RL78/G24

Over-Current Protection Using the Timer KB3 Forced Output Stop Function

Introduction

This application note describes an example of using the forced output stop function of RL78/G24 timer KB3. A power supply circuit configured outside the MCU might be placed in the over-voltage or over-current state due to an error such as short-circuit. In such cases, the forced output stop function protects the circuit by setting the timer output to Hi-Z or fixed output state without using CPU program control.

Target Device

RL78/G24

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. Overview of Specifications

The PWM output function of timer KB3 controls the LED brightness. At this time, the current measurement resistance converts the LED current to voltage, and then the comparator determines whether an over-current condition exists. If an over-current condition is detected, the LED is turned off by fixing the KBO00 output to inactive level.

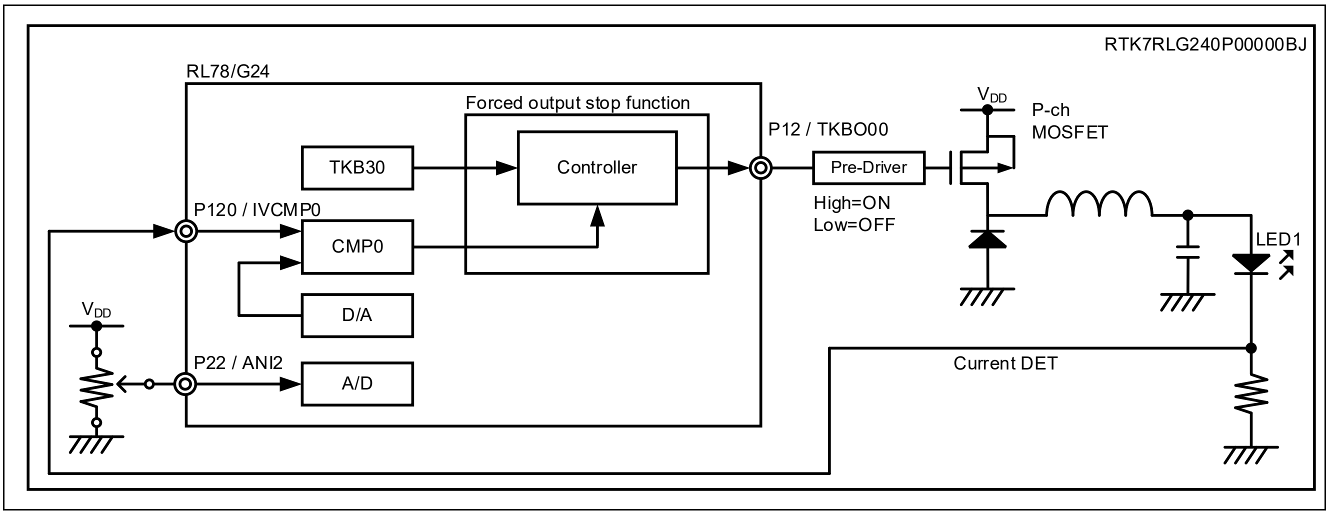
The duty ratio of timer KB3 is changed according to the input voltage to the P22/ANI2 pin to change the LED current. If increasing the duty ratio causes the over-current detection threshold to be exceeded, timer KB3 is placed in the forced output stop status. One second later, the software generates a forced output stop cancellation trigger to cancel the forced output stop status. However, whenever an over-current condition exists, trigger input is disabled and the forced output stop status is not canceled.

Table 1-1 describes the peripheral functions and their usage. Figure 1-1 shows the system configuration for over-current protection using the forced output stop function 1.

Table 1-1 Peripheral Functions and Their Usage

Peripheral Function	Usage
16-bit timer KB30 (TKB30)	PWM output from the TKBO00 pin and TKBO01 pin
Comparator (CMP0)	Compares the input voltage and the D/A converter 0 for reference voltage
D/A Converter (DAC0)	Sets the over current detection threshold
A/D converter (Advanced mode enabled)	Perform A/D conversion of analog input voltage of the P22/ANI2 pin

Figure 1-1 System Configuration for Over-Current Protection Using Forced Output Stop Function 1

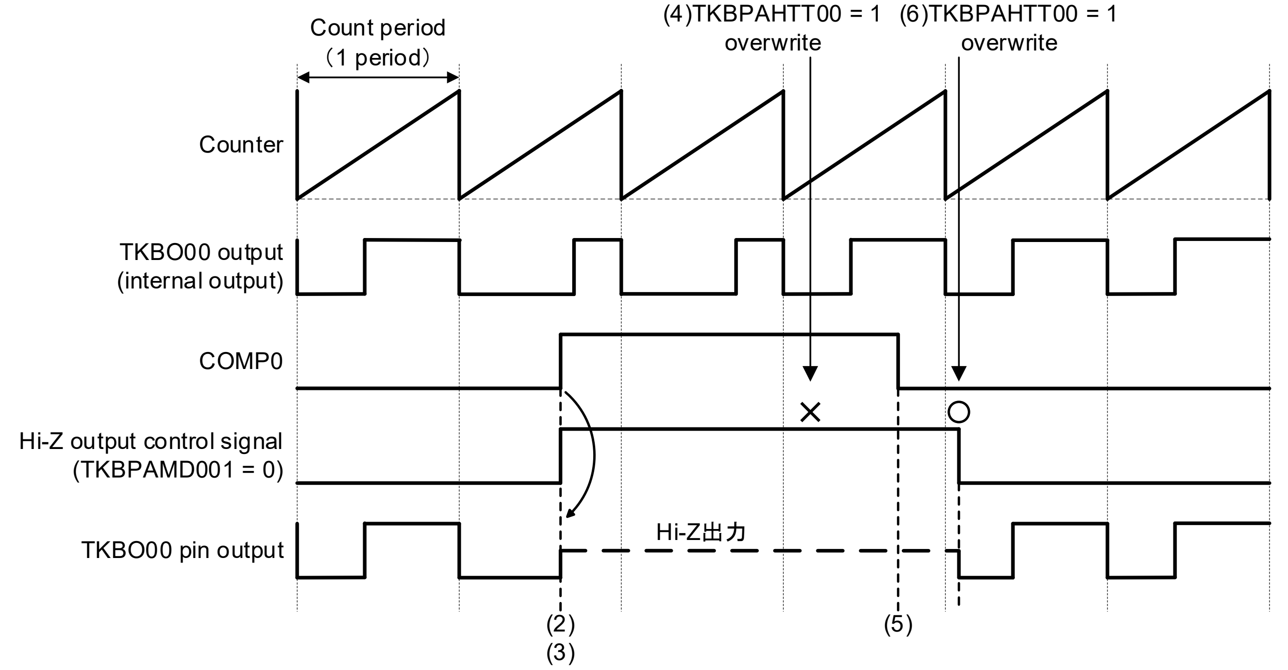


Note By using “RL78/G24 DC/DC LED DC/DC LED Control Evaluation Board”, it is possible to operate the evaluation board standalone without the need for circuit assembly. For details, please refer to “RL78 Family RTK7RLG240P00000BJ RL78/G24 DC/DC LED Control Evaluation Board User’s Manual”.

