APPLICATION NOTE

RX62T

180-degree Sinusoidal-wave with Hall sensor

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Introduction

This application note describes a method of driving a sensored Brushless DC Motor (BLDCM) with 180-degree sinusoidal wave controlled by RX62T. The motor control firmware algorithm and experimental result are shown in the following chapters.

Target Device

RX62T

Contents

Figure

1. System Configuration

Target board is RX62T Evaluation Board which is made in Renesas Electronics Taiwan. E1 connector interface to debug program, hall sensor input circuit to capture hall signal; inverter circuit to drive BLDC motor; variable resistor (VR) to control the motor rotational speed; UART port to output MCU information to terminal; switch button to control the motor spinning direction.

In this application note, we'll use 120-degree trapezoidal control for startup only (The solution of this control method please refer application note "RX62T 120-degree Trapezoidal-wave with Hall Sensor"). Once the commutating is successful and revolution error is smaller than 60 rpm (i.e. Speed Command – Speed < 60 rpm), change control method from 120-degree trapezoidal to 180-degree sinusoidal control. The flowchart of sine-wave control is shown in chapter 3.

Figure 1-1 System Configuration

Table 1-1 lists the jumper setting for the hall signals input. Table 1-2 lists the jumper setting for the CPU mode selection.

Jumper	J9	J10	J11
Pins	2-3	2-3	2-3

Table 1-1 Jumper Setting for Hall Sensor Control

Jumper	J1	J2	J3	J4
Single chip mode	-	1-2	1-2	2-3
Boot mode	-	1-2	2-3	2-3

Table 1-2 CPU Mode Setting

2. Block Diagram

MTU3 is mainly used module in this application note. Channel 3 and channel 4 are used for PWM output, which is set as reset-synchronized mode. Channel 6 is used for calculating rotational speed. Channel 1 is an auxiliary counter for 1ms and 2ms timing. Three GPIOs connect with three hall sensor input signals. ADC receives VR value to control rotational speed.

