RL78/G23

Remote Control Signal Reception (NEC Format, STOP Mode)

Introduction

This application note describes how to receive remote control signals using a remote control signal receiver (REMC) and STOP mode.

The applicable remote control format is NEC (including header, 32-bit data, and repeat code).

Target Device

RL78/G23

When applying the sample program covered in this application note 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. Specification

1.1 Overview of Specification

In this application note, a remote control signal receiver (REMC) is used. LEDs are turned on according to the remote control code received by the remote control signal receiver (REMC). When no remote control signal input is detected for 10 seconds, the MCU shifts to STOP mode. When a remote control signal input is detected in STOP mode, the application performs the remote control signal reception processing using the low-speed peripheral clock (f_{SXP}).

Also, at startup, frequency correction processing is performed for the low-speed on-chip oscillator clock used for the low-speed peripheral clocks. For details on frequency compensation processing, see the application note "Low-speed On-chip Oscillator (LOCO) Clock Frequency Correction".

Table 1-1 lists peripheral functions and their use. Figure 1-1 shows an overview of sample code operation. Table **1-2** shows the relation between remote control signal input and LED ON/OFF state.

Table 1-1 Peripheral Function and Use

Peripheral Function	Use
Remote control signal receiver (REMC)	Remote control signal reception
Channels 1 of time array unit 0 (TAU0)	STOP mode transition decision timer
32-bit interval timer channel 0, 1	Used for calibration of LOCO.
P03, P02, P43, P42, P77, P41, P31, P76	Output pins to LED1-LED8

Figure 1-1 Overview of Operation

<Remote control signal input>

RL78/G23

LED display
(According to remote control signals)
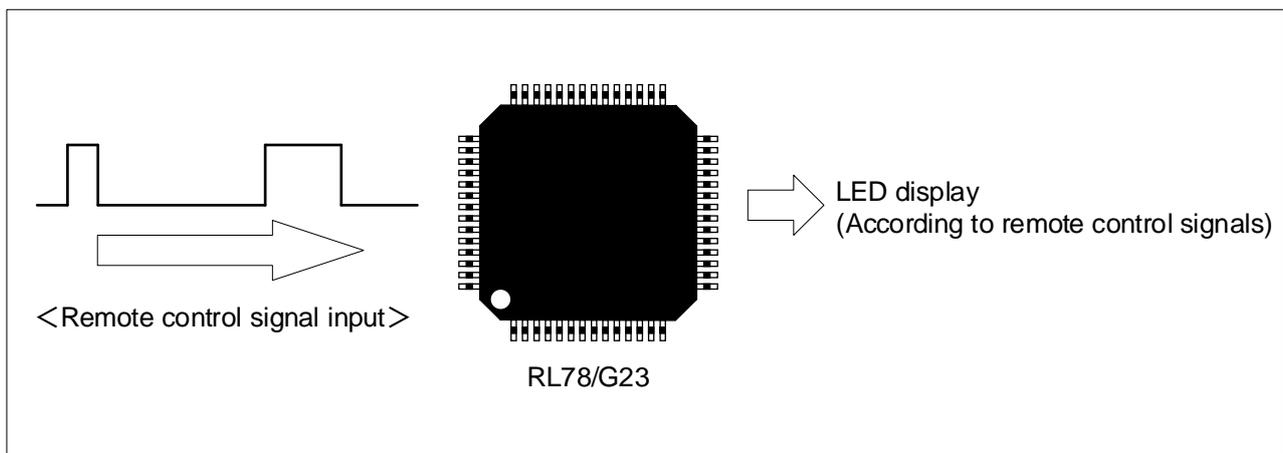
Table 1-2 Relation between Remote Control Signal Input and LED ON/OFF State

Remote Control Signal Input	LED1 to LED8 ON/OFF State
No input	All LEDs OFF
Channel 1 select	LED1 ON
Channel 2 select	LED2 ON
Channel 3 select	LED3 ON
Channel 4 select	LED4 ON
Channel 5 select	LED5 ON
Channel 6 select	LED6 ON
Channel 7 select	LED7 ON
Channel 8 select	LED8 ON
Other signal inputs	All LEDs OFF
No input (STOP mode)	All LEDs OFF

1.2 Details of Operation

This application note shows an example of use of the remote control signal receiver (REMC). The REMC receives NEC-format remote control signals (including header, 32-bit data, and repeat code). When the application recognizes that the relevant channel button was pressed, it turns on the corresponding LED. Figure 1-2 shows the remote control signal (NEC format including header, 32-bit data, and repeat code) reception timing.

Figure 1-2 Remote Control Signal Reception Timing
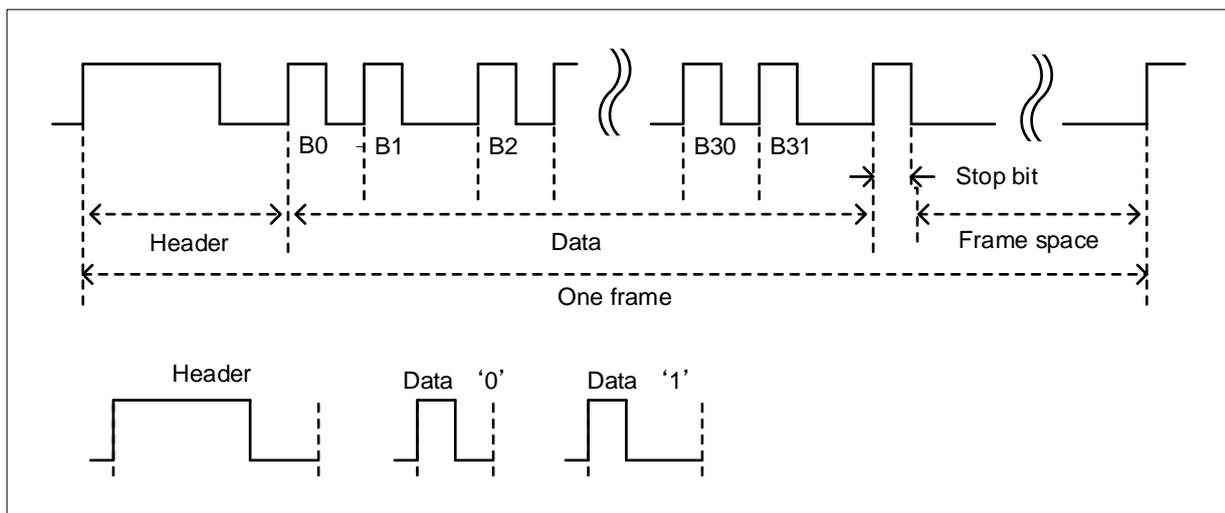
Table 1-3 shows the correspondence between remote control input signals and remote control signal data. When the third byte (B16 to B23 in Figure 1-2) of the received remote control signal data matches the signal data in Table 1-3, the application recognizes that the relevant channel button was pressed.

Table 1-3 Correspondence between Remote Control Input Signals and Signal Data

Remote Control Input Signal	Signal Data
Channel 1	0x10
Channel 2	0x11
Channel 3	0x12
Channel 4	0x13
Channel 5	0x14
Channel 6	0x15
Channel 7	0x16
Channel 8	0x17

When no remote control signal input is detected for 10 seconds, the application shifts to STOP mode. (When the repeat code is received, the REMC recognizes that a remote control signal was detected.) When a remote control signal is detected in STOP mode, the application performs the remote control signal reception processing using the low-speed peripheral clock (f_{SXP}). Upon receiving the REMC interrupt request signal, the application transitions from SNOOZE mode to normal operation mode.

