

# RL78/G14

RESH-OS-MC-20001

Rev.1.00

Nov 03, 2011

## Power Tool 120 deg. Reference Development

### Introduction

This document will provide an overview of power tool 120 degree reference development. This solution is based on Renesas Electronics' next-generation MCU (RL78 family), which combines advanced features from both the 78K and R8C families. Same as mainstream power tool products in market, BLDC control is used in this solution.

### Target Device

RL78/G14 Group

### Contents

1. Overview .....	2
2. System Diagram.....	3
3. Configuration of R5F104BE .....	4
4. Control theory.....	9
5. Hardware structure.....	13
6. Hardware and test data.....	19
7. Software flowchart.....	22
APPENDIX .....	25

## 1. Overview

### 1.1 Overview

120 degree control method are widely used in power tool controller, this kind of control mode not only include the torque variation caused by phase change, but also include the torque variation caused by the step performance caused by the control theory itself. This project adopts new method to overcome the torque variation on the basis of 120 control mode.

The RL78 Family is Renesas Electronics' next-generation microcontroller family combining advanced features from both the 78K and R8C families to deliver low power consumption and high performance. As one member of RL78 family, RL78/G14 achieves reduced system power consumption overall, and supports multifunctional consumer and industrial applications without requiring additional external components. Since there is built-in three-phase PWM output timer and two-phase encoder timer: Motor control, it is suitable to be used for Brushless DC motor control.

RL78/G14 is used to develop the 120 degree control method for the power tool controller. The main functions are list below:

- 120 degree sinusoidal wave control;
- Close-loop control of current;
- Three-step speed control;
- Over current protection;
- Thermal protection;

### 1.2 Electrical Specifications

Size:	50mm(L)*46.8mm(W)
Storage Environment:	-20 ~ 85 °C , 40% ~ 95% RH
Operation Environment:	0 ~ 70 °C , 40% ~ 95% RH
Rated Voltage:	DC 14V
Rated Current:	3.5A
Rated Power:	50W
Speed:	High level: 0~2400 RPM
	Middle level: 0~1800 RPM
	Low level: 0~1100 RPM

