

# SH7216 Series

R01AN0059ET0100

Rev.1.00

## Digital Power Control for PFC

Sep 30, 2010

### Introduction

This application note describes the design of a Power Factor Correction(PFC) based on the Renesas SH7216 microcontrollers.

This PFC provide a reference design using Renesas SH7216 MCU, which has the fast processing core and I/O port for the controller needs.

### Target Device

SuperH RISC engine Family SH7216 Series

### Contents

1. System Architecture .....	2
2. Specifications .....	3
3. System Configuration / Control Block Diagram.....	4
4. Hardware block diagram analysis .....	5
5. Software description.....	6
6. Experimental Result .....	9

### 1. System Architecture

The following is online UPS platform composed of PFC, Inverter, Boost, PFC and SH7216 CPU board. UPS function is controlled fully by SH7216. This document only describes PFC how controlled by SH7216 CPU board.

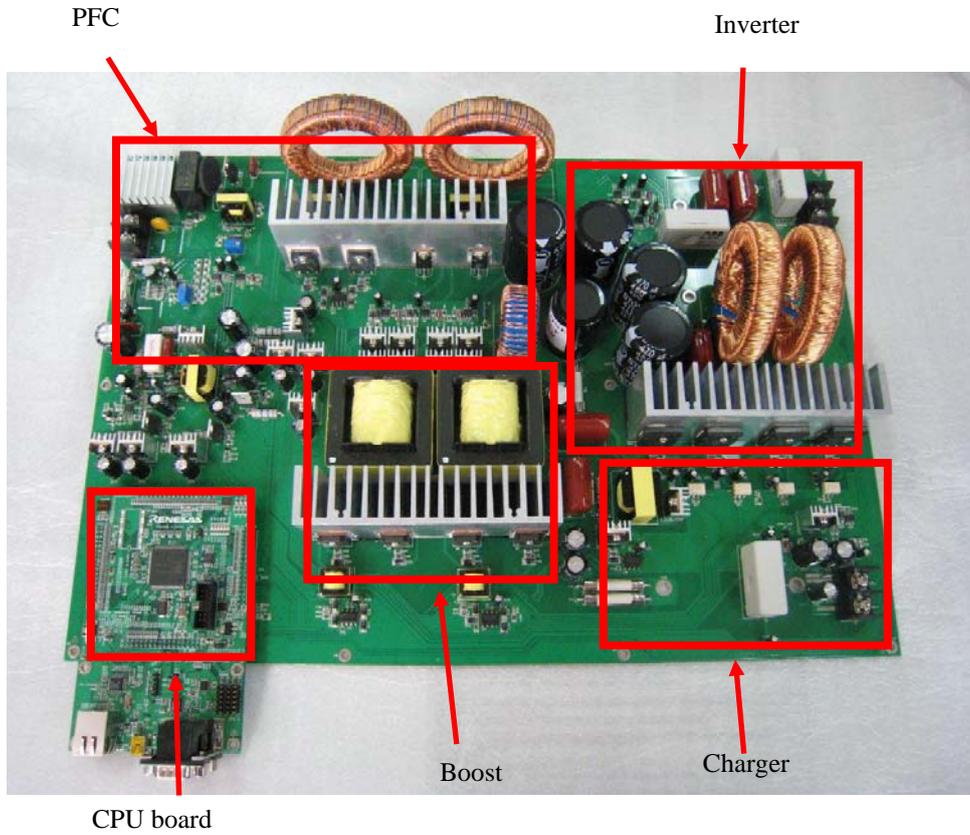


Figure 1-1 Online UPS platform

The PFC system consists of two main portions. These are:

- CPU Board
- PFC Board

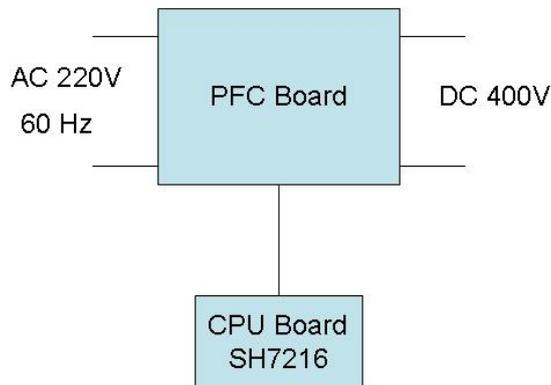


Figure 1-2 Block diagram

## 2. Specifications

The detail designed specifications of the power stage board are shown in Table 2-1.