Figure 1-3 shows the transition (to STOP mode) timing. Figure 1-4 shows the state transition diagram.

Figure 1-3 Transition (to STOP Mode) Timing
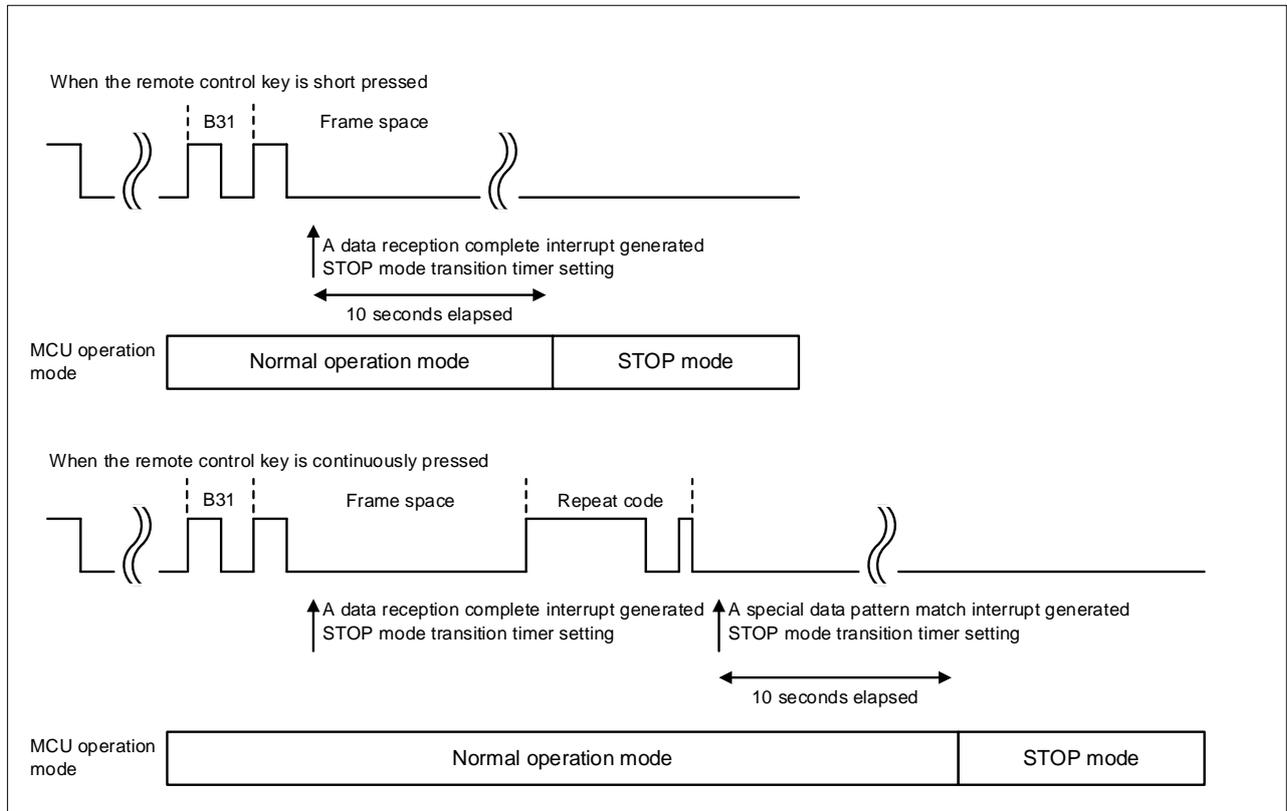
Figure 1-4 Remote Control Signal Reception State Transition Diagram

Note 1.   When the MCU detects the edge of the remote control signal in STOP mode, the remote control signal reception processing is performed in STOP mode. When the MCU receives a data reception complete interrupt request, it transitions to normal operating mode.
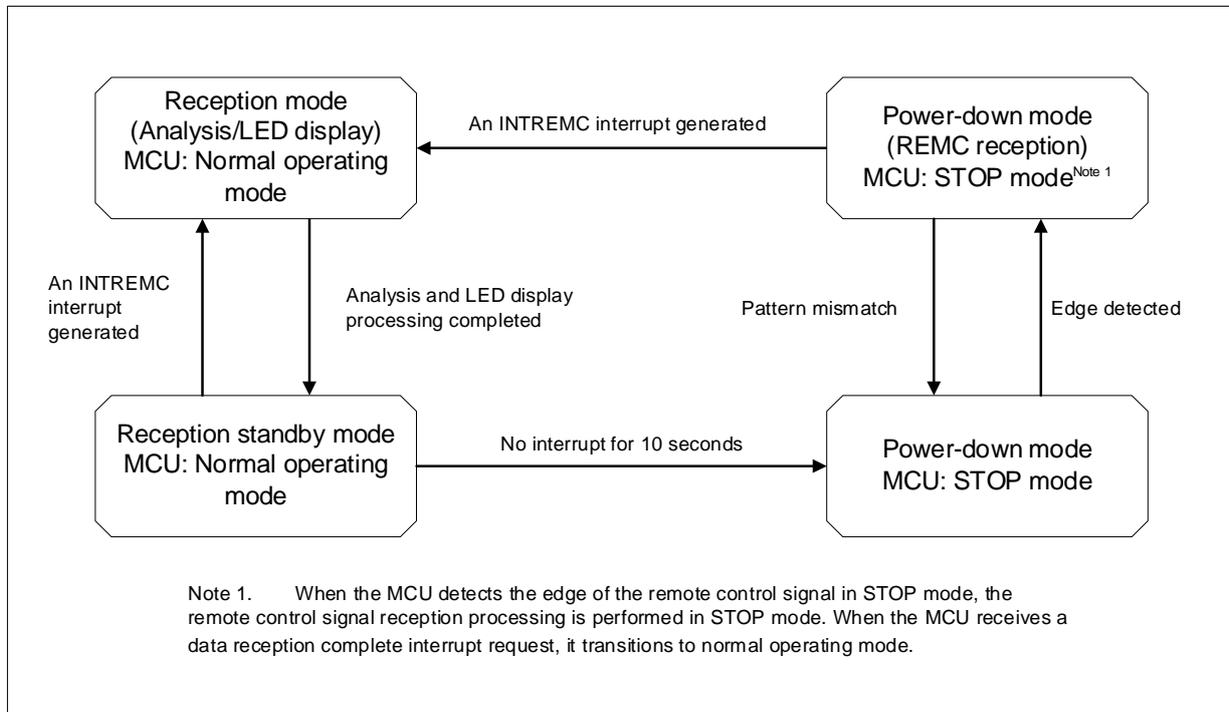
The following describes the main settings for peripheral functions.

(1) Timer array unit 0 (TAU0) channel 1 (for deciding transition to STOP mode)
- Set the timer operation mode to interval timer mode.
- Operating clock: CK00, clock source: $f_{CLK}/2^{13}$
- Interval period: 10,000 ms (10 seconds)
- Disable interrupts at count start.
- Enable INTTM01 interrupts (interrupt priority level 3).

(2) 32-bit interval timer
- Set to 16-bit capture mode.
- Select fIHP as the operating clock.
- Select fSXP (low-speed on-chip oscillator) as the capture trigger operating clock.

