To our customers,

Old Company Name in Catalogs and Other Documents

On April 1st, 2010, NEC Electronics Corporation merged with Renesas Technology Corporation, and Renesas Electronics Corporation took over all the business of both companies. Therefore, although the old company name remains in this document, it is a valid Renesas Electronics document. We appreciate your understanding.

Renesas Electronics website: http://www.renesas.com

April 1st, 2010
Renesas Electronics Corporation

Issued by: Renesas Electronics Corporation (http://www.renesas.com)

Send any inquiries to http://www.renesas.com/inquiry.

Notice

1. All information included in this document is current as of the date this document is issued. Such information, however, is subject to change without any prior notice. Before purchasing or using any Renesas Electronics products listed herein, please confirm the latest product information with a Renesas Electronics sales office. Also, please pay regular and careful attention to additional and different information to be disclosed by Renesas Electronics such as that disclosed through our website.
2. Renesas Electronics does not assume any liability for infringement of patents, copyrights, or other intellectual property rights of third parties by or arising from the use of Renesas Electronics products or technical information described in this document. No license, express, implied or otherwise, is granted hereby under any patents, copyrights or other intellectual property rights of Renesas Electronics or others.
3. You should not alter, modify, copy, or otherwise misappropriate any Renesas Electronics product, whether in whole or in part.
4. Descriptions of circuits, software and other related information in this document are provided only to illustrate the operation of semiconductor products and application examples. You are fully responsible for the incorporation of these circuits, software, and information in the design of your equipment. Renesas Electronics assumes no responsibility for any losses incurred by you or third parties arising from the use of these circuits, software, or information.
5. When exporting the products or technology described in this document, you should comply with the applicable export control laws and regulations and follow the procedures required by such laws and regulations. You should not use Renesas Electronics products or the technology described in this document for any purpose relating to military applications or use by the military, including but not limited to the development of weapons of mass destruction. Renesas Electronics products and technology may not be used for or incorporated into any products or systems whose manufacture, use, or sale is prohibited under any applicable domestic or foreign laws or regulations.
6. Renesas Electronics has used reasonable care in preparing the information included in this document, but Renesas Electronics does not warrant that such information is error free. Renesas Electronics assumes no liability whatsoever for any damages incurred by you resulting from errors in or omissions from the information included herein.
7. Renesas Electronics products are classified according to the following three quality grades: "Standard", "High Quality", and "Specific". The recommended applications for each Renesas Electronics product depends on the product's quality grade, as indicated below. You must check the quality grade of each Renesas Electronics product before using it in a particular application. You may not use any Renesas Electronics product for any application categorized as "Specific" without the prior written consent of Renesas Electronics. Further, you may not use any Renesas Electronics product for any application for which it is not intended without the prior written consent of Renesas Electronics. Renesas Electronics shall not be in any way liable for any damages or losses incurred by you or third parties arising from the use of any Renesas Electronics product for an application categorized as "Specific" or for which the product is not intended where you have failed to obtain the prior written consent of Renesas Electronics. The quality grade of each Renesas Electronics product is "Standard" unless otherwise expressly specified in a Renesas Electronics data sheets or data books, etc.

   "Standard": Computers; office equipment; communications equipment; test and measurement equipment; audio and visual equipment; home electronic appliances; machine tools; personal electronic equipment; and industrial robots.

   "High Quality": Transportation equipment (automobiles, trains, ships, etc.); traffic control systems; anti-disaster systems; anti-crime systems; safety equipment; and medical equipment not specifically designed for life support.

   "Specific": Aircraft; aerospace equipment; submersible repeaters; nuclear reactor control systems; medical equipment or systems for life support (e.g. artificial life support devices or systems), surgical implantations, or healthcare intervention (e.g. excision, etc.), and any other applications or purposes that pose a direct threat to human life.
8. You should use the Renesas Electronics products described in this document within the range specified by Renesas Electronics, especially with respect to the maximum rating, operating supply voltage range, movement power voltage range, heat radiation characteristics, installation and other product characteristics. Renesas Electronics shall have no liability for malfunctions or damages arising out of the use of Renesas Electronics products beyond such specified ranges.
9. Although Renesas Electronics endeavors to improve the quality and reliability of its products, semiconductor products have specific characteristics such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Further, Renesas Electronics products are not subject to radiation resistance design. Please be sure to implement safety measures to guard them against the possibility of physical injury, and injury or damage caused by fire in the event of the failure of a Renesas Electronics product, such as safety design for hardware and software including but not limited to redundancy, fire control and malfunction prevention, appropriate treatment for aging degradation or any other appropriate measures. Because the evaluation of microcomputer software alone is very difficult, please evaluate the safety of the final products or system manufactured by you.
10. Please contact a Renesas Electronics sales office for details as to environmental matters such as the environmental compatibility of each Renesas Electronics product. Please use Renesas Electronics products in compliance with all applicable laws and regulations that regulate the inclusion or use of controlled substances, including without limitation, the EU RoHS Directive. Renesas Electronics assumes no liability for damages or losses occurring as a result of your noncompliance with applicable laws and regulations.
11. This document may not be reproduced or duplicated, in any form, in whole or in part, without prior written consent of Renesas Electronics.
12. Please contact a Renesas Electronics sales office if you have any questions regarding the information contained in this document or Renesas Electronics products, or if you have any other inquiries.

(Note 1) "Renesas Electronics" as used in this document means Renesas Electronics Corporation and also includes its majority-owned subsidiaries.

(Note 2) "Renesas Electronics product(s)" means any product developed or manufactured by or for Renesas Electronics.

SH7144/45 Group

Complementary PWM 3-Phase Output

1. Specifications

Three-phase PWM waveform output is performed with a non-overlapping relationship between positive and negative phases, as shown in figure 1.

The duty cycle can be changed between 0% and 100% by setting an arbitrary value in RAM.

$$\text{Duty cycle} = \frac{\text{Pulse high width}}{\text{Pulse period}} \times 100\ (\%)$$

Toggle waveform output is performed synchronized with the period.

When operating with on-chip peripheral clock Pϕ = 40.0 MHz, the output pulse period can be set arbitrarily in the range 50.0 ns to 1.63 ms.

