RX62T

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120-degree Trapezoidal-wave with Sensorless

Introduction

This document provides an idea that using back Electromotive Force (back-EMF) signal to realize sensorless control. Without any sensor signal input, the rotor's location is unknown, so driving rotor to get PWM pulse via six-step trapezoidal control method phase by phase for startup period, once the BEMF is captured by MCU successfully, change back-EMF signal as input signal source. The control algorithm and experimental result are shown in the following chapters.

The reader should already have some understanding of six-step commutation methods, such as Hall sensor commutation, to provide background to the techniques described here. Besides, please read the six-step motor drive with Hall sensor application note referred to in the Reference section at the end of this document.

Target Device

RX62T

Contents

1. System Configuration

Target board is RX62T Motor Control Development Board designed by Renesas Electronics Taiwan. Table 1-1 lists the jumper setting that switch input signal as BEMF source, which will be compared by $V_{CC}/2$ and input into RX62T. Use three timer channels to realize this sensorless control. The operating mode is set as input capture mode at rising and falling edge. The detailed explanation is described in chapter 3. Table 1-2 lists the jumper setting for the CPU mode selection.

Figure 1-1 System Configuration

Jumper	J9	J10	J11
Pins	1-2	1-2	1-2

Table 1-1 Jumper Setting for Sensorless 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 the main module that is used in this application. Ch3 and ch4 are used for PWM output, which is set as reset-synchronized mode. Ch2 is used for calculating rotational speed. Ch0, ch6 and ch7 are used for calculating BEMF signal which is generated by phase U, V, and W. ADC receives VR value to control rotational speed.

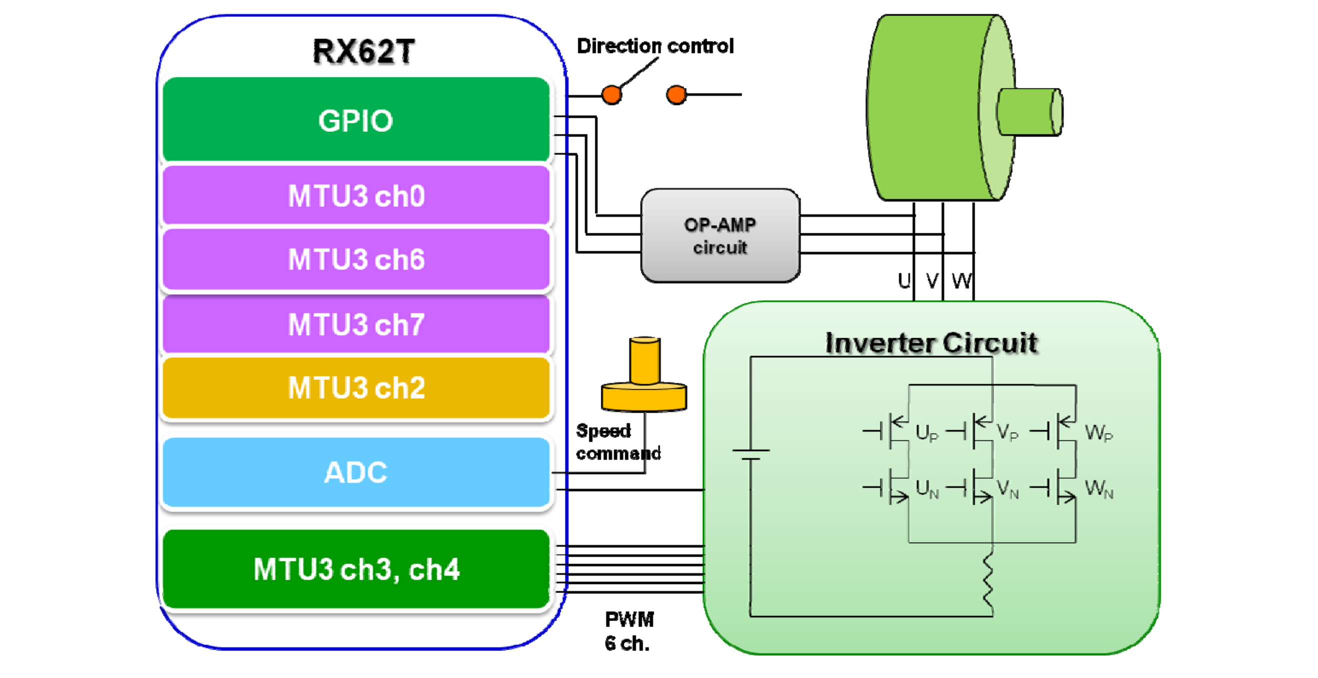


Figure 2-1 Block Diagram

3. Idea for Capturing BEMF Signal

Without any hall sensor detection, BEMF is one of many possible methods for sensorless control. In this application note, it is used to realize sensorless control. As shown in Figure 3-1, Phase U BEMF is an example for explanation.

