RX210 and RX21A Groups

MTU2 Complementary PWM Output Port Switching Using the MPC

R01AN1203EJ0102
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Abstract

This application note describes a sample code that changes the output ports for a three-phase complementary PWM (pulse-width modulation) output with a non-overlapping relationship between the positive and negative phases generated by multifunction timer unit 2 (MTU2) using the multifunction pin controller (MPC) in the RX210 and RX21A Groups.

Products

RX210 and RX21A Groups

When using this application note with other Renesas MCUs, careful evaluation is recommended after making modifications to comply with the alternate MCU.

Contents

1. Specifications

This sample program outputs a three-phase complementary PWM waveform using the MTU2a's complementary PWM mode functions and switches the ports that output the complementary PWM waveform according to a switch input.

An active-low complementary PWM waveform is output from MTU2a channels 3 and 4. An interrupt is generated every output period, the duty is increased or decreased in the interrupt handler, and that adjustment is reflected in the output.

The sample program also reads a switch input signal from pin P34 and changes the complementary PWM output port when the input has been confirmed.

Table 1.1 lists the peripheral functions used and their applications and figure 1.1 presents an overview of this operation.

Table 1.1 Peripheral Functions Used and Their Applications

Peripheral Function	Application
P34	Reads the switch input signal
MTU2a	Generates pulse outputs
MPC	Changes a port for complementary PWM output from the MTU2a.

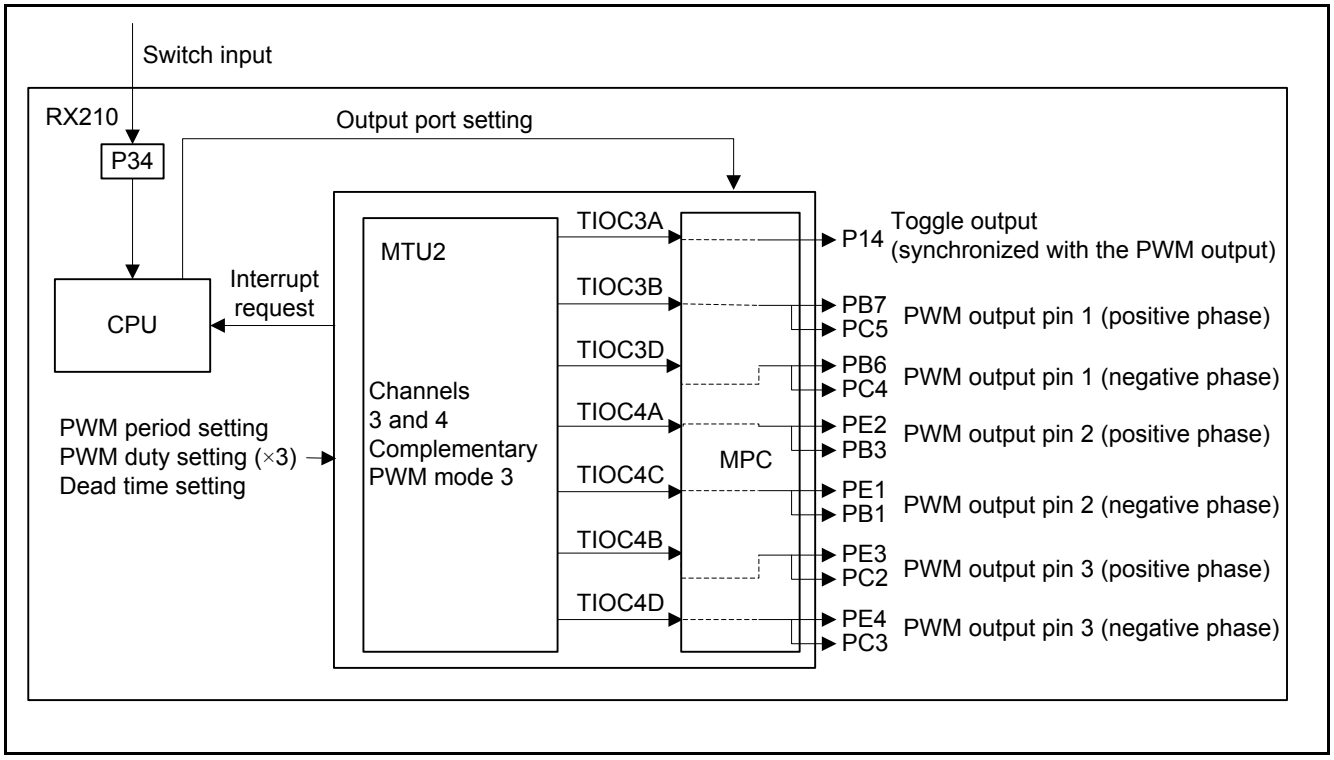

Figure 1.1 Operational Overview

2. Confirmed Operating Condition

Operation of the sample code in this application note has been verified under the following conditions.

Table 2.1 Confirmed Operating Condition

Item	Description
Microcontroller used	R5F52108ADFP (RX210 Group)
Operating frequency	Main clock: 20.0 MHz Sub-clock: 32.768 kHz PLL: Main clock divided by 2 and multiplied by 10 System clock (ICLK): 50 MHz (PLL divided by 2) Peripheral module clock B (PCLKB): 25 MHz (PLL divided by 4)
Operating voltage	5.0 V is supplied from E1.
Integrated development environment	Renesas Electronics Corporation High-performance Embedded Workshop Version 4.09.00.007
C compiler	RX Family C/C++ Compiler V.1.02
	-cpu=rx200 -output=obj="$(CONFIGDIR)\$(FILELEAF).obj" -debug –nologo (The integrated development environment default settings are used.)
iodefine.h version	Version 1.0B
Endian order	Little endian
Operating mode	Single-chip mode
Processor mode	Supervisor mode
Sample code version	Version 1.00
Board used	Renesas Starter Kit for RX210 (Product number: R0K505210C000BE)

3. Reference Application Notes

For additional information associated with this document, refer to the following application notes.

- RX210 Group Initial Setting Rev. 1.00 (R01AN1002EJ)
- RX21A Group Initial Setting Rev. 1.10 (R01AN1486EJ)

The initial setting functions in the reference application notes are used in the sample code in this application note. The revision numbers of the reference application notes are current as of when this application note was made. However the latest version is always recommended. Visit the Renesas Electronics Corporation website to check and download the latest version.

4. Hardware

4.1 Pins Used

Table 4.1 lists the pins used and their functions.

Table 4.1 Pin Functions

Pin	I/O	Function
PB7/MTIOC3B	Output	Complementary PWM output
PB6/MTIOC3D	Output	Complementary PWM output
PE2/MTIOC4A	Output	Complementary PWM output
PE1/MTIOC4C	Output	Complementary PWM output
PE3/MTIOC4B	Output	Complementary PWM output
PE4/MTIOC4D	Output	Complementary PWM output
PC5/MTIOC3B	Output	Complementary PWM output
PC4/MTIOC3D	Output	Complementary PWM output
PB3/MTIOC4A	Output	Complementary PWM output
PB1/MTIOC4C	Output	Complementary PWM output
PC2/MTIOC4B	Output	Complementary PWM output
PC3/MTIOC4D	Output	Complementary PWM output
P34	Input	Complementary PWM output pin switching input (SW3 on RSK board)

5. Software

5.1 Operational Overview

During initialization, the sample program performs complementary PWM output from the MTIOC3B, MTIOC3D, MTIOC4A, MTIOC4C, MTIOC4B, and MTIOC4D pins using the MTU2a output. The output ports for these pins are set to PB7, PB6, PE2, PE1, PE3, and PE4, respectively.