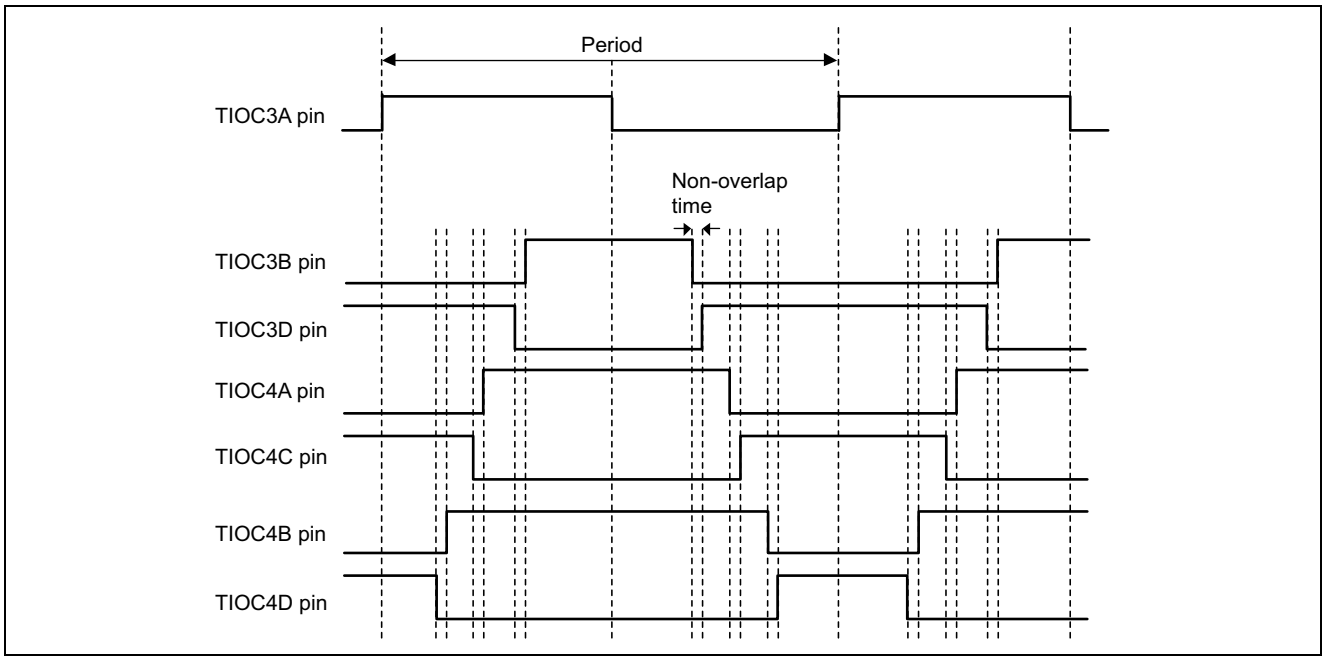


Figure 1 Complementary PWM 3-Phase Output Waveforms

2. Functions Used

In this sample task, 3-phase PWM waveform output with a non-overlapping relationship between positive and negative phases is performed using MTU channels 3 and 4.

Figure 2 shows a block diagram of the MTU/ch3, ch4 as used in this sample task. This sample task uses the following functions.

- A function that performs 3-phase PWM waveform output with a non-overlapping relationship between positive and negative phases (complementary PWM mode)
- A function that transfers buffer register (TGRC/D_3, TGRC/D_4) contents to compare registers (TGRA/B_3, TGRA/B_4) when a compare match occurs
- A function that outputs a toggle waveform synchronized with the PWM waveform period

