

RX62T

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120-degree Trapezoidal-wave with Hall Sensor

July 01, 2012

Abstract

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

Target Device

RX62T

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1. Introduction

The 6-step method is one of the simplest methods for driving 3-phase BLDC motors. It is also known as 120-Degree trapezoidal, since it drives each winding for 120-degrees of the electrical rotation and leaves the winding un-driven for 60 degrees.

1.1 System Configuration

Target board is RX62T Evaluation Board designed by Renesas Electronics Taiwan. We use E1 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, 120-degree trapezoidal control with hall sensor is applied. Table 1-1 lists the jumper setting for the hall signals input. Table 1-2 lists the jumper setting for the CPU mode selection.

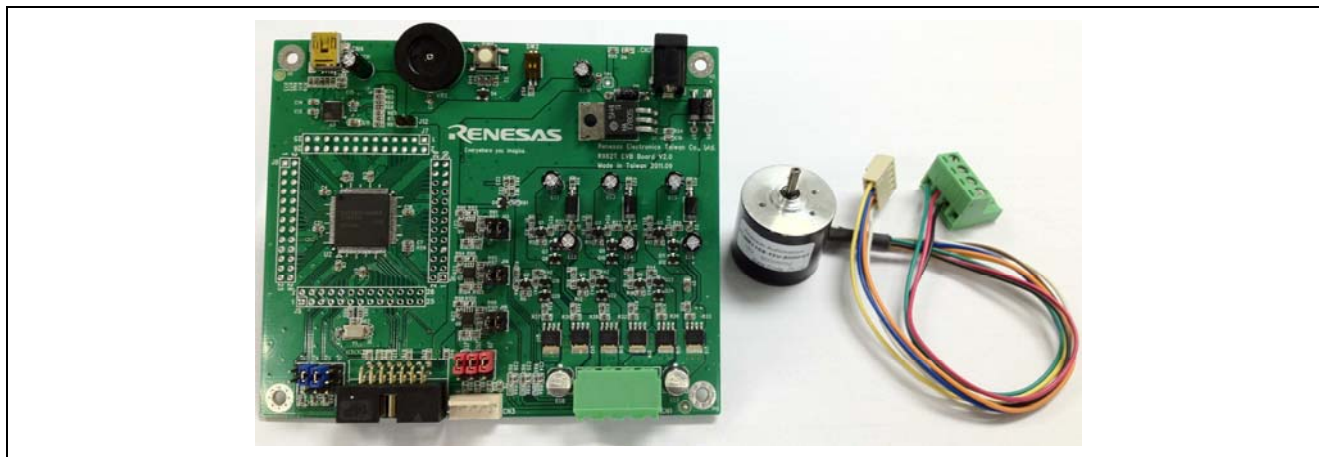


Figure 1-1 System Configuration

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

1.2 Block Diagram

MTU3 module is mainly used in this example. Ch3 and ch4 are used for PWM output, which mode setting are reset-synchronized mode. Ch6 is used for calculating rotational speed. Ch1 is an auxiliary counter for 1ms and 2ms timing. Three GPIO connect with three hall sensor input signal. ADC receives VR value as a speed command to control rotational speed.