(3) I/O ports
- P03, P02, P43, P42, P77, P41, P31 and P76 pins: Set as output ports.

(3)   Remote control signal receiver (REMC)

- Operating clock: f_{SXP}

- Enable digital filters (three-time match). Digital filter sampling clock: f_{SXP}

- Disable transitions from STOP mode to SNOOZE mode.

- Reception mode: Format C pattern. Enable input/output signal inversion.

- Pattern settings: Shown below

Table 1-4   Pattern Settings

Item		Setting value [Note]
Pattern end width		643
Header pattern	Maximum width	521
	Minimum width	400
Data 0 pattern	Maximum width	43
	Minimum width	30
Data 1 pattern	Maximum width	86
	Minimum width	59
Special data pattern	Maximum width	397
	Minimum width	302

Note.   The above settings are with a Low-speed on-chip oscillator clock frequency (f_{IL}) of 32,765 kHz + 0.2 %. In RL78/G23, an error of f_{IL} is within $\pm$15 %. When using f_{IL} as f_{SXP}, you may need to correct f_{IL}. For the correction method of f_{IL}, refer to the Application Note for RL78/G23 Low-speed On-chip Oscillator (LOCO) Clock Frequency Correction (R01AN5557).

- Number of compare bits: 15, compare value: 0xE718

- No data capture at the time of a receive error

- Enable compare match interrupts, data reception complete interrupts, and special data pattern match interrupts.

- Set interrupt mode to normal interrupt mode (interrupt priority level 3).

2. Operation Confirmation Conditions

The operation of the sample code provided with this application note has been tested under the following conditions.

Table 2-1 Operation Confirmation Conditions

Item	Description
MCU used	RL78/G23 (R7F100GLG)
Board used	RL78/G23-64p Fast Prototyping Board (RTK7RLG230CLG000BJ)
Operating frequency	・　　High-speed on-chip oscillator clock (f_{IH}): 32 MHz ・　Low-speed on-chip oscillator clock (f_{IL}): 32.768 kHz
Operating voltage	5.0V (can be operated at 2.0 V to 5.5 V) LVD0 operations (V_{LVD0}): Reset mode 　At rising edge TYP. 1.90 V (1.84 V to 1.95 V) 　At falling edge TYP. 1.86 V (1.80 V to 1.91 V)
Integrated development environment (CS+)	CS+ for CC V8.11.00 from Renesas Electronics Corp.
C compiler (CS+)	CC-RL V1.13.00 from Renesas Electronics Corp.
Integrated development environment (e2studio)	e2studio V2024-01 (24.1.0) from Renesas Electronics Corp.
C compiler (e2studio)	CC-RL V1.13.00 from Renesas Electronics Corp.
Integrated development environment (IAR)	IAR Embedded Workbench for Renesas RL78 V4.21.2 from IAR Systems Corp.
C compiler (IAR)	IAR C/C++ Compiler for Renesas RL78 V4.21.2.2420 from IAR Systems Corp.
Smart Configurator	V1.9.0 from Renesas Electronics Corp.
Board support package (BSP)	V1.40 from Renesas Electronics Corp.
Remote controller used	ATV-102 supplied by Asahi Electrochemical Co., Ltd. (NEC TV ⑩①⑥)

3.   Hardware Descriptions

3.1   Example of Hardware Configuration

Figure **3**-**1** shows an example of the hardware configuration used in the application note.

Figure 3-1 Hardware Configuration
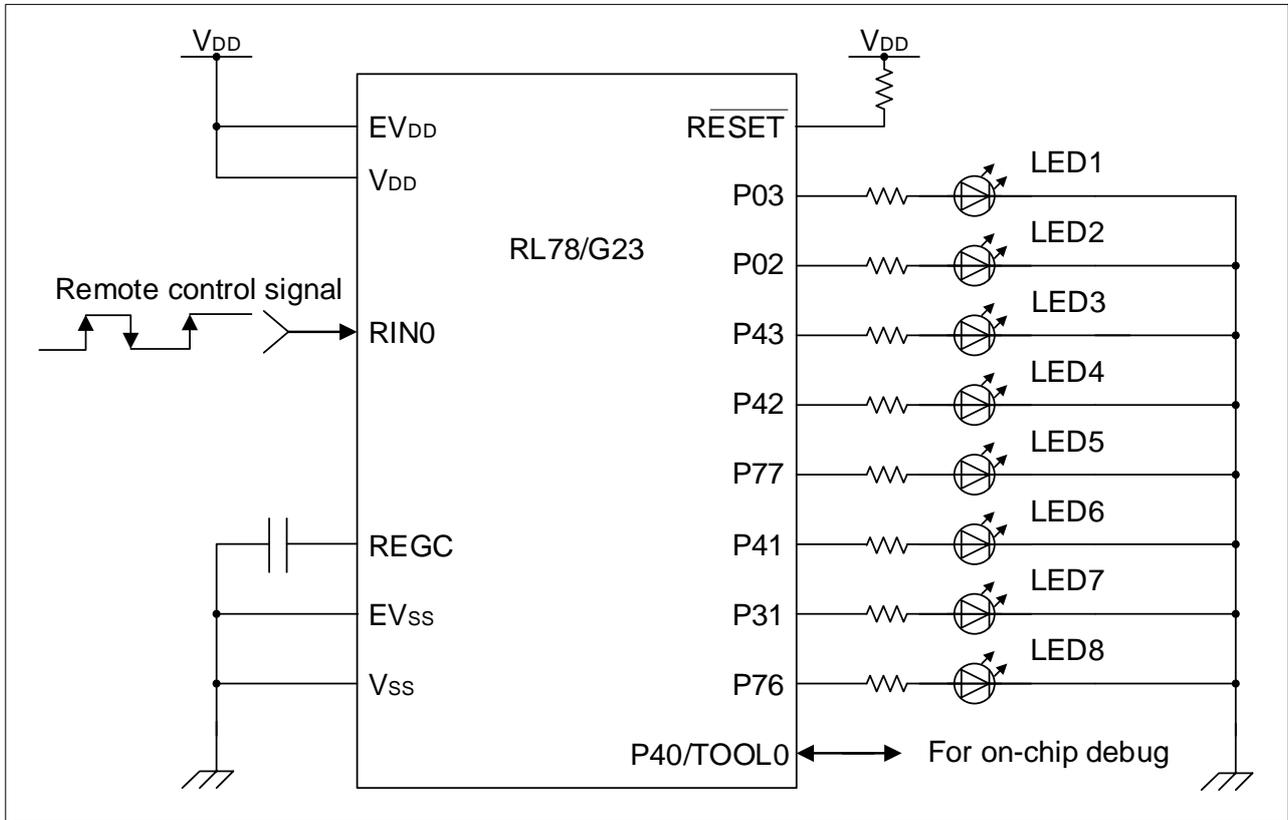
Note 1.   This schematic circuit diagram is simplified to show the outline of connections. When creating actual circuits, design them using appropriate pin processing so that the circuits meet electrical characteristics. (Connect input-only ports to V_{DD} or V_{SS} individually through a resistor.)

Note 2.   Connect pins (with a name beginning with EV_{SS}), if any, to V_{SS}, and connect pins (with a name beginning with EV_{DD}), if any, to V_{DD}.