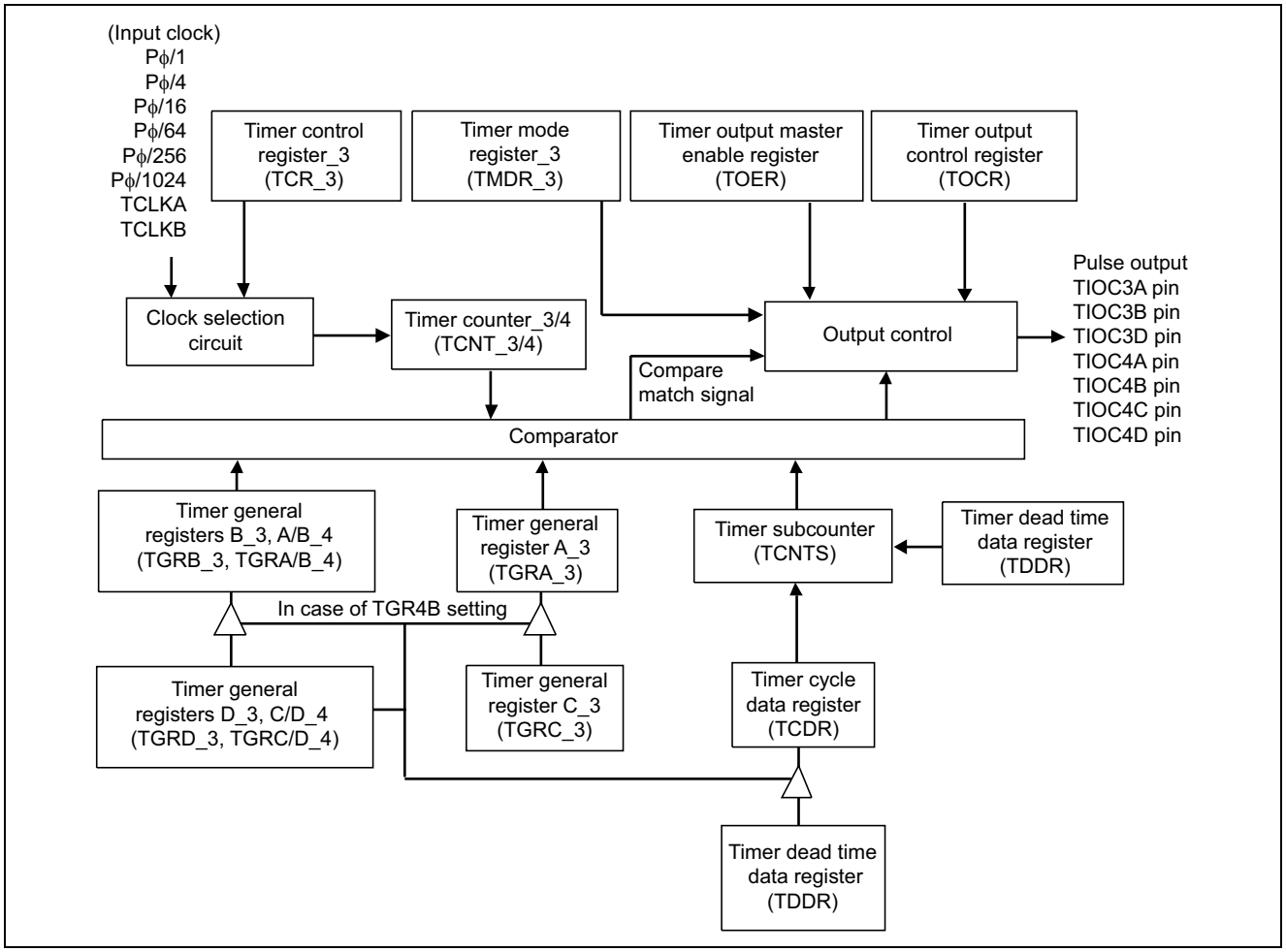


Figure 2 Block Diagram of MTU/ch3, ch4

Table 1 shows the function assignments used in this task. PWM pulses are output by assigning MTU functions as shown in the table.

Table 1 Function Assignments

Pin or Register Name	Function Assignment
TIOC3A	Toggle output synchronized with PWM period
TIOC3C	PWM output 1
TIOC3D	Negative-phase waveform in non-overlapping relationship with PWM output 1
TIOC4A	PWM output 2
TIOC4B	PWM output 3
TIOC4C	Negative-phase waveform in non-overlapping relationship with PWM output 2
TIOC4D	Negative-phase waveform in non-overlapping relationship with PWM output 3
TOCR	Enabling/disabling of toggle output synchronized with PWM period
TOER	MTU output pin output enabling/disabling
TCR_3	Selection of ch3 timer counter clearing source and input clock
TMDR_3	Ch3, ch4 set to complementary PWM mode
TGRA_3	TCNT_3 upper-limit value setting (1/2 carrier period + dead time)
TGRC_3	TGRA_3 buffer register
TGRB_3	Output pulse transition point setting (compare register)
TGRA_4	
TGRB_4	
TGRC_4	TGRA_4 buffer register
TGRD_4	TGRB_4 buffer register
TDDR	Dead time setting
TCDR	TCNT_4 upper-limit value setting (1/2 carrier period)
TCBR	TCDR buffer register

3. Principles of Operation

Figure 3 illustrates the principles of operation. Complementary PWM waveform output is performed by SH7145 hardware and software processing.

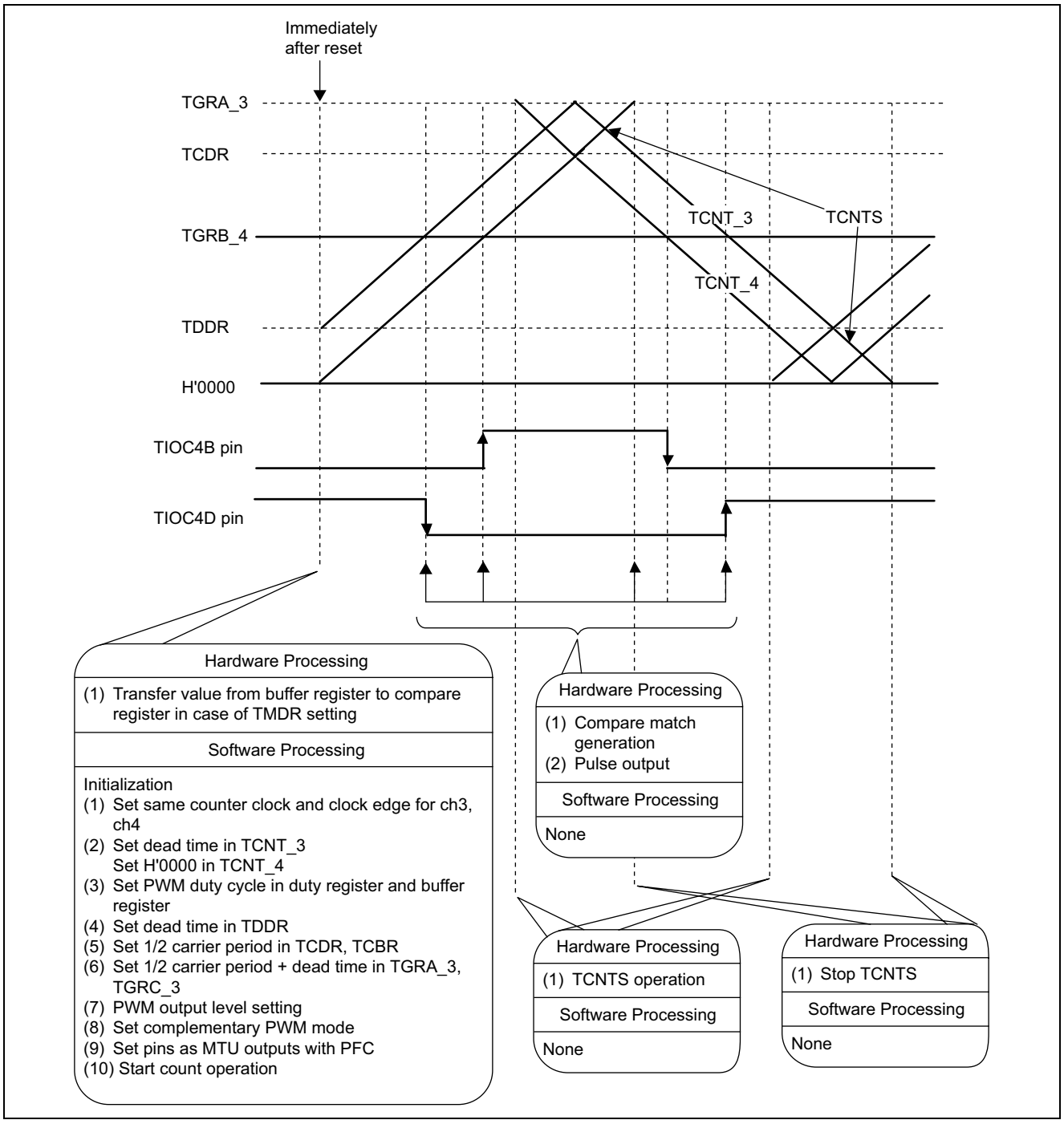


Figure 3 Principles of Operation of Complementary PWM Single-Phase Waveform Output

Figure 4 shows the PWM waveform output method. When complementary PWM mode is set, the following rules apply to data transfer and compare operations.

