

## RX Family

### Example of Using the High-Resolution Function with GPTW/HRPWM

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#### Introduction

The RX66T Group MCUs are equipped with a general PWM timer (GPTW) and a high-resolution PWM waveform generation circuit (HRPWM), and the two can be used in combination to generate high-resolution PWM waveforms.

The descriptions in this application note target RX Family devices equipped with the GPTW and the HRPWM. When using this application note with Renesas MCUs other than the RX66T Group, careful evaluation is recommended after making modifications to comply with the alternate MCU.

#### Target Devices

RX Family devices with the GPTW and HRPWM

#### Confirmed Devices

RX66T Group

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## 1. GPTW and HRPWM Specifications

### 1.1 Overview

The RX66T incorporates a high-resolution PWM waveform generation circuit (HRPWM) that shapes PWM waveforms generated by GPTW0 to GPTW3 with a minimum resolution of approximately 195 ps.

**Table 1.1 Specifications for the High-Resolution PWM**

Item	Description
Channel	Channels 0 to 3
GPTW operating modes	<ul style="list-style-type: none"><li>• Sawtooth-wave PWM mode</li><li>• Sawtooth-wave one-shot pulse mode</li><li>• Triangle-wave PWM mode 1/2/3</li></ul>
Functions	<ul style="list-style-type: none"><li>• The duty can be changed with a resolution of 1/32 of the PCLKC period.</li><li>• The timing of rising and falling edges of PWM waveforms can be individually adjusted.</li><li>• Waveforms generated by the GPTW can be output as they are, bypassing the HRPWM.</li></ul>
Operating frequency (PCLKC)	80 to 160 MHz

The figure below shows a block diagram of the GPTW and HRPWM. Whether to output the waveform generated by the HRPWM (see (a) of Figure 1.1) or bypass the circuit and output the GPTW output as is (see (b) of Figure 1.1) can be selected. Since this setting is valid on a per-channel basis, the GTIOCnA and GTIOCnB (n = 0 to 3) pins of each channel reflect the same setting.

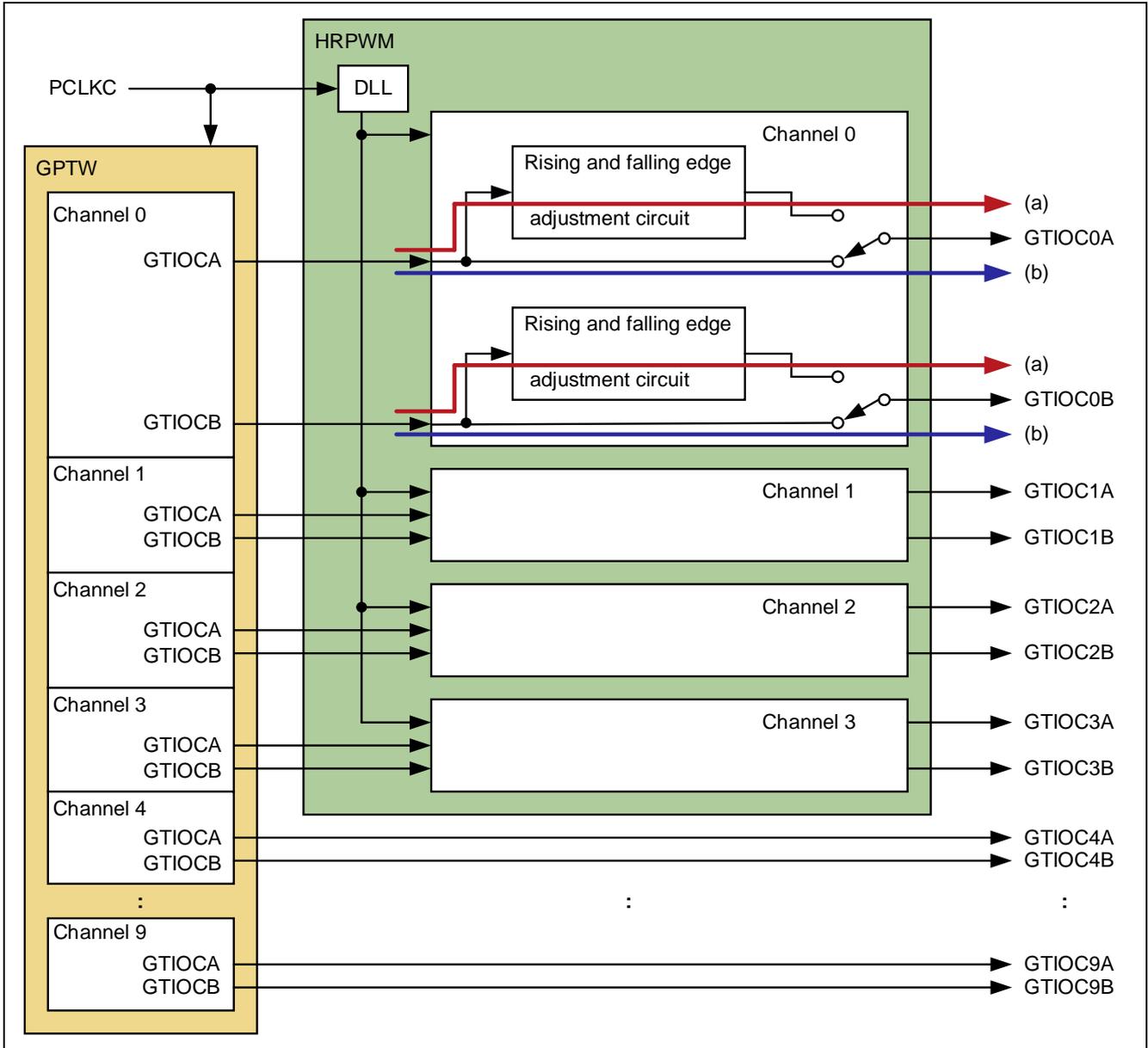


Figure 1.1 Block Diagram of GPTW and HRPWM

### 1.2 Operation

The HRPWM delays the timing of rising and falling edges of PWM signals which are output from the GPTW (channels 0 to 3) with a resolution of 1/32 of the PCLKC period (tC) (approximately 195 ps minimum) based on a delay locked loop (DLL) that operates with PCLKC as the reference phase. The delayed PWM signals are output from the GTIOCnA and GTIOCnB pins (n = 0 to 3).

The amount of delay can be adjusted in the range of 0/32 to 31/32 of tC. Delay amounts exceeding this range cannot be set.

To set a delay amount exceeding this range, change the value of the general PWM timer compare capture register m (GTCCRm) in the GPTW.

The PWM waveform generated by the HRPWM is output with a delay of three cycles of PCLKC compared to when bypassed, even if the delay is set to 0 (0/32 of tC).

In sawtooth-wave PWM mode, sawtooth-wave one-shot pulse mode, and triangle-wave PWM mode 1/2/3 of the GPTW, the output waveforms for each mode and those passing through the HRPWM are shown in Figure 1.2, Figure 1.3, and Figure 1.4.