The **U** is an input signal which is a compared value that gets form Phase U BEMF after comparing with **V_{CC}/2**. In Figure 3-1, a spike will be generated by 6-Step Motor Drive at the phase changed, so we know that the 3rd interrupt*1 is the zero-crossing point. After knowing the zero-crossing point, U_P PWM should output by delaying 30-degree (i.e. output at 7th interrupt*1 in this example; note: '7th' in Figure 3-1 is just an example for explanation).

*1 each interrupt is generated by a MTU3 timer which mode is set as input capture mode at rising and falling edge, and saving the counter value per interrupt, for more detailed explanation, see Figure 3-2.

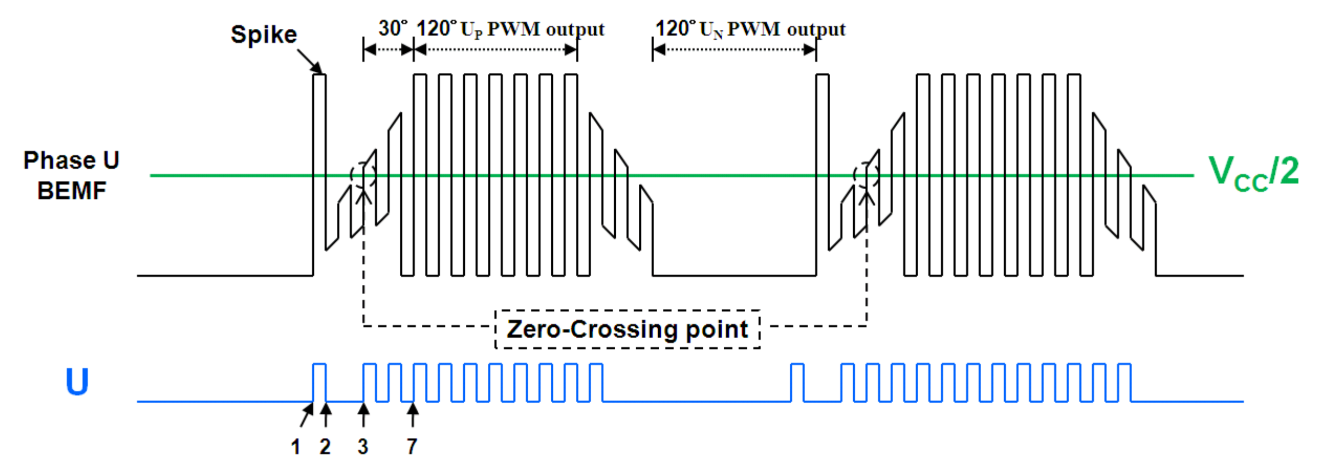


Figure 3-1 Zero-crossing Point Calculation

Figure 3-2 shows how to determine zero-crossing point at rising and falling edge by BEMF signals.

Define 'Temp' for saving counter value (i.e. TCNT), and TCNT is cleared at rising and falling edge of input signal; 'CntA' for counting the number of interrupt; and 'Value A' is the compared value that we set for knowing the timing of timing.

Four points:

(1) In Figure 3-2, TCNT value will greater than 'Value A' only when spike is generated (refer Figure 3-1).

(2) Set 'CntA' to 1 when 'Temp' greater than 'Value A', and add 1 in the next interrupt (i.e. CntA++).

(3) While low condition is matched with user setting, set fictitious H1 to low (in this example is 7th). F_H1 low represents U_P PWM is outputted after delaying 30-degree, so it needs to tune 'CntA' for the real condition.

(4) The end of the U_P phase output is uncountable, so we use the Phase V BEMF to determine the rising time of F_H1. In figure 3-2, **V** is Phase V BEMF signal, which timer mode is same as U used. Once the interrupt procedure in V is generated and read 'Temp' value is greater than the minimum 'Temp' value (i.e. 'Temp'= 17), set F_H1 to high.

