

To our customers,

---

## Old Company Name in Catalogs and Other Documents

---

On April 1<sup>st</sup>, 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 1<sup>st</sup>, 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.

# H8S Family

## Using the 14-Bit PWM Function

### Introduction

This application note presents an example usage of the 14-bit PWM function of the H8S/2100 Series to implement a D/A converter.

### Target Device

H8S/2114

H8S/2110B

H8S/2140B

H8S/2141B

H8S/2160B

H8S/2161B

H8S/2145B

H8S/2189

H8S/2168

H8S/2148

H8S/2144

H8S/2138

H8S/2134

H8S/2128

### Contents

1. Specifications .....	2
2. Conditions for Application .....	4
3. Functional Description .....	5
4. Description of Operation .....	7
5. Description of Software .....	8
6. Flowchart.....	11
7. Program Listing .....	12

### 1. Specifications

- The 14-bit PWM module outputs a PWM signal from the PWXi ( $i = 0, 1$ ) pin. By passing this PWM output signal through a low-pass filter (RC network) as shown in figure 1, an analog output (D/A-converted signal) is produced. In this sample task, we use the output on the PWX0 pin.
- In 10-MHz operation, the internal clock frequency is selectable from among  $\phi$ ,  $\phi/2$ ,  $\phi/64$ ,  $\phi/128$ ,  $\phi/256$ ,  $\phi/1024$ ,  $\phi/4096$ , and  $\phi/16384$ . In this sample task,  $\phi/2$  is selected. For specific values, please see table 1.
- In this sample task, we measure the analog outputs corresponding to duty cycles in the range from 0/256 to 255/256. The relationship between duty cycle and analog voltage is given in table 2.

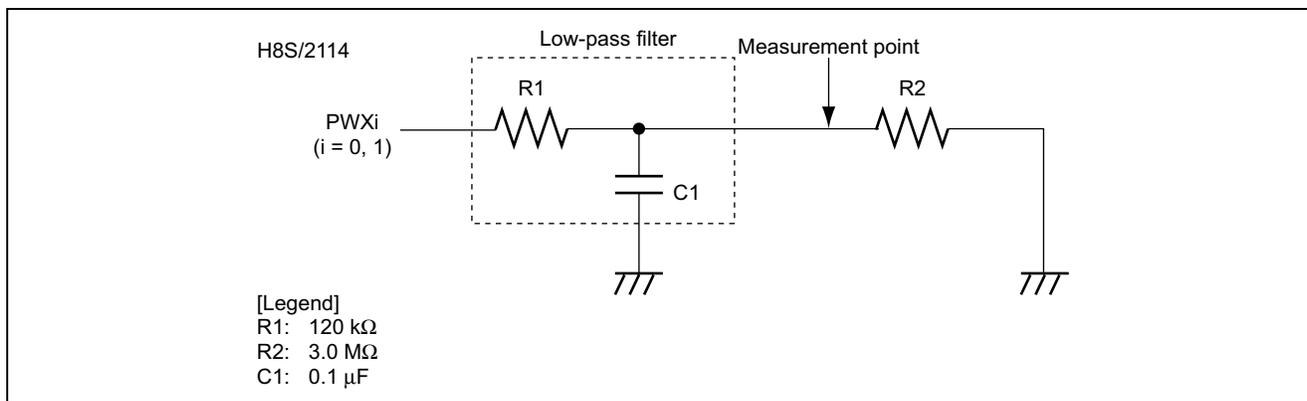


Figure 1 Example Circuit for Use as a D/A Converter

Table 1 Resolution, PWM Base Cycle, and PWM Conversion Cycle when  $\phi = 10$  MHz  
(CFS = 1 with 14-bit conversion accuracy)

Internal Clock	Resolution	PWM Base Cycle	PWM Conversion Cycle	Frequency
$\phi$	0.1 $\mu$ s	25.6 $\mu$ s	1.64 ms	39.1 kHz
$\phi/2$	0.2 $\mu$ s	51.2 $\mu$ s	3.28 ms	19.5 kHz
$\phi/64$	6.4 $\mu$ s	1.6 ms	102.4 ms	625 Hz
$\phi/128$	12.8 $\mu$ s	3.3 ms	211.2 ms	303 Hz
$\phi/256$	25.6 $\mu$ s	6.6 ms	422.4 ms	151.5 Hz
$\phi/1024$	102.4 $\mu$ s	26.2 ms	1.7 s	38.2 Hz
$\phi/4096$	409.6 $\mu$ s	104.9 ms	6.7 s	9.5 Hz
$\phi/16384$	1638.4 $\mu$ s	419.4 ms	26.8 s	2.4 Hz