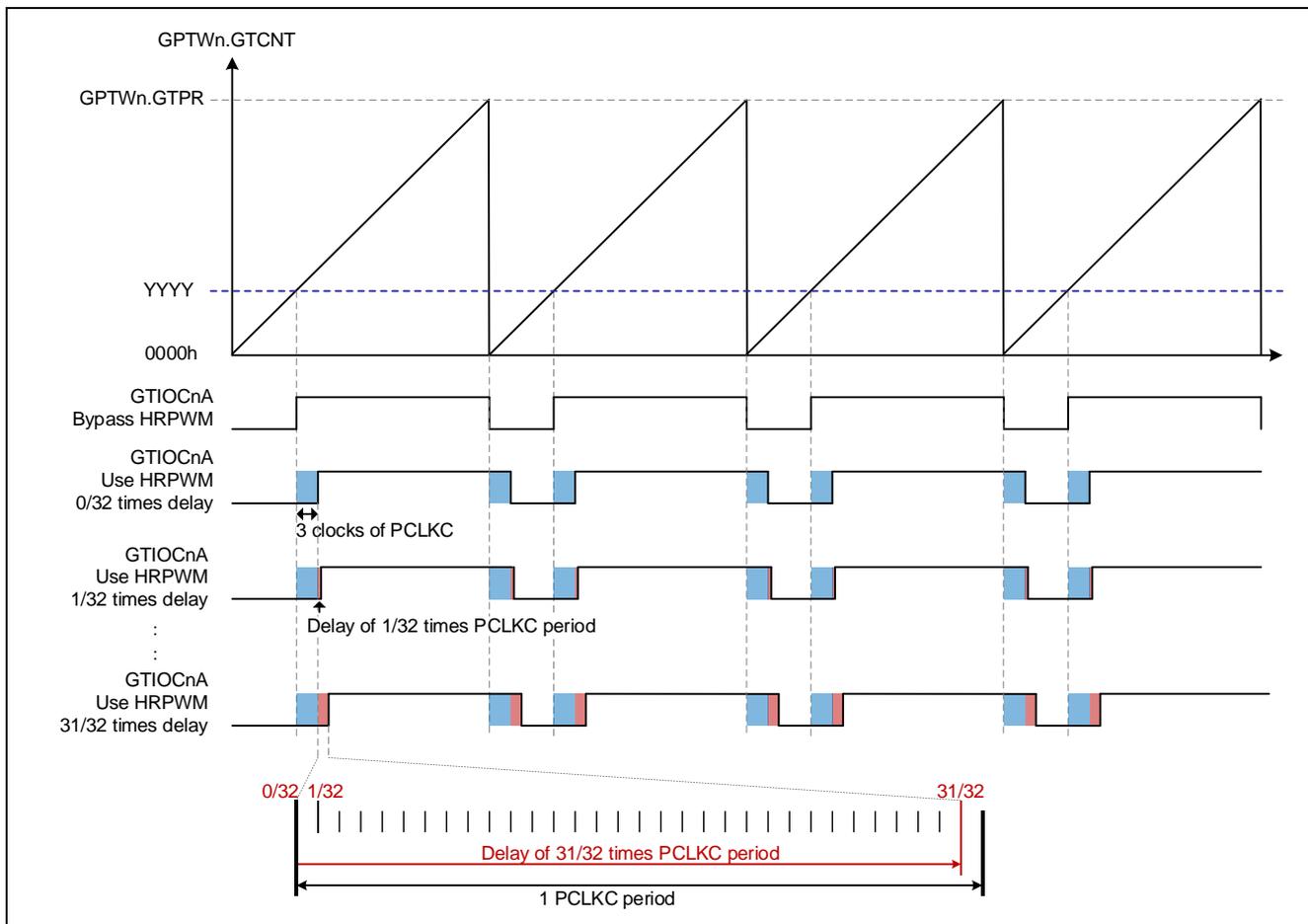


Figure 1.2 Sawtooth-Wave PWM Mode

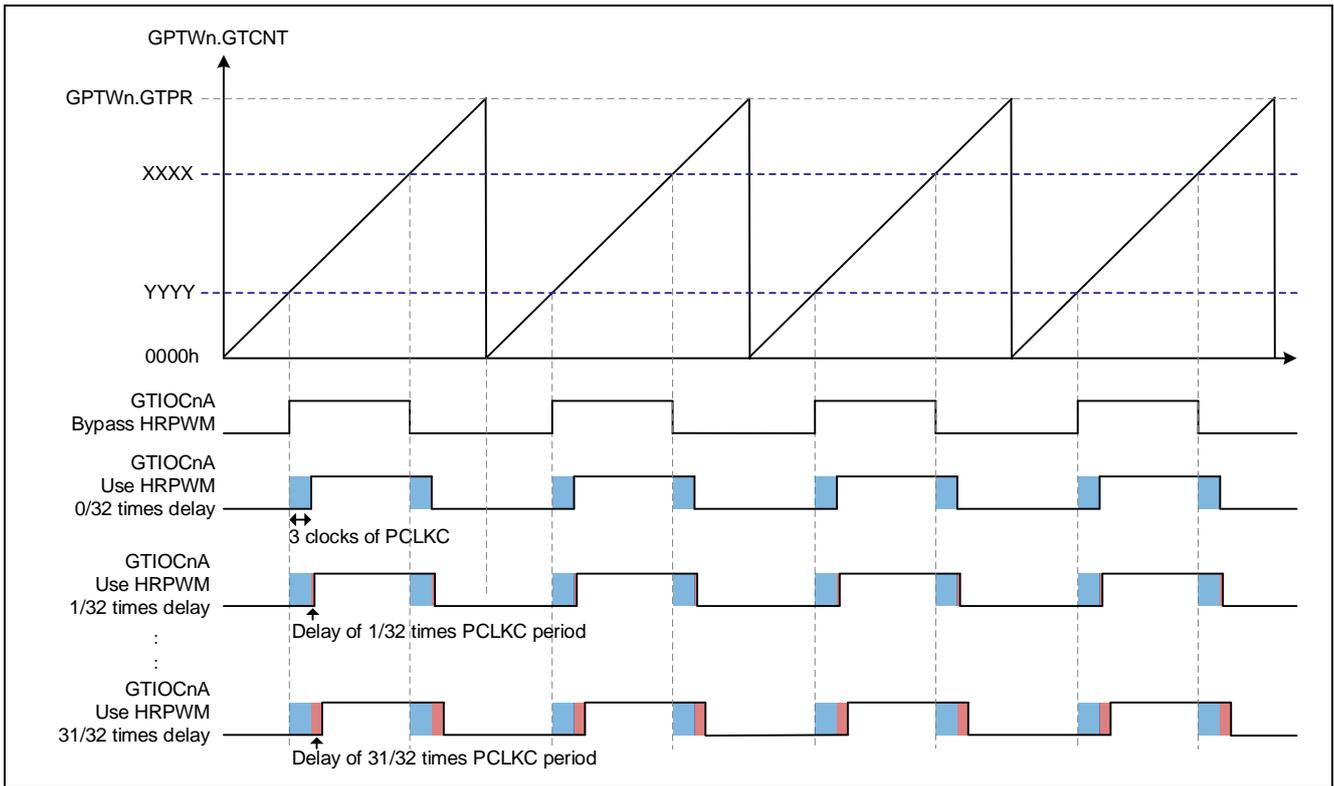


Figure 1.3 Sawtooth-Wave One-Shot Pulse Mode

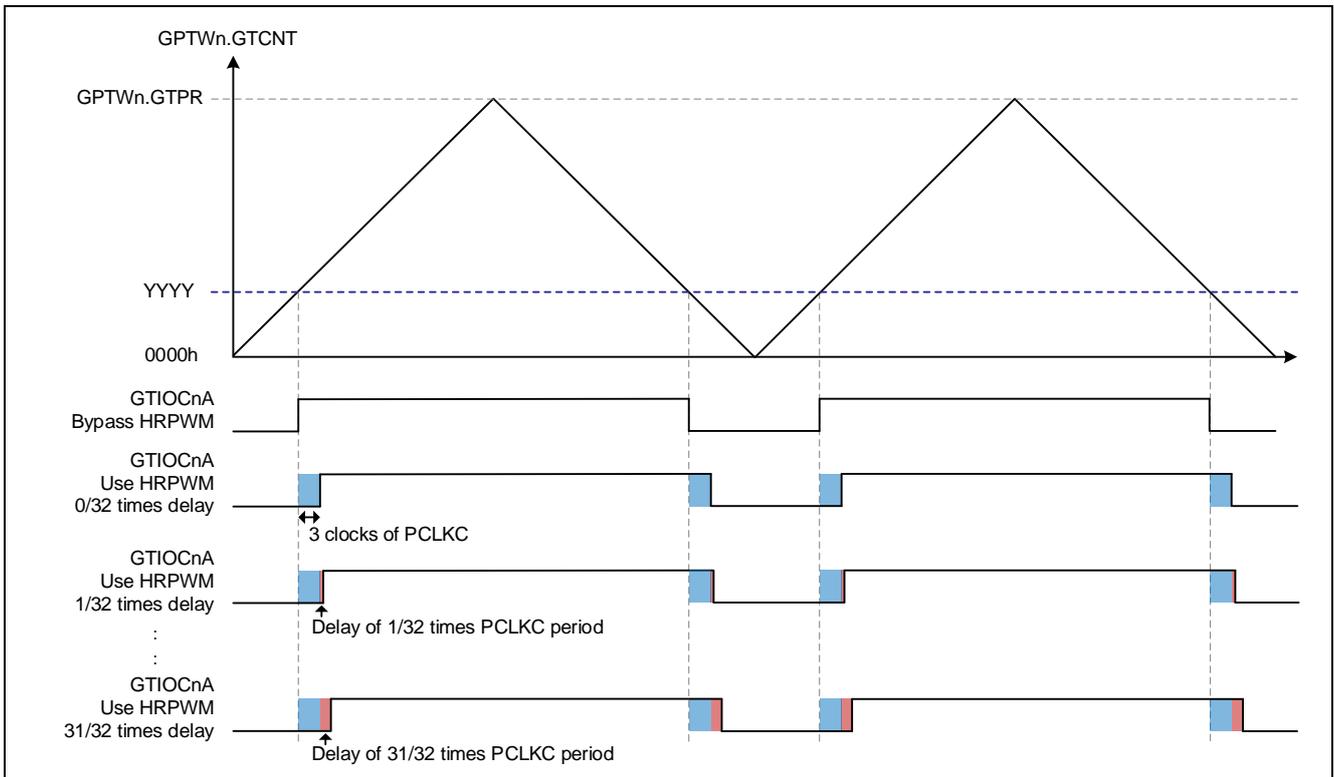


Figure 1.4 Triangle-Wave PWM Mode

The amount of delay set in each register is reflected in the pins via temporary registers. The reflection timing depends on the PWM output operating mode of the GPTW. For details, refer to section 25.3.2, Transfer Timing of HRREARnA, HRREARnB, HRFEARnA, and HRFEARnB Register Settings (n = 0 to 3), in the RX66T Group User's Manual: Hardware.

Since the HRPWM has an internal DLL, it is necessary to set the HROCR.DLLEN bit to 1b and wait for a stability time (20  $\mu$ s) before operation. To further ensure the output of the PWM waveform, set the HROCR.HRRST bit to 0b, then wait for 12 cycles of PCLKC.

Figure 1.5 shows the flow for the HRPWM initial settings. The settings in Figure 1.5 are generated by the R\_Config\_GPTn\_Create function (n = 0 to 3) in the Smart Configurator.

Figure 1.5 (a): When using the Smart Configurator, the wait time is automatically generated according to the set value of the system clock (ICLK).

Figure 1.5 (b): When using the Smart Configurator, the wait time is automatically generated according to the set value of the ICLK and PCLKC.

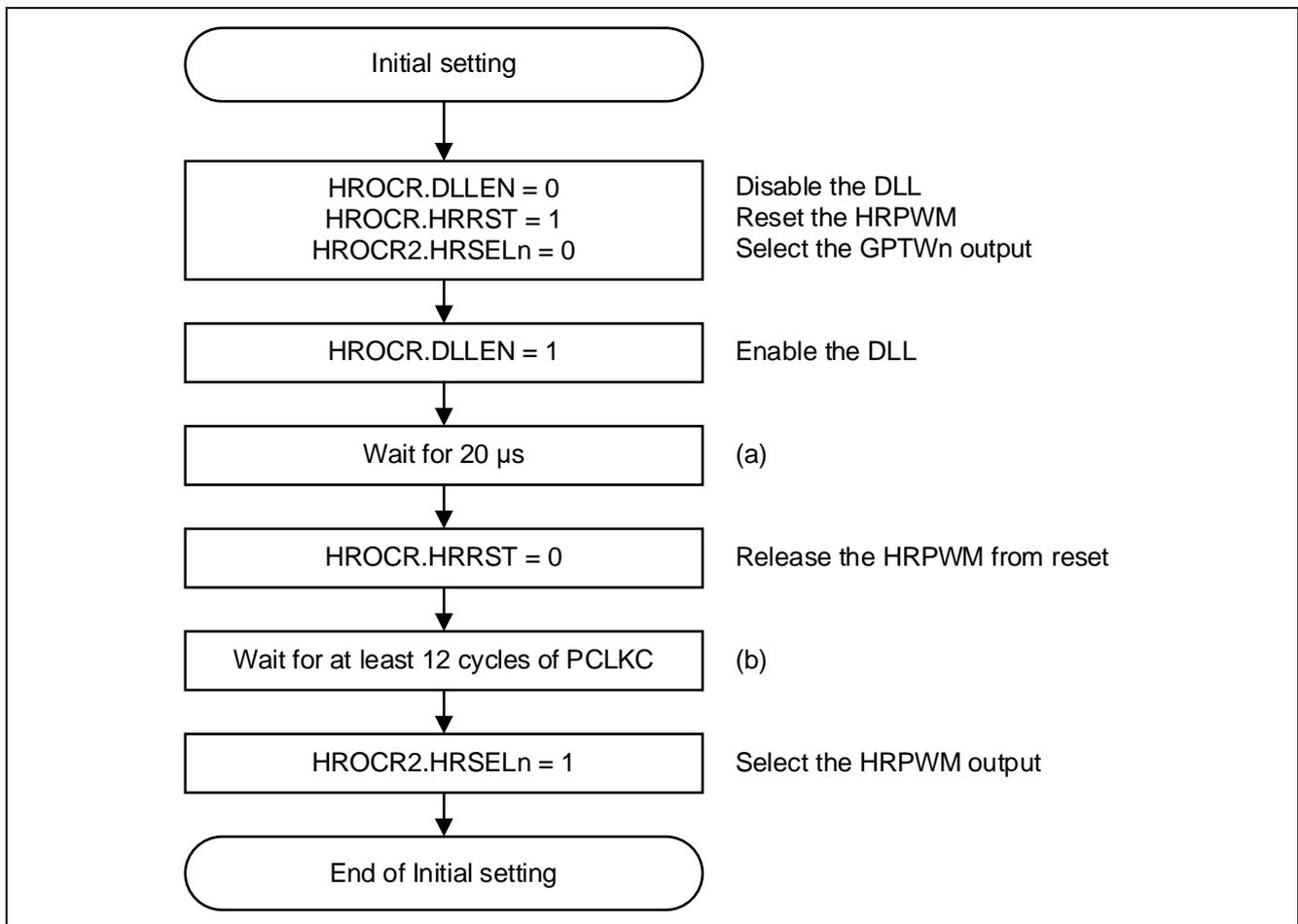


Figure 1.5 HRPWM Initial Setting Flow (n = 0 to 3)

### 1.3 Usage Notes

#### 1.3.1 Notes on Selecting Timer Prescaler in the GTCNT Counter While Using the HRPWM

The PWM signals output from the GPTW are generated based on the GTCNT counter operating at resolution equivalent to one clock period which is set by the GPTWn.GTCR.TPCS[3:0] bits ( $n = 0$  to  $3$ ). Note that, when the TPCS[3:0] bits are other than 0000b (PCLKC/1), a delay at resolution of  $0/32 \times tC(PCLKC)$  to  $31/32 \times tC(PCLKC)$  is applied to edges of the PWM signals at low resolution generated based on a selected clock if a setting for the GPTWn.GTCCRm register ( $m = A$  to  $F$ ) is changed.

For details, refer to section 25.4.2, Note on Selecting Timer Prescaler in the GTCNT Counter While Using the HRPWM, in the RX66T Group User's Manual: Hardware.