Note 3.   Set V_{DD} to a voltage not less than the reset release voltage (V_{LVD0}) set by the LVD0.

3.2   List of Pins to be Used

Table 3-1 lists the pins to be used and their functions.

Table 3-1 Pins to be Used and Their Function

Pin name	I/O	Functions
RIN0/P70	Input	Remote control signal input
P03	Output	LED (LED1) control port
P02	Output	LED (LED2) control port
P43	Output	LED (LED3) control port
P42	Output	LED (LED4) control port
P77	Output	LED (LED5) control port
P41	Output	LED (LED6) control port
P31	Output	LED (LED7) control port
P76	Output	LED (LED8) control port

Caution   In this application note, only the used pins are processed. When actually designing your circuit,
make sure the design includes sufficient pin processing and meets electrical characteristic
requirements.

4. Software Explanation

4.1 Setting of Option Byte

Table 4-1 shows the option byte settings.

Table 4-1 Option Byte Settings

Address	Setting Value	Contents
000C0H / 040C0H	11101111B	Disables the watchdog timer. (Counting stopped after reset)
000C1H / 040C1H	11111110B	LVD0 detection voltage: reset mode At rising edge TYP. 1.90 V (1.84 V to 1.95 V) At falling edge TYP. 1.86 V (1.80 V to 1.91 V)
000C2H / 040C2H	11101000B	HS mode, High-speed on-chip oscillator clock (f_{IH}): 32 MHz
000C3H / 040C3H	10000101B	Enables on-chip debugging

4.2 List of Constants

Table 4-2 lists the constants that are used in the sample code.

Table 4-2 Constant

Constant Name	Setting Value	Description
R_REMC_BUFF_SIZE	32	REMC receive buffer size
R_NEC_DATA_LEN	4	Remote control data length (NEC format)
R_NEC_DATA_CODE_POS	2	Data storage location (NEC format)
R_NEC_DATA_CODE_01	0x10	Channel 1 data (NEC format)
R_NEC_DATA_CODE_02	0x11	Channel 2 data (NEC format)
R_NEC_DATA_CODE_03	0x12	Channel 3 data (NEC format)
R_NEC_DATA_CODE_04	0x13	Channel 4 data (NEC format)
R_NEC_DATA_CODE_05	0x14	Channel 5 data (NEC format)
R_NEC_DATA_CODE_06	0x15	Channel 6 data (NEC format)
R_NEC_DATA_CODE_07	0x16	Channel 7 data (NEC format)
R_NEC_DATA_CODE_08	0x17	Channel 8 data (NEC format)
R_LED_ALL_OFF	0	Data for turning off all LEDs
R_INTR_STATE_NONE	0x00	No interrupt detected
R_INTR_STATE_RECV_END	0x01	REMC reception complete interrupt generated
R_INTR_STATE_SPC_DATA	0x02	REMC special data pattern reception interrupt generated
R_INTR_STATE_TIME_OUT	0x03	Timeout occurred
LIOTRM_MAX	11111111B	Maximum value of the LIOTRM register
LIOTRM_MIN	00000000B	Minimum value of the LIOTRM register
CCNT_MAX	7860	Upper threshold of clock count
CCNT_MIN	7765	Lower threshold of clock count

4.3 List of Variables

Table **4-3** lists global variables.

Table 4-3 Global Variables

Type	Variable Name	Description	Function Used
uint8_t	g_remc_buf [R_REMC_BUF_SIZE]	REMC receive buffer	main
r_intr_state_t	g_intr_state	Interrupt flag	main, r_Config_REMC_callback_receiveend, r_Config_REMC_callback_specialdata, r_Config_TAU0_1_interrupt
uint8_t	s_custom_code_match	REMC compare match flag	r_Config_REMC_callback_comparematch, r_is_custom_code_match
uint8_t	calibration_count	Calibration count value	R_Main_Calibrate_LOCO()
uint8_t	calibrate_history	Calibration history	R_Main_Calibrate_LOCO()
uint16_t	count_value	Count value (Used as an argument of R_Trimming_OCO)	R_Trimming_OCO()
uint16_t	max	Upper threshold of count	R_Main_Calibrate_LOCO()
uint16_t	min	Lower threshold of count	R_Trimming_OCO()

4.4 Lists of Functions

Table **4-4** shows a list of functions.

Table 4-4 Functions

Function Name	Outline
r_calibration_main	Frequency correction processing
r_Config_REMC_callback_receiveend	REMC reception complete interrupts
r_Config_REMC_callback_comparematch	REMC compare match interrupts
r_Config_REMC_callback_specialdata	REMC special data pattern match interrupts
r_is_custom_code_match	Compare match check
r_port_set_LED	LED lighting control
r_Config_TAU0_1_interrupt	STOP mode transition timer interrupts

4.5   Specification of Functions

The function specifications of the sample code are shown below.

---

r_calibration_main

Outline	Frequency correction processing
Header	None
Declaration	void r_calibration_main(void)
Description	Execute the R_Main_Calibrate_LOCO and R_Trimming_OCO functions to correct the frequency of the low-speed on-chip oscillator clock.
	Refer to the application note "RL78/G23 Low-speed On-chip Oscillator (LOCO) Clock Frequency Correction (R01AN5557)" for details.
Argument	None
Return Value	None

---

r_Config_REMC_callback_receiveend

Outline	REMC reception complete interrupts
Header	Config_REMC.h
Declaration	static void r_Config_REMC_callback_receiveend(void)
Description	Sets R_INTR_STATE_RECV_END for the interrupt flag g_intr_state.
Argument	None
Return Value	None

---

r_Config_REMC_callback_comparematch

Outline	REMC compare match interrupts
Header	Config_REMC.h
Declaration	static void r_Config_REMC_callback_comparematch(void)
Description	Sets the REMC compare match flag s_custom_code_match to 1.
Argument	None
Return Value	None

---

r_Config_REMC_callback_specialdata

Outline	REMC special data pattern match interrupts
Header	Config_REMC.h
Declaration	static void r_Config_REMC_callback_specialdata(void)
Description	Sets R_INTR_STATE_SPC_DATA for the interrupt flag g_intr_state.
Argument	None
Return Value	None

---

r_is_custom_code_match

Outline	Compare match check
Header	Config_REMC.h
Declaration	uint8_t r_is_custom_code_match(void)
Description	Returns the REMC compare match flag s_custom_code_match.
	s_custom_code_match is set to 0.
Argument	None
Return Value	1: Compare match occurred.
	0: Compare match is not present.