## 2. System Diagram

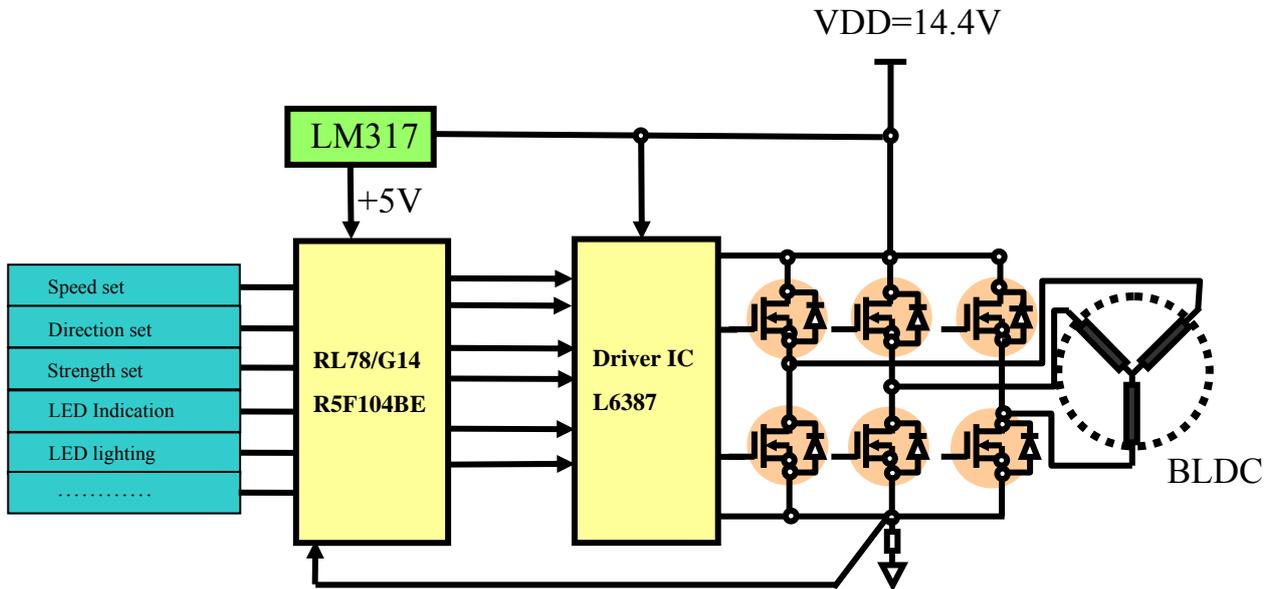


Figure 2-1 120 degree control system diagram

### 3. Configuration of R5F104BE

#### 3.1 Pin of R5F104BE

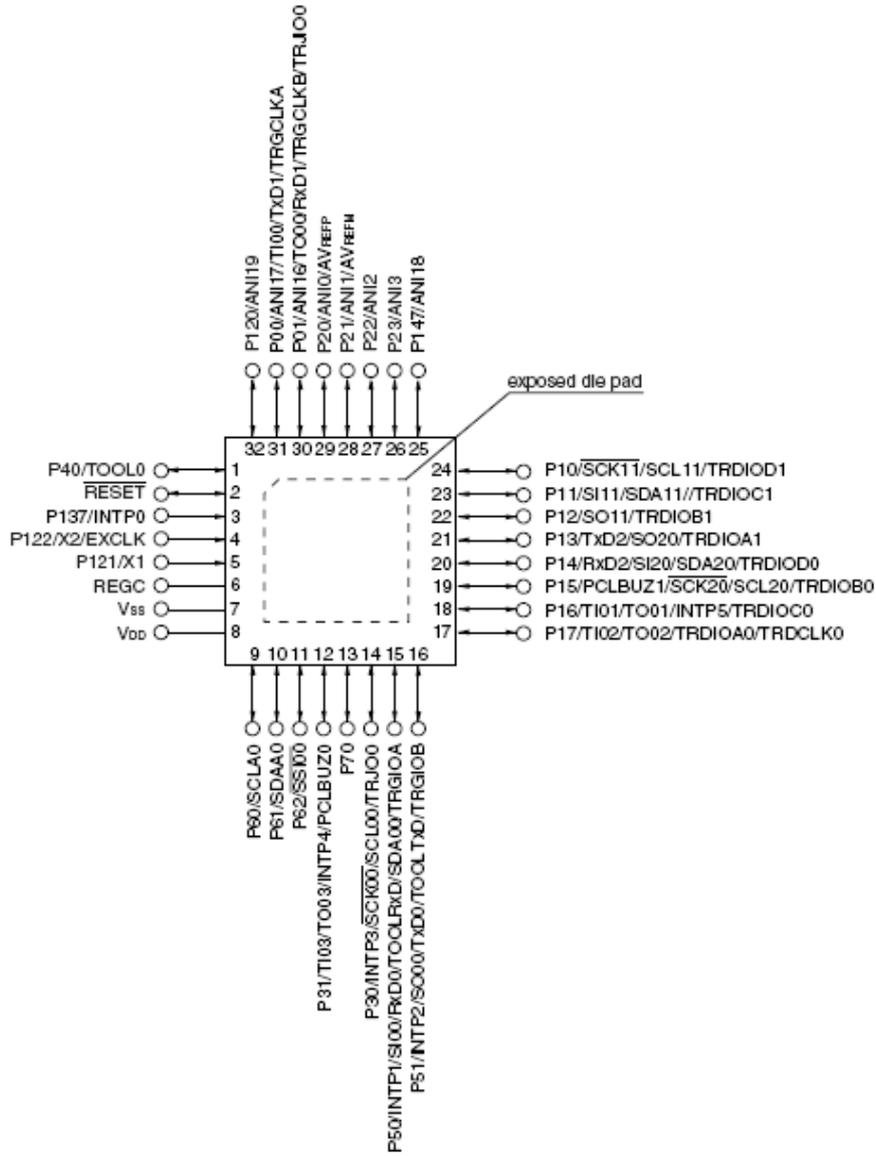


Figure 3-1 Pin of R5F104BE

3.2 Structure of R5F104BE

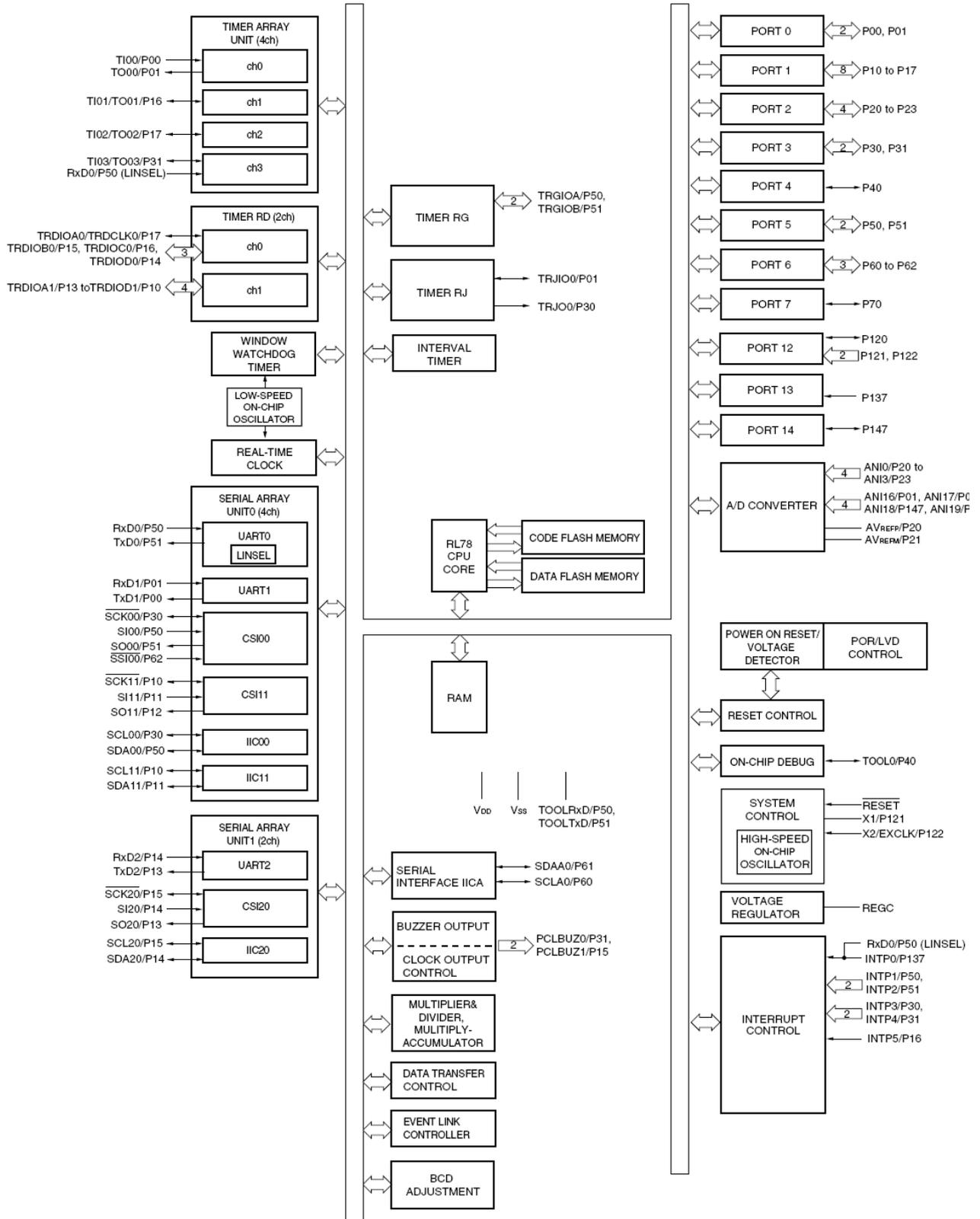


Figure 3-2 Structure of R5F104BE

3.3 Function list of R5F104xx

Table 3-1 Function List

Item		R5F104Ax	R5F104Bx	R5F104Cx	R5F104Ex																														
Pin Count		30	32	36	40																														
Internal memory	Flash memory (KB)	16 to 64	16 to 64	16 to 64	16 to 64																														
	RAM (KB)	2.5 to 5.5	2.5 to 5.5	2.5 to 5.5	2.5 to 5.5																														
	Data Flash (KB)	4	4	4	4																														
Memory Space		1MB																																	
Main system Clock (Oscillation frequency)	High-speed system clock	X1 (crystal/ceramic) oscillation, external main system clock input (EXCLK) 1 to 20 MHz: VDD = 2.7 to 5.5 V, 1 to 8 MHz: VDD = 1.8 to 2.7 V, 1 to 4 MHz: VDD = 1.6 to 1.8 V																																	
	Internal high-speed oscillation clock	Internal oscillation 64 MHz/48 MHz/32 MHz/24 MHz/16 MHz/12 MHz/8 MHz/4 MHz/1 MHz (TYP.)																																	
Internal low-speed oscillation clock (For WDT)		Internal oscillation (Watchdog timer, Real-time clock, Interval timer clock) 15 kHz (TYP.): VDD = 1.6 to 5.5 V																																	
General-purpose register		8 bits . 32 registers (8 bits . 8 registers . 4 banks)																																	
Minimum instruction execution time		0.03125 μs (Internal high-speed oscillation clock: fIH = 32 MHz operation)																																	
		0.05 μs (High-speed system clock: fMX = 20 MHz operation)																																	
		30.5 μs (Subsystem clock: fSUB = 32.768 kHz operation)																																	
Instruction set		<ul style="list-style-type: none"> <li>• 8-bit operation, 16-bit operation</li> <li>• Multiplication (8 bits × 8 bits, 16 bits × 16 bits), Division (16 bits ÷ 16 bits, 32 bits ÷ 32 bits)</li> <li>• Product-sum operation (16 bits × 16 bits + 32 bits)</li> <li>• Bit manipulation (Set, reset, test, and Boolean operation), etc.</li> </ul>																																	
I/O port		<table border="1"> <thead> <tr> <th></th> <th>30-pin products</th> <th>32-pin products</th> <th>36-pin products</th> <th>40-pin products</th> </tr> </thead> <tbody> <tr> <td>Total</td> <td>26</td> <td>28</td> <td>32</td> <td>36</td> </tr> <tr> <td>CMOS I/O</td> <td>21</td> <td>22</td> <td>26</td> <td>28</td> </tr> <tr> <td>CMOS input</td> <td>3</td> <td>3</td> <td>3</td> <td>5</td> </tr> <tr> <td>CMOS output</td> <td>-</td> <td>-</td> <td>-</td> <td>-</td> </tr> <tr> <td>N-ch open-drain I/O (6 V tolerance)</td> <td>2</td> <td>3</td> <td>3</td> <td>3</td> </tr> </tbody> </table>					30-pin products	32-pin products	36-pin products	40-pin products	Total	26	28	32	36	CMOS I/O	21	22	26	28	CMOS input	3	3	3	5	CMOS output	-	-	-	-	N-ch open-drain I/O (6 V tolerance)	2	3	3	3
	30-pin products	32-pin products	36-pin products	40-pin products																															
Total	26	28	32	36																															
CMOS I/O	21	22	26	28																															
CMOS input	3	3	3	5																															
CMOS output	-	-	-	-																															
N-ch open-drain I/O (6 V tolerance)	2	3	3	3																															