Figure 1-2 shows an example of over-current protection output using forced output stop function 1.

(1) TKBO00 of timer KB3 is set to PWM output.
(2) When the comparator detects a voltage higher than the reference voltage, COMP0 is set to High.
(3) Upon detection of the rising edge in (2), TKBO00 after control is set to Hi-Z output.
(4) Writing 1 to the cancellation trigger (TKBPAHTT00 bit) is disabled in the over current state.
(5) When the voltage drops below the reference voltage, COMP0 is set to Low.
(6) After (5), writing 1 to the cancellation trigger (TKBPAHTT00 bit) resumes the PWM output from TKBO00.

Figure 1-2 Example of Over-Current Protection Output Using Forced Output Stop Function 1



2. Operation Confirmation Conditions

The sample code described in this application note has been confirmed under the following conditions.

Table 2-1 Operation Confirmation Conditions

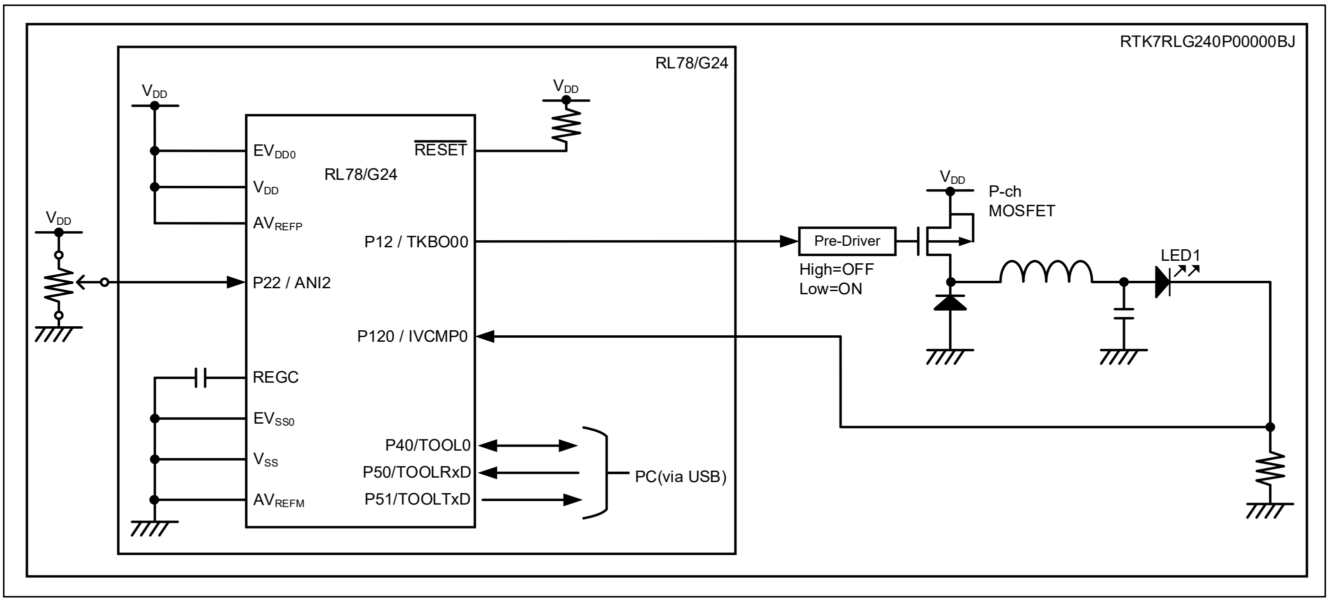
Item	Description
MCU used	RL78/G24 (R7F101GLG)
Operating frequency	• High-speed On-chip Oscillator Clock (f_{HOCO}): 8MHz • PLL Oscillator Circuit Output (f_{PLL}): 96MHz • CPU/Periferal Hardware Clock (f_{CLK}): 48MHz
Operating voltage	• 3.3V (Can operate between 2.7V to 5.5V) • LVD0 Operation (V_{LVD0}): Reset Mode Rising edge TYP. 2.97V Falling edge TYP. 2.91V
Integrated development environment (CS+)	CS+ for CC V8.12.00 Manufactured by Renesas Electronics
C compiler (CS+)	CC-RL V1.14.00 Manufactured by Renesas Electronics
Integrated development environment (e^2 studio)	e^2 studio 2024-10 (24.10.0) Manufactured by Renesas Electronics
C compiler (e^2 studio)	CC-RL V1.14.00 Manufactured by Renesas Electronics
Integrated development environment (IAR)	IAR Embedded Workbench for Renesas RL78 V5.10.3 Manufactured by IAR Systems
C compiler (IAR)	
Smart Configurator	V.1.11.0
Board Support Package (r_bsp)	V.1.70
Emulator	CS+, e^2 studio: COM port IAR: E2 Emulator Lite
Board used	RL78/G24 DC/DC Control Evaluation Board (RTK7RLG240P00000BJ)

3. Hardware Description

3.1 Example of Hardware Configuration

Figure 3-1 shows the hardware configuration example used in the sample code for this application.

Figure 3-1 Example of Hardware Configuration



Note 1. This simplified circuit diagram was created to show an overview of connections only. When actually designing your circuit, make sure the design includes appropriate pin handling and meets electrical characteristic requirements (connect each input-only port to VDD or VSS through a resistor).

Note 2. Connect any pins whose name begins with EVSS to VSS, and any pins whose name begins with EVDD to VDD, respectively.

Note 3. VDD must not be lower than the reset release voltage (VLVD0) that is specified for the LVD0.

Note 4. It is prohibited to fix the TKBO terminal to a Low output using a general-purpose output port because the “RL78/G24 DC/DC LED Control Evaluation Board” controls the P-channel MOSFET.
The LED may be damaged due to overcurrent.

3.2 List of used Pins

Table 3-1 shows the pins used and their functions.

Table 3-1 Pins Used and Their Functions

Pin Name	I/O	Function
P12 / TKBO00	Output	PWM Output (LED1 control)
P120 / IVCMP0	Input	LED1 Current sensing Analog Input
P22 / ANI2	Input	LED1 Brightness control potentiometer

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 Description

4.1 Smart Configurator Settings

The following describes the Smart Configurator settings in this sample code. The items and their descriptions in each table in the Smart Configurator settings are contained in the description of the configuration screen.

4.1.1 System settings

The following shows the system settings used in this sample code.