---

r_port_set_LED

Outline	LED lighting control
Header	Config_PORT.h
Declaration	void r_port_set_LED(uint8_t num)
Description	Turns on the LED specified by argument "num". When R_LED_ALL_OFF is specified, all LEDs are turned off.
Argument	uint8_t num: Number of LED (1 to 8) to be turned on
Return Value	None

r_Config_TAU0_1_interrupt

Outline	STOP mode transition timer interrupts
Header	Config_TAU0_1.h
Declaration	static void __near r_Config_TAU0_1_interrupt(void)
Description	Sets R_INTR_STATE_TIME_OUT for the interrupt flag g_intr_state.
Argument	None
Return Value	None

4.6　Flowcharts

4.6.1　Main Processing

Figure 4-1 and Figure 4-2 show the flowchart of the main processing.
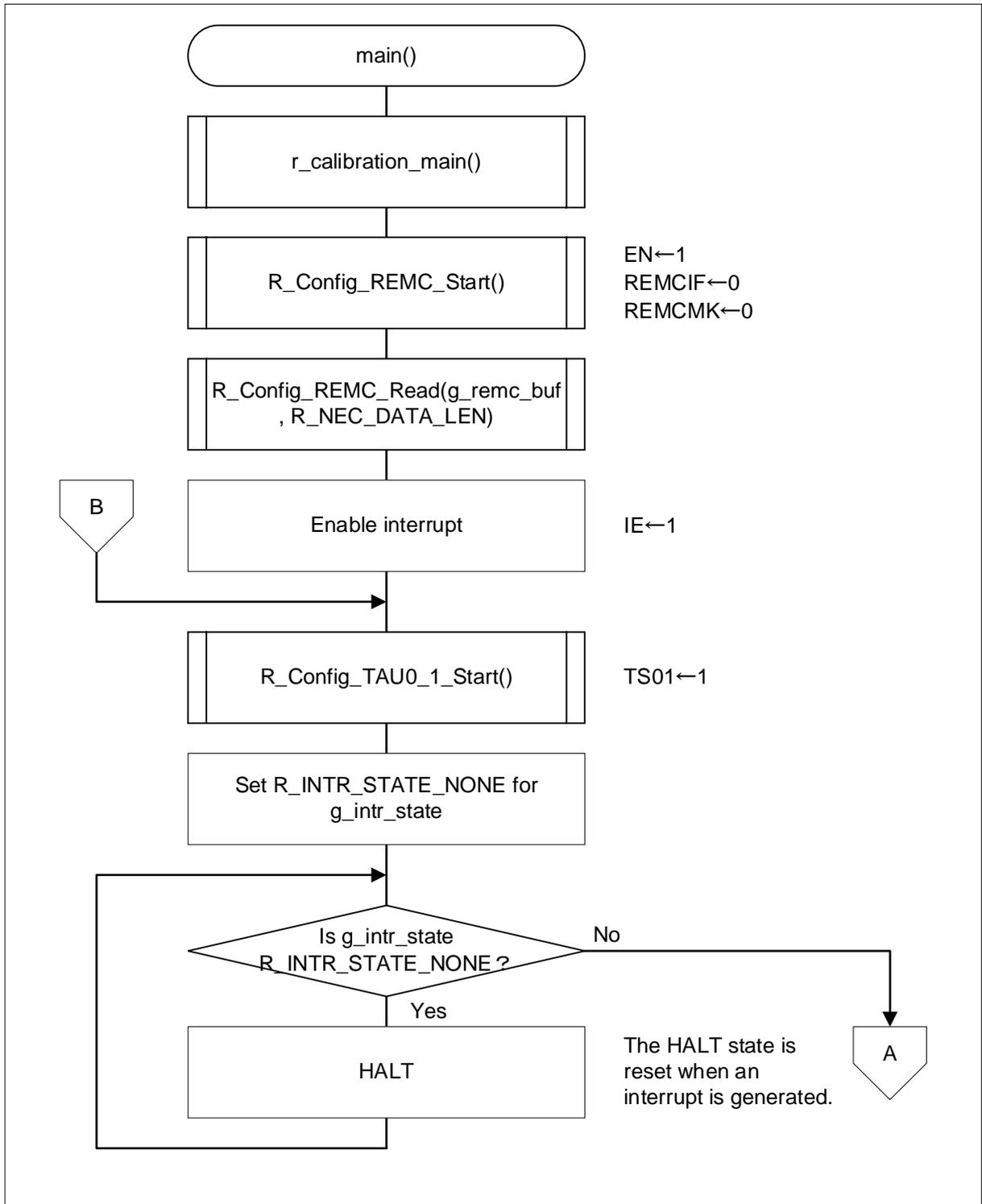
Figure 4-1 Main Processing (1/2)

Figure 4-2 Main Processing (2/2)
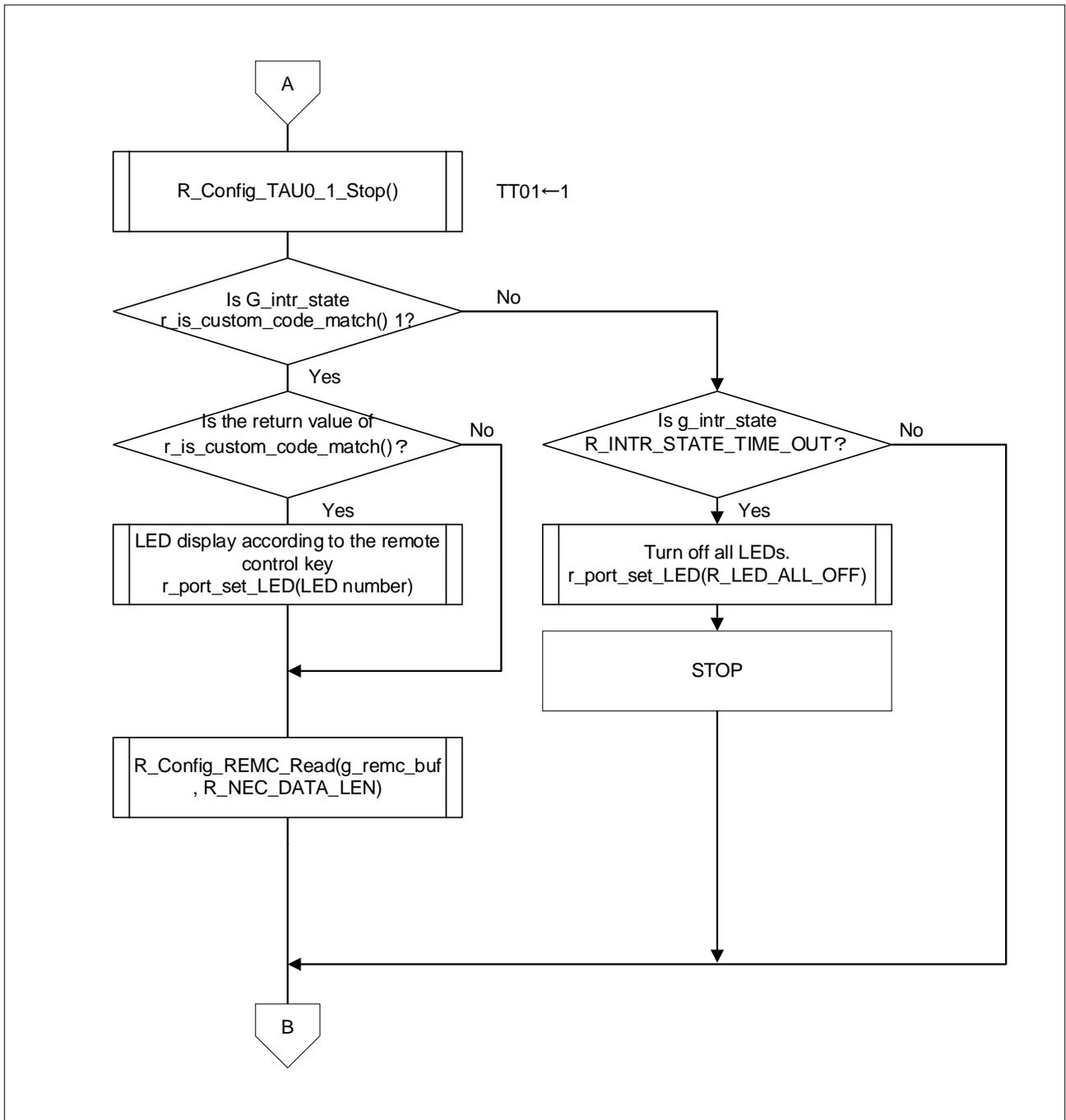
4.6.2 Frequency Correction Processing

Figure 4-3 show the flowchart of the frequency correction processing.