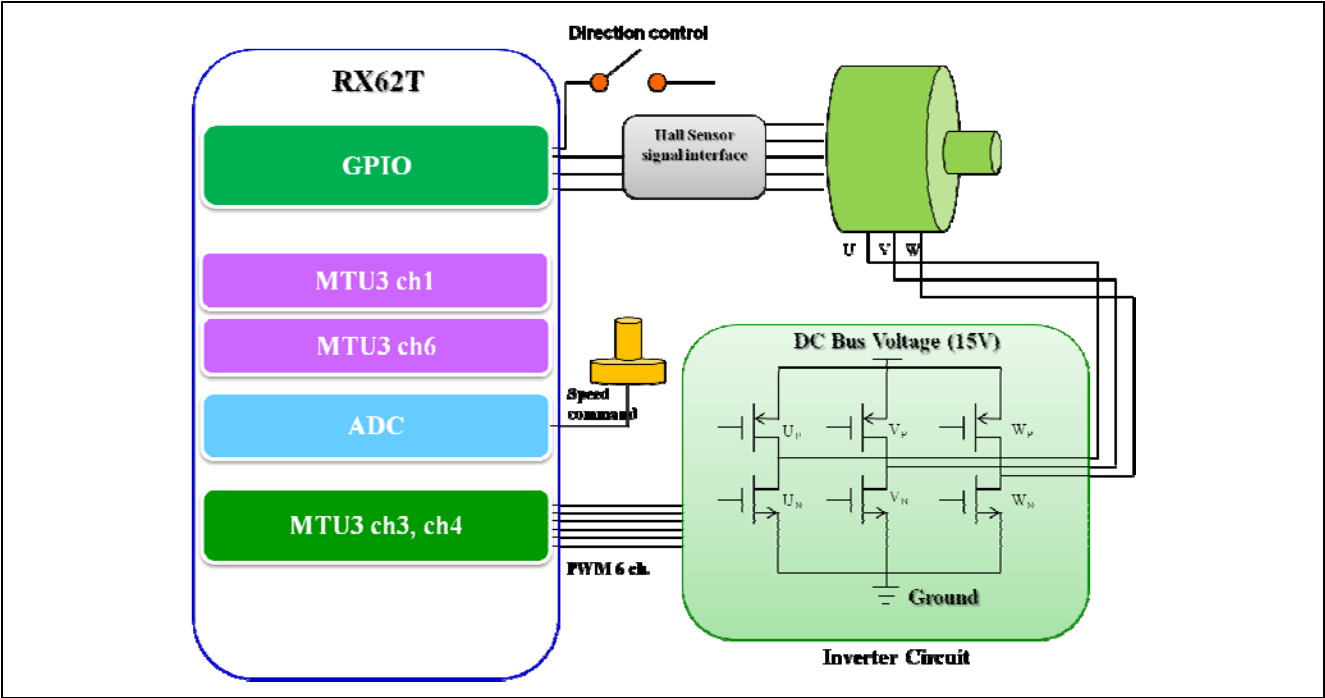


Figure 1-2 System Block Diagram

1.3 Controlling Phase Voltage

The basic voltage control for the three windings of the motor is performed using Phase-Width Modulation (PWM). In chapter 1.2, we showed how we will connect the microcontroller to the power inverter stage to control the gates of the MOSFETs. In effect, the PWM duty cycle controls the voltage at the motors terminal. There are various modulation methods used in today’s inverter drives. Typically modulation techniques are Upper modulation, Lower Modulation, rotating Modulation, or Balanced Modulation. For this application note we will be showing Upper modulation only. Figure 1-3 shows the basic upper modulation waveforms. Note that in this method, only the “P” or upper MOSFETs are modulated.