Table 2-1 System specifications

	PFC
Input Voltage	AC 220 V
Output Voltage	DC 400 V
Output Waveform	DC
Type/Topology	Boost type
Max. Input Current	AC 6.364 A
Max. Output Current	DC 3.5 A
Max. Output Power	1.4 kW

CPU Board:

- Renesas Microcontroller: SH7216

### **NOTE:**

The use of high voltage power supplies is extremely dangerous. Only authorized personnel working in a controlled environment are allowed to change the system configuration, at their own risk.

The voltage supply in the standard configuration is 220Vac.

Renesas does not assume any responsibility for any voluntary modification of the standard demonstration hardware as well as over any misuse of the proposed system.

### 2.1 CPU Board

The CPU board can be used to control the online UPS for PFC, Boost, Charger and Inverter. The microcontroller responsible for the following tasks for PFC :

- 1) PFC and close loop regulation algorithm
- 2) Relay management
- 3) MOSFETs management.

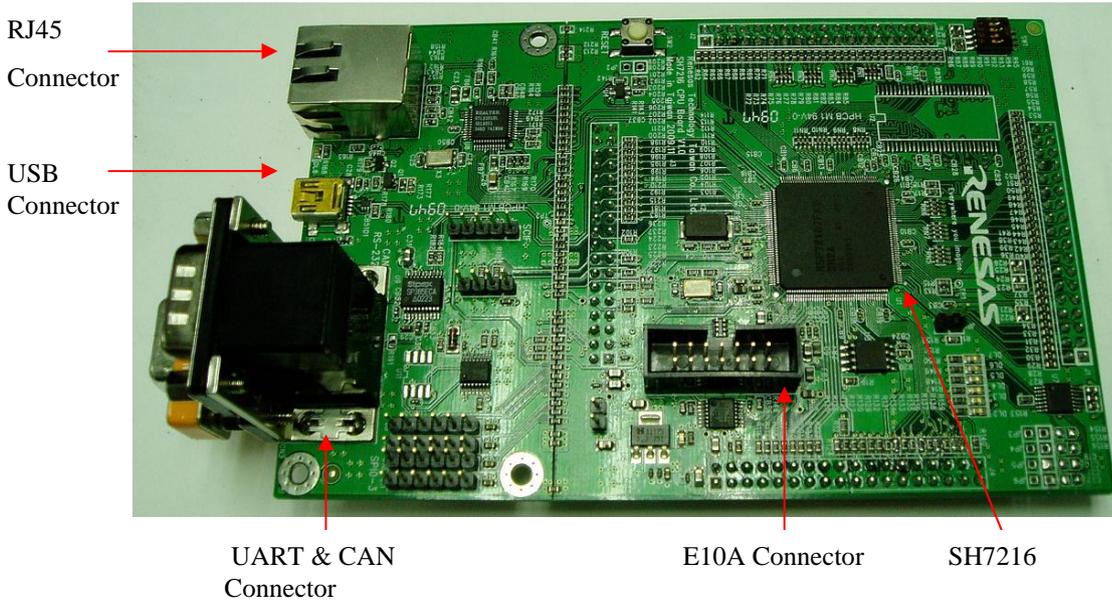


Figure 2-0-1 CPU Board

### 3. System Configuration / Control Block Diagram

Figure 3-1 is to show control diagram of PFC, it consists of PI control, ADC and PWM.