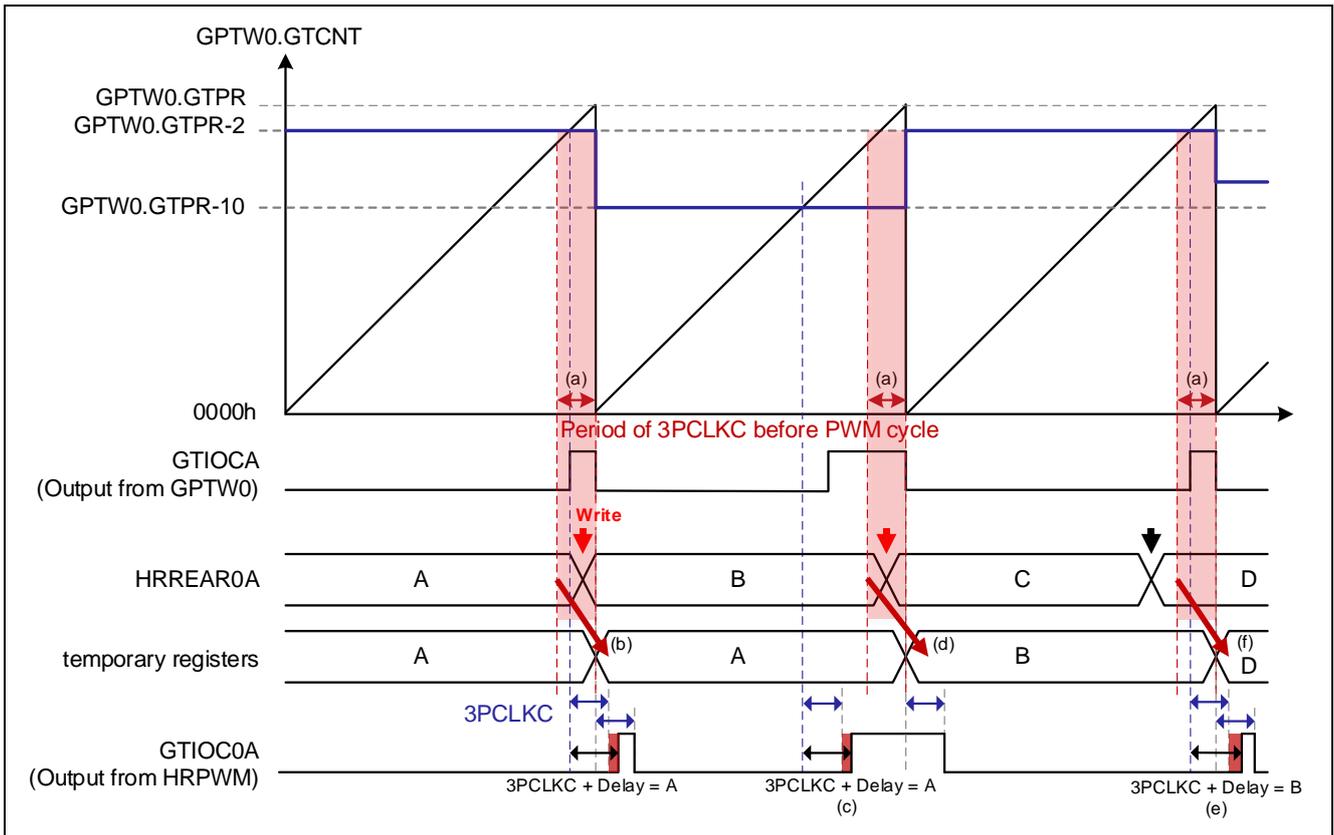
#### 1.3.2 Notes on Delay Settings for the HRPWM

If the update timing of the HRFEARnA, HRREARnA, HRFEARnB, and HRREARnB registers is within 3 cycles of PCLKC before a PWM cycle (within the range between GTPR-0x0003 and GTPR in saw-wave mode, or within the range between 0x0003 and 0x0000 in triangle-wave mode), the values before the update are transferred to temporary registers. Therefore, if an updated value is to be reflected in the next cycle, change the register value 3 cycles of PCLKC before the PWM cycle.

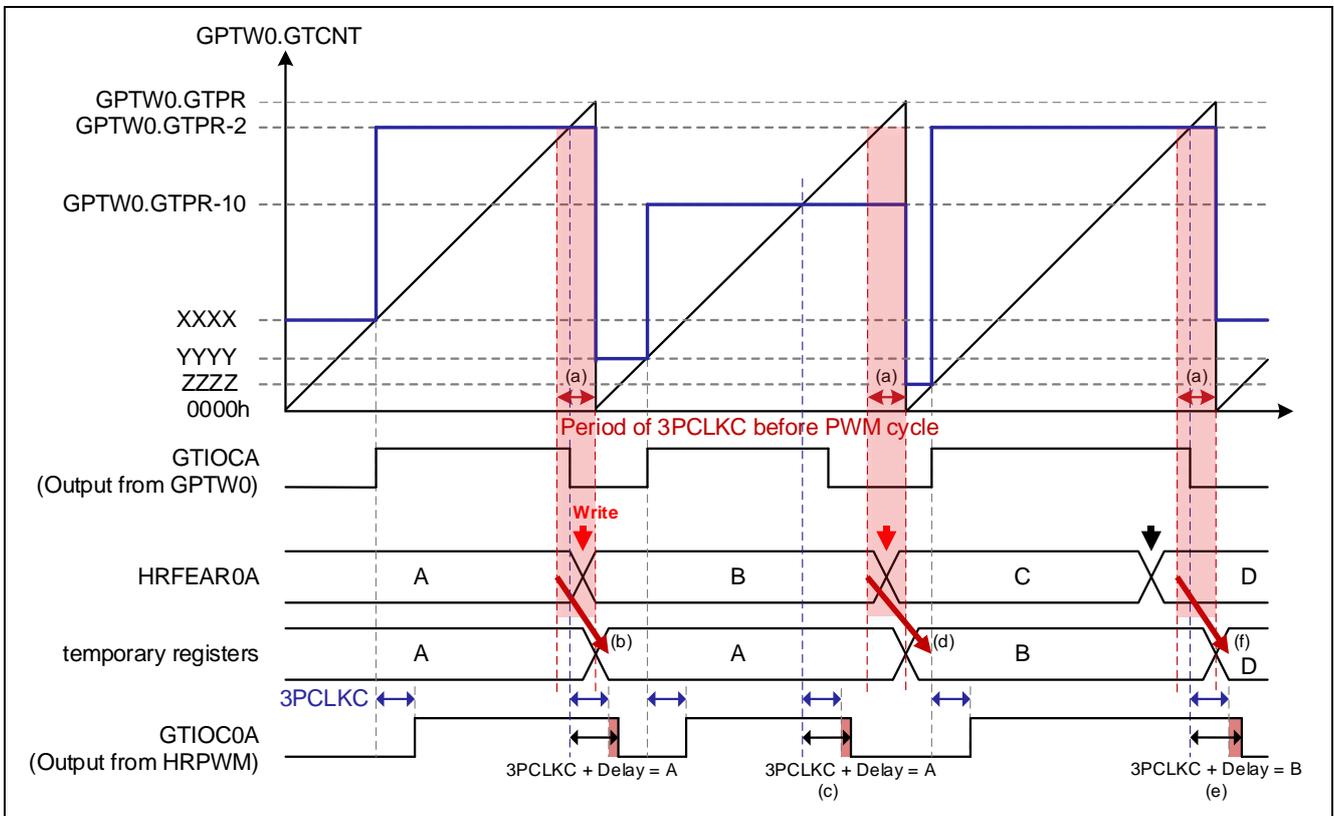
Operational examples of the notes on delay settings in GPTW's sawtooth-wave PWM mode, sawtooth-wave one-shot pulse mode, and triangle-wave PWM modes 1/2/3 are shown in Figure 1.6, Figure 1.7, and Figure 1.8.

The value set in the HRREAR0A register is transferred to the temporary register at the end of the cycle, and the value set in the temporary register becomes the delay amount of the GTIOC0A output waveform. However, in notes (b) and (d), the values "B" and "C" set in the HRREAR0A register are not transferred to the temporary register. Therefore, the delay amounts in (c) and (e) are the previous delay amounts "A" and "B".

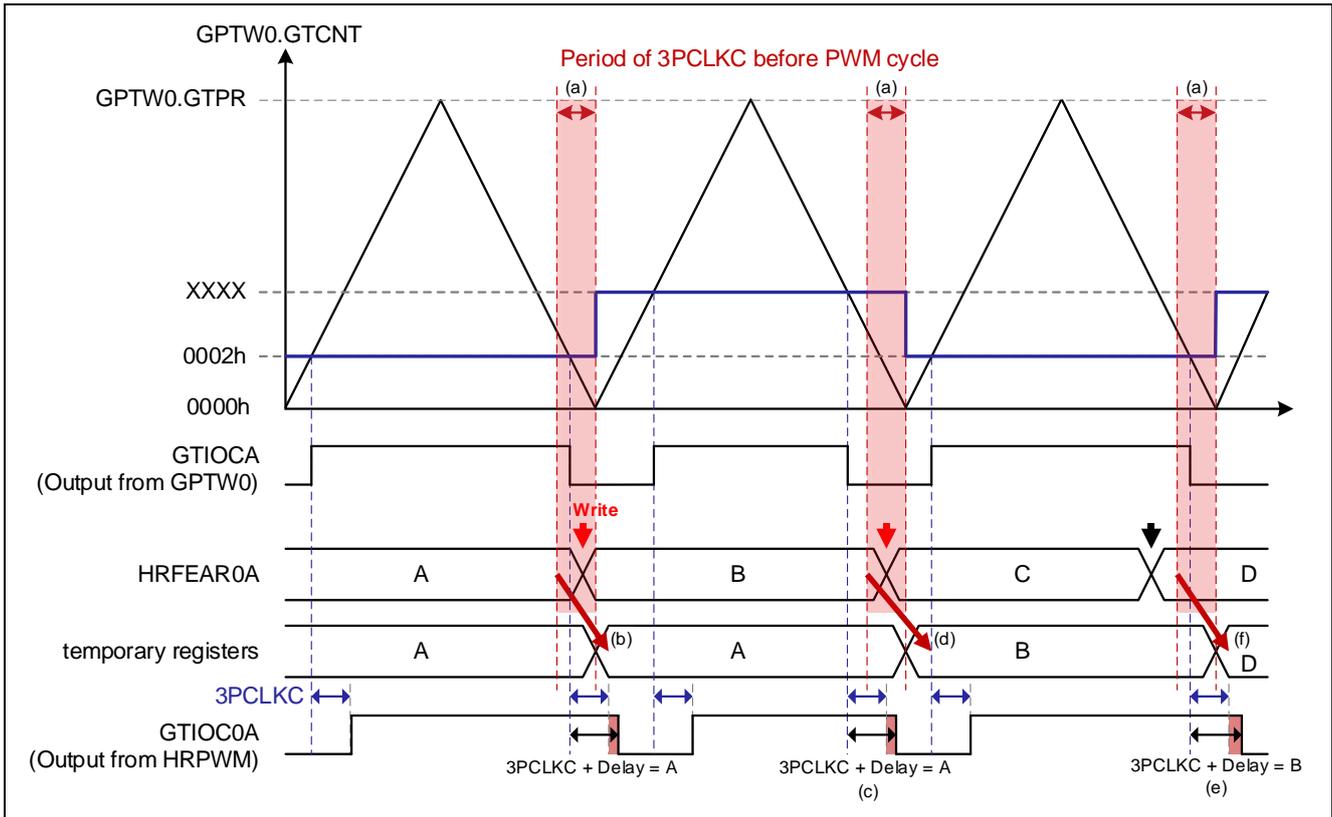
- (a): Period of 3 cycles of PCLKC before a PWM cycle
- (b): The value "B" set in the HRFEAR0A register is not transferred to the temporary register at the end of the cycle.
- (c): The temporary register remains to be A, so the amount of delay also retains A (the amount of delay does not become B).
- (d): The value "C" set in the HRFEAR0A register is not transferred to the temporary register at the end of the cycle.
- (e): B is transferred to the temporary register, so the amount of delay is B (the amount of delay does not become C).
- (f): Since the notes above are not applicable, the value "D" set in the HRFEAR0A register is transferred to the temporary register at the end of the cycle.



**Figure 1.6 Operational Examples of the Notes on Delay Settings in Sawtooth-Wave PWM Mode HRPWM (Delay at the Rising Edge)**



**Figure 1.7 Operational Examples of the Notes on Delay Settings in Sawtooth-Wave One-Shot Pulse Mode HRPWM (Delay at the Falling Edge)**



**Figure 1.8 Operational Examples of the Notes on Delay Settings in Triangle-Wave PWM Mode 1/2/3 HRPWM (Delay at the Falling Edge)**

### 1.3.3 Notes on Resetting the HRPWM

Setting the HROCR.HRRST bit to 1b resets the internal state of HRPWM. If the HRPWM is reset during operation, the PWM output is fixed to low after 5 cycles of PCLKC.

Setting the HROCR.HRRST bit to 0b releases the internal reset state of the HRPWM. After the reset is released, wait for 12 cycles of PCLKC.

## 2. Operation Confirmation Conditions

The operation of the sample code described in this application note has been confirmed under the conditions listed in the table below.