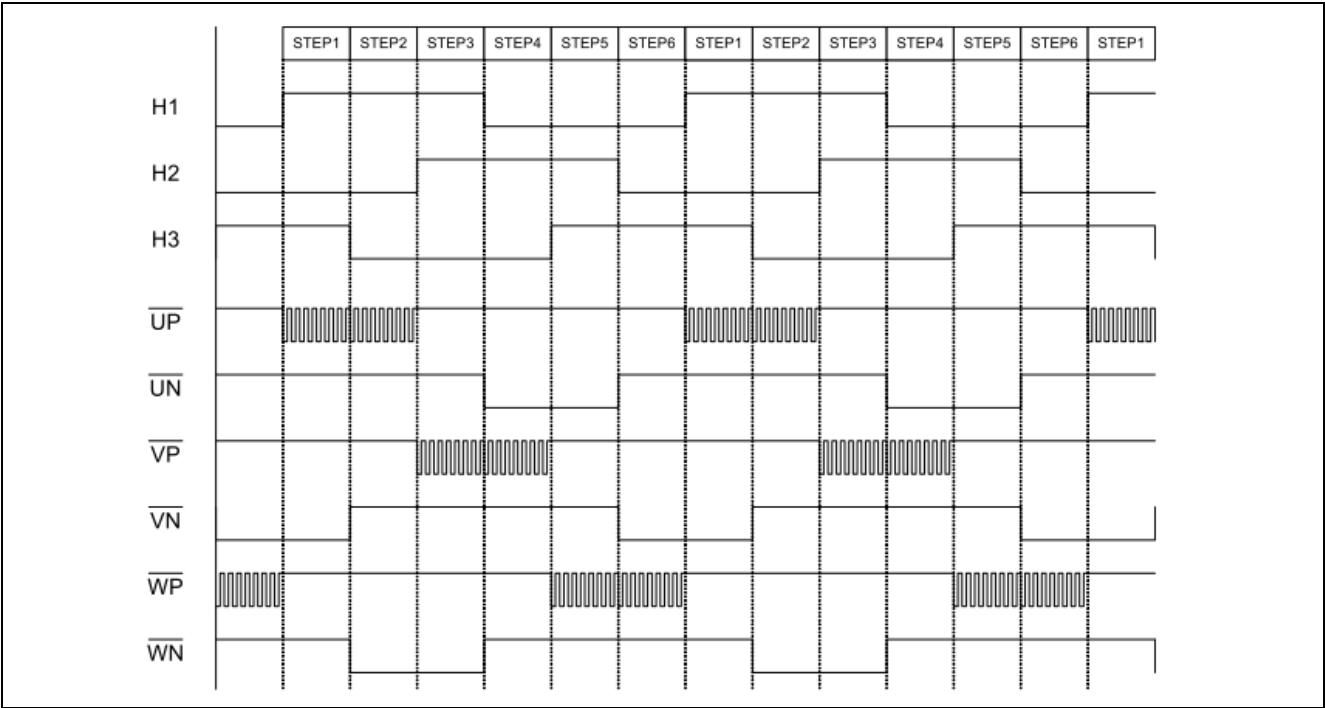


Figure 1-3 Upper Modulation (Active-low Drive)

Now we have control over the voltage on the windings (and indirectly the current) through the use of a PWM timer, but we must present these signals in the appropriate sequence to properly commutate the motor. In order to do this, we must know the rotor position. We will do this with the Hall sensors which sense the position of the rotor. They can do this because they are positioned relative to each motor phase winding in the stator coils (see Figure 1.4). Figure 1.5 shows a typical HALL cell signature. Note that the state changes every 60° for one electrical cycle. We can then read these on GPIO pins of the RX62T and decode them into a 60° rotor position. The number of electrical cycles in one mechanical rotation is based on the number of “pole-pairs” (magnetic poles) in the motor. For the figure given this is 1 pole pair, in this application note, 2 pole-pairs motor is used.