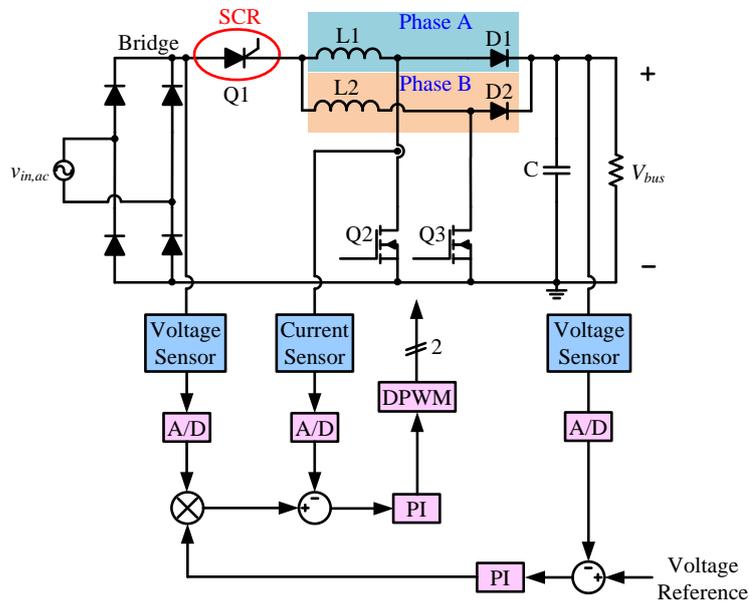


Figure 3-1 Control diagram for PFC

### 4. Hardware block diagram analysis

The purpose of PFC is to let input current following in same phase with input voltage waveform. The circuit of PFC used in this system is shown in Figure 4-1. The basic topology is an interleave PFC. The input side of PFC circuit is diode bridge-rectifier. The MOSFET controls the input current waveform. The output of PFC is 400V DC.

Soft-start function for PFC is used to avoid inrush current caused by output capacitor. During UPS power on, the filter capacitors are completely discharged and act as short circuit, which will cause a high inrush current. Therefore this current may damage the power devices. With soft-start function the capacitor voltage will increase gradually. Therefore  $dv/dt$  is low and inrush current can be significantly decreased. PFC soft-start function is implemented by Silicon Controlled Rectifier (SCR). The schematic is shown in Fig. 4-1 and operational waveforms are shown in Fig. 4-2.

