RL78/G1N

LED Electronic Safe Box

Introduction

This document describes a method about how to use the RL78/G1N microcontroller in the LED electronic safe box.

Target Device

RL78/G1N

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1. Description

1.1 Abstract

The essential part of the electronics safe box is the electronic cipher lock, which is fixed between the two metal layers of the door. In lock status, the electronic cipher lock works by entering a predetermined code on the keypad, the MCU will send a command to trigger the locking mechanism to open the door if the code is checked as correct by the MCU program. In unlock status, the electric cipher lock works by entering a random code on the keypad, and the code is recorded in EEPROM IC by the MCU program, then the MCU sends a command to trigger the locking mechanism to close the door. There are two sets of code which can be used to open the lock in this system: password and super password. Both of them can be modified. In addition, the buzzer can indicate the key pressing and error operations.

The appearance of the demo example is shown in Figure 1.1, and the photo of the circuit board of electronic safe box is shown in Figure 1.2.

Figure 1.1 Appearance of Electronic Safe Box (example)

Figure 1.2 Photo of Circuit Board of Electronic Safe Box

The RL78/G1N built-in high-current drive ports can directly drive six-digit LED characters (up to 48 LED), making it suitable for any level of LED display and touch button control LED display applications.

This document provides the safe box solution based on Renesas low cost microcontroller RL78/G1N.

1.2 Specifications and Main Technical Parameters

Technical Parameters

Power supply: 4.5 V (1.5V battery x 3)

Low power consumption current (Whole Board) :20 μA (TYP.) at STOP mode

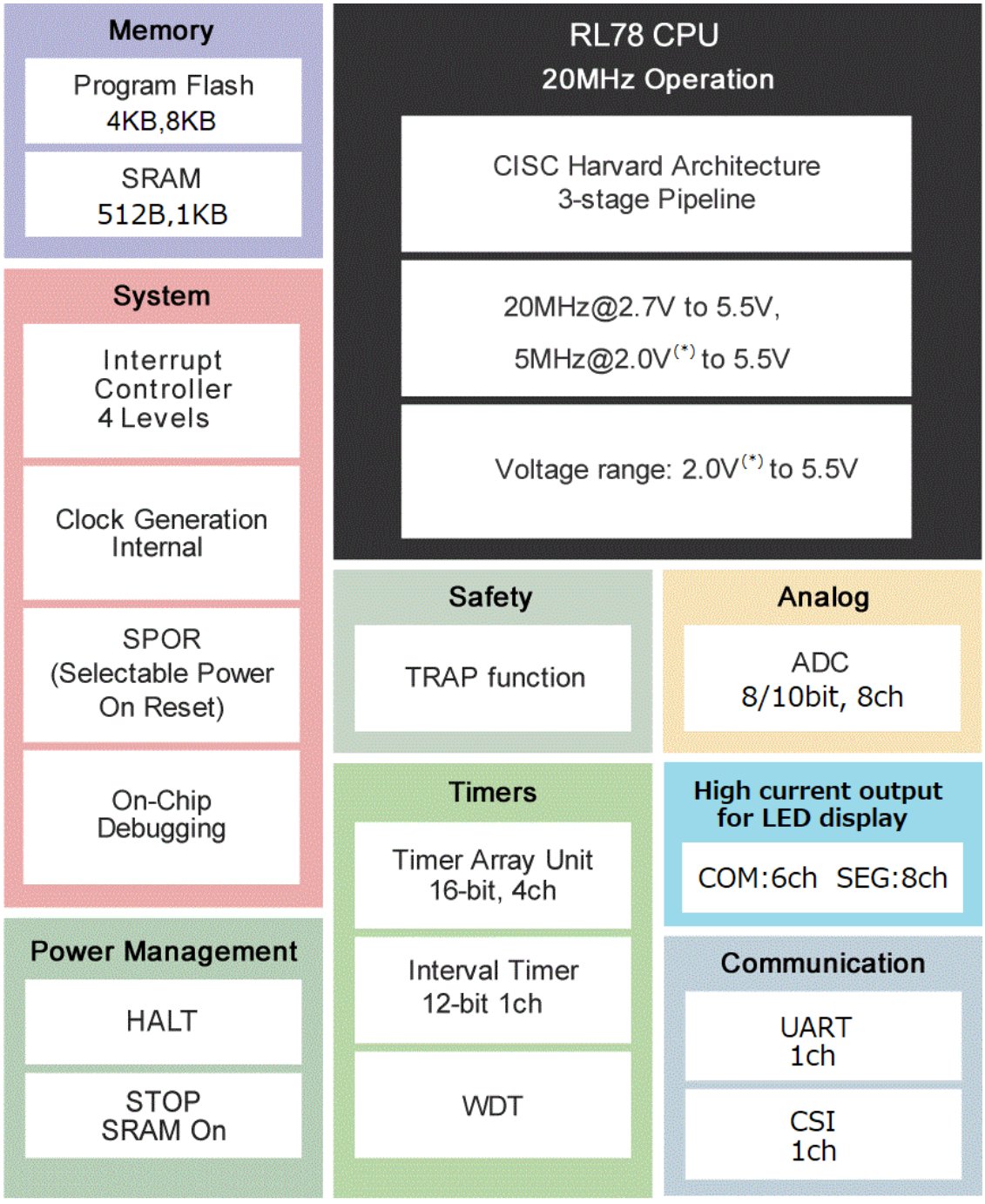
Specifications

Low power consumption function:	After the system is powered on, it operates in low power consumption mode. When an external interrupt (the key is pressed) occurs, the system enters normal operation mode.
LED indication function:	When the system is powered on, the LED will display the software version. If the key is pressed, the LED will turn on and display the digits and the characters.
KEY Matrix:	Users can input and modify the password by Keypad.
Speaker sound:	> 60 dB
Motor:	Low Speed
Operating temperature:	-10°C ~ 60°C
Operating humidity:	5 ~ 99% RH (No condensate water)

2. RL78/G1N Microcontroller

2.1 RL78/G1N Block Diagram

Figure 2.1 shows the block diagram of the RL78/G1N (20-pin products).



* Use this product within the voltage range from 2.25 to 5.5 V because the detection voltage (VSPOR) of the selectable power-on-reset (SPOR) circuit should also be considered.

Figure 2.1 RL78/G1N (20-pin products) Block Diagram

2.2 Key Features

Ultra-low power consumption technology

● VDD = single power supply voltage of 2.0 to 5.5 V

(Use this product within the voltage range from 2.25 to 5.5 V because the detection voltage (VSPOR) of the selectable power-on-reset (SPOR) circuit should also be considered.)

● HALT mode

● STOP mode

RL78 CPU core

● CISC architecture with 3-stage pipeline

● Minimum instruction execution time: Can be changed from high speed (0.05 μs: @ 20 MHz operation with high-speed on-chip oscillator) to low speed (1.0 μs: @ 1 MHz operation)

● Address space: 1 MB

● General-purpose registers: 8-bit register × 8

● On-chip RAM: 512 B to 1 KB

Code flash memory

● Code flash memory: 4 KB to 8 KB

● On-chip debug function

High-speed on-chip oscillator

● Select from 20 MHz, 10 MHz, 5 MHz, 2.5 MHz, and 1.25 MHz

● High accuracy: ±2.0% (VDD = 2.0 to 5.5 V, TA = -20 to +85°C)

Operating ambient temperature

● TA = -40 to +85°C

Power management and reset function

● On-chip selectable power-on-reset (SPOR) circuit

Serial interface

● CSI: 1 channel

● UART: 1 channel

Timer

● 8-/16-bit timer: 4 channels

● 12-bit interval timer: 1 channel

● Watchdog timer: 1 channel (operable with the dedicated low-speed on-chip oscillator)

A/D converter

● 8/10-bit resolution A/D converter (VDD = 2.4 to 5.5 V)

● Analog input: 8 channels

I/O port

● I/O port: 18 (N-ch open drain output [VDD withstand voltage]: 14)

(P-ch open drain output [VDD withstand voltage]: 6)

● High current pin

● Can be set to N-ch open drain and on-chip pull-up resistor

● On-chip key interrupt function

● On-chip clock output/buzzer output controller

Others

● On-chip BCD (binary-coded decimal) correction circuit

The RL78/G1N is widely used in common technologies for industry, office, home appliance, healthcare, security, city and detectors application.

2.3 Pin Configuration

Figure 2.2 shows the pin configuration of the RL78/G1N (20-pin products).

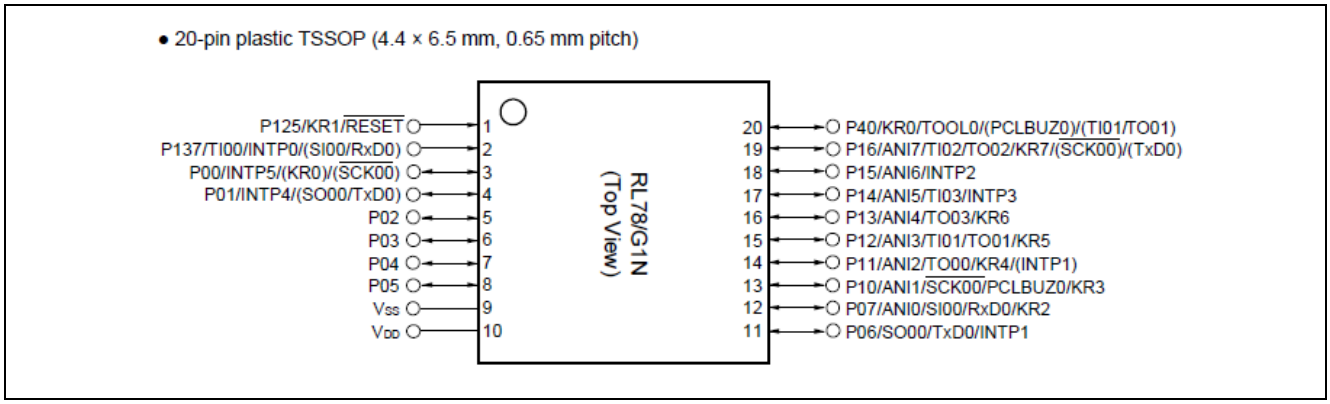


Figure 2.2 RL78/G1N (20-pin Products) Pin Configuration

3. Outline of System Function

3.1 Introduce the System of Electronic Safe Box

The main tasks of the electronic safe box described in this document include keypad control, LED display control, locking mechanism control and buzzer control. The principle of locking mechanism is moving the door latch from the left to right (the direction of locking) or from the right to left (the direction of unlocking) through the DC motor rotating. That means controlling the lock mechanism is equivalent to controlling the DC motor. There are two aspects in DC motor control, one is controlling the motor to start or stop rotating and the other is monitoring the load current of motor in case of overcurrent.

The system block diagram of electronic safe box is shown in Figure 3.1.

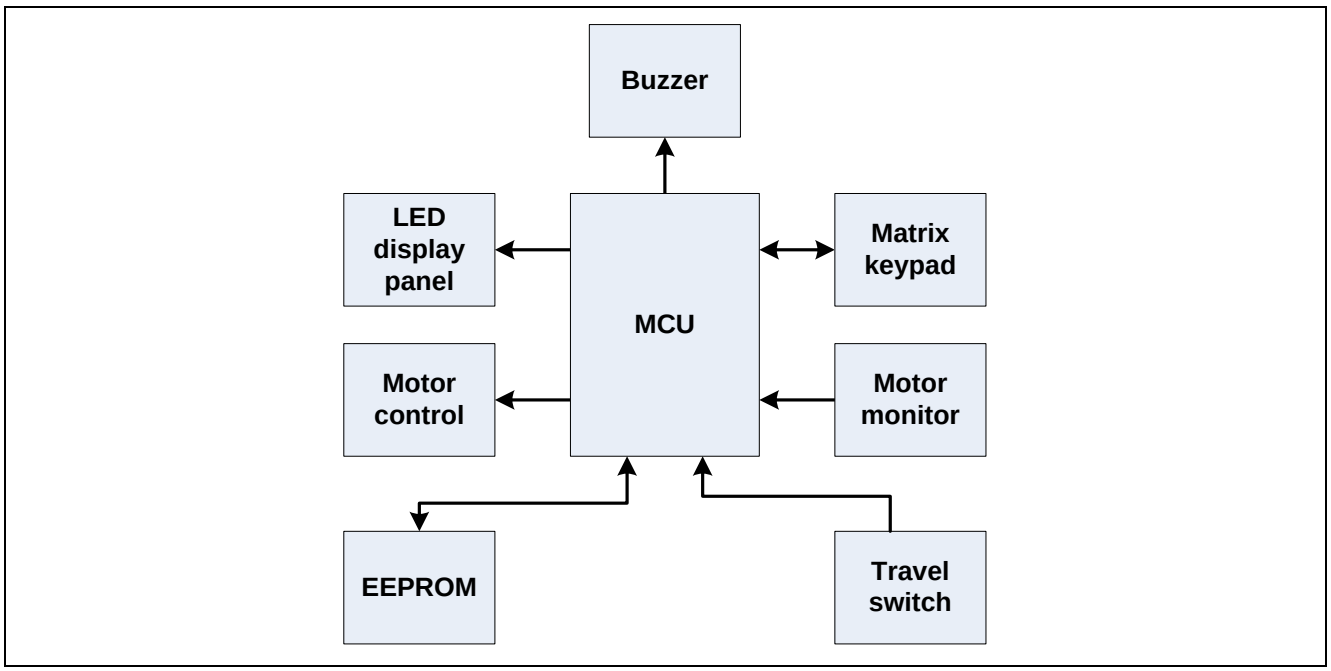


Figure 3.1 System Block Diagram of Electronic Safe Box

3.2 Description of Operation

3.2.1 Operation of Closing the Door

In the door opened status, enter any 6 digits numbers then press the [Lock] key, we will hear one beep tone and the motor starts rotating (the door latch will be moved in the locking direction through the rotating motor), at the same time, LED display panel displays the characters of string of "CLOSE-" one by one from left to right on the screen. When the door latch is moved to the end (lock is closed completely), the motor will be stopped and the string of "CLOSED" will be displayed for 2 seconds.

After entering 6 digits code, if we press any key except for [Lock] key, we will hear five beep tones which is the error prompt tone, the string of "Error-" will be displayed for 2 seconds and the door will not be closed.

The photo of a successful door-closing case is shown in Figure 3.2.