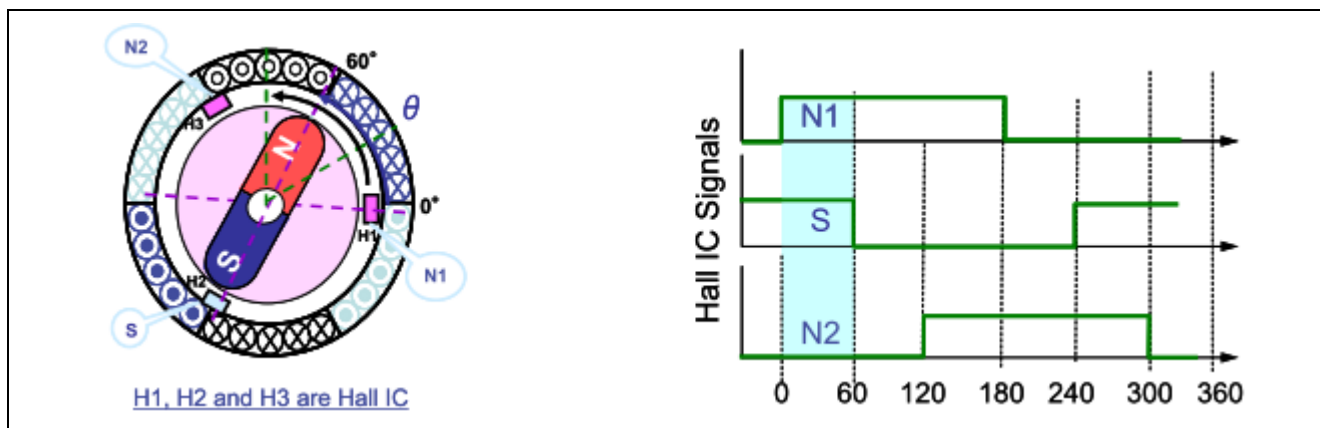


Figure 1-4 Hall Mounting and Typical HALL Signature

1.4 Commutating

So now we can control the voltage, we know where the rotor is so let's put them together. A motor manufacturer's data sheet will typically tell you "...when you see this HALL signature, drive these phase windings". Figure 1-5 shows a typical commutation sequence. For this motor, when we see the HALL signature for STEP1, we drive UP and VN. The rotor will move because the torque being caused by the magnetic fields in the stator coils are being applied at the correct angle to the magnets on the rotor and they will attempt to align. When we see the Hall signature change state to indicate Step 2 we switch the drive from UP and VN to UP and WN, and the rotor will continue to move. This will continue for the entire cycle until we are back at Step one and the process repeats. This is how we commutate the motor;

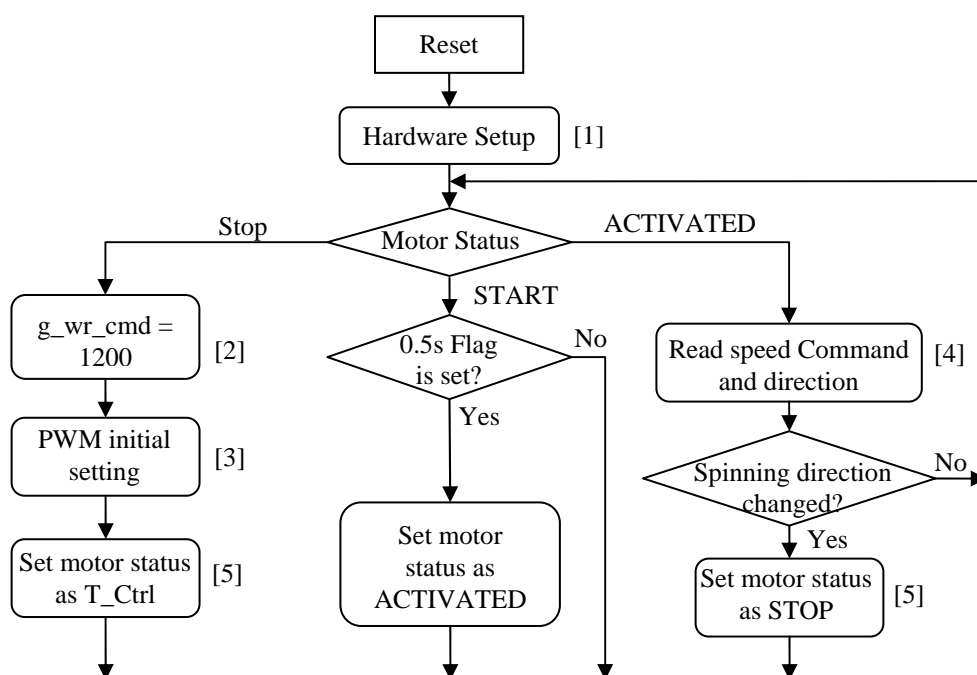
■ = Transistor Active

Step	Up	Vp	Wp	
1	■	■	■	
	■	■	■	
2	■	■	■	
	■	■	■	
3	■	■	■	
	■	■	■	
4	■	■	■	
	■	■	■	
5	■	■	■	
	■	■	■	
6	■	■	■	
	■	■	■	

Figure 1-5 Typical Commutation Sequence

2. Programming

Chapter 2 is going to show how program is designed in this application note. Figure 2-1 shows the main routine that describes how program is executed. The carrier frequency of this sample code is 15 KHz, which stands for one PWM duty cycle will be calculated 15K times in one second, each interrupt procedure is shown in Figure 2-2. The maximum duty and minimum duty of the PWM in this example are limited at 80% and 10% respectively. The limitation of PWM duty depends on each motor's specification. Figure 2-4 and 2-5 show how mechanical speed in a rotating motor is measured.



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, see Figure 2-3. Besides, read switch value to control motor spinning direction. Speed command can be operated only in motor status as ACTIVATED.
- [5] Change motor status according to each function.