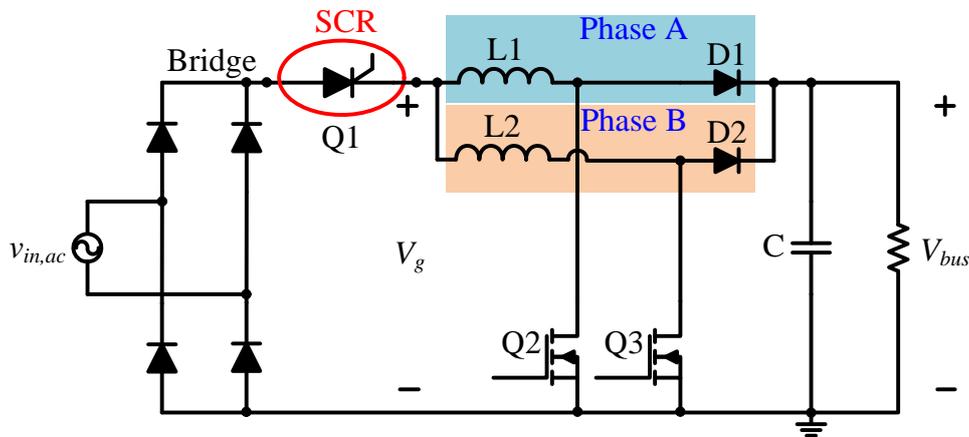


Figure 4-1 PFC circuit

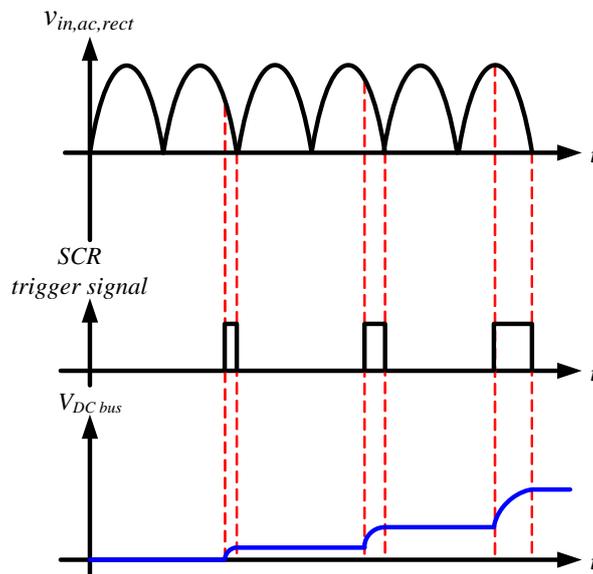
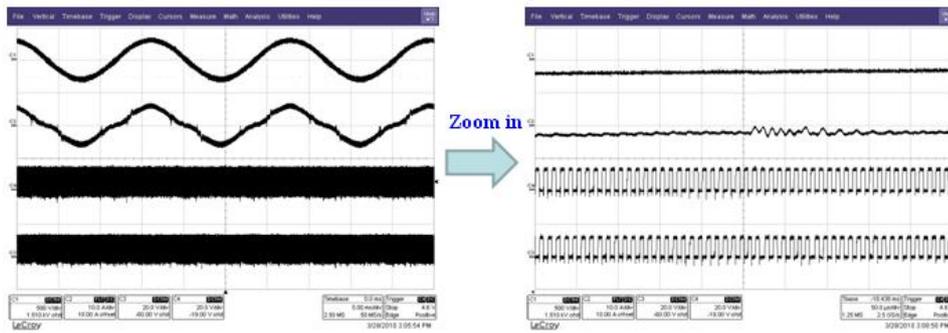


Figure 4-2 Software start operational waveform

The carrier frequency is 50KHz for PWM to control two power MOSFETs.



- Ch1: Input Voltage (500V/div)
- Ch2: Input Current (10A/div)
- Ch3: Phase A PWM (20V/div)
- Ch4: Phase B PWM (20V/div)

Figure 4-3 Phase A and B PWM control signal

The following table is measurement for efficiency of PFC.

Table 4-1 Efficiency table of PFC

Power	PF	Input power	Output power	Efficiency	Output voltage
100	0.856	113	105	0.929	397
200	0.914	215	207	0.962	397
300	0.931	317	308	0.971	397
400	0.949	418	405	0.968	397
500	0.966	520	505	0.971	397
600	0.976	625	605	0.968	397
700	0.984	729	707	0.970	397
800	0.988	828	805	0.972	397
900	0.990	932	906	0.972	397
1000	0.991	1036	1005	0.970	397
1100	0.992	1142	1104	0.966	397
1200	0.992	1245	1204	0.967	397
1300	0.992	1345	1305	0.970	396
1400	0.991	1451	1406	0.968	396

## 5. Software description

List and description of the software modules and functions

The main settings are:

**io\_set\_cpg:** performs the PLL initialization

WDT.WRITE.WTCSR = 0xa51e;

=> WDT stop, WDT count clock setting  
=> 1/4096 x P-clock (50MHz; 20.97msec)

WDT.WRITE.WTCNT = 0x5a85;

=> Counter initial setting 10msec

CPG.FRQCR.WORD = 0x0303;

=> Clockin = 12.5MHz

=> I Clock = 200MHz, B Clock = 50MHz

=> P Clock = 50MHz

CPG.MCLKCR.BIT.MSDIVS = 1;

=> MTU2S = 100MHz

CPG.ACLKCR.BIT.ASDIVS = 3;

