RL78/G23

Middle-speed On-chip Oscillator (MOCO) Clock Frequency Correction

Introduction

This application note explains how to correct the oscillation clock frequency of the middle-speed on-chip oscillator (MOCO) by using the middle-speed on-chip oscillator trimming register (MIOTRM) incorporated in RL78/G23.

An error in the oscillation frequency of the middle-speed on-chip oscillator (MOCO) is detected using a hi-speed on-chip oscillator (HOCO) and the middle-speed on-chip oscillator trimming register (MIOTRM) is adjusted to set the oscillation frequency of the MOCO close to 4 MHz.

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. Specifications

1.1 Overview of Specifications

In this application note, an error in the clock oscillation frequency of the MOCO is detected using a HOCO. The HIOTRM register is adjusted to set the oscillation frequency of the MOCO close to 4 MHz.

When the start switch is pressed, the 32-bit interval timer counts the period of MOCO. The HOCO is used for the count clock of the 32-bit interval timer. If the count value measured by the 32-bit interval timer is beyond the target range, the MIOTRM register is adjusted to set the oscillation frequency of the MOCO close to 4 MHz. The target range of the MOCO oscillation frequency is 4 MHz ± 1.3% (3.948 MHz to 4.052 MHz) under the condition of HOCO frequency ±1.0%.

32-bit interval timer measures period of the middle-speed on-chip oscillator. To enhance accuracy, the pulse interval is measured four times to detect an error in the oscillation frequency of the MOCO.

Caution: Specified times and calibration methods in this sample code are used as examples. In this sample code, input from the start switch is used to start calibration, to simplify processing flows and to provide clear understanding. Adjust the timing of starting calibration and the intervals between start timings according to the system. This application note describes two calibration methods. Select the method most appropriate to the system for use.

Table 1-1 lists the peripheral functions to be used and their uses.

Table 1-1 Peripheral Function and Use

Peripheral Function	Use
Pin input edge detection interrupt	Used for the correction start switch.
32-bit interval timer channel 0, 1	Used for calibration of MOCO.
Timer Array Unit channel 0	Used to prevent chattering on the correction start switch.

1.2 Outline of Operation

The following describes the settings of peripheral functions.

(1) Initialization of external interrupt (INTP0)

The settings are shown in Table 1-2

Table 1-2 Initial Setting Conditions of External Interrupt (INTP0)

Item	Description
Valid edge	Falling edge

(2) Initialization of 32-bit interval timer

Use in 16-bit capture mode.

The settings are shown in Table 1-3.

Table 1-3 Initial Setting Conditions of 32-bit interval timer (Channel 0 and 1)

Item	Description
Operating mode	16-bit capture mode
Operating clock (fITL0)	fIHP
Count source division ratio	fITL0 (non-devided)
Capture trigger	Interrupt on compare match with ITLCMP01
Capture clock	fSXP
Interval of capture trigger	128 counts

(3) Initialization of Timer Array Unit

The settings are shown in Table 1-4.

Table 1-4 Initial Setting Conditions of timer array unit channel 0

Item	Description
Operating mode	Interval timer
Operating clock	CK00
Count source division ratio	fCLK/2^8
Interval period	10 ms

1.3 Description of Calibration Methods

This section describes the two calibration methods to be used in this application note.

Use the 32-bit interval timer in 16-bit capture mode to measure the period of the middle-speed on-chip oscillator.

Select the interrupt on compare match with ITLCMP01 for the capture trigger and generate a trigger every 128 counts with the clock of the middle-speed on-chip oscillator (4 MHz).

Select a high-speed on-chip oscillator clock (32 MHz) for the count clock.

To enhance accuracy, the subsystem clock cycle is measured four times, and the four captured values are added up to calculate an error in the MOCO oscillation clock frequency.

The target frequency range should be within ±2LSB (±0.3%) of the trimming register (MIOTRM).

The calculated value of the count for four captures is the value in the following table.