Figure 4-3 Frequency Correction Processing
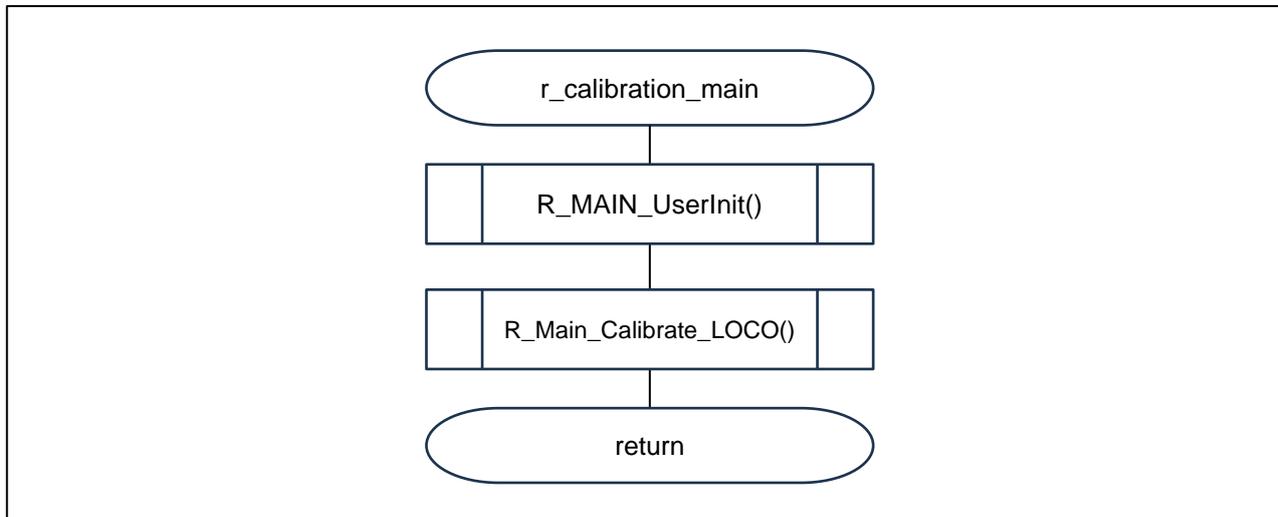
4.6.3 REMC Reception Complete Interrupts

Figure 4-4 shows the flowchart of the REMC **r**eception complete interrupts.

Figure 4-4 REMC Reception Complete Interrupts

```
      ┌──────────────────────────────────────┐
      │   r_Config_REMC_callback_receiveend() │
      └──────────────────────────────────────┘
                        │
      ┌──────────────────────────────────────┐
      │   Set R_INTR_STATE_RECV_END for       │
      │   g_intr_state                        │
      └──────────────────────────────────────┘
                        │
      ┌──────────────────────────────────────┐
      │              return                   │
      └──────────────────────────────────────┘
```
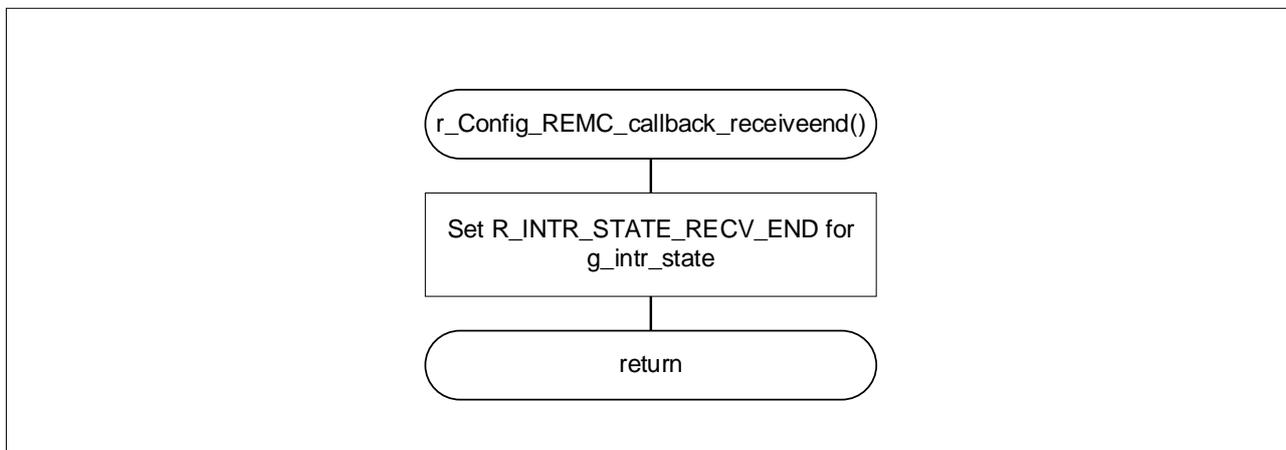
4.6.4 REMC Compare Match Interrupts

Figure 4-5 shows the flowchart of the REMC **c**ompare **m**atch **i**nterrupts.

Figure 4-5 REMC Compare Match Interrupts

```
      ┌──────────────────────────────────────┐
      │  r_Config_REMC_callback_comparematch()│
      └──────────────────────────────────────┘
                        │
      ┌──────────────────────────────────────┐
      │     Set s_custom_code_match to 1      │
      └──────────────────────────────────────┘
                        │
      ┌──────────────────────────────────────┐
      │              return                   │
      └──────────────────────────────────────┘
```
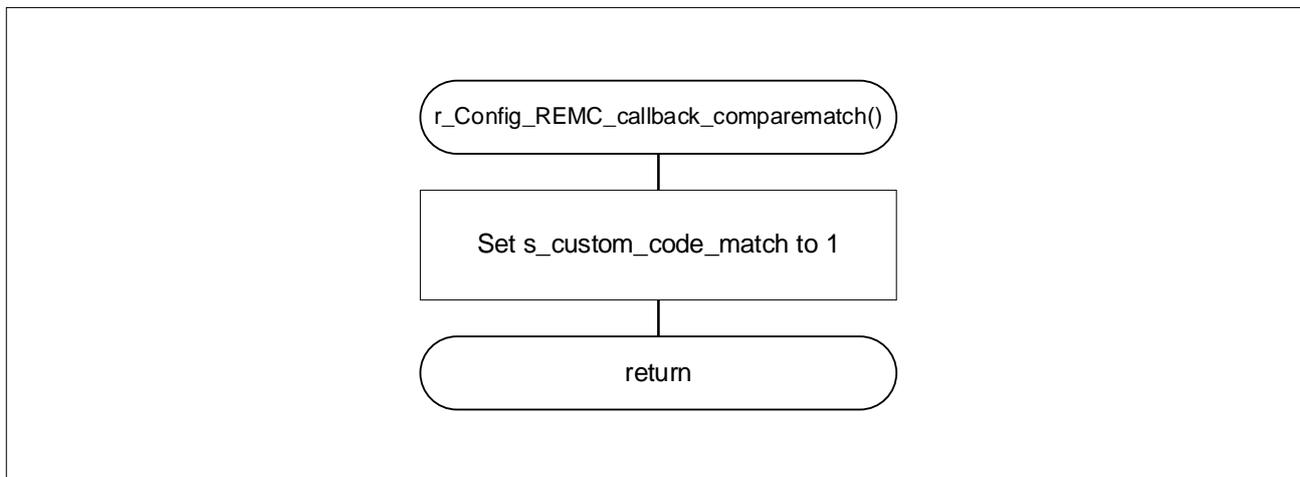
4.6.5 REMC Special Data Pattern Match Interrupts

Figure 4-6 shows the flowchart of the REMC special data pattern match interrupts.

