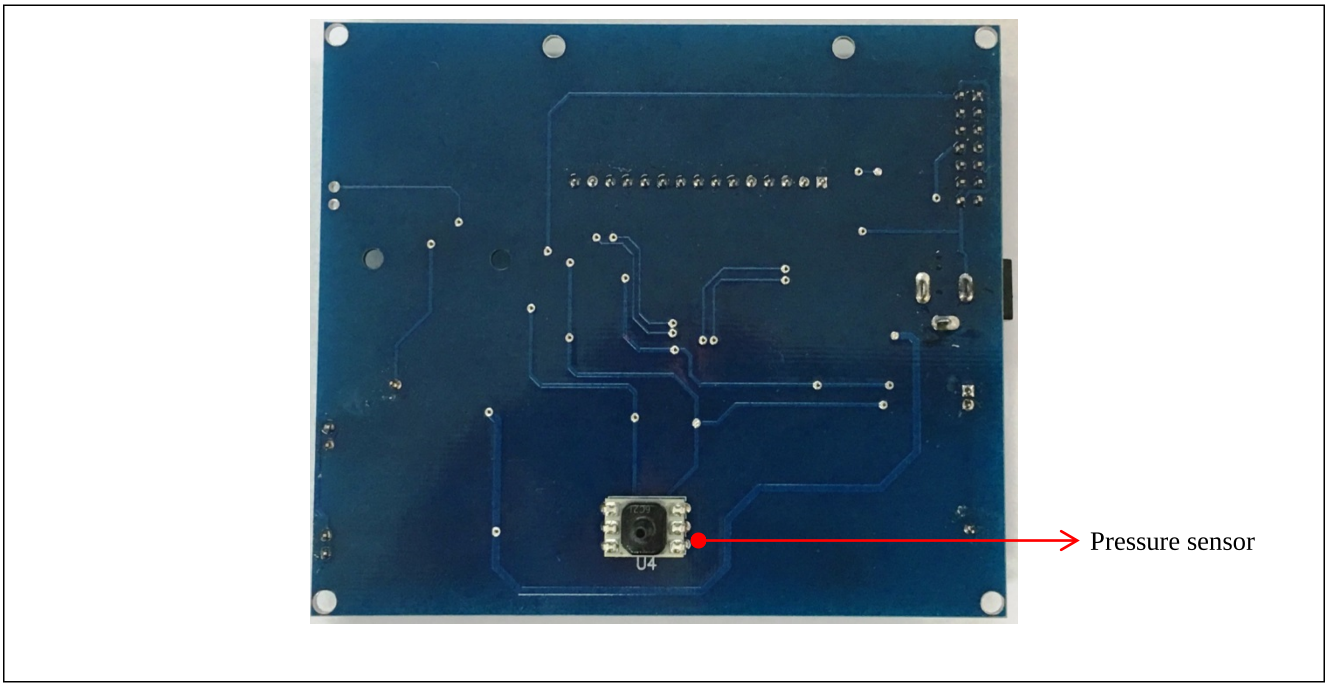

Figure 2.2 The Bottom View of Smart Blood Pressure Monitor Demo Board

2.2 Hardware Block Diagram

The hardware block diagram of the smart blood pressure monitor is shown in Figure 2.3.

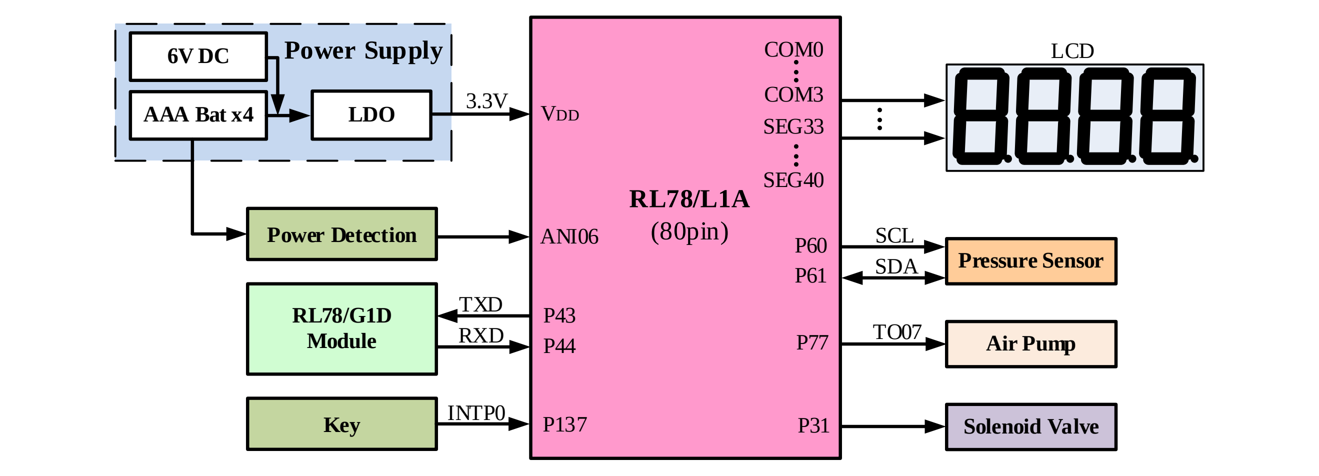

Figure 2.3 The Hardware Block Diagram of the Smart Blood Pressure Monitor

2.3 Main MCU

The demo board of the smart blood pressure monitor uses a RL78/L1A (R5F11MMF) as main MCU. The Flash ROM size of RL78/L1A is 96 KB and the RAM size is 5.5 KB. The peripheral functions of RL78/L1A and their applications are shown in Table 2.1.

Table 2.1 Peripheral Functions and Their Applications

Peripheral functions	Usage
Channel 0, 1 of TAU0	Communicate with RL78/G1D by UART
12-bit interval timer	10ms timer, used to monitor UART timeout and trigger for the profile notification and sample pressure data, etc.
COM0~COM3	Control the 4 COMs of the LCD
SEG33~SEG40	Control the 8 SEGs of the LCD
P60	Control the SCL port of IIC
P61	Control the SDA port of IIC
P31	Control the port for solenoid valve to release air rapidly
P74~P76	Control the port for LED0~LED2
P77/TO07	PWM output to control the air pump
P137/INTP0	Input port for the "Start/Stop" key
P141/ANI06	A/D sampling: the detection of the battery voltage

The main control circuit of RL78/L1A is shown in Figure 2.4.