The complementary PWM output is disabled at the time the SW3 input is confirmed on the RSK.

After the output is disabled, the complementary PWM output ports (MTIOC3B, MTIOC3D, MTIOC4A, MTIOC4C, MTIOC4B, and MTIOC4D) are switched to PC5, PC4, PB3, PB1, PC2, and PC3, respectively, and then complementary PWM output is enabled again.

After that, each time a new value of the SW3 input is confirmed, the output ports are switched alternately between one set (PC5, PC4, PB3, PB1, PC2, and PC3) and the other set (PB7, PB6, PE2, PE1, PE3, and PE4).

Switching ports is performed using the following procedure.

- MTU output is disabled.
- The port modes for the current MTU output pins are set to “not used as peripheral function pins”.
- The port functions for the current MTU output pins are set to the general-purpose I/O pin function.
- The port functions for the new MTU output pins are set to the peripheral function pins.
- The port modes for the new MTU output pins are set to MTU output pins.
- MTU output is enabled.

Figure 5.1 shows the timing chart for this operation.

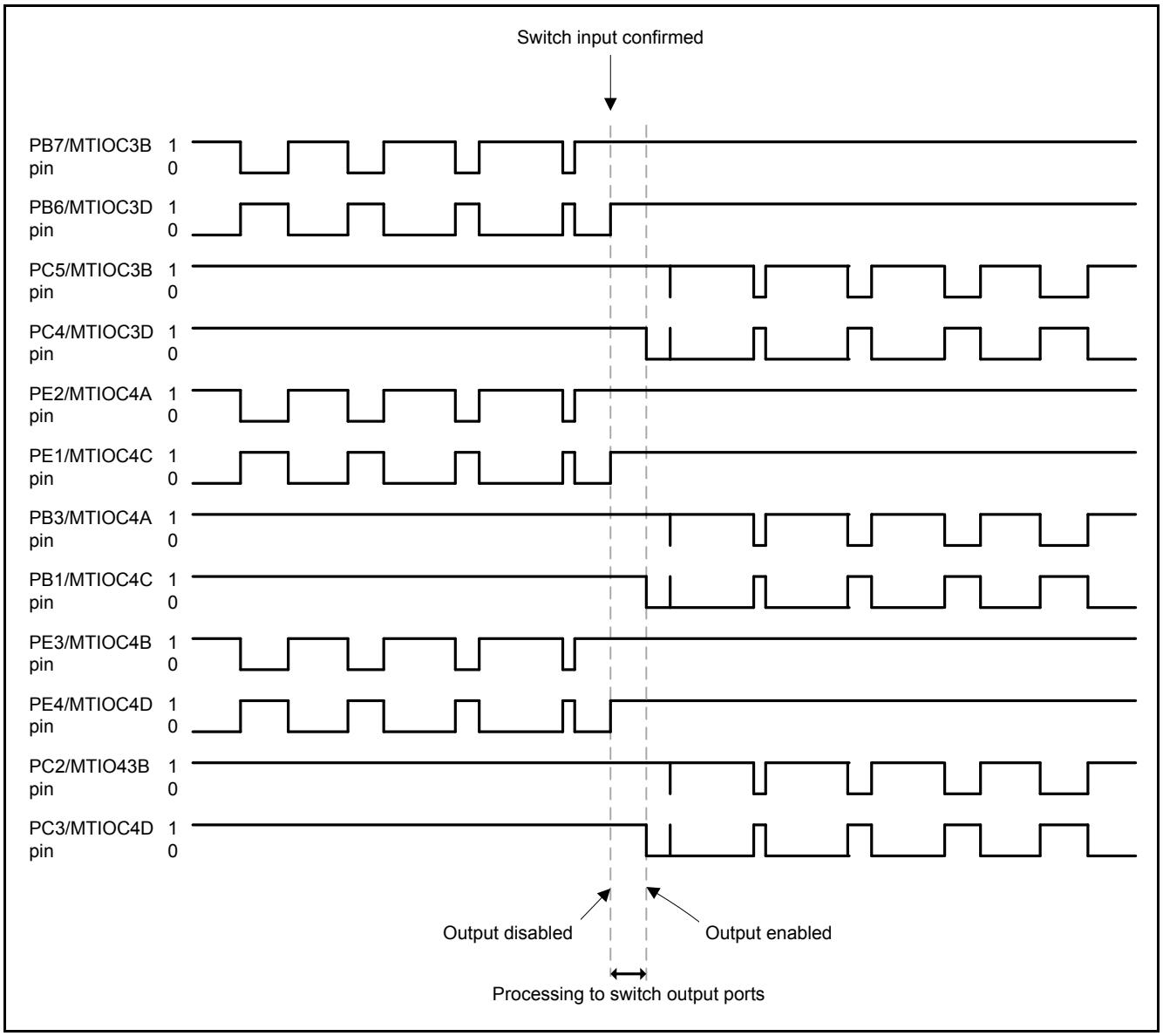

Figure 5.1 Timing Chart

5.2 File Composition

Table 5.1 lists the files used for the sample code. Note that the files generated automatically by the integrated development environment are not shown.

Table 5.1 File Composition

File	Overview	Remarks
main.c	Main processing	
non_existent_port_init.c	Nonexistent port initialization	
non_existent_port_init.h	External reference include header for nonexistent port initialization	
clock_init.c	Clock initialization	
clock_init.h	External reference include header for clock initialization	
intprg.c	Interrupt handling	
pwm.c	Sets up PWM output	

5.3 Option Settings Memory

Table 5.2 lists the states of the option settings memory used by the sample code. Set these locations to appropriate values for your user system as required.

Table 5.2 Option Settings Memory Set by the Sample Code

Symbol	Address	Set value	Description
OFS0	FFFF FF8Fh – FFFF FF8Ch	FFFF FFFFh	Stops IWDT after a reset Stops WDT after a reset
OFS1	FFFF FF8Bh – FFFF FF88h	FFFF FFFFh	Disables voltage monitoring resets after a reset Disables HOCOC oscillation after a reset
MDES	FFFF FF83h – FFFF FF80h	FFFF FFFFh	Little endian (in single-chip mode)

5.4 Constants

Table 5.3 lists the constants used in the sample code.

Table 5.3 Constants Used in the Sample Code

Constant	Set Value	Description
LOW	0	Output value for low
HIGH	1	Output value for high
OUT1	0	Complementary PWM output port setting: output 1
OUT2	1	Complementary PWM output port setting: output 2
DEAD_TIME	25	Dead time
CYCLE	1250	Carrier period
C_CYCLE	625	Carrier half period
PUL_CYCLE	650	Carrier half period + dead time

5.5 Variables

Table 5.4 lists the global variables.

Table 5.4 Global Variables

Type	Name	Description	Function
unsigned char	sw3_fix	Confirmed value of the complementary PWM output port switching input	input_read chg_out_port
unsigned char	c_loop	Time measurement counter used in main loop	main
int	Duty_select	Output duty increment/decrement direction	int_mtu2_tgia3
unsigned short	Pul_pwm_duty1	Set value for the complementary PWM output duty (MTIOC3B and MTIOC3D)	int_mtu2_tgia3
unsigned short	Pul_pwm_duty2	Set value for the complementary PWM output duty (MTIOC4A and MTIOC4C)	int_mtu2_tgia3
unsigned short	Pul_pwm_duty3	Set value for the complementary PWM output duty (MTIOC4B and MTIOC4D)	int_mtu2_tgia3

5.6 Functions

Table 5.5 lists the functions.

