RX Family and M16C family

Guide for Migration from the M16C to the RX : Timers (MTU2/MTU3/GPTW)

Abstract

This document describes migration from the timers in the M16C Family (Timer A and Timer B) to the timers in the RX Family (MTU2a, MTU3a and GPTWa).

Products

RX Family

M16C Family

When this document explains the migration from the M16C Family to the RX Family, the M16C/65C Group is used as an example of the M16C Family, and the RX231 Group, RX261 Group, and RX660 Group are used as examples of the RX Family. When applying this application note to other microcontrollers, make the necessary modifications according to the specifications of the target microcontroller and conduct thorough evaluation.

There are differences in the terminology between the M16C Family and RX Family.

The table below shows the differences in terminology related to timers.

Differences in Terminology Between the RX Family and the M16C Family

Item	M16C Family	RX Family
Timer modules	Timer A Timer B etc.	General Purpose PWM Timer (GPTWa) *1 Compare match timer (CMT) Compare match timer (CMTW) *2 16-bit timer pulse unit (TPUa) 8-bit timers (TMR and TMRb) Multifunction timer pulse unit 2 (MTU2a) *3 Multifunction timer pulse unit 3 (MTU3a) *2 etc.
Peripheral function operating clocks	Peripheral function clocks: fC, fC32, fOCO40M, fOCO-F, fOCO-S, f1	Peripheral module clocks: PCLKA, PCLKB
Timer operating clocks (hereinafter count clock)	Count source	Count clock
Function for selecting peripheral function input and output for pins	Function select register and input function select register *5	MPC *4
Registers for peripheral functions	I/O registers	I/O registers

Notes: 1. Available in the RX261 Group.
Notes: 2. Available in the RX660 Group.
Notes: 3. Available in the RX231 Group.
Notes: 4. The MPC is not available in some groups.
Notes: 5. Only available in the M32C Series and R32C Series.

Contents

1. Peripheral Functions Used

This document shows an example of operation that uses MTU2a of the RX231, MTU3a of the RX660, GPTWa of the RX261, and Timer A and Timer B of the M16C. MTU2a and MTU3a are hereinafter referred to as MTU.

Table 1-1 shows Peripheral Functions and Modes Used in Relation to the Operating Example.

Table 1-1 Peripheral Functions and Modes Used in Relation to the Operating Example

No	Operation	M16C		RX231,RX660		RX261	
		Peripheral Function	Mode	Peripheral Function	Mode	Peripheral Function	Mode
1	Outputting a PWM waveform	Timer A	PWM mode, timer mode [*1]	MTU	PWM mode 1	GPTWa	Sawtooth-wave PWM Mode 1
2	One-shot timer (single pulse output)		One-shot timer mode				
3	Measuring a pulse period	Timer B	Pulse period measurement mode		Normal mode		
4	Measuring a pulse width		Pulse width measurement mode				

Note: 1. In timer mode, only a pulse with a duty cycle of 50% can be output.

1.1 Outputting a PWM Waveform

This section describes the differences in the operation that outputs a PWM waveform from an output pin between the case where MTU is used in PWM mode 1 on the RX231 and RX660, the case where GPTWa is used in sawtooth-wave PWM mode 1 on the RX261, and the case where Timer A is used in timer mode on the M16C Family MCU.

The PWM mode 1 of MTU uses a timer counter (TCNT) and multiple compare registers (TGR). The output will be High, Low, or inverted based on a compare match between the TCNT counter and the TGR register. At this point, one cycle is achieved by clearing the TCNT counter when a compare match occurs between the TCNT counter and the TGR register. In addition, the duty cycle can be set by a compare match between another TGR register and the TCNT counter.

The example of outputting the PWM waveform in this section uses a compare register (TGRA, TGRB). The TGRB register is the compare register for the period (TCNT counter clear) and TGRA register is the compare register for duty cycle setting. The output is set to “Initial output is low”, “High output when the TCNT counter compare matche the TGRA”, and “Low output when the TCNT counter compare matche the TGRB”. In this example, to achieve a 50% duty cycle for M16C, the TGRA register is set to a compare match value that is half of the TGRB register.

As an application example of the PWM mode 1 of MTU, setting the same value of TGRA and TGRB register can output a pulse with 100% duty cycle, and setting the TGRA register to a value larger than TGRB register can output a pulse with 0% duty cycle. Because Timer A in the M16C Family cannot output a pulse with a duty cycle of 100%, timer output is stopped, and control must be performed by ports.

The sawtooth-wave PWM mode 1 of GPTWa uses a timer counter (GTCNT), a period setting register (GTPR), and a duty cycle setting compare registers (GTCCRA). The output will be High, Low, inverted, or retained based on a compare match between the GTCNT counter and the GTPR register or the GTCNT counter and the GTCCRA register. In addition, one cycle is achieved by clearing the GTCNT counter when a compare match occurs between the GTCNT counter and the GTPR register.