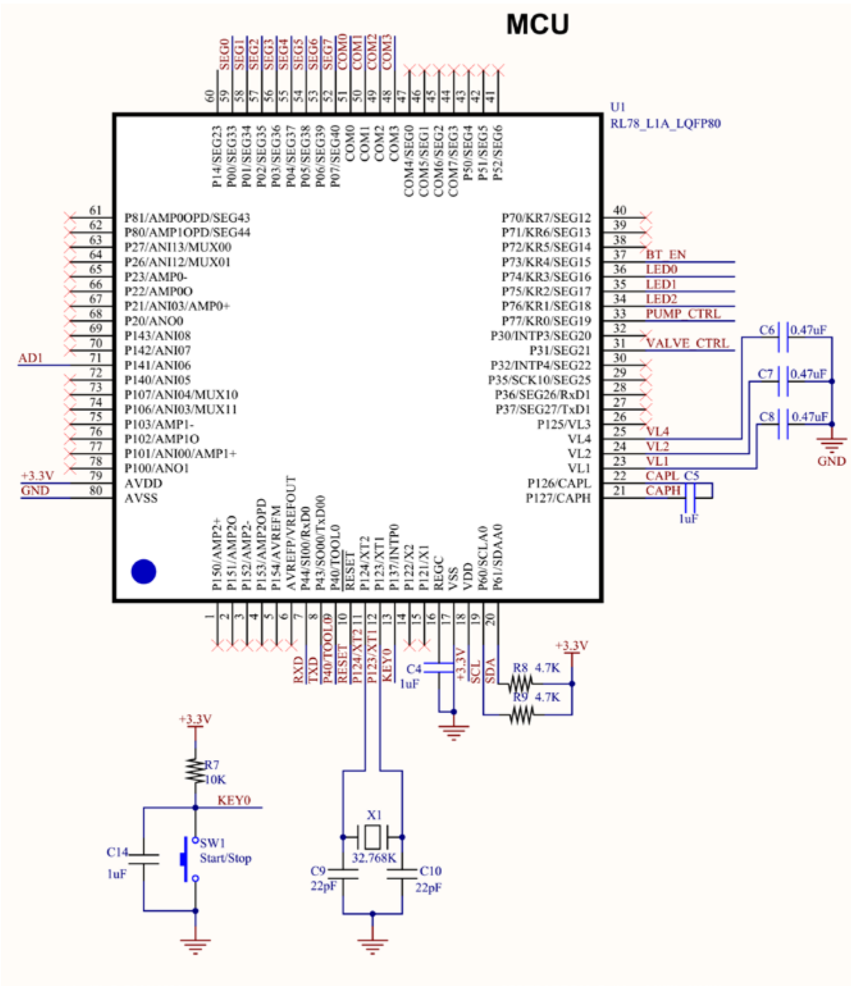

Figure 2.4 The Main Control Circuit of RL78/L1A

2.4 BLE MCU

The demo board of the smart blood pressure monitor uses RL78/G1D module (RTK0EN0002C01001BZ) as BLE MCU which is a daughter board from the RL78/G1D evaluation board (RTK0EN0001C01001BZ). RL78/G1D module is shown in Figure 2.5.

Figure 2.5 RL78/G1D Module

The RL78/G1D evaluation board (RTK0EN0001C01001BZ) is shown in Figure 2.6.

Figure 2.6 The RL78/G1D Evaluation Board

In this application, the RL78/L1A controls the RL78/G1D module to realize the BLE function by UART. The interface circuit of the RL78/G1D module is shown in Figure 2.7.

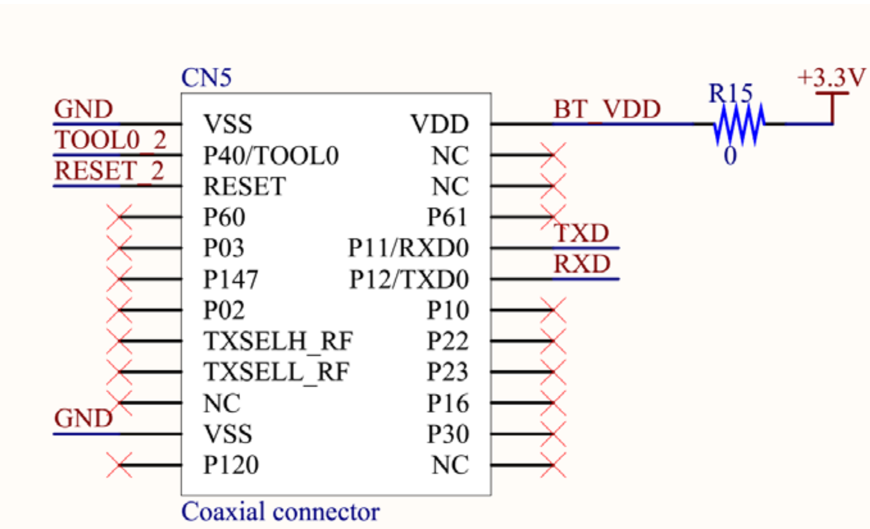

Figure 2.7 The Interface Circuit of RL78/G1D Module

2.5 Power Supply Circuit

The smart blood pressure monitor uses 4 AAA batteries or DC 6V input as power supply. Switch SW2 to power for the smart blood pressure monitor. The stable 3.3V is got through a chip XC6206-3.3V. The battery voltage is sampled through the A/D port. The DC 6V is supplied to the air pump and the solenoid valve directly. The power supply circuit is shown in Figure 2.8.