Table 5.5 Functions

Function	Description
main	Main processing
port_init	Port initialization
non_existent_port_init	Nonexistent port initialization
clock_init	Clock initialization
peripheral_init	Peripheral function initialization
mtu2_init	MTU2a initialization
int_mtu2_tgia3	TGIA3 interrupt handler
input_read	Reads the switch input.
chg_out_port	Switches the complementary PWM output ports.

5.7 Function Specifications

This section lists the specifications of the functions in the sample code.

main	
Overview	Main processing
Header	None
Declaration	void main(void)
Description	Initializes the SFRs and peripheral functions. Reads the switch input and switches the complementary PWM output ports every 5 ms.
Arguments	None
Return values	None

non_existent_port_init	
Overview	Nonexistent port initialization
Header	non_existent_port_init.h
Declaration	void non_existent_port_init(void)
Description	Initializes the nonexistent ports.
Arguments	None
Return values	None
Remarks	For details on this function, refer to the Initial Setting application note for the product used. There are cases where ports that do not exist must be initialized due to the number of pins in the particular microcontroller product used. This processing is not required for products that include the RSK used by this system.

clock_init	
Overview	Clock initialization
Header	clock_init.h
Declaration	void clock_init(void)
Description	Initializes the clocks.
Arguments	None
Return values	None
Remarks	For details on this function, refer to the Initial Setting application note for the product used.

peripheral_init	
Overview	Peripheral function initialization
Header	None
Declaration	void peripheral_init(void)
Description	Initializes the used peripheral functions.
Arguments	None
Return values	None

mtu2_init	
Overview	MTU2a initialization
Header	None
Declaration	void mtu2_init(void)
Description	Sets the complementary PWM output ports to high-level output. Sets channels 3 and 4 to complementary PWM mode 3. Sets the output period to 200 µs and the dead time to 4 µs. Sets MTU3.TGRD, MTU4.TGRC, and MTU4.TGRD to be the buffer registers for MTU3.TGRB, MTU4.TGRA, and MTU4.TGRB, respectively.
Arguments	None
Return values	None

int_mtu2_tgia3	
Overview	TGIA3 interrupt handler
Header	None
Declaration	void int_mtu2_tgia3(void)
Description	Sets the output duty increase/decrease direction and increments or decrements the duty by 1.
Arguments	None
Return values	None

input_read	
Overview	Read switch input
Header	None
Declaration	void input_read(void)
Description	Reads the input state of the SW3 on the RSK and confirms the input value if the input level matches four times consecutively.
Arguments	None
Return values	None

chg_out_port	
Overview	Change complementary PWM output ports
Header	None
Declaration	void chg_out_port(void)
Description	Switches the complementary PWM output ports.
Arguments	None
Return values	None

5.8 Flowcharts

5.8.1 Main Processing

Figure 5.2 shows the flowchart for the main processing.

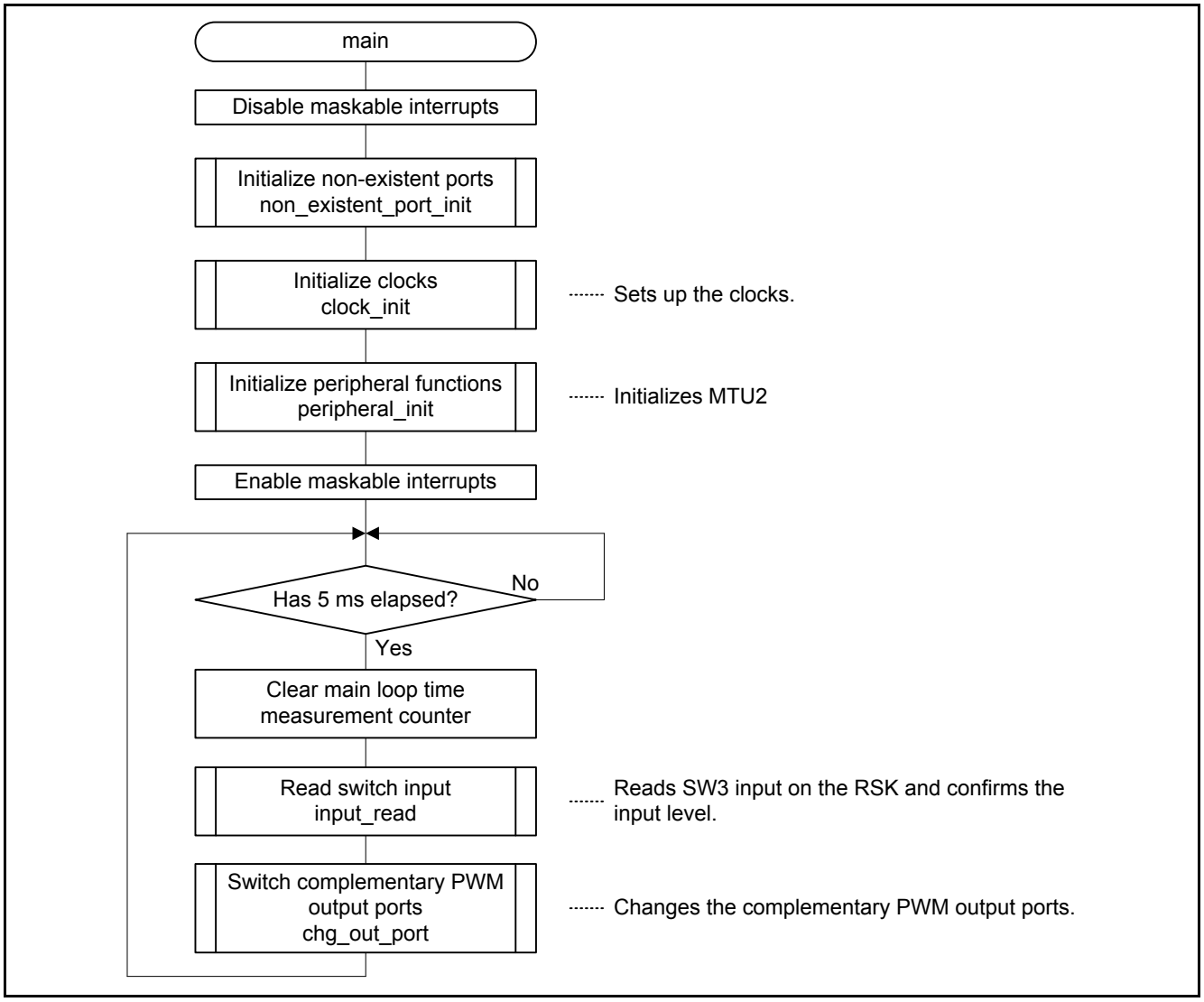

Figure 5.2 Main Processing

5.8.2 Peripheral Function Initialization

Figure 5.3 shows the flowchart for peripheral function initialization.