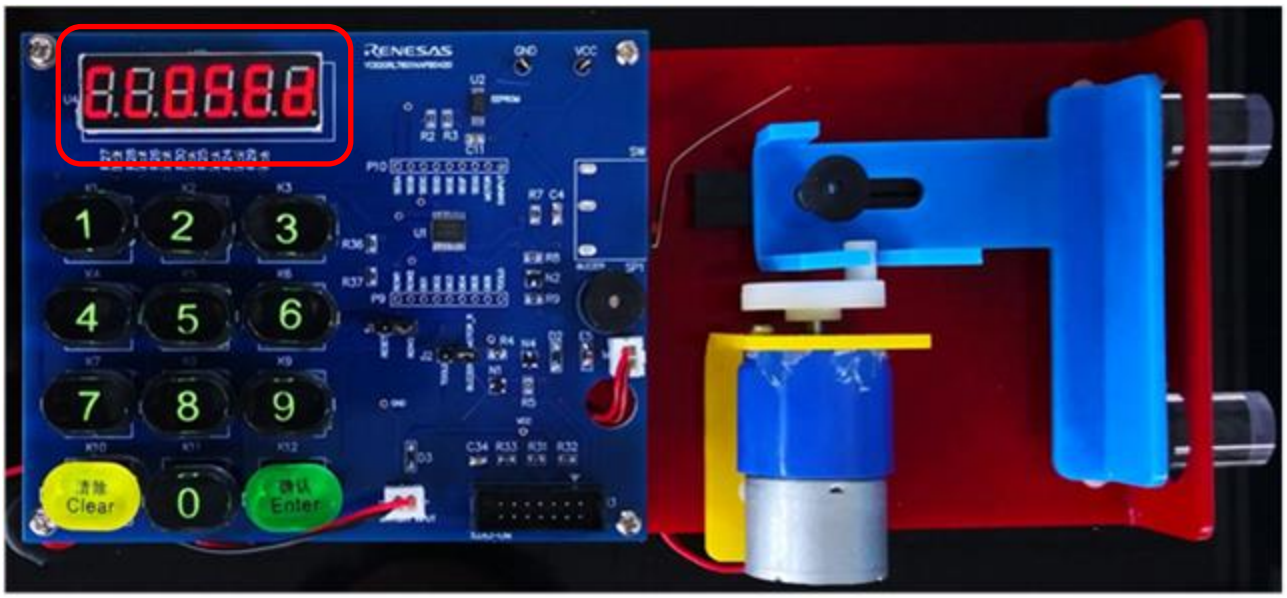


Figure 3.2 Photo of a Successful Door-closing Case

3.2.2 Operation of Opening the Door

In the door closed status, enter the password (the code setting to lock the door) or super password, if the password is correct, one beep tone will be heard and the motor starts rotating (the door latch will be moved in the unlocking direction through the rotating motor), at the same time, LED display panel displays the characters of the string of "-OPEN-" one by one from left to right on the screen. When the door latch moves to the end (lock is opened completely), the travel switch will be closed with one beep tone. The motor will be stopped immediately and the string of "OPENED" will be displayed for 2 seconds.

The photo of a successful door-opening case is shown in Figure 3.3.

Figure 3.3 Photo of a Successful Door-opening Case

In case of incorrect code, five beep tones sound after the 6th number is entered, the string of "Error-" will be displayed for 2 seconds on the screen and the door remains closed. The electronic safe box will enter hold mode after inputting incorrect code 5 times continuously. The string of "HOLD15" will be displayed for 15 seconds on the screen. In the hold mode, normal operation is prohibited. The string of "HOLD" will be displayed for 2 seconds if any key is pressed. The safe box will exit the hold mode automatically after 15 minutes.

The photo of entering the hold mode is shown in Figure 3.4.

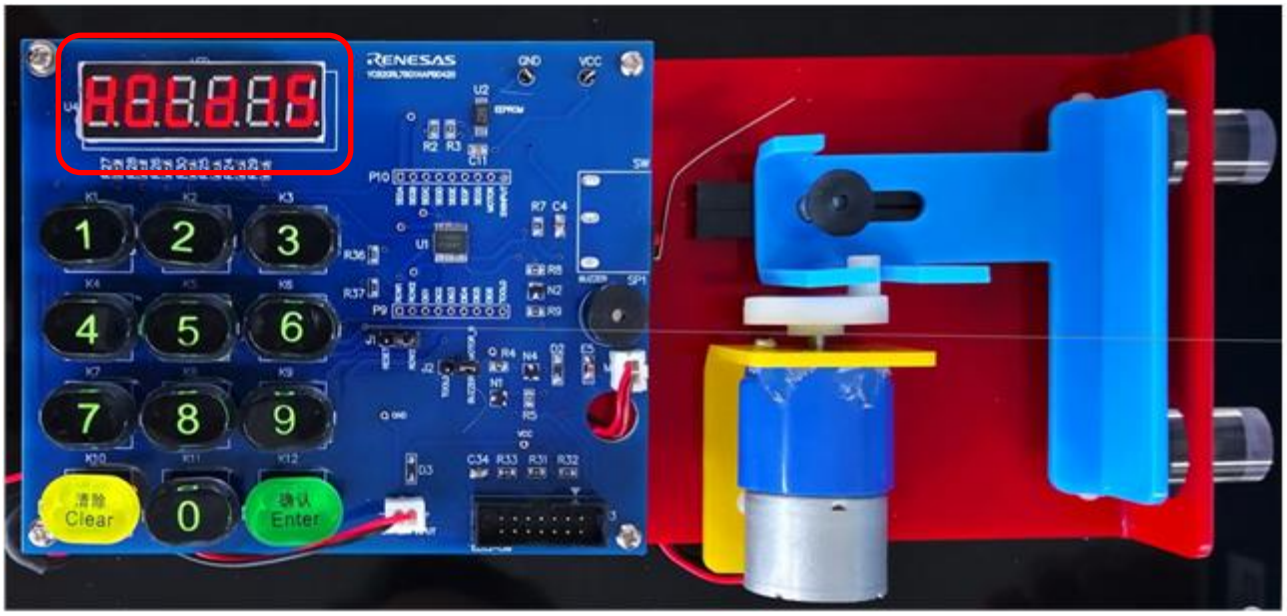


Figure 3.4 Photo of Entering the Hold Mode

3.2.3 Operation of Password Modification

Password is a group of 6 digits numbers entered to lock the door successfully. In the door opened status, enter any 6 digits numbers then press the [Lock] key, the new password will be saved in EEPROM if it is different from the previous password. The new password can be used to open the door. This process is called password modification.

3.2.4 Operation of Super Password Modification

The super password has the higher permission. It can be used to open the door also. In the door opened status, the safe box will enter the password modification mode when pressing the [Clear] key twice continuously, the string of "PROG" will be displayed for 2 seconds. When the characters disappear, please enter the super password within 15 seconds. If the input numbers are the correct super password, the string of "NEW" will be displayed for 2 seconds. When the characters disappear, please enter the 6 digits numbers of new super password within 15 seconds. The string of "AGAIN" will be displayed for 2 seconds after input the 6th number. When the characters disappear, please enter the new super password again within 15 seconds, if the twice inputs are the same, the new super password will be saved in the EEPROM and the string of "DONE" will be displayed for 2 seconds, it means the super password modification is successful.

The operation illustration of super password modification is shown in Figure 3.5.

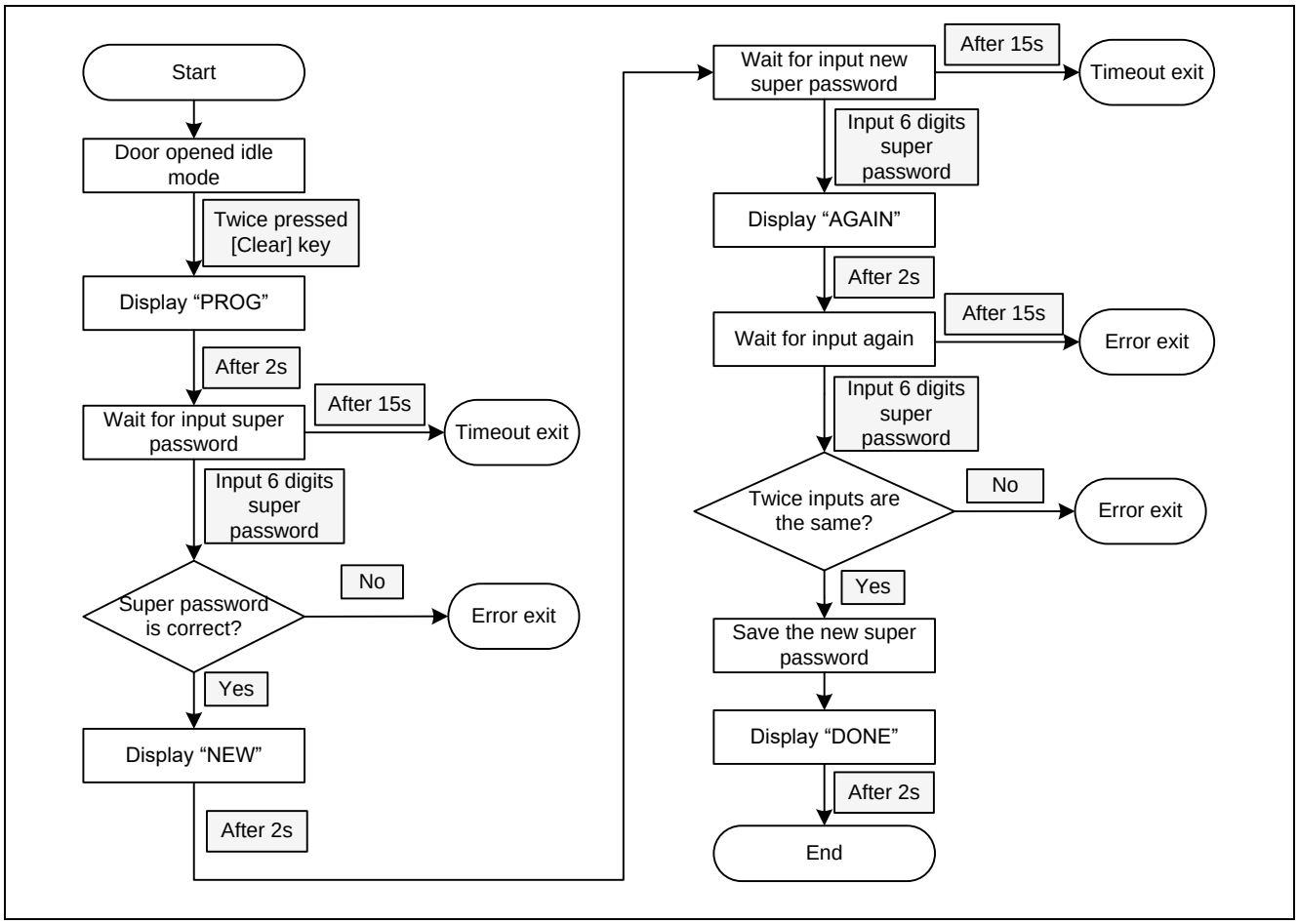


Figure 3.5 Operation Illustration of Super Password Modification

3.2.5 Specification of Error Messages

There are 4 kinds of error messages in the electronic safe box operation. The error messages and their reasons are shown in Table 3.1.

Table 3.1 Error Messages and Their Reasons

Error message contents	Reasons
Error-	Entered the incorrect password or pressed the error key.
Error1	The door latch is jammed or the travel switch is in trouble.
Error2	The door latch is blocked (the door is half-open).
Error3	EEPROM IC is in trouble.

4. Introduction of Hardware

4.1 Introduction of PCB Board

The PCB board is composed of the MCU and control circuit, keypad, LED display panel and programming interface.

The view of the PCB board of electronic safe box is shown in Figure 4.1.

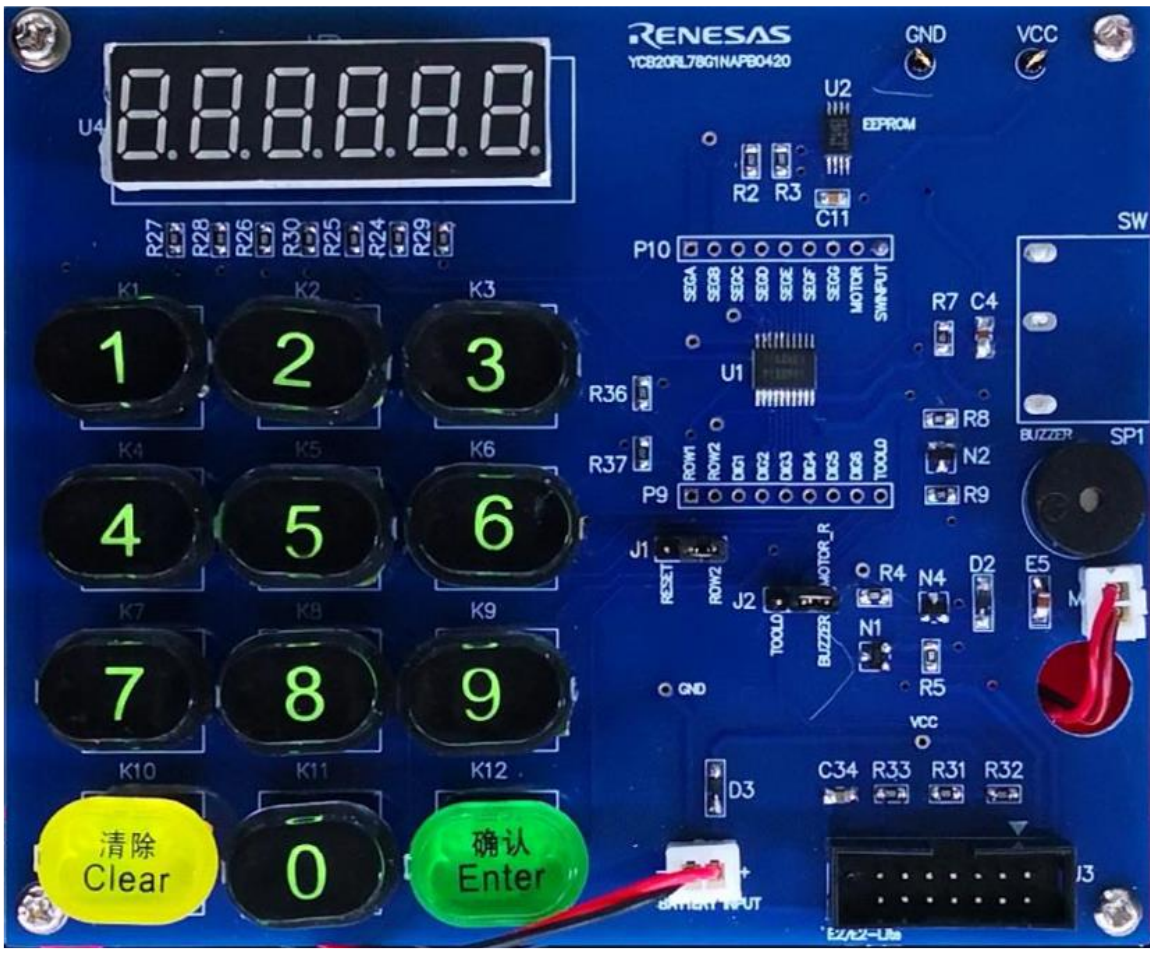


Figure 4.1 View of Main Board of Electronic Safe Box

4.2 Hardware Block Diagram

The electronic safe box consists of keypad control circuit, LED display panel control circuit, buzzer control circuit, motor control and monitor circuit, travel switch circuit, EEPROM interface circuit and main MCU.

The hardware block diagram of electronic safe box is shown in Figure 4.2.