In the example of outputting the PWM waveform in this section, it is set to “Initial output is low”, “High output when the GTCNT counter compare matche the GTCCRA”, and “Low output when the GTCNT counter compare matche the GTPR”. In this example, to achieve a 50% duty cycle for M16C, the GTCCRA register is set to a compare match value that is half of the GTPR register.

As an application example of the sawtooth-wave PWM mode 1 of GPTWa, when the GTUDDTYC.OADTY, OBDTY bit value is set, the duty cycle 0%/100% output function can output pulses with 0% and 100% duty cycle of the pulse.

Figure 1-1 shows Example of Outputting a PWM Waveform. Table 1-2 shows Operational Overview of Outputting a PWM Waveform.

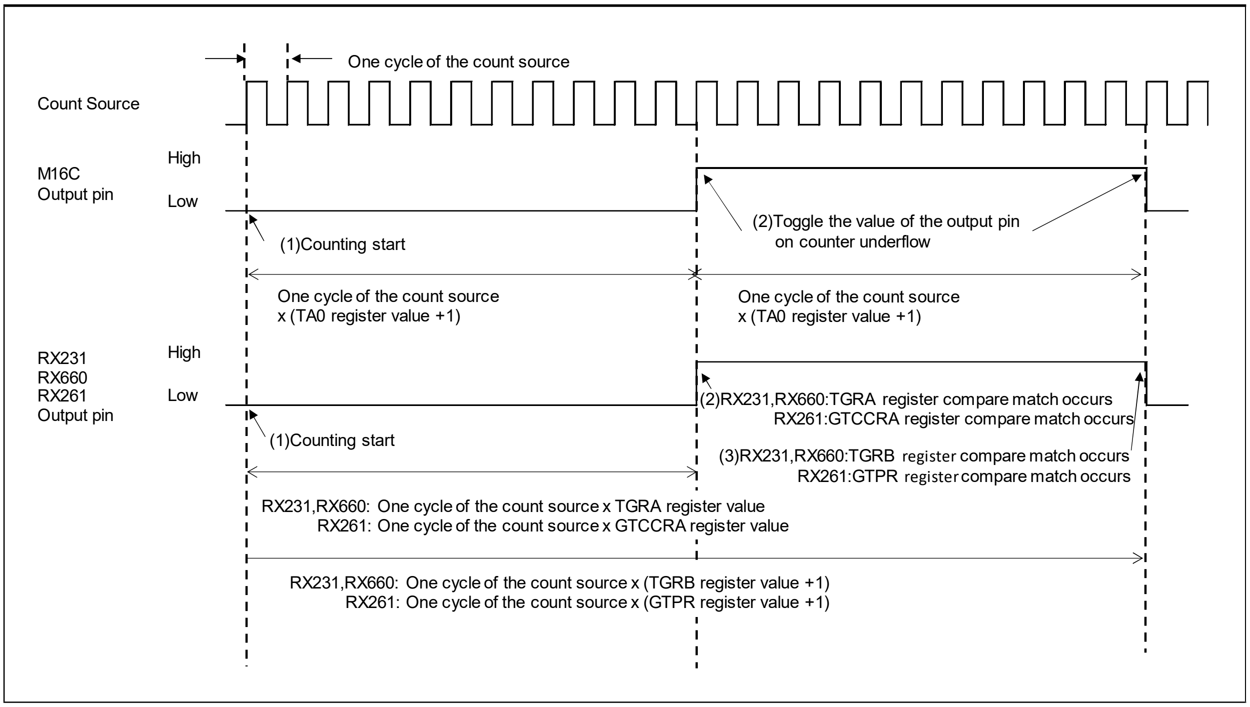

Figure 1-1 Example of Outputting a PWM Waveform

Table 1-2 Operational Overview of Outputting a PWM Waveform

Item	M16C/65C Timer A	RX231,RX660 MTU	RX261 GPTWa
Operating mode	**Timer mode**	**PWM mode 1**	**Sawtooth-wave PWM mode 1**
Overview of operations	(1) Counting starts The count operation is started. (2) Counter underflows Each time the counter underflows, output pin is inverted.	(1) Counting starts The count operation is started. (2) TGRA register compare match occurs When the TCNT counter and the TGRA register value match, TGRA register compare match occurs, and output pin changes from low to high. (3) TGRB register compare match occurs When the TCNT counter and the TGRB register value match, TGRB register compare match occurs, and output pin changes from high to low. When TGRB register compare match occurs, the TCNT counter value is cleared.	(1) Counting starts The count operation is started. (2) GTCCRA register compare match occurs When the GTCNT counter and the GTCCRA register value match, GTCCRA register compare match occurs, and output pin changes from low to high. (3) GTPR register compare match occurs When the GTCNT counter and the GTPR register value match, GTPR register compare match occurs, and the output pin changes from high to low. When GTPR register compare match occurs, the GTCNT counter value is cleared.

