R8C/32A series

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120-Degree Trapezoidal Wave Method for brushless DC motor

Introduction

This sample code is to introduce how to use the GPIO and Timer RC for doing 120-Degree Trapezoidal Wave driver on a brushless DC motor. The speed is controlled by an external PWM signal. The target device is R8C/32A which is 20 pins package.

Target Device

R8C/32A series

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1. The configuration of the system

The configuration of the system is shown in Figure. R8C/32A is the main processor in the system and outputs the PWM signals to control the inverter circuits. The BLDCM has three hall sensors and the signals are used to detect the position of the rotor. The speed of BLDCM is controlled by the external PWM signal and we use the timer RA to capture the frequency of the signal for controlling the rotating speed.

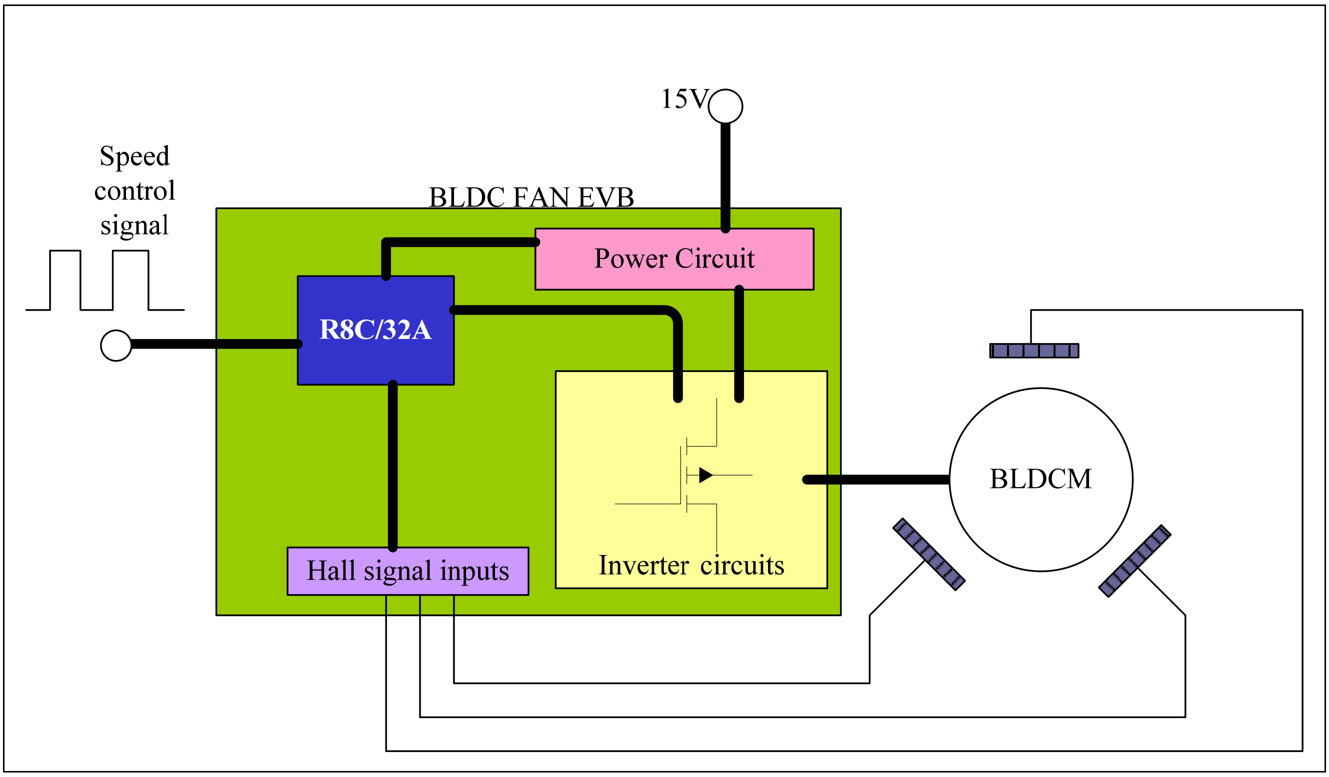


Figure 1 Configuration of system

2. Hardware specification

The hardware EVB is shown in Figure 2. This is the BLDC FAN EVB. The EVB is including of inverter circuit and MCU circuit. The interface of the debugging and programming is though E8A which is the emulator designed by Renesas Electronics.