**Table 2.1 Operation Confirmation Environments**

Item	Description
MCU	R5F566TEADFP (included in Renesas Starter Kit for RX66T)
Operating frequency	Main clock: 8 MHz PLL: 160 MHz (main clock x 1/1 x 20) HOCO: Stopped LOCO: Stopped System clock (ICLK) 160 MHz (PLL x 1/1) Peripheral module clock A (PCLKA): 80 MHz (PLL x 1/2) Peripheral module clock B (PCLKB): 40 MHz (PLL x 1/4) Peripheral module clock C (PCLKC): 160 MHz (PLL x 1/1) Peripheral module clock D (PCLKD): 40 MHz (PLL x 1/4) FlashIF clock (FCLK): 40 MHz (PLL x 1/4)
Operating voltage	3.3 V
Integrated development environment	Renesas Electronics e <sup>2</sup> studio Version 2022-10
C compiler*1	Renesas Electronics C/C++ Compiler Package for RX Family V3.04.00 Compiler options The integrated development environment default settings are used.
RX Smart Configurator	V2.15.0
Board support package (r_bsp)	V7.20
Endian	Little endian
Operating mode	Single-chip mode
Processor mode	Supervisor mode
Sample code version	V1.00
Board	Renesas Starter Kit for RX66T (Product number: RTK50566T0CxxxxBE)
Emulator	E2-Lite

Note: 1. Import the same version of the toolchain (C compiler) as specified in the original project. If the same toolchain is not located in the import destination, the toolchain cannot be selected, and an error will occur.

Check the toolchain selection status on the project settings screen.

Refer to FAQ 3000404 for setting methods.

FAQ 3000404: 'Program "make" not found in PATH' error when attempting to build an imported project (e<sup>2</sup> studio)

### 3. GPTW Sample Codes

#### 3.1 Common

##### 3.1.1 Sample Code List

This application note provides the following sample codes created with the Smart Configurator.

Sample codes can be downloaded from the Renesas Electronics website.

**Table 3.1 GPTW Sample Code List**

Name	Description	Ref.
Sawtooth-Wave PWM Mode + HRPWM r01an6642_rx66t_gptw_sawtooth_pwm_hrpwm.zip	<ul style="list-style-type: none"><li>• Sawtooth-wave PWM mode</li><li>• Rising and falling edges adjusted</li></ul>	3.2
Triangle-Wave PWM Mode 1 + HRPWM r01an6642_rx66t_gptw_triangle_pwm1_hrpwm.zip	<ul style="list-style-type: none"><li>• Triangle-wave PWM mode 1</li><li>• Rising and falling edges adjusted</li></ul>	3.3

### 3.1.2 Folder Structure

The main folder structure of a sample code is as follows.

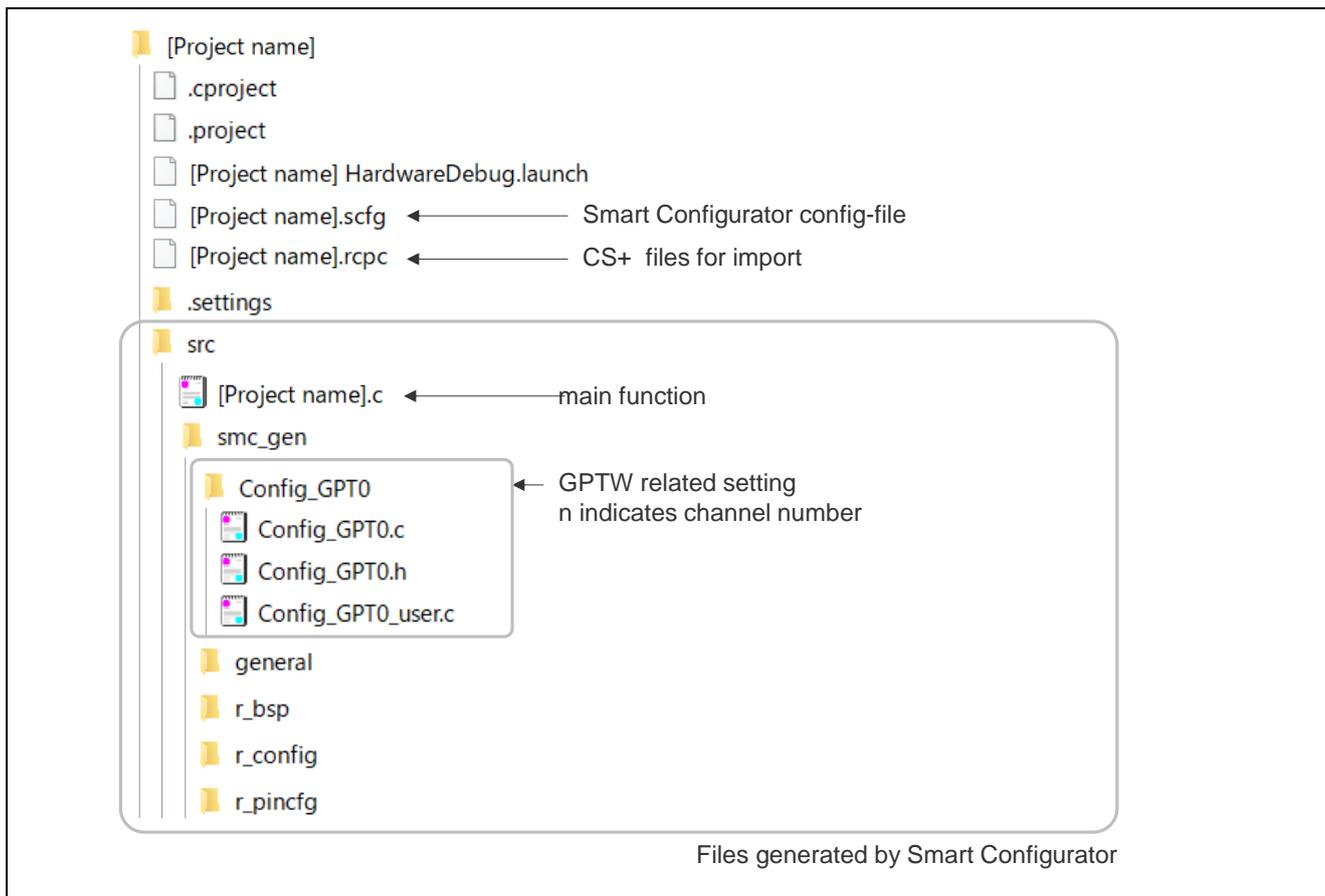


Figure 3.1 GPTW Folder Structure

### 3.1.3 File Structure

The main file structure of a sample code is as follows.

**Table 3.2 GPTW File Structure**

File Name	Description
[Project name].c	<p><u>main Function</u> This is the main function. The Smart Configurator generates an empty function. The necessary processing for each sample code is described here.</p>
Config_GPTn.c* <sup>1</sup>	<p><u>R_Config_GPTn_Create function</u> This is the GPTW's initialization function. The initialization function based on the settings in the Smart Configurator is generated by the Smart Configurator. The call for this function is generated by the Smart Configurator. This function is called in the R_SystemInit function executed before the main function.</p>
	<p><u>R_Config_GPTn_Start function</u> This is the GPTW's count start function. This function is generated by the Smart Configurator. In the sample codes, this function is called from the main function.</p>
	<p><u>R_Config_GPTn_Stop function</u> This is the GPTW's count stop function. This function is generated by the Smart Configurator. This function is not used in the sample codes.</p>
Config_GPTn_user.c* <sup>1</sup>	<p><u>r_Config_GPTn_Create_UserInit function</u> This is the GPTW's user initialization function. The Smart Configurator generates an empty function. The necessary processing for each sample code is described here. This is the last function to be called in the R_Config_GPTn_Create function generated by the Smart Configurator.</p>
	<p><u>r_Config_GPTn [interrupt name] interrupt function</u> This is the interrupt handler function. The Smart Configurator generates an empty function. The necessary processing for each sample code is described here.</p>
Config_GPTn.h* <sup>1</sup>	<p>This is the header file that defines GPTW related functions. This file is included in the r_smc_entry.h file generated by the Smart Configurator. To use GPTW related functions, be sure to include the r_smc_entry.h file.</p>

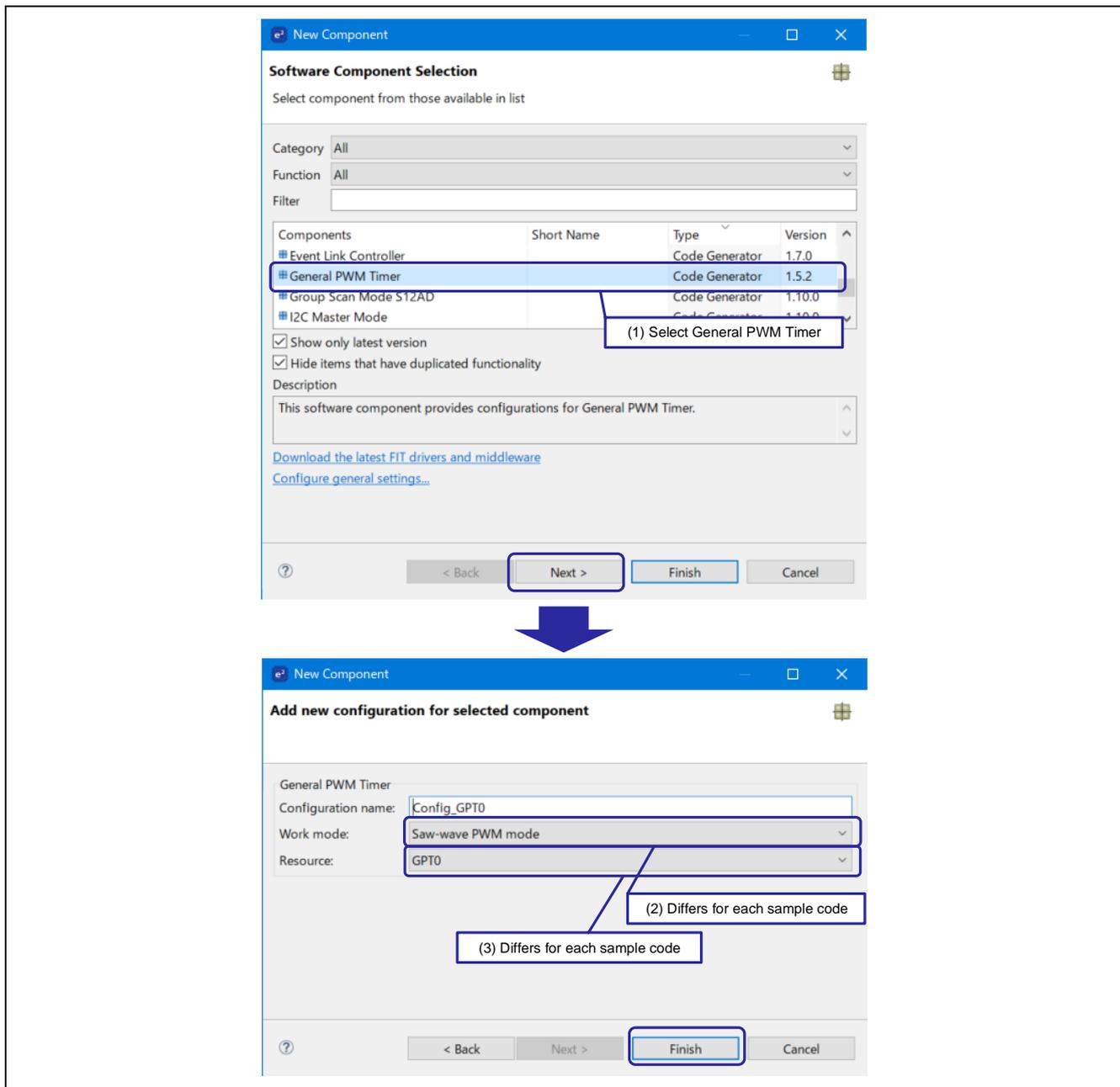
Note: 1. n indicates a channel number.

### 3.1.4 Adding Components

The sample codes use the Smart Configurator to add the GPTW as described below.

**Table 3.3 Adding Components**

Item	Description
Component	General PWM timer ((1) in the figure below)
Configuration name	Sample codes use the default setting name.
Operation	Refer to the section for each sample code ((2) in the figure below).
Resource	Refer to the section for each sample code ((3) in the figure below).



**Figure 3.2 Adding Components**

### 3.1.5 Pin Settings

Figure 3.3 shows an example of pin settings using the Smart Configurator.

Configure the pins after setting the GPTW. For GPTW settings, refer to “Smart Configurator Settings” for each sample code.

Pin settings are carried out in the R\_Config\_GPTn\_Create function generated by the Smart Configurator.