**Table 2 Relationship between Duty Cycle and Analog Output**

No.	Duty Cycle	DADRA Setting	Analog Output [V]		
			Theoretical Value* <sup>1</sup>	(1)* <sup>2</sup>	(2)* <sup>2</sup>
1	0/256 (no additional pulse)	H'0003	0.00	0.01	0.00
2	1/256(no additional pulse)	H'0103	0.01	0.03	0.01
3	20/256(no additional pulse)	H'1403	0.26	0.25	0.26
4	40/256(no additional pulse)	H'2803	0.52	0.49	0.51
5	60/256(no additional pulse)	H'3C03	0.77	0.73	0.76
6	80/256(no additional pulse)	H'5003	1.03	0.99	1.04
7	100/256(no additional pulse)	H'6403	1.29	1.23	1.29
8	120/256(no additional pulse)	H'7803	1.55	1.49	1.48
9	140/256(no additional pulse)	H'8C03	1.81	1.73	1.79
10	160/256(no additional pulse)	H'A003	2.06	1.98	2.06
11	180/256(no additional pulse)	H'B403	2.32	2.23	2.31
12	200/256(no additional pulse)	H'C803	2.58	2.48	2.57
13	220/256(no additional pulse)	H'DC03	2.84	2.71	2.82
14	240/256(no additional pulse)	H'F003	3.09	2.95	3.06
15	250/256(no additional pulse)	H'FA03	3.22	3.09	3.21
16	255/256(no additional pulse)	H'FF03	3.29	3.15	3.28
17	255/256 (additional pulse: 63/63)* <sup>3</sup>	H'FFFF	—	3.16	3.29
18	PWM output fixed at high level (100% duty cycle)	—	3.30	3.17	3.29

Notes 1. The theoretical values of the analog output are calculated from the following formula:

$$\text{Analog output (theoretical value)} = V_{cc} \times (\text{DA13 to DA6})/256,$$

where  $V_{cc} = 3.3 \text{ V}$ ,  $0 \leq (\text{DA13 to DA6}) \leq 255$

2. Values of R1, R2, and C1 in figure 1:

(1)  $R1 = 120 \text{ k}\Omega$ ,  $R2 = 3.0 \text{ M}\Omega$ ,  $C1 = 0.1 \text{ }\mu\text{F}$

(2)  $R1 = 120 \text{ k}\Omega$ ,  $R2 = \text{no resistor connected (open)}$ ,  $C1 = 0.1 \text{ }\mu\text{F}$

The R2 value in the figure is chosen on the assumption that the input impedance of an actually connected device is  $3 \text{ M}\Omega$ .

The values shown here are reference values that suited our environment. Before actually using the circuit, evaluate the values on your system.

3. By superposing an additional pulse, the analog voltage can be set in finer steps. When the PWM function is used, the configuration of a 255/256 duty cycle with a 63/63 additional pulse leads to the maximum analog output that can be obtained through DADRA setting.