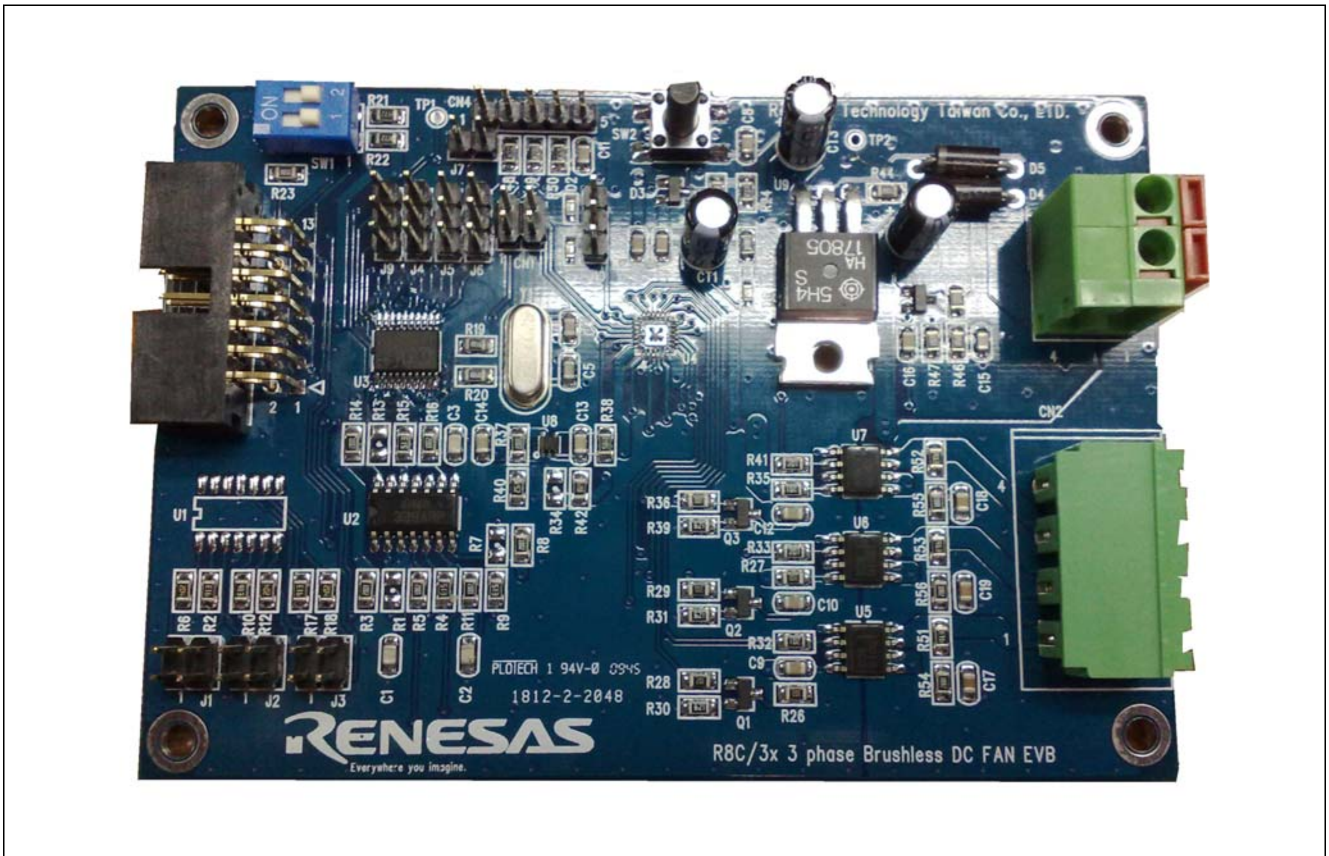


Figure 2 Hardware EVB

The main items of the EVB are shown in table 1. The main parts are including of MCU, regulator and Power MOSFET.