- Data Transfer
  - In period Ta, data written to a buffer register is always transferred to a temporary register.
  - In period Tb1, when the transfer mode is set to transfer at the peak, data is not transferred from a buffer register to a temporary register. In period Tb2, the operation is the same as in period Ta. Similarly, when a trough setting is made, data is not transferred in period Tb2.
  - Data transfer to a buffer register can be performed arbitrarily.
- Compare Match
  - In period Tb, two registers—the temporary register and compare register—and three counters—TCNT_3/4 and TCNTS—are compared, and the PWM waveform is controlled.
  - In area (a), pre-change data and compare matches (3) and (4) have priority.
  - In area (b), post-change data and compare matches (1) and (2) have priority.

  Generation of a compare match whereby the output waveform goes to the active level (compare match (1) or (3)) occurs only after generation of a compare match whereby the respective output waveform goes to the positive level (compare match (4) or (2)).

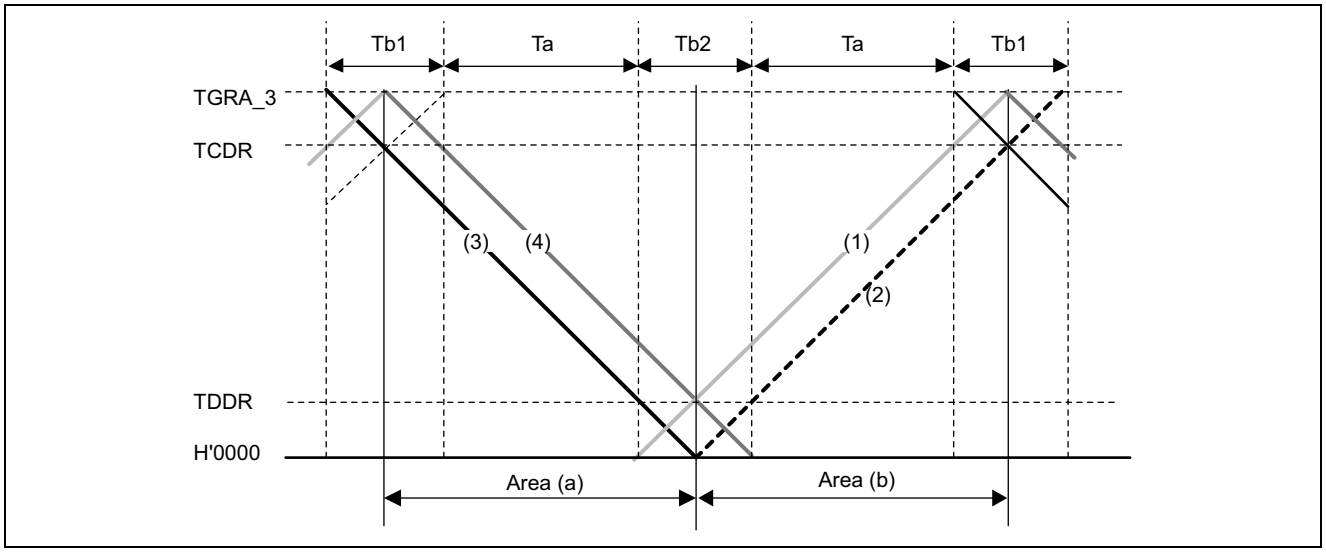


Figure 4 Principles of Operation of PWM Waveform Output Method

Figure 5 illustrates the principles of operation. Complementary PWM waveform output is performed by SH7145 hardware and software processing.