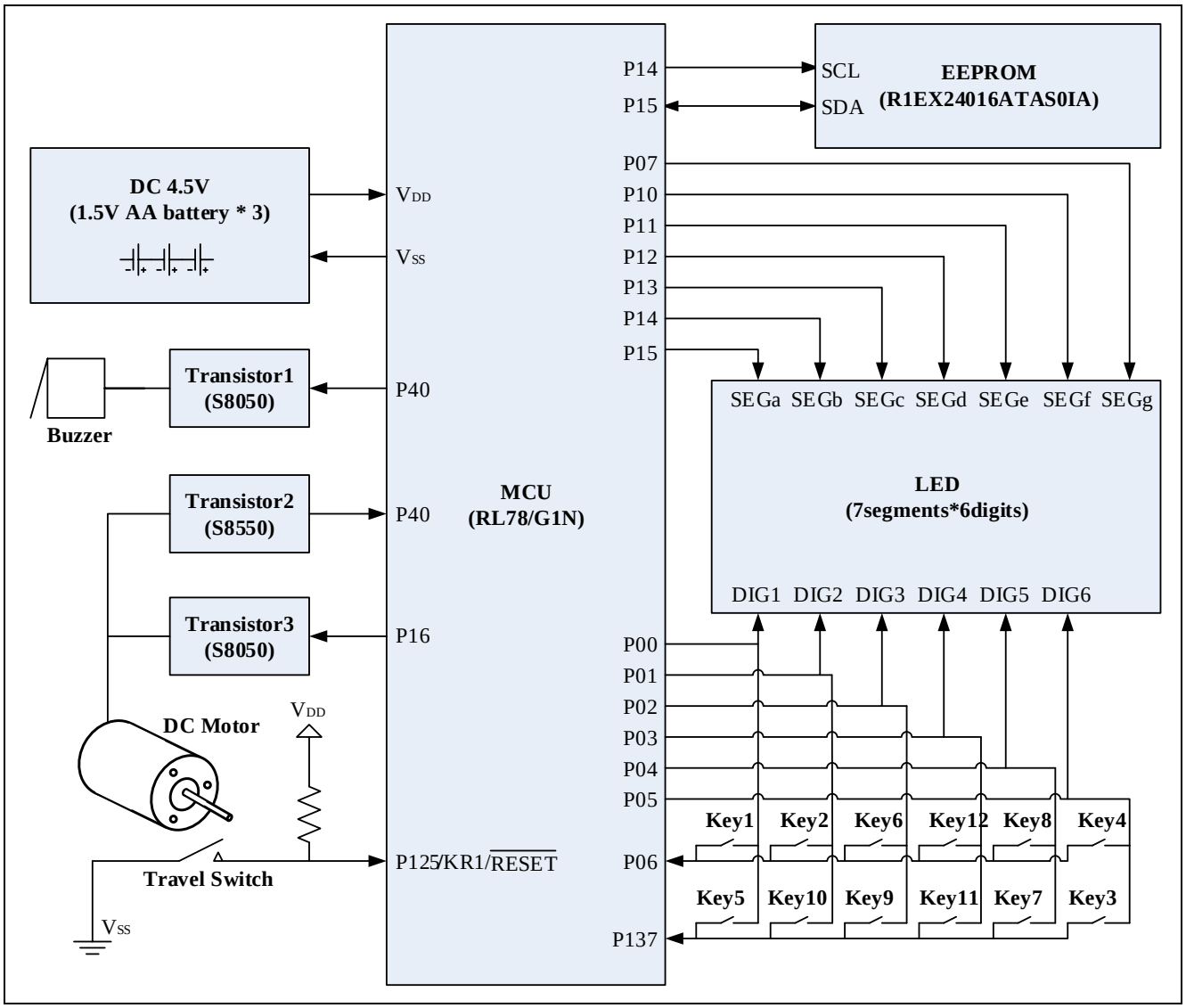


Figure 4.2 Hardware Block Diagram

Note: P40 is reused as buzzer control port and motor control port; P14 is reused as "SEGb" port and clock port of IIC bus; P15 is reused as "SEGa" port and data port of IIC bus; Reset/P12 pin is used as port function.

4.3 Main MCU

Electronic safe box uses RL78/G1N as its main MCU. The Flash ROM size of RL78/G1N is 8KB and the RAM size is 1KB.

The peripheral functions of RL78/G1N and their applications are shown in Table 4.1.

Table 4.1 Peripheral Functions and Their Applications

Peripheral functions	Usage
Channel 0 of TAU0	The interval timer of key and LED scan; The interval timer of main loop.
Channel 1 of TAU0	Interval timer is used to start reading the value of key.
12-bit interval timer	The counter is used to count the mode timeout period.
P125/KR1	Input pin of travel switch.
P40	Output pin of buzzer and input pin of motor monitor circuit.
P00	COM_1 output and key scan output pin.
P01	COM_2 output and key scan output pin.
P02	COM_3 output and key scan output pin.
P03	COM_4 output and key scan output pin.
P04	COM_5 output and key scan output pin.
P05	COM_6 output and key scan output pin.
P15	SEGa output pin and data port of EEPROM IC.
P14	SEGb output pin and clock port of EEPROM IC.
P13	SEGc output pin.
P12	SEGd output pin.
P11	SEGe output pin.
P10	SEGf output pin.
P07	SEGg output pin.
P06/INTP1	Key scan input pin.
P137/INTP0	Key scan input pin.

4.4 Matrix Keypad Control Circuit

Electronic safe box uses a 2 x 6 matrix keypad. The keypad has 12 keys including 10 number keys ([0] ~ [9]) and 2 function keys ([Lock] and [Clear]).

The matrix keypad control circuit is shown in Figure 4.3.

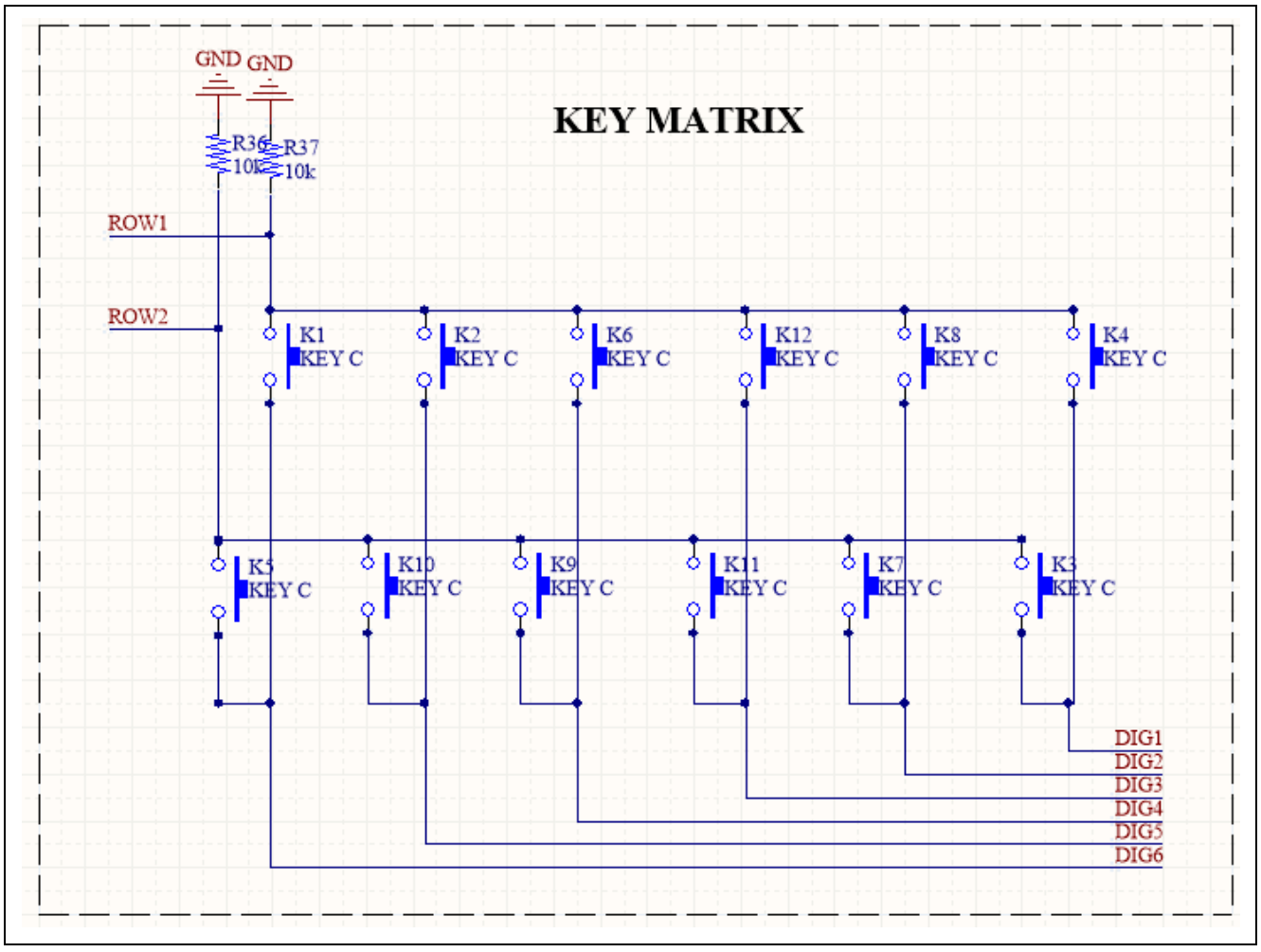


Figure 4.3 Matrix Keypad Control Circuit

4.5 LED Display Panel Control Circuit

RL78/G1N microcontroller has 6 ports (P-ch open-drain) to control the LED digits (COM pins), and 8 ports (N-ch open-drain) to control the LED segments (SEG pins). The highest of the out current of COM pin can reach 120mA when the pin is in the output mode of P-ch open-drain. So the external drive circuit is no need.

In this demo, 6 COM pins and 7 SEG pins are used. The LED display panel control circuit is shown in Figure 4.4.

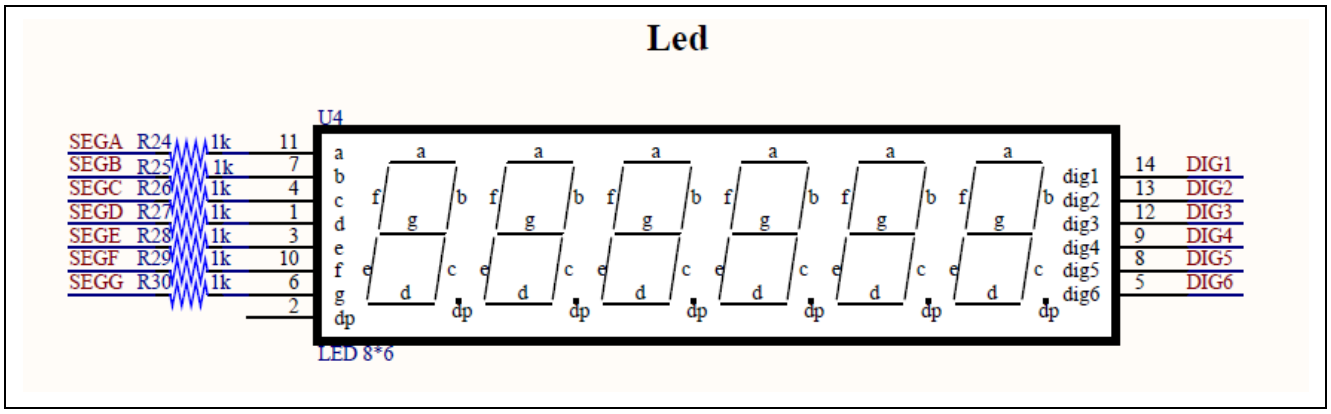


Figure 4.4 LED Display Panel Control Circuit

4.6 Buzzer Control Circuit

The operation of electronic safe box needs the key pressed feedback tone and the error prompt tone which are generated by buzzer control circuit.

The buzzer control circuit is shown in Figure 4.5.

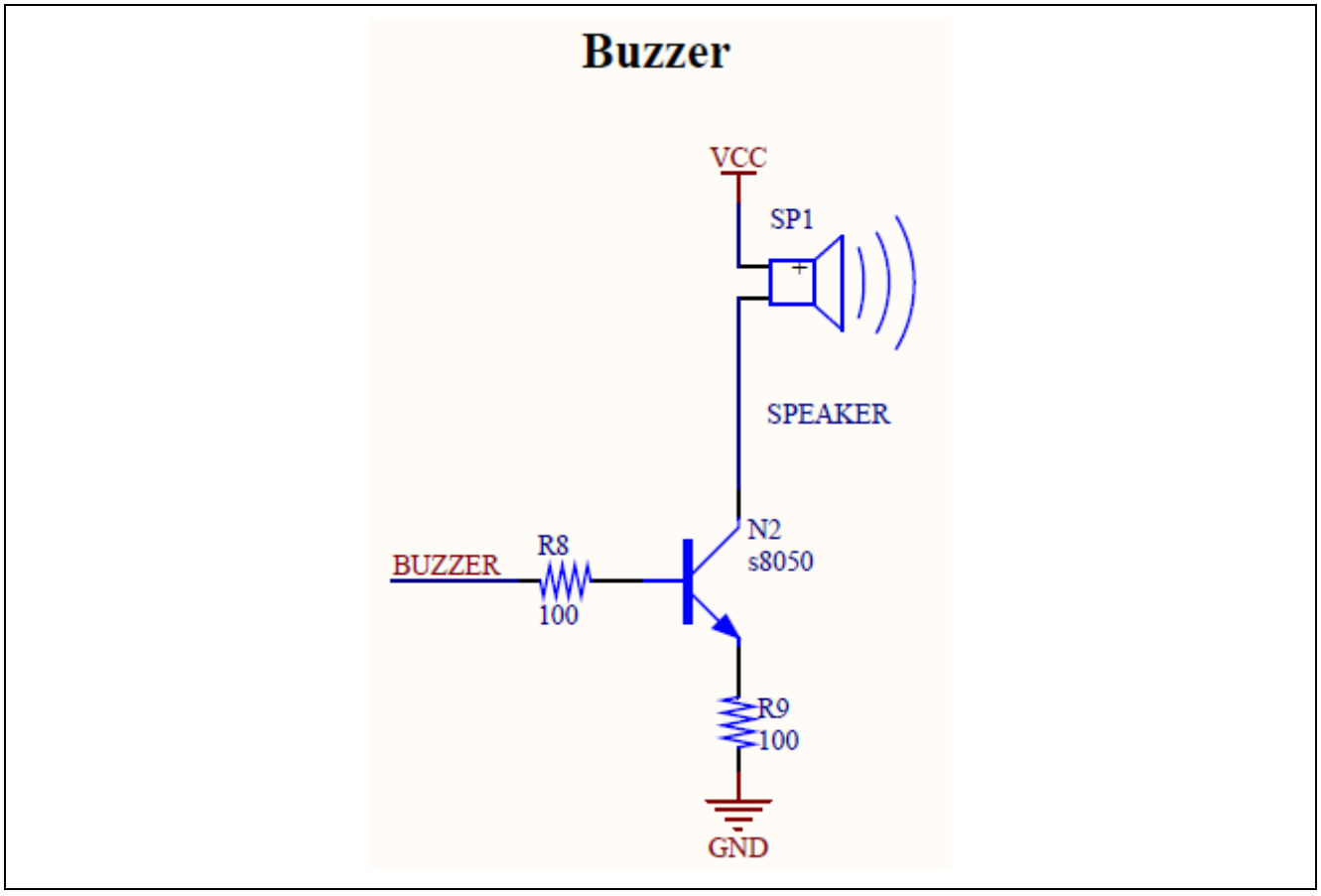


Figure 4.5 Buzzer Control Circuit

4.7 DC Motor Monitor and Control Circuit

The door latch of electronic safe box is moved by motor rotation. A I/O port is needed to monitor the load current of motor if the door latch is jammed or blocked (If the door latch is jammed or blocked, the motor will be jammed, then the load current of motor will become very high).