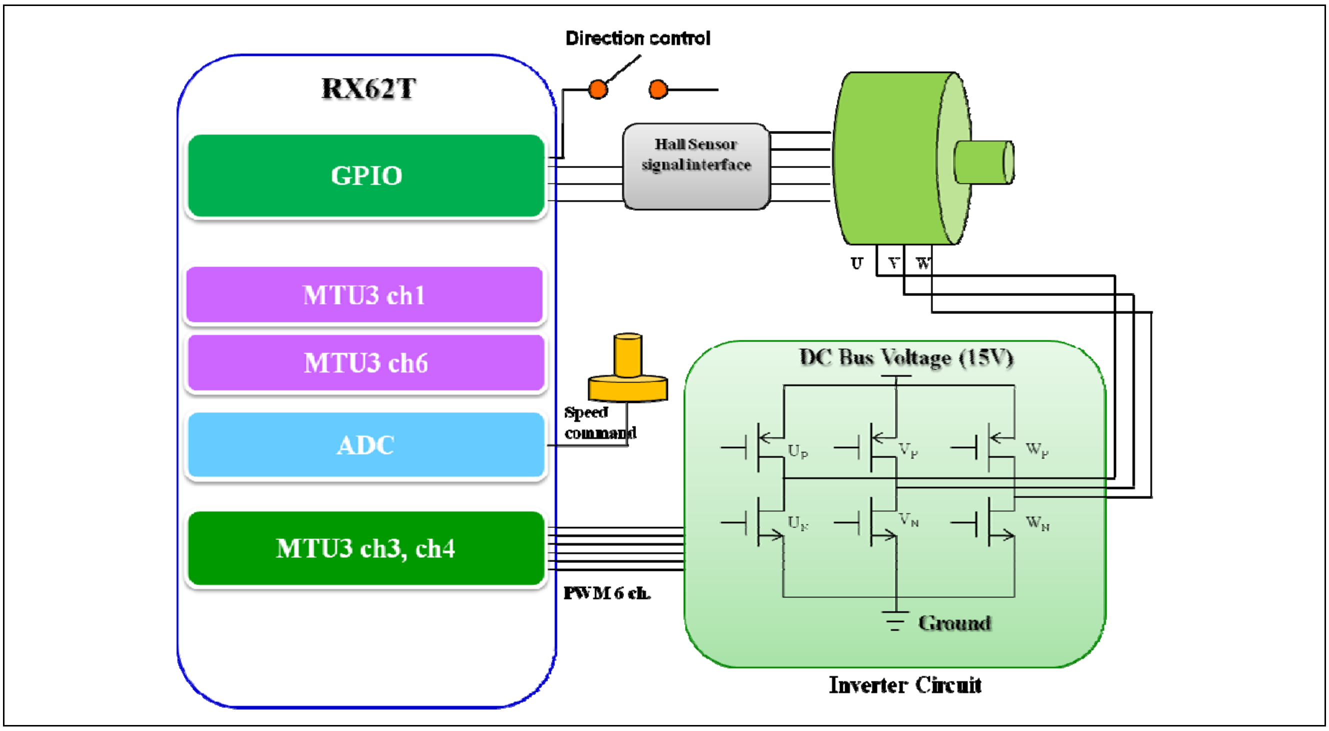
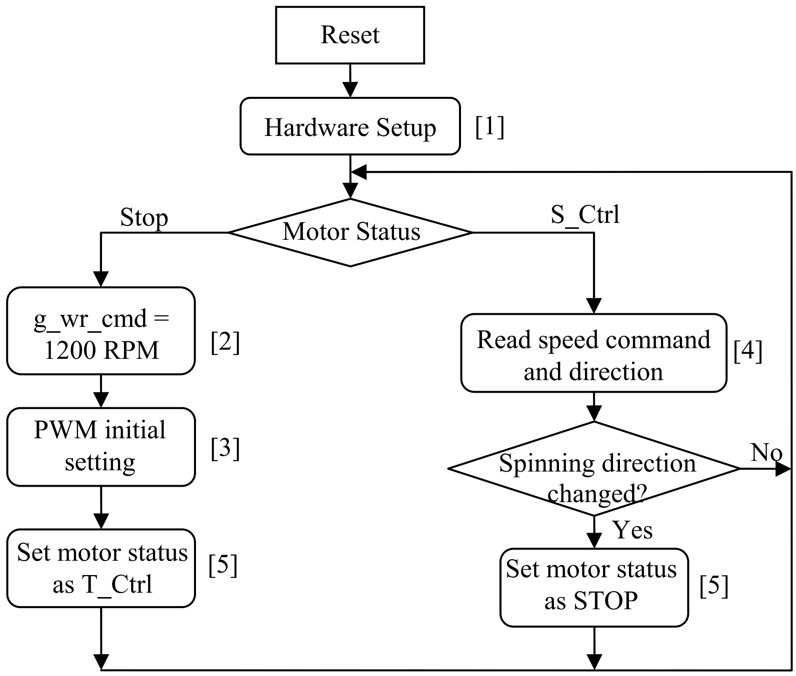


Figure 2-1 Block Diagram

3. Flowchart

Chapter 3 is going to explain how program is designed. Figure 3-1 shows the main routine that describes how program is executed. The carrier frequency is 15 KHz, which stands for one PWM duty cycle will be calculated 15K times in one second, and each interrupt operating procedure shows in Figure 3-6. The maximum and minimum duties of the PWM are limited at 80% and 10% respectively. The limitation of PWM duty should depend on each motor's specification. Figure 3-3 and 3-4 show how mechanical speed is measured.

As described in chapter 1, paragraph 2. We start the motor with 120-degree trapezoidal control. For angle being estimated precisely, we change to sinusoidal control while revolution error smaller than 60 rpm. Besides, once direction is changed during sinusoidal control, PWM output will be disabled and motor status will be changed to STOP for restarting control procedure.



Main:

[1] Initial the peripheral function in hardware setup after power on reset. Set ICLK = 100 MHz, A/D operating as single mode, and auxiliary timer counter MTU3 ch1 and ch6. Set motor status as STOP.

[2] Initial speed command is 1200 RPM.

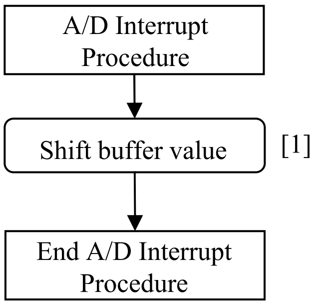
[3] In PWM initial setting, set MTU3 ch3 and ch4 as reset-synchronized mode, and interrupt carrier frequency is 15 KHz.