Figure 2-1 Main Control Procedure

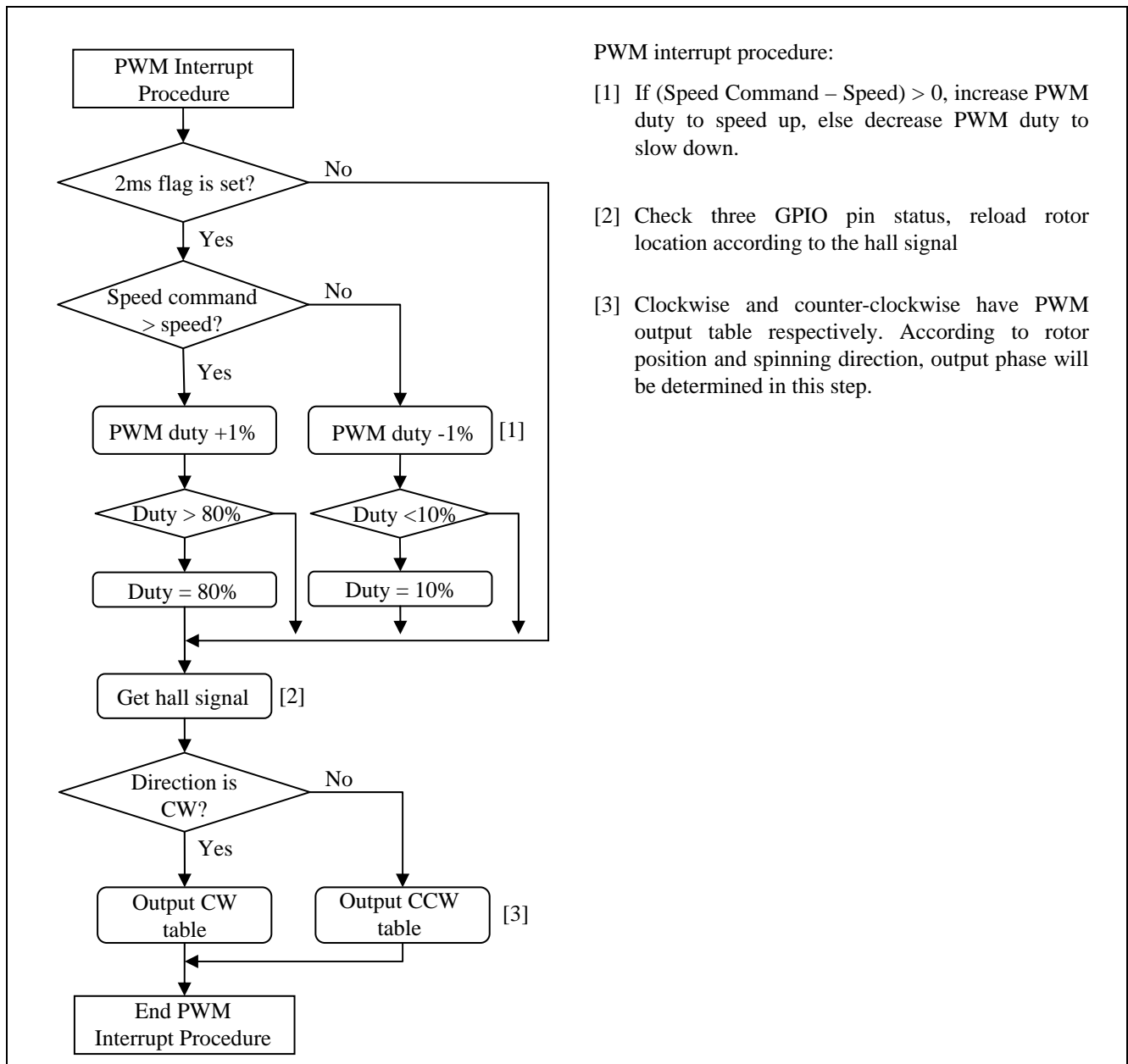


Figure 2-2 MTU3 Ch3 and Ch4 PWM Duty Calculation Procedure

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, then the result will be stored in buf1, and others saved value will be shifted in sequence. Four variables will be summed up and divided by 4, which used as speed command.