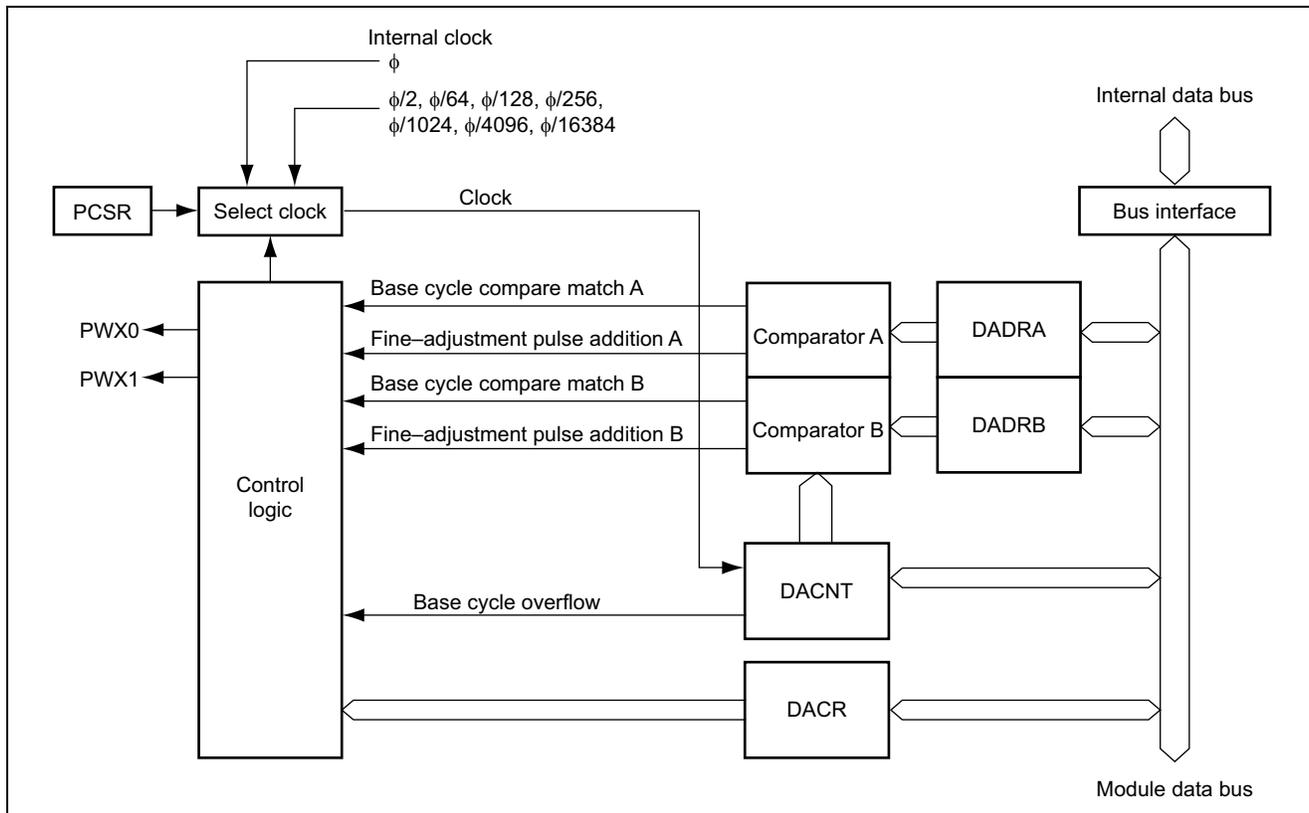
## 2. Conditions for Application

Table 3 Conditions for Application

Item	Description
Operating frequency	System clock ( $\phi$ ): 10 MHz
Operating mode	Mode 6 (MD2 = 1, MD1 = 1, MD0 = 0) Mode 2 (MD2 = 0, MD1 = 1, MD0 = 0)
Development tool	HEW: version 4.00.00.027
C/C++ compiler	H8S, H8/300 Series C/C++ Compiler: version 6.0.3.0 (from Renesas Technology Corp.)
Compiler options	-cpu = 2000A:24, -code = asmcode, -optimize = 1

### 3. Functional Description

This sample task applies the 14-bit PWM function to output pulses with a controlled duty cycle (0/256 to 255/256) from a PWM output pin. Figure 2 is a block diagram of the 14-bit PWM module, and is followed by a description of the module.



**Figure 2 Block Diagram of 14-bit PWM Module**

- For reduced ripple in analog output, the PWM module divides the pulse into multiple base cycles.
- Choice of eight resolutions: 1, 2, 64, 128, 256, 1024, 4096, or 16384 system clock cycles
- The base cycle can be selected as either  $T \times 64$  or  $T \times 256$ , where  $T$  = resolution.
- Duty cycles ranging 0 to 100% can be set with 1/256 resolution (100% duty cycle is realizable as a port output).
- The input clock for the PWM timer is selectable from among  $\phi$ ,  $\phi/2$ ,  $\phi/64$ ,  $\phi/128$ ,  $\phi/256$ ,  $\phi/1024$ ,  $\phi/4096$ , and  $\phi/16384$ . The system clock ( $\phi$ ) is the reference clock used to drive the CPU and peripheral functions. The resolution, base cycle time, and conversion cycle time for PWM are calculated from the selected internal clock frequency by using the following formulae.