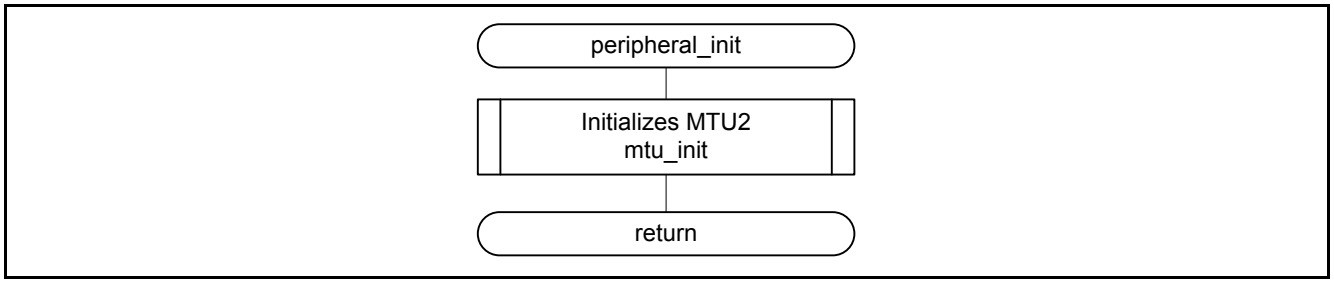

Figure 5.3 Peripheral Function Initialization

5.8.3 MTU2a Initialization

Figure 5.4 to 5.7 show the flowchart for MTU2a initialization.

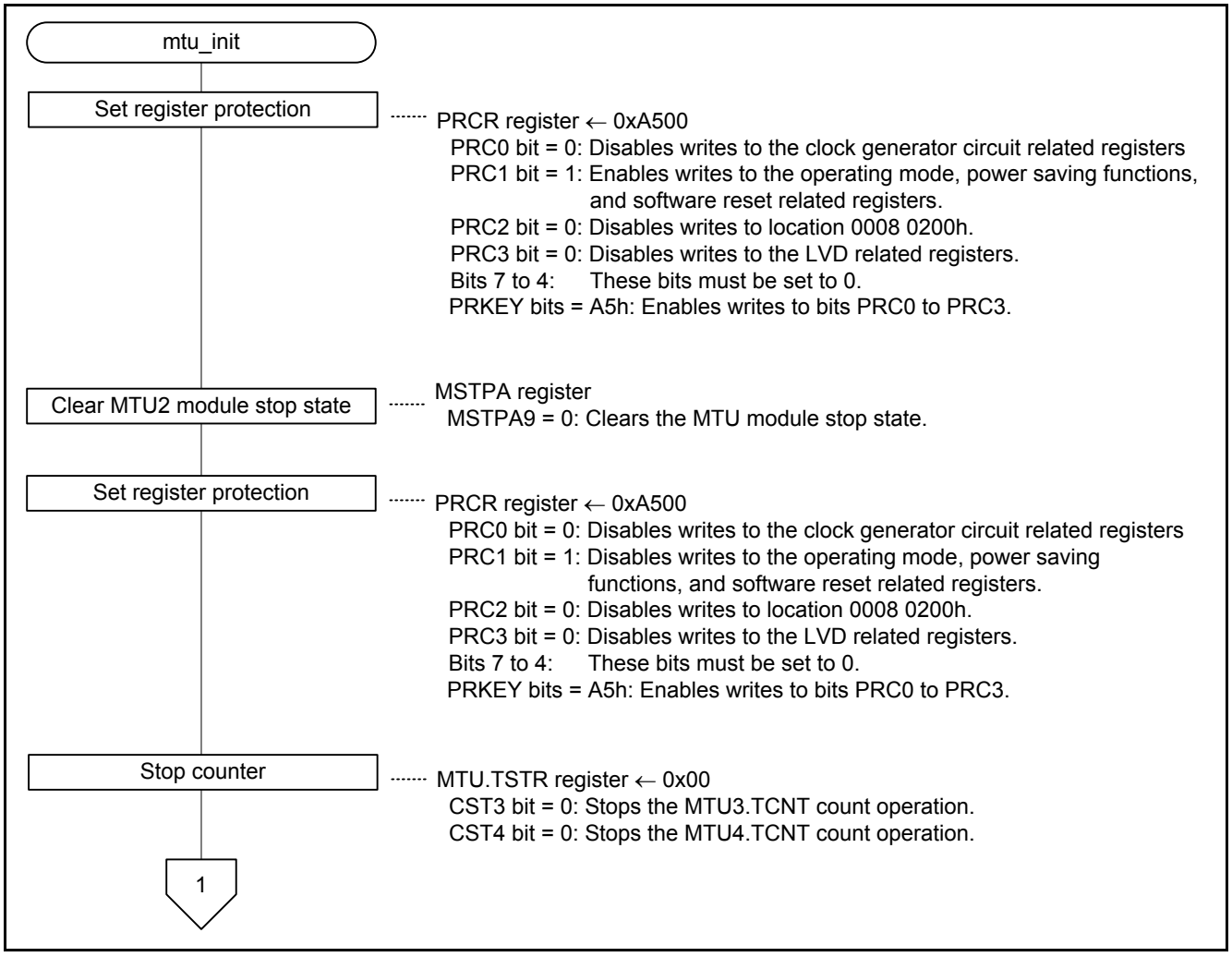

Figure 5.4 MTU2a Initialization (1/4)