[4] Read speed command after A/D conversion is completed, which value is averaged by the sum of 4 buffer values; please see Figure 3-2. Besides, read switch value to control motor spinning direction. Speed command can be operated only in motor status as S_Ctrl.

[5] Change motor status according to each case.

Figure 3-1 Main Control Procedure

To get more precisely speed command value, we set four variables for saving A/D conversion results. In Fig 3-2, the interrupt procedure is triggered while A/D conversion is completed. Conversion result will be stored in buf1, and others will be shifted in sequence. Four variables will be summed up and divided by 4, which used as speed command.



A/D interrupt procedure: Once A/D conversion is completed, interrupt is generated.

[1] Define four variables: buf1, buf2, buf3 and buf4, and

Buf4 = buf3

Buf3 = buf2

buf2 = buf1

buf1= A/D conversion result

Figure 3-2 Speed Command Value form A/D

Speed calculation is one of the most important issues in motor control process. In this example, a two-pole-pairs motor is used, which generates 2 pulses in one revolution. One timer is selected to calculate motor rotation speed. As shown in Figure 3-3, timer operating frequency is 390625Hz, counter value will be saved in TGRA at rising and falling edge.

In this case, motor rotation speed is 60 rpm (i.e. 1 rps, Revolutions Per Second). While rising and falling edge is to trigger timer for capturing counter value, the TGRA value should be 97656. Depending on this condition, we calculate the ratio between 97656 and TGRA, and this is how we estimate motor rotation speed in this program. Speed calculation procedure is shown in Figure 3-4.

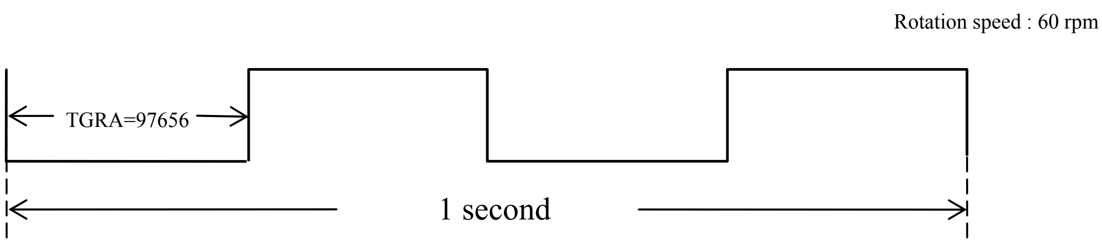
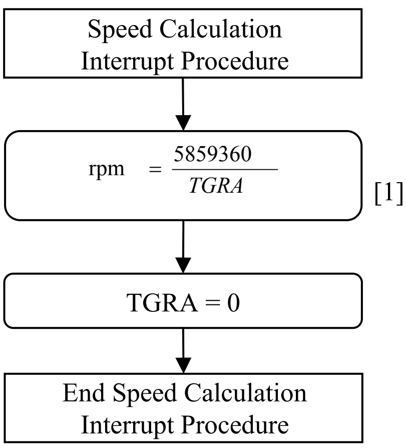


Figure 3-3 Hall Signal of 2 pole-pairs' Motor in One Revolution



Speed calculation:

[1] Operation setting: timer frequency = ICLK/256 = 100MHz/ 256=390625Hz, input capture mode at both edge.

Counter clear by TGRA input capture has been set for TCNT. After calculation is finished, clear TGRA.

$$rpm = 60 \times rps = 60 \times \frac{97656}{TGRA} = \frac{5859360}{TGRA}$$

(**rpm**: **R**evolution(s) **P**er **M**inute)

Figure 3-4 Motor Speed Calculation Procedure

In sinusoidal control, we set a look-up table which has 2^{10} points between 0° and 360° in X-axis and magnification of Y-axis form 1 ~ -1 to 2^{13} ~ -2^{13}, the figure explanation is shown in Fig3-5. 3-phase hall sensors provide angular resolution of 60-degree, so before the transition to next phase, each PWM duty cycle will accord with speed to estimate how far it has changed and sets a specific angle for a suitable output , the equation is shown in Fig3-6.