Note that the system settings used in this sample code are the same for integrated development environments e^2 studio and CS+ but are different for IAR. Specify appropriate settings according to your environment.

Figure 4-1 shows the system settings used in this sample code (e^2 studio and CS+).

To perform COM port debugging on the RL78/G24 Fast Prototyping Board (RTK7RLG240C00000BJ), you need to appropriately specify the settings in the integrated development environment (e^2 studio and CS+). For details, see **7.1 Using COM Port Debugging with the e^2 studio** in the **RL78/G24 Fast Prototyping Board User's Manual (R20UT5091)**.

Figure 4-1 System Configuration (e^2 studio, CS+)

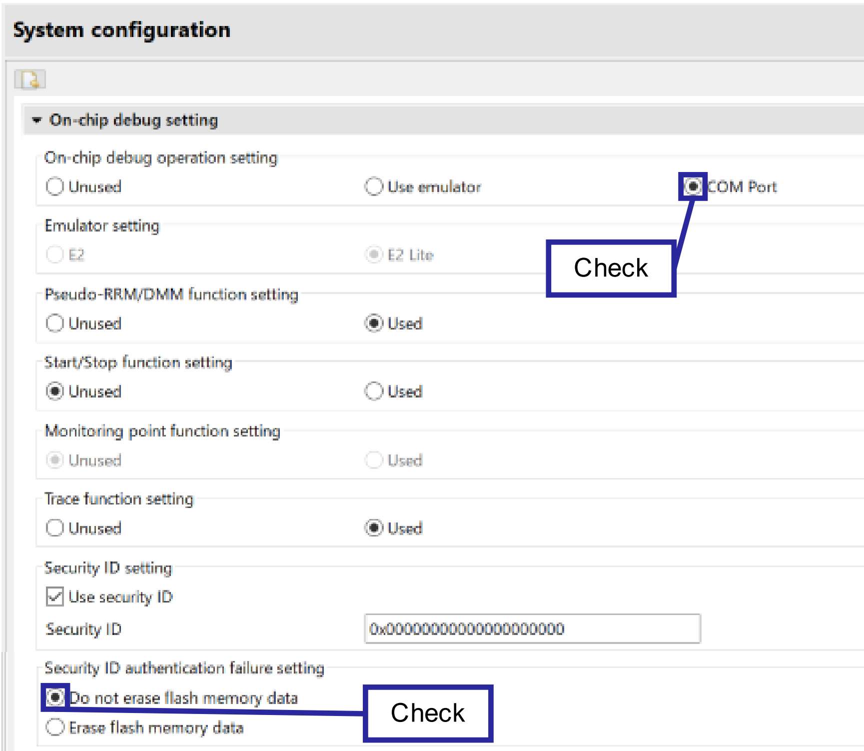
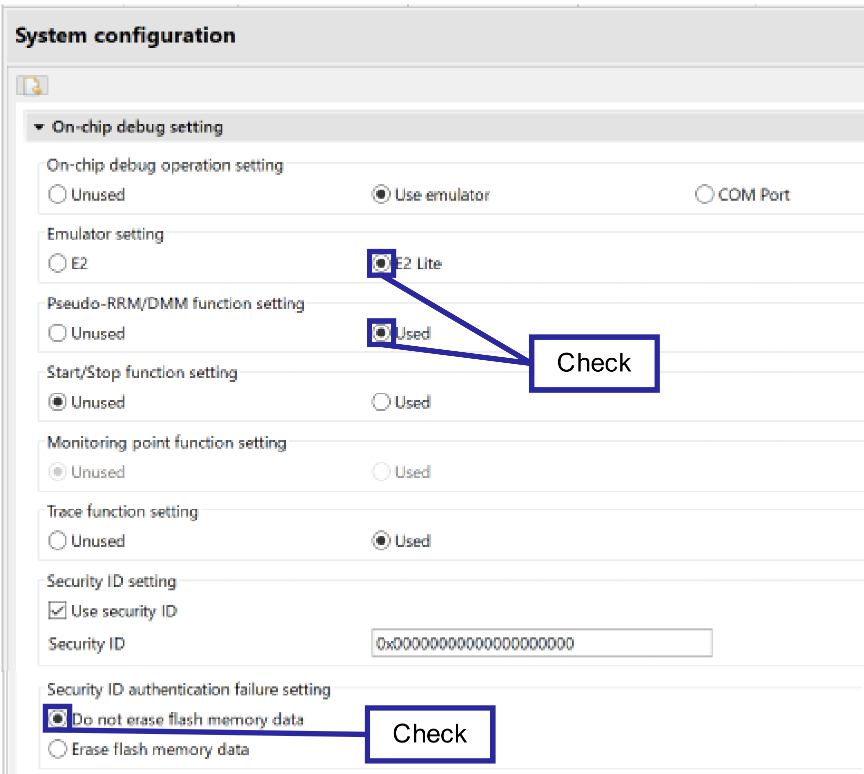


Figure 4-2 shows the system configurations used in this sample program for IAR.

Figure 4-2 System Configurations (IAR)



4.1.2 Component Configurations

This section presents the component configurations used in this sample code.

Table 4-1 Component Configurations (Timer KB3)

Item	Content
Component	PWM output
Configuration Name	Config_TKB0
Resource	TKB0
Operation	Standalone mode (period controlled by the TKBCRn0 register)