Table 1-5 Range of Count Values

MOCO Clock Frequency (f_{IM})		Count Value Obtained through Four Times of Capture (Calculated Value)
4MHz		4096
4MHz – 0.3%	3.988MHz	4108.325
4MHz + 0.3%	4.012MHz	4083.749

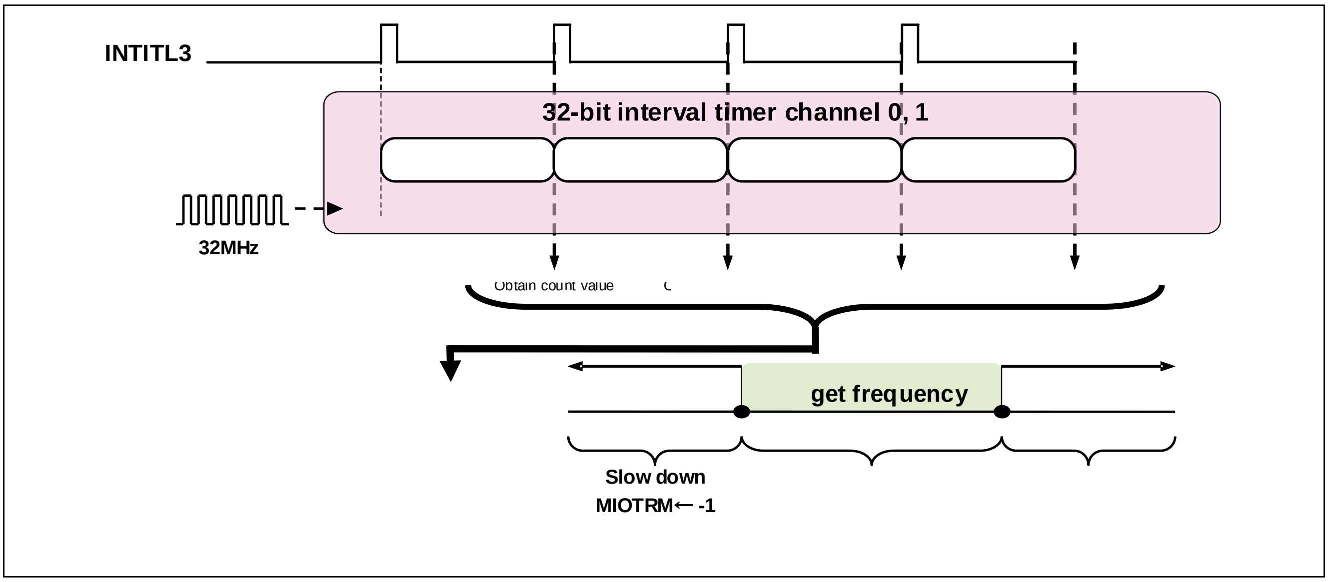
Shown in Table 1-5, the target range of the count value obtained through four times of capture is set to 4084 to 4108.

When the frequency accuracy of the high-speed on-chip oscillator is within ±1.0%, the frequency accuracy of the medium-speed on-chip oscillator will be within ±1.3%.

If the obtained count value is 4083 or less, this means that the MOCO clock is slower than the target frequency. If it is 4109 or more, this means that the MOCO clock is faster than the target frequency. Determine the direction of correction of the MIOTRM register value (speeding up/slowing down), according to the count value, and perform calibration by incrementing the MIOTRM register value by ±1. When the count value is within the target range, the calibration is completed.

Figure 1-1 gives an example of calibration.