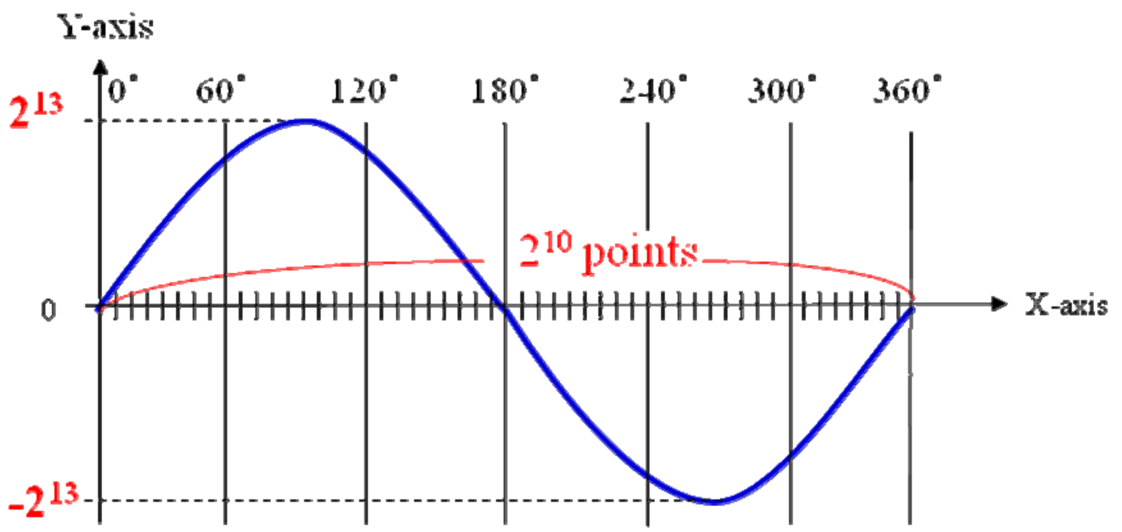
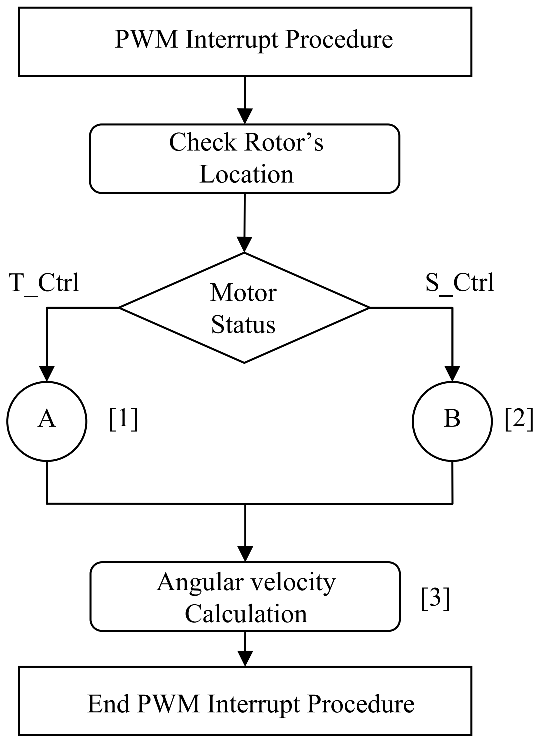


Figure 3-5 Resolution of Sine Wave

Sinusoidal PWM duty calculation and angle calculation procedure are shown in Figure 3-6 to Figure 3-8.



PWM interrupt procedure:

[1] Procedure 'A' shows in Figure 3-7

[2] Procedure 'B' shows in Figure 3-8

[3] Angular velocity can be calculated by rotational speed. In this example. 2 pole pairs motor is used that generates 2 sine-waves per radius which has 1024 point. So Δ_θ can be calculated as following equation:

$$\Delta_\theta = \frac{\frac{wr(RPM)}{60} \times 1024 \times Pole\ Pairs}{15000}$$