Timer <div style="border: 1px solid black; padding: 2px; width: fit-content; margin-left: 20px;">Timer outputs</div>	<ul style="list-style-type: none"> <li>• 16-bit timer: 8 channels</li> <li>• Watchdog timer: 1 channel</li> <li>• Real-time counter: 1 channel</li> <li>• Interval timer: 1 channel</li> </ul>	
A/D converter	8/10-bit resolution , 8 channels	
Serial interface	[30-pin, 32-pin products] <ul style="list-style-type: none"> <li>• CSI: 1 channel/UART: 1 channel/simplified I2C: 1 channel</li> <li>• CSI: 1 channel/UART: 1 channel/simplified I2C: 1 channel</li> <li>• CSI: 1 channel/UART (UART supporting LIN-bus): 1 channel/simplified I2C: 1 channel</li> </ul> [36-pin, 40-pin products] <ul style="list-style-type: none"> <li>• CSI: 1 channel/UART: 1 channel/simplified I2C: 1 channel</li> <li>• CSI: 1 channel/UART: 1 channel/simplified I2C: 1 channel</li> <li>• CSI: 2 channels/UART (UART supporting LIN-bus): 1 channel/simplified I2C: 2 channels</li> </ul>	
Multiplier/divider	<ul style="list-style-type: none"> <li>• 16 bits × 16 bits = 32 bits (Unsigned or signed)</li> <li>• 16 bits ÷ 16 bits = 16 bits, 32 bits ÷ 32 bits = 32 bits (Unsigned)</li> <li>• 16 bits × 16 bits + 32 bits = 32 bits (Unsigned or signed)</li> </ul>	
Data transfer controller (DTC)	29 sources	
Vector interrupt source	Internal	24
	External	7
Reset	<ul style="list-style-type: none"> <li>• Reset by RESET pin</li> <li>• Internal reset by watchdog timer</li> <li>• Internal reset by power-on-reset</li> <li>• Internal reset by voltage detector</li> <li>• Internal reset by illegal instruction execution Note</li> <li>• Internal reset by RAM parity error</li> <li>• Internal reset by illegal-memory access</li> </ul>	
Voltage detector	When voltage rises: between 1.63 V and 3.98 V (14 stages) When voltage drops: between 1.67 V and 4.06 V (14 stages)	
Power supply voltage	VDD = 1.6 to 5.5 V	
Operating ambient temperature	TA = -40 to +85 C	

## 3.4 Pin function of R5F104BE

Table 3-2 Pin Function Configuration

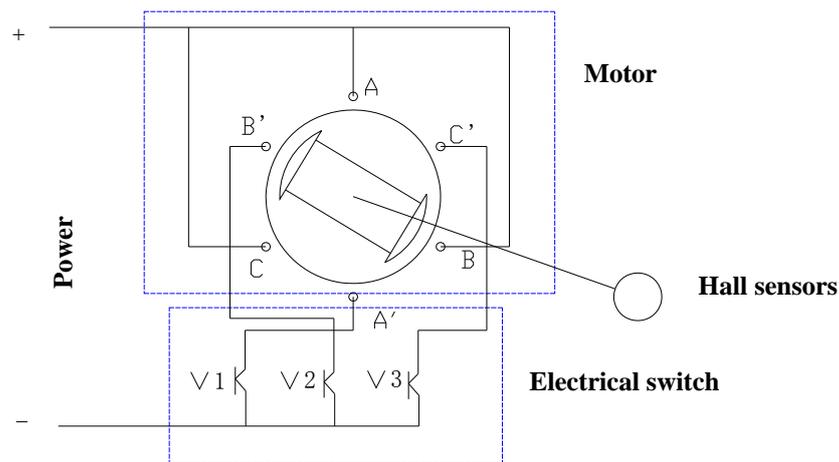
Pin NO.	Pin name	Pin Function	Note
1	P40/TOOL0	Program interface	Input/Output
2	RESET	Reset	Input
3	P137/INTP0	AD analog input	over-current protection
4	P122/X2/EXCLK	Not used	
5	P121/X1	Not used	
6	REGC	Group via cap	
7	VSS	Group	
8	VDD	Power	
9	P60/SCLA0	Direction control	Input
10	P61/SDAA0	Strength indication 3	output
11	P62/SSI00	Strength indication 2	output
12	P31/TI03/TO03/INTP4/PCLBUZ0	Strength indication 1	output
13	P70	unused	
14	P30/INTP3/SCK00/SCL00/TRJ00	HALL W	Input
15	P50/INTP1/SI00/RxD0/TOOLRxD/SDA00/TRGIOA	HALL U	Input
16	P51/INTP2/SO00/TxD0/TOOLTxD/TRGIOB	HALL V	Input
17	P17/TI02/TO02/TRDIOA0/TRDCLK0	LED Lighting	For lighting
18	P16/TI01/TO01/INTP5/TRDIOC0	Tact Switch	Input
19	P15/PCLBUZ1/SCK20/SCL20/TRDIOB0	Drive of U High	PWM output
20	P14/RxD2/SI20/SDA20/TRDIOD0	Drive of U Low	PWM output
21	P13/TxD2/SO20/TRDIOA1	Drive of V High	PWM output
22	P12/SO11/TRDIOB1	Drive of W High	PWM output
23	P11/SI11/SDA11/TRDIOC1	Drive of V Low	PWM output
24	P10/SCK11/SCL11/TRDIOD1	Drive of W Low	PWM output
25	P147/ANI18	AD analog input	Speed control
26	P23/ANI3	AD analog input	Over-current protection
27	P22/ANI2	AD analog input	Thermal protection
28	P21/ANI1/AVREFM	Not used	
29	P20/ANI0/AVREFP	AD power reference	
30	P01/ANI16/TO00/RxD1/TRGCLKB/TRJIO0	Failure indication	Output
31	P00/ANI17/TI00/TxD1/TRGCLKA	Tact switch	
32	P120/ANI19	Battery check	

## 4. Control theory

### 4.1 Basic control theory of BLDC

The motors used in most power tool are Brushless DC motor, which the rated power is commonly very low. External rotor structure is usually adopted to drive the power tool directly, but the power is very low because of its low rated speed. Which cause the motor much bigger than other types of motor which have the same power value.

BLDC motor consists of motor, position sensor and electrical circuit. The stator is often made of several phases (such as 3 phases, four phases and five phases etc.), the rotor is consists of permanent magnet which arranged with different pole pairs. Figure 4-1 shows a three phases, two poles BLDC motor.

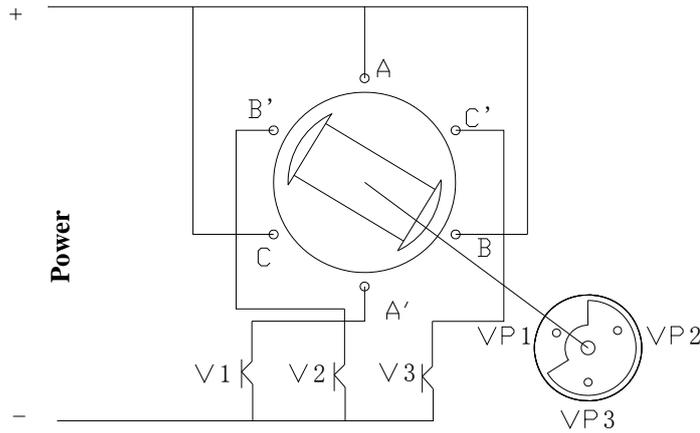


**Figure 4-1 Structure of three phases, two poles BLDC motor**

Three stator coils are connected with correspondent power devices in electrical circuit, A, B, C phase coils each connected with power switch V1, V2, V3. Position sensors are used to detect the rotor position.

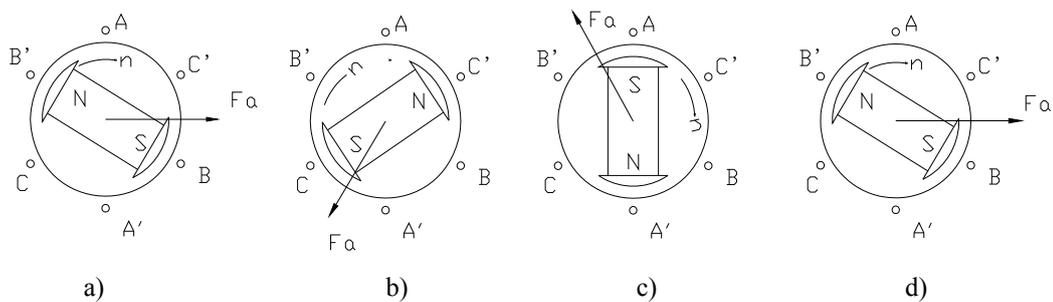
When one of the stator coils are power on, the current will cause torque by the interaction with magnetic field caused by the rotor permanent magnetism, and the torque will cause the rotor running, the rotor position will be converted to electrical signal by position sensors to control the electrical switches, thus make the each coils of stator are switched on sequentially, the stator phase current will also change sequentially according to the position of rotor. Because of the power on sequence of electrical switches are synchronous with the rotor angle, thus cause the same effect of mechanical phase change.