The DC monitor and control circuit is shown in Figure 4.6.

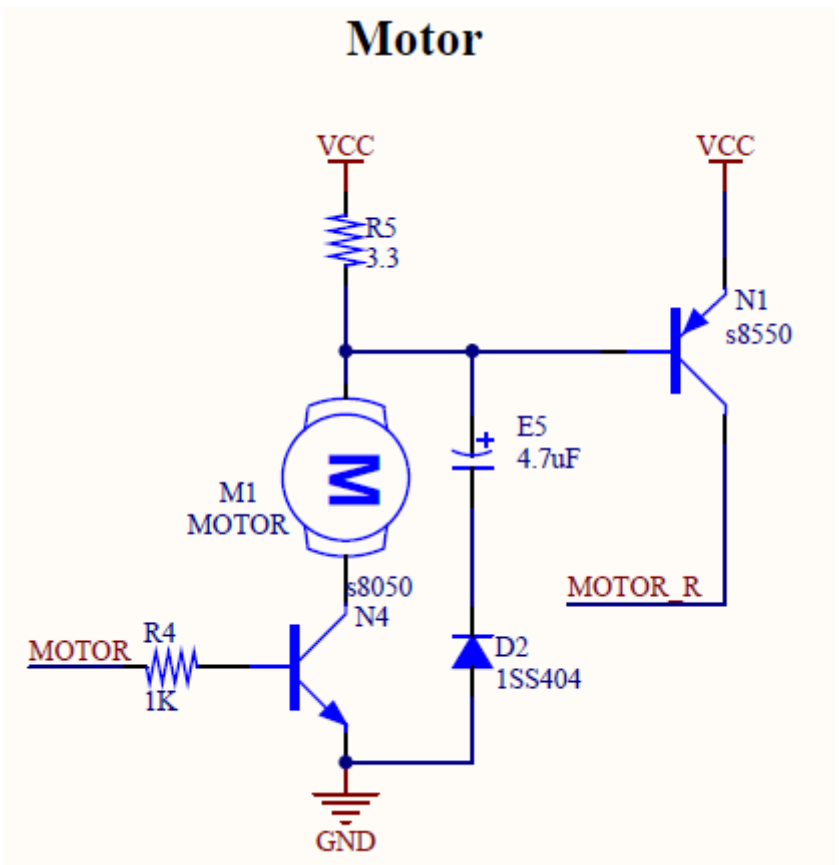


Figure 4.6 DC Monitor and Control Circuit

The electronic safe box uses this circuit to detect the state of MOTOR_R port to judge the state of motor:

- If the MOTOR_R port is the low level, the motor works normally.
- If the MOTOR_R port is the high level, the load current out of range, that means motor is in trouble (such as motor is jammed), in this condition, the motor should be stopped immediately.

Electronic safe box uses this circuit to control the state of MOTOR port to start or stop the motor:

- If the MOTOR port is set to the low level, the motor will stop rotating.
- If the MOTOR port is set to the high level, the motor will start rotating.

4.8 Travel Switch Control Circuit

In the door opening mode, the door latch will be moved in the direction of opening the lock. There is a travel switch at the end of the path of opening lock direction. When the lock is opened completely, the travel switch will turn on. Electronic safe box uses this circuit to detect the position of the door latch, when the door latch has arrived at the end point, the motor will be stopped immediately.

The travel switch control circuit is shown in Figure 4.7.

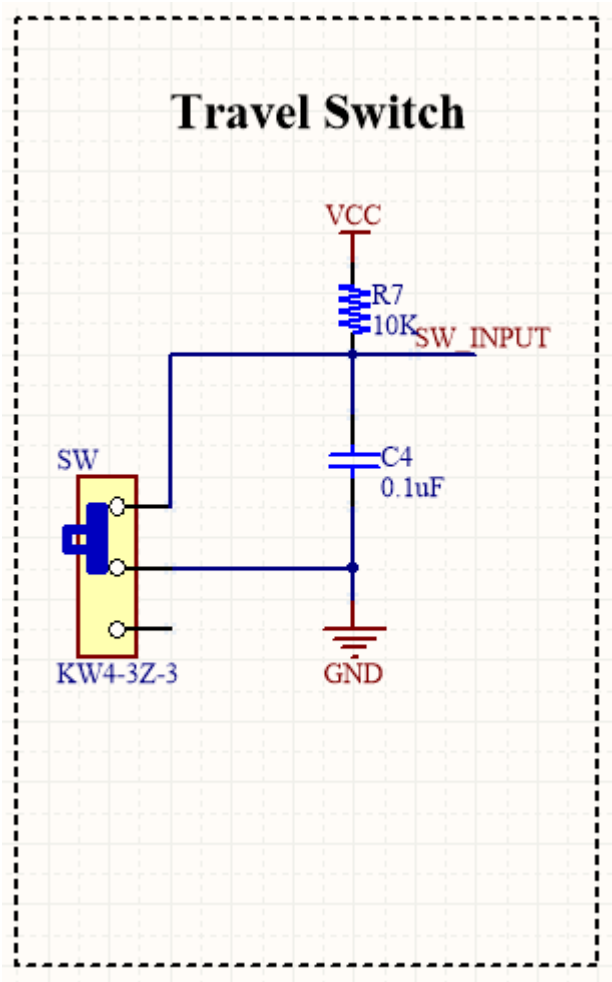


Figure 4.7 Travel Switch Control Circuit

4.9 EEPROM Interface Circuit

The electronic safe box needs a storage device to save the password and super password. In this demo we use the R1EX24016ATAS0I which is the IIC interface EEPROM IC.

The EEPORM interface circuit is shown in Figure 4.8.

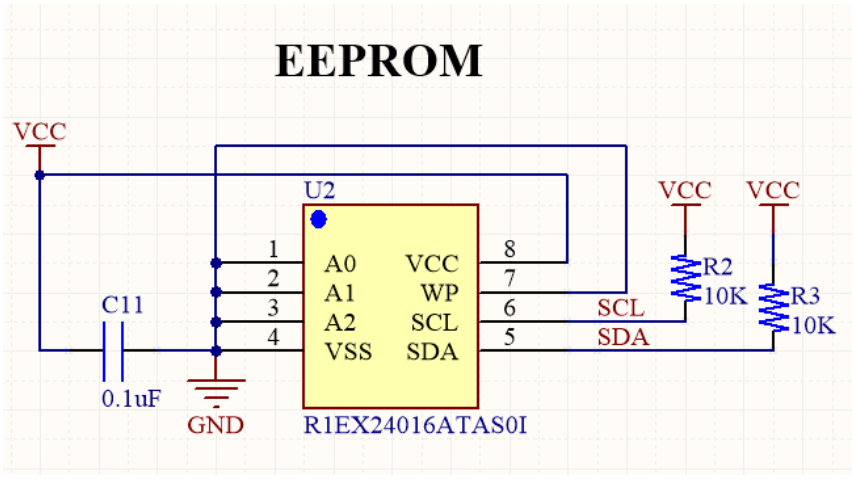


Figure 4.8 EEPROM Interface Circuit

4.10 External DC 4.5V Power

The electronic safe box uses the battery group as power supply. The battery box is composed of 3 AA size batteries, the batteries are connected in series and the output voltage is 4.5V.

4.11 Schematic

The schematic of the main board is shown in Figure 4.9.

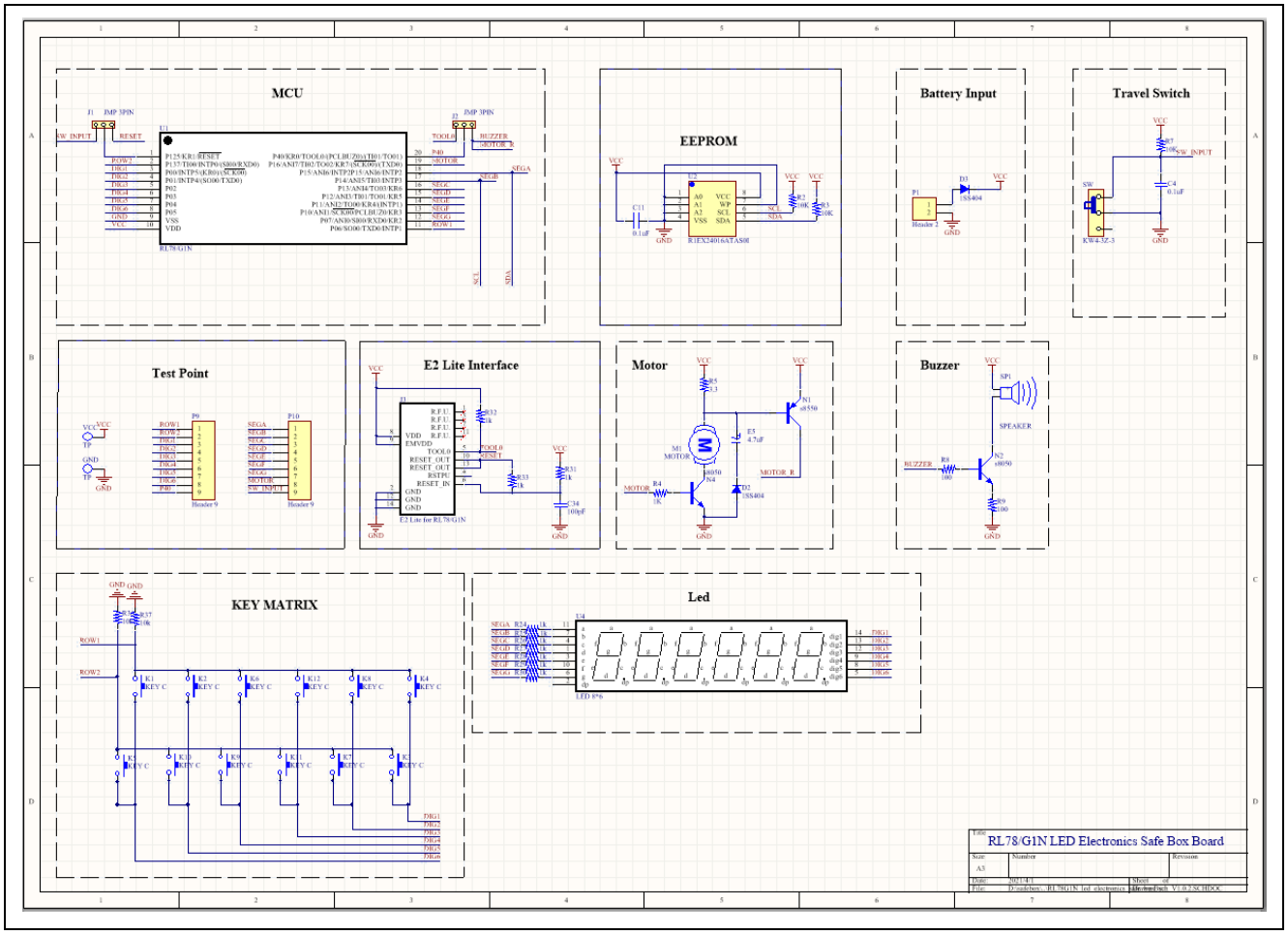


Figure 4.9 Schematic of PCB Board

4.12 PCB

The PCB of the main board is shown in Figure 4.10.

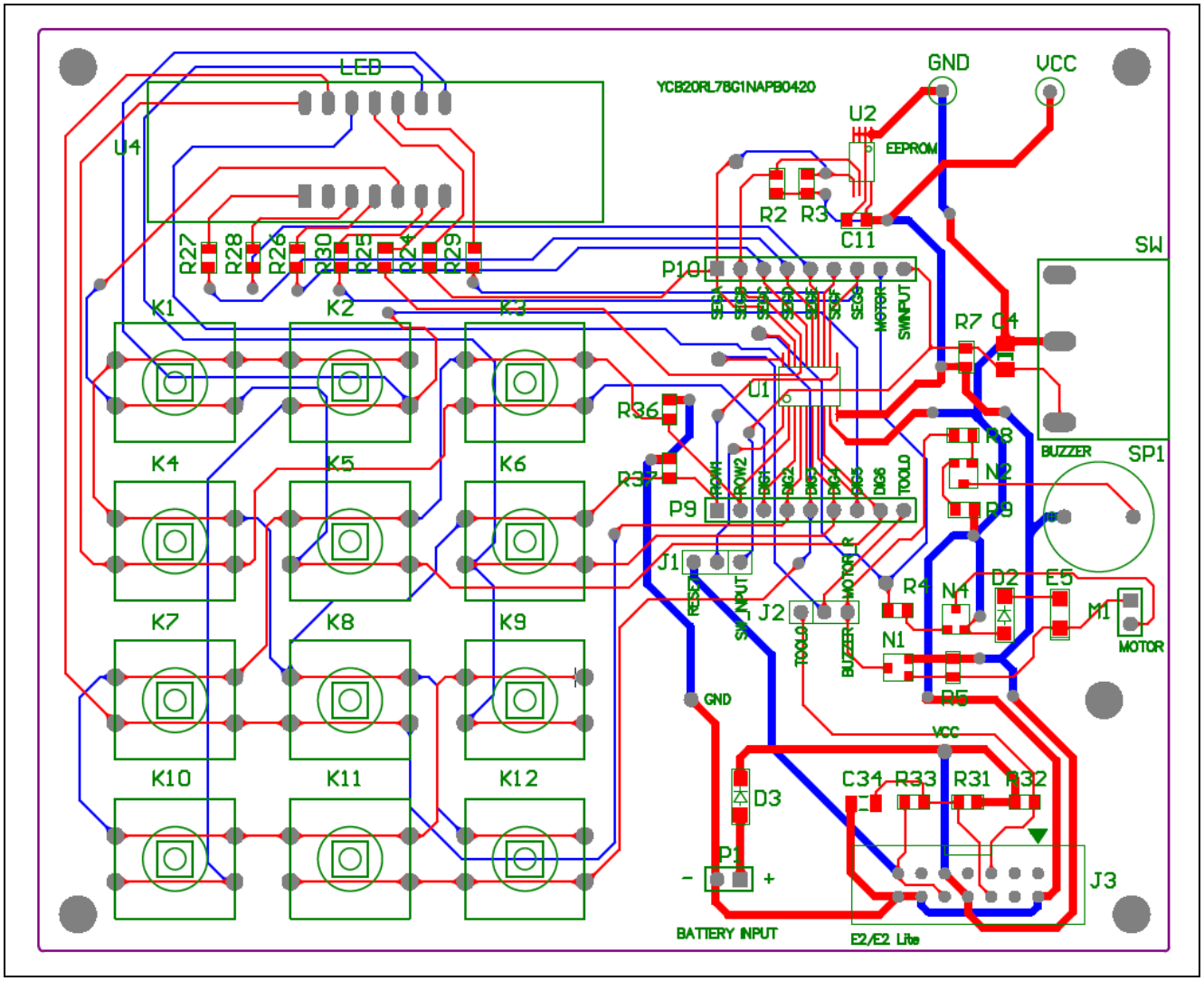


Figure 4.10 PCB of the Board

4.13 BOM List

Table 4.2 and Table 4.3 list the bill of materials of electronic safe box.