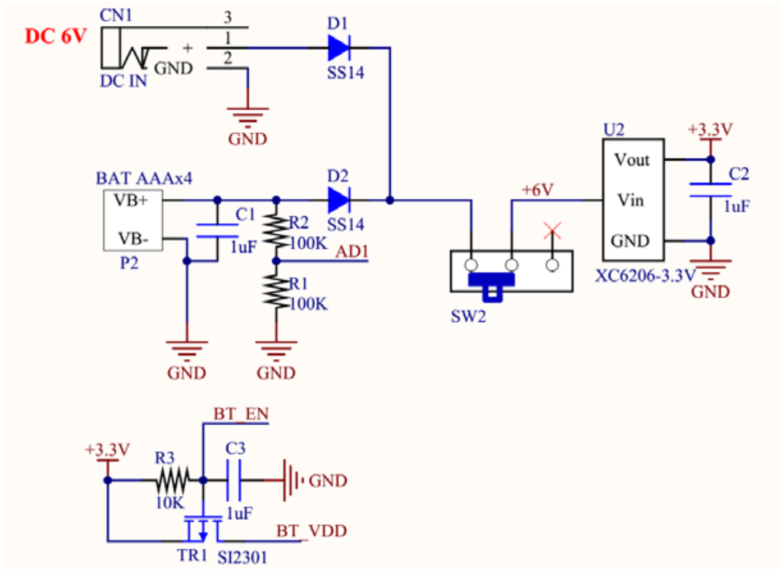

Figure 2.8 The Power Supply Circuit

2.6 Pressure Detection Circuit

The pressure sensor used in this application is the ABPDANN005PG2A3 of Honeywell. This pressure sensor has a 12-bit digital output of I^{2}C with high accuracy and good linearity. The pressure range is 0~5 psi, and the corresponding blood pressure value is about 0~258mmHg which matches the design requirement of the blood pressure monitor.

The pressure detection circuit is shown in Figure 2.9.

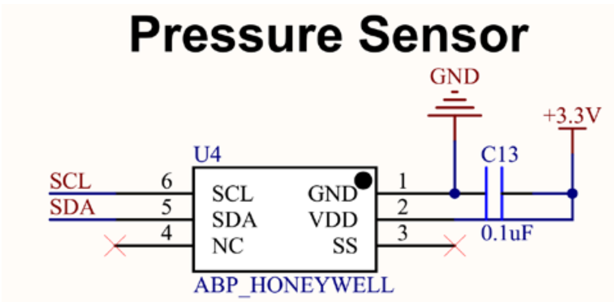

Figure 2.9 The Pressure Detection Circuit

2.7 Air Pump and Solenoid Valve Control Circuit

The control circuit of the air pump and solenoid valve is used by a NPN digital transistor DTC114 and a P channel MOSFET (IRLML6402). The DTC114 and the IRLML6402 have switching speed above 1MHz, which is suitable for the high speed PWM control. MAP-AM-265 (manufactured by MITSUMI) is used as the air pump, the rated voltage is 6V, the maximum pressure can reach 400mmHg. The solenoid valve selects KSV05B of Yujin Electronic, the rated voltage is 6V, the exhaust time that reduces from 300mmHg to 15mmHg needs only 3 seconds. The air pump and the solenoid valve control circuit are shown in Figure 2.10.

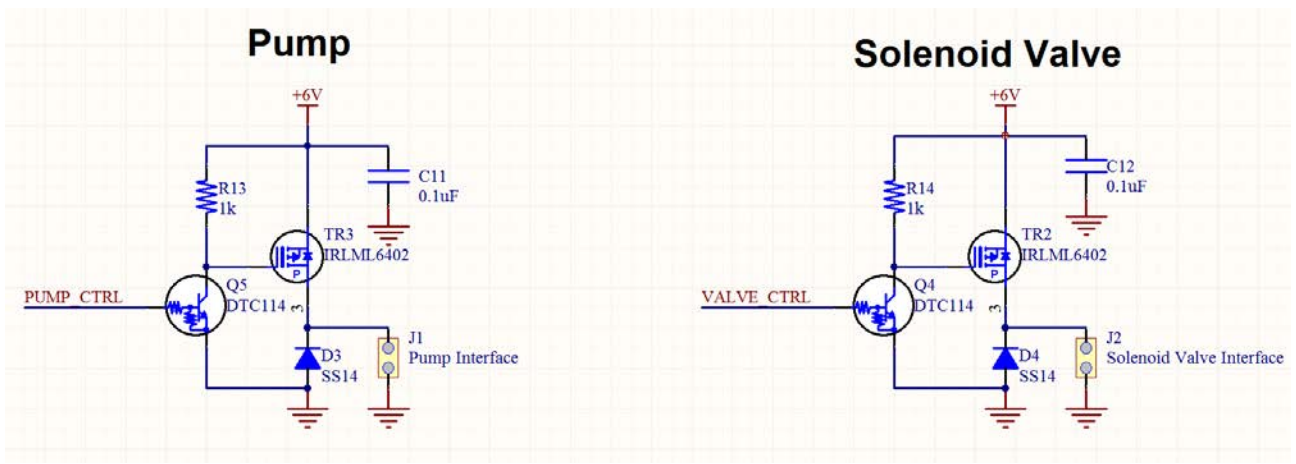

Figure 2.10 The Air Pump and the Solenoid Valve Control Circuit

2.8 LCD Control Circuit

A LCD with 4 COMs and 8 SEGs is used for display. RL78/L1A has 4-8 COM pins and 28-32 SEG pins that can independently implement the LCD drive control. About the relationship between display and each pin of the LCD, please refer to Table 2.2.

Table 2.2 The Pin Relationship of LCD with 4 COMs and 8 SEGs

Pin Name	SEG0	SEG1	SEG2	SEG3	SEG4	SEG5	SEG6	SEG7
COM0	1d	1p	2d	2p	3d	3p	4d	-
COM1	1e	1c	2e	2c	3e	3c	4e	4c
COM2	1g	1b	2g	2b	3g	3b	4g	4b
COM3	1f	1a	2f	2a	3f	3a	4f	4a

The control circuit of the LCD is shown in Figure 2.11.