1.2 One-Shot Timer

This section describes the difference in the operation that outputs a pulse only once from an output pin between the case where MTU is used in PWM mode 1 on the RX231 and RX660, the case where sawtooth-wave PWM mode 1 is used on the RX261, and the case where Timer A is used in one-shot timer mode on the M16C.

The MTU uses PWM mode 1. After the reset, the pin multiplexed with the output pin of MTU is configured as I/O input port, setting the PDR register to output and the PODR register to Low changes them to the I/O output port with a Low level. Next, the initial configuration of MTU will be performed. Configure TCNT counter to start by software upon an external trigger. TGRB compare register is the period, and TGRA compare register is the duty cycle. The output is set to “Initial output is high“, “Low output when the TCNT counter compare match the TGRA register”, and “Low output when the TCNT counter compare match the TGRB register”. The interrupt processing with an external trigger switches the I/O output port to the output pin of MTU and starts the MTU timer at the same time. Since the initial output of MTU is high, the high pulse is output from the timer start until it is a compare match with TGRA register and switched to low output. The MTU timer is stopped by a compare match interrupt of TGRA register, and the pin is switched to the initially configured I/O output port (Output is low) to prepare for the next external trigger. At this point, clear the value of the TCNT counter. This allows one-shot timer mode of M16C to be implemented with a pulse width set by the value in TGRA register. The value of TGRA register used to set the pulse width should not exceed the value of TGRB register, which represents the period.

The GPTWa uses sawtooth-wave PWM mode 1. After the reset, the pin multiplexed with the output pin of GPTWa is configured as the I/O input port, setting the PDR register to output and the PODR register to Low changes them to the I/O output port with a Low level as with MTU. Next, the initial configuration of GPTWa will be performed. The GTCNT counter is driven by an external trigger, with the GTPR register is the period and the GTCCRA compare register is the duty cycle. The output is set to “Initial output is low“, “output is high when counting is started”, “Low output when the GTCNT counter compare match the GTCCRA register”, and “Low output when the GTCNT counter compare match the GTPR register (Low output at the end of a cycle)”. And the output is set to output is Low when counting is stopped. In the case of GPTWa, unlike MTU, the timer can be started in response to an external trigger, at this point, switch from the I/O output port to the GPTWa output pin. When an external trigger is input, the timer starts and simultaneously switches from Low output to high output at the same time. After that, the output switches to low upon a GTCCRA register compare match. The GPTWa timer is stopped by a compare match interrupt of GTCCRA register and clear the value of the GTCNT counter. This allows one-shot timer mode of M16C to be implemented with a pulse width set by the value in GTCCRA register. The value of GTCCRA register used to set the pulse width should not exceed the value of GTPR register, which represents the period.

Figure 1-2 shows Example of outputting a one-shot pulse. Table 1-3 shows Operational Overview of the One-Shot Timer.