Resolution (minimum pulse width) =  $1/\text{Internal clock frequency}$

PWM base cycle = Resolution  $\times$  256

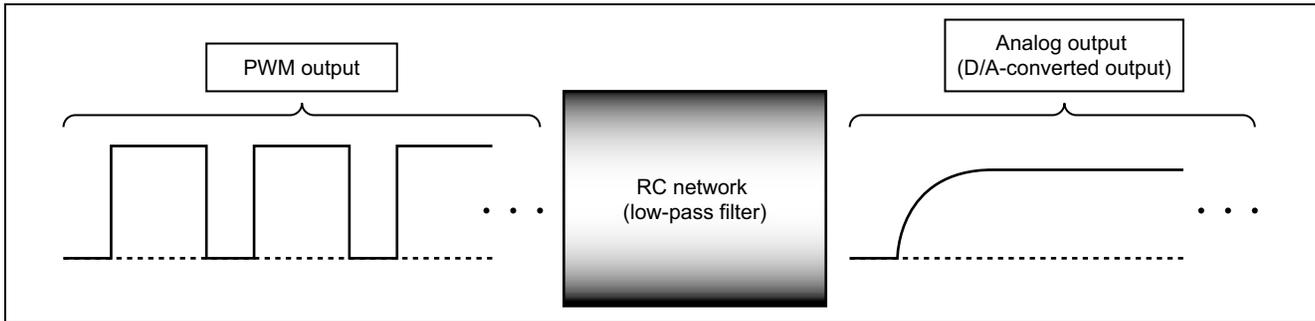
PWM conversion cycle = PWM base cycle  $\times$  64

- **PWMX (D/A) counter H, L (DACNTH, DACNTL)**  
 DACNT is a readable/writable 14-bit up counter that counts the input clock pulses. The input clock is selected by the clock select bit (CKS) of the DACR register.  
 DACNT provides the time base for the two-channel PWM (D/A). When operating the PWM function with 14-bit precision, all bits of DACNT are used. In operation with 12-bit precision, only the 12 lower-order bits are used; the two higher-order bits are ignored.
  
- **PWMX (D/A) data registers A and B (DADRA, DADRB)**  
 DADR consists of a pair of 16-bit readable/writable registers, DADRA and DADRB, which correspond to channel A (PWM0) and channel B (PWM1), respectively, of the PWMX (D/A) module. The least significant bit of DADRA has no function, and the value read from this bit is always 1. The data for D/A conversion is set in the higher-order 14 bits of DADR. This value is continuously compared with the DACNT value to determine the duty cycle of the output waveform within each base cycle and also determines whether or not an additional pulse, which is equal in width to the resolution, is superposed. Such operation only proceeds if the DADR setting is within the range that corresponds to the current value of the carrier frequency select bit (CFS). If a value outside the range for the current CFS setting is selected, the PWM output is held constant.  
 In operation with 12-bit precision, the two lower-order data bits (DA1 and DA0) are fixed to 0 and the higher-order 12 data bits are regarded as valid. The two lower-order bits correspond to the two higher-order bits of the counter (DACNT).
  
- **PWMX (D/A) control register (DACR)**  
 DACR is an 8-bit readable/writable register used to enable the PWM outputs and select the output phase and resolution.
  
- **Peripheral clock select register (PCSR)**  
 PCSR is an 8-bit readable/writable register that, in combination with the clock select bit (CKS) in DACR, selects the clock for the PWMX module.