Figure 1-1 Example of Calibration



2. Operation Confirmation Conditions

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

Table2-1 Operation Confirmation Conditions

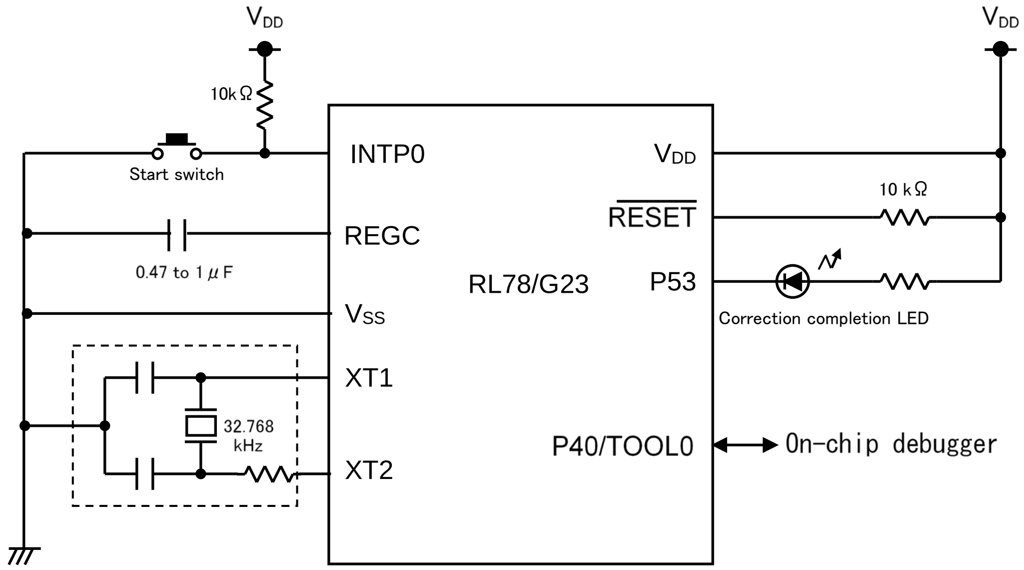
Item	Description
MCU used	RL78/G23 (R7F100GLG)
Board used	RL78/G23 Fast Prototyping Board (RTK7RLG230CLG000BJ)
Operating frequency	High-speed on-chip oscillator clock: 32 MHz CPU/peripheral hardware clock: 32 MHz Middle-speed on-chip oscillator (MOOC) clock: 4MHz
Operating voltage	3.3 V (can be operated at 1.8 V to 5.5 V) 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)
Integrated development environment (CS+)	CS+ V8.05.00 from Renesas Electronics Corp.
C compiler (CS+)	CC-RL V1.10.00 from Renesas Electronics Corp.
Integrated development environment (e2studio)	e2 studio V2021-04 (21.4.0) from Renesas Electronics Corp.
C compiler (e2studio)	CC-RL V1.10.00 from Renesas Electronics Corp.
Integrated development environment (IAR)	IAR Embedded Workbench for Renesas RL78 V4.21.1 from IAR Systems Corp.
C compiler (IAR)	IAR C/C++ Compiler for Renesas RL78 V4.21.1 from IAR Systems Corp.
Smart configurator (SC)	V1.0.1 from Renesas Electronics Corp.
Board support package (BSP)	V1.00 from Renesas Electronics Corp.

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



Caution: 1. The purpose of this circuit is only to provide the connection outline and the circuit is simplified accordingly. When designing and implementing an actual circuit, provide proper pin treatment and make sure that the hardware's electrical specifications are met (connect the input-only ports separately to V_{DD} or V_{SS} via a resistor).

2. Connect any pins whose name begins with EV_{SS} to V_{SS} and any pins whose name begins with EV_{DD} to V_{DD}, respectively.

3. V_{DD} must be held at not lower than the reset release voltage (V_{LVD}) that is specified as LVD.

3.2 List of Pins Used

Table3-1 lists the pins used and their functions.

Table3-1 Pins used and their functions.

Pin Name	I/O	Description
P137/INTP0	Input	Start switch: Connects the switch for starting calibration.
P53	Output	Correction completion LED: Connects the LED that indicates correction completion.

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/010C0H	11101111B	Disables the watchdog timer. (Counting stopped after reset)
000C1H/010C1H	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/010C2H	11101000B	HS mode, High-speed on-chip oscillator clock (f_{IH}): 32 MHz
000C3H/010C3H	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 Constants

Constant Name	Setting Value	Description
MIOTRM_MAX	11111111B	Maximum value of the MIOTRM register
MIOTRM_MIN	00000000B	Minimum value of the MIOTRM register
CCNT_MAX	4109	Upper threshold of clock count
CCNT_MIN	4083	Lower threshold of clock count

4.3 List of Variables

Table 4-3 lists the global variables.

Table 4-3 Global Variables

Type	Variable Name	Contents	Function Used
uint8_t	calibration_count	Calibration count value	R_Main_Calibrate_MOCO() R_Trimming_OCO()
uint8_t	calibrate_history	Calibration history	R_Main_Calibrate_MOCO() R_Trimming_OCO()
uint16_t	count_value	Count value (Used as an argument of R_Trimming_OCO)	R_Main_Calibrate_MOCO() R_Trimming_OCO()
uint16_t	max	Upper threshold of count	R_Main_Calibrate_MOCO() R_Trimming_OCO()
uint16_t	min	Lower threshold of count	R_Main_Calibrate_MOCO() R_Trimming_OCO()

4.4 List of Functions

Table 4-4 shows a list of functions.