Figure 4-2 shows the theory diagram of the half-bridge control of three phases, two poles BLDC motor. Photo-electric devices are use as the position sensors. The power logic unit consists of three power MOSFET. The control theory will be discussed below according to the half-bridge control.



**Figure 4-2 Three phase brushless motor**

The discrepancy of space position of three photo-electrical devices VP1、VP2 and VP3 are 120 degree each. Via the function of photo-electrical, the rotor position can be achieved.



**Figure 4-3 Commutation sequence and the rotation of magnetic field**

The rotor position of figure 4-2 is same as that of figure 4-3a). at this position, the power MOSFET V1 is switched on and the current flows into coil A-A', the torque caused by the interaction between the coil current and rotor magnetic will make the rotor rotate as the direction shown in figure 4-3b). when the rotor locate at the position as in figure 4-3b), the power MOSFET V1 will be switched off and V2 will be switched on, the current will be changed form coil A-A' to B-B', and the rotor will continue to rotate as the direction shown in figure 4-3b). When the rotor reaches the position shown as in figure 4-3c), the power MOSFET V2 will be switched off and V3 will be switched on, the current will be flowed through C-C', thus the rotor will continue rotate to the position shown in figure 4-3a).

With the change of position sensor signal, the stator coil will be switched on and off sequentially, then the phase current will be changed sequentially. During the phase change period, the rotating magnetic field generated by the coils of the stator is not continuous. This kind of rotating magnetic field has three state in 360 degree range, each state lasts 120 degree. The relationship between each coil and rotor magnetic field are showed in figure 4-3. Figure 4-3a) is the first state, Fa is the magnetic force generated by coil A-A', then the interaction between the coil current and rotor magnetic field will make the rotor rotate clockwise. After 120 degree, the rotor will be in the second state, the coil A-A' will be switched off and coil B-B' will be switched on, the magnetic field generated by stator coil rotate 120 degree range shown as in figure 4-3b), and the motor rotor continue to rotate clockwise. After another

120 degree, the third state. the coil B-B' will be switched off and C-C' will be switched on, the magnetic field generated by stator coil rotate another 120 degree, shown in figure 4-3c ). It will make the rotor rotate 120 degree and then get the initial position. Figure 4-4 shows the switch on sequence of each coil.

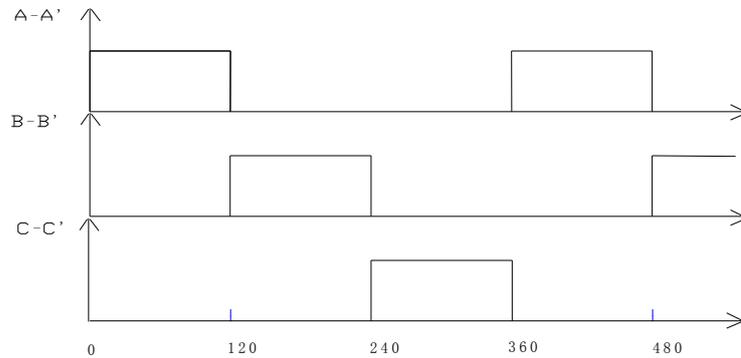


Figure 4-4 the switch on sequence of each coil

The electrical circuit of three phases, half-control bridge is simple. But the efficiency of the motor is very low because the switch on time of each phase is only 1/3 of the total time. And during the control period, the variation range of torque is very high, from  $T_m/2$  to  $T_m$ . So in most circuits the three phases, full-control circuit is adopted.

### 4.2 Introduction of Three-phase, full-control theory of Y connection motor

Figure 4-5 shows a three-phase, full-control circuit, the motor is Y connection motor. VT1、VT2、VT3、VT4、VT5、VT6 are power MOSFET, used to control the current of each phase. The control methods include 120 degree control mode and 180 control mode.

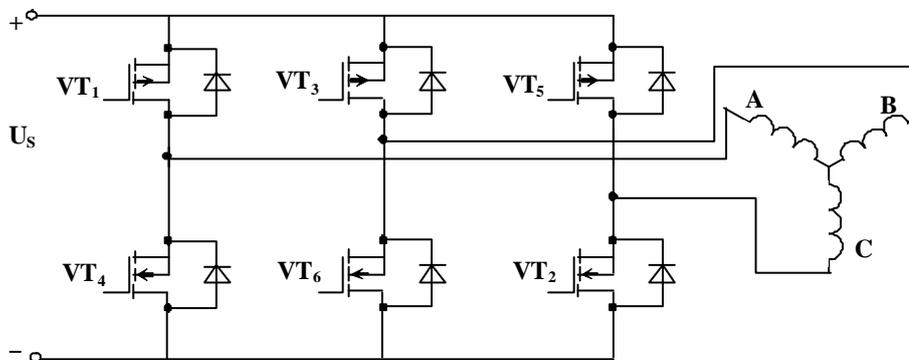
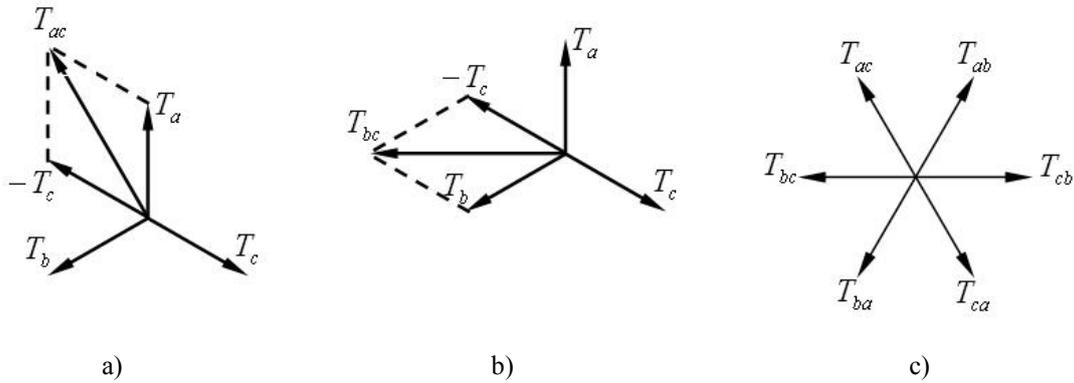


Figure 4-5 Three-phase, full-control circuit for Y connection

### 4.3 120 degree control mode

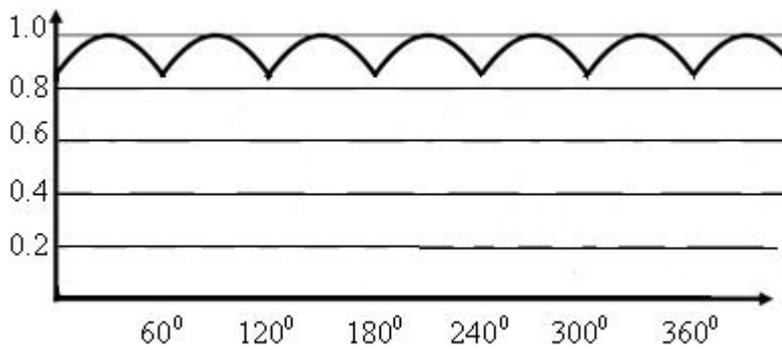
120 degree control mode means there are two power MOSFETs are switched on at each moment, one power MOSFET will be changed to another each 1/6 period, each power MOSFET will be switched on for 120 degree. The sequence of all the power MOSFETs is VT1VT2、VT2VT3、VT3VT4、VT4VT5、VT5VT6、VT6VT1、... . When VT1 and VT2 are switched on, the current flow into coil A from VT1 and out coil C from VT2, then to the power. Assume the torque is positive when the current flows into a coil A, then the torque will be negative when the current flows out one

phase, so the synthesis torque are shown in figure 4-6a), and the amplitude is  $\sqrt{3}T_a$ , the direction locates at the angular bisector of  $T_a$  and  $-T_c$ . Figure 4-6c) shows the direction of all the synthesis torque.



**Figure 4-6 The synthesis torque of 120 degree control mode**

To one BLDC motor, the synthesis torque of 120 degree control is  $\sqrt{3}$  times bigger than that of half-bridge control. The output torque are shown if figure 4-7, we can see that the variation range of the synthesis torque is between  $0.87T_m$  and  $T_m$ .