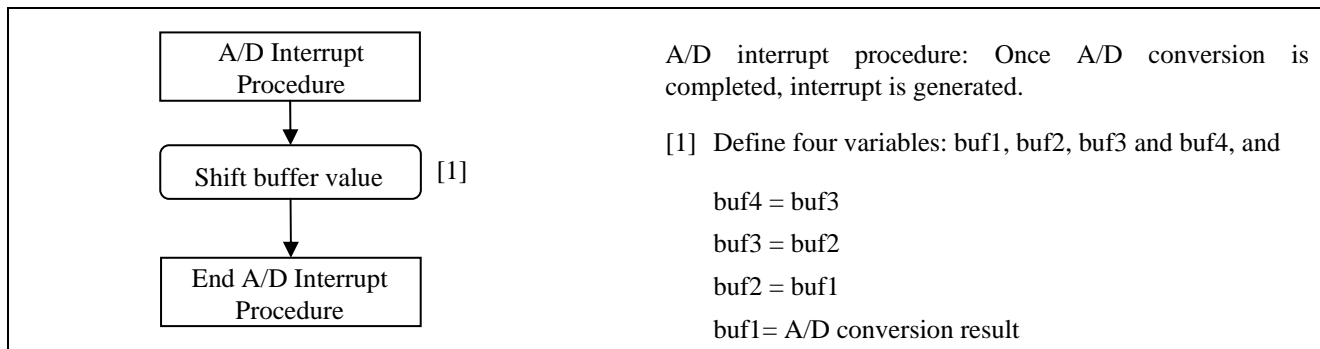


Figure 2-3 Procedure of Saving A/D Conversion Result

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 2-4, 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 2-5.