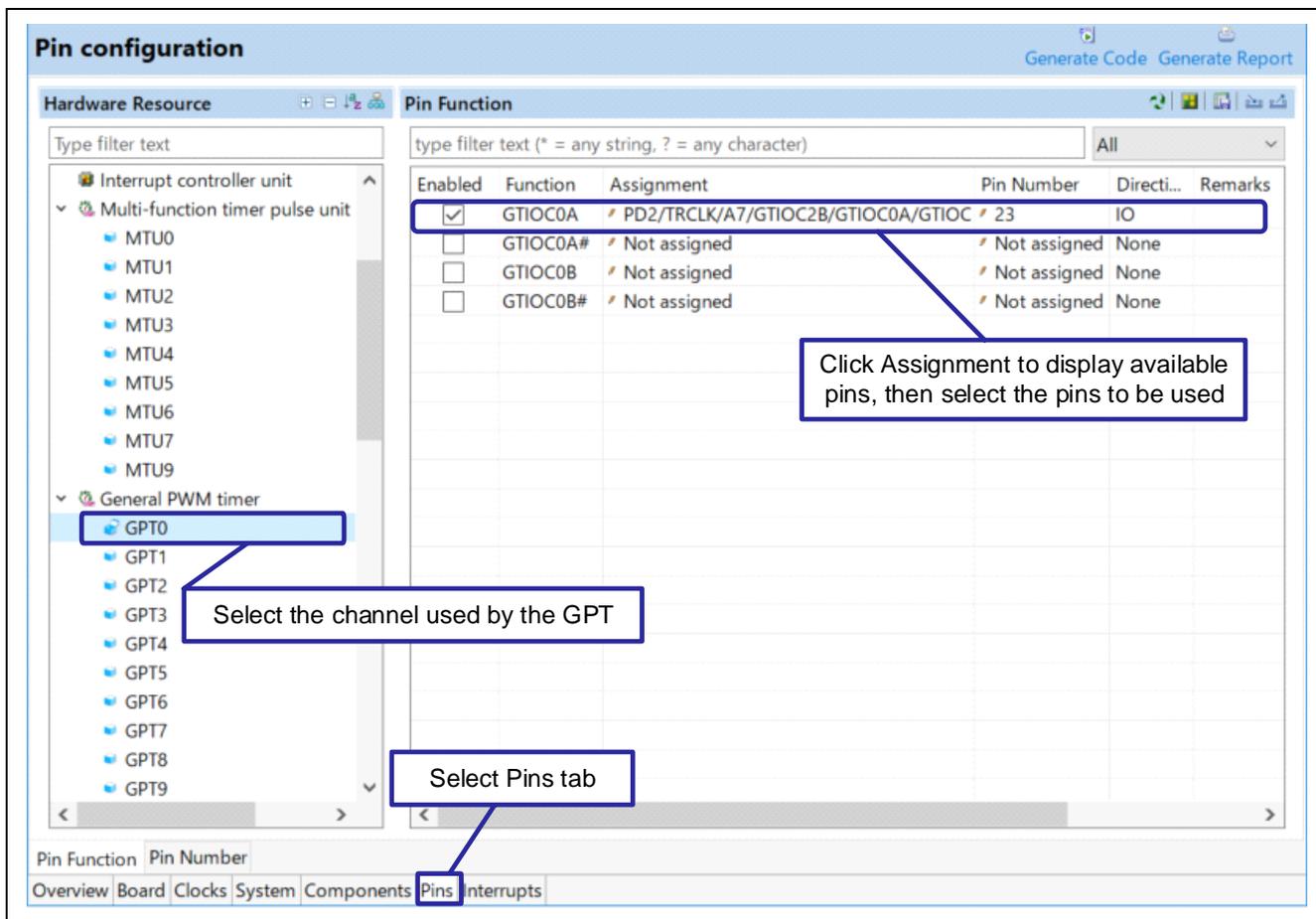


Figure 3.3 Pin Settings

### 3.1.6 Interrupt Settings

Figure 3.4 shows an example of interrupt settings using the Smart Configurator. For details on software configurable interrupt A, refer to section 14.4.5.1, Software Configurable Interrupt A, in the RX66T Group User's Manual: Hardware.

Configure interrupts after setting the GPTW settings. For GPTW settings, refer to "Smart Configurator Settings" for each sample code.

Interrupt settings can be configured in the R\_Config\_GPTn\_Create function, R\_Config\_GPTn\_Start function, and R\_Config\_GPTn\_Stop function, all of which are generated by the Smart Configurator.

The interrupt handler function is created with the name r\_Config\_GPTn\_[interrupt name]\_interrupt in the Config\_GPTn\_user.c file generated by the Smart Configurator.

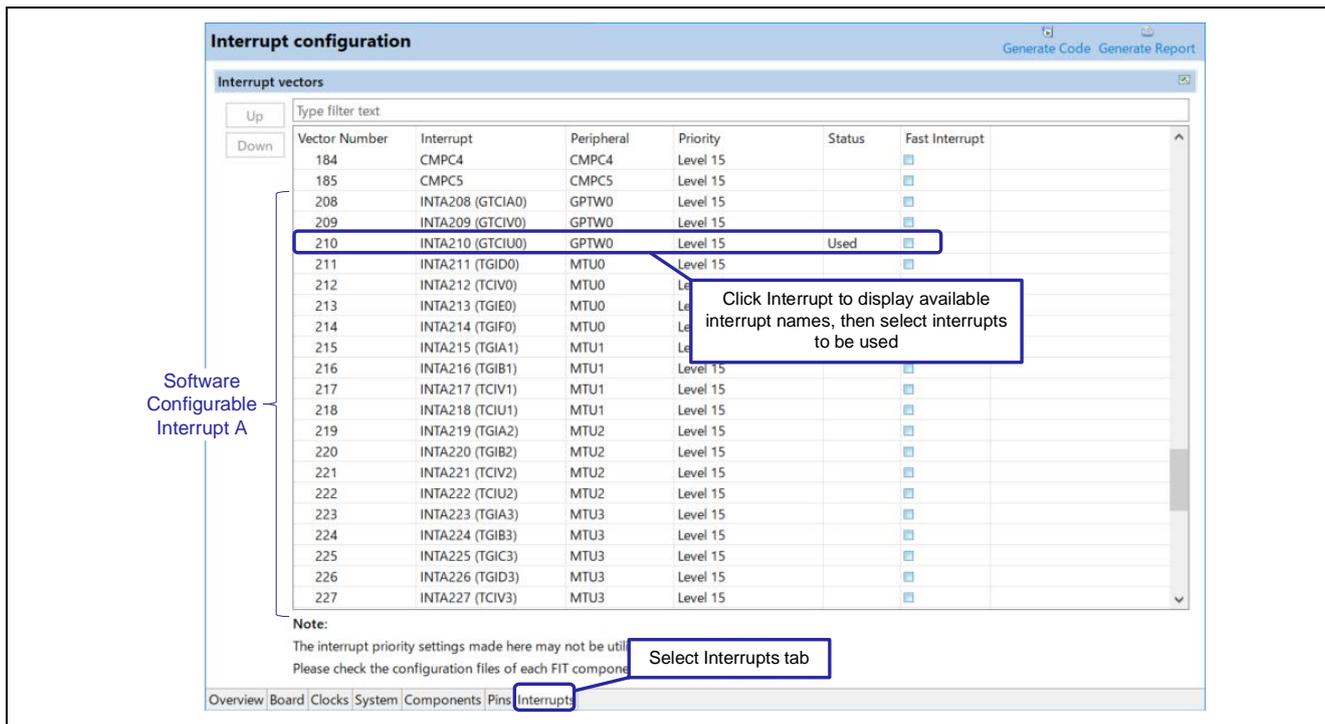


Figure 3.4 Interrupt Settings

Only GTCIE0, GTCIF0 and GDTE0 are selected for GPTW interrupts by default in the Interrupts tab of the Smart Configurator. To use interrupts configured in the Components tab, the interrupts must be selected in the Interrupts tab. The following shows the status and error message when a selection is missing.

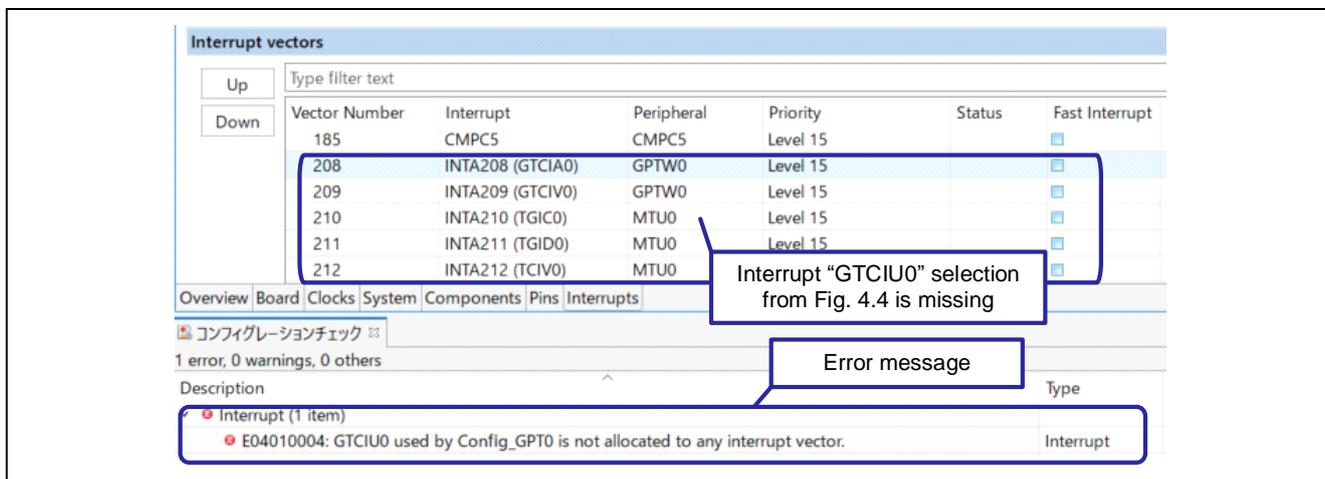


Figure 3.5 Interrupt Settings (Interrupt Selection Missing)

### 3.2 Sawtooth-Wave PWM Mode + HRPWM

- Target sample code file name: r01an6642\_rx66t\_gptw\_sawtooth\_pwm\_hrpwm.zip

#### 3.2.1 Overview

This sample code outputs a high-resolution PWM waveform using sawtooth-wave PWM mode of the GPTW and the HRPWM.

The following list provides the GPTW settings used in the sample code.

- Use sawtooth-wave PWM mode
- Use channel 0
- Carrier period = 400  $\mu$ s
- Timer counter clock = 160 MHz (PCLKC/1)
- Use GTPR as period register
  - Count direction = up-counting
- Use GTCCRA for compare matches of the duty cycle output
  - Set the GTIOC0A pin as the PWM output pin
  - High output at GTCCRA compare match
  - Low output at counting starts, low output at counting stops
  - Low output at cycle end
- Use GTCCRB for compare matches of the duty cycle output.
  - Set the GTIOC0B pin as the PWM output pin
  - High output at GTCCRB compare match
  - Low output at counting starts, low output at counting stops
  - Low output at cycle end
- Software source count start enabled
- High-resolution PWM waveform output enabled
  - Apply delay of 0/32 times PCLKC period to rising/falling edges of the GTIOC0A pin
  - Apply delay of 31/32 times PCLKC period to rising/falling edges of the GTIOC0B pin

Set in Smart Configurator.  
Refer to section 3.2.3 for details on the setting method.

The structure of this sample code is shown below.

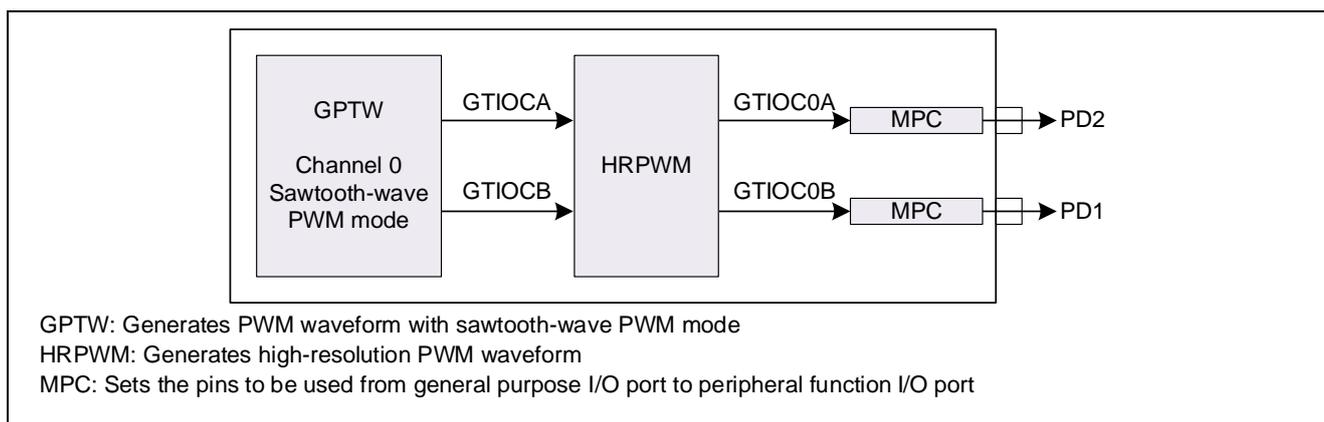


Figure 3.6 Sample Code Structure

### 3.2.2 Operation Details

This section describes the operation of this sample code.