Figure 4-3 Configuration of Timer KB3

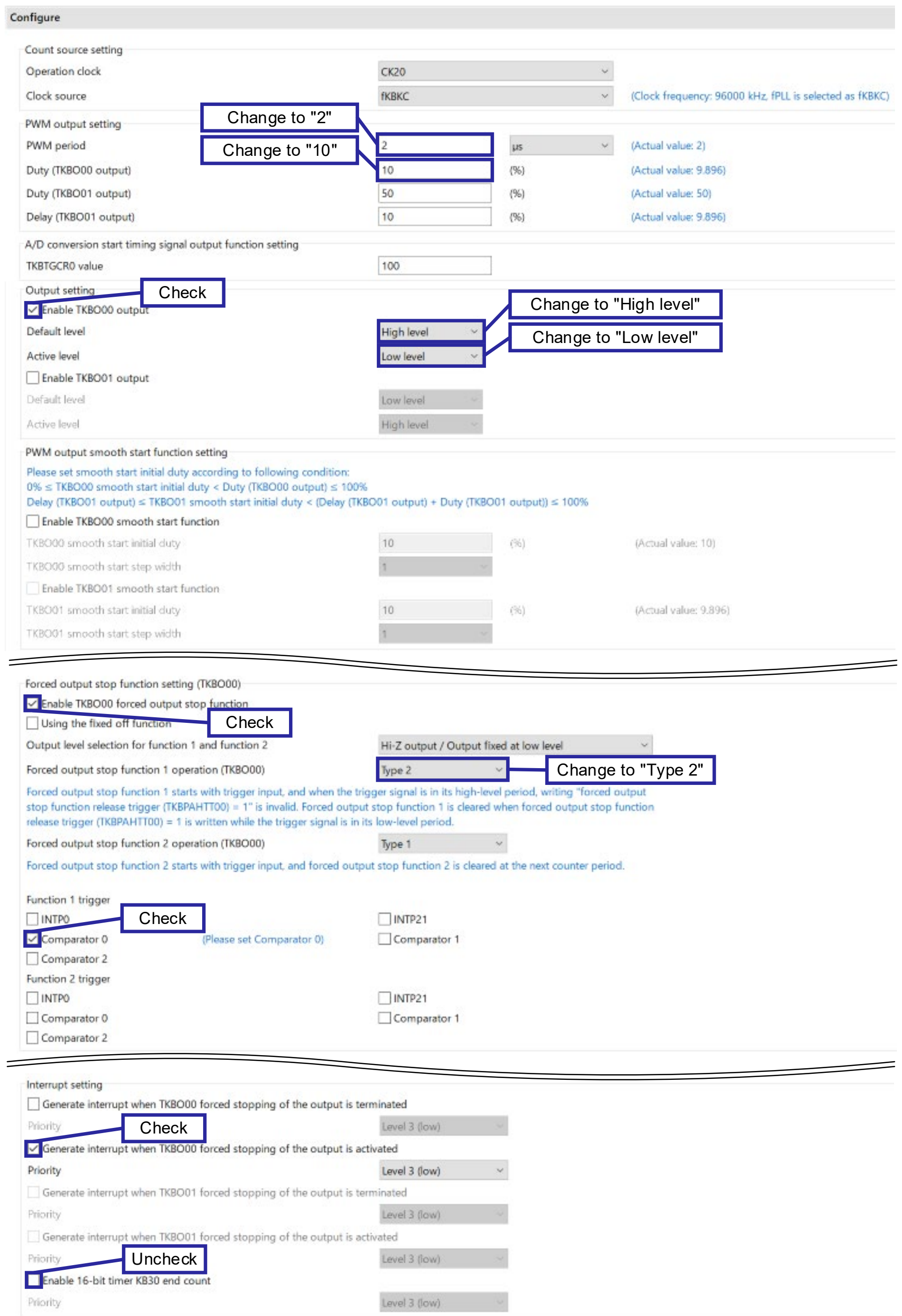


Table 4-2 Component Configurations (D/A Converter)

Item	Content
Component	D/A converter
Configuration Name	Config_DAC0
Resource	DAC0

Figure 4-4 Configuration of D/A converter

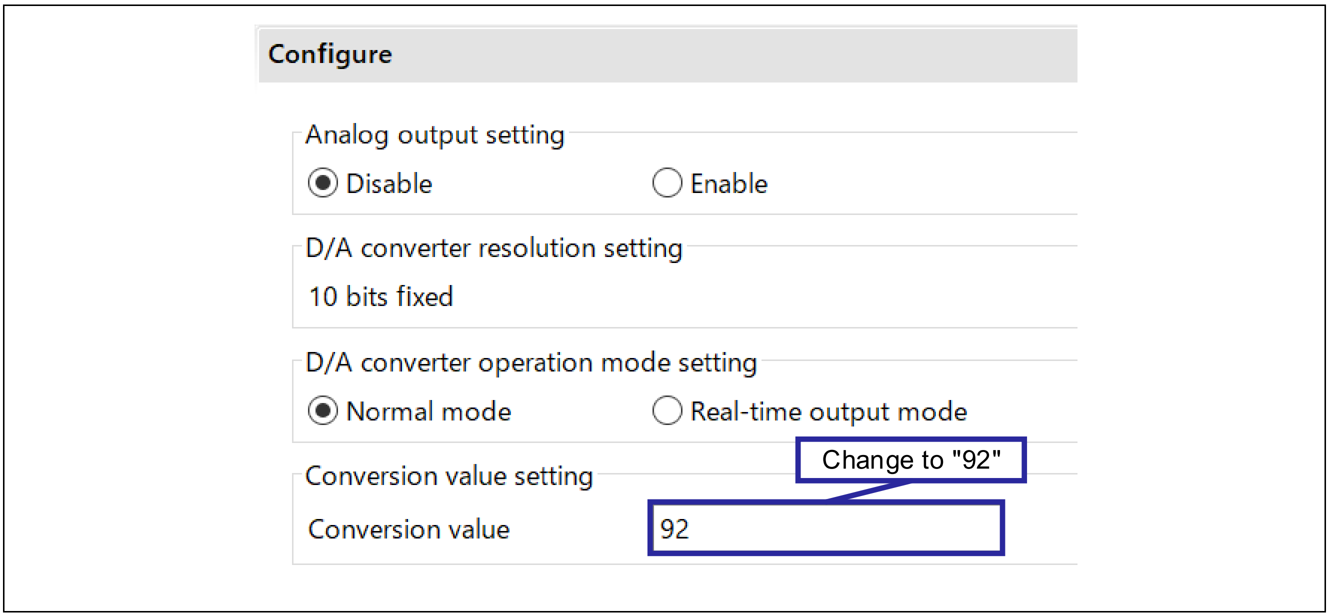


Table 4-3 Component Configurations (Comparator)