The power limitations of the EVB are listed in table2.

Table1 Key parts of the EVB

Item	Part	Description
1	R5F21322AN	MCU,R8C/32A series ,20 pin
2	HA17805	3-terminal Fixed Voltage Regulator
3	HAT3010	Power MOSFET, one PMOS and one NMOS

Table2 Power specification of EVB

Maximum input voltage	24 volt
Maximum output current	1A (depended on the specification of the Power MOSFET)

3. Software specification

3.1 120-degree trapezoidal wave method

The application introduces how to use R8C/32A to do the 120-Degree Trapezoidal Wave driver for a brushless DC motor. The used modules are shown in the Figure3. Three GPIO pins are used for switching the PMOS and are not chopping. Those pins control the PMOS on/off at each segment. The PWM mode 1 of Timer RC is used to output three PWM signals for switching NMOS. Hall sensor signal is got through key interrupt and external interrupt. Finally, timer RA is used for external PWM signals to get the speed command for the system.

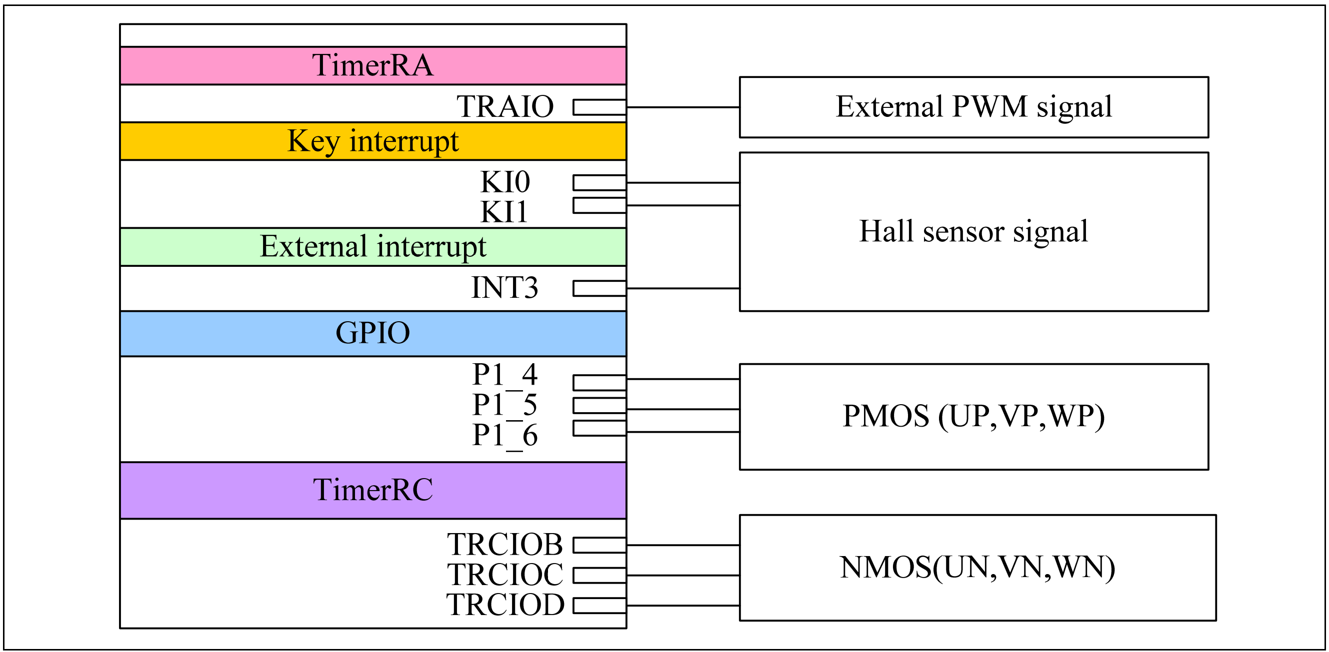


Figure 3 Used modules of R8C/32A

When using the 120-Degree Trapezoidal Wave method, the locations of hall sensors are very important. The relationship between the back EMF signal of the BLDCM and the hall sensors is needed firstly. The example is shown in Figure 4. The figure will be different from different motor. The switch table of the 120-Degree Trapezoidal Wave method can be got by the Figure 4.

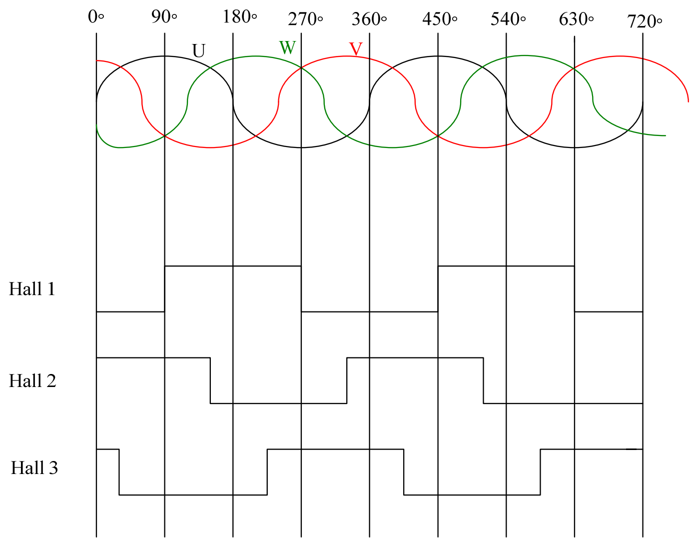


Figure 4 Relationship of Back-EMF and hall sensor signal