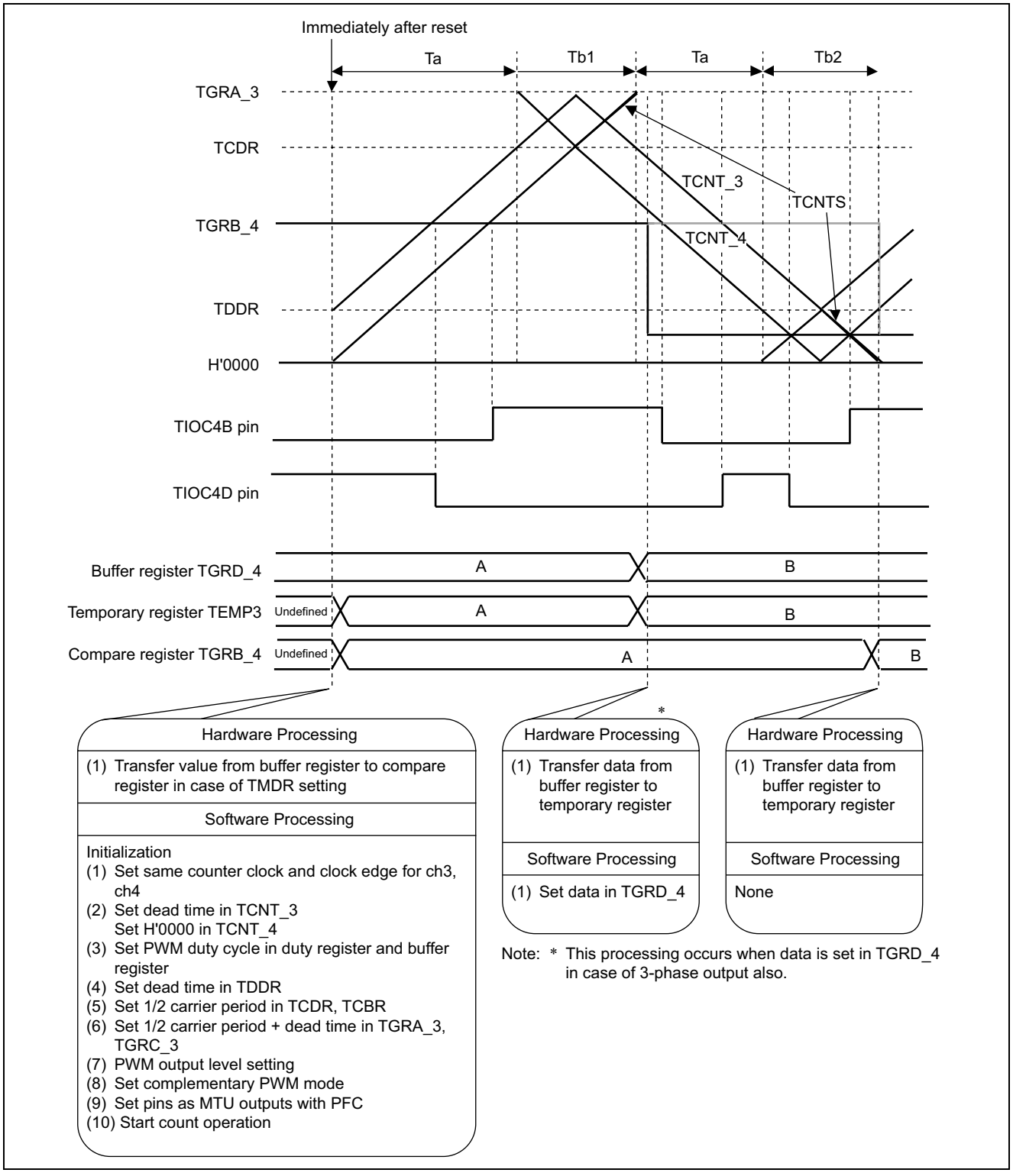


Figure 5 Principles of Operation of Complementary PWM Single-Phase Waveform Output

Figure 6 illustrates the principles of operation. Three-phase PWM output is performed from the ch3 and ch4 PWM output pins (TIOC3B/D, TIOC4A/B/C/D) by SH7145 hardware and software processing as shown in the figure.

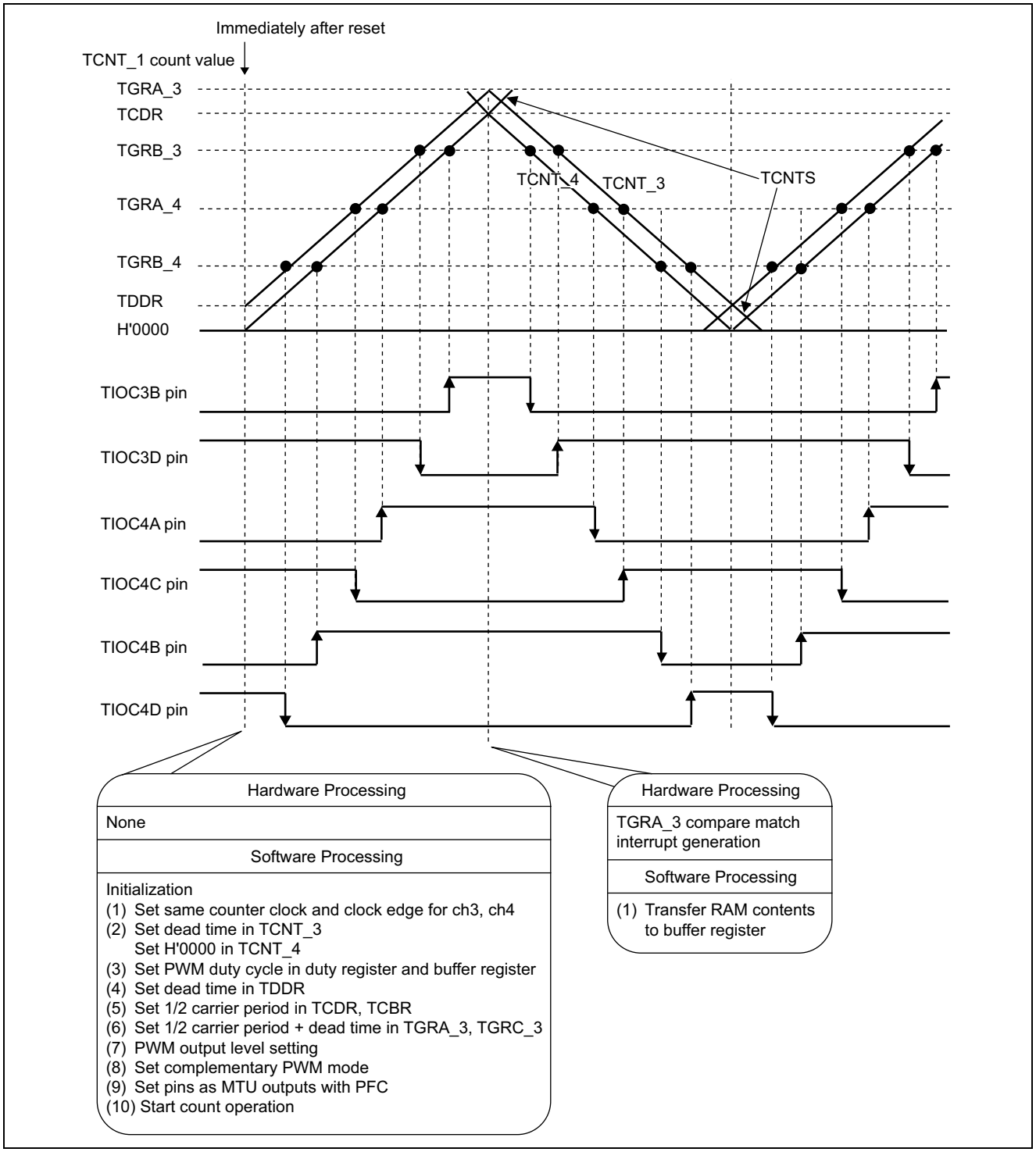


Figure 6 Principles of Operation of PWM Waveforms

Figure 7 illustrates the principles of operation. Toggle output synchronized with the PWM period is performed from the TIOC3A pin by SH7145 hardware and software processing.