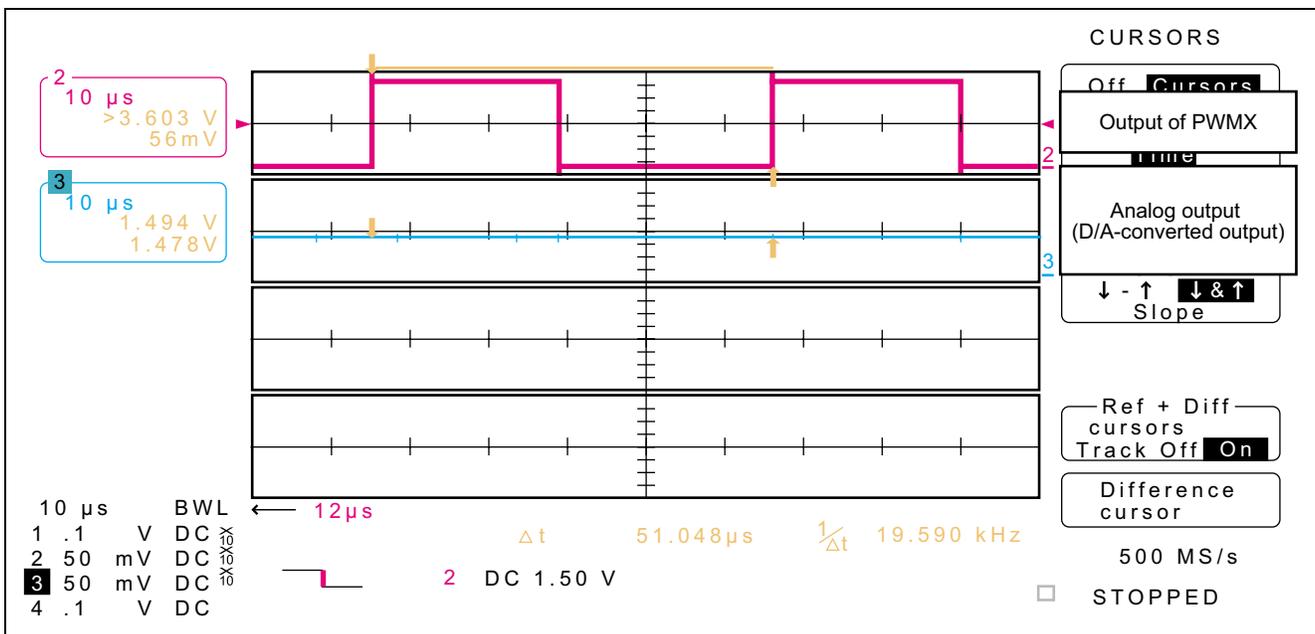
Note: The register descriptions above apply to the H8S/2114 group. When using a device from another group of the H8S/2100 series, consult the corresponding datasheet.

### 4. Description of Operation

This section explains the operation of this sample task. Figure 3 illustrates the D/A converter operation using the 14-bit PWM function. The pulses output from the PWXi (i = 0, 1) pin are smoothed by the RC network (low-pass filter) to produce an analog output (D/A-converted output). For reference, figure 4 shows an example of a D/A-converted waveform generated by using the 14-bit PWM function.



**Figure 3 Operation of a D/A Converter Driven by the 14-bit PWM Function**



**Figure 4 D/A-Converted Waveform Generated by Using the 14-bit PWM Function (for Reference)**

## 5. Description of Software

### 5.1 Module

Table 4 describes the single module of this sample task.

**Table 4 Description of Module**

Module	Label	Function
Main Routine	main	Implements 14-bit PWM output on the PWX0 pin

### 5.2 Arguments

No argument is used in this sample task.

### 5.3 Internal Registers

Table 5 describes the internal registers used in this sample task.

**Table 5 Description of Internal Registers**

Register	Function	Address	Setting
DACR	OEA PWM (D/A) Control Register (Output enable A) Enables or disables the output on channel A (PWX0) of the PWMX (D/A) module. 0: Output on channel A (PWX0) is disabled. 1: Output on channel A (PWX0) is enabled.	H'FFFA0 Bit 2	1
OS	PWM (D/A) Control Register (Output select) Selects the output phase of the PWMX (D/A) module. In this sample task, phase-inverted output is selected. 0: Direct PWM output 1: Inverted PWM output	H'FFFA0 Bit 1	1
CKS	PWM (D/A) Control Register (Clock select) In combination with the PCSR register, selects one of eight resolutions as that for the PWMX (D/A) module. In this sample task, resolution = 2 system clock cycles ( $t_{cyc}$ ) is selected. 0: PWMX (D/A) operates with resolution = one system clock cycle ( $t_{cyc}$ ). 1: PWM (D/A) operates with resolution = 2, 64, 128, 256, 1024, 4096, or 16384 system clock cycles ( $t_{cyc}$ ).	H'FFFA0 Bit 0	1