Table 4.2 BOM List of the Board

Descriptor	Comment	Package	Number
0.1uF	C4, C34	C1206	2
0.1uF	C11	0805	1
1SS404	D2, D3	D1N	2
4.7uF	E5	ELEC A	1
JMP 3PIN	J1, J2	JMP-3 A	2
MOTOR	M1	HDR1X2	1
s8550	N1	SOT-23-3	1
s8550	N2, N4	SOT-23-3	2
Header 2	P1	HDR1X2	1
10K	R2, R3, R7, R36, R37	0805	5
1K	R4, R24, R25, R26, R27, R28, R29, R30, R31, R32, R33	0805	11
3.3	R5	0805	1
100	R8, R9	0805	2
SPEAKER	SP1	BUZZER A	1
KW4-3Z-3	SW	KW4-3Z-3E	1
RL78/G1N	U1	TSSOP-20	1
R1EX24016ATAS0I	U2	TSSOP-8	1
TP	GND, VCC	TP A	2
E2 Lite for RL78/G1N	J3	IDC-14 DIP A (2.54)	1
KEY C	K1, K2, K3, K4, K5, K6, K7, K8, K9, K10, K11, K12	KEY DIP [12 X 12]	12
Header 9	P9, P10	HDR1X9	2
LED 8*6	U4	LG3661BH	1

5. Introduction of Software

5.1 Integrated Development Environment and Option Byte Settings

The integrated development environment of electronic safe box is shown in Table 5.1.

Table 5.1 Integrated Development Environment

Item	Contents
Microcontroller used	RL78/G1N
Operating Frequency	High-speed on-chip oscillator (20MHz)
Operating Voltage	4.5V (Use this product within the voltage range from 2.25 to 5.5 V because the detection voltage (VSPOR) of the selectable power-on-reset (SPOR) circuit should also be considered.)
Integrated development environment	CS+ for CC V8.04.00 (Renesas Electronics Corporation)
C complier	CCRL V1.09.00 (Renesas Electronics Corporation)
Integrated development environment	E2 studio v20.7.0.R20200710-0958 (Renesas Electronics Corporation)
C complier	CCRL V1.09.00 (Renesas Electronics Corporation)

The option byte setting of electronic safe box is shown in Table 3.2.

Table 5.2 Option Byte Setting

Address	Setting	Description
000C0H	11100000B	Watchdog timer operation is disabled. (Count is stopped after reset)
000C1H	11101011B	SPOR detection voltage: rising edge 2.57V(typ.), falling edge 2.40V(min.) P125/KR1/$\overline{\text{RESET}}$ pin: port function
000C2H	11111001B	HOCO: 20MHz Operation voltage range: 2.7V~5.5V
000C3H	00000101B	On-chip debugging is disabled.

5.2 Flow Chart of Main Program

The flow chart of main program is shown in Figure 5.1.

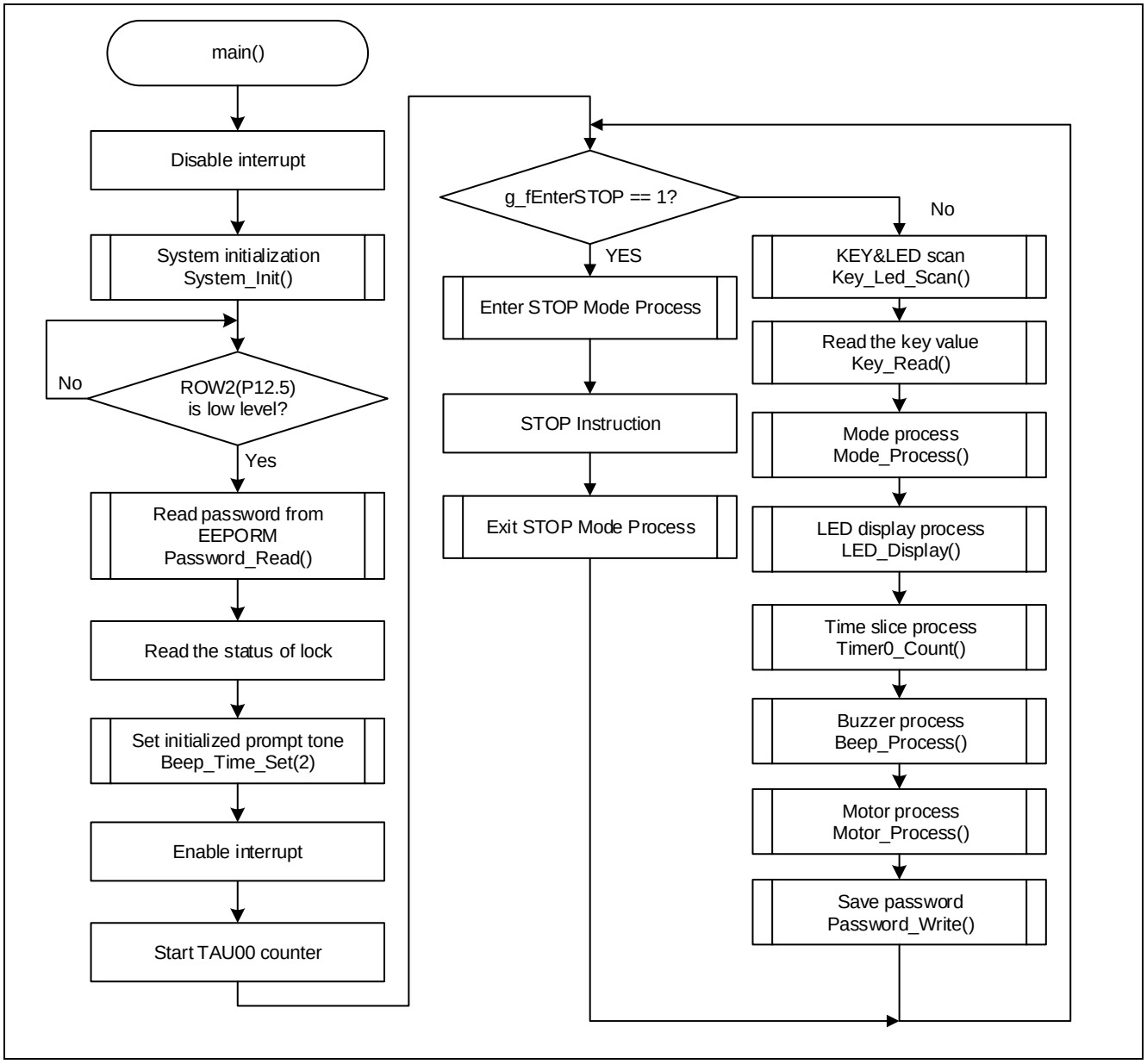


Figure 5.1 Flow Chart of Main Program

5.3 Flow Chart of KEY&LED Scan

The flow charts of KEY&LED scan are shown in Figure 5.2 and Figure 5.3.

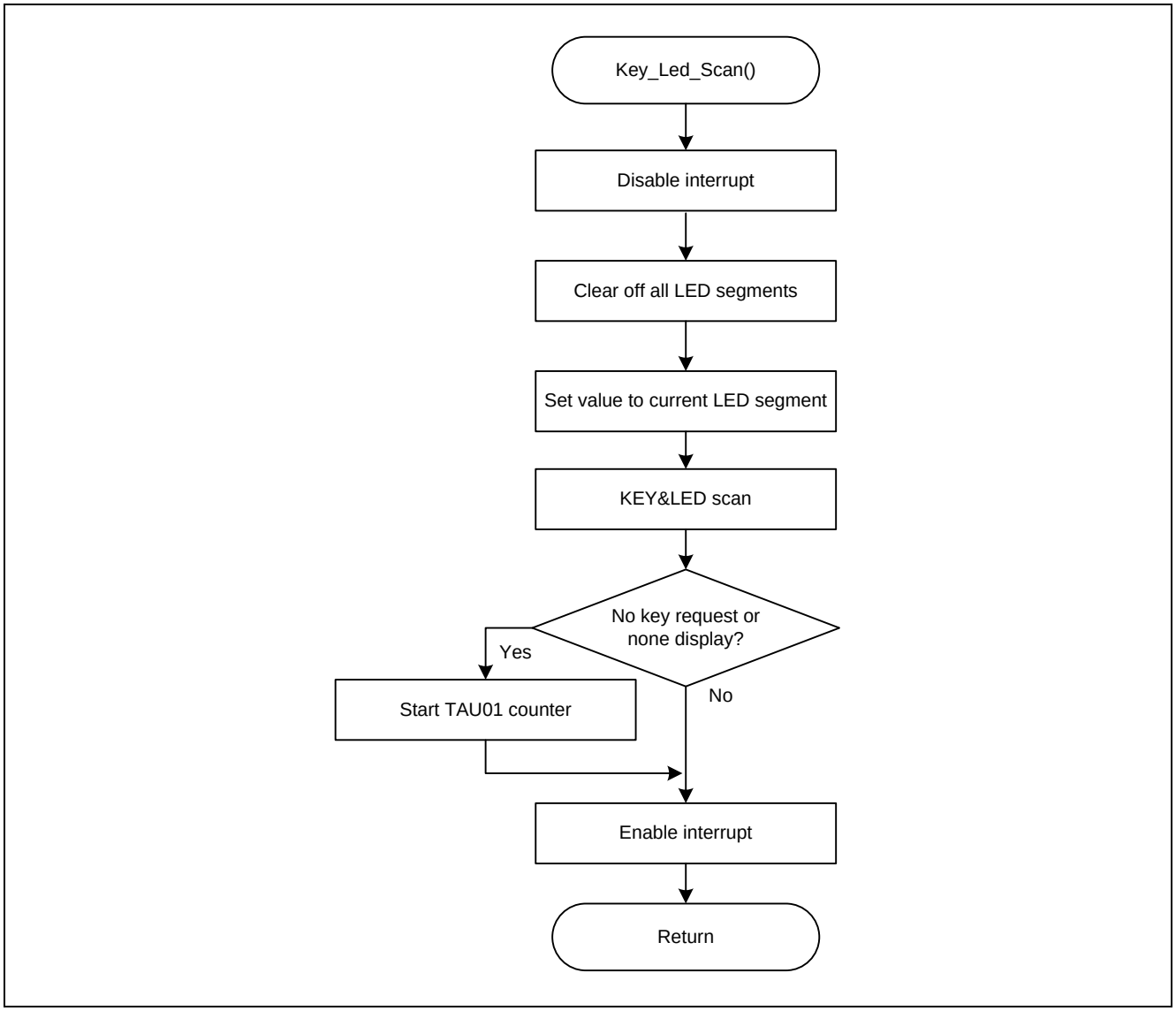


Figure 5.2 Flow Chart of KEY&LED Scan (1/2)

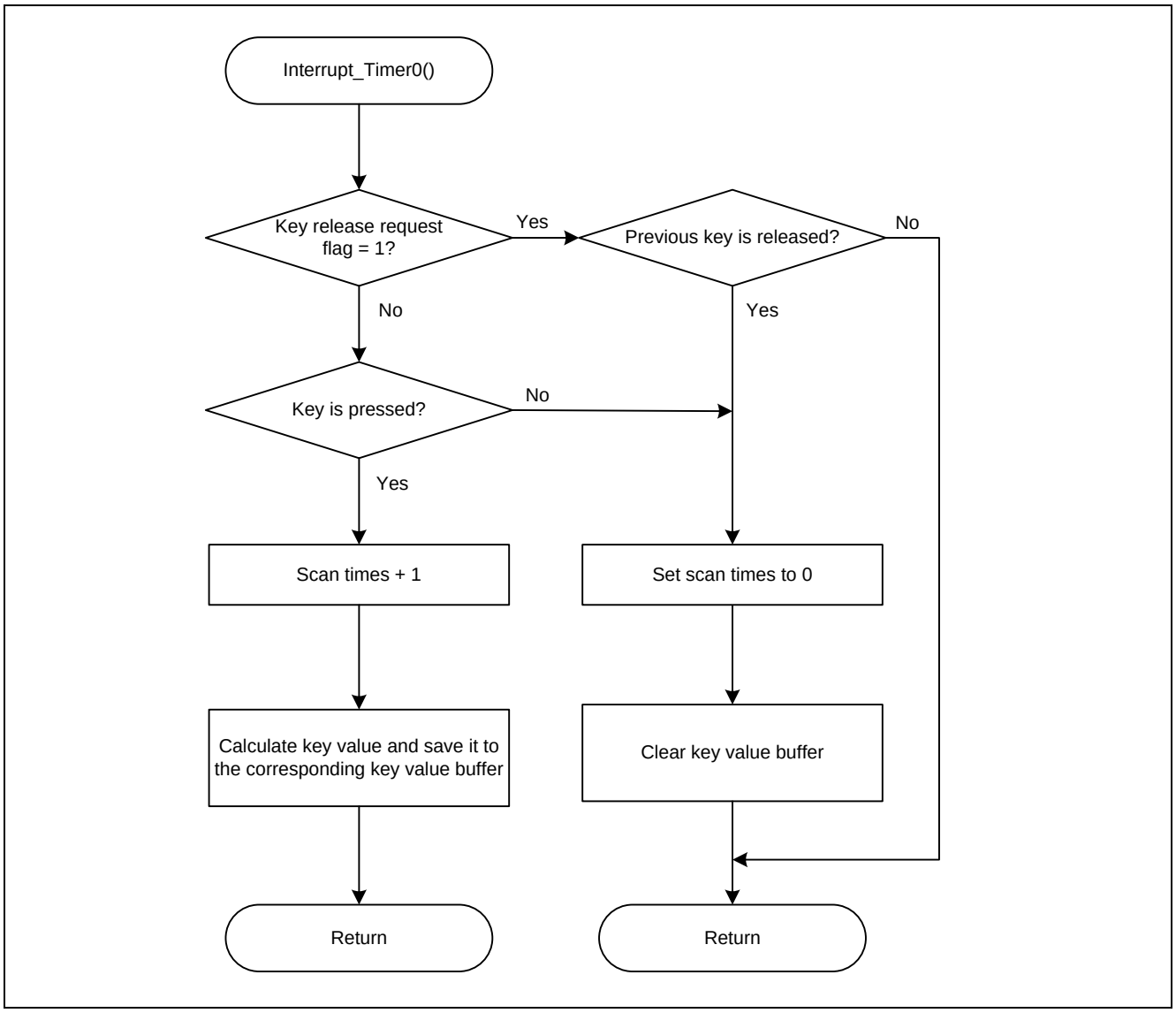


Figure 5.3 Flow Chart of KEY&LED Scan (2/2)

5.4 Flow Chart of Mode Processing

The flow charts of mode processing is shown in Figure 5.4, Figure 5.5, Figure 5.6, Figure 5.7, Figure 5.8, Figure 5.9, Figure 5.10, Figure 5.11 and Figure 5.12.