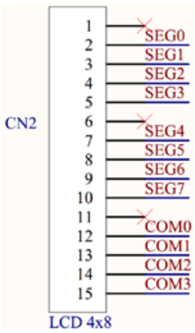

Figure 2.11 The LCD Control Circuit

2.9 LCD Control Circuit

The LED control circuit consists of the NPN digital transistors and the current limitation resistors to indicate which parameter is displayed in the LCD. LED0 (red) indicates systolic pressure, LED1 (yellow) indicates diastolic pressure, and LED2 (blue) indicates pulse. The LED control circuit is shown in Figure 2.12.

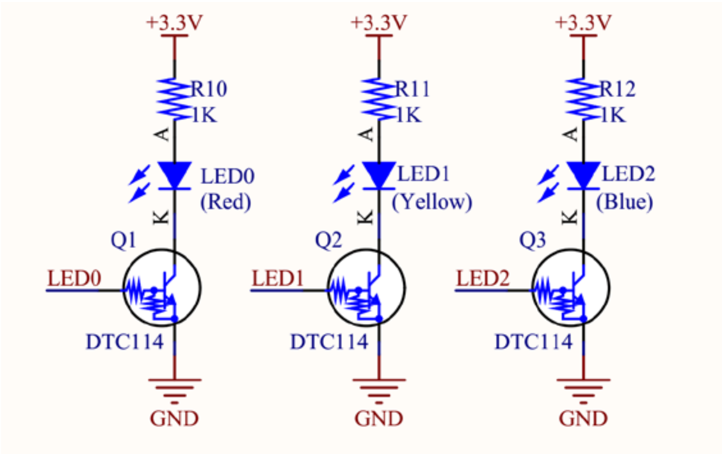

Figure 2.12 The LED Control Circuit

3. Schematic, PCB and Bill of Materials

3.1 Schematic

The schematic of the smart blood pressure monitor is shown in Figure 3.1 and Figure 3.2.

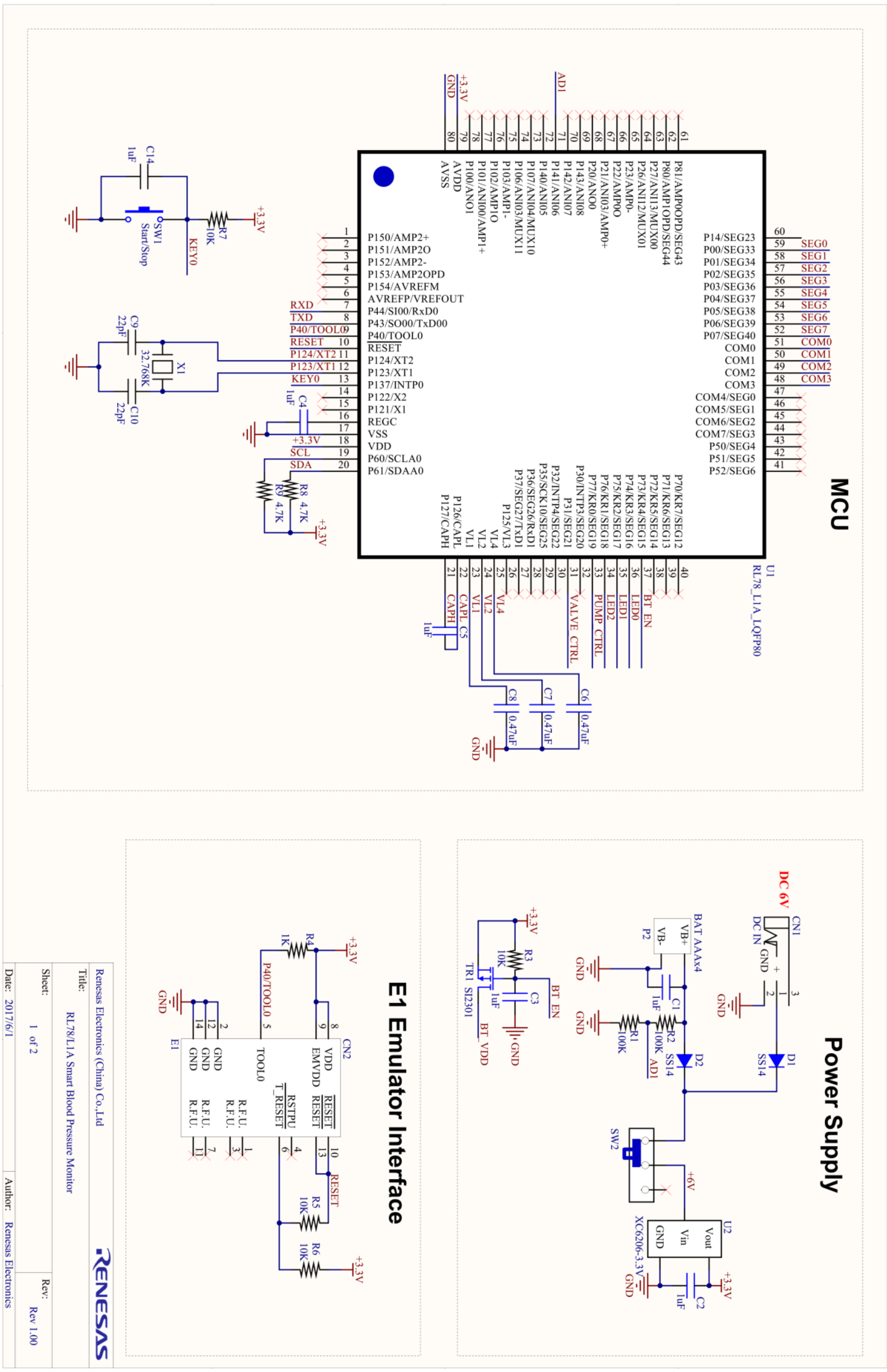

Figure 3.1 The Schematic (1/2)