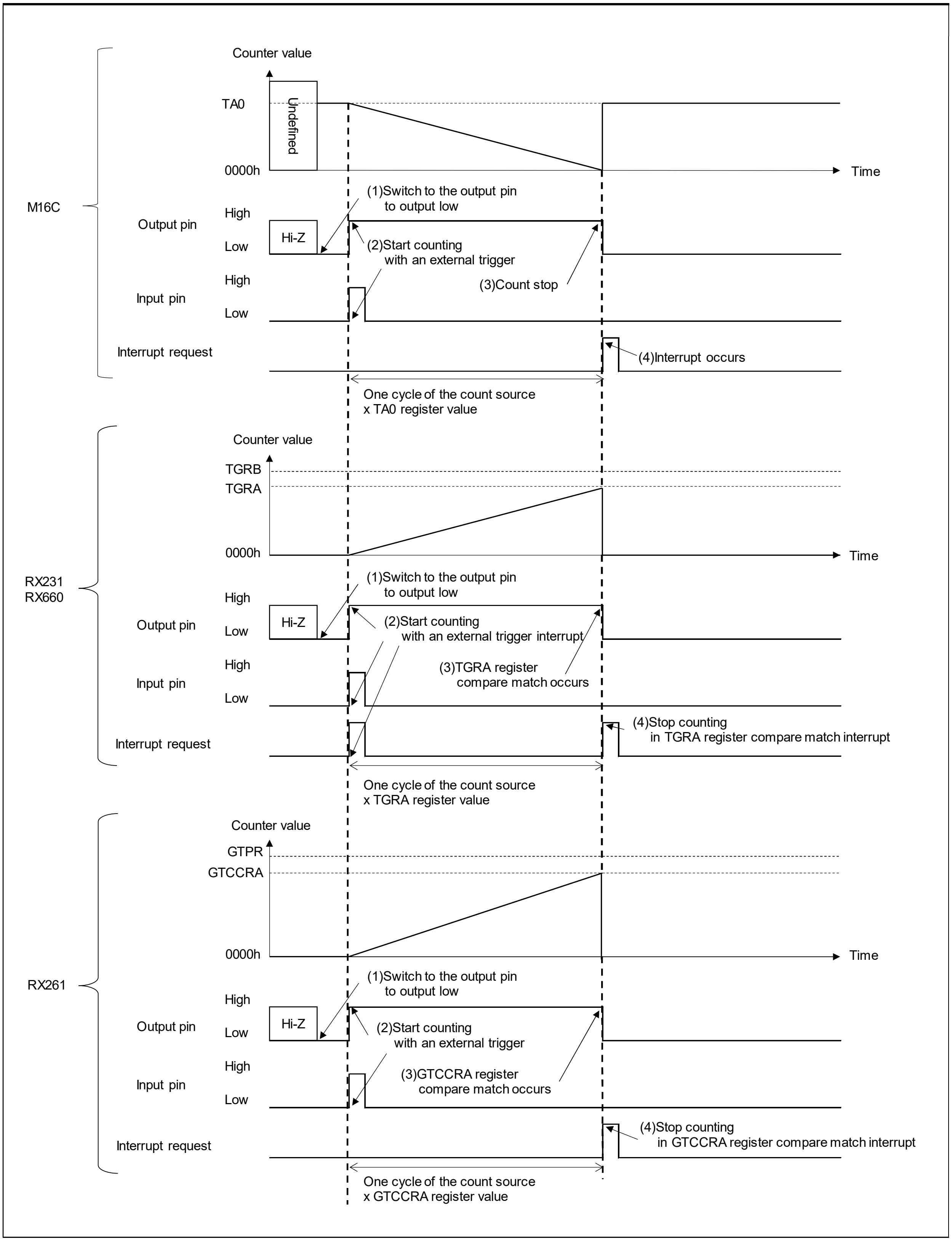

Figure 1-2 Example of outputting a one-shot pulse

Table 1-3 Operational Overview of the One-Shot Timer

Item	M16C/65C Timer A	RX231,RX660 MTU	RX261 GPTWa
Operating mode	**One-shot timer mode**	**PWM mode 1**	**Sawtooth-wave PWM mode 1**
Overview of operations	(1) Switch to the output pin to output low After reset, the pin function is configured as I/O input port, so during Timer A initialization, switch them to I/O output port and output low. After initializing Timer A, the function selection register switches the pin function from the I/O output port pin to the pulse output pin of Timer A. (2) Start counting with an external trigger The Timer A starts counting with an external trigger. At the same time the count starts, the output pin changes from low to high. (3) Counting stops When the Timer A count value becomes 0000h, the count stops, and the output pin changes from high to low. (4) Interrupt occurs Timer A interrupt occurs when the Timer A count value becomes 0000h.	(1) Switch to the output pin to output low After reset, the pin function is configured as the I/O input port, so switch them to the I/O output port and output low. At the same time, perform the initialization of MTU. (2) Start counting with an external trigger interrupt The MTU starts counting the timer in the program of the external trigger interrupt processing, and at the same time, MPC switches the pin function from the I/O port to the MTU pin, the output pin changes from low to high. (3) TGRA register compare match occurs When the TCNT counter and the TGRA register value match, TGRA register compare match occurs, and the output pin changes from high to low. (4) Stop counting in TGRA register compare match interrupt The TGRA register compare match interrupt processing program stops MTU counting, clearing the TCNT counter, and switch the pin function from the MTU pin to the I/O output port pin.	(1) Switch to the output pin to output low After reset, the pin function is configured as the I/O input port, so during GPTWa initialization, switch them to the I/O output port and output low. After initializing GPTWa, MPC switches the pin function from the I/O output port pin to the GPTWa pin. (2) Start counting with an external trigger The GPTWa starts counting with an external trigger. At the same time the count starts, the output pin changes from low to high. (3) GTCCRA register compare match occurs When the GTCNT counter and GTCCRA register values match, GTCCRA register compare match occurs, and output pin changes from high to low. (4) Stop counting in GTCCRA register compare match interrupt The GTCCRA register compare match interrupt processing program stops GPTWa counting, clearing the GTCNT counter.

1.3 Measuring a Pulse Period

This section describes the differences in the operation that measures the period from one rising edge to the next rising edge of a pulse input to an external input pin between the case where the MTU is used in normal mode on the RX231 and RX660, the case where the GPTWa is used in sawtooth-wave PWM mode 1 on the RX261, and the case where the Timer B is used in pulse period measurement mode on the M16C.

The input capture function in normal mode of the MTU uses a timer counter (TCNT) and a capture register (TGR). When using the input capture function, the input edge of the pin is detected, and the TCNT countervalue can be transferred to the TGR register. There are two types of interrupts: an input capture interrupt that occurs when an input edge on the pin is detected, and an overflow interrupt that occurs when the TCNT counter overflows, each can be used independently.