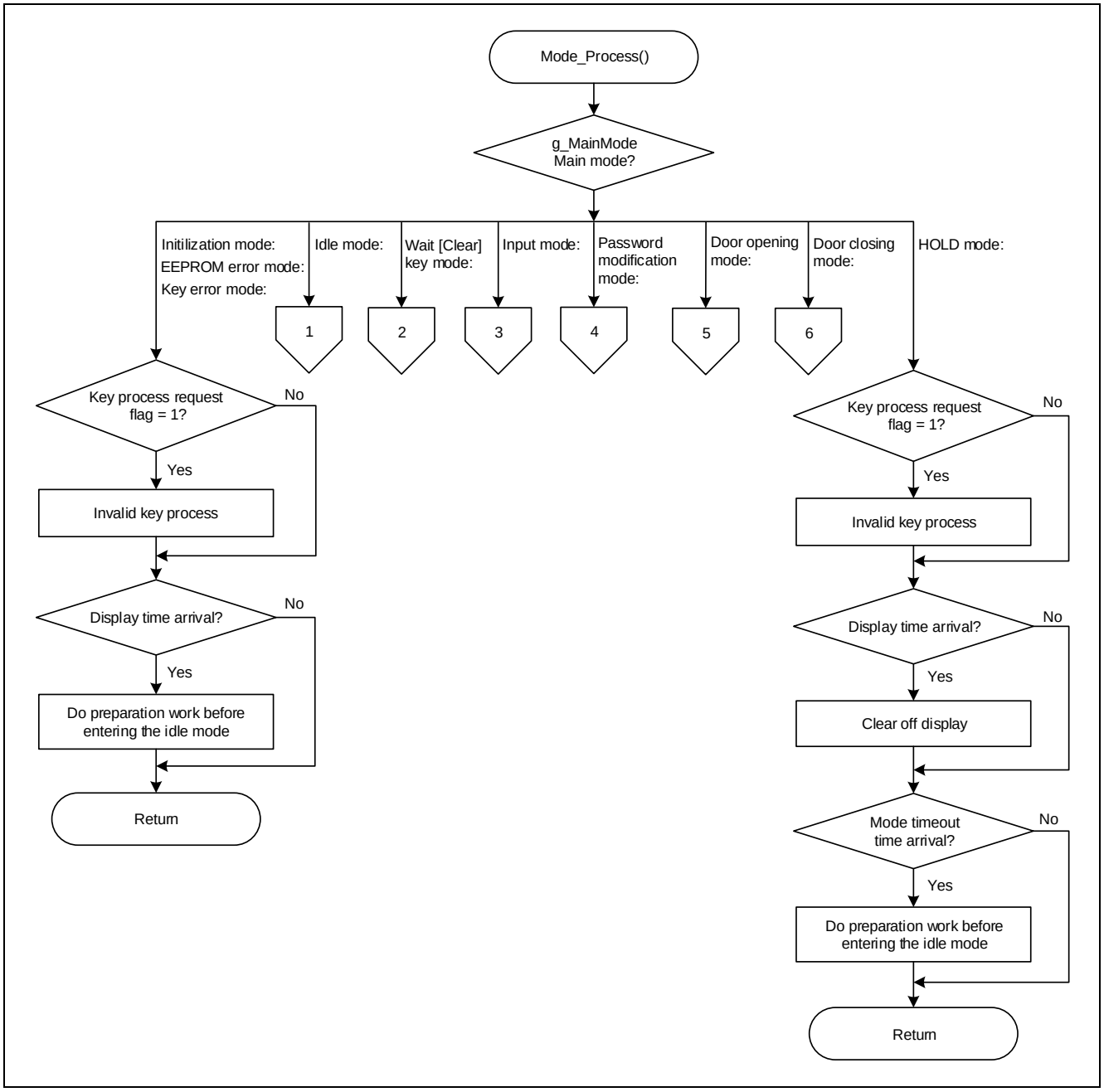


Figure 5.4 Flow Chart of Mode Processing (1/9)

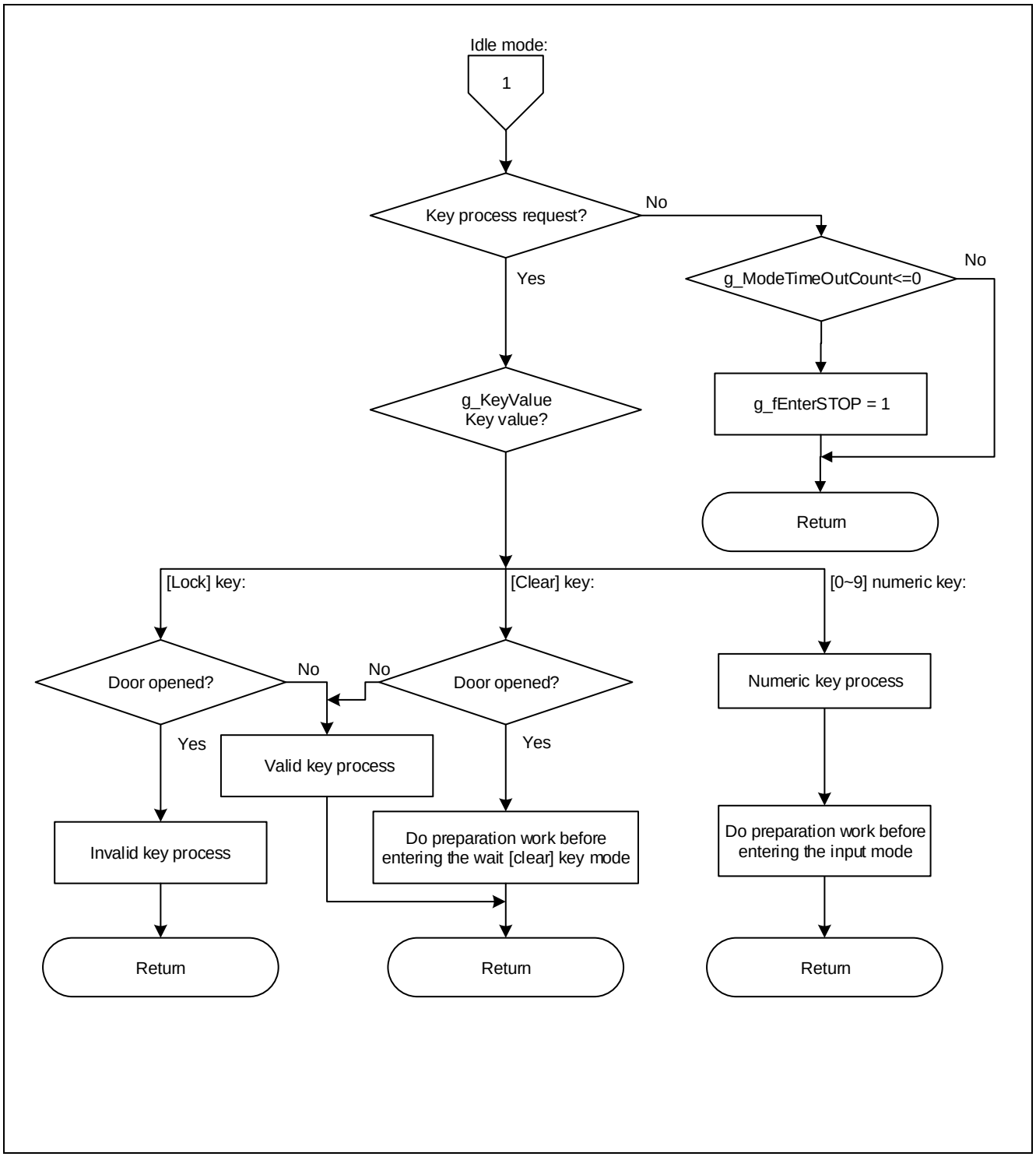


Figure 5.5 Flow Chart of Mode Processing (2/9)

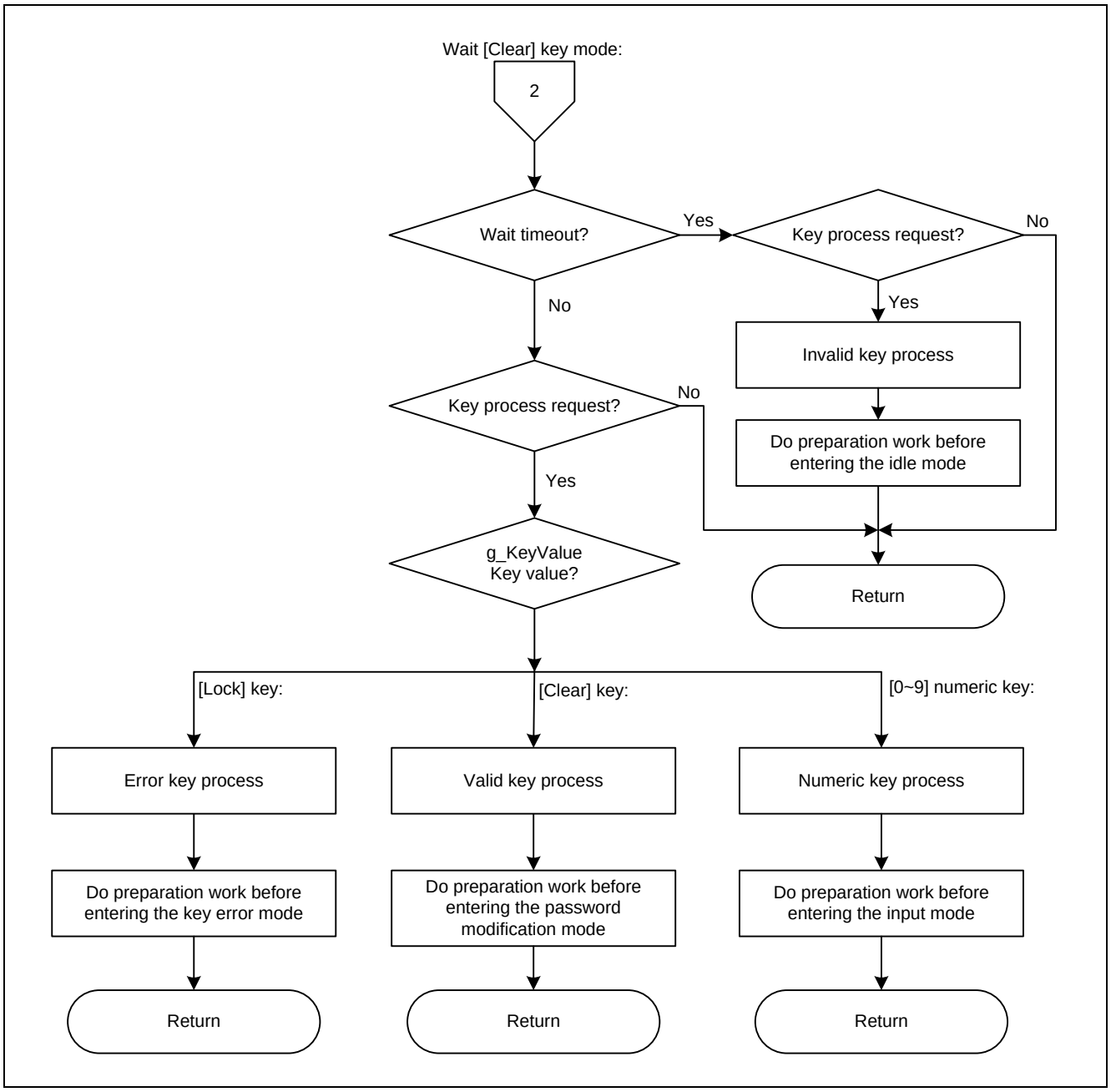


Figure 5.6 Flow Chart of Mode Processing (3/9)

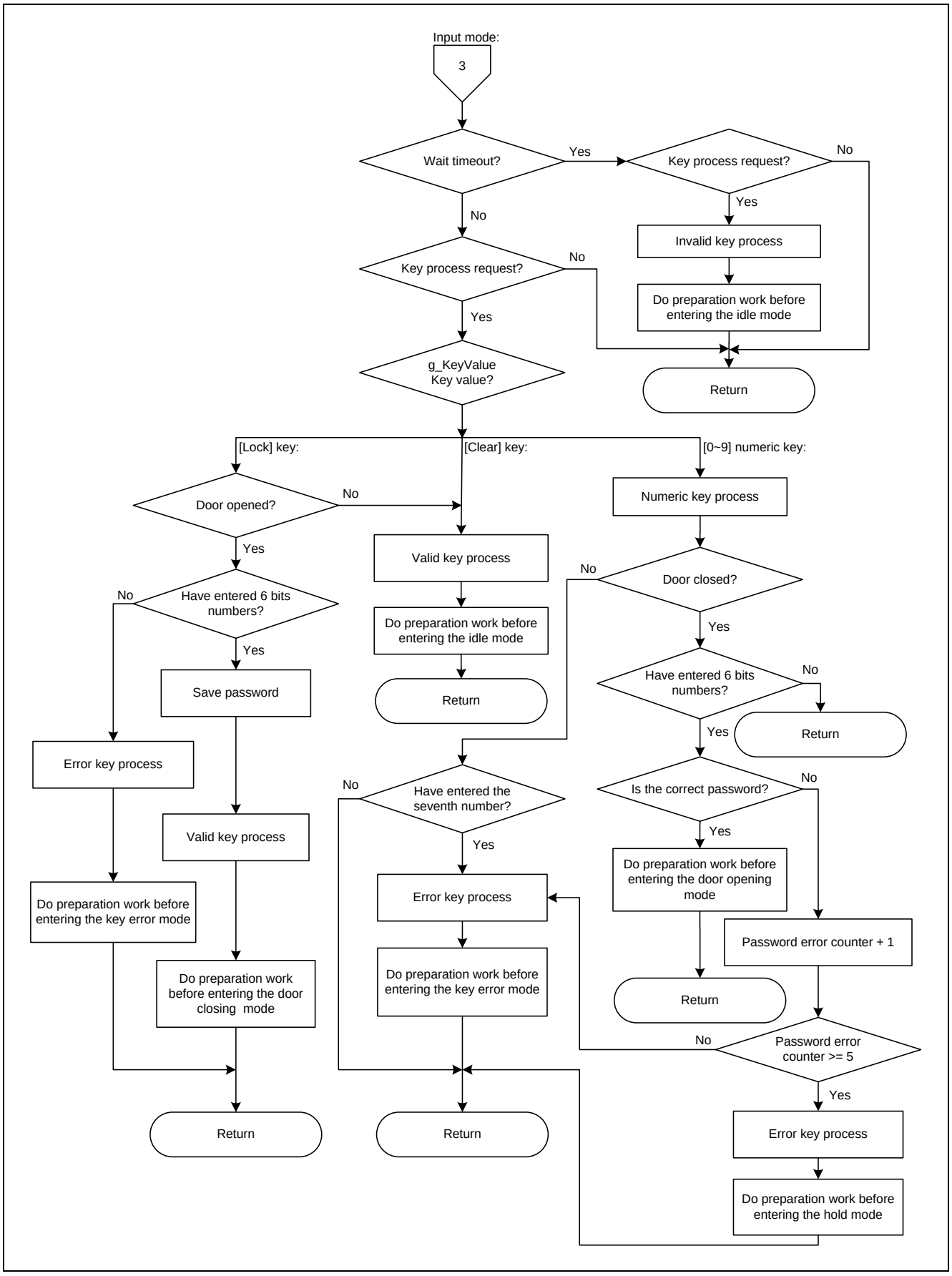


Figure 5.7 Flow Chart of Mode Processing (4/9)