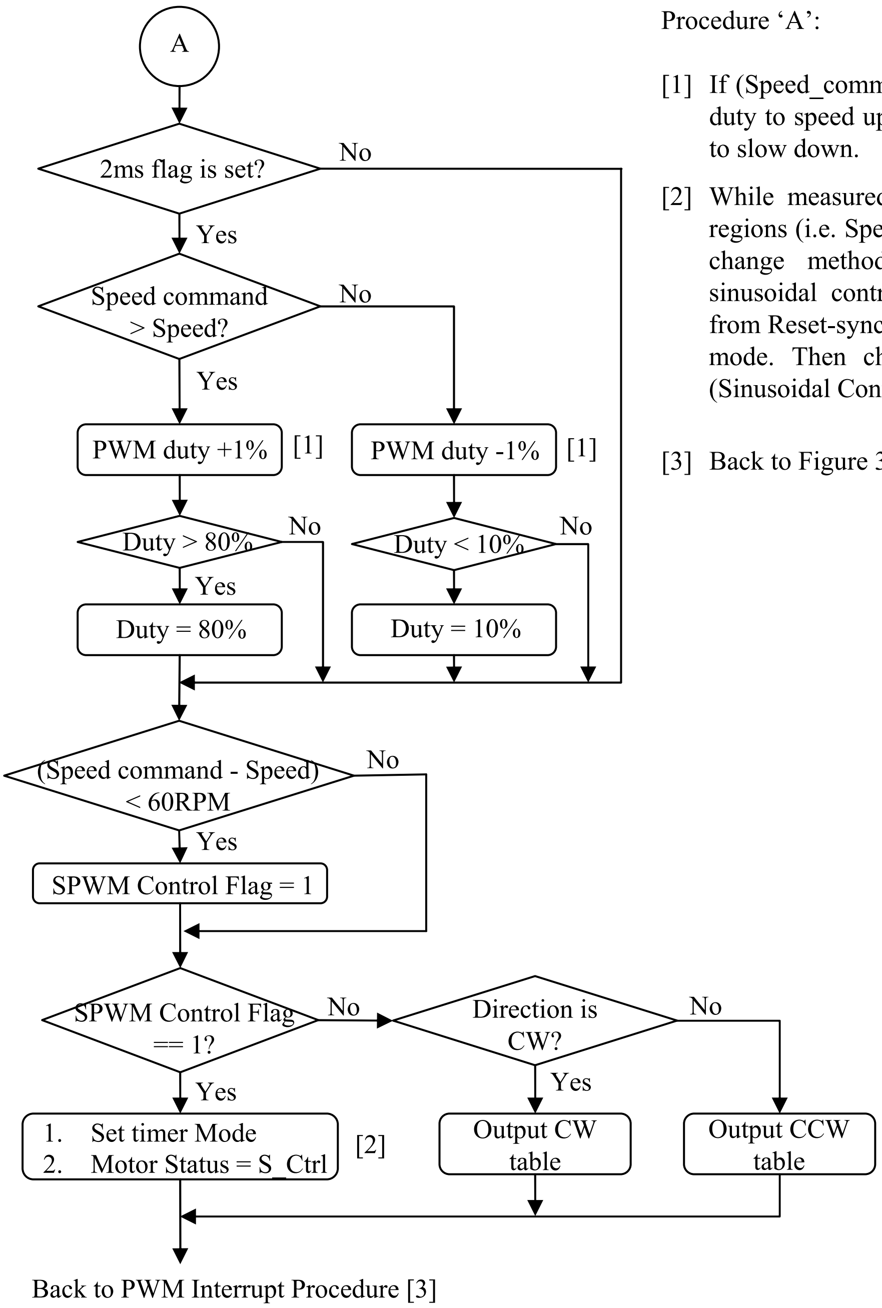
$$= \frac{wr(RPM) \times Pole\ Pairs}{878.9}$$