Table 4-4 Functions

Function Name	Outline
R_Main_Calibrate_MOCO	Calibration process
R_Trimming_OCO	MOCO clock correction

4.5 Specification of Functions

The function specifications of the sample code are shown below.

[Function Name] R_Main_Calibrate_MOCO

Outline	Calibration process
Header	None
Declaration	void R_Main_Calibrate(void)
Description	Frequency measurement and correction process for the middle-speed on-chip oscillator.
Argument	None
Return Value	None
Outline	None

[Function Name]R_Trimming_OCO

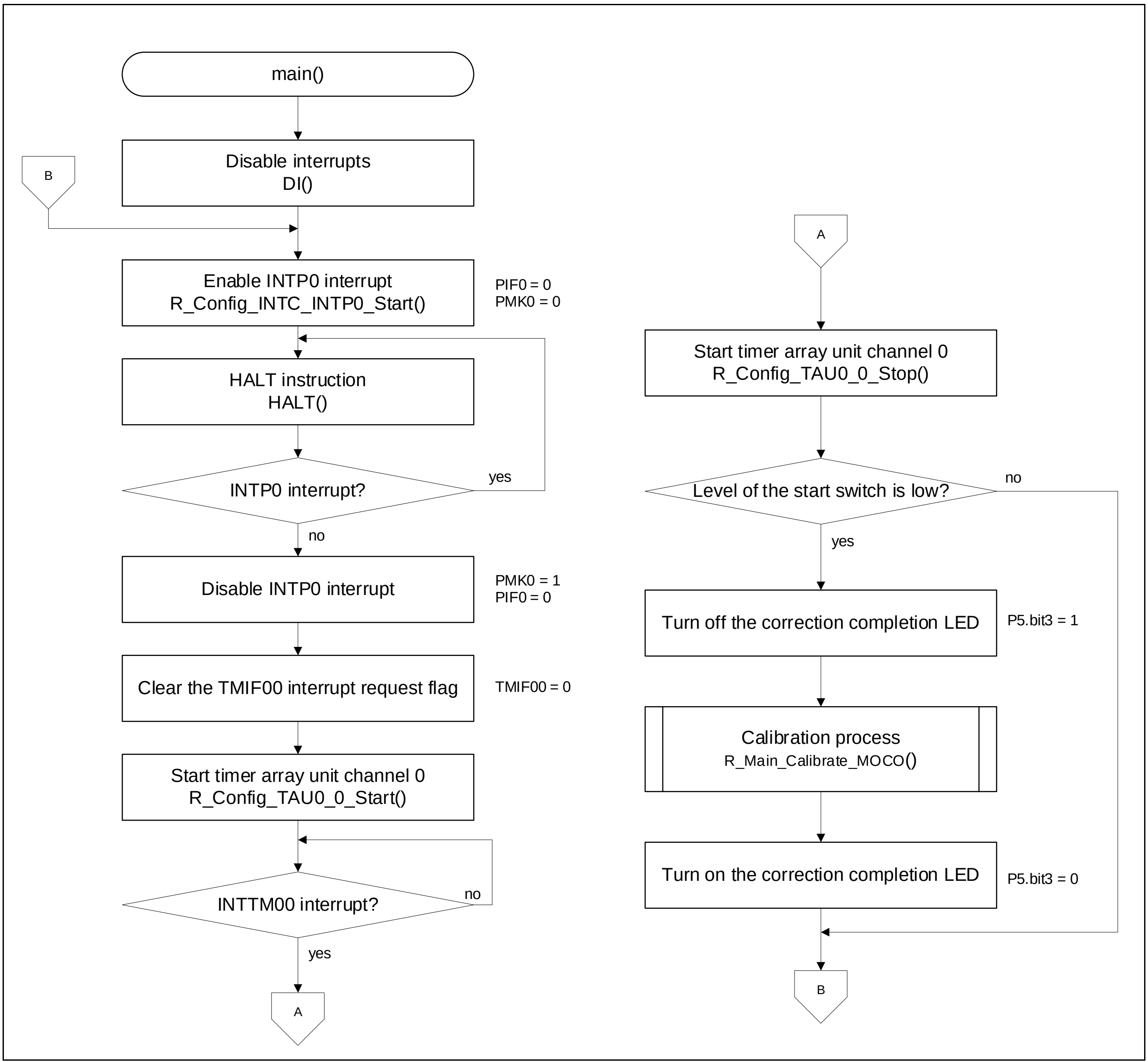
Outline	MOCO clock correction	
Header	None	
Declaration	uint8_t R_Trimming_OCO(uint16_t count)	
Description	This function sets the MIOTRM according to the argument and then determines whether to continue calibration.	
Argument	count	: [Target clock count value]
Return Value	[0]: Calibration ends. [1]: Calibration continues.	
Outline	None	