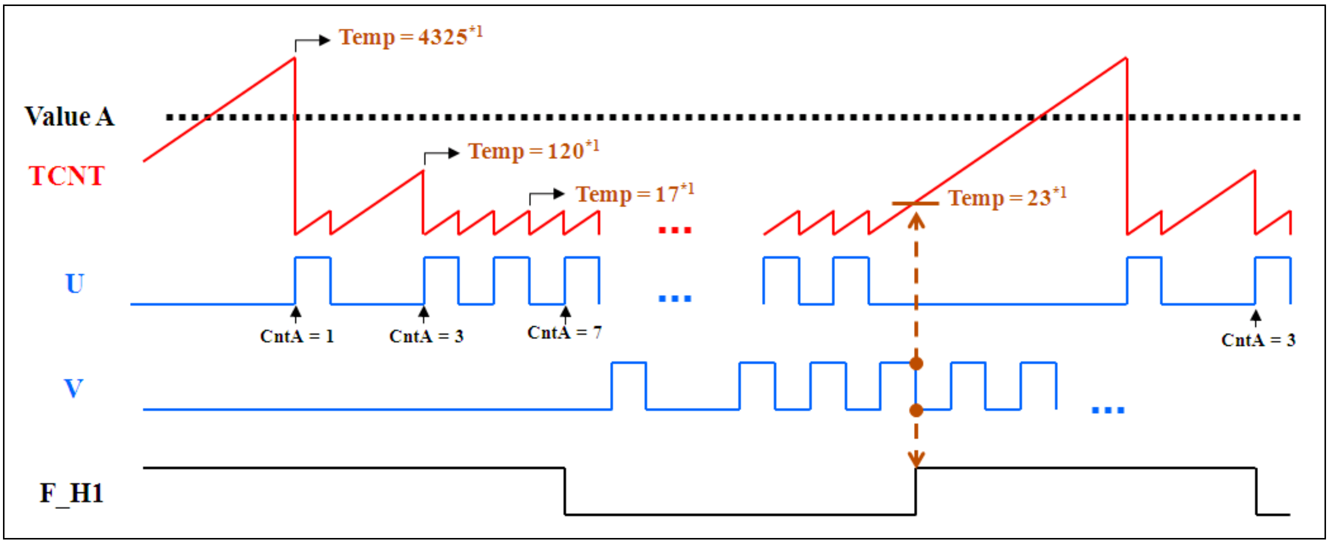


Figure 3-2 Calculation of Fictitious Signal

*1 'Temp' value in Figure 3-2 is an example for explanation. The value should be performed in realistic condition.

Three phases BEMF relationship is shown in Figure 3-3. Red arrow ( ) indicates the rising edge of fictitious hall signal timing. Each phase rising condition is determined by another phase, so three timer channels are realized for this idea.

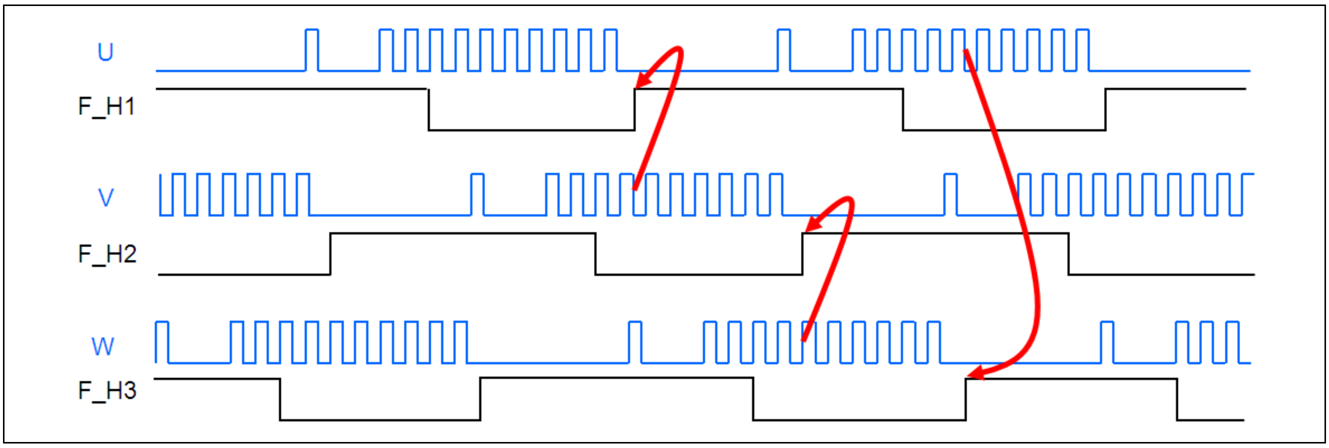
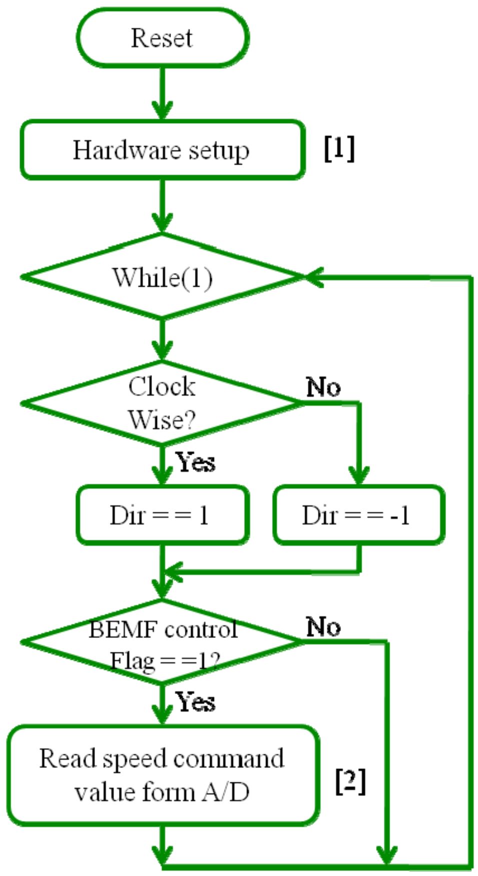