=> AD = 50MHz

STB.CR3.BYTE = 0x02;

=> Module Standby Clear

=> HIZ,MTU2S,MTU2,POE2,IIC3,ADC0,Reserve(1),FLASH

=> Module Standby Clear

=> SCIF3,Reserve(0),CMT,Reserve(1),EtherC

STB.CR4.BYTE = 0xE2;

=> Module Standby Clear

STB.CR5.BYTE = 0x12;

=> SCIO,SCI1,SCI2,SCI4,ADC1

**pfc\_init:** performs the MTU2 initialization

ADC0.ADCR.BIT.ADCS = 0x0;

=> AD0 initialization

ADC0.ADANSR.BIT.ANS0 = 0x1;

ADC0.ADANSR.BIT.ANS1 = 0x1;

ADC0.ADANSR.BIT.ANS2 = 0x1;

ADC0.ADANSR.BIT.ANS3 = 0x1;

ADC0.ADBYPSR.BIT.SH = 0x1;

=> AD1 initialization

ADC1.ADCR.BIT.ADCS = 0x0;

ADC1.ADANSR.BIT.ANS0 = 0x1;

ADC1.ADANSR.BIT.ANS1 = 0x1;

ADC1.ADANSR.BIT.ANS2 = 0x1;

ADC1.ADANSR.BIT.ANS3 = 0x1;

MTU2S.TSTR.BYTE = 0x0;

=> Clear MTU2S counter

MTU2S3.TCR.BIT.TPSC = 0x0;

=> MTU2S3 TCNT clearing disabled

MTU2S3.TCR.BIT.CKEG = 0x0;

=> MTU2S3 Count at rising edge

MTU2S4.TCR.BIT.TPSC = 0x0;

=> MTU2S4 TCNT clearing disabled

MTU2S4.TCR.BIT.CKEG = 0x0;

=> MTU2S4 Count at rising edge

MTU2S.TDDR = 1;

=> MTU2S dead time

MTU2S3.TGRB = 495;

MTU2S3.TGRD = 495;

MTU2S4.TGRA = 300;

=> PFC output

MTU2S4.TGRC = 300;

=> PFC output

MTU2S4.TGRB = 200;

=> PFC output

MTU2S4.TGRD = 200;

=> PFC output

MTU2S.TCDR = 500;

=> triangle waveform setting 100K

MTU2S.TCBR = 500;

=> triangle waveform setting 100K

MTU2S3.TGRA = 501;

=> triangle waveform setting 100K

MTU2S3.TGRC = 501;

=> triangle waveform setting 100K

MTU2S.TOCR1.BIT.PSYE = 0x1;

=> toggle output

MTU2S.TOCR1.BIT.TOCS = 0x1;

=> TIOC4D

MTU2S.TOCR2.BIT.OLS3N = 0x0;

=> TIOC4B

MTU2S.TOCR2.BIT.OLS3P = 0x1;

MTU2S.TOCR2.BIT.OLS2N = 0x1;

=> TIOC4C

MTU2S.TOCR2.BIT.OLS2P = 0x0;

=> TIOC4A

MTU2S.TOCR2.BIT.OLS1N = 0x0;

=> TIOC3D

MTU2S.TOCR2.BIT.OLS1P = 0x1;

=> TIOC3B

MTU2S3.TMDR.BIT.MD = 0xF;

=> output high at peak value

MTU2S.TOER.BIT.OE3B = 0x1;

=> TIOC3B Pin output

MTU2S.TOER.BIT.OE3D = 0x1;