Item	Content
Component	Comparator
Configuration Name	Config_COMP0
Resource	COMP0

Figure 4-5 Configuration of Comparator

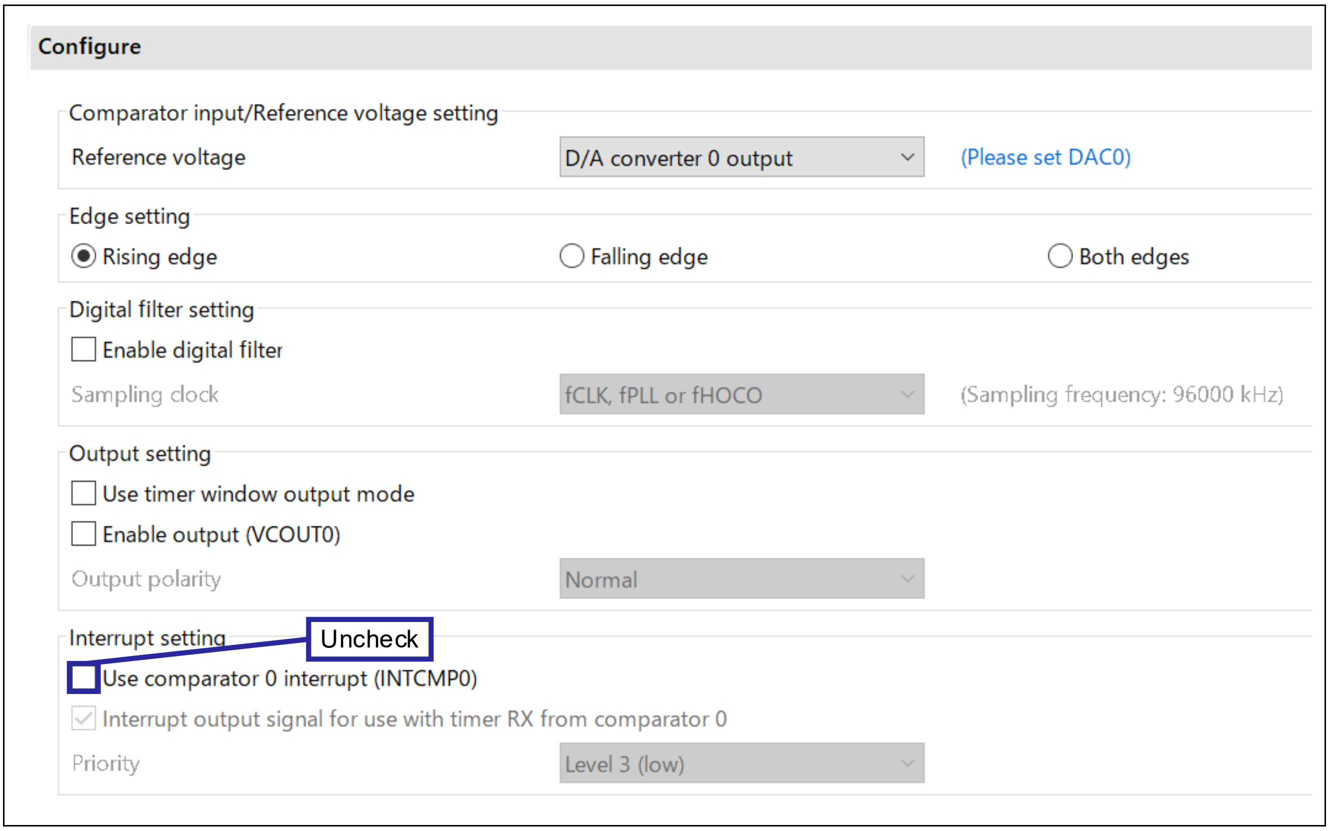


Table 4-4 Component Configurations (A/D Converter)

Item	Content
Component	A/D Converter
Configuration Name	Config_ADC
Resource	ADC
Operation Mode	Advanced mode

Figure 4-6 Configuration of A/D Converter (1/2)

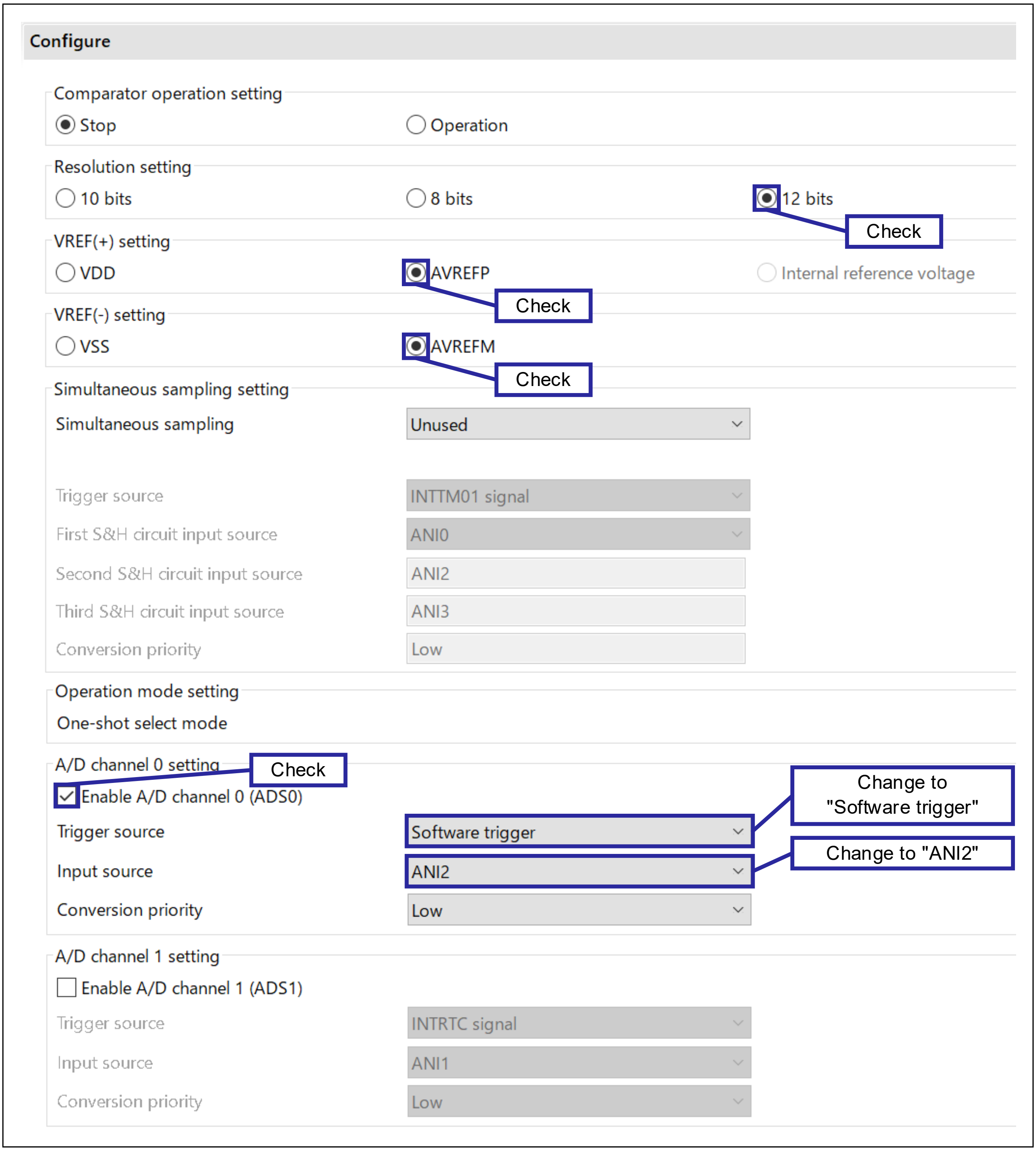
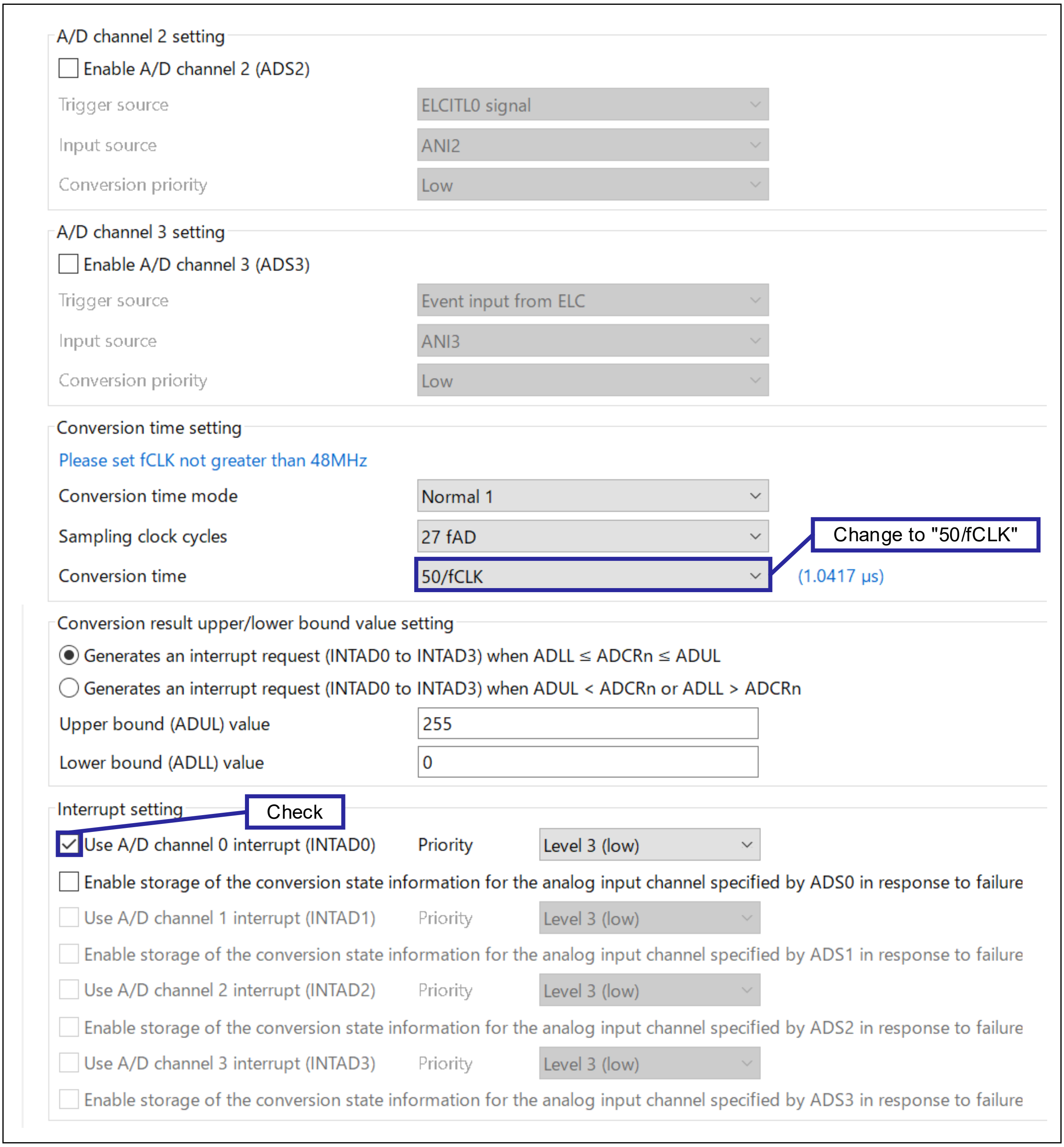