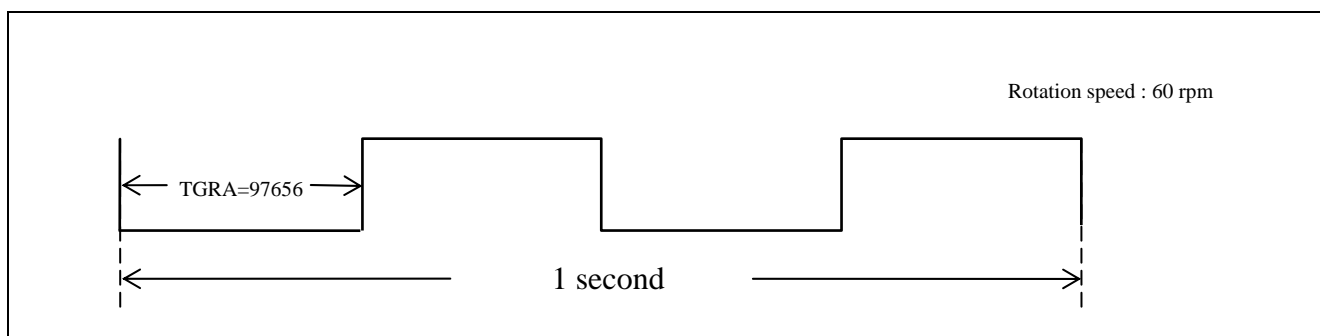


Figure 2-4 Hall Signal of 2 Pole-pairs' Motor for One Revolution

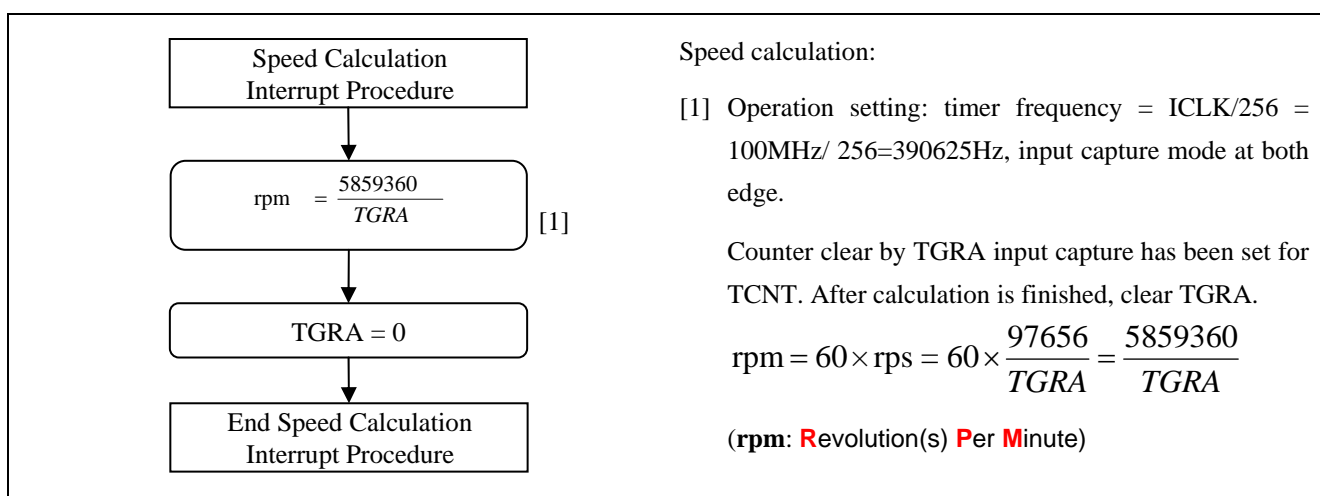


Figure 2-5 Motor Speed Calculation Procedure

3. Implementation and Testing

The specification of BLDC motor is shown in Figure 3-1 and Figure 3-2. The model number of target motor is BLWR110S-15V-8000, maximum speed can up to 8000 rpm, and in this experimental result, we can drive target motor up to 8000 rpm under PWM duty is 80%, the minimum speed of this motor without any loading is 300 rpm. PHASE A, PHASE B and PHASE C stand for U, V and W respectively.