Figure 3-3 Relation between 3 Phase BEMF signal and Fictitious Signal

The program flowcharts are shown in chapter 4.

4. Flowchart

Chapter 4 shows setting procedure of main, PWM, and BEMF in sample program. In addition, speed calculation method is also described in this chapter, too.



Main:

[1] After power on reset, initial the peripheral function in hardware setup. Set ICLK = 100 MHz, A/D is operated as single mode, and MTU3 timer channels 0, 6 and 7 for BEMF used; ch2 to calculate rotational speed; and ch3 and ch4 to output PWM command.

[2] Speed command for motor can be operated only when BEMF control flag is set,

Figure 4-1 Main Function Control Procedure

Four poles motor is used in this example, which means 2 cycles is generated in one revolution. Operating frequency is 1562500Hz for one timer channel (i.e. ICLK/64 = 100MHz/64) to calculate the period of fictitious hall signal at falling edge, and the 1 rps (Revolutions Per Second) value between two falling edge is 781250. In figure 4-2, The reading value saved in TGRA is 390625. Base on 1 rps condition, calculate the ratio of presenting value saved in TGRA, it can get the current speed is 2 rps (i.e. 120 rpm). And that is the speed calculation method used in this application note.

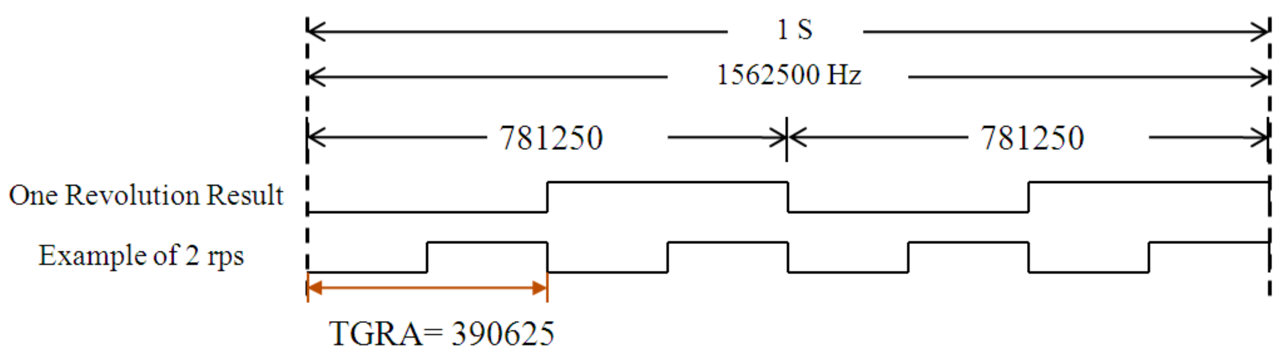
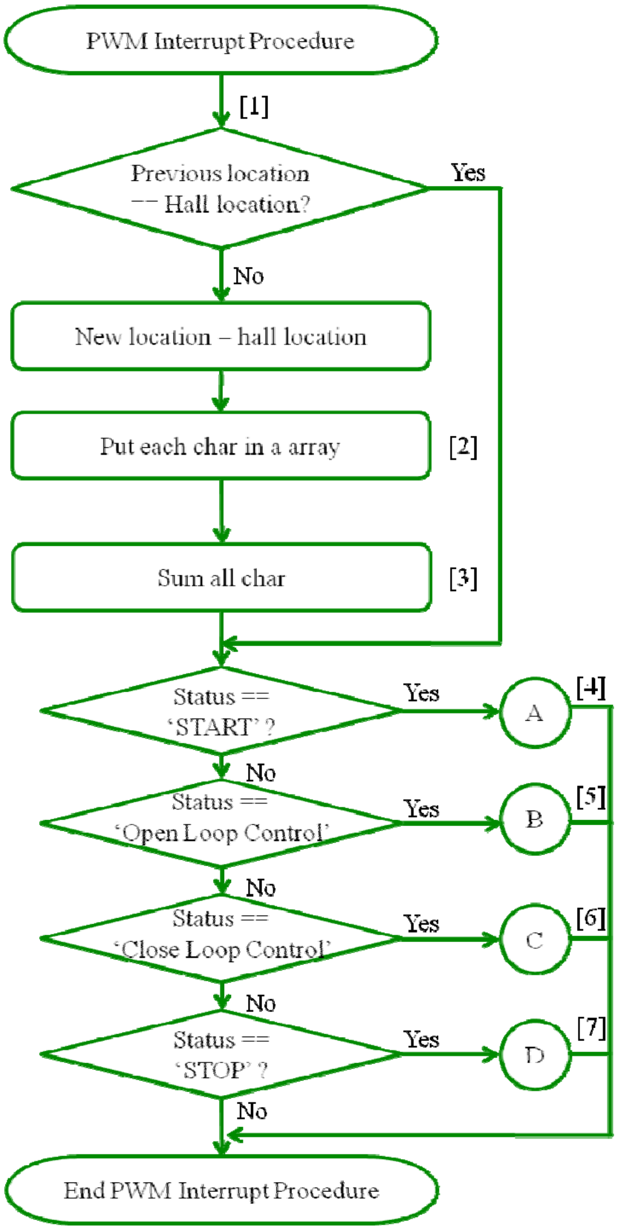


Figure 4-2 Example of Speed Calculation

Figure 4-3 shows the PWM duty output setting procedure that includes no BEMF signal input (i.e. open-loop control), and BEMF signal input (i.e. close-loop control).



MTU3, MTU4 PWM Interrupt

[1] Check the hall location with previous saved value

[2] For each value, save it into an array which we defined, such as array_Hall = [5 4 6 2 3 1], and each value is determined at BEMF procedure, please see Figure 4-8, step [7].

[3] Sum all value to check the status of motor, if sum value == 21. Its means motor is activated successfully in open loop method, then set BEMF control flag to 1.

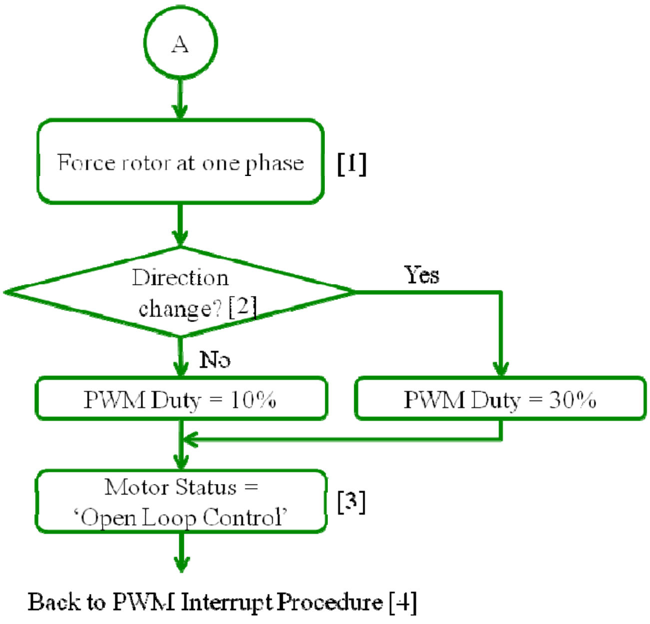
[4] In 'A', rotor will be constrained at one phase by output particular PWM signal.

[5] In 'B', six phases PWM will be generated in sequence for several times. Once the motor is activated successfully, change motor status to 'Close Loop Control'.

[6] In 'C', use fictitious hall signal as input signal.

[7] In 'D', if motor direction is changed or if motor activate is fail, change status to 'STOP' to restart the control procedure.