Figure 4-7 Configuration of A/D Converter (2/2)



4.2 Folder Structure

Table 4-5 shows the structure of the source files/header files used in the sample code. Note that files automatically generated by the integrated development environment and files from the BSP environment are excluded.

Table 4-5 Folder Structure

Folder/File Name	Description	Generated by Smart Configurator
\r01an7257_tkb3_force_output_stop<DIR>NOTE 2	Sample code folder	
\src<DIR>	Program storage folder	
main.c	Sample code source file	
\smc_gen<DIR>	Smart configurator generated folder	√
\Config_ADC<DIR>	ADC program storage folder	√
Config_ADC.c	ADC source file	√
Config_ADC.h	ADC header file	√
Config_ADC_user.c	ADC interrupt source file	√
\Config_COMP0<DIR>	COMP0 program storage folder	√
Config_COMP0.c	COMP0 source file	√
Config_COMP0.h	COMP0 header file	√
Config_COMP0_user.c	COMP0 interrupt source file	√NOTE 1
\Config_DAC0<DIR>	DAC0 program storage folder	√
Config_DAC0.c	DAC0 source file	√
Config_DAC0.h	DAC0 header file	√
Config_DAC0_user.c	DAC0 interrupt source file	√NOTE 1
\Config_TKB0<DIR>	TKB0 program storage folder	√
Config_TKB0.c	TKB0 source file	√
Config_TKB0.h	TKB0 header file	√
Config_TKB0_user.c	TKB0 interrupt source file	√
¥general<DIR>	Initialization and common program storage folder	
¥r_bsp<DIR>	BSP program storage folder	
¥r_config<DIR>	Program storage folder	

Note: "<DIR>" indicates a directory.

Note 1. This sample code does not use it.

Note 2. The sample code for IAR contains the r01an6893_trd2_pwm.ipcf file.
For details on the .ipcf file, please refer to "RL78 Smart Configurator User’s Guide: IAR” (R20AN0581).

4.3 List of Option Byte Settings

Table 4-6 shows the option byte settings.

Table 4-6 Option Byte settings

Address	Setting Value	Description
000C0H/040C0H	1110 1111B (EFH)	Watchdog Timer stopped operation (Count stops after reset release)
000C1H/040C1H	1111 1011B (FBH)	LVD0 reset mode Detection voltage: Rising 2.97V / Falling 2.91V
000C2H/040C2H	1110 1010B (EAH)	Flash operation mode: High-speed main mode. High-speed on-chip oscillator frequency: 8MHz
000C3H/040C3H	1000 0101B (85H)	On-chip debug operation allowed

4.4 List of Constants

Constant is not used in the sample code.

4.5 List of Variables

Table 4-7 shows the variables used in the sample code.

Table 4-7 Variables Used in the Sample Code

Variable Name	Type	Content	Function that used the variables
g_result_buffer0	uint16_t	Channel 0 A/D conversion result storage	r_Config_ADC_ad0_interrupt

4.6 List of Functions

Table 4-8 lists the functions used in the sample code. However, functions generated by the Smart Configurator that have not been modified are excluded.