In the pulse period measurement example in this section, each time a rising edge is detected on the external input pin, the value in the TCNT counter is transferred to the TGRA register, at which time the TCNT counter is set to be cleared. Each time the overflow interrupt occurred, the variable counts the number of overflows, and when the input capture interrupt occurred, the TGRA register value and the number of overflows counted are used to calculate the pulse period.

The GPTWa uses the input capture function of sawtooth-wave PWM mode 1.
In the example of pulse period measurement in this section, the specifications are the same as the MTU.

Figure 1-3 shows Example of Measuring the Pulse Period. Table 1-4 shows Operational Overview of Measuring the Pulse Period.

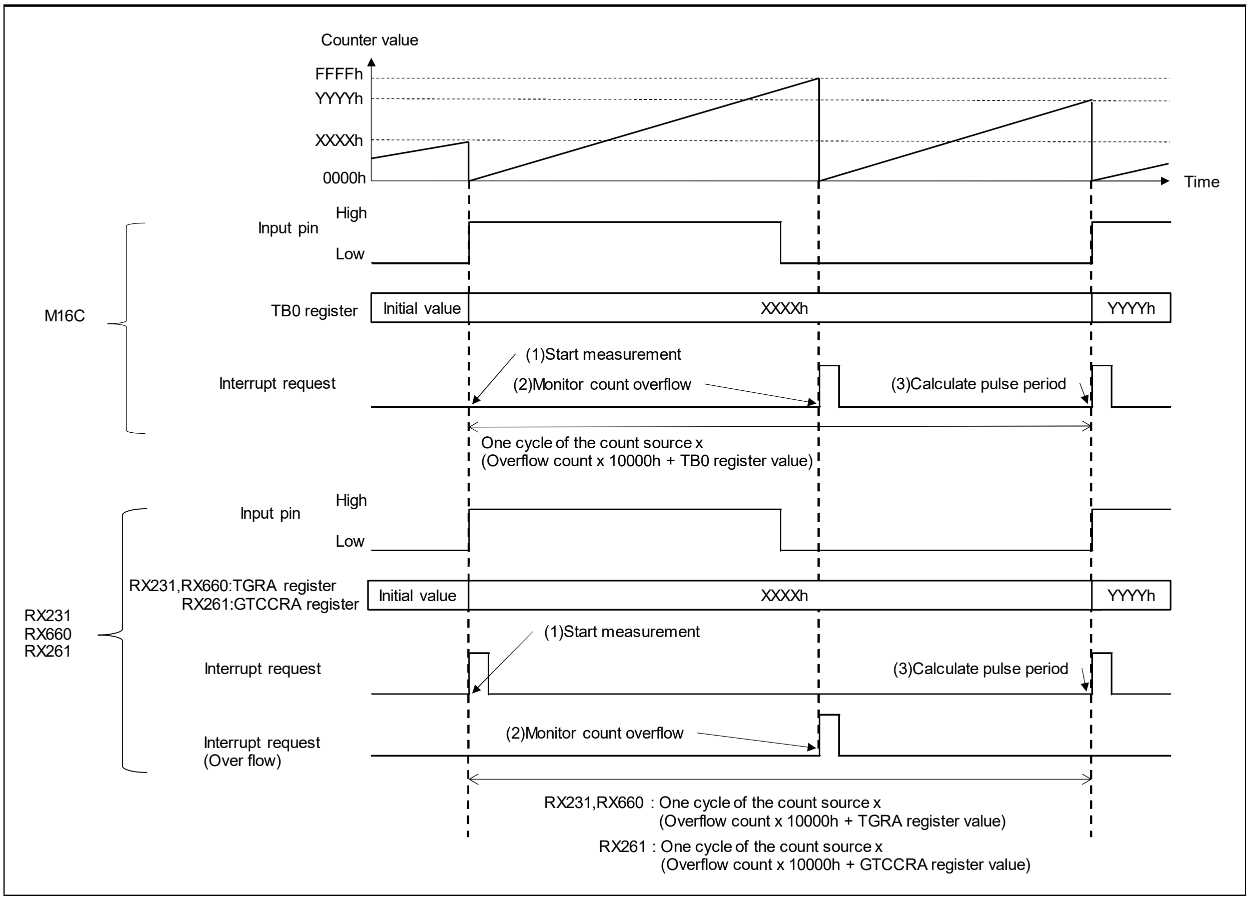

Figure 1-3 Example of Measuring the Pulse Period

Table 1-4 Operational Overview of Measuring the Pulse Period

Item	M16C/65C Timer B	RX231,RX660 MTU	RX261 GPTWa
Operating mode	**Pulse period measurement mode**	**Normal mode**	**Sawtooth-wave PWM mode 1**
Overview of operations	(1) Measurement starts When a rising edge of a pulse input on an external input pin is detected, clear the counter on Timer B0 and start measuring the pulse period. (2) Monitoring of a counter overflow starts When Timer B0 counter overflows, the Timer B0 interrupt occurs. Read the overflow flag in the interrupt process, and count the number of overflows. (3) Pulse period is calculated When a rising edge of a pulse input on an external input pin is detected, the pulse period is calculated based on the number of overflows and the TB0 register value in the Timer B0 interrupt process.	(1) Measurement starts When a rising edge of a pulse input on an external input pin is detected, clear the TCNT counter and start measuring the pulse period. (2) Monitoring of a counter overflow starts When TCNT counter overflows, the overflow interrupt occurs. Count the number of overflows in the interrupt process. (3) Pulse period is calculated When a rising edge of a pulse input on an external input pin is detected, the pulse period is calculated based on the number of overflows and the TGRA register value in the TGRA register input capture interrupt process.	(1) Measurement starts When a rising edge of a pulse input on an external input pin is detected, clear the GTCNT counter and start measuring the pulse period. (2) Monitoring of a counter overflow starts When GTCNT counter overflows, the overflow interrupt occurs. Count the number of overflows in the interrupt process. (3) Pulse period is calculated When a rising edge of a pulse input on an external input pin is detected, the pulse period is calculated based on the number of overflows and the GTCCRA register value in the GTCCRA register input capture interrupt process.

1.4 Measuring a Pulse Width

This section describes the differences in the operation that measures the pulse width from one rising edge to the next falling edge of a pulse input to an external input pin between the case where the MTU is used in normal mode on the RX231 and RX660, the case where the GPTWa is used sawtooth-wave PWM mode 1 on the RX261, and the case where the Timer B is used in pulse width measurement mode on the M16C.

For pulse width measurement, both the MTU and the GPTWa use the input capture function as well as Measuring a Pulse Period in Chapter 1.3. In this section, in order to measure the pulse width of both high and low, the input capture trigger is used at both edges of the external input signal.

Figure 1-4 shows Example of Measuring the Pulse Width. Table 1-5 shows Operational Overview of the Example of Measuring the Pulse Width.