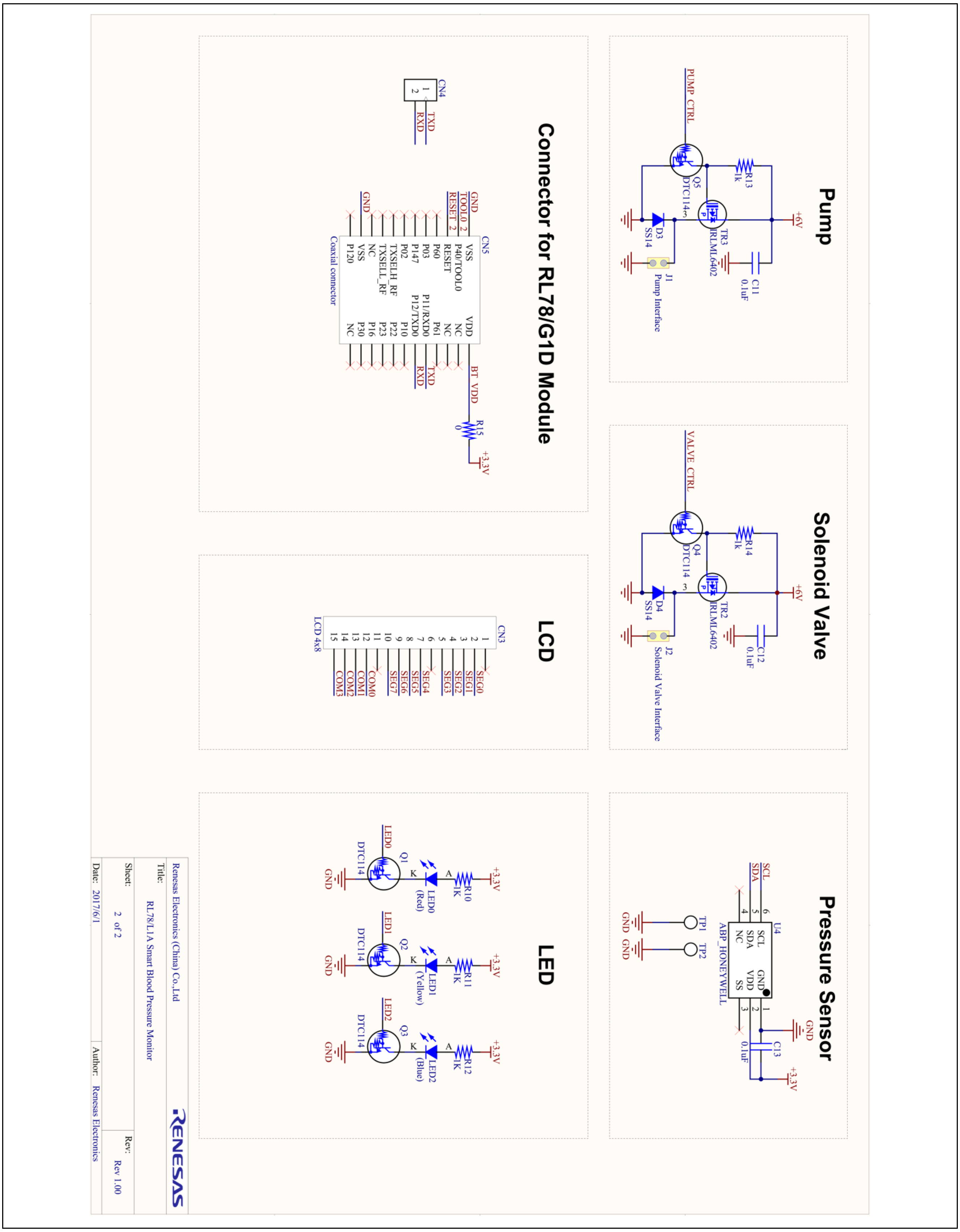

Figure 3.2 The Schematic (2/2)

3.2 PCB

The PCB of the smart blood pressure monitor is shown in Figure 3.3.