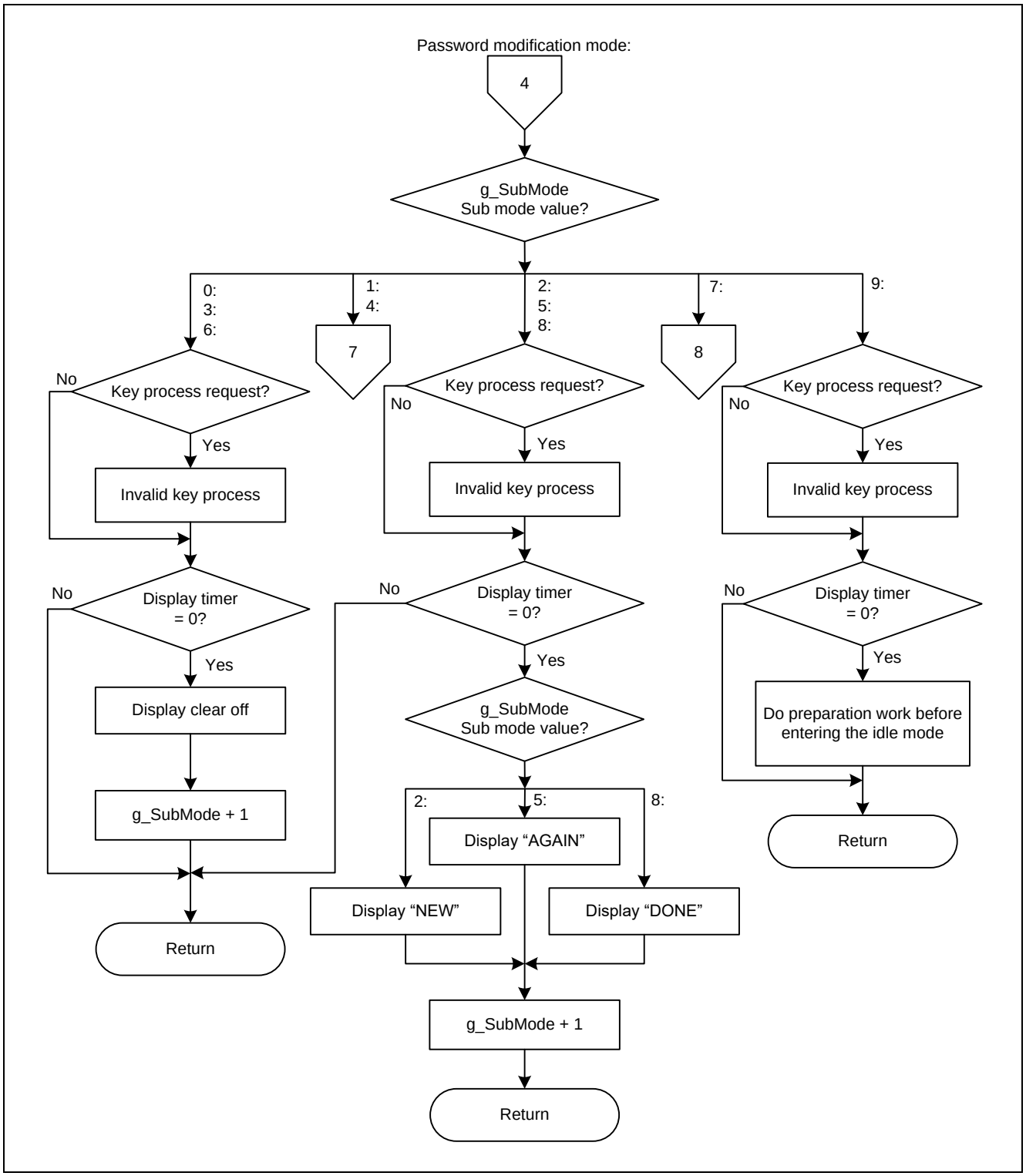


Figure 5.8 Flow Chart of Mode Processing (5/9)

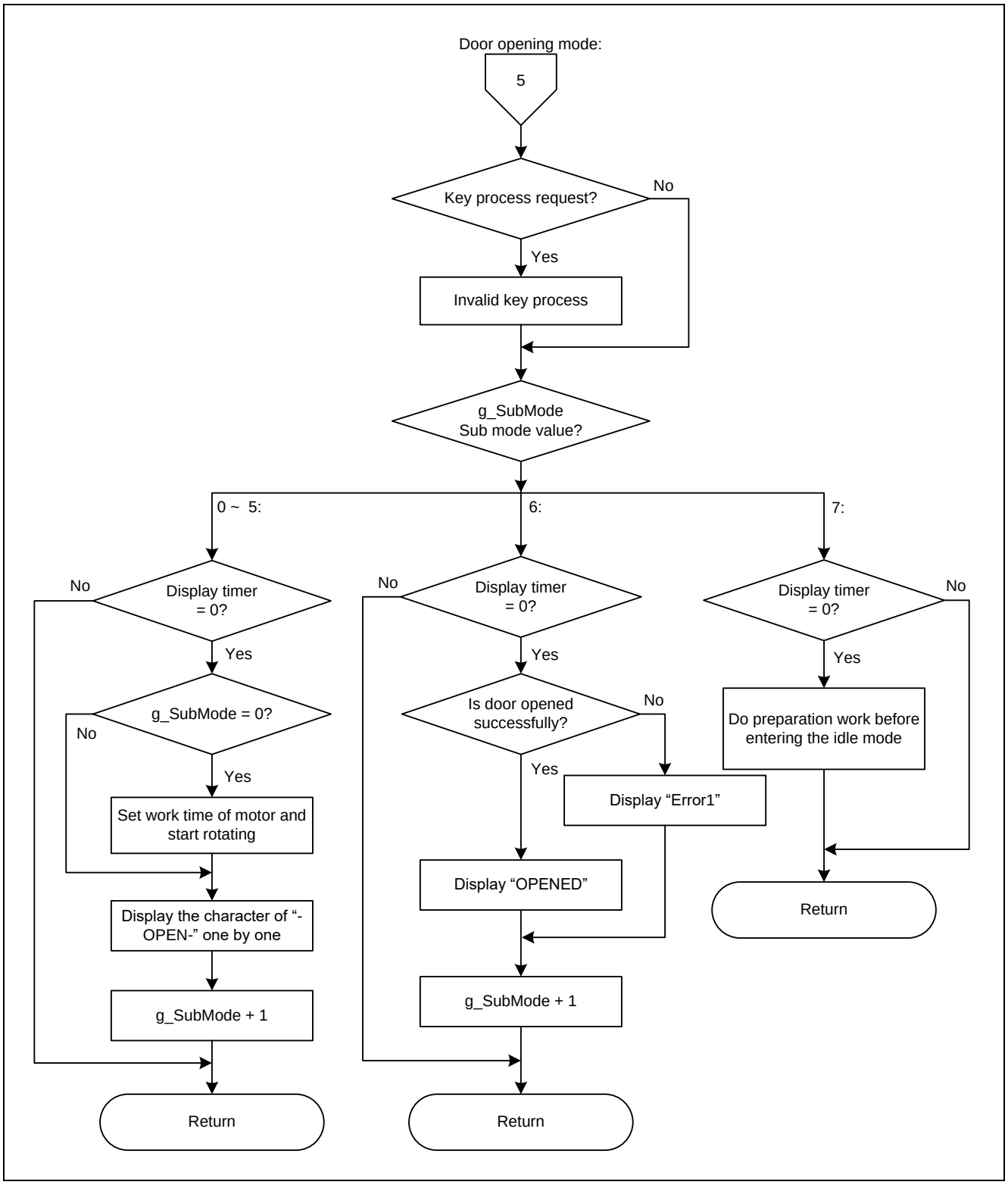


Figure 5.9 Flow Chart of Mode Processing (6/9)

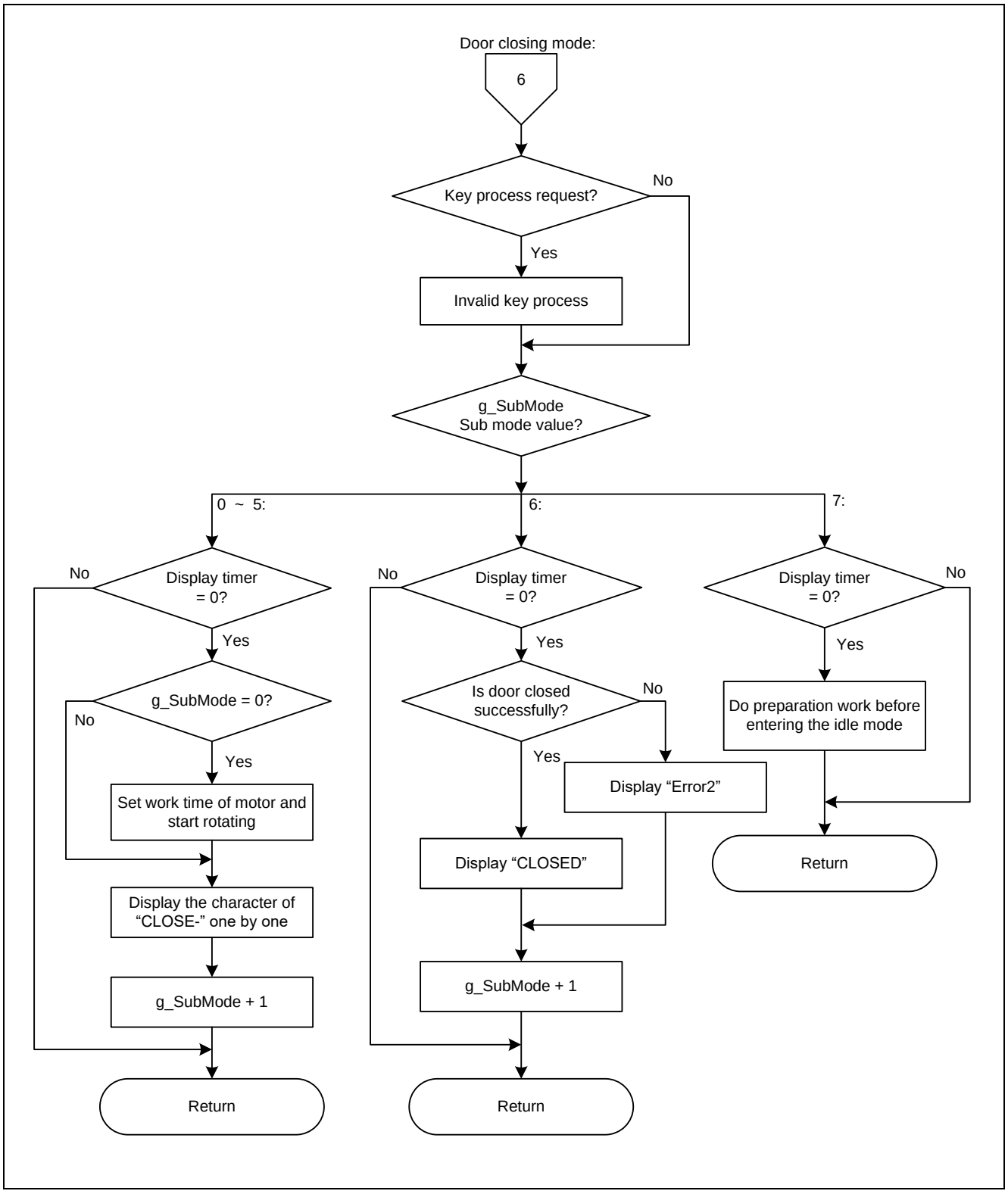


Figure 5.10 Flow Chart of Mode Processing (7/9)

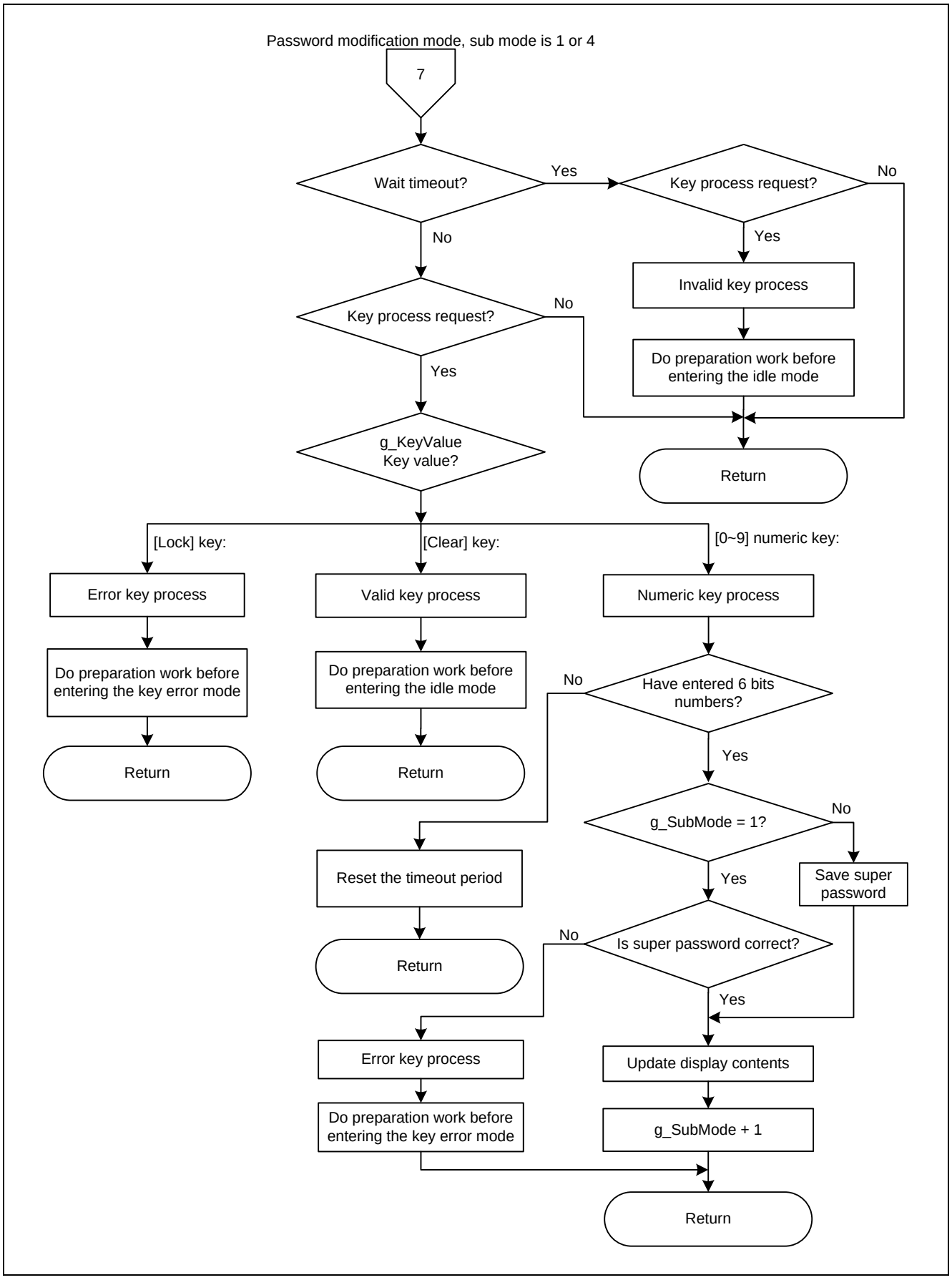


Figure 5.11 Flow Chart of Mode Processing (8/9)