Figure 4-3 PWM Control Procedure



Procedure 'A':

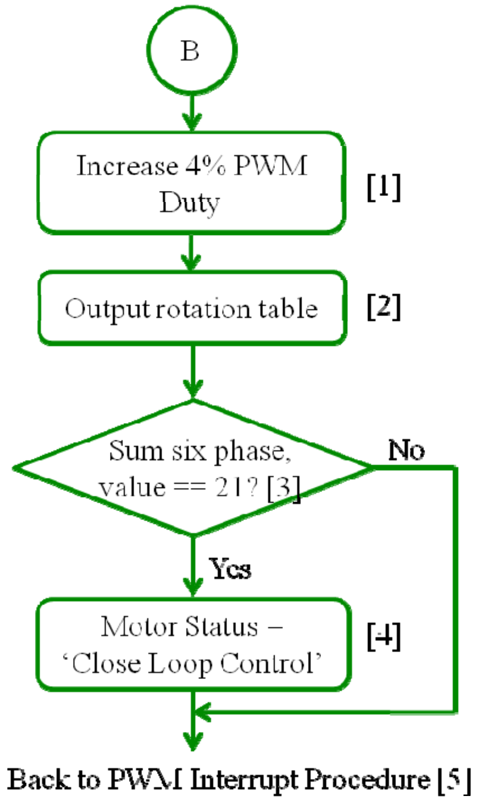
[1] Because the rotor's location is unknown, we enable one phase PWM to constrain rotor at a fixed location.

[2] Check spinning direction. If changed, output higher PWM duty to force rotor's location.

[3] Change Motor Status to 'Open Loop Control'.

[4] Back to Fig 4-3

Figure 4-4 Motor Status is 'START' in PWM Control Procedure



Procedure 'B':

[1] Add PWM duty by each interrupt

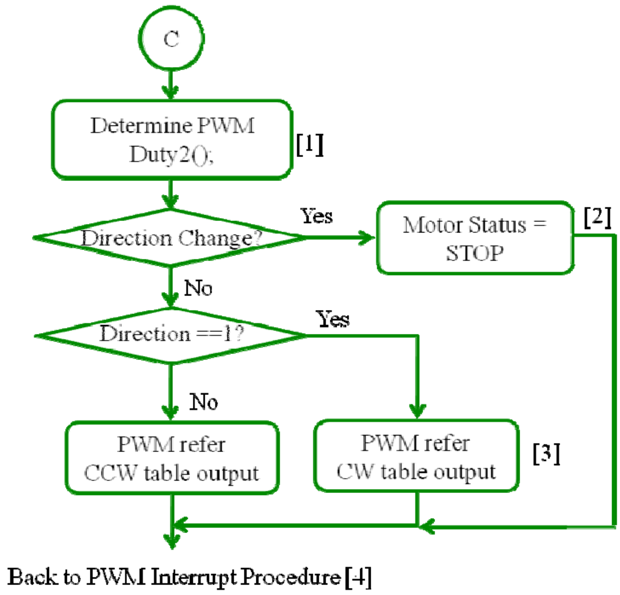
[2] At this stage, each phase will follow six-step commutation methods without any

[3] Check whether motor is running successfully

[4] Change Motor Status to 'Close Loop Control'

[5] Back to Fig 4-3

Figure 4-5 Motor Status is 'Open Loop Control' in PWM Control Procedure



Procedure 'C':

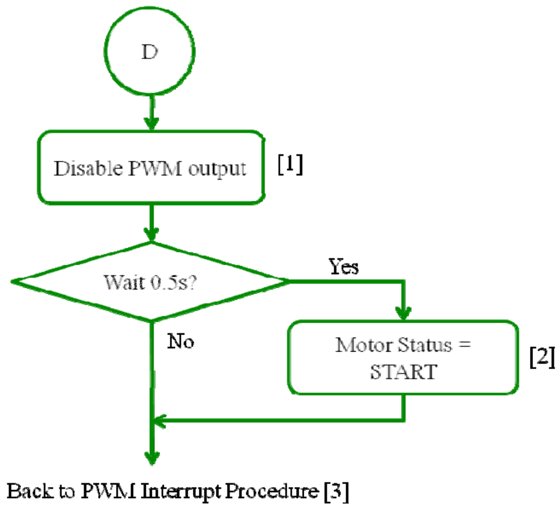
[1] After changing Motor status to 'Close Loop Control', PWM duty will be calculated according to rotational speed.

[2] Check direction. If changed, turn off the PWM output and set Motor Status to 'STOP' to restart.