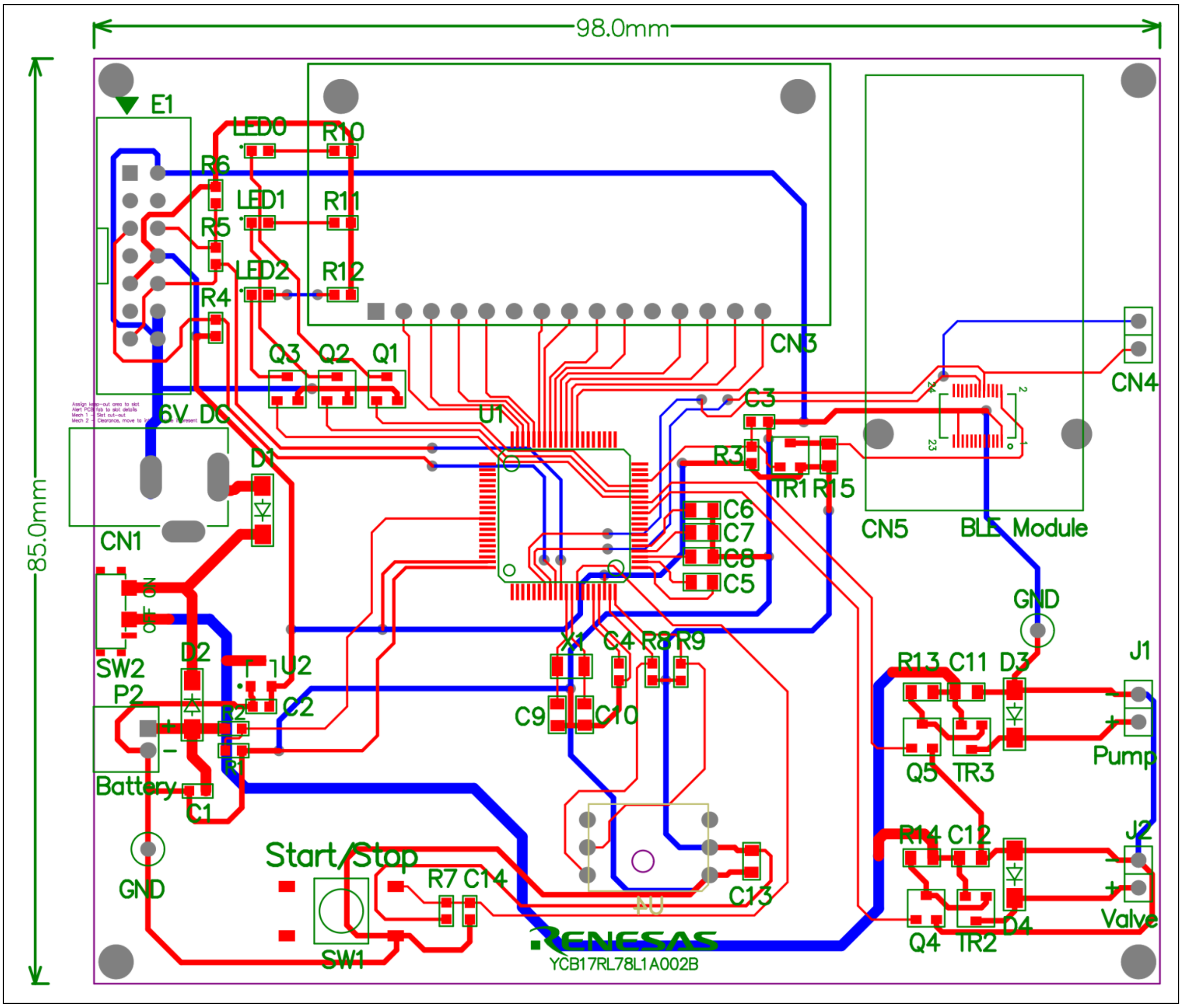

Figure 3.3 The PCB

3.3 Bill of Materials

The bill of the materials of the smart blood pressure monitor is shown in Table 3.1.

Table 3.1 The Bill of the Materials

Designator	Quantity	Part Name	Manufacturer	Description
C1, C2, C3*, C4, C14	5	GRM188R61C105KA12D	Murata	Capacitor (1uF,16V, ±10%, 0603)
C5	1	GRM216C81C105KA12	Murata	Capacitor (1uF,16V, ±10%, 0805)
C6, C7, C8	3	GRM219R71C474KA01D	Murata	Capacitor (0.47uF,16V, ±20%, 0805)
C9, C10	2	GRM21A5C2E220JW01D	Murata	Capacitor (22pF,250V, ±5%, 0805)
C11, C12, C13	3	GRM21BR71H104KA01L	Murata	Capacitor (0.1uF,50V, ±10%, 0805)
CN1	1	MJ-180PH	MULTICOMP	Power supply connector(5.5x2.1mm)
CN3	1	−	−	LCD 4 COM x 8 SEG
CN4	1	146850	TE Connectivity	Header 2x1, 2-Pin, 2.54mm
CN5	1	24 5602 024 000 829H+	KYOCERA	RL78/G1D BLE Module Socket
D1, D2, D3, D4	4	SS14	ON Semiconductor	Schottky Rectifier (DO-214AC)
E1	1	2514-6002UB	3M Limited	Header 7x2, 14-Pin, 2.54mm
J1, J2	2	146850	TE Connectivity	Header 2x1,2-Pin, 2.54mm
LED0	1	XZMDK53W-1	SunLED	LED (Red, 0603, SMD)
LED1	1	XZMYK53W-1	SunLED	LED (Yellow, 0603, SMD)
LED2	1	XZCBD53W-1	SunLED	LED (Blue, 0603, SMD)
P2	1	440055-2	TE Connectivity	Header, 2-Pin, 2mm
Q1, Q2, Q3, Q4, Q5	5	DTC114YUAFRA	ROHM	NPN transistor (50V, 100mA, SOT-23)
R1, R2	2	ERA3AEB104V	Panasonic	Resistor (100KΩ, ±0.1% 0603)
R3*, R5, R7	3	ERJ3GEYJ103V	Panasonic	Resistor (10KΩ, ±5% 0603)
R4, R6, R10, R11, R12	5	ERJ3GEYJ102V	Panasonic	Resistor (1KΩ, ±5% 0603)
R8, R9	2	ERJ3GEYJ472V	Panasonic	Resistor (4.7KΩ, ±5% 0603)
R13, R14	2	ERJ6GEYJ102V	Panasonic	Resistor (1KΩ, ±5% 0805)
R15	1	ERJ6GEY0R00V	Panasonic	Resistor (0Ω, 0805)
SW1	1	1571563-4	TE Connectivity	Push switch (6x6mm SMD)
SW2	1	MSK-1102	Homyet Parts	Toggle switch
TP1, TP2	2	−	−	Test point (Φ0.9mm)
TR1*	1	SI2301-TP	MCC	P-Channel MOSFET(SOT-23)
TR2, TR3	2	IRLML6402PbF	Infineon	P-Channel MOSFET(SOT-23)
U1	1	R5F11MMF	Renesas	RL78/L1A (LQFP-80)
U2	1	XC6206P332MR	Torex Semiconductor	REG LDO 3.3V 0.15A (SOT23-3)
U4	1	ABPDANN005PG2A3	Honeywell	ABP series pressure sensor
X1	1	ABS07-32.768KHZ-T	ABRACON	32.768KHZ, SMD, 3.2mm x 1.5mm

*: Not mount

4. Introduction of Software

4.1 Integrated Development Environment

The integrated development environments of the smart blood pressure monitor are shown in Table 4.1 and 4.2.

Table 4.1 Integrated Development Environments for CS+

Item	Contents
Integrated development environment	CS+ for CC V5.00.00 (Renesas Electronics Corporation)
C complier	CC-RL V1.04.00 (Renesas Electronics Corporation)
Debugger	E1 (Renesas Electronics Corporation)

Table 4.2 Integrated Development Environments for e2 Studio

Item	Contents
Integrated development environment	e2 studio V5.3.1.002 (Renesas Electronics Corporation)
C complier	CC-RL V1.04.00 (Renesas Electronics Corporation)
Debugger	E1 (Renesas Electronics Corporation)

4.2 List of Option Byte Setting

The option byte setting of the smart blood pressure monitor is shown in Table 4.3.