Note 1: *wr* is a variable that is used for saving speed in program

Note 2: 15000 is the carrier frequency of PWM control

Note 3: T_Ctrl: Trapezoidal Control
S_Ctrl: Sinusoidal Control

Figure 3-6 MTU3 Ch3 and Ch4 PWM Duty Calculation Procedure



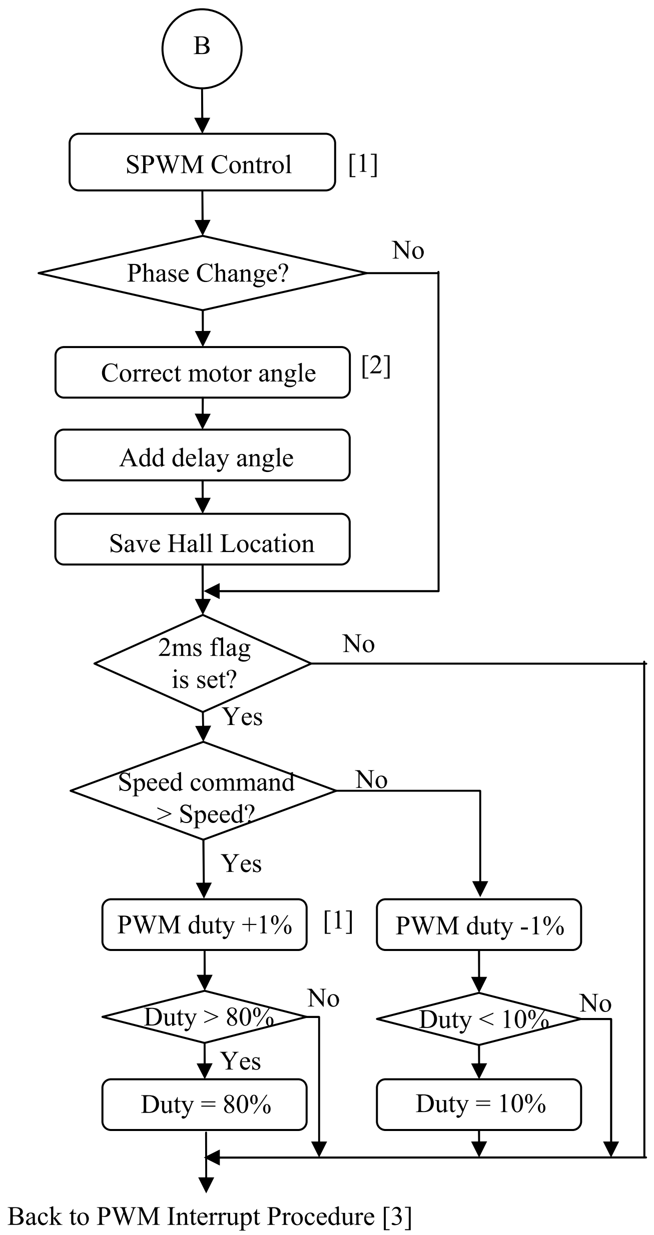
Procedure ‘A’:

[1] If (Speed_command –Speed) > 0, increase PWM duty to speed up motor, else decrease PWM duty to slow down.

[2] While measured speed reaches stable operating regions (i.e. Speed Command – Speed < 60 rpm), change method form trapezoidal control to sinusoidal control, and reconfigure timer mode from Reset-synchronized mode to complementary mode. Then changing motor status as S_Ctrl (Sinusoidal Control).

[3] Back to Figure 3-6.

Figure 3-7 Procedure ‘A’ while Motor Status as T_Ctrl



Procedure 'B':

[1] SPWM is the abbreviation of Sinusoidal PWM. In this procedure, three PWM duties of U, V, W will be outputted according with rotor's location. Rotor's location is calculated in Fig. 3-6,

[2] To avoid error condition, phase changed will be checked for 3 times. After confirmation, correct the angle. Angle is outputted with a different direction by look-up table which is set in advanced.

[3] Back to Figure. 3-6.

Figure 3-8 Procedure 'B' while Motor Status as S_Ctrl

4. Implementation and Testing

4.1 Specification of BLDC motor

The specification of BLDC motor is shown in Figure 4-1 and Figure 4-2. The model number of target motor is BLWR110S-15V-8000. Maximum speed can up to 8000 rpm in spec. In this experimental result, we can drive target motor up to 7200 rpm under PWM duty is 75%, the minimum speed of this motor without any loading is 600 rpm.

Description	Motor Wire Color	Cable Adder Color
Hall Supply	Yellow	Red/White
Hall A	Blue	Orange/White
Hall B	Orange	Orange
Hall C	Brown	Yellow/White
Hall Ground	White	Black/White
Phase A	Green	Yellow
Phase B	Red	Red
Phase C	Black	Black