[3] Clockwise and counter clockwise have its output table respectively.

[4] Back to Fig 4-3

Figure 4-6 Motor Status is 'Close Loop Control' in PWM Control Procedure



Procedure 'D':

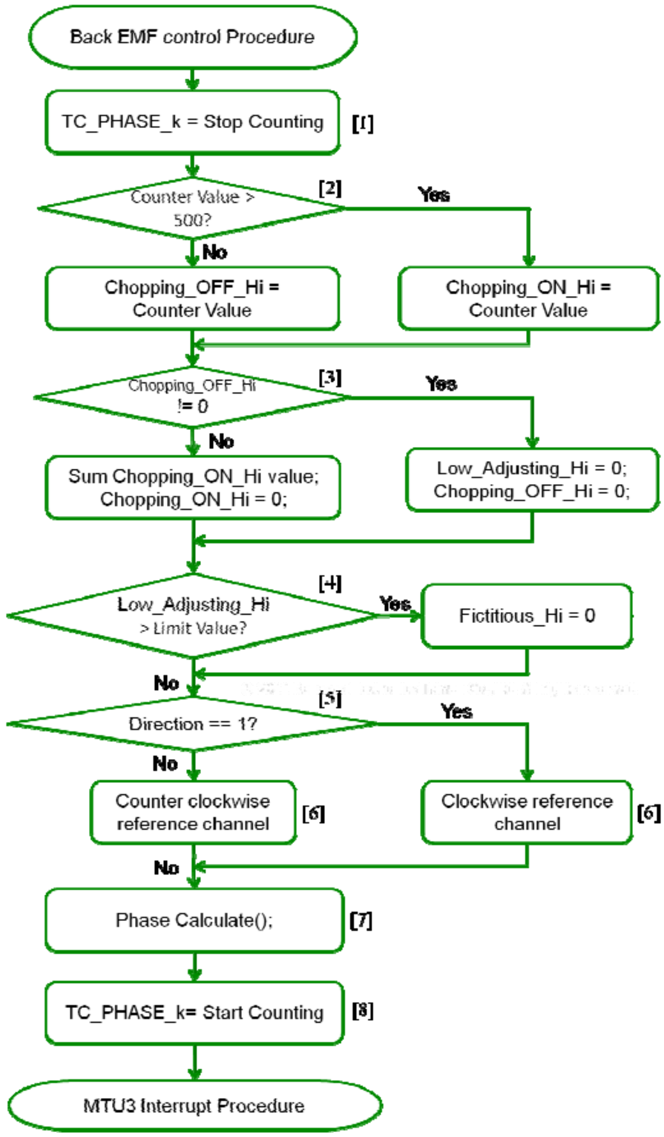
[1] Turn off the PWM output

[2] Waiting for 0.5s, then changing Motor Status to 'START' to restart program.

[3] Back to Fig 4-3

Figure 4-7 Motor Status is 'STOP' in PWM Control Procedure

Three phase BEMF signals are used the same procedure, and idea for this flowchart please see Chapter 3.



BEMF process

[1] Count operation is stopped, k = U, V, W.

[2] Check counter value bigger than 500, and save counter value in different conditions happened.

[3] Check Hi phase to verify the timing of Spike. If TCNT value greater than ValueA, as mentioned in Chapter 3, clear CntA to 0 in this step.

[4] If compare match with value that user set, set F_Hi to low.

[5] Check spinning direction

[6] Different direction has different reference signal, see NOTE 3, and the F_Hi high condition is determined in this step.

[7] Use saved value F_H1, F_H2, and F_H3 to determine the latest information of rotor's location.

[8] Performs count operation

Figure 4-8 BEMF Control Procedure

Note1. i = 1, 2, 3

Note 2 Three phase BEMF signals use the same procedure.

Note 3 Different condition of spinning direction has different reference table, the reference channel for falling edge of zero-crossing point are shown in below table:

Interrupt source / Direction	Phase U	Phase V	Phase W
Clockwise	Phase W	Phase U	Phase V
Counter Clockwise	Phase V	Phase W	Phase U

5. Implementation and Testing

The experimental results are shown as below.

As shown in Figure 5-1, ch2 gets form ch1 signal which filtered by $V_{CC}/2$. Use ch3 is calculated fictitious signal, which setting procedure is mentioned in Chapter3. In this figure, sets rising edge compared value = 10, and falling edge compared value = 500 as the best condition. Ch4 stands for the U_P PWM output for 120 degree. In this figure, motor rotational speed is 4092 rpm with loading.