Table 4.3 Option Byte Setting

Address	Setting	Description
000C0H/010C0H	11101110B	Watchdog timer operation is stopped (count is stopped after reset)
000C1H/010C1H	11111111B	LVD: closed
000C2H/010C2H	11100000B	HOCO: 24 MHz, operation voltage range: 2.7 V~3.6 V
000C3H/010C3H	10000101B	On-chip debugging is enabled.

4.3 Installation Procedure

4.3.1 Write the Firmware onto Host MCU

1. Connect the E1 emulator to the demo board. Then connect the E1 emulator to PC.
2. Supply the power to the demo board.
3. Run RFP (Renesas Flash Programmer V3.02.01) and create a workspace by selecting [File] → [Create New Run], select [RL78] as [Microcontroller] and push [Connect] button.
4. Select 'HostSample.hex' on [Operation] tab → [Program File].
5. Push [Start] button on [Operation] tab to start writing and confirm that [SUCCESS] is displayed.

4.3.2 Write the Firmware onto BLE MCU

1. Connect the E1 emulator to the RL78/G1D evaluation board (RTK0EN0001D01001BZ) and connect the E1 emulator to PC.
2. Supply power to the RL78/G1D evaluation board (RTK0EN0001D01001BZ).
3. Run RFP (Renesas Flash Programmer V3.02.01) and create a workspace by selecting [File] → [Create New Project], select [RL78] as [Microcontroller] and push [Connect] button.
4. Uncheck Erase and P.V checkbox on the [Block Setting] tab → [Code Flash 1] → [Block255] and all blocks of [Data Flash 1].
5. Select 'rBLE_Mdm_CCRL.hex' on [Operation] tab → [Program File].
6. Push [Start] button on [Operation] tab to start writing and confirm that [SUCCESS] is displayed.

Note: The firmware of RL78/G1D is from the BLE protocol stack V1.20, the firmware path:
RL78_G1D\Project_Source\renesas\tools\project\CS_CCRL\BLE_Modem\rBLE_Mdm\DefaultBuild\rBLE_Mdm_CCRL.hex

4.4 Flow Chart

4.4.1 Main Sequence Chart

The main sequence chart is shown in Figure 4.1.

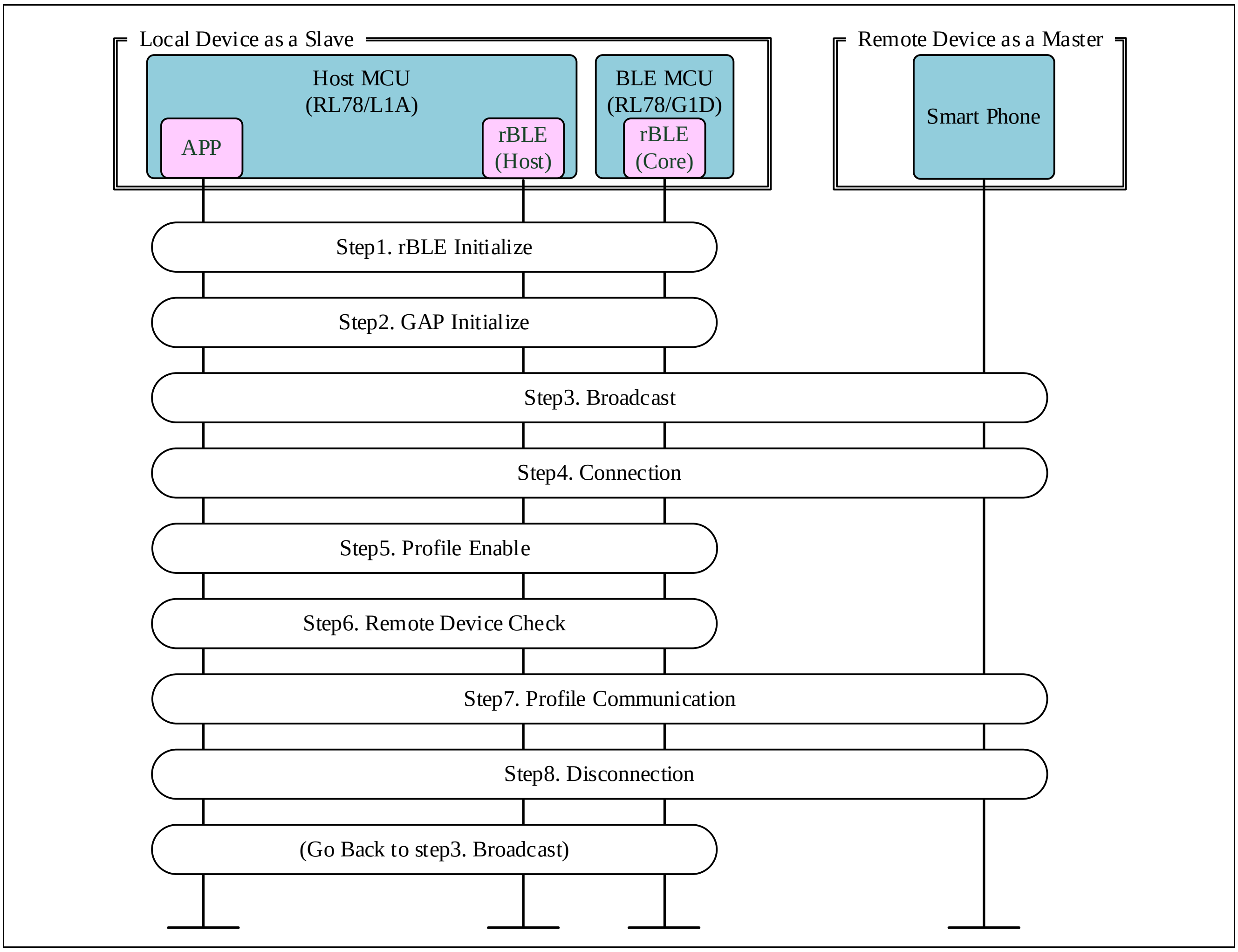

Figure 4.1 The Main Sequence Chart

4.4.2 Flow Chart of the Firmware's Main Program

The flow chart of the firmware's main program is shown in Figure 4.2.