The sample code sets amounts of delay to the rising/falling edges of the PWM waveform in the sawtooth-wave PWM mode of the GPTW, and outputs the waveform generated by the HRPWM from the GTIOC0A and GTIOC0B pins.

Figure 3.7 (a): Setting 0/32 times PCLKC as the amount of delay causes the GPTW output waveform to reflect a delay of 3 cycles of PCLKC.

Figure 3.7 (b): Setting 31/32 times the PCLKC period as the amount of delay causes the GPTW output waveform to reflect a delay of 31/32 times PCLKC.

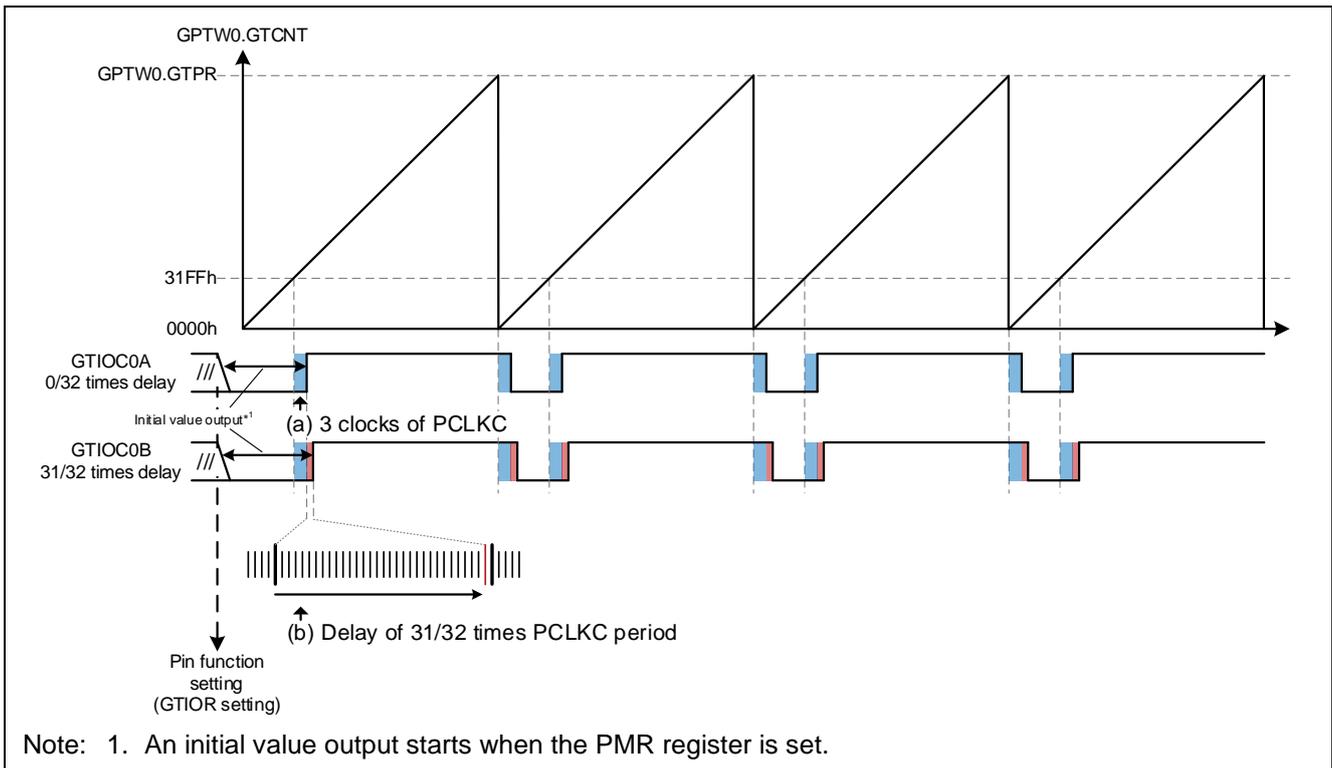


Figure 3.7 Sample Code Operations

### 3.2.3 Smart Configurator Settings

The sample code uses the Smart Configurator to add the GPTW as described below. For details on how to add components, see section 3.1.4, Adding Components.

**Table 3.4 Adding Components**

Item	Description
Component	General PWM timer
Configuration name	Config_GPT0
Operation	Sawtooth-wave PWM mode
Resource	GPT0

The screenshot shows the Smart Configurator interface for configuring the GPT0 component. The 'Basic setting' section is expanded, showing the following configurations:

- Timer counter clock = 160 MHz (PCLKC):** The clock source is set to PCLKC with a frequency of 160.000 MHz.
- Carrier period = 400 μs:** The timer operation period is set to 400 μs.
- Count direction = up-counting:** The count direction is set to Up-counting.
- Counter initial value = 0:** The counter initial value is set to 0.
- Use GPTW0.GTCCRA for compare matches:** The compare match register is set to GTCCRA with an initial value of 12799.
- Set the GTIOC0A pin as the PWM output pin:** The PWM output pin is set to PCLKC.
- Set the output duty by compare matches:** The output duty is determined by compare matches.
- Low output at counting starts, low output at counting stops:** The output at start/stop is set to Start output 0; stop output 0.
- High output at GPTW0.GTCCRA compare match:** The output at compare match is set to Output 1.
- Low output at cycle end:** The output at cycle end is set to Output 0.
- Software source count start enabled:** The software source count start option is checked.

**Figure 3.8 GPT0 Settings (1/3)**

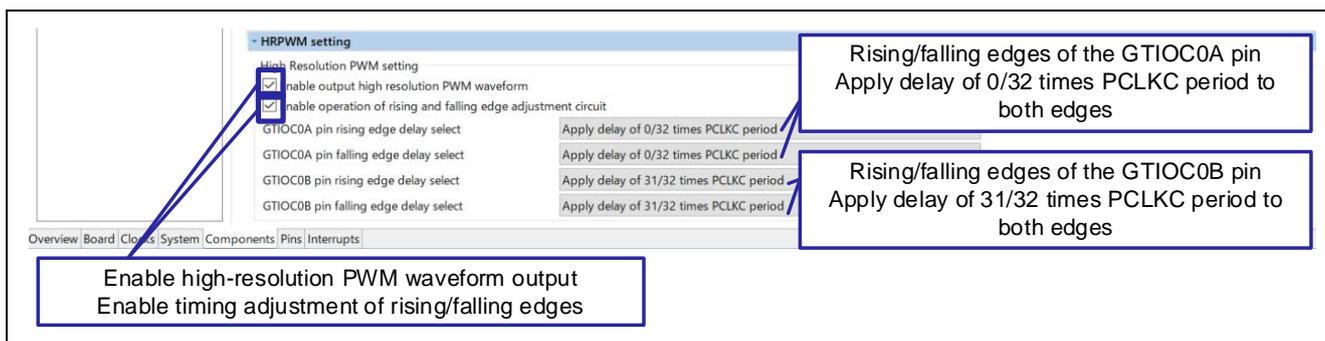


Figure 3.9 GPT0 Settings (2/3)

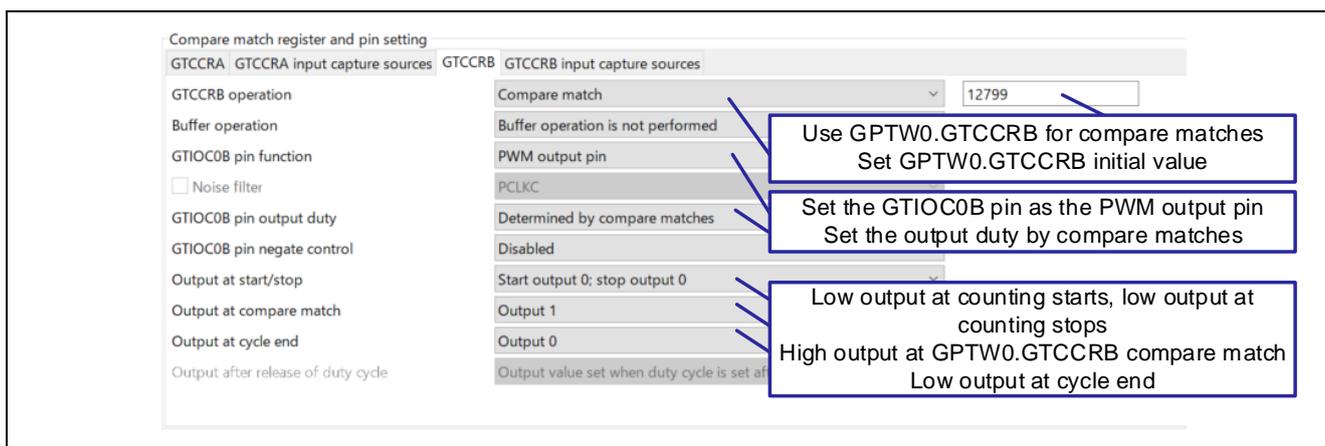


Figure 3.10 GPT0 Settings (3/3)

3.2.4 Flowchart

The following flowchart shows the main function processing added after code generation by the Smart Configurator.

Counting starts in the main function.

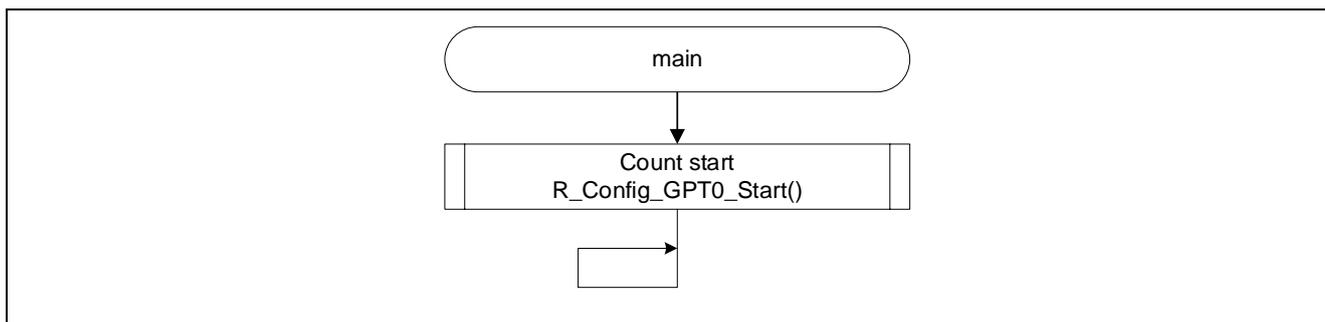


Figure 3.11 main Function

### 3.3 Triangle-Wave PWM Mode 1 + HRPWM

- Target sample code file name: r01an6642\_rx66t\_gptw\_triangle\_pwm1\_hrpwm.zip

#### 3.3.1 Overview

This sample code outputs a high-resolution PWM waveform using triangle-wave PWM mode 1 (32-bit transfer at trough) of the GPTW and the HRPWM.

To facilitate observation of the delay generated by the HRPWM, the GPTW output waveforms are set to active high and no dead time for both the positive and negative phases.

The following list provides the GPTW settings used in the sample code.

- Use triangle-wave PWM mode 1
- Use channel 0
- Carrier period = 400  $\mu$ s
- Timer counter clock = 160 MHz (PCLKC/1)
- Use GTPR as period register
  - Count direction = up-counting
- Use GTCCRA for compare matches of the duty cycle output
  - Set the GTIOC0A pin as the PWM output pin
  - Toggle output at GTCCRA compare match
  - Low output at counting starts, low output at counting stops
  - Retain output at cycle end
- Use GTCCRB for compare matches of the duty cycle output
  - Set the GTIOC0B pin as the PWM output pin
  - Toggle output at GTCCRB compare match
  - Low output at counting starts, low output at counting stops
  - Retain output at cycle end
- Software source count start enabled
- High-resolution PWM waveform output enabled
  - Apply delay of 0/32 times PCLKC period to rising/falling edges of the GTIOC0A pin
  - Apply delay of 31/32 times PCLKC period to rising/falling edges of the GTIOC0B pin

Set in Smart Configurator.  
Refer to section 3.3.3 for details on the setting method.