**Figure 4-7 Output torque of 120 degree control**

## 5. Hardware structure

### 5.1 Power and power detection

Figure 5-1 shows the structure of power and power detection circuit.

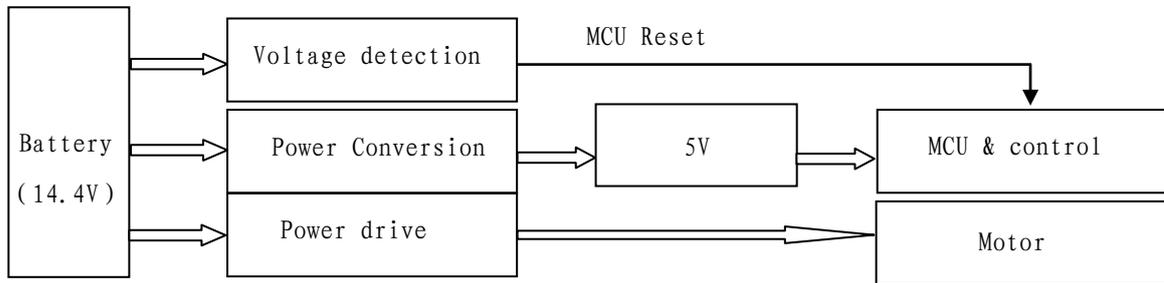


Figure 5-1 Power block diagram

#### 5.1.1 Function description

The power of power tool are supply with battery, the battery in this solution are 14.4V.

14.4V voltage is supplied to driver ICs and power MOSFETs, by controlling the duty cycle of drive signal of power MOSFET, the current will be controlled thus control the speed of the motor.

To avoid the over-discharge of the battery, the voltage of the battery need to be detected and switch off the power MOSFETs when the voltage lower than 12V to protect the battery.

5V voltage is created by LM317 from 14.4V conversion, it is used to power MCU and other logic control circuit, so it is also critical and need to be monitored.

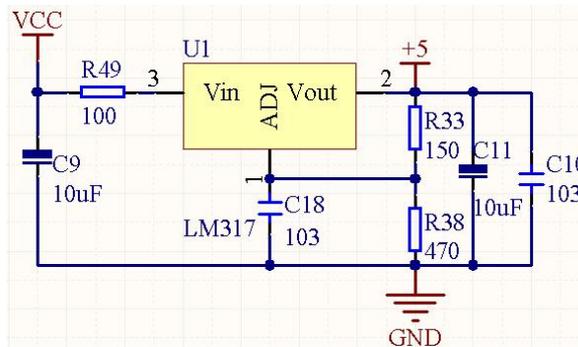
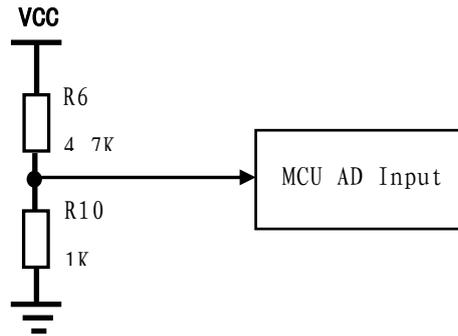


Figure 5-2 +5V creation

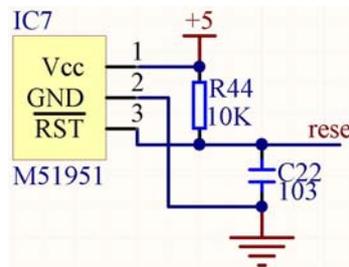
VCC in figure 5-2 is the battery power 14.4V, R49 is protection resistor, used to reduce the voltage input to LM317T, then reduce the power consumption of LM317. LM317 is a chip used to regulate voltage, its output is set to 5V.

### 5.1.2 Voltage detection circuit



**Figure 5-3 Battery voltage detection**

Since the tolerance of MCU AD analog input cannot exceed 6V while VCC normally is more than 14V, we cannot monitor VCC directly, so we use a voltage divider circuit to satisfy the tolerance. The battery voltage can be monitored by sampling the divided voltage which is input to built-in AD module of MCU, in case the battery voltage is lower than the pre-set threshold value, software will execute related behavior.

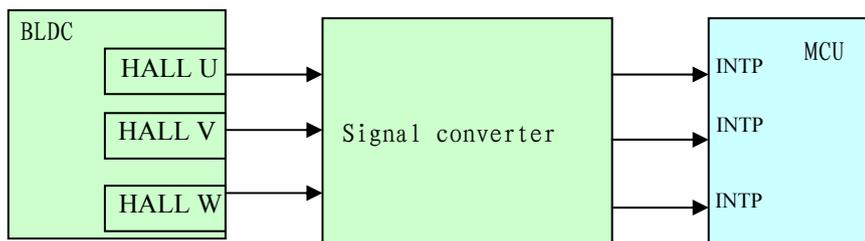


**Figure 5-4 +5V detection**

M51951 is integrated circuits designed for detecting supply voltage and resetting logic circuits such as CPUs. Normally when +5V voltage is lower than 4.2V by due to exceptional situation during system operating, M51951 will output a valid signal(low) to reset MCU.

## 5.2 HALL signal detection

The HALL signal detection module is shown as the figure below:



**Figure 5-5 Hall input block**

### 5.2.1 Function description

HALL signal detection circuit used to get the rotor position, three hall signals are input to the interrupt input interface. During 180 degree control, the speed and detailed angular also can be achieved via HALL signals.

### 5.2.2 HALL signal detection circuit

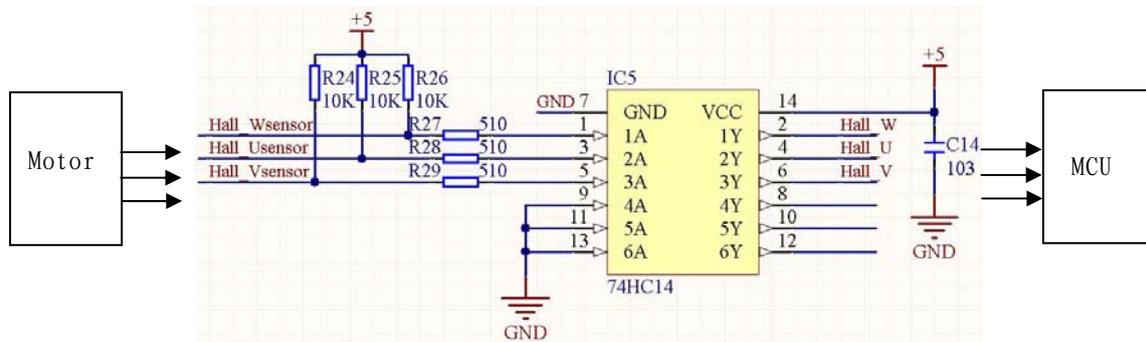


Figure 5-6 Hall input circuit

### 5.3 LED Indication

#### 5.3.1 Function description

As a part of interface between the power tool and user, LED can indicate the system operating status.

#### 5.3.2 Circuit

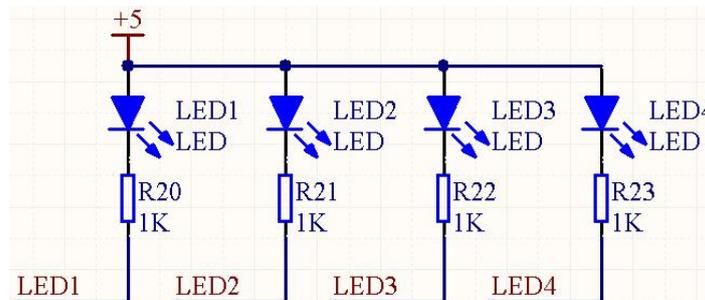


Figure 5-7 LED indication

In this application, we use 4 LEDs, LED1~LED3 are used to indicate strength level, while LED4 is used for system fault indication.