=> TIOC3D Pin output

MTU2S.TOER.BIT.OE4A = 0x1;	=> TIOC4A Pin output
MTU2S.TOER.BIT.OE4C = 0x1;	=> TIOC4C Pin output
MTU2S.TOER.BIT.OE4B = 0x1;	=> TIOC4B Pin output
MTU2S.TOER.BIT.OE4D = 0x1;	=> TIOC4D Pin output
INTC.IPR12.WORD = 0xF000;	=> Interrupt Priority of MTU2S3
INTC.IPR13.WORD = 0xF000;	=> Interrupt Priority of MTU2S5
MTU2S3.TIER.BIT.TGIEA = 0x1;	=> Active MTU2S3 interrupt
MTU2S5.TIER.BIT.TGIEU = 0x1;	=> Active MTU2S5 interrupt
MTU2S5.TCNTCMPCLR.BIT.CLRU = 0x1;	=> compare match clear
MTU2S5.TIORU.BIT.IOC = 0x0;	=> compare match
MTU2S5.TGRU = 1000;	=> output high at lower value
PFC.PDCRL3.BIT.PD10MD = 0x5;	=> TIOC3BS
PFC.PDIORL.BIT.B10 = 0x1;	
PFC.PDCRL3.BIT.PD11MD = 0x5;	=> TIOC3DS
PFC.PDIORL.BIT.B11 = 0x1;	
PFC.PDCRL4.BIT.PD12MD = 0x5;	=> TIOC4AS
PFC.PDIORL.BIT.B12 = 0x1;	
PFC.PDCRL4.BIT.PD13MD = 0x5;	=> TIOC4BS PFC output A phase (Left side)
PFC.PDIORL.BIT.B13 = 0x1;	
PFC.PDCRL4.BIT.PD14MD = 0x5;	=> TIOC4CS PFC output B phase (Right side)
PFC.PDIORL.BIT.B14 = 0x1;	
PFC.PDCRL4.BIT.PD15MD = 0x5;	=> TIOC4DS
PFC.PDIORL.BIT.B15 = 0x1;	
PFC.PECRL3.BIT.PE10MD = 0x0;	=> Active relay
PFC.PEIORL.BIT.B10 = 0x1;	
PFC.PECRL3.BIT.PE11MD = 0x0;	=> Active relay
PFC.PEIORL.BIT.B11 = 0x1;	
MTU2S.TSTR.BYTE = 0xC0;	=> MTU2S3/MTU2S4 performs count operation
MTU2S5.TSTR.BYTE = 0x4;	=> MTU2S5 performs count operation
PE.DR.BIT.B10 = 0x1;	

The figure 6 shows the flow chart of the operations performed by the software.