The structure of this sample code is shown below.

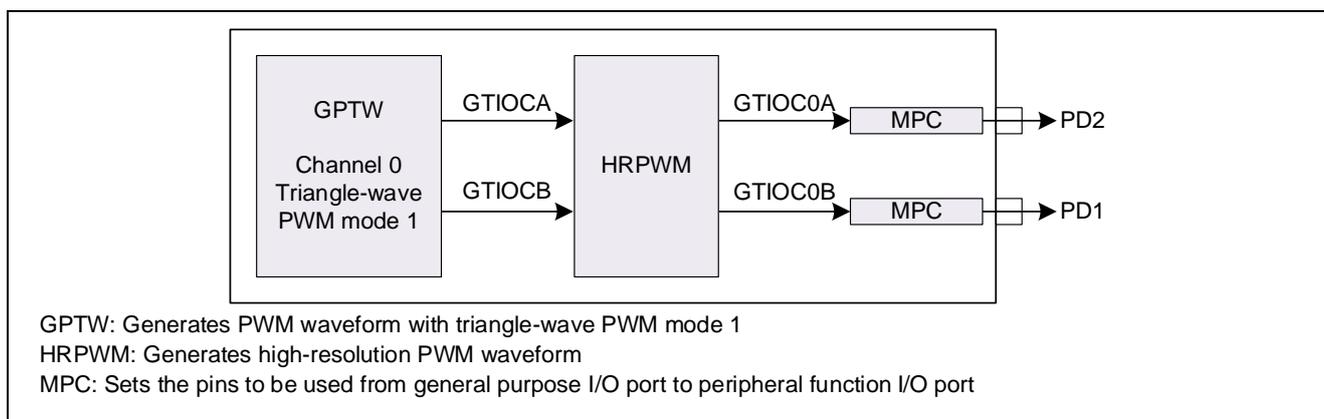


Figure 3.12 Sample Code Structure

### 3.3.2 Operation Details

This section describes the operation of this sample code.

The sample code sets amounts of delay to the rising/falling edges of the PWM waveform in the triangle-wave PWM mode of the GPTW, and outputs the waveform generated by the HRPWM from the GTIOC0A and GTIOC0B pins.

Figure 3.13 (a): Setting 0/32 times PCLKC as the amount of delay causes the GPTW output waveform to reflect a delay of 3 cycles of PCLKC.

Figure 3.13 (b): Setting 31/32 times the PCLKC period as the amount of delay causes the GPTW output waveform to reflect a delay of 31/32 times PCLKC.

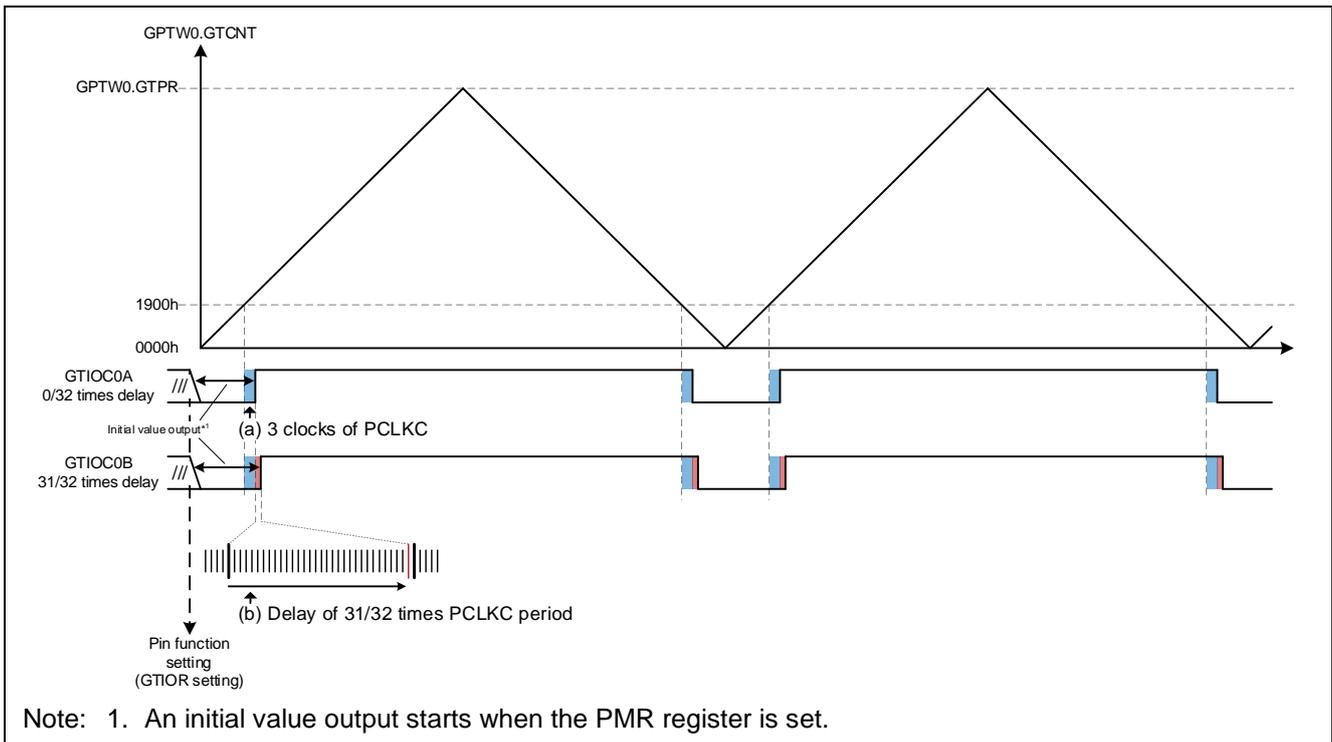


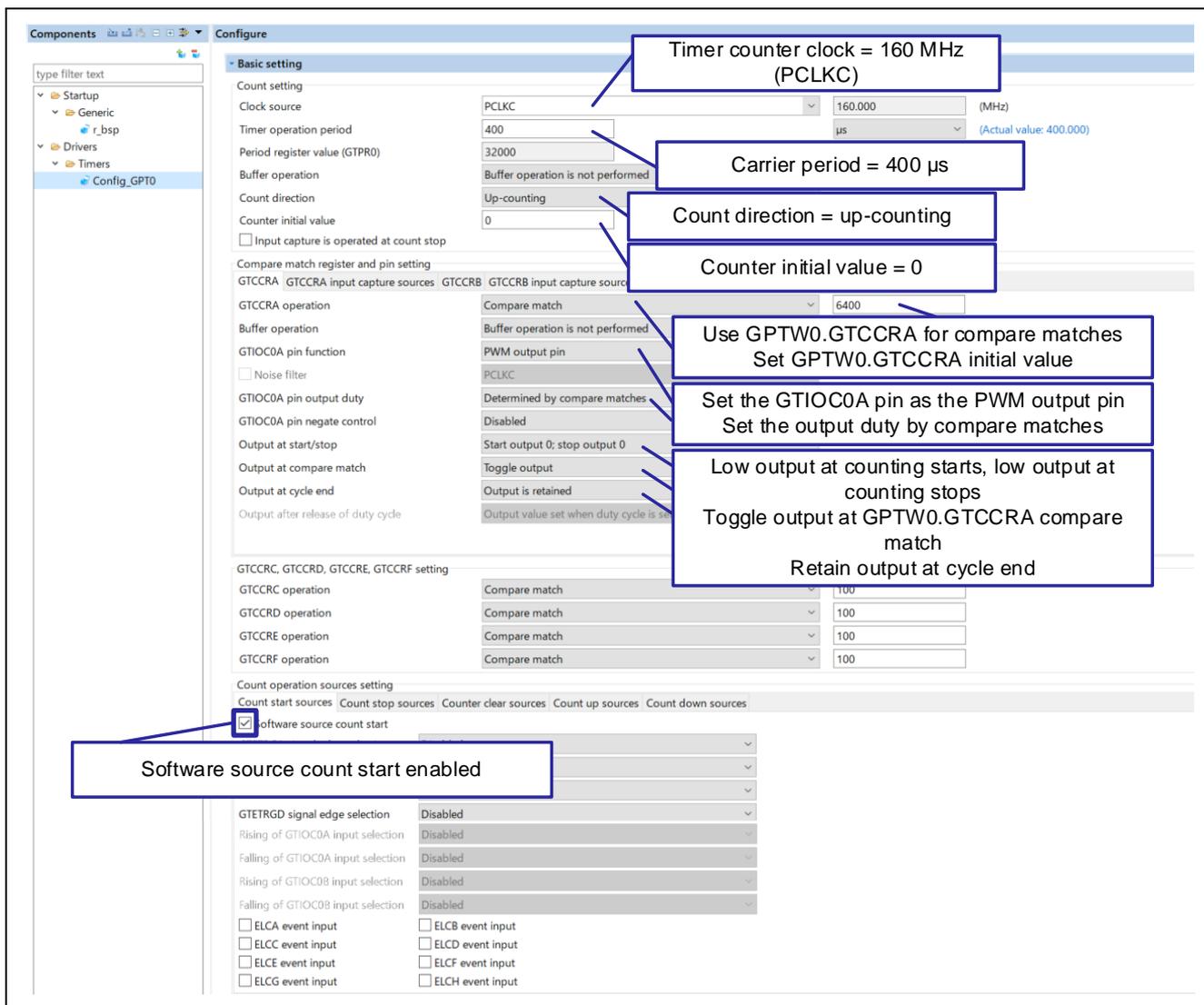
Figure 3.13 Sample Code Operations

### 3.3.3 Smart Configurator Settings

The sample code uses the Smart Configurator to add the GPTW as described below. For details on how to add components, see section 3.1.4, Adding Components.

**Table 3.5 Adding Components**

Item	Description
Component	General PWM timer
Configuration name	Config_GPT0
Operation	Triangle-wave PWM mode 1
Resource	GPT0



**Figure 3.14 GPT0 Settings (1/3)**

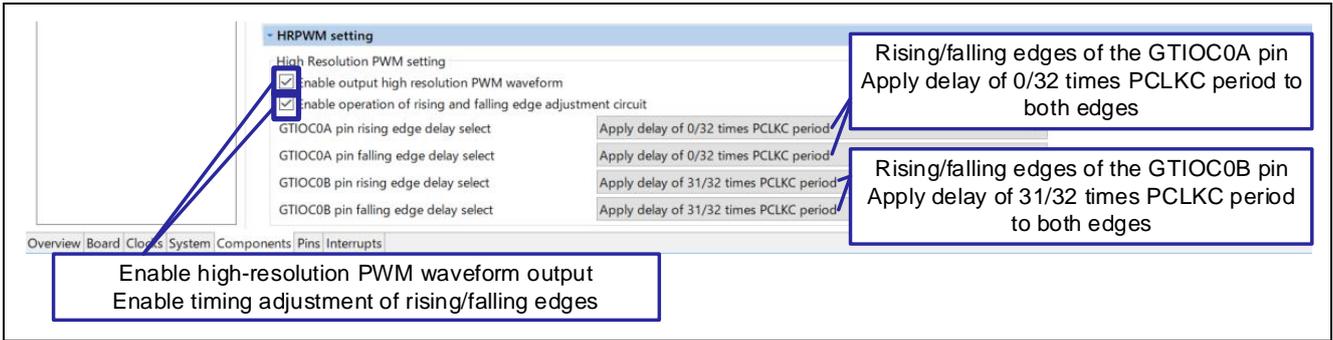


Figure 3.15 GPT0 Settings (2/3)

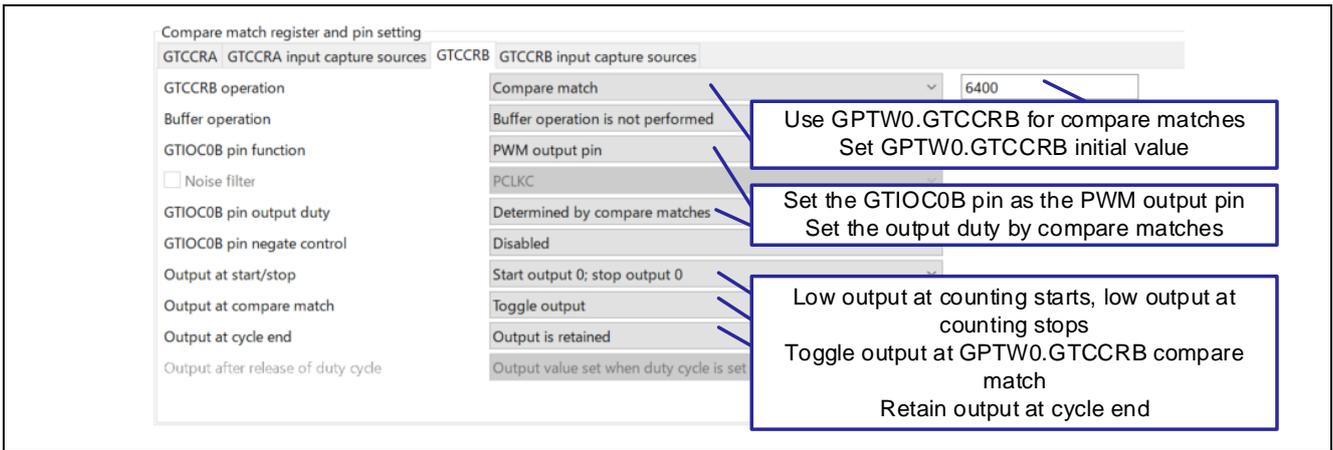


Figure 3.16 GPT0 Settings (3/3)

3.3.4 Flowchart

The figure below shows the processing of the main function added after code generation by the Smart Configurator.