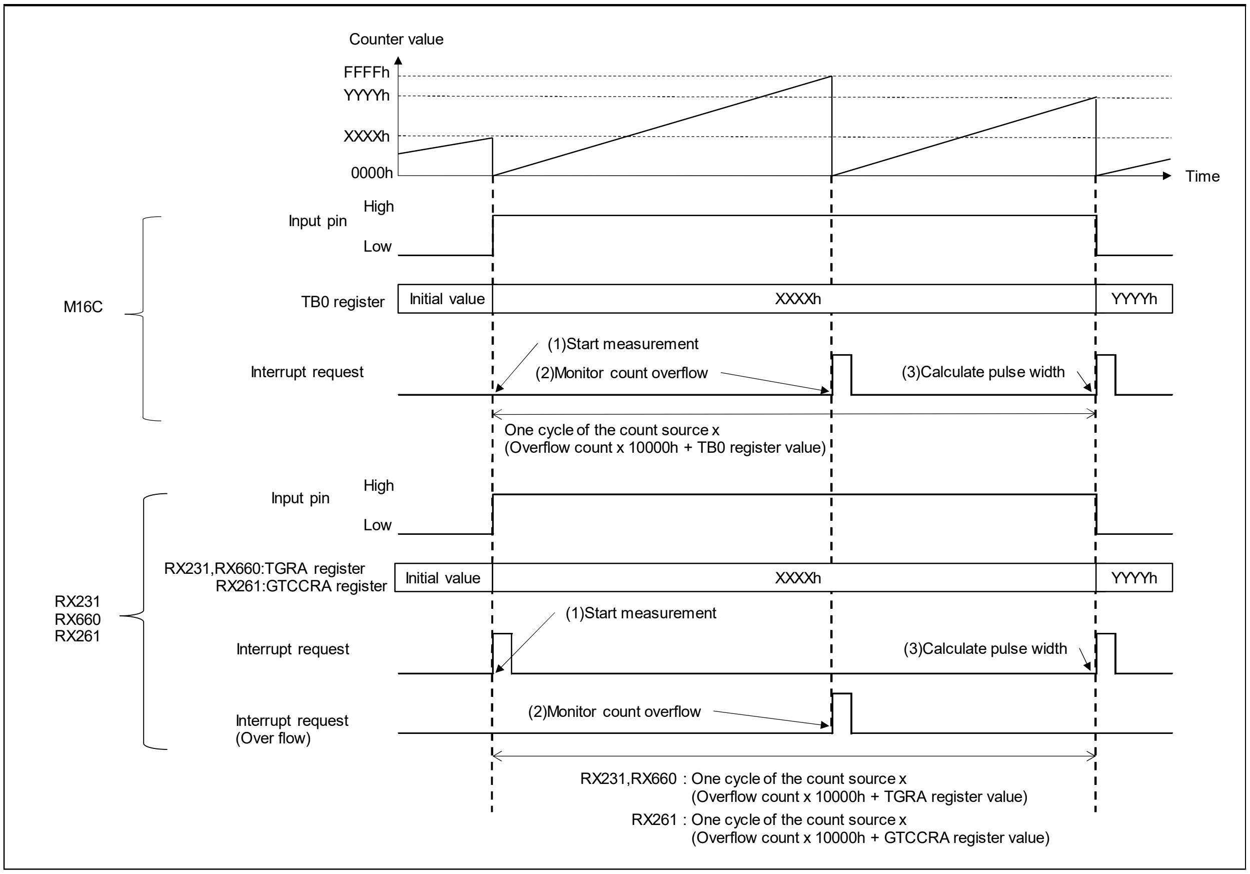

Figure 1-4 Example of Measuring the Pulse Width

Table 1-5 Operational Overview of the Example of Measuring the Pulse Width

Item	M16C/65C Timer B	RX231,RX660 MTU	RX261 GPTWa
Operating mode	**Pulse width measurement mode**	**Normal mode**	**Sawtooth-wave PWM mode 1**
Overview of operations	(1) Measurement starts When a rising edge or falling edge of a pulse input on an external input pin is detected, clear the counter on Timer B0 and start measuring the pulse width. (2) Monitoring of a counter overflow starts When Timer B0 counter overflows, the Timer B0 interrupt occurs. Read the overflow flag in the interrupt process, and count the number of overflows. (3) Pulse width is calculated When a rising edge or falling edge of a pulse input on an external input pin is detected, the pulse width is calculated based on the number of overflows and the TB0 register value in the interrupt process.	(1) Measurement starts When a rising edge or falling edge of a pulse input on an external input pin is detected, clear the TCNT counter and start measuring the pulse width. (2) Monitoring of a counter overflow starts When TCNT counter overflows, the overflow interrupt occurs. Count the number of overflows in the interrupt process. (3) Pulse width is calculated When a rising edge or falling edge of a pulse input on an external input pin is detected, the pulse width is calculated based on the number of overflows and the TGRA register value in the TGRA register input capture interrupt process.	(1) Measurement starts When a rising edge or falling edge of a pulse input on an external input pin is detected, clear the GTCNT counter and start measuring the pulse width. (2) Monitoring of a counter overflow starts When GTCNT counter overflows, the overflow interrupt occurs. Count the number of overflows in the interrupt process. (3) Pulse width is calculated When a rising edge or falling edge of a pulse input on an external input pin is detected, the pulse width is calculated based on the number of overflows and the GTCCRA register value in the GTCCRA register input capture interrupt process.

2. Related Sections in the RX User's Manual: Hardware