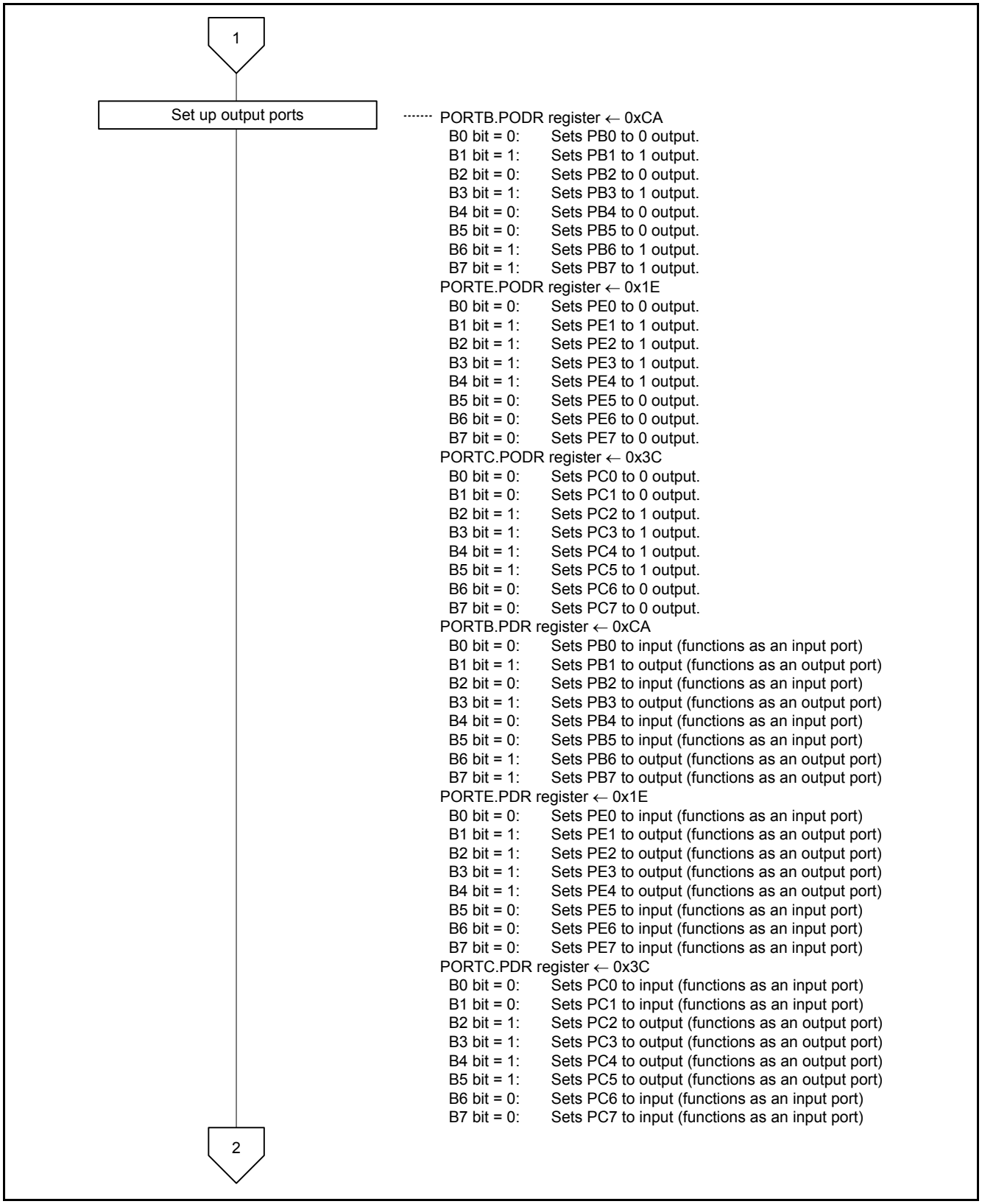

Figure 5.5 MTU2a Initialization (2/4)

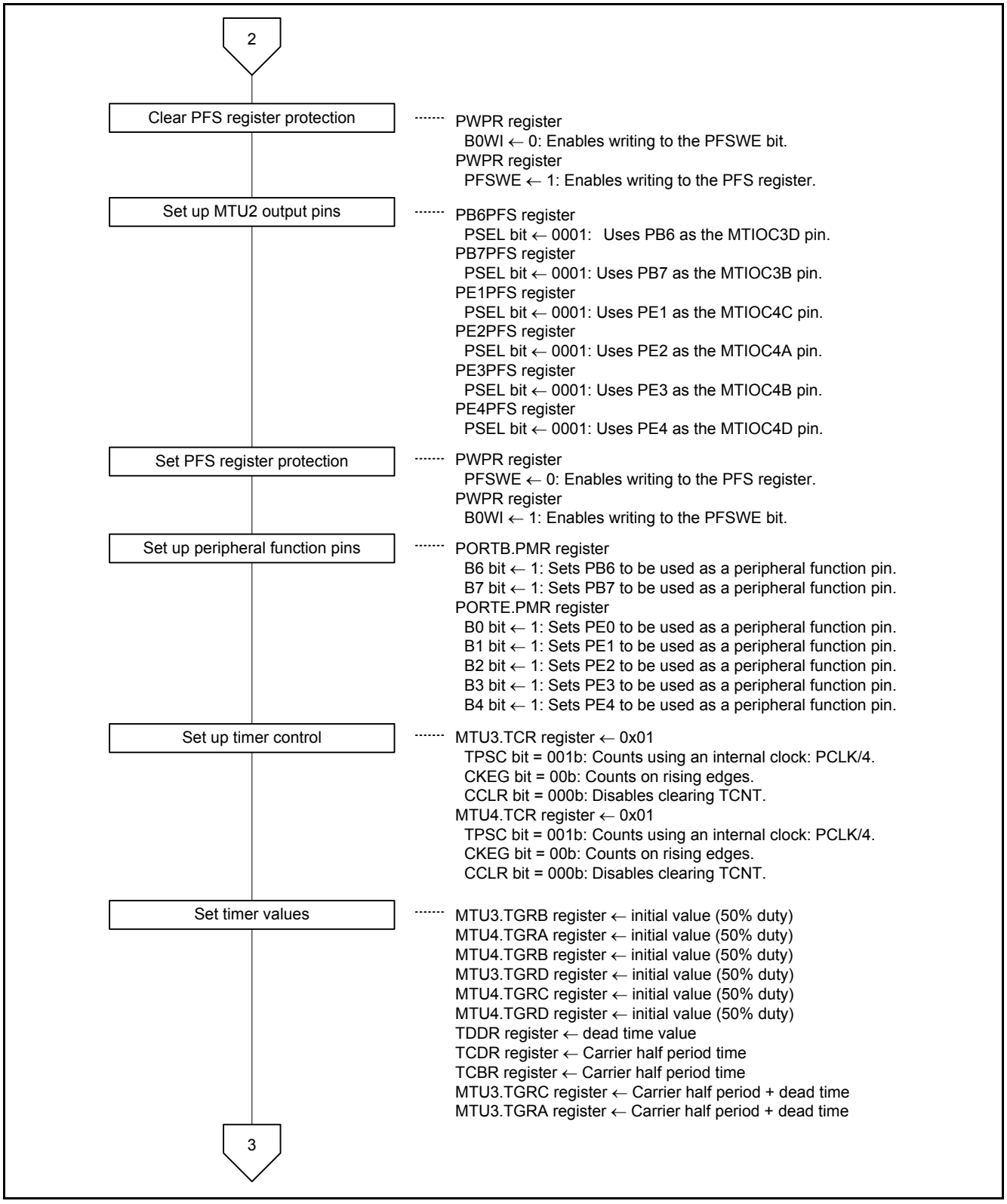

Figure 5.6 MTU2a Initialization (3/4)