Figure 4-6 REMC Special Data Pattern Match Interrupts

```
         ┌──────────────────────────────────┐
         │  r_Config_REMC_callback_specialdata() │
         └──────────────────────────────────┘
                          │
         ┌──────────────────────────────────┐
         │   Set R_INTR_STATE_SPC_DATA for  │
         │            g_intr_state          │
         └──────────────────────────────────┘
                          │
         ┌──────────────────────────────────┐
         │              return              │
         └──────────────────────────────────┘
```
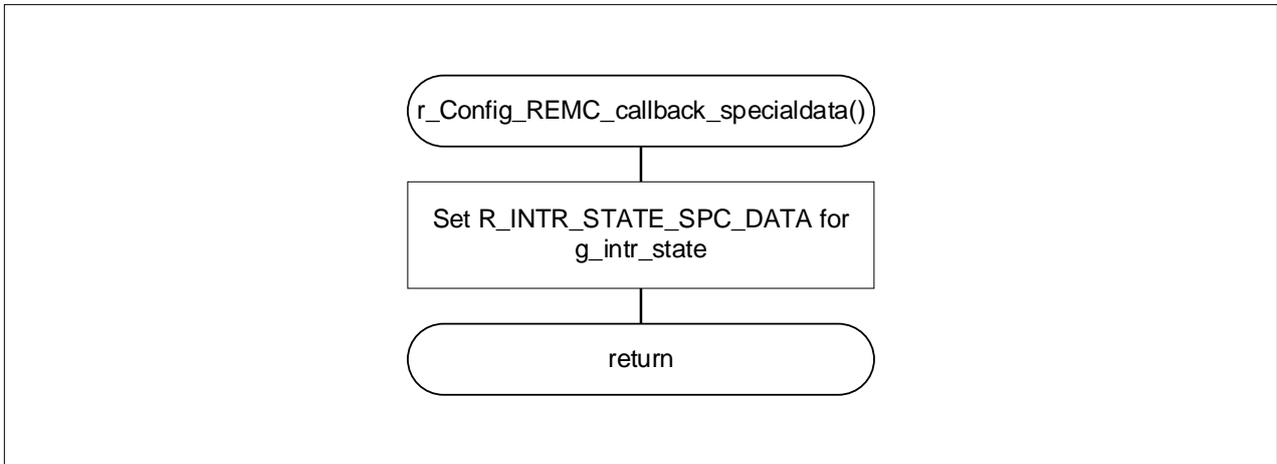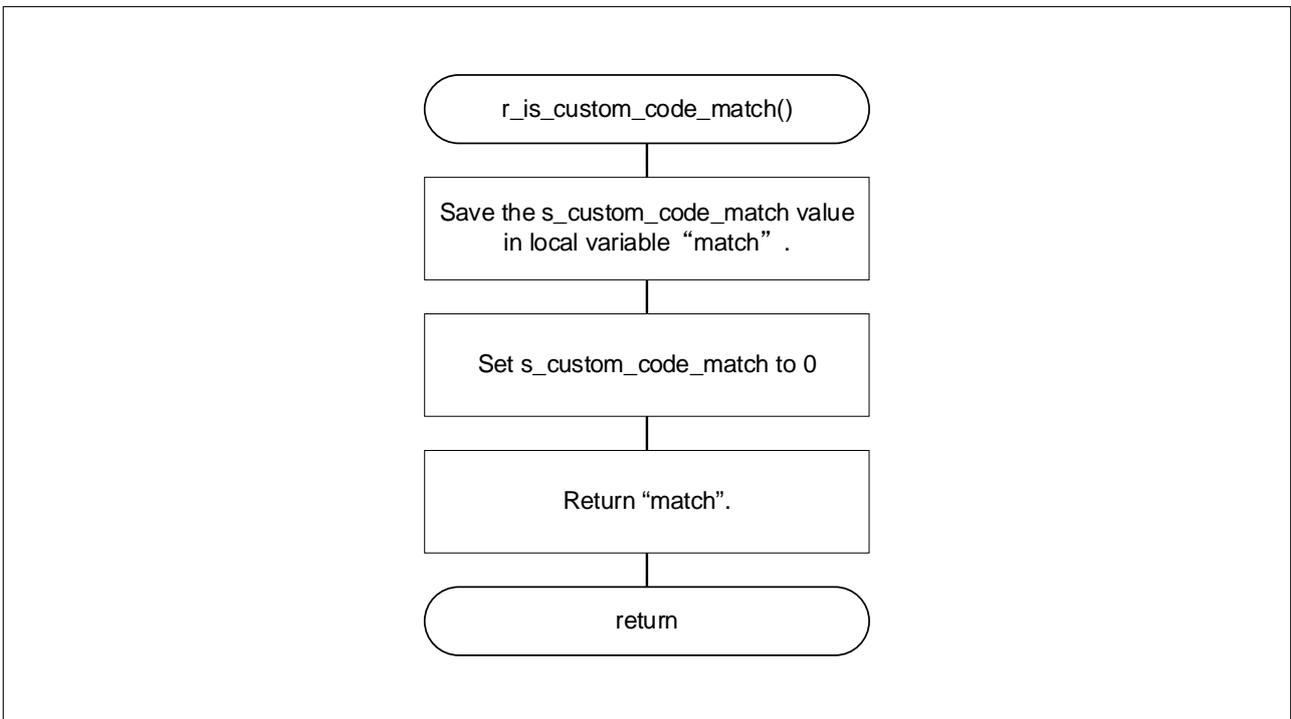
4.6.6 Compare Match Check

Figure 4-7 shows the flowchart for checking compare match.