When migrating from the M16C Family to the RX Family, refer to the following sections of the RX User's Manual: Hardware.

- Multi-Function Timer Pulse Unit 2(RX231)
- Multi-Function Timer Pulse Unit 3(RX660)
- General-Purpose PWM Timer (RX261)
- Clock Generation Circuit
- Low Power Consumption
- Interrupt Controller,CPU
- I/O Ports,MPC
- Register Write Protection Function

3. Appendix

3.1 Points on Migration From the M16C Family to the RX Family

This chapter explains points on migration from the M16C Family to the RX Family.

3.1.1 Interrupts

For the RX Family, when an interrupt request is received while all of the following conditions are met, the interrupt occurs.

- The I flag (PSW.I bit) is 1.
- Registers IER and IPR in the ICU are set to enable interrupts.
- The interrupt request enable bit for peripheral functions is enabled.

Table 3-1 shows Comparison of Conditions for Interrupt Generation Between the RX and the M16C.

Table 3-1 Comparison of Conditions for Interrupt Generation Between the RX and the M16C

Item	M16C	RX
I flag	When the I flag is set to 1 (enabled), the maskable interrupt request can be accepted.	
Interrupt request flag	When there is an interrupt request from a peripheral function, the interrupt request flag becomes 1 (interrupt requested).	
Interrupt priority level	Selected by setting bits ILVL2 to ILVL0.	Selected by setting the IPR[3:0] bits.
Interrupt request enable	—	Controlled by using the IER register.
Interrupt enable for peripheral functions	—	Interrupts can be enabled or disabled in each peripheral function.

For more information, refer to sections Interrupt Controller (ICU), CPU, and sections for other peripheral functions used in the User’s Manual: Hardware.

3.1.2 I/O Ports

In the RX Family, the MPC must be configured in order to assign I/O signals from peripheral functions to pins.

Before controlling the input and output pins in the RX Family, the following two items must be set.

- In the MPC.PFS register, select the peripheral functions that are assigned to the appropriate pins.
- In the PMR register for I/O ports, select the function for the pin to be used as a general I/O port or I/O port for a peripheral function.

Table 3-2 shows Comparison of I/O Settings for Peripheral Function Pins Between the RX and the M16C.