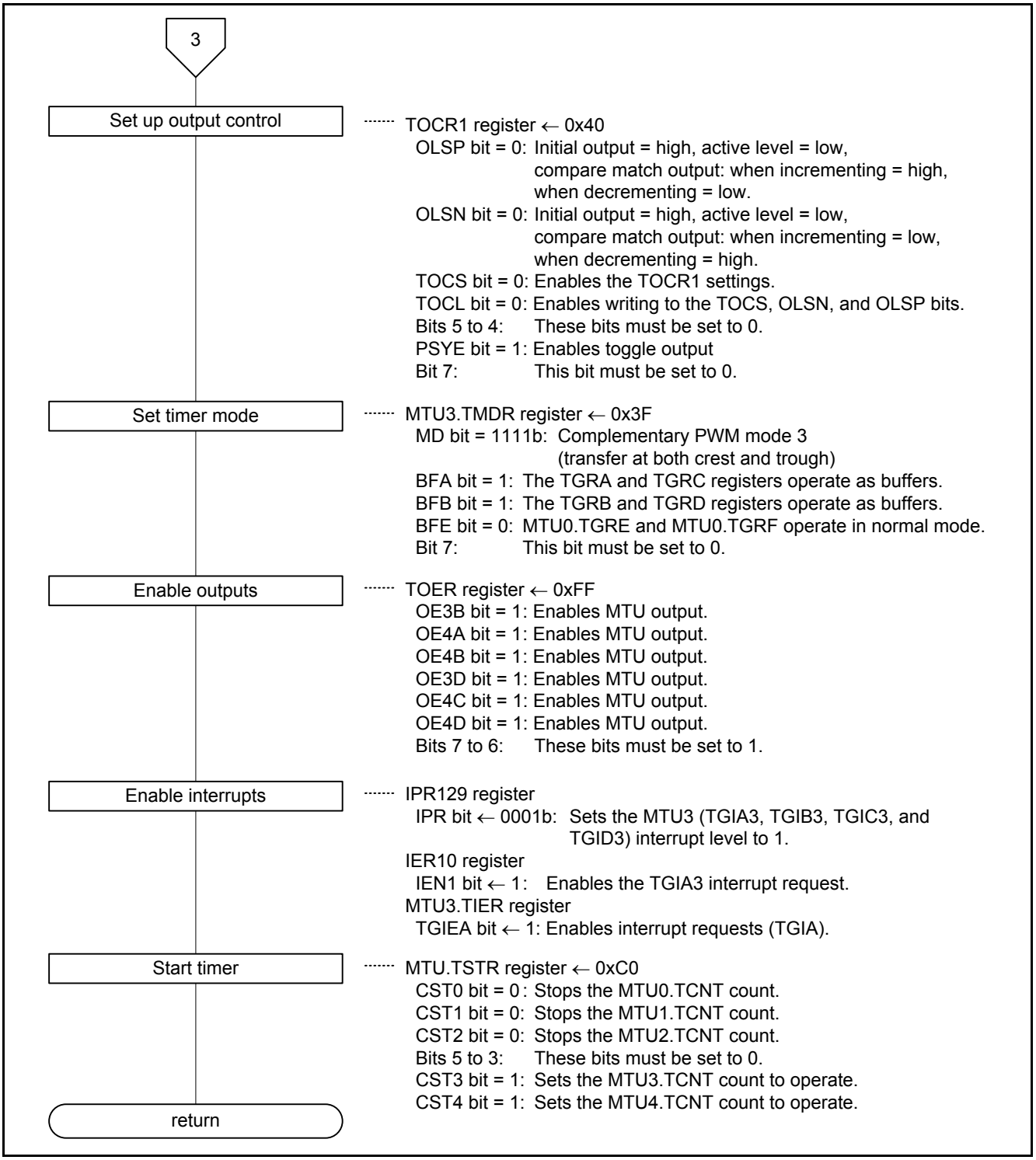

Figure 5.7 MTU2a Initialization (4/4)

5.8.4 TGIA3 Interrupt Handler

Figure 5.8 shows the flowchart for the TGIA3 interrupt handler.

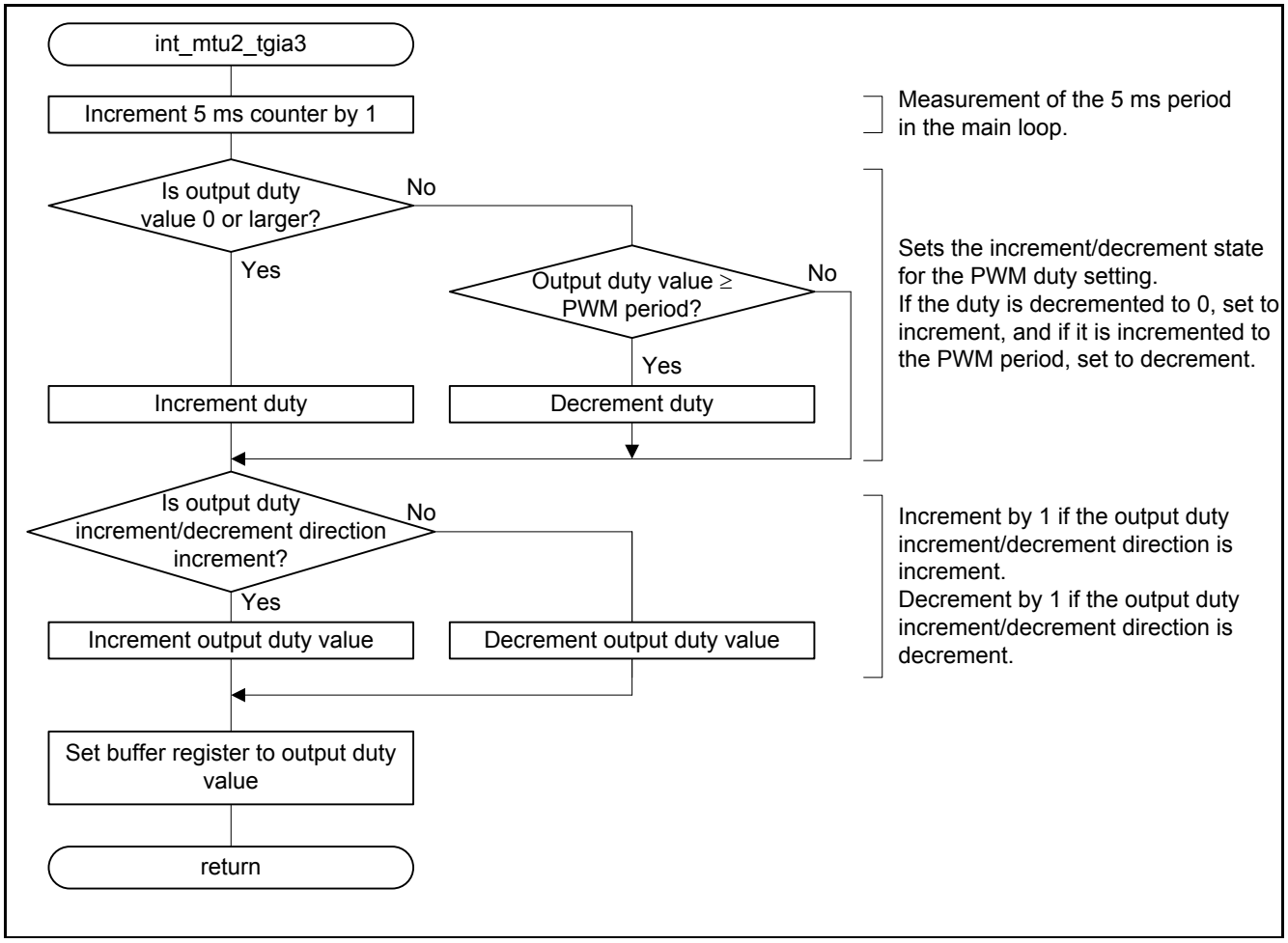

Figure 5.8 TGIA3 Interrupt Handler

5.8.5 Read Switch Input

Figure 5.9 shows the flowchart for reading switch input.