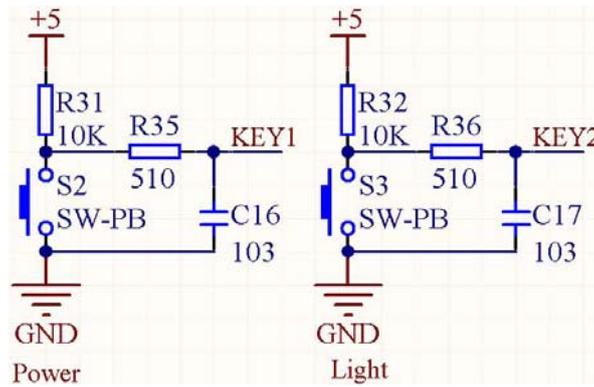
### 5.4 Switch setting

#### 5.4.1 Function description

Several switches are used for system setting, such as strength level setting, LED lighting setting and direction setting.

#### 5.4.2 Circuit

(1) strength level and LED lighting setting



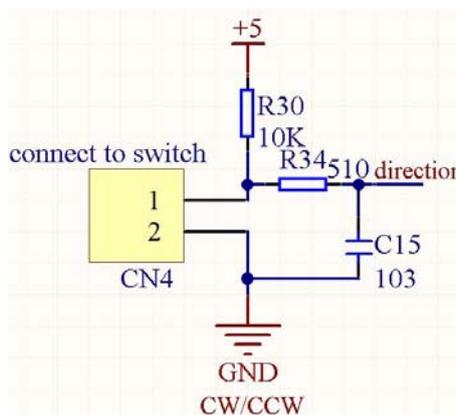
**Figure 5-8 Strength level and LED lighting control**

In this circuit, we use 2 tact switch: S2 and S3. S2 is used for strength level while S3 for LED lighting.

The strength level of the power tool is divided 3 levers: weak level, middle level and strong level, the strength level can be modified by pressing the S2.

We add white-LED lighting circuit in order to use the power tool in dark environment, the white-LED can be switch on or off by pressing S3.

(2) CW/CCW Rotation Control



**Figure 5-9 CW and CCW rotation control**

CN4 is a self-locking switch and is used to control CW/CCW rotation.

## 5.5 Power and power drive

### 5.5.1 Function description

Power drive circuit used to convert the control signal of MCU to drive signal of MOSFET, by controlling the state of each MOSFET, the current of the motor can be controlled.

The dead time of the two MOSFETs of each phase should be bigger than the time needed to switch off a MOSFET.

### 5.5.2 Circuit of power drive

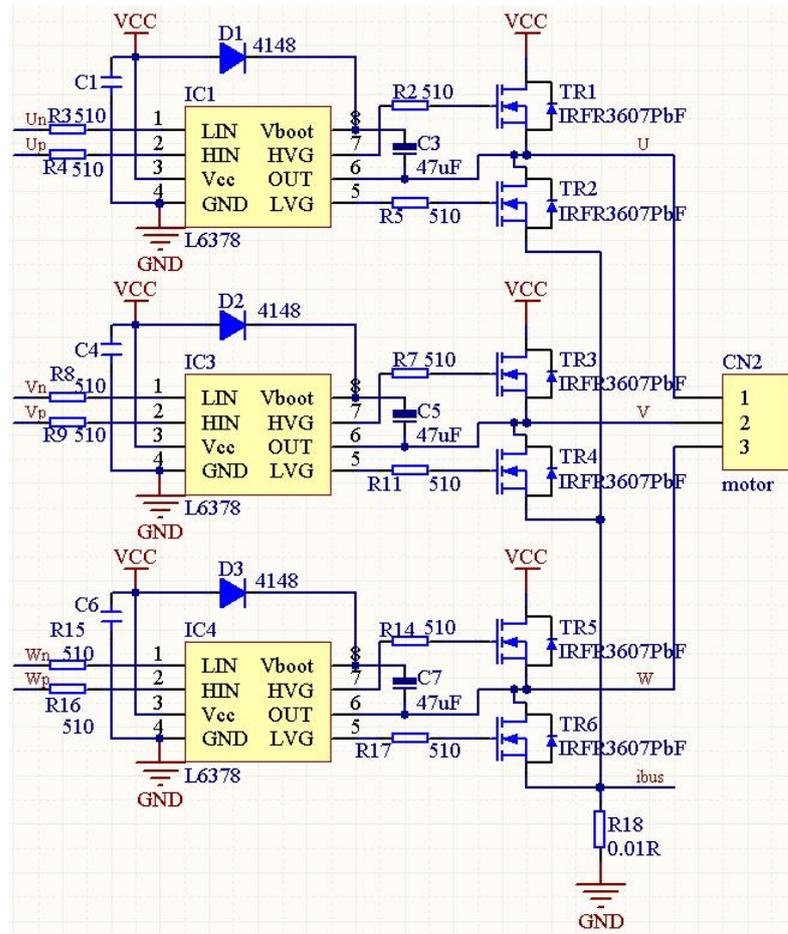


Figure 5-10 Motor driver circuit

Figure 5-10 shows the circuit of the whole 3 phase.

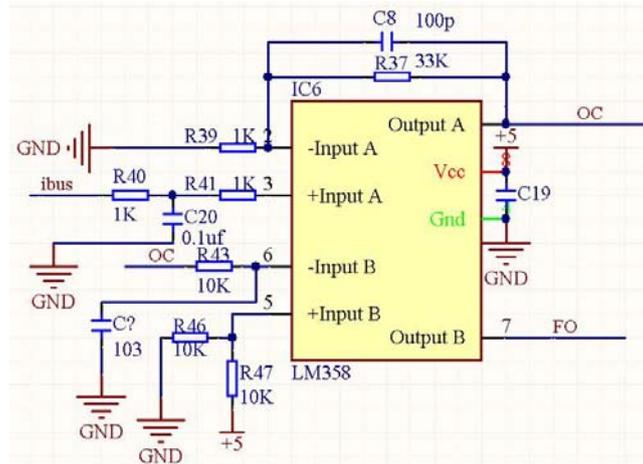
Compare to traditional circuit using discrete components for power drive, the above circuit use a integrated driver IC L6387, the circuit can make the system more reliable and reduce the components.

## 5.6 Current sampling and protection circuit

### 5.6.1 Function description

Current sampling circuit used to current control and current protection. Actual value of the current can be achieved by AD module, thus current close-loop control can be realized. Current protection can be realized by internal circuit.

### 5.6.2 Current sampling circuit



**Figure 5-11 Operational amplifier circuit**

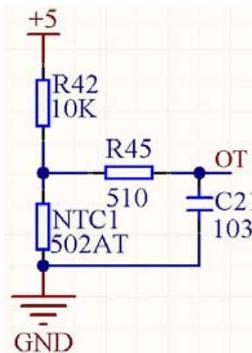
R18 on figure in part 5.5 is a current-sampling resistor, due to the amplitude of *ibus* is too small to be detected by AD module in MCU, we need to use a operational amplifier LM358 to amplify *ibus*, the circuit as showed above. LM358 is a dual operational amplifiers, we use input A to amplify *ibus*, the other amplifier input B is used to be a Comparator to compare the amplified signal *OC* with pre-set voltage.

## 5.7 Thermal protection

### 5.7.1 Function description

The current consumption probably is close to 4A while the size of PCB is small, it is necessary to implement thermal protection in circuit.

### 5.7.2 Thermal protection circuit



**Figure 5-12 Thermal protection circuit**

The figure 5-12 shows thermal protection circuit, OT is the signal which is connected to AD analog input. If the temperature of the PCB board increase, the resistance of NTC1 will decrease, thus AD module can sample the OT variation.

## 6. Hardware and test data

### 6.1 Specifications of BLDC Motor

The technical data of the motor are as follows:

Rated Voltage: 14.4V

Rated Current: 3.5A

Rated Power: 50W

Speed: High level: 0~2400 RPM Middle level: 0~1800 RPM Low level: 0~1100 RPM

The commutation logic table of the motor shown as below table :

**Table 6-1 commutation logic table**

HALL Sensors			Top			Low		
SU	SV	SW	UT	VT	WT	UL	VL	WL
0	0	1	1	0	0	0	0	1
0	1	1	1	0	0	0	1	0
1	1	1	0	0	1	0	1	0
1	1	0	0	0	1	1	0	0
1	0	0	0	1	0	1	0	0
0	0	0	0	1	0	0	0	1

### 6.2 Main Control Board



**Figure 6-1 Main board of the controller**

### 6.3 Operation method and test data

#### 6.3.1 Test outline

Following steps should be done when run a BLDC motor by using the controller:

- 1) Connect all cables to the BL motor correctly, including hall signals, phase lines and power supply.
- 2) Set correct DC +14.4V on DC power supply.
- 3) Power on the system.
- 4) Test the related value at 3 speed level with no load.