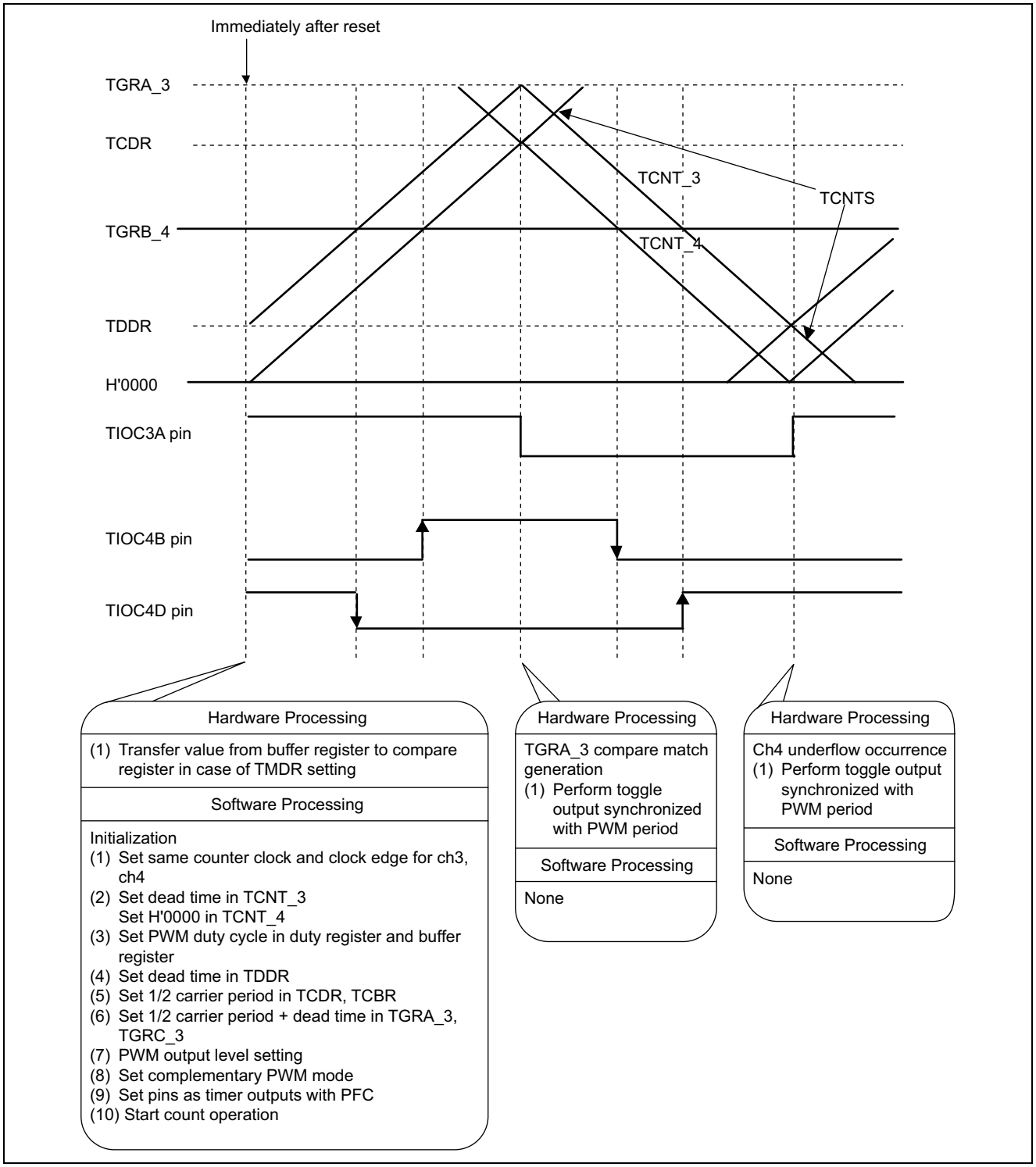


Figure 7 Principles of Operation of Toggle Waveform Output Synchronized with PWM Period

4. Software

(1) Modules

Module Name	Label	Function Assignment
Main routine	comple	Complementary PWM output setting
Data setting	setdata	Sets waveform transition timing in buffer register

(2) Arguments

Label or Register Name	Function	Data Length	Module	Input/Output
pul_cyc1	Used to set pulse 1/2 period + dead time value Pulse period is calculated using following equation: Pulse period (ns) = timer value × ϕ period (25.0 ns at 40.0 MHz operation)	1 word	Main routine	Input
pul_duty3d	Used to set TIOC pin output waveform transition timing			
pul_duty4c				
pul_duty4d				
c_cyc	PWM carrier period register value setting			
dead_time	Non-overlap time setting		Main routine Data setting	

(3) Internal Registers Used

Register Name	Function	Address	Set Value
P_STBY.MSTCR2	MTU module standby mode clearing	H'FFFF861E	H'd0fd
P_PORTE.PEIORL	Sets TIOC3B/D, TIOC4A/B/C/D pins as outputs	H'FFFF83B4	H'fb00
P_PORTE.PECRL1	Sets pin functions as TIOC3B/D, TIOC4A/B/C/D	H'FFFF83B8	H'5545
P_MTU34.TCR_3	MTU/ch3 counter clock and clock edge setting	H'FFFF8200	H'01
P_MTU34.TCR_4	MTU/ch4 counter clock and clock edge setting	H'FFFF8201	H'01
P_MTU34.TIER_3	Enables TGIA_3 interrupt	H'FFFF8208	H'41
P_MTU34.TGRA_3	1/2 carrier period + dead time setting	H'FFFF8218	pul_cyc1
P_MTU34.TGRC_3	P_MTU34.TGRA_3 buffer register (same value set as P_MTU34.TGRA_3)	H'FFFF8224	pul_cyc1
P_MTU34.TCNT_3	Dead time setting	H'FFFF8210	dead_time
P_MTU34.TCNT_4	H'0000 set	H'FFFF8212	H'0000
P_MTU34.TGRB_3	Setting of PWM duty cycle output from TIOC3B, TIOC3D	H'FFFF821A	pul_duty3d
P_MTU34.TGRA_4	Setting of PWM duty cycle output from TIOC4A, TIOC4C	H'FFFF821C	pul_duty4c
P_MTU34.TGRB_4	Setting of PWM duty cycle output from TIOC4B, TIOC4D	H'FFFF821E	pul_duty4d
P_MTU34.TGRD_3	P_MTU34.TGRB_3 buffer register (same value set as P_MTU34.TGRB_3)	H'FFFF8226	pul_duty3d