Table 4-8 List of Functions

Function Name	Description	Source File
main	Main process	main.c
r_Config_ADC_ad0_interrupt	A/D converter channel 0 interrupt process	Config_ADC_user.c
r_Config_TKB0_activated0_interrupt	Interrupt process during forced output stop activation	Config_TKB0_user.c

4.7 Function Specifications

The following describes the function specifications of the sample code.

[Function name] main

Overview	Main processing
Headers	r_smc_entry.h
Declaration	void main (void);
Description	This function specifies the initial settings of the A/D converter, comparator, D/A converter, and TKB30, and generates software triggers.
Arguments	None
Return values	None
Remarks	None

[Function name] r_Config_ADC_ad0_interrupt

Overview	A/D converter channel 0 interrupt processing
Headers	r_cg_macrodriver.h, r_cg_userdefine.h, Config_ADC.h
Declaration	static void __near r_Config_ADC_ad0_interrupt(void);
Description	When simultaneous update of compare registers is enabled, this function reads the A/D conversion result from the ADCR0 register and then stores the result in the variable of the internal RAM. This function calculates the duty ratio based on the stored conversion results, and then changes the duty ratio of TKB30.
Arguments	None
Return values	None
Remarks	None

[Function name] r_Config_TKB0_activated0_interrupt

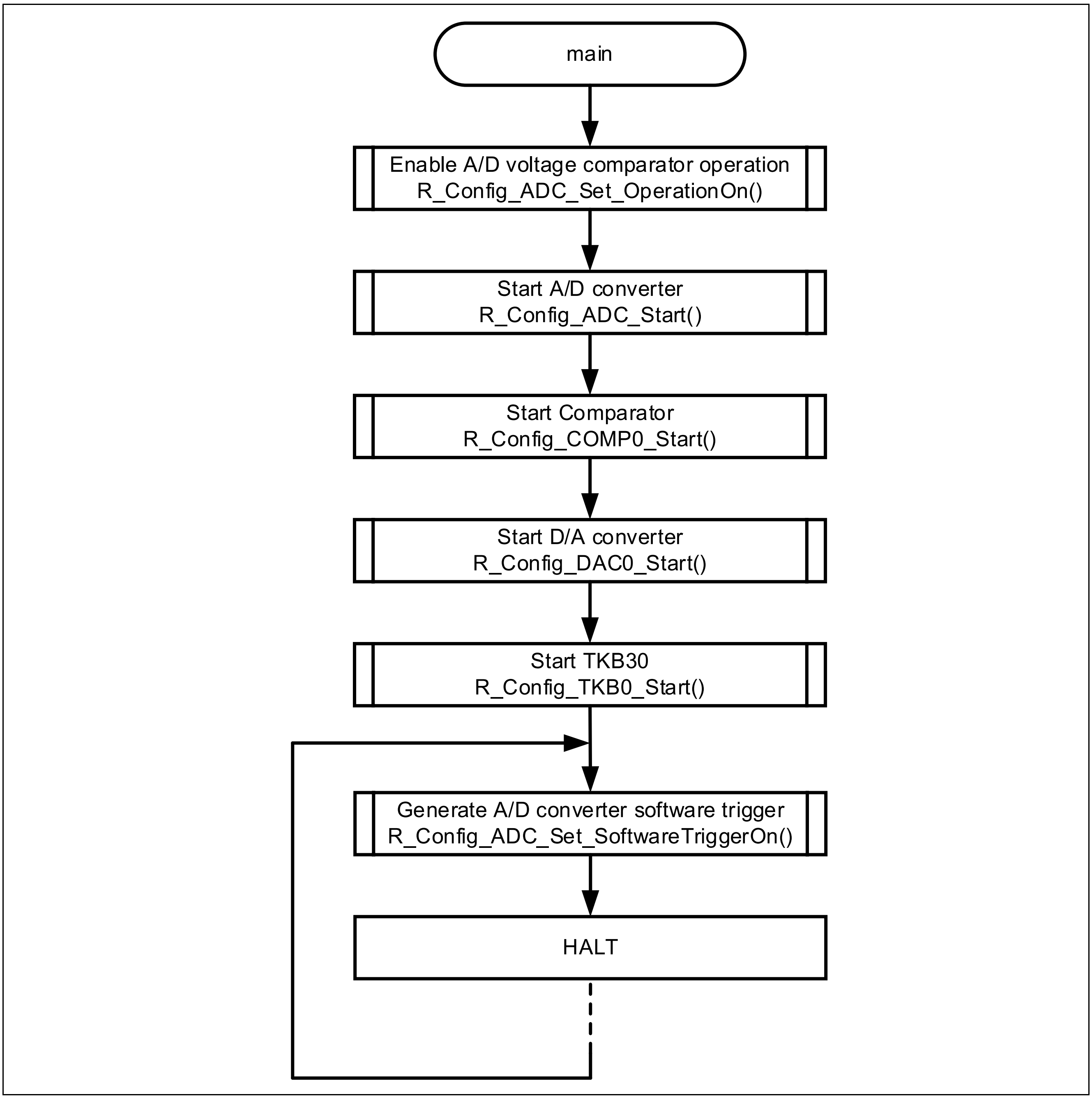
Overview	Interrupt processing when forced output stop is started
Headers	r_cg_macrodriver.h, r_cg_userdefine.h, Config_TKB0.h
Declaration	static void __near r_Config_TKB0_activated0_interrupt(void);
Description	After one second delay of software from the time a forced output stop occurs, this function generates a trigger to cancel the forced output stop function.
Arguments	None
Return values	None
Remarks	None

4.8 Flowchart

4.8.1 Main Process

Figure 4-8 shows the flowchart for the main process.