Register	Function	Address	Setting
DACNT	REGS PWMX (D/A) Counter (Register select) Registers DADRA and DACR are allocated to the same address, as are registers DADR B and DACNT. The REGS bit selects which register pair is accessible. 0: Access to DADRA and DADR B is enabled. 1: Access to DACR and DACNT is enabled.	H'FFFA6 Bit 0	0/1
DADRA	DA13 to DA6 PWMX (D/A) Data Register A These 8 higher-order bits of the data for D/A conversion set the duty cycle of the PWM output.	H'FFFA0 Bits 7 to 0	H'00 to H'FF
	DA5 to DA0 PWMX (D/A) Data Register A These 6 lower-order bits of the data for D/A conversion select whether or not an additional pulse is superposed on the output.	H'FFFA1 Bits 7 to 2	H'00 to H'3F
	CFS PWMX (D/A) Data Register A (Carrier frequency select) In this sample task, base cycle = resolution (T) × 256 is selected. 0: PWM (D/A) module operates with base cycle = resolution (T) × 64. The value of DA13 to DA0 ranges from H'0100 to H'3FFF. 1: PWM (D/A) module operates with base cycle = resolution (T) × 256. The value of DA13 to DA0 ranges from H'0040 to H'3FFF.	H'FFFA0 Bit 1	1
PCSR	PWCKXB Peripheral Clock Select Register (PWMX clock select) These bits select the clock for PWMX when the CKS bit in DACR is 1. For details, see table 6. In this sample task, resolution = 2 system clock cycles ( $t_{cyc}$ ) is selected.	H'FFF82 Bits 5, 4, 0	0 0 0
STCR	IICE Serial Timer Control Register (I2C master enable) When the RELOCATE bit is clear, controls access to the PWMX registers (DADRAH/DACR, DADR L, DADR BH/DACNTH, DADRBL/DACNTL) by the CPU.	H'FFFC3 Bit 4	1
P4DDR	Port 4 Data Direction Register Here, sets the PWX0/P46 pin as an output pin.	H'FFFB5 Bit 6	1
MSTPCR H	MSTP11 Module Stop Control Register H (MSTP11) Here, used to take the 14-bit PWM timer (PWMX) out of the module stop mode. 0: Module stop mode is cancelled. 1: Module stop mode is set.	H'FFF86 Bit 3	0

**Table 6 Internal Clock Selection**

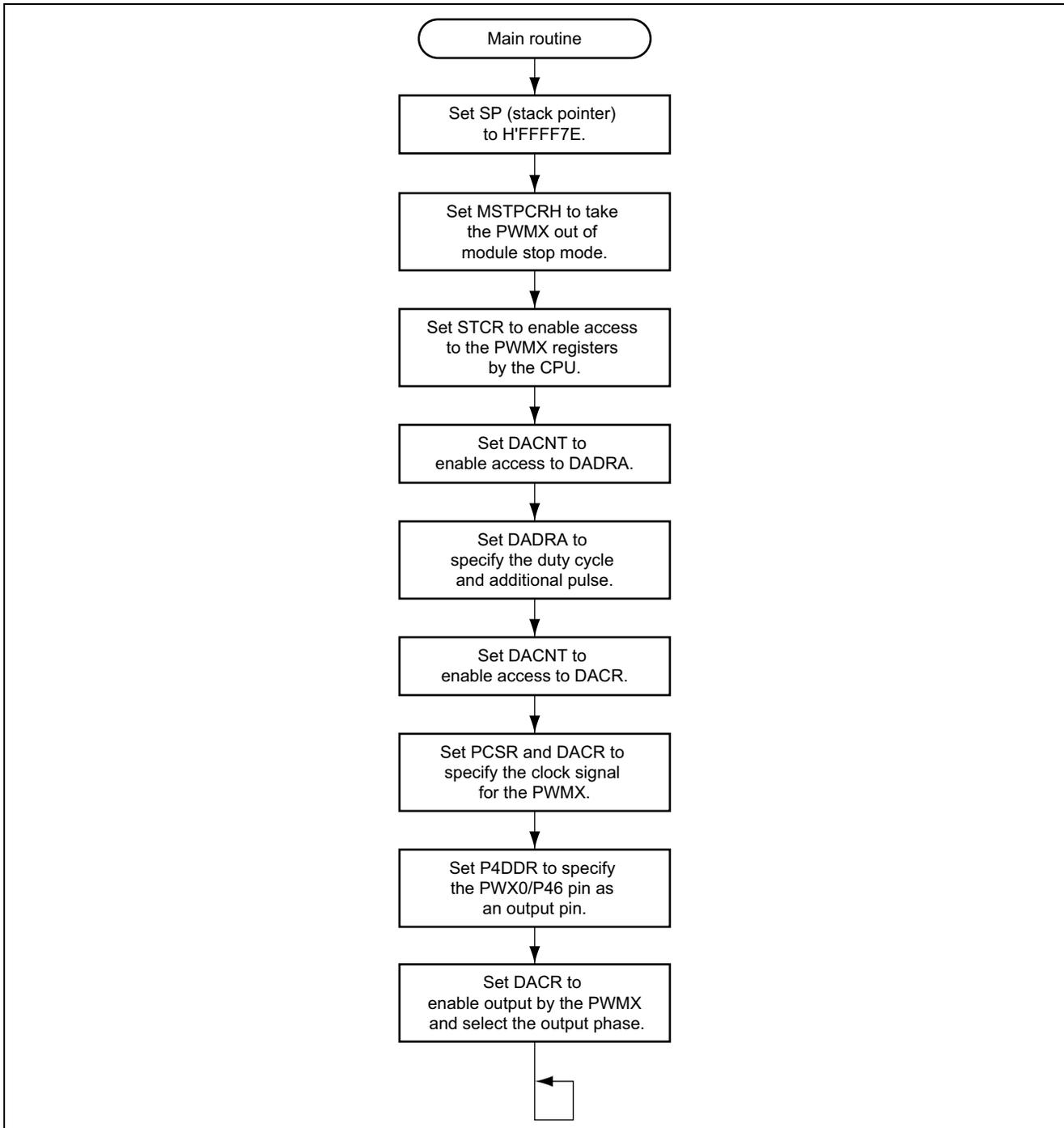
PWCKXC	PWCKXB	PWCKXA	Resolution (T)
0	0	0	Operates on system clock cycle ( $t_{cyc}$ ) $\times$ 2
0	0	1	Operates on system clock cycle ( $t_{cyc}$ ) $\times$ 64
0	1	0	Operates on system clock cycle ( $t_{cyc}$ ) $\times$ 128
0	1	1	Operates on system clock cycle ( $t_{cyc}$ ) $\times$ 256
1	0	0	Operates on system clock cycle ( $t_{cyc}$ ) $\times$ 1024
1	0	1	Operates on system clock cycle ( $t_{cyc}$ ) $\times$ 4096
1	1	0	Operates on system clock cycle ( $t_{cyc}$ ) $\times$ 16384
1	1	1	Setting prohibited