#### 6.3.2 Test result

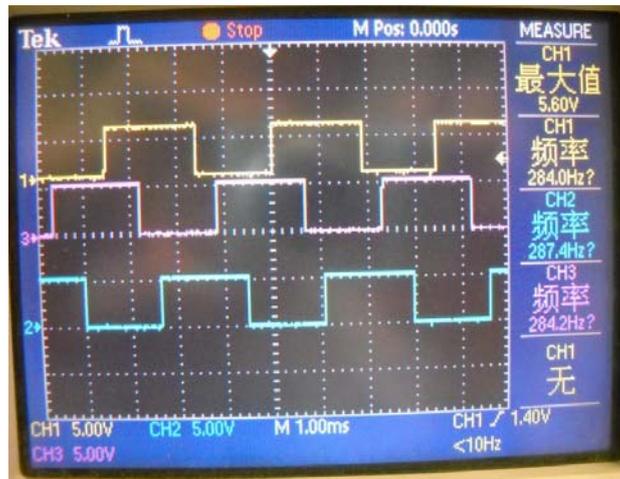


Figure 6-2 Hall signal at low speed

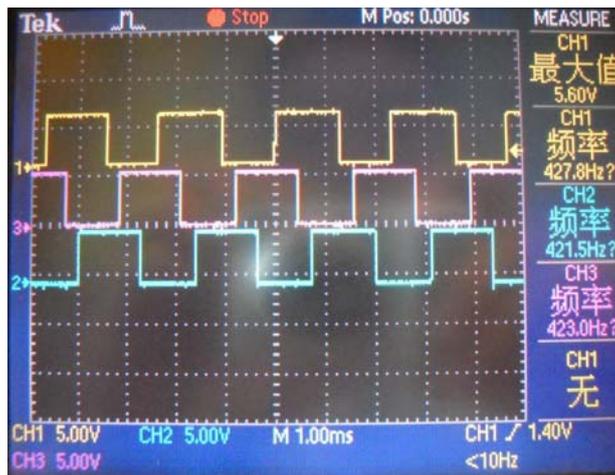


Figure 6-3 Hall signal at mid speed

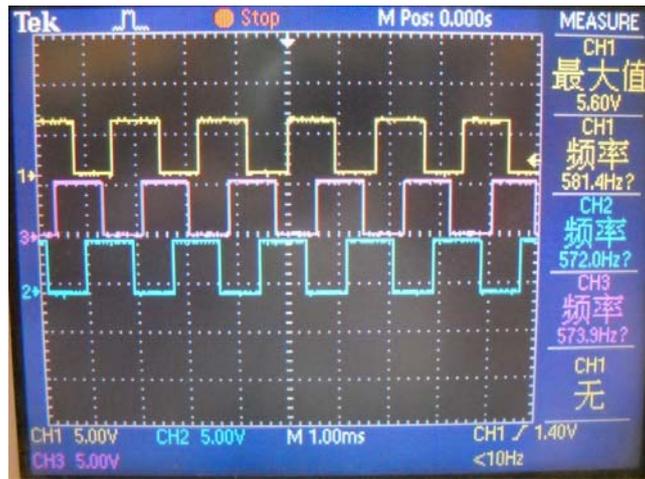


Figure 6-4 Hall signal at high speed



Figure 6-5 Phase driver high side signal

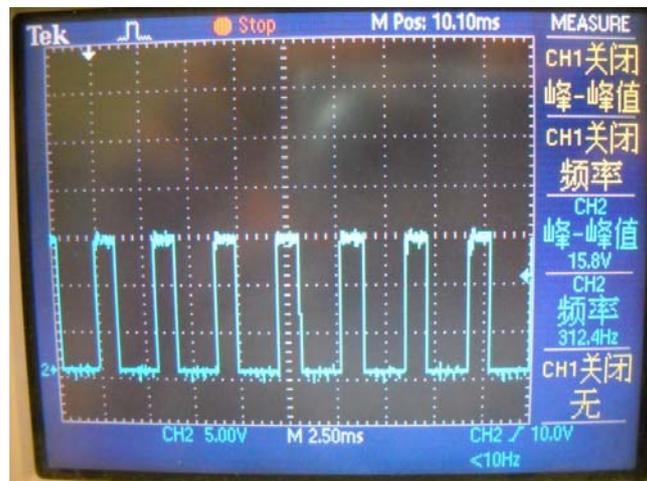


Figure 6-6 Phase driver low side signal

### 7. Software flowchart

Software design can be divided into main function, hall interrupt, speed calculate, close-loop of speed, close-loop of current, timer interrupt, space vector calculate, over current protect function and so on.

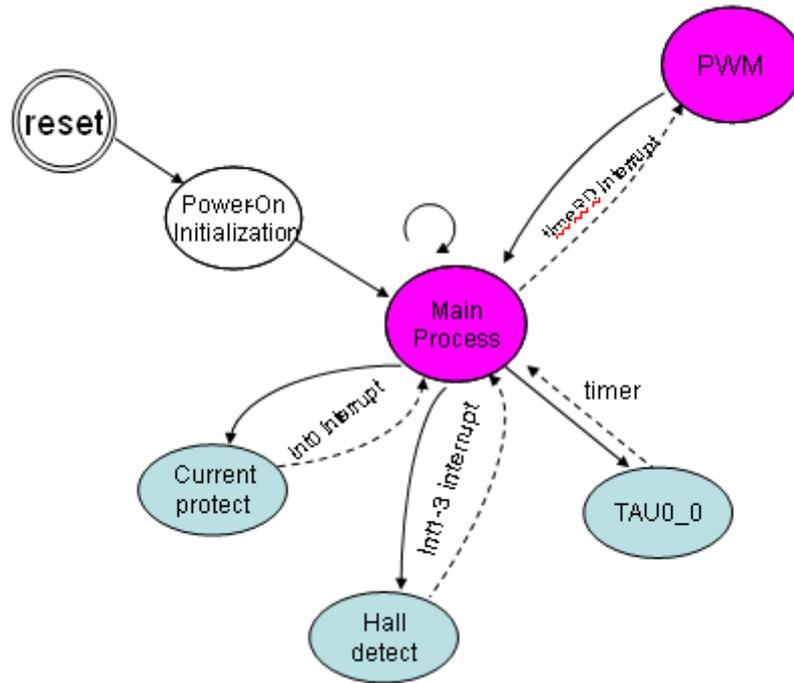


Figure 7-1 System architecture

#### 7.1 Main function

Figure 7-2 shows the flowchart of main function.

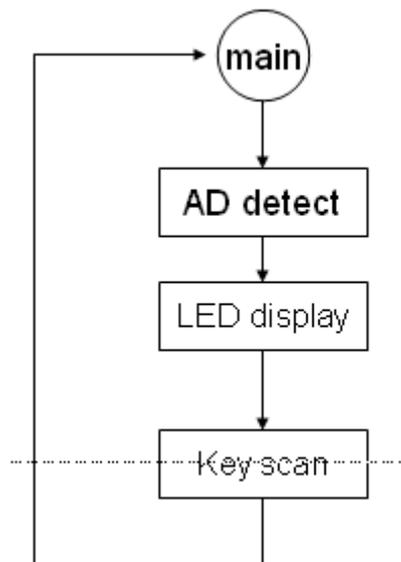


Figure 7-2 Main function flowchart

### 7.2 Hall interrupt

Figure 7-3 shows the flowchart of hall interrupt.

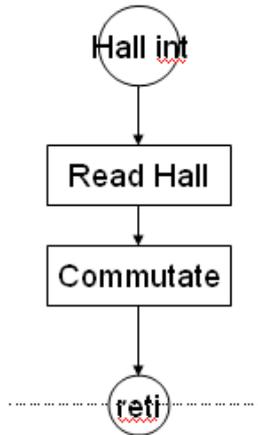


Figure 7-3 Hall interruption flowchart

### 7.3 Run mode and Speed Control

Figure 7-4 shows the flowchart of speed calculation.