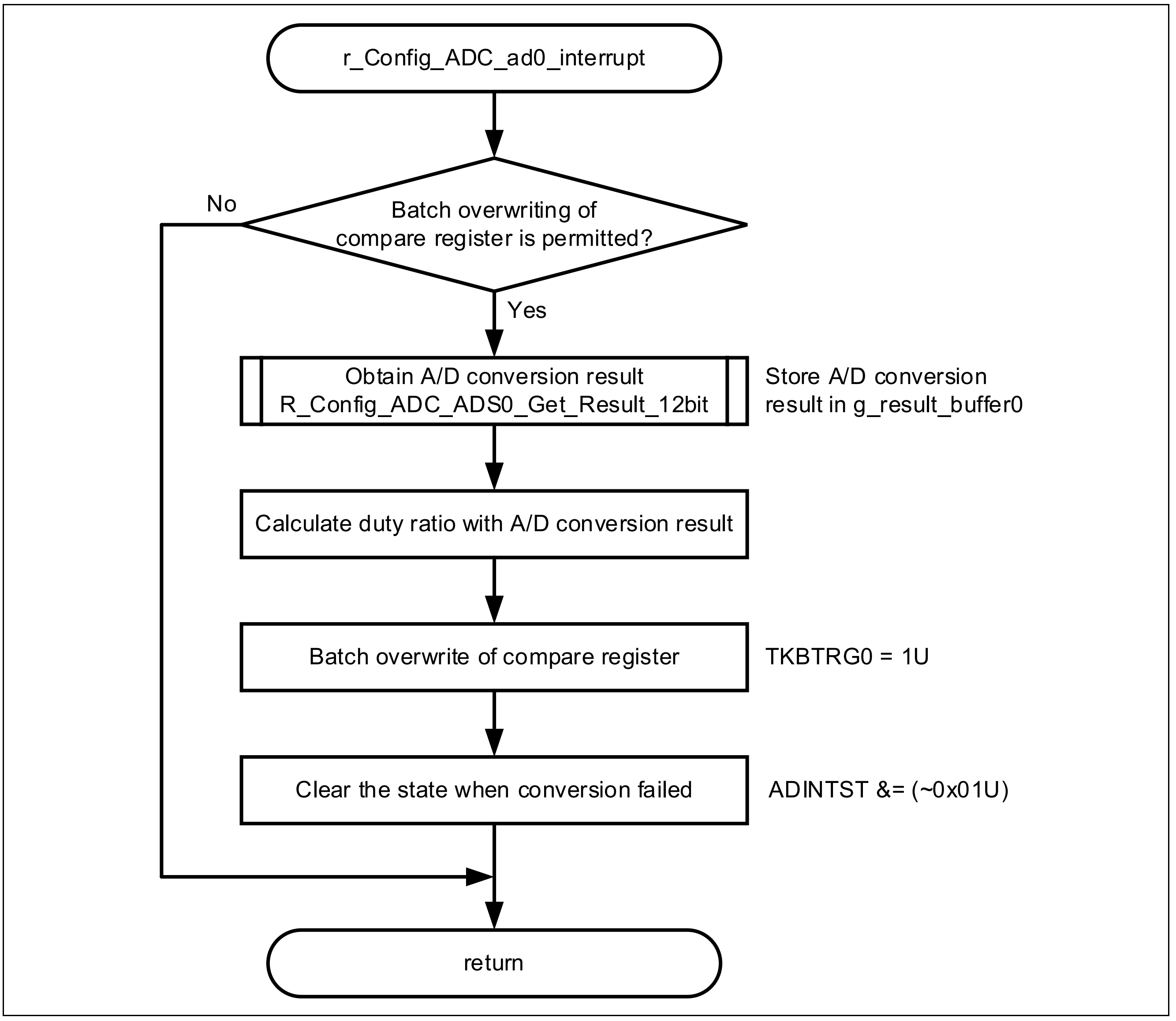
Figure 4-8 Main Process



4.8.2 r_Config_ADC_ad0_interrupt function

Figure 4-9 shows the flowchart of r_Config_ADC_ad0_interrupt function.

Figure 4-9 r_Config_ADC_ad0_interrupt function

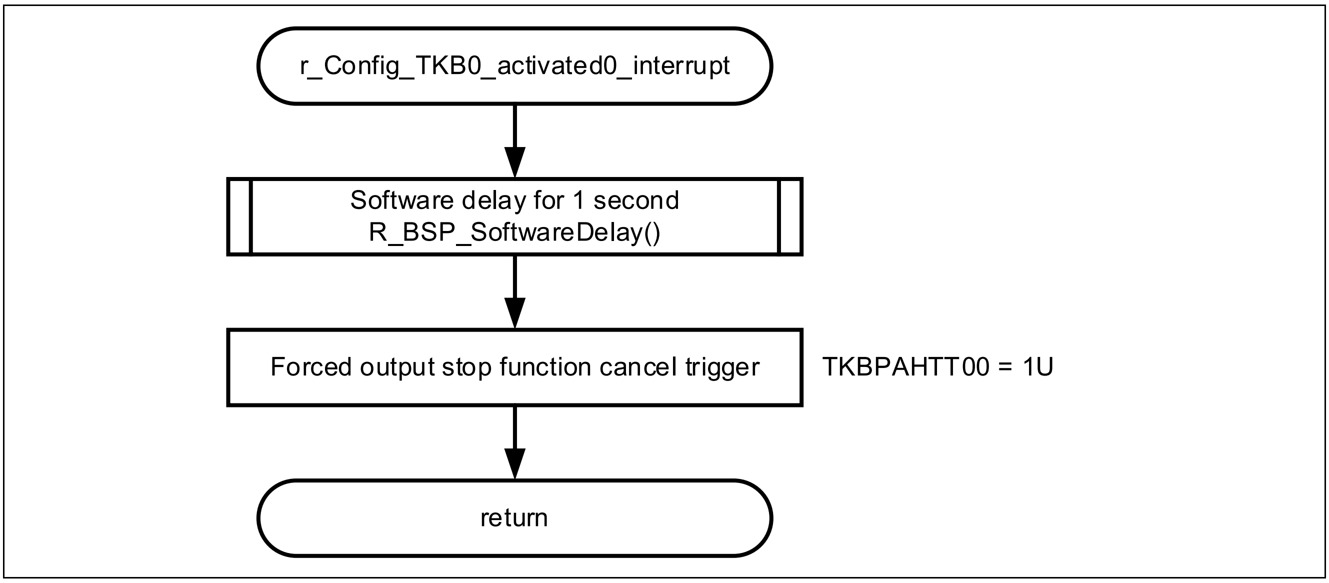


Note. For the 16-bit timer KB30, a simultaneous rewrite process is required to activate the value set in the compare register. Since there is a specific procedure for setting the related registers for the simultaneous rewrite, please refer to “RL78/G24 User’s Manual: Hardware,” section ”15.4.4 Batch overwrite operation” for detailed instructions.

4.8.3 r_Config_TKB0_activated0_interrupt function

Figure 4-10 shows the flowchart of r_Config_TKB0_activated0_interrupt function.

Figure 4-10 r_Config_TKB0_activated0_interrupt function



5. Sample Code

Sample code can be downloaded from the Renesas Electronics website.

6. Reference Documents

RL78/G24 User’s Manual: Hardware (R01UH0961)

RL78 family User's Manual: Software (R01US0015)

RL78/G24 Fast Prototyping Board User’s Manual (R20UT5091)

RL78 Smart Configurator User’s Gude: CS+ (R20AN0580)

RL78 Smart Configurator User’s Gude: e2 studio (R20AN0579)

RL78 Smart Configurator User’s Gude: IAR (R20AN0581)

RL78 family RTK7RLG240P00000BJ RL78/G24 DC/DC LED Control Evaluation Board User’s Manual (R20UT5371)

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

Technical Update/Technical News

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

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	Dec.10.24	—	First Edition

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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