Register Name	Function	Address	Set Value
P_MTU34.TGRC_4	P_MTU34.TGRA_4 buffer register (same value set as P_MTU34.TGRA_4)	H'FFFF8228	pul_duty4c
P_MTU34.TGRD_4	P_MTU34.TGRB_4 buffer register (same value set as P_MTU34.TGRB_4)	H'FFFF822A	pul_duty4d
P_MTU34.TDDR	Dead time setting	H'FFFF8216	dead_time
P_MTU34.TCDR	1/2 carrier period setting	H'FFFF8214	c_cyc
P_MTU34.TCBR	P_MTU34.TCDR buffer register (same value set as P_MTU34.TCDR)	H'FFFF8222	c_cyc
P_MTU34.TOCR	Enabling of toggle output synchronized PWM period, and positive-phase/negative phase output level setting	H'FFFF820B	H'43
P_MTU34.TMDR_3	Sets complementary PWM mode	H'FFFF8202	H'ff
P_MTU34.TOER	Output enable setting for PWM waveform output pins	H'FFFF820A	H'ff
P_INTC.IPRE	Sets 15 as MTU channel 3 interrupt priority level	H'FFFF8350	H'00f0

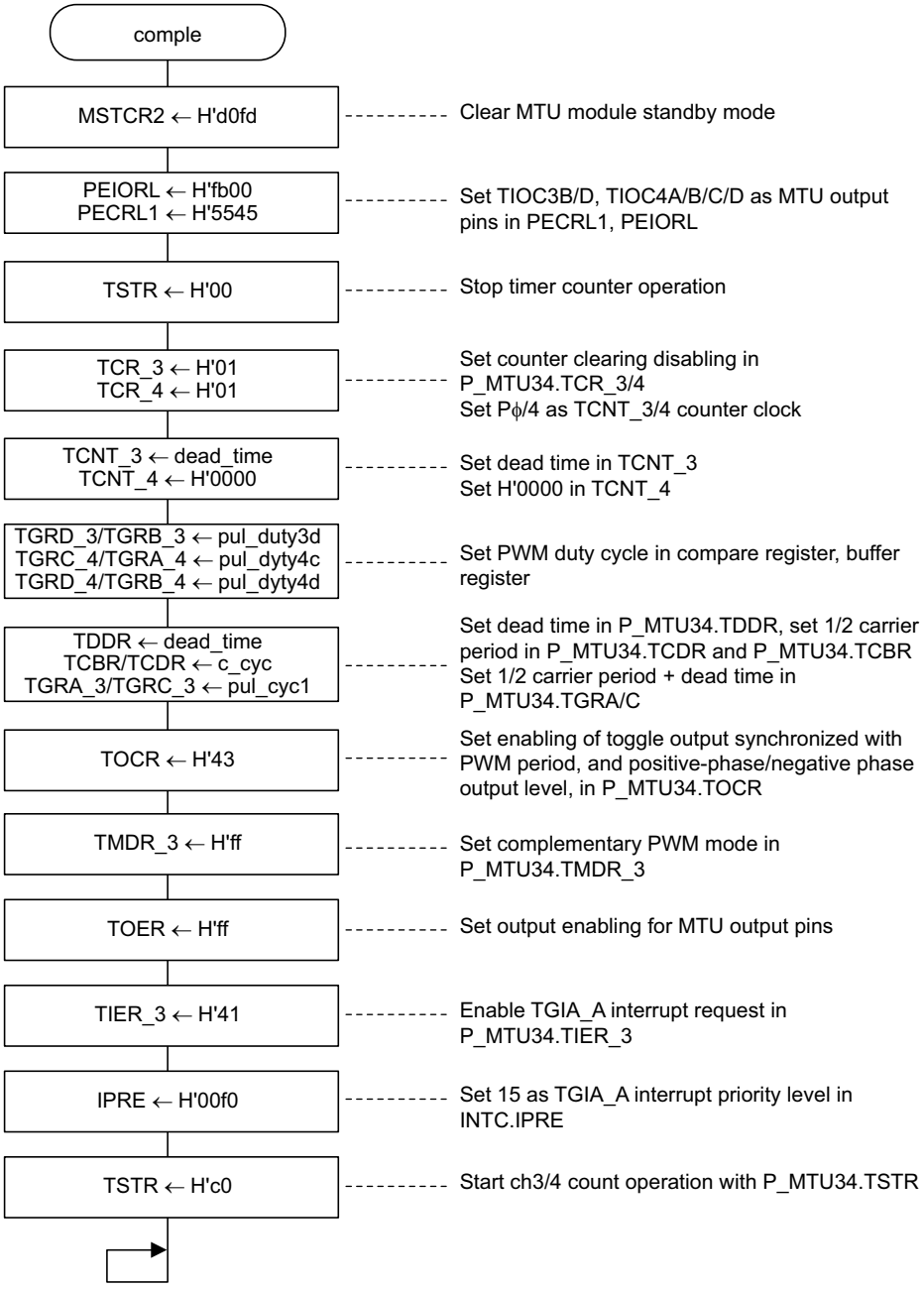
(4) RAM Used

This sample application does not use any RAM apart from the arguments.

Note: SH7145 header file names are used for register label names.