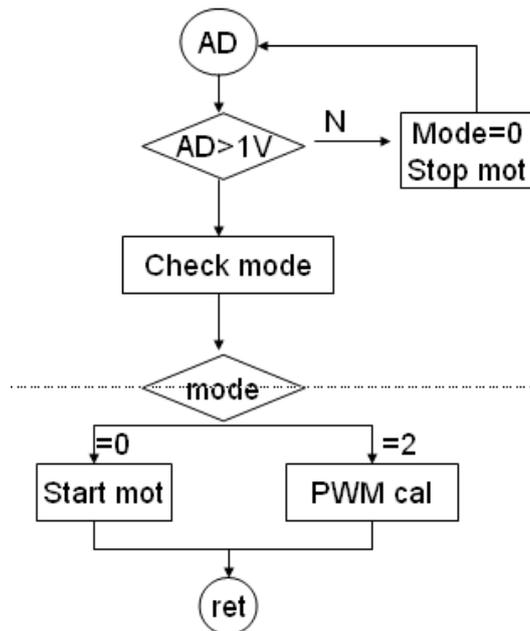


Figure 7-4 Motor operation flowchart

### 7.4 Current Control and Protect

Figure 7-5 shows the flowchart of current control and protect function.

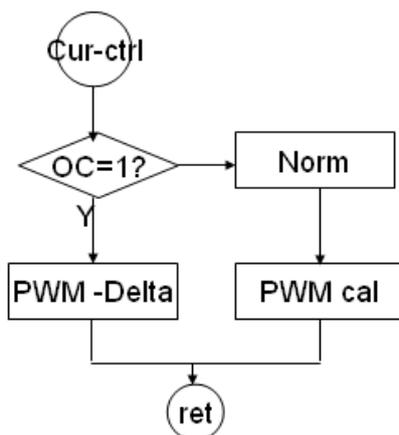


Figure 7-5 Current control flowchart

### 7.5 Timer interrupt

Figure 7-6 shows the flowchart of timer interrupt.

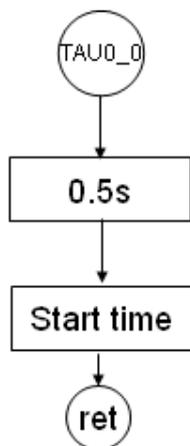


Figure 7-6 Timer control

### 7.6 Over current protect

Figure 7-7 shows the flowchart of over current function.

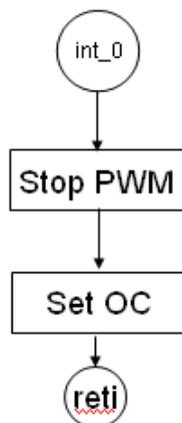
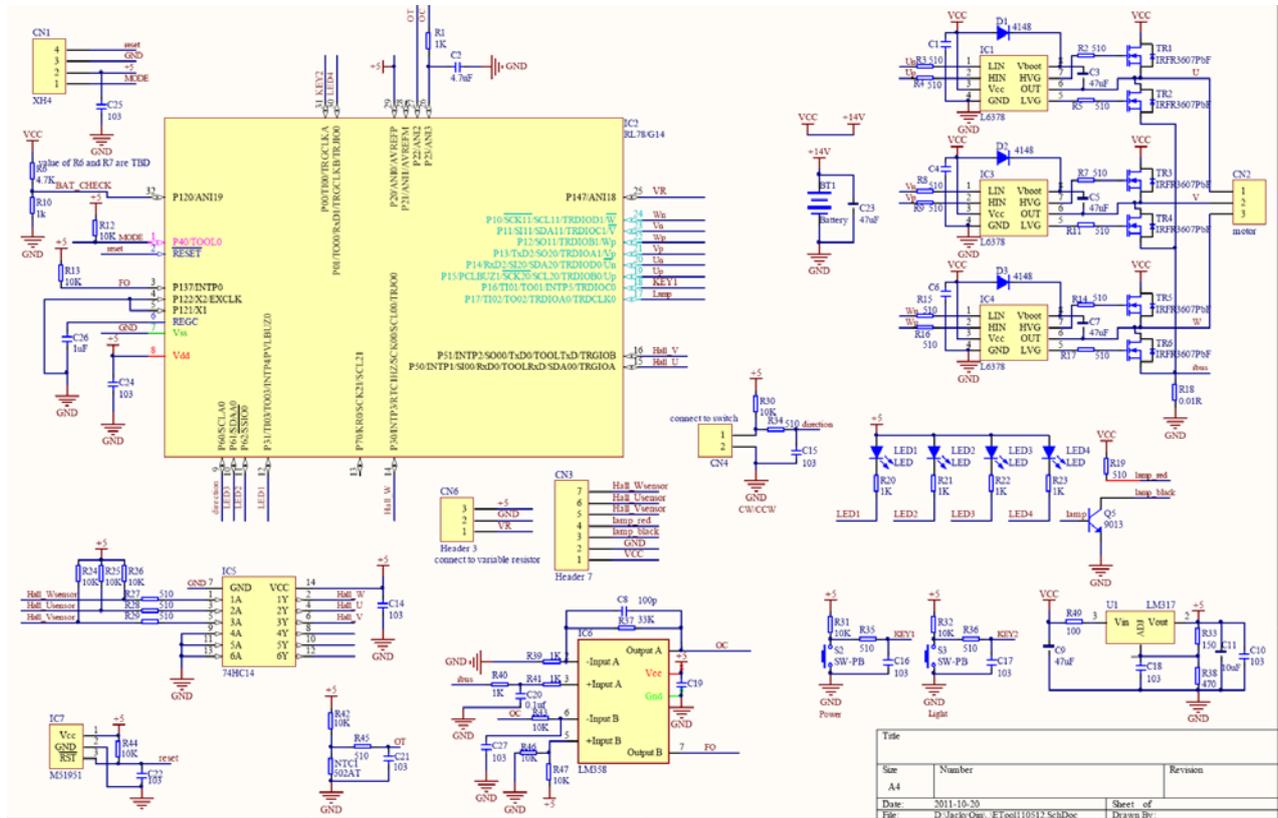


Figure 7-7 Over-current control

APPENDIX

Schematic



## 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.



## 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

- 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.
- 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.
- You should not alter, modify, copy, or otherwise misappropriate any Renesas Electronics product, whether in whole or in part.
- 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.
- 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.
- 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.
- 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.
- 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.
- 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.
- 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.
- This document may not be reproduced or duplicated, in any form, in whole or in part, without prior written consent of Renesas Electronics.
- 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.



瑞萨电子中国销售 · 技术支持网点:

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

### 瑞萨电子(中国)有限公司

北京市海淀区知春路27号量子芯座17层

邮编: 100191 电话: +86 10 8235 1155 传真: +86 10 8235 7679

长春分公司 吉林省长春市朝阳区西安大路727号中银大厦A座1609室

邮编: 130061 电话: +86 431 8859 7533 传真: +86 431 8680 2944

大连分公司 辽宁省大连市中山区中山路88号天安国际大厦21楼2103室

邮编: 116001 电话: +86 411 3980 5858 传真: +86 411 3980 5877

青岛分公司 山东省青岛市市南区香港中路10号颐和国际大厦A栋23A楼07室

邮编: 100191 电话: +86 532 6677 7600 传真: +86 532 6677 7608

上海分公司 上海市浦东新区陆家嘴环路1233号汇亚大厦205室

邮编: 200120 电话: +86 21 5877 1818 传真: +86 21 6887 7858

成都分公司 四川省成都市二环路南三段15号天华大厦608室

邮编: 610041 电话: +86 28 8512 5224 传真: +86 28 8512 5334

深圳分公司 广东省深圳市福田区益田路4068号卓越时代广场18楼1807-09室

邮编: 518048 电话: +86 755 8283 5080 传真: +86 755 2399 5080

### 瑞萨电子(上海)有限公司

上海市浦东新区陆家嘴环路1233号汇亚大厦205室

邮编: 200120 电话: +86 21 5877 1818 传真: +86 21 6887 7858

### 瑞萨电子香港有限公司

香港九龙旺角太子道西193号新世纪广场第2座16楼1601-1613室

电话: +852 2265 6688 传真: +852 2886 9022

瑞萨电子大中国地区(包括香港)代理及分销商的联系方式请访问: <http://cn.renesas.com/buy>