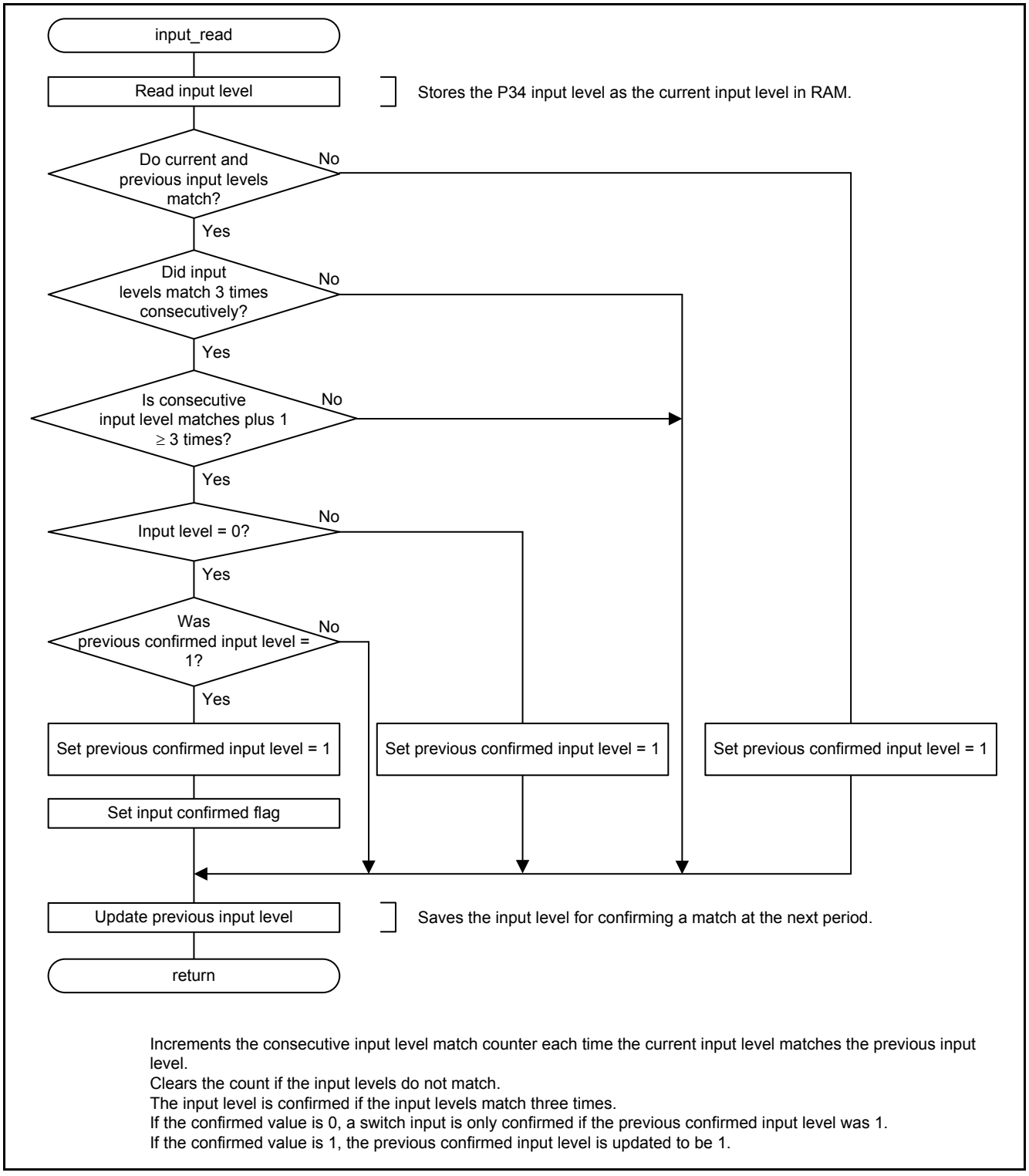

Figure 5.9 Reading Switch Input

5.8.6 Complementary PWM Output Port Switching

Figure 5.10 and 5.11 shows the flowchart for complementary PWM output port switching.

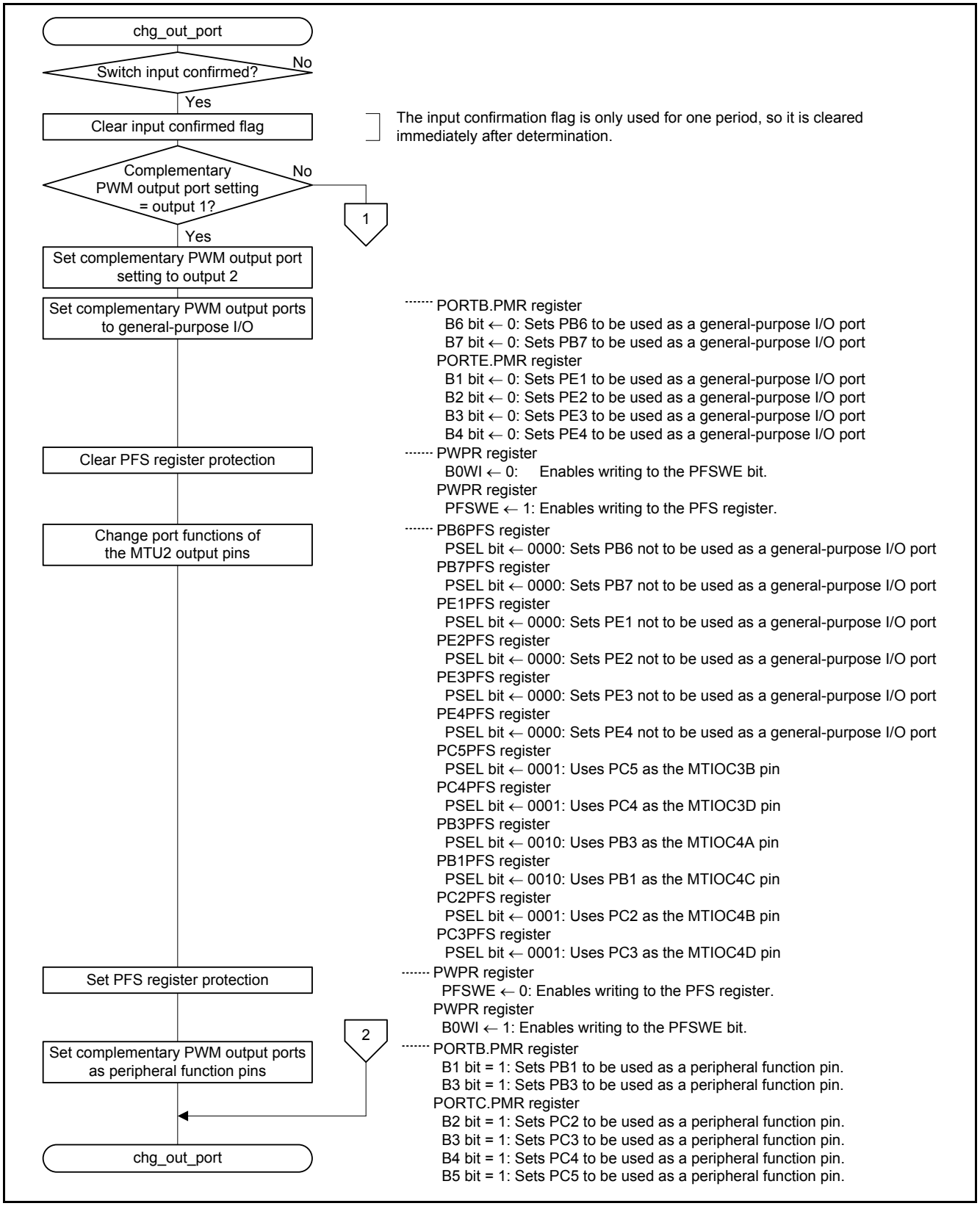

Figure 5.10 Complementary PWM Output Port Switching (1/2)