4.6 Flowcharts

4.6.1 Main Processing

Figure 4-1 shows the flowchart of the main processing.

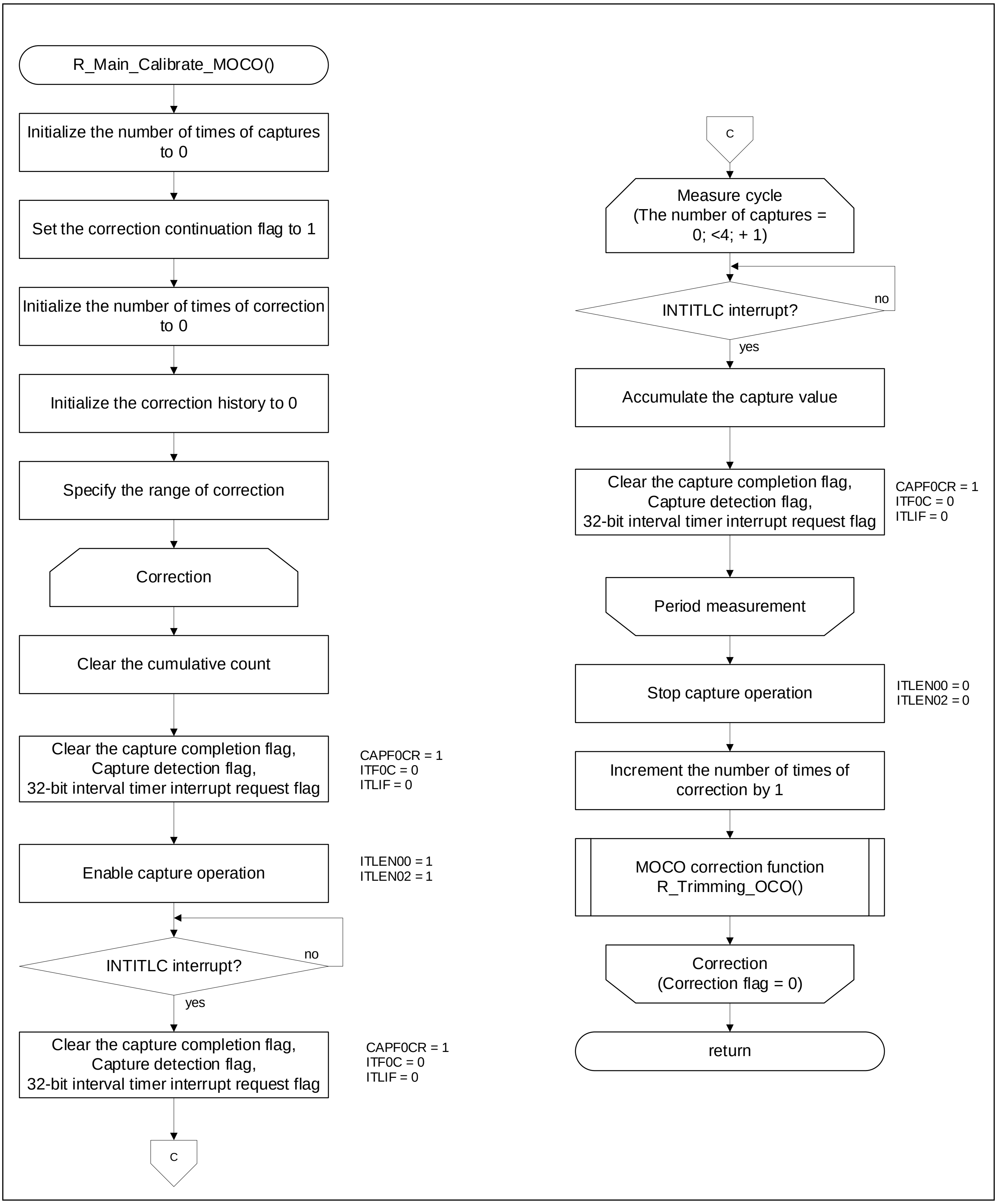
Figure 4-1 Main Processing



4.6.2 Calibration process

Figure 4-2 show the flowchart for calibration process.