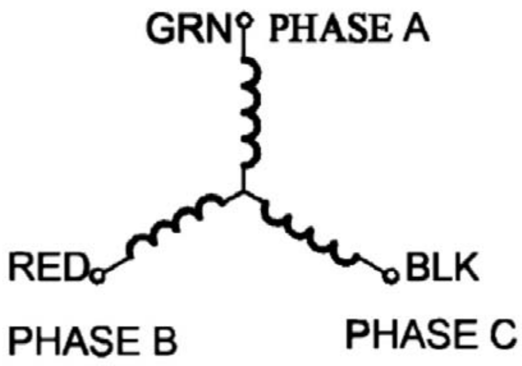


Figure 4-1 U, V, and W Description of BLWR110S

Winding Type:	Star, 4 Poles	Max. Radial Force:	15N @ 10mm from the flange
Hall Effect Angle:	120 degree electrical angle	Max. Axial Force:	10N
Shaft Run Out:	0.025mm	Insulation Class:	Class B
Radial Play:	0.02mm@450g	Dielectric Strength:	500VDC for one minute
End Play:	0.08mm@450g	Insulation Resistance:	100MOhm, 500VDC

Figure 4-2 BLWR110S Specification

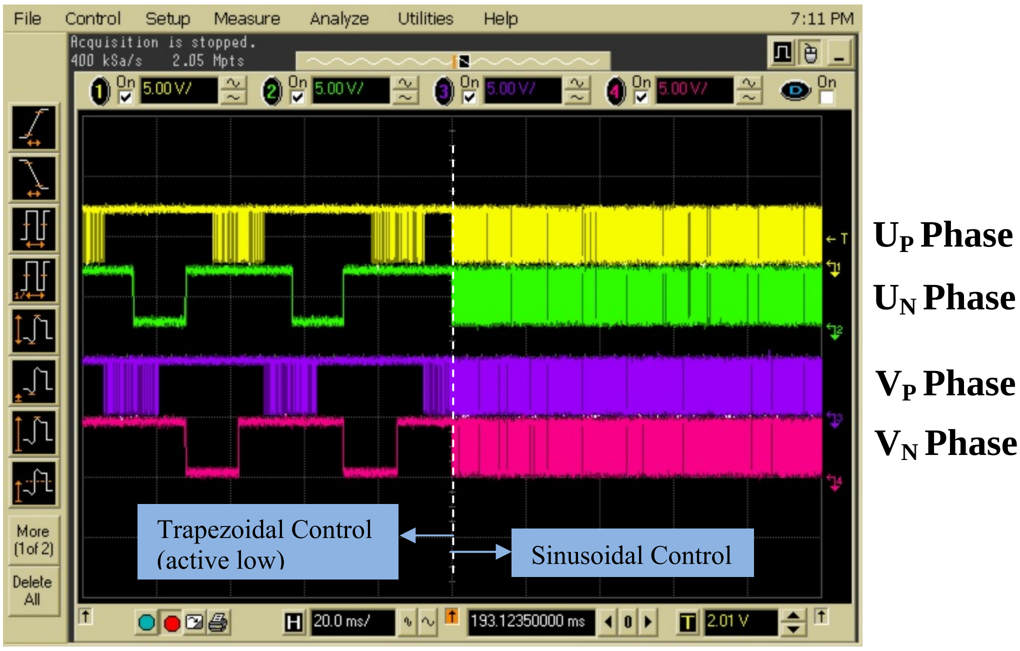
The Capability of this target board is shown in Table 3-1.

Ietm	Value	Unit
CPU loading	3.41	%
Max. Speed	7200	rpm
Min. Speed	600	rpm
Timer Used	4	channel
Input BUS voltage	15	V

Table 4-1 Capability of RX62T Evaluation Board for Sinusoidal Control

4.2 Experimential result

In this application note, we used 120 degree trapezoidal control to startup only. When rotational speed reaches stable operating regions, stop timer operation and PWM output, then changing mode form Reset-synchronized to complementary mode. As shown in Fig 4-3, high-side and low-side MOSFET will input PWM signal simultaneously after changing control method form trapezoidal control to sinusoidal control. In addition, we added low pass filters at three phases output to get result Fig 4-4, each phase PWM duty according with rotor's location and reference table to output a corresponding value to inverter. As you can see in Fig 4-5, different PWM duty cycle is outputted simultaneously in each phase after control method form trapezoidal to simusoidal control.