Ch1 : Phase U BEMF signal

Ch2 : Input signal that is compared with $V_{CC}/2$

Ch3 : Fictitious H1 Hall signal, with low condition CntA ==10, high condition Temp > 500

Ch4 : PWM output of U_P

Figure 5-1 Experimental Result

The capability of this target board is shown in Table 5-1.

Ietm	Value	Unit
CPU loading	9.68	%
Max. Speed	8000	RPM
Min. Speed	1000	RPM
Timer Used	6	channel
Input BUS voltage	15	V

Table 5-1 Capability of RX62T Motor Control Development Board

Figure 5-2 is the relation between three phase fictitious hall signals and phase U current. And rotational speed is 3021 rpm with loading.

Figure 5-2 Phase U Current with Loading

Figure 5-3 shows three phase BEMF signal.

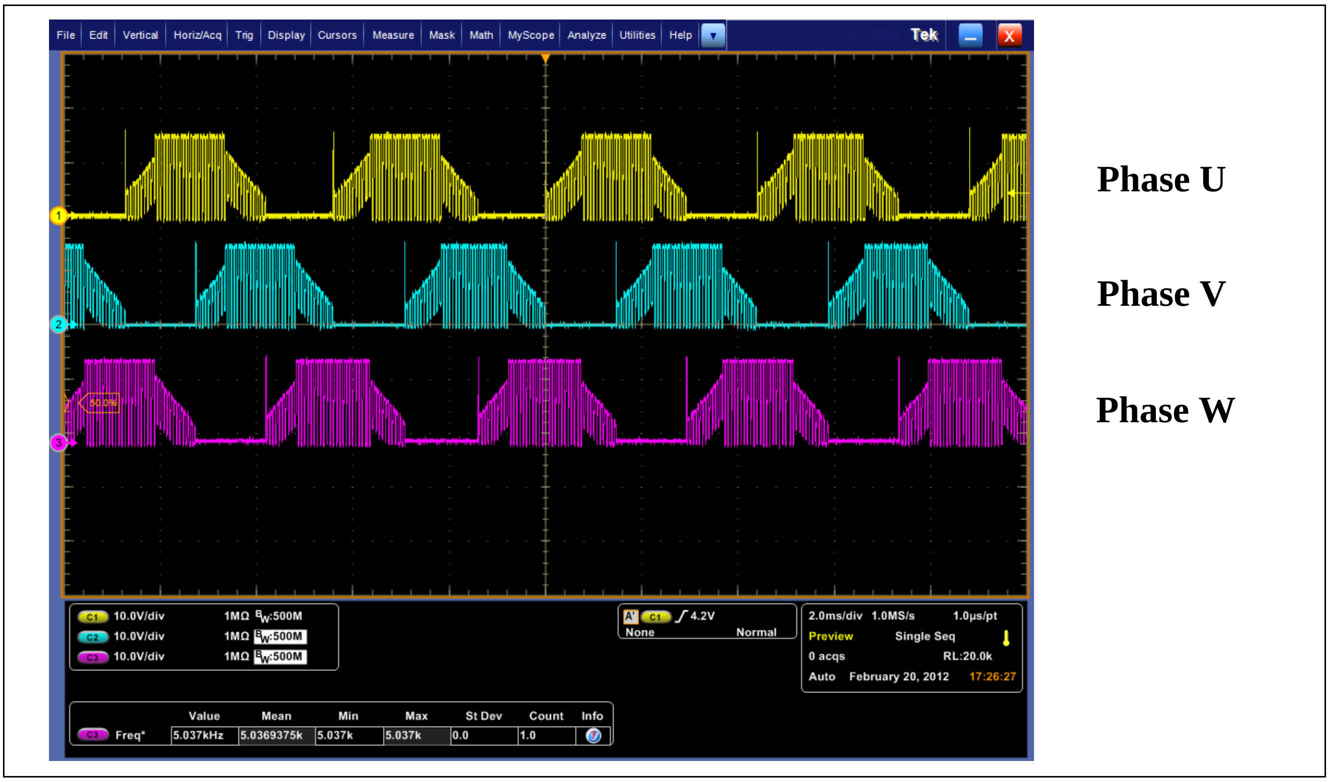


Figure 5-3 Three Phase BEMF Signal

6. Reference

Application Notes

REU05B0074-0100/Rev 1.00 Six-Step Trapezoidal Control of a BLDC Motor Using Hall Sensors

Hardware Manual

RX62T Group, Hardware Manual Rev. 1.3

(Use the latest version on the home page: http://www.renesas.com)

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Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	Jun.01.12	—	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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