Figure 4-2 Calibration process



4.6.3 MOCO Correction Function

Figure 4-3 and Figure 4-4 show the flowcharts for the MOCO correction function.

Figure 4-3 MOCO Correction Function (1/2)

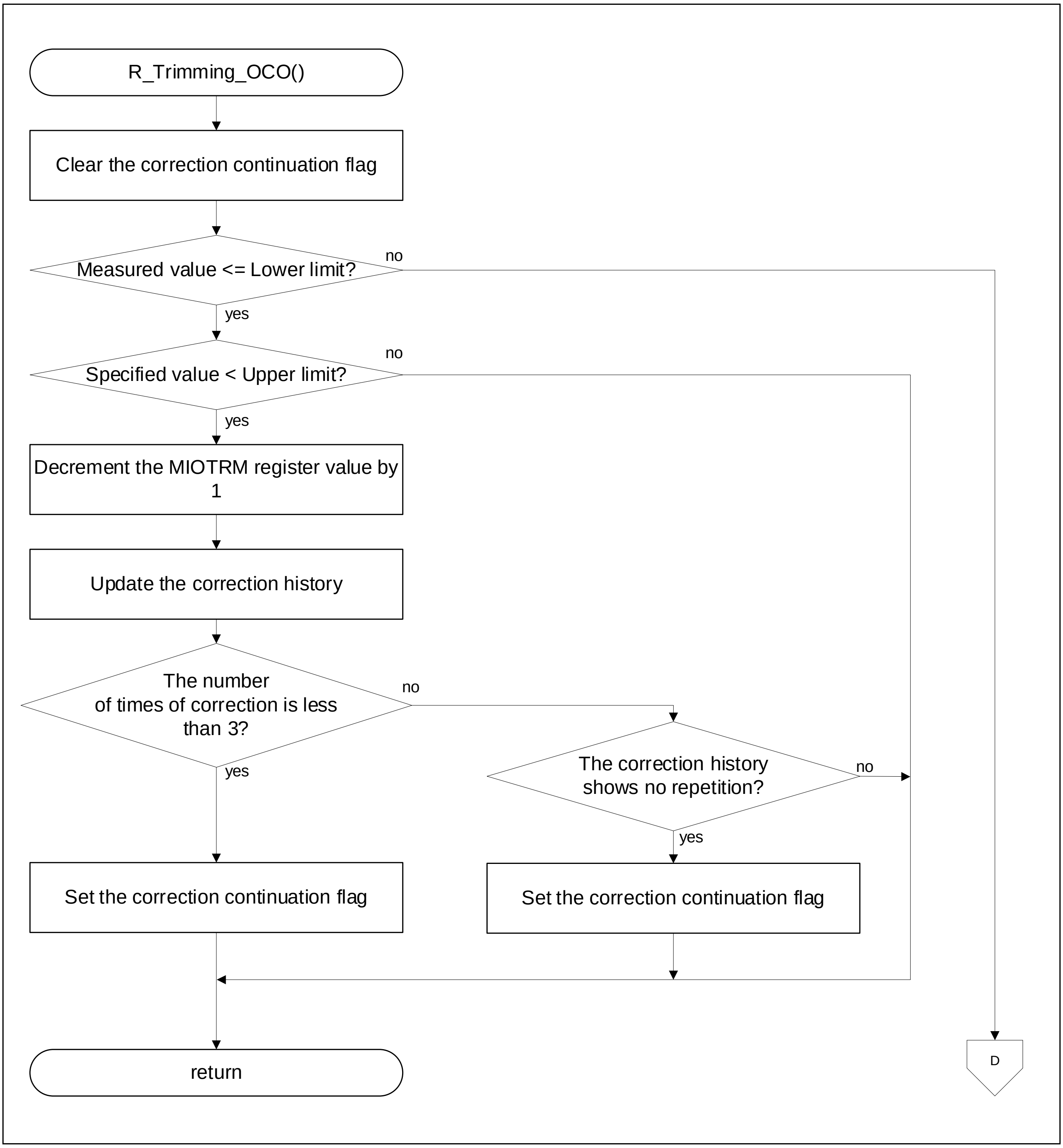
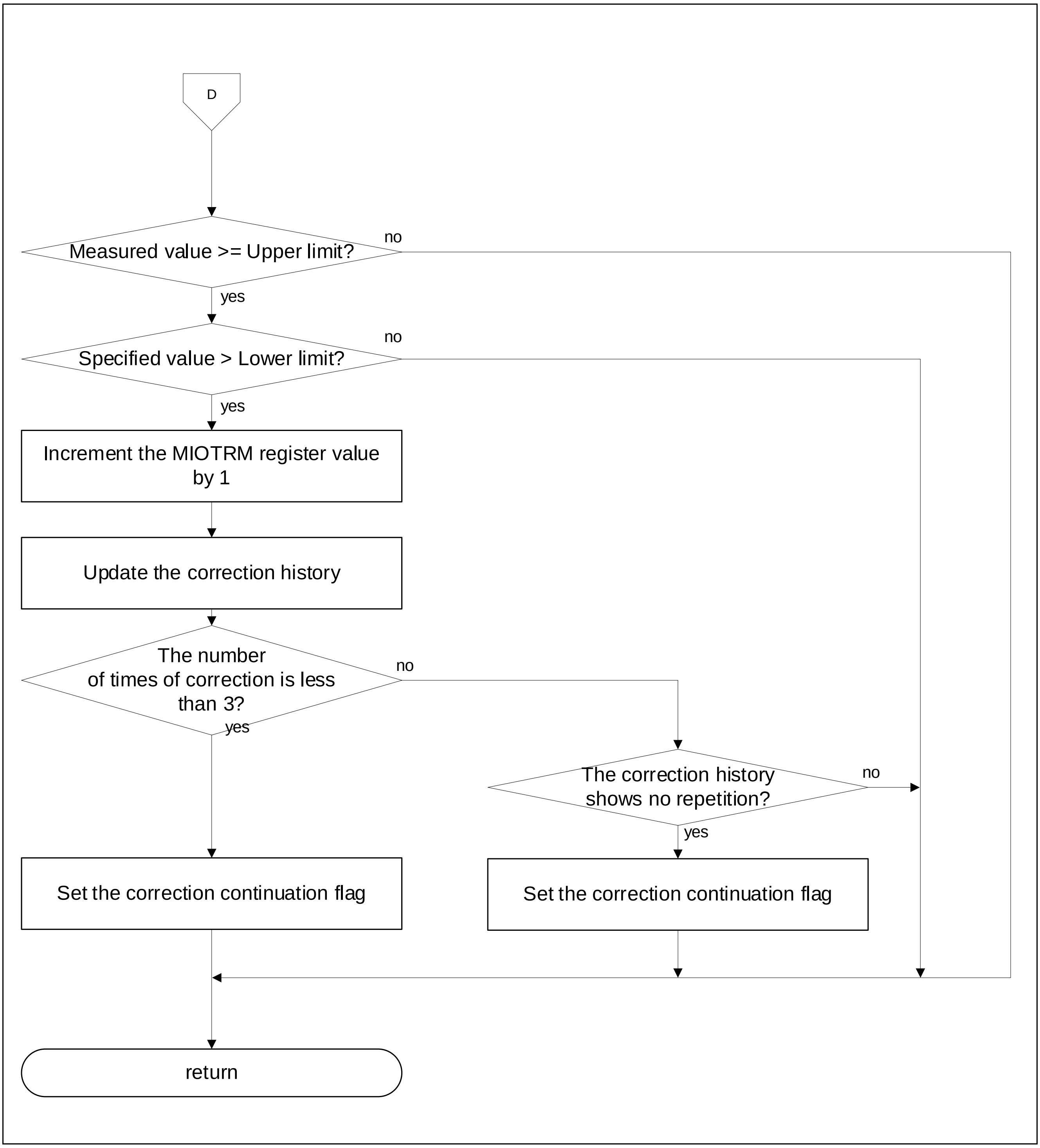


Figure 4-4 MOCO Correction Function (2/2)



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

Technical update
The latest versions 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	Apr.01.21	—	First Edition
1.01	May.18.21	7	Updated the Operation Confirmation Conditions

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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