Note. (1) (U_P, U_N, V_P, V_N) define in Fig 2-1.
(2) Active low in inverter circiut

Figure 4-3 Changing PWM Control

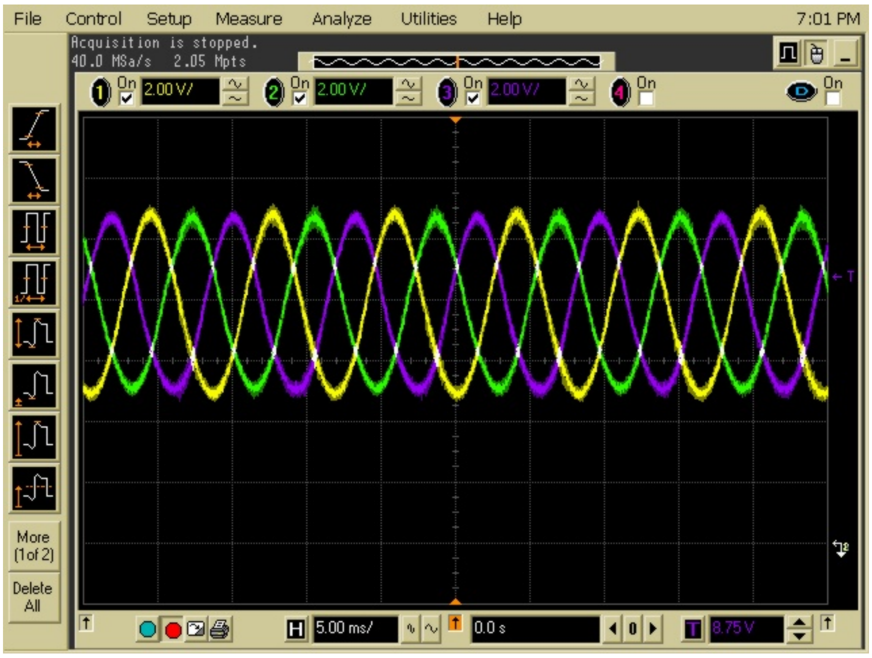
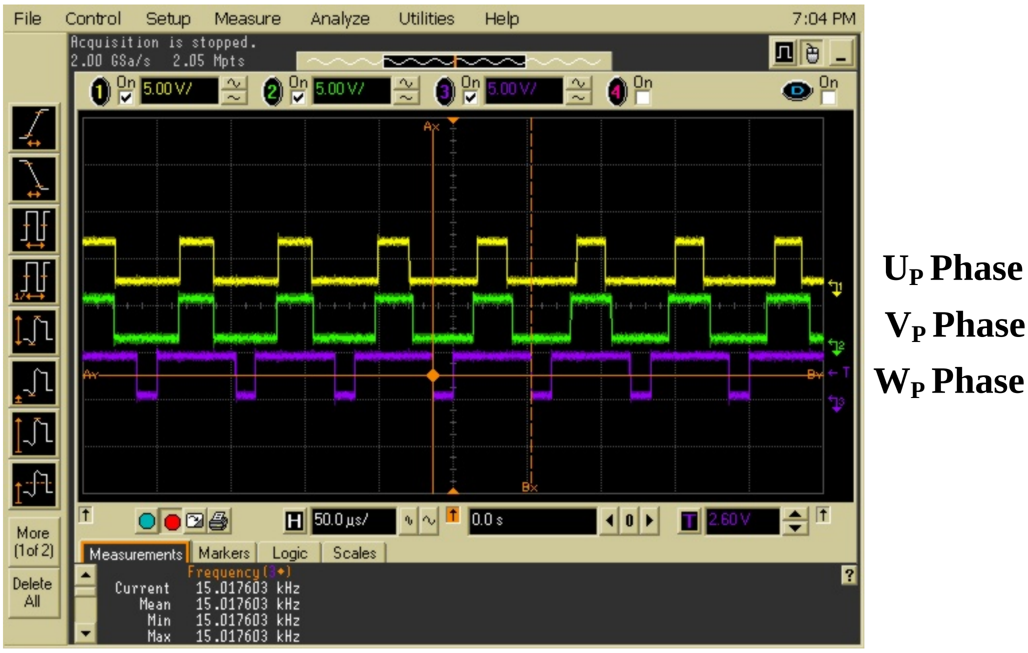


Figure 4-4 Sinusoidal Wave Control on U, V, W



Note. U_P, V_P, W_P define in Fig 2-1.

Figure 4-5 PWM Output Result of U_P, V_P, W_P

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Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	July.12.12	—	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 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 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 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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