Table 3-2 Comparison of I/O Settings for Peripheral Function Pins Between the RX and the M16C

Function	M16C (in the case of the M16C/65C)	RX (in the case of the RX231, RX261, and RX660)
Select the pin function	These are not available in the M16C. *1 When a mode is set for a peripheral function, appropriate pins are assigned as I/O pins for the peripheral function.	With the PFS register, I/O ports for peripheral functions can be assigned by selecting from multiple pins.
Switch between general I/O port and peripheral function		With the PMR register, the corresponding pin function can be selected as a general I/O port or a peripheral function.

Note: 1. Register for similar functions are available in the M32C Series and R32C Series.

For more information, refer to the Multi-Function Pin Controller (MPC) and I/O port sections in the User's Manual: Hardware.

3.1.3 Module Stop Function

The RX Family has the ability to stop each peripheral module individually.

By transitioning unused peripheral modules to the module stop state, power consumption can be reduced.

After the reset is released, all modules (with a few exceptions) are in the module stop state.

Registers for modules in the module stop state cannot be written to or read.

For more information, refer to the Low Power Consumption section in the User's Manual: Hardware.

3.2 I/O Register Macros

Macro definitions listed in Table 3-3 Macro Usage Examples can be found in the RX I/O register definitions (iodefine.h).

The readability of programs can be achieved with these macro definitions.

Table 3-3 shows Macro Usage Examples.

Table 3-3 Macro Usage Examples

Macro	Usage Example
IR("module name", "bit name")	**IR(MTU0, TGIA0)** = 0 ; The IR bit corresponding to MTU0.TGIA0 is cleared to 0 (no interrupt request is generated).
DTCE("module name", "bit name")	**DTCE (MTU0, TGIA0)** = 1 ; The DTCE bit corresponding to MTU0.TGIA0 is set to 1 (DTC activation is enabled).
IEN("module name", "bit name")	**IEN(MTU0, TGIA0)** = 1 ; The IEN bit corresponding to MTU0.TGIA0 is set to 1 (interrupt enabled).
IPR("module name", "bit name")	**IPR(MTU0, TGIA0)** = 0x02 ; The IPR bit corresponding to MTU0.TGIA0 is set to 2 (interrupt priority level 2).
MSTP("module name")	**MSTP(MTU)** = 0 ; The MTU0 Module Stop bit is set to 0 (module stop state is canceled).
VECT("module name", "bit name")	#pragma interrupt (Excep_MTU0_TGIA0 (vect = **VECT(MTU0, TGIA0)**)) The interrupt function is declared for the corresponding MTU0.TGIA0 register.

3.3 Intrinsic Functions

The RX Family has intrinsic functions for setting control registers and special instructions. When using intrinsic functions, include machine.h.

Table 3-4 shows Examples of Differences in the Settings of Control Registers and Descriptions of Special Instructions Between the RX and the M16C.

Table 3-4 Examples of Differences in the Settings of Control Registers and Descriptions of Special Instructions Between the RX and the M16C

Item	Description	
	M16C	RX
Set the I flag to 1	asm(“fset i”);	setpsw_i (); (0)
Set the I flag to 0	asm(“fclr i”);	clrpsw_i (); (0)
Expanded into the WAIT instruction	asm(“wait”);	wait(); (0)
Expanded into the NOP instruction	asm(“nop”);	nop(); (0)

Note: 1. The machine.h file must be included.

4. Reference Documents

User's Manual: Hardware

RX230/RX231 Group User's Manual: Hardware (R01UH0496EJ)
RX260/RX261 Group User's Manual: Hardware (R01UH1045 EJ)
RX660 Group User's Manual: Hardware (R01UH0937 EJ)
M16C/65C Group User's Manual: Hardware (R01UH0093 EJ)
If you are using a product that does not belong to the RX231, RX261, RX660, or M16C/65C Group, refer to the applicable user's manual for hardware.
The latest versions can be downloaded from the Renesas Electronics website.

Technical Update/Technical New

The latest information can be downloaded from the Renesas Electronics website.

User's Manual: Development Tools

RX Family CC-RX Compiler User's Manual (R20UT3248 EJ)
M16C Series, R8C Family C Compiler Package (M3T-NC30WA)
（The latest versions can be downloaded from the Renesas Electronics website.

REVISION HISTORY

Rev.	Date	Description	
		Page/Section	**Summary**
1.00	Dec. 16, 2013	—	First edition issued
1.10	July 1, 2014	All	Format overhaul
		2	Added table “Differences in Terminology”
		Section 1.2	Changed setting value for TGRD register from FFFFh to FFFEh
		19	Deleted references to non-maskable interrupts
2.00	June 12, 2023	All	The product model of the target device for the RX Family MCU was changed from RX210 to RX231/RX660.
2.01	Oct 21, 2025	-	Title updated
3.00	Dec.12.25	All	Added RX261 to the target device for the RX family. Also added GPTW to the RX comparison function. The contents of the document have been significantly revised.

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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