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

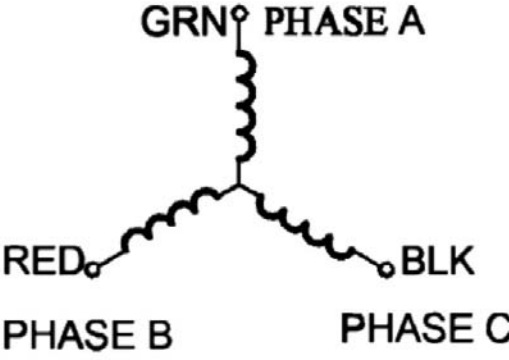


Figure 3-1 U, V, and W Description of BLWR110S

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

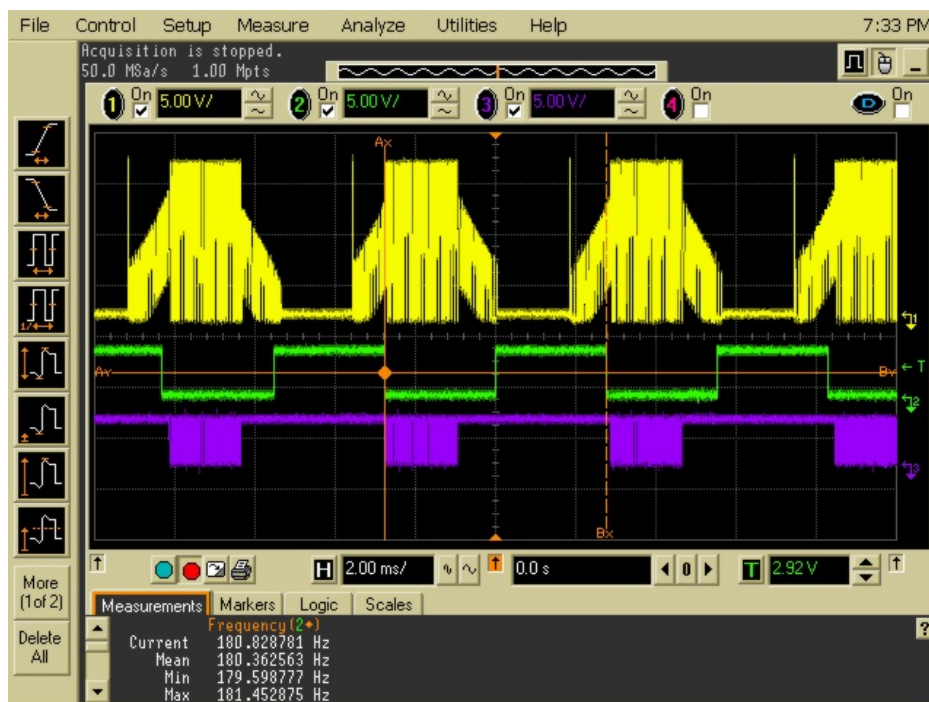
Figure 3-2 BLWR110S Specification

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

Item	Value	Unit
CPU loading	1.42	%
Max. Speed	8000	rpm
Min. Speed	300	rpm
Timer Used	4	channel
Input BUS voltage	15	V

Table 3-1 Capability of RX62T Evaluation Board

Figure 3-3 shows the relationship between Hall A and U back Electromotive Force (EMF) signal. As you can see, U_p PWM chopping period is outputted for 120-degree.



Phase U BEMF

Hall A

U_P Phase PWM

Figure 3-3 BEMF and Hall Signal

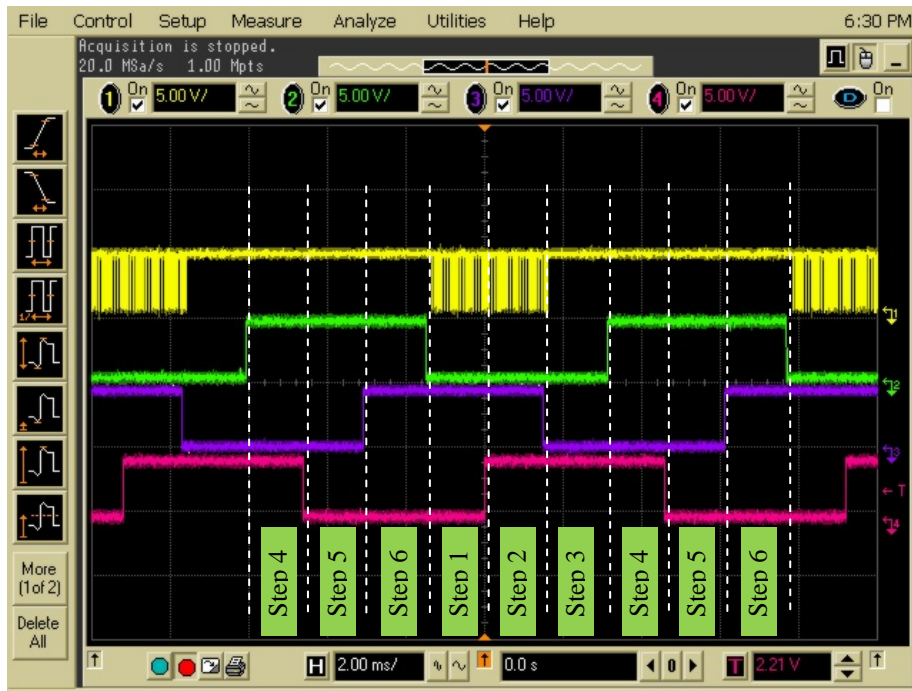
Figure 3-5 shows three hall sensor signals feedback to RX62T. While power is turning on, rotor's location is detected by three hall sensor. According to each phase, PWM is outputted that depends on look-up table which shows from the code piece in Figure 3-4. We have defined the steps in such a manner as to provide a direction look-up into the drive tables (i.e. STEP1 through STEP6 equal 1 through 6 respectively).

```

/* switch table for pwm output */
const unsigned char Output_CW[8] =
{
    /* WF VF UF */
    0xD8, /* output disable */
    0xDB, /* STEP 1 */
    0xDD, /* STEP 2 */
    0xD9, /* STEP 3 */
    0xDE, /* STEP 4 */
    0xDA, /* STEP 5 */
    0xDC, /* STEP 6 */
    0xD8, /* output disable */
};

```

Figure 3-4 Pin Drive Look-up Tables



U_P Phase PWM

Hall A

Hall B

Hall C

Figure 3-5 6-step PWM Signals (Active-low)

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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.

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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.

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