Counting starts in the main function.

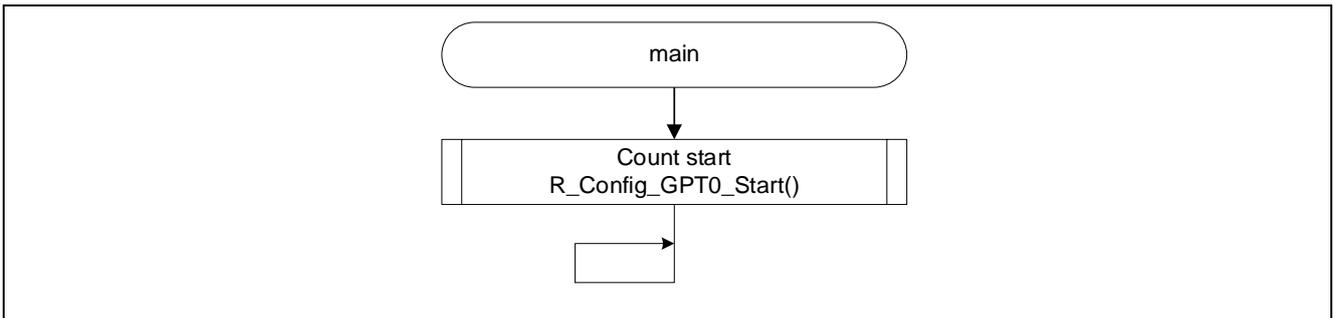


Figure 3.17 main Function

### 4. How to Import the Project

The sample code is provided in the format of an e<sup>2</sup> studio project. This chapter describes how to import a project into e<sup>2</sup> studio and CS+. After the import is complete, confirm the build and debugger settings.

Also visit the following Renesas Electronics website:

<https://www.renesas.com/software-tool/migration-e2studio-to-csplus>

#### 4.1 Importing with e<sup>2</sup> studio

When using the sample code in e<sup>2</sup> studio, import it into e<sup>2</sup> studio using the following steps.

(The actual screen may vary according to the version of e<sup>2</sup> studio you are using.)

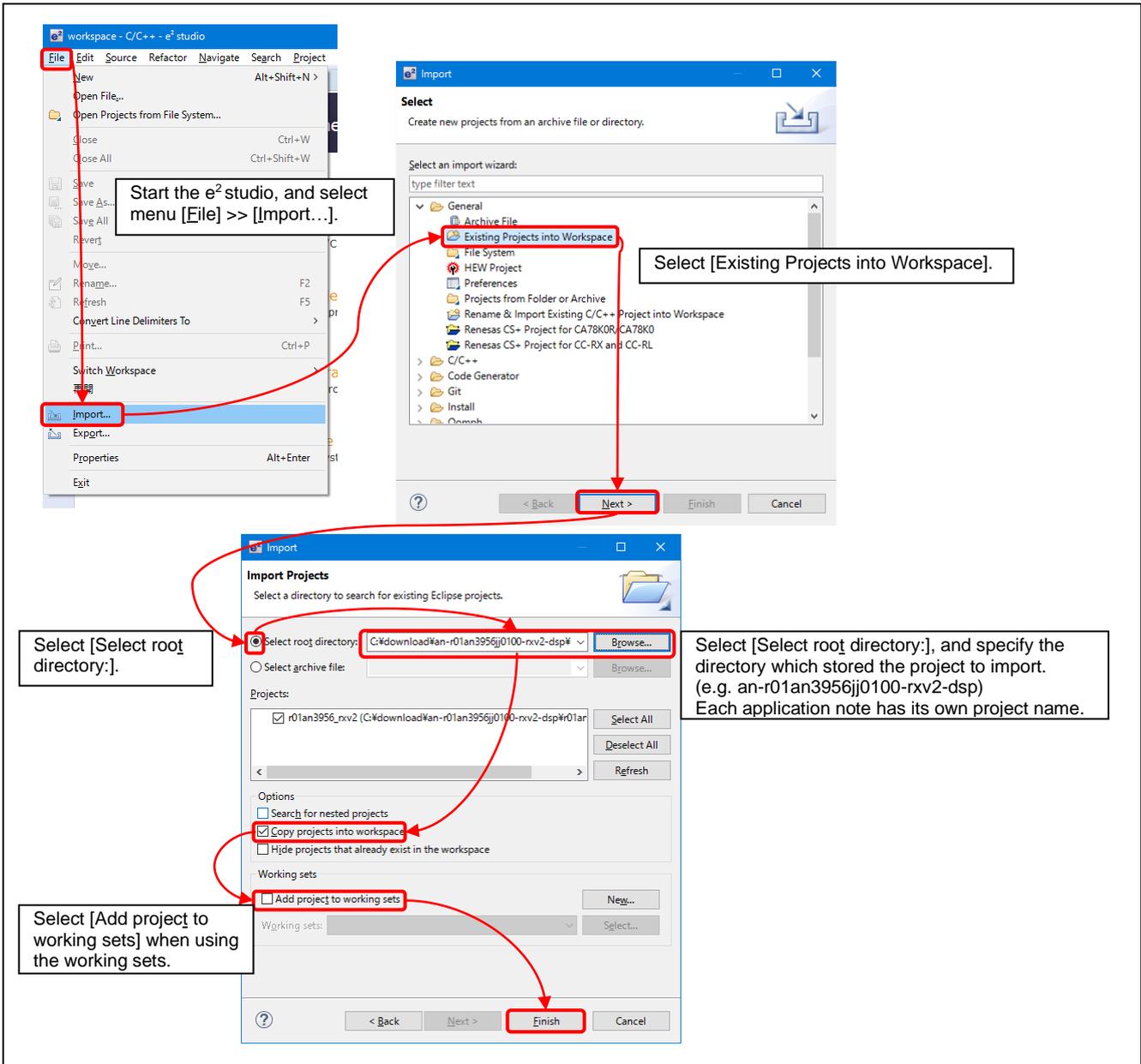


Figure 4.1 How to Import a Project into e<sup>2</sup> studio

### 4.2 Importing with CS+

When using the sample code with CS+, import the code to CS+ using the following steps.

(The actual screen may vary according to the version of CS+ you are using.)

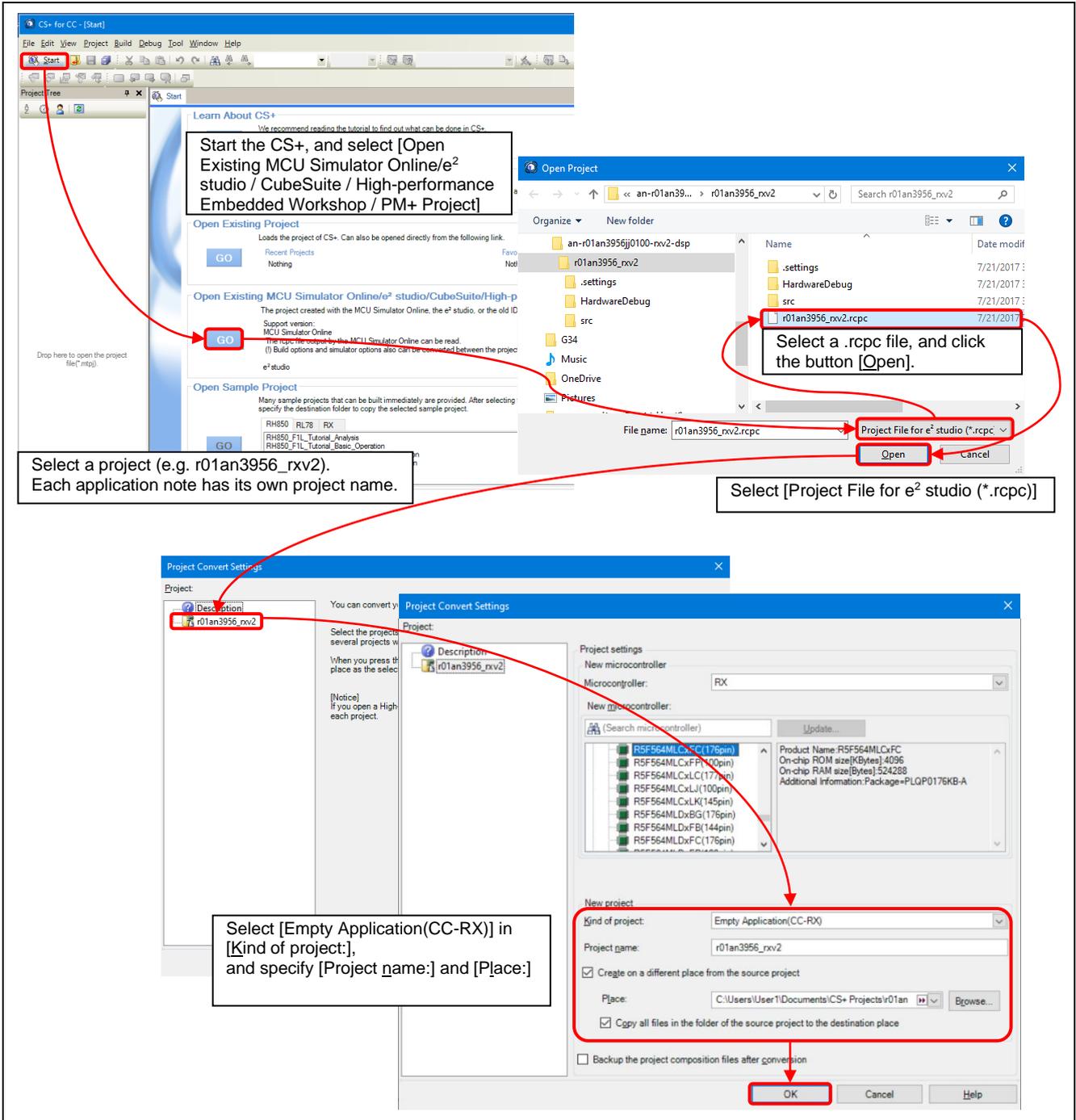


Figure 4.2 How to Import a Project into CS+

## 5. Reference Documents

- User's Manual: Hardware  
RX66T Group User's Manual: Hardware (R01UH0749)  
(Please obtain the latest version from the Renesas Electronics Corp. website.)
- Technical Updates/Technical News  
(Please obtain the latest version from the Renesas Electronics Corp. website.)
- User's Manual: Development Environment  
RX Family CC-RX Compiler User's Manual (R20UT3248)  
(Please obtain the latest version from the Renesas Electronics Corp. website.)
- User's Manual: Development Environment  
RX66T Group Renesas Starter Kit User's Manual (R20UT4150)  
(Please obtain the latest version from the Renesas Electronics Corp. website.)

**Revision History**

Rev.	Date	Description	
		Page	Summary
1.00	Nov. 01, 2023	—	First edition issued

# General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

## 1. 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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