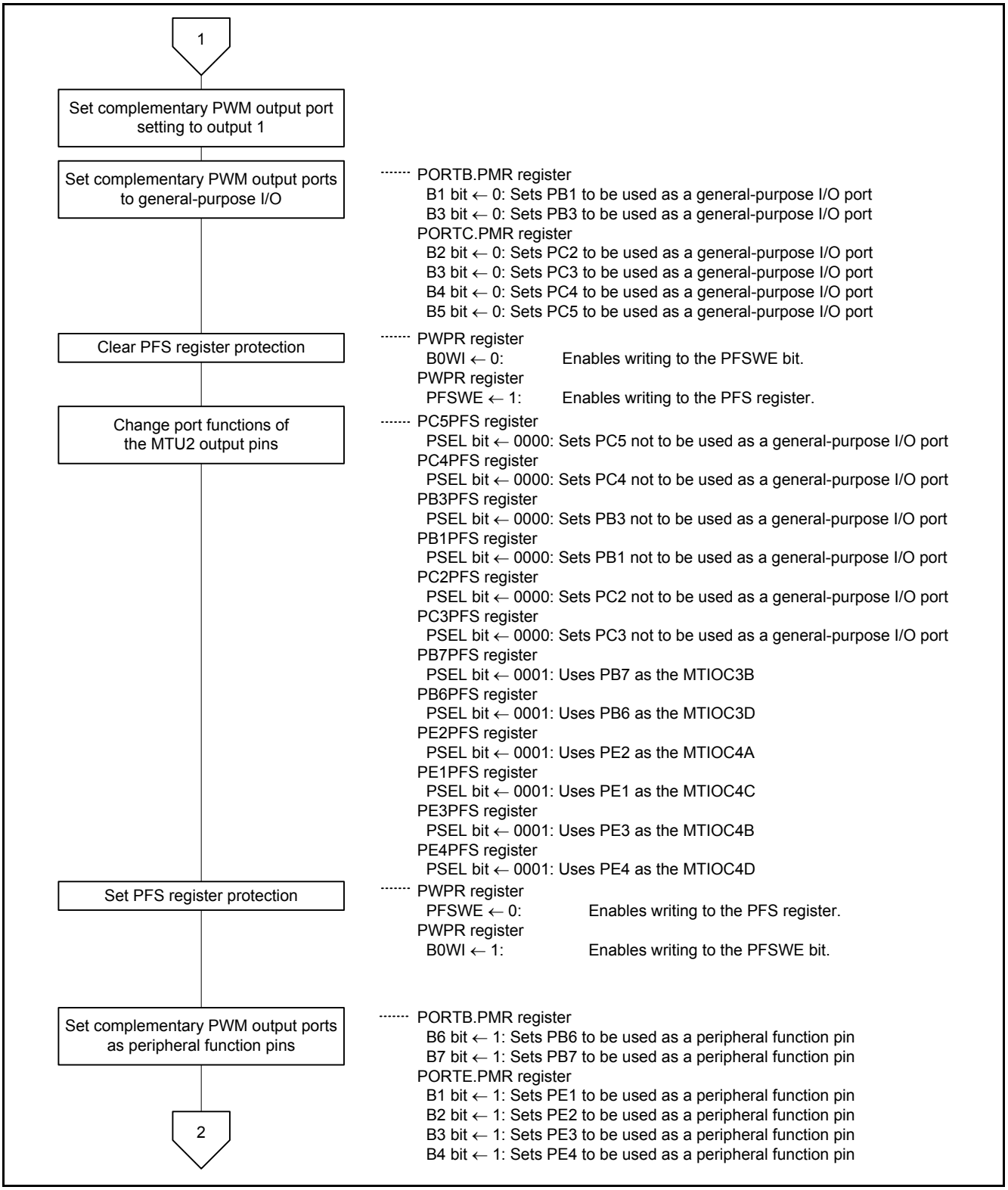

Figure 5.11 Complementary PWM Output Port Switching (2/2)

6. Applying This Application Note to the RX21A Group

The sample code accompanying this application note has been confirmed to operate with the RX210 Group. To make the sample code operate with the RX21A Group, use this application note in conjunction with the RX21A Initial Setting application note.

To use this application note with the RX21A Group, modify the main.c and pwm.c files accompanying this application note as shown steps (1) to (5) below, and then refer to “5. Applying the RX200 Series Application Note to the RX21A Group” in the RX21A Group Initial Setting application note.

(1) Change the #include for “iodefine.h” to “../iodefine.h” in main.c and pwm.c.

(2) Add a #include for “r_init_stop_module.h” in main.c.

(3) In main.c, change the #includes for “clock_init.h” and “non_existent_port_init.h” to “r_init_clock.h” and “r_init_non_existent_port.h”, respectively.

```
11  /***********************************************************************/
12  #include    <machine.h>
13  #include    "../iodefine.h"
14  #include "r_init_clock.h"
15  #include "r_init_stop_module.h"
16  #include "r_init_non_existent_port.h"
17
```

(4) In main.c, add a call for the R_INIT_StopModule() function in the main function.

(5) In main.c, change the calls for “non_existent_port_init()” and “clock_init()” in the main function to calls for “R_INIT_NonExistentPort()” and “R_INIT_Clock()”, respectively.

```
40  * Return Value         : none
41  *""FUNC COMMENT END""*************************************************/
42  void main(void)
43  {
44      /* ---- Disable maskable interrupts ---- */
45      clrpsw_i();
46
47      R_INIT_StopModule();
48      /* ---- Initialize non-existent ports ---- */
49      R_INIT_NonExistentPort();
50      /* ---- Initialize the clock ---- */
51      R_INIT_Clock();
52      /* peripheral initialize */
53      peripheral_init();
54      /* ---- Disable maskable interrupts ---- */
55      setpsw_i();
56
57
58      while(1){
59          while(c_loop <= 25);                /* 5ms wait */
60          c_loop = 0;
61          input_read();                       /* read input information */
62          chg_out_port();                     /* change output port */
63      }
64  }
```

7. Sample Code

Sample code can be downloaded from the Renesas Electronics website.

8. Reference Documents

User's Manual: Hardware
RX210 Group User's Manual: Hardware Rev.1.50 (R01UH0037EJ)
RX21A Group User's Manual: Hardware Rev.1.00 (R01UH0251EJ)
The latest versions can be downloaded from the Renesas Electronics website.

Technical updates and technical news
(The latest technical information can be downloaded from the Renesas Electronics Corporation website.)

C compiler manual
RX210 C Compiler Package, Version 1.02
C Compiler User's Manual, Revision 1.00
(Download the latest version of this manual from the Renesas Electronics Corporation website.)

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REVISION HISTORY	RX210 and RX21A Groups Application Note MTU2 Complementary PWM Output Port Switching Using the MPC

Rev.	Date	Description	
		Page	Summary
1.00	Sep. 25, 2012	—	First edition issued
1.01	July 1, 2014	1	Products: Added the RX21A and RX220 Groups.
		4	3. Reference Application Notes: Added the Initial Setting application notes for the RX21A and RX220 Groups.
		10	Modified the description of reference application note in the following functions: non_existent_port_init and clock_init.
		21	6. Applying This Application Note to the RX21A or RX220 Group: Added.
		22	8. Reference Documents: Added the User's Manual: Hardware for the RX21A and RX220 Groups.
1.02	Oct. 1, 2014	—	Deleted the RX220 Group from the target products. (Refer to the "RX220 Group Application Example of Exclusive Operation of Two Motors by One Set of Complementary PWM Outputs Rev.1.00" application note (R01AN2234JJ) for the RX220 Group. It also provides the sample code.)

General Precautions in the Handling of MPU/MCU Products

The following usage notes are applicable to all MPU/MCU 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. 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 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. Unused pins should be handled as described under Handling of Unused Pins in the manual.

2. Processing at Power-on

   The state of the product is undefined at the moment 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 moment 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 moment 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 moment when power is supplied until the power reaches the level at which resetting has been specified.

3. Prohibition of Access to Reserved Addresses

   Access to reserved addresses is prohibited.

   — The reserved addresses are provided for the possible future expansion of functions. Do not access these addresses; the correct operation of LSI is not guaranteed if they are accessed.

4. Clock Signals

   After applying a reset, only release the reset line after the operating clock signal has become stable. When switching the clock signal during program execution, wait until the target clock signal has 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. Moreover, 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.

5. Differences between Products

   Before changing from one product to another, i.e. to a product with a different part number, confirm that the change will not lead to problems.

   — The characteristics of an MPU or MCU in the same group but having a different part number may differ in terms of the 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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