## 5.4 RAM Usage

RAM is not used in this sample task.

6. Flowchart

6.1 Main routine



## 7. Program Listing

```

/*****
/*
/* This program is 14bit PWM output program for H8S/2114 evaluation.
/*
/*
/* File name : pwm14.c
/* Frequency : 10MHz
/* CPU TYPE : H8S/2114
*****/

/*****
* Include
*****/

#include <stdio.h> /* Input/Output library file
#include <machine.h> /* Built-in function file
#include "2114.h" /* H8S/2114 I/O register definition file

/*****
* Prototype
*****/

void main(void); /* Main routine

/*****
* RAM allocation
*****/

/*****
* main : Main routine
*****/

void main(void)

#pragma section

#pragma asm

    mov.l    #H'FFFF7E,sp          ; Initialize stack pointer

#pragma endasm

{

/* Module stop mode reset */

    MSTPCR.BYTE.H = 0x37;          /* Reset PWM module stop mode

/* Enable PWMX register access */

    STCR.BYTE = 0x10;

```

```

/* Enable DADRA,DADRE access */

PWMX.REGS1.ST_DACNT.BIT.REGS = 0;

/* Duty & Add pulse set */

PWMX.REGS0.ST_DADRA.WORD = 0x7803;          /* Duty cycle = 120/256, Add pulse = 0/63 */

/* Enable DACR,DACNT access */

    PWMX.REGS1.ST_DACNT.BIT.REGS = 1;

/* PWX0 clock select */

PWMX.REGS1.ST_DACR.BIT.CKS = 1;
PWMX.PCSR.BYTE = 0x00;          /* Resolution = tcyc x 16384 */

/* PWX0 output select */

PWMX.REGS1.ST_DACR.BIT.OS = 1;    /* Select inverted output */

/* PWM output port set */

    P4.DDR = 0x40;          /* Set PWX0 (P46) */

/* PWX0 output enable */

    PWMX.REGS1.ST_DACR.BIT.OEA = 1;

    while(1);          /* End */

}

```

### Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	Jul.22.05	—	First edition issued

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.