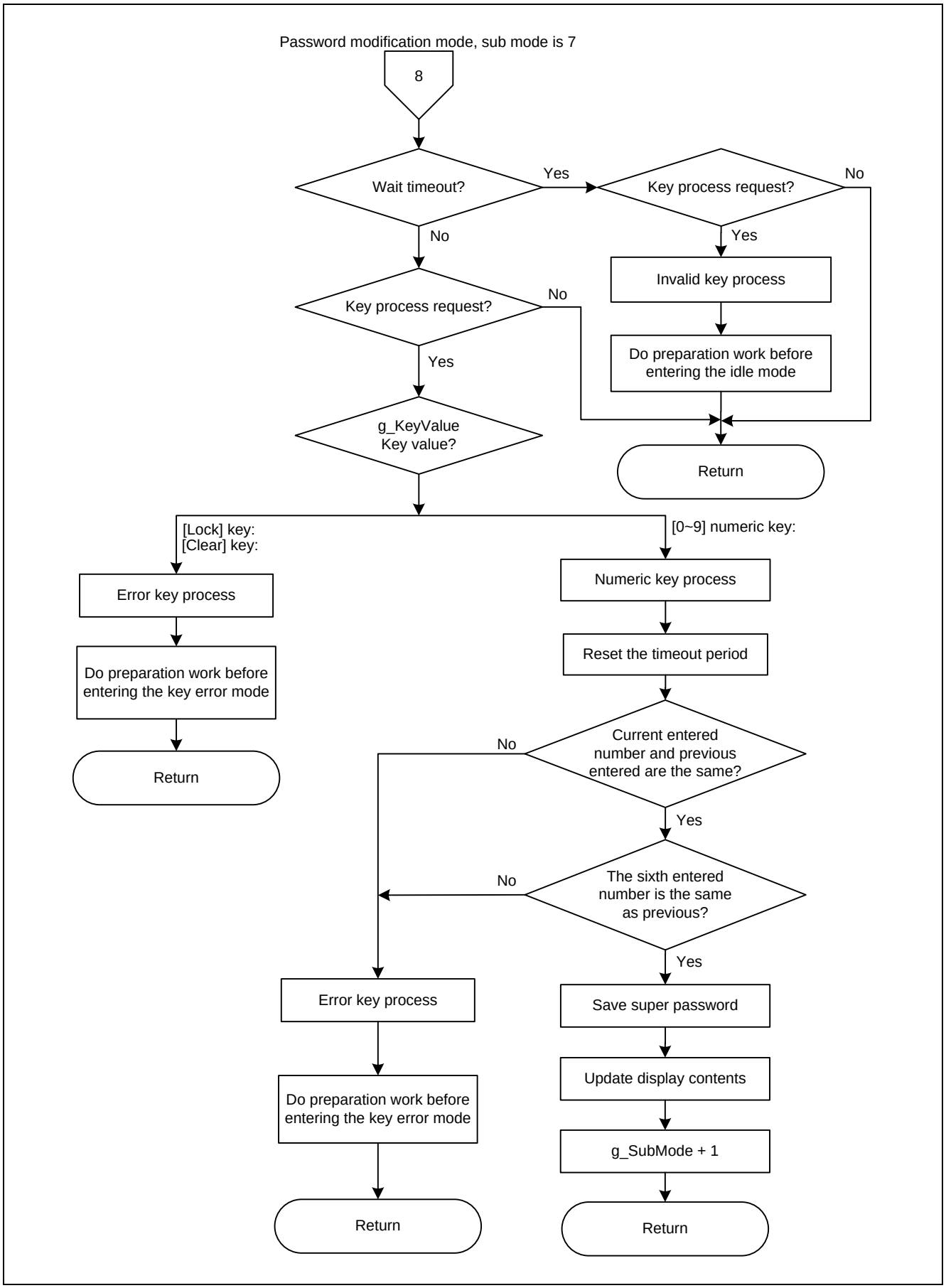


Figure 5.12 Flow Chart of Mode Processing (9/9)

5.5 Flow Chart of Motor Processing

The flow chart of motor processing is shown in Figure 5.13.

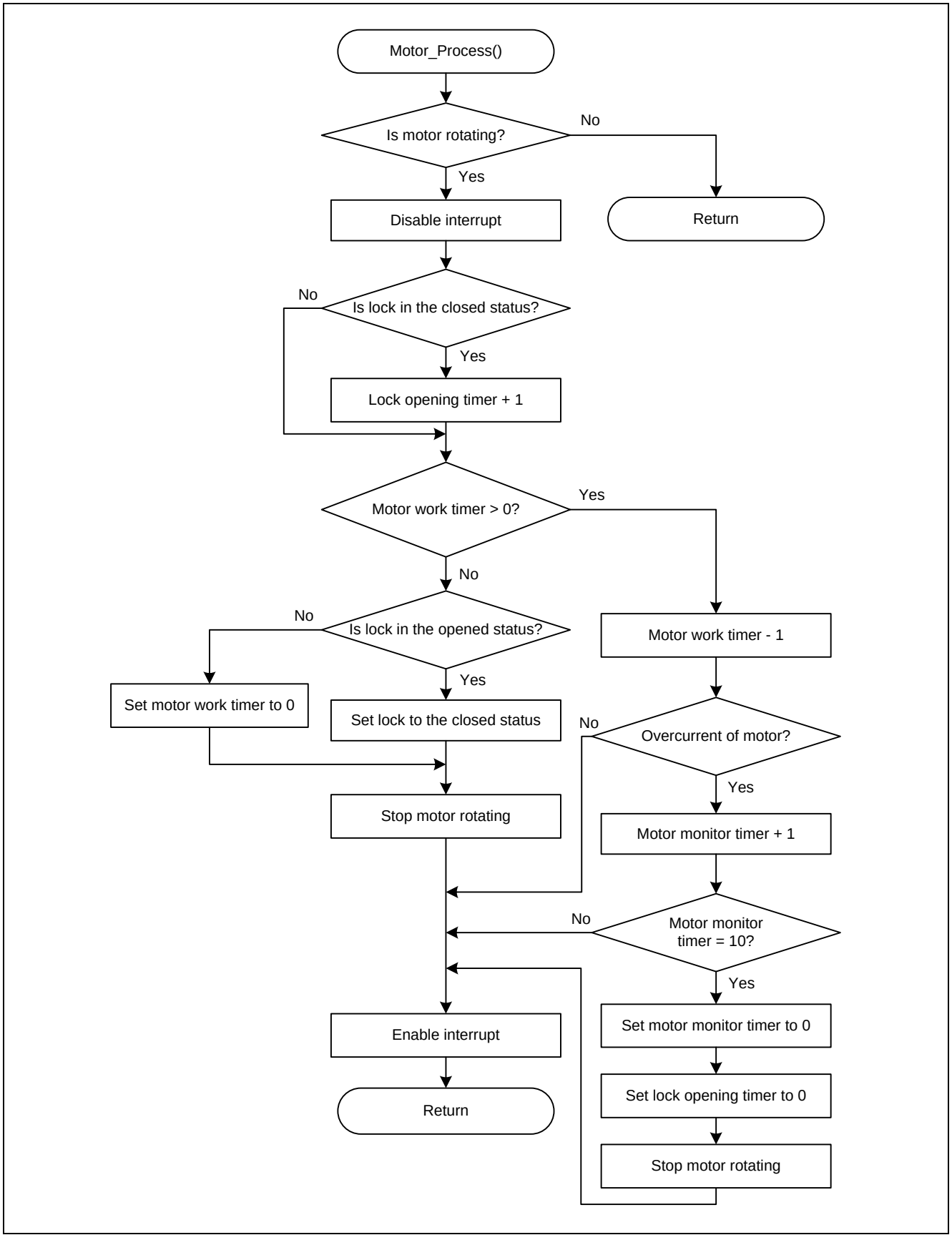


Figure 5.13 Flow Chart of Motor Processing

5.6 Flow Chart of Buzzer Processing

The flow chart of buzzer processing is shown in Figure 5.14.

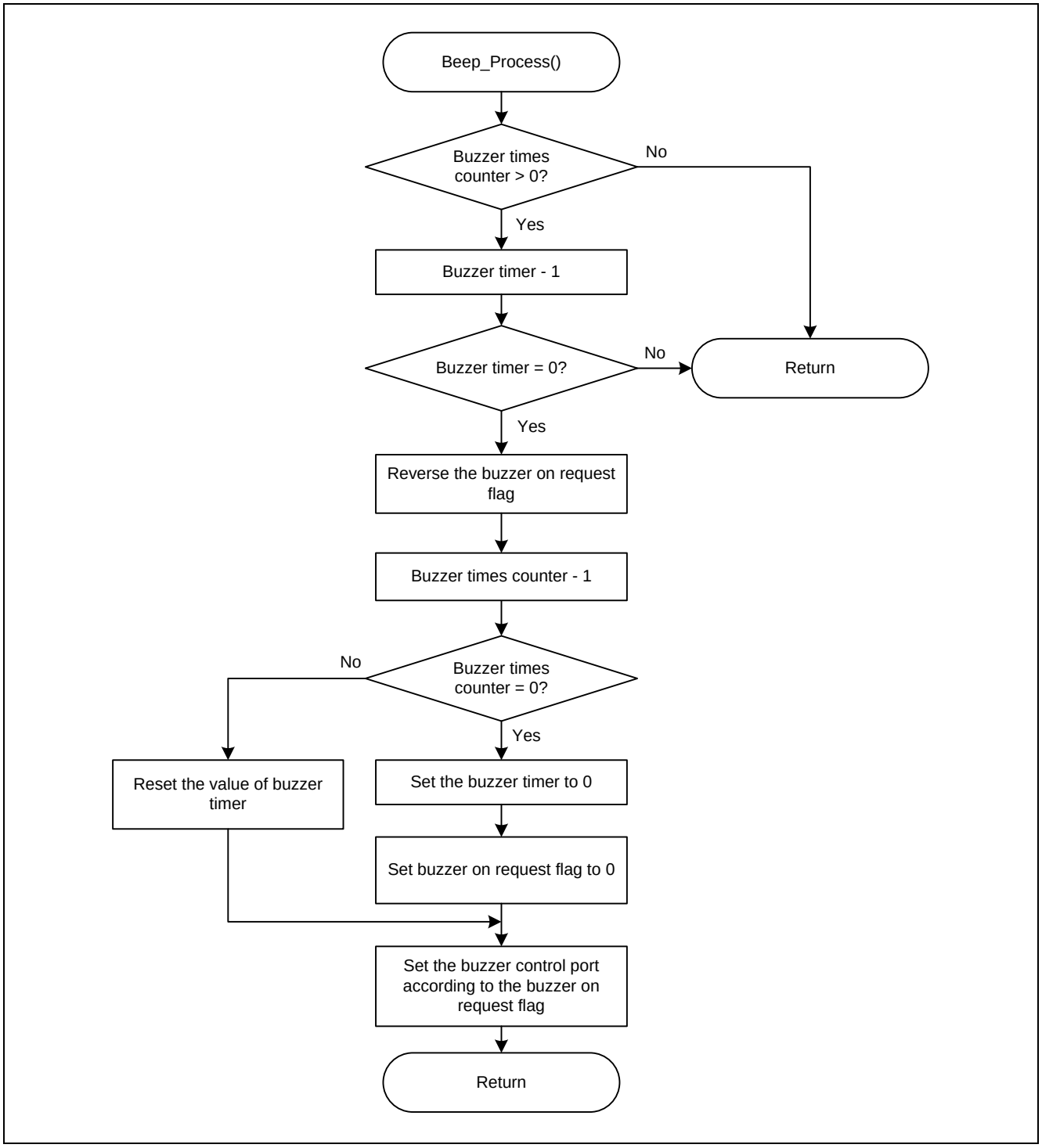


Figure 5.14 Flow Chart of Buzzer Processing

5.7 Flow Chart of Travel Switch Processing

The flow chart of travel switch processing is shown in Figure 5.15.

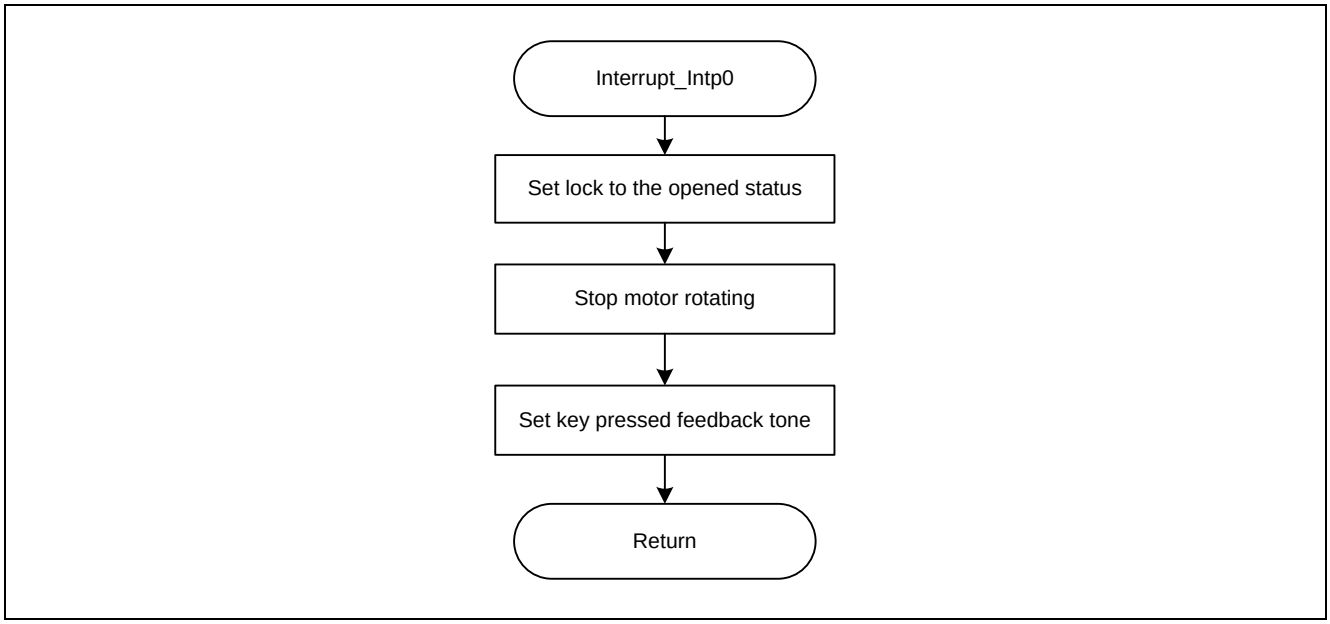


Figure 5.15 Flow Chart of Travel Switch Processing

6. Sample Code

The sample code is available on the Renesas Electronics Website.

7. Reference Documents

User's Manual

RL78/G1M, G1N User's Manual: Hardware (R01UH0904E)

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.

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Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Jul.30, 2020		First edition issued
1.10	Apr.8, 2021	14, 20	Updated the EEPROM IC (R1EX24016ATAS0I)

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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