5. Flowcharts

(1) Main routine



6. Program Listing

```
/*------------------------------------------------------------------------*/
/*                              INCLUDE FILE                              */
/*------------------------------------------------------------------------*/
#include <machine.h>
#include "iodefine_7145F.h"
/*------------------------------------------------------------------------*/
/*                             PROTOTYPE                                  */
/*------------------------------------------------------------------------*/
extern void comple(void);
#pragma interrupt(setdata)
/*------------------------------------------------------------------------*/
/*                             RAM ALLOCATION                             */
/*------------------------------------------------------------------------*/
#define pul_cyc1          (*(unsigned short *)0xffffe000)
#define pul_duty3d        (*(unsigned short *)0xffffe002)
#define pul_duty4c        (*(unsigned short *)0xffffe004)
#define pul_duty4d        (*(unsigned short *)0xffffe006)
#define c_cyc             (*(unsigned short *)0xffffe008)
#define dead_time         (*(unsigned short *)0xffffe00a)
/*------------------------------------------------------------------------*/
/*                             MAIN PROGRAM                               */
/*------------------------------------------------------------------------*/
void comple(void)
{
  P_STBY.MSTCR2.WORD = 0xd0fd;     /* MTU module standby mode clear */
  P_PORTE.PEIORL.WORD = 0xfb00;    /* TIOC3B/D,TIOC4A/B/C/D = output */
  P_PORTE.PECRL1.WORD = 0x5545;

  P_MTU34.TSTR.BYTE = 0x00;        /* Stop timer count */
  P_MTU34.TCR_3.BYTE = 0x01;       /* Don't clear TCNT_3 */
  P_MTU34.TCR_4.BYTE = 0x01;       /* Don't clear TCNT_4 */
  P_MTU34.TCNT_3 = dead_time;      /* Set dead time */
  P_MTU34.TCNT_4 = 0x0000;
  P_MTU34.TGRD_3 = pul_duty3d;     /* TGRB_3 buffer register */
  P_MTU34.TGRB_3 = pul_duty3d;     /* PWM output1 compare register */
  P_MTU34.TGRC_4 = pul_duty4c;     /* TGRA_4 buffer register */
  P_MTU34.TGRA_4 = pul_duty4c;     /* PWM output2 compare register */
  P_MTU34.TGRD_4 = pul_duty4d;     /* TGRB_4 buffer register */
  P_MTU34.TGRB_4 = pul_duty4d;     /* PWM output3 compare register */
  P_MTU34.TDDR = dead_time;        /* Dead time register */
  P_MTU34.TCBR = c_cyc;            /* 1/2 carrier period */
  P_MTU34.TCDR = c_cyc;            /* TCDR buffer register */
  P_MTU34.TGRA_3 = pul_cyc1;       /* 1/2 carrier period + dead time */
  P_MTU34.TGRC_3 = pul_cyc1;       /* TGRA_3 buffer register */
  P_MTU34.TOCR.BYTE = 0x43;        /* Timer output control register */
  P_MTU34.TMDR_3.BYTE = 0xff;      /* Set complementary-pwm mode */
  P_MTU34.TOER.BYTE = 0xff;        /* Timer output enable register */
  P_MTU34.TIER_3.BYTE = 0x41;      /* Timer interrupt enable register */

  INTC.IPRE.WORD = 0x00f0;         /* Set initialize level = 15 */
  set_imask(0x0);                  /* Set imask level = 0 */
  P_MTU34.TSTR.BYTE = 0xc0;        /* Start timer counter3/4 */
```

```
   while(1);                          /* Loop */

 void setdata()
  {
    P_MTU34.TSR_3.BYTE &= 0xfe;      /* interrupt flag clear */
    P_MTU34.TCBR = c_cyc;
    P_MTU34.TGRC_3 = pul_cyc1;
    P_MTU34.TGRD_3 = pul_duty3d;
    P_MTU34.TGRC_4 = pul_duty4c;
    P_MTU34.TGRD_4 = pul_duty4d;
   }
```

Keep safety first in your circuit designs!

1. Renesas Technology Corp. puts the maximum effort into making semiconductor products better and more reliable, but there is always the possibility that trouble may occur with them. Trouble with semiconductors may lead to personal injury, fire or property damage.
   Remember to give due consideration to safety when making your circuit designs, with appropriate measures such as (i) placement of substitutive, auxiliary circuits, (ii) use of nonflammable material or (iii) prevention against any malfunction or mishap.

Notes regarding these materials

1. These materials are intended as a reference to assist our customers in the selection of the Renesas Technology Corp. product best suited to the customer's application; they do not convey any license under any intellectual property rights, or any other rights, belonging to Renesas Technology Corp. or a third party.
2. Renesas Technology Corp. assumes no responsibility for any damage, or infringement of any third-party's rights, originating in the use of any product data, diagrams, charts, programs, algorithms, or circuit application examples contained in these materials.
3. All information contained in these materials, including product data, diagrams, charts, programs and algorithms represents information on products at the time of publication of these materials, and are subject to change by Renesas Technology Corp. without notice due to product improvements or other reasons. It is therefore recommended that customers contact Renesas Technology Corp. or an authorized Renesas Technology Corp. product distributor for the latest product information before purchasing a product listed herein.
   The information described here may contain technical inaccuracies or typographical errors.
   Renesas Technology Corp. assumes no responsibility for any damage, liability, or other loss rising from these inaccuracies or errors.
   Please also pay attention to information published by Renesas Technology Corp. by various means, including the Renesas Technology Corp. Semiconductor home page (http://www.renesas.com).
4. When using any or all of the information contained in these materials, including product data, diagrams, charts, programs, and algorithms, please be sure to evaluate all information as a total system before making a final decision on the applicability of the information and products. Renesas Technology Corp. assumes no responsibility for any damage, liability or other loss resulting from the information contained herein.
5. Renesas Technology Corp. semiconductors are not designed or manufactured for use in a device or system that is used under circumstances in which human life is potentially at stake. Please contact Renesas Technology Corp. or an authorized Renesas Technology Corp. product distributor when considering the use of a product contained herein for any specific purposes, such as apparatus or systems for transportation, vehicular, medical, aerospace, nuclear, or undersea repeater use.
6. The prior written approval of Renesas Technology Corp. is necessary to reprint or reproduce in whole or in part these materials.
7. If these products or technologies are subject to the Japanese export control restrictions, they must be exported under a license from the Japanese government and cannot be imported into a country other than the approved destination.
   Any diversion or reexport contrary to the export control laws and regulations of Japan and/or the country of destination is prohibited.
8. Please contact Renesas Technology Corp. for further details on these materials or the products contained therein.