Figure 4-7 Compare Match Check

```
         ┌──────────────────────────────────┐
         │      r_is_custom_code_match()     │
         └──────────────────────────────────┘
                          │
         ┌──────────────────────────────────┐
         │  Save the s_custom_code_match value │
         │   in local variable "match".     │
         └──────────────────────────────────┘
                          │
         ┌──────────────────────────────────┐
         │    Set s_custom_code_match to 0  │
         └──────────────────────────────────┘
                          │
         ┌──────────────────────────────────┐
         │          Return "match".         │
         └──────────────────────────────────┘
                          │
         ┌──────────────────────────────────┐
         │              return              │
         └──────────────────────────────────┘
```

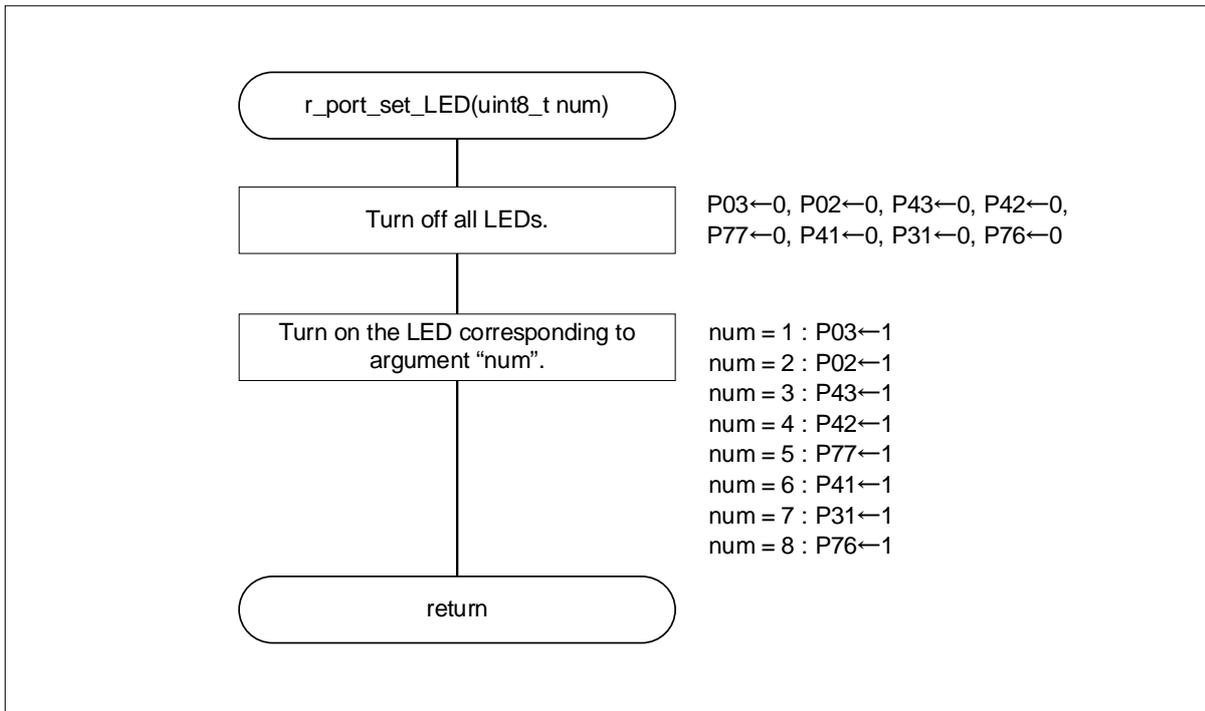### 4.6.7 LED Lighting Control

Figure 4-8 shows the flowchart for LED lighting control.

Figure 4-8 LED Lighting Control

```
        ┌───────────────────────────────┐
        │   r_port_set_LED(uint8_t num)  │
        └───────────────────────────────┘
                        │
        ┌───────────────────────────────┐      P03←0, P02←0, P43←0, P42←0,
        │        Turn off all LEDs.      │      P77←0, P41←0, P31←0, P76←0
        └───────────────────────────────┘
                        │
        ┌───────────────────────────────┐      num = 1 : P03←1
        │  Turn on the LED corresponding │      num = 2 : P02←1
        │     to argument "num".         │      num = 3 : P43←1
        └───────────────────────────────┘      num = 4 : P42←1
                        │                       num = 5 : P77←1
                        │                       num = 6 : P41←1
                        │                       num = 7 : P31←1
        ┌───────────────────────────────┐      num = 8 : P76←1
        │            return              │
        └───────────────────────────────┘
```
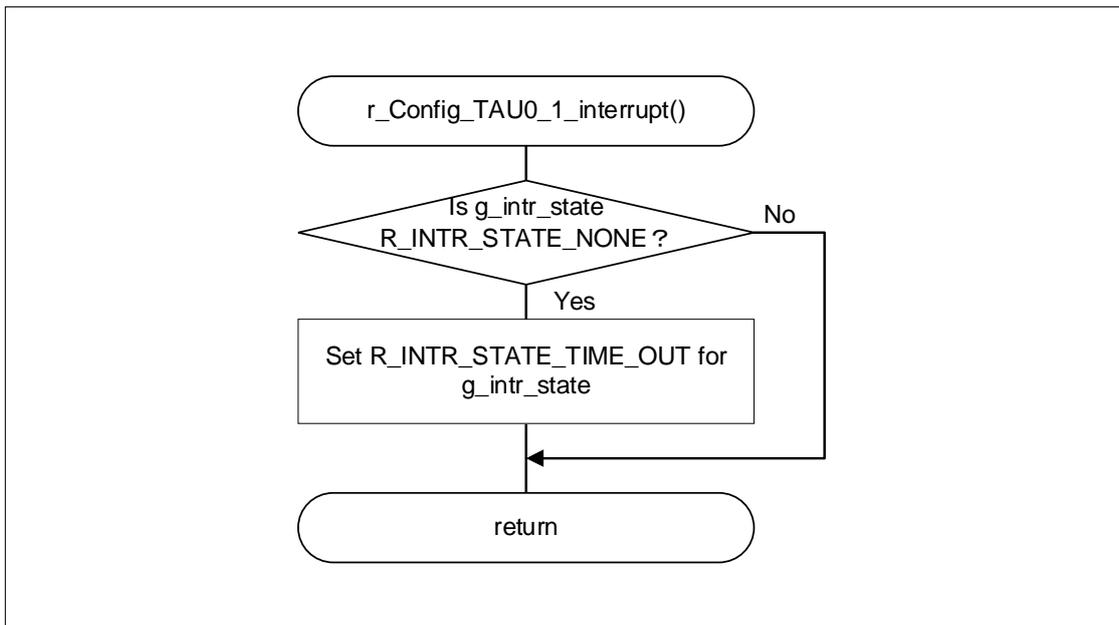
4.6.8 STOP Mode Transition Timer Interrupts

Figure 4-9 shows the flowchart of the STOP mode transition timer interrupts.

Figure 4-9 STOP Mode Transition Timer Interrupts

```
        ┌───────────────────────────────┐
        │    r_Config_TAU0_1_interrupt() │
        └───────────────────────────────┘
                        │
                   ╱─────────────╲
                  ╱ Is g_intr_state ╲      No
                 ⟨ R_INTR_STATE_NONE? ⟩───────┐
                  ╲                 ╱         │
                   ╲───────────────╱          │
                        │ Yes                 │
        ┌───────────────────────────────┐     │
        │  Set R_INTR_STATE_TIME_OUT for │     │
        │         g_intr_state           │     │
        └───────────────────────────────┘     │
                        │◄────────────────────┘
                        │
        ┌───────────────────────────────┐
        │            return              │
        └───────────────────────────────┘
```

5. Sample Code

Sample code can be downloaded from the Renesas Electronics website.

6. Reference Documents

RL78/G23 User's Manual: Hardware (R01UH0896)
RL78 family user's manual software (R01US0015)
RL78/G23 Low-speed On-chip Oscillator (LOCO) Clock Frequency Correction (R01AN5557E)
The latest versions can be downloaded from the Renesas Electronics website.

Technical update
The latest versions can be downloaded from the Renesas Electronics website.

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Revision History

		Description	
Rev.	Data	Page	Point
1.00	2021.12.28	—	First Edition
2.00	2024.2.7	—	Added frequency correction processing

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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