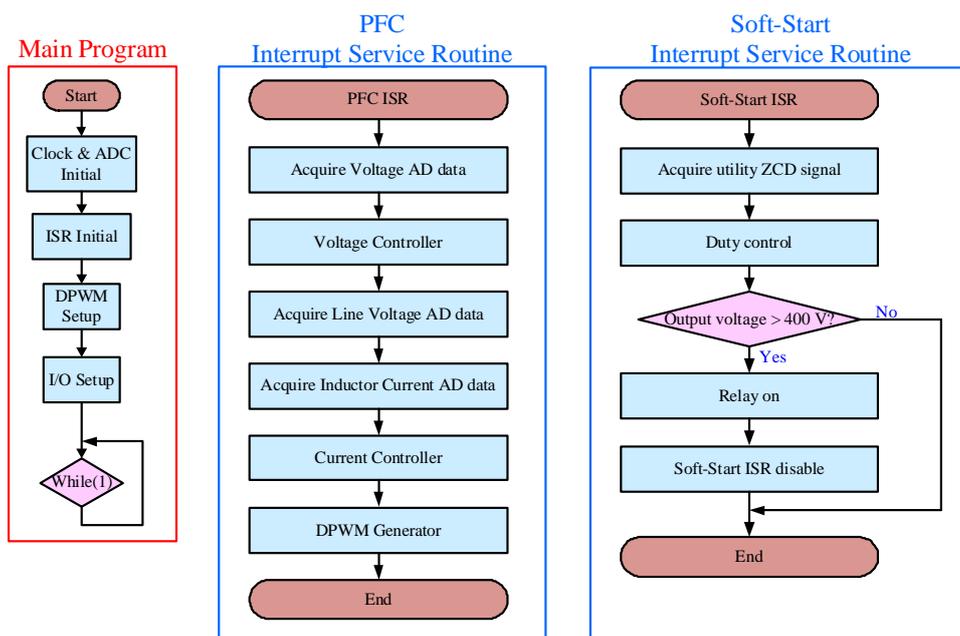


Figure 5-1 Flow Chart for PFC

### 6. Experimental Result

Pout = 700Watt

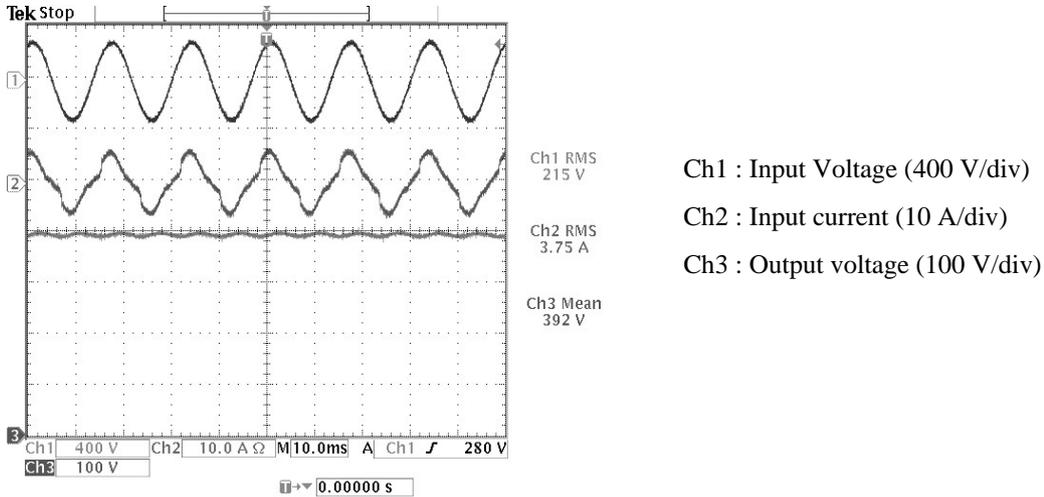


Figure 6-1 Pout=700Watt

Pout = 1400Watt

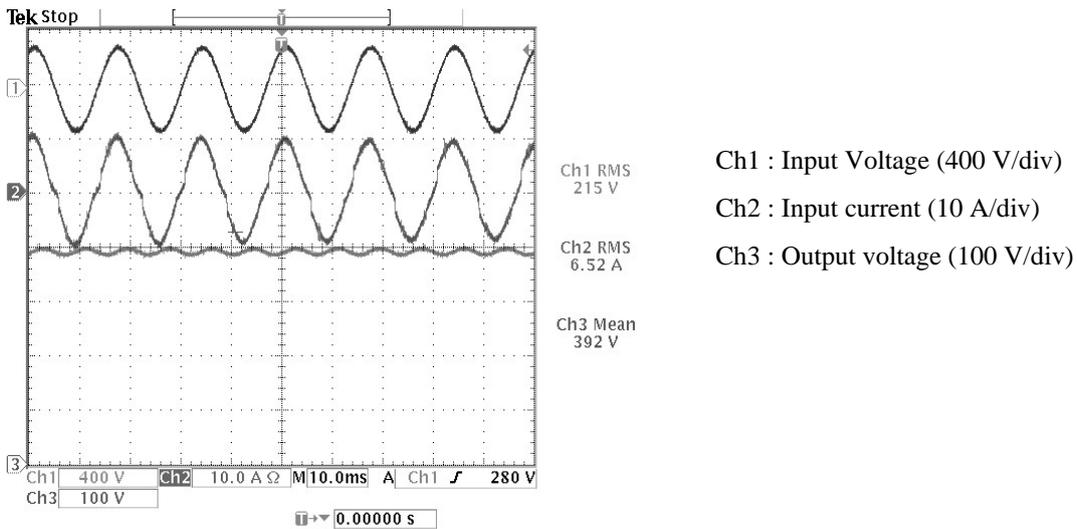


Figure 6-2 Pout=1400Watt

## Website and Support

Renesas Electronics Website

<http://www.renesas.com/>

Inquiries

<http://www.renesas.com/inquiry>

All trademarks and registered trademarks are the property of their respective owners.

## Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	Sep.30.10	—	First edition issued

## 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 manual, refer to the relevant sections of the manual. If the descriptions under General Precautions in the Handling of MPU/MCU Products and in the body of the manual differ from each other, the description in the body of the manual takes precedence.

### 1. Handling of Unused Pins

Handle unused pins in accord 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 one with a different type number, confirm that the change will not lead to problems.

- The characteristics of MPU/MCU in the same group but having different type numbers may differ because of the differences in internal memory capacity and layout pattern. When changing to products of different type numbers, implement a system-evaluation test for each of the products.

## 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.



### SALES OFFICES

Renesas Electronics Corporation

<http://www.renesas.com>

Refer to "<http://www.renesas.com/>" for the latest and detailed information.

#### Renesas Electronics America Inc.

2880 Scott Boulevard Santa Clara, CA 95050-2554, U.S.A.  
Tel: +1-408-588-6000, Fax: +1-408-588-6130

#### Renesas Electronics Canada Limited

1101 Nicholson Road, Newmarket, Ontario L3Y 9C3, Canada  
Tel: +1-905-898-5441, Fax: +1-905-898-3220

#### Renesas Electronics Europe Limited

Dukes Meadow, Millboard Road, Bourne End, Buckinghamshire, SL8 5FH, U.K.  
Tel: +44-1628-585-100, Fax: +44-1628-585-900

#### Renesas Electronics Europe GmbH

Arcadiastrasse 10, 40472 Düsseldorf, Germany  
Tel: +49-211-6503-0, Fax: +49-211-6503-1327

#### Renesas Electronics (China) Co., Ltd.

7th Floor, Quantum Plaza, No.27 ZhiChunLu Haidian District, Beijing 100083, P.R.China  
Tel: +86-10-8235-1155, Fax: +86-10-8235-7679

#### Renesas Electronics (Shanghai) Co., Ltd.

Unit 204, 205, AZIA Center, No.1233 Lujiazui Ring Rd., Pudong District, Shanghai 200120, China  
Tel: +86-21-5877-1818, Fax: +86-21-6887-7858 / -7898

#### Renesas Electronics Hong Kong Limited

Unit 1601-1613, 16/F., Tower 2, Grand Century Place, 193 Prince Edward Road West, Mongkok, Kowloon, Hong Kong  
Tel: +852-2886-9318, Fax: +852-2886-9022/9044

#### Renesas Electronics Taiwan Co., Ltd.

7F, No. 363 Fu Shing North Road Taipei, Taiwan, R.O.C.  
Tel: +886-2-8175-9600, Fax: +886-2-8175-9670

#### Renesas Electronics Singapore Pte. Ltd.

1 HarbourFront Avenue, #06-10, Keppel Bay Tower, Singapore 098632  
Tel: +65-6213-0200, Fax: +65-6278-8001

#### Renesas Electronics Malaysia Sdn.Bhd.

Unit 906, Block B, Menara Amcorp, Amcorp Trade Centre, No. 18, Jln Persiaran Barat, 46050 Petaling Jaya, Selangor Darul Ehsan, Malaysia  
Tel: +60-3-7955-9390, Fax: +60-3-7955-9510

#### Renesas Electronics Korea Co., Ltd.

11F., Samik Lavied' or Bldg., 720-2 Yeoksam-Dong, Kangnam-Ku, Seoul 135-080, Korea  
Tel: +82-2-558-3737, Fax: +82-2-558-5141