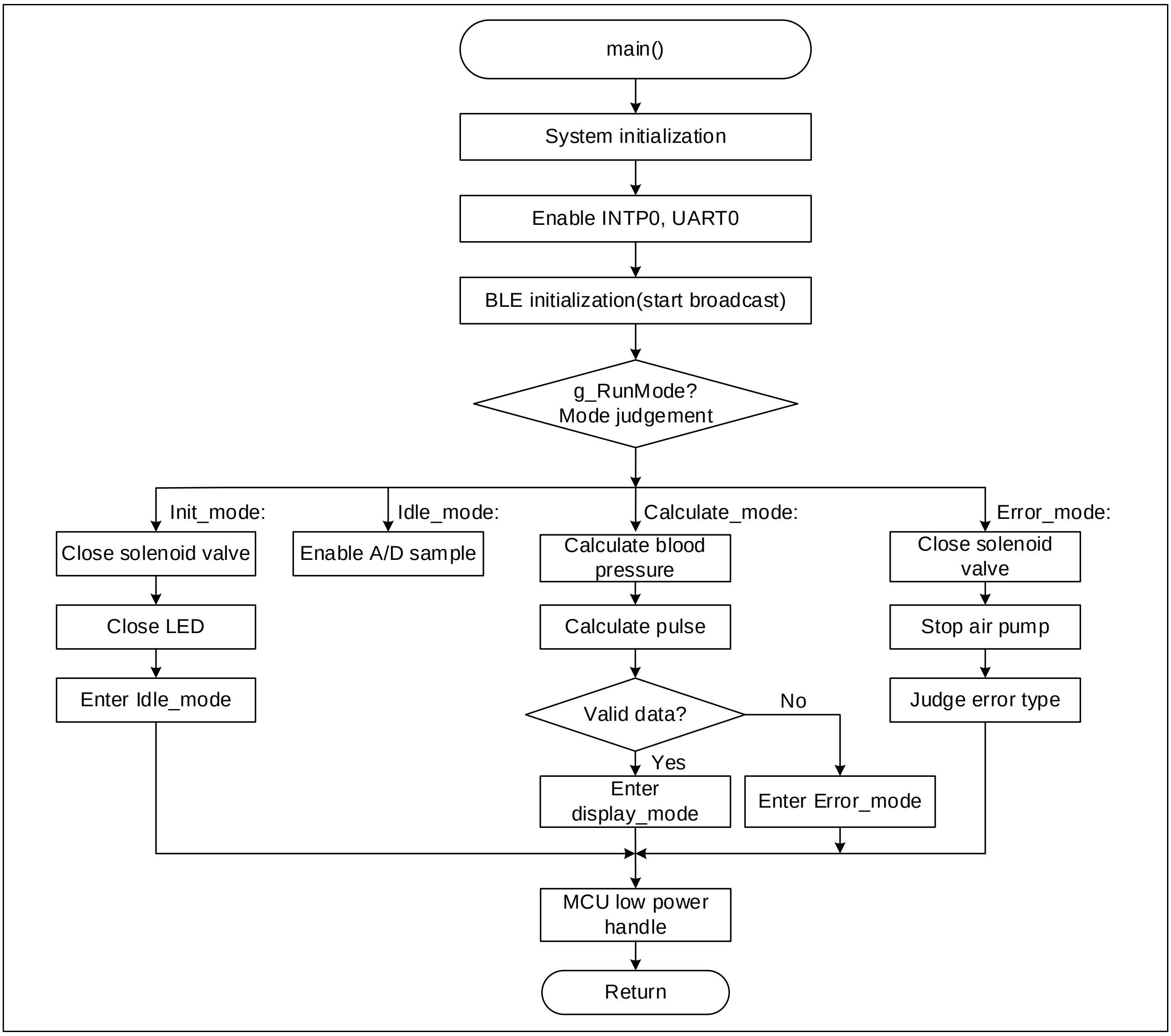

Figure 4.2 The Flow Chart of the Firmware's Main Program

4.4.3 Flow Chart of Smartphone APP

The flow chart of the smartphone APP is shown in Figure 4.3.

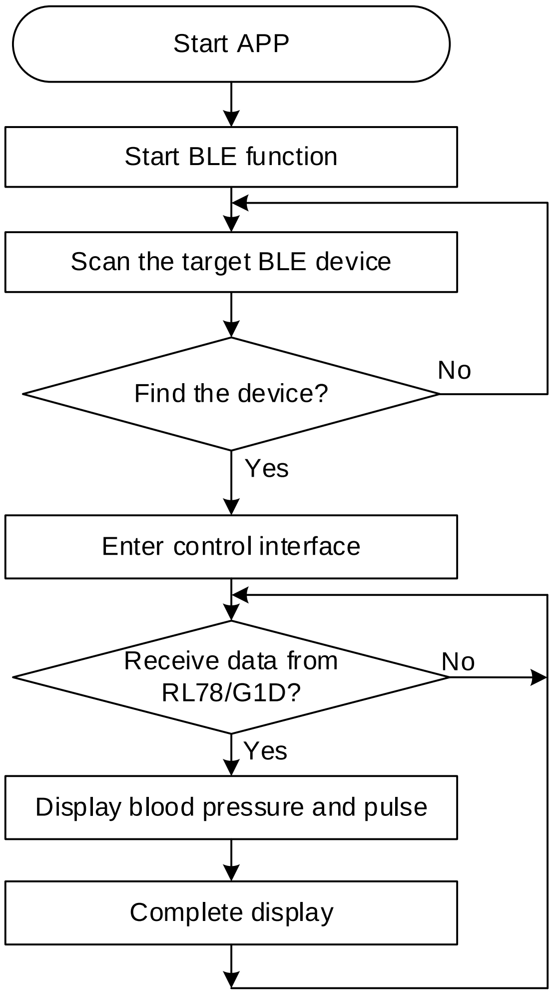

Figure 4.3 The Flow Chart of the Smartphone APP

5. Sample Code

The sample code is available on the Renesas Electronics Website.

6. Reference Documents

User's Manual

RL78 Family User's Manual: Software (R01US0015E)

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

Rev.	Date	Description	
		Page	Summary
1.00	Sep.15.2017	–	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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