The 120-Degree Trapezoidal Wave method is to turn on only one upper arm and only one down arm simultaneously. Every time only two Power MOSFET are turned on. Then, the current will follow into two wires at the same time. The three-phase inverter has six switches. There are six kinds of possible statuses. The switch table can be constructed as table 3. The system will turn the switch according to the table3. The current will follow into the wires according to the status of the switches. All the status is shown in the Figure 5.There are only six kinds of the possible conditions beyond the table 3.

For the 120-Degree Trapezoidal Wave method, the most important thing is to get the information of the position of the rotor. Then, controller is designed to turn on the correct switches so that the motor can rotate.

However, we can find two status (0,0,0) and (1,1,1) which is a symbol to warn about the incorrect signals from hall sensors. The situation should be considered carefully for designing a system. In this sample code , turning off the switches is used when the situation of (0,0,0) and (1,1,1) happen.

Table3 Switch table

Hall sensor signals			Upper Arm SWs			Down Arm SWs			The turned SWs	Active wires
H1	H2	H3	UP	VP	WP	UN	VN	WN	Turned on switches	Path though wires
0	0	0	------	------	------	------	------	------	None	None
0	0	1	------	ON	------	ON	------	------	VP,UN	V,U
0	1	0	ON	------	------	------	------	ON	UP,WN	U,W
0	1	1	------	ON	------	------	------	ON	VP,WN	V,W
1	0	0	------	------	ON	------	ON	------	WP,VN	W,V
1	0	1	------	------	ON	ON	------	------	WP,UN	W,U
1	1	0	ON	------	------	------	ON	------	UP,VN	U,V
1	1	1	------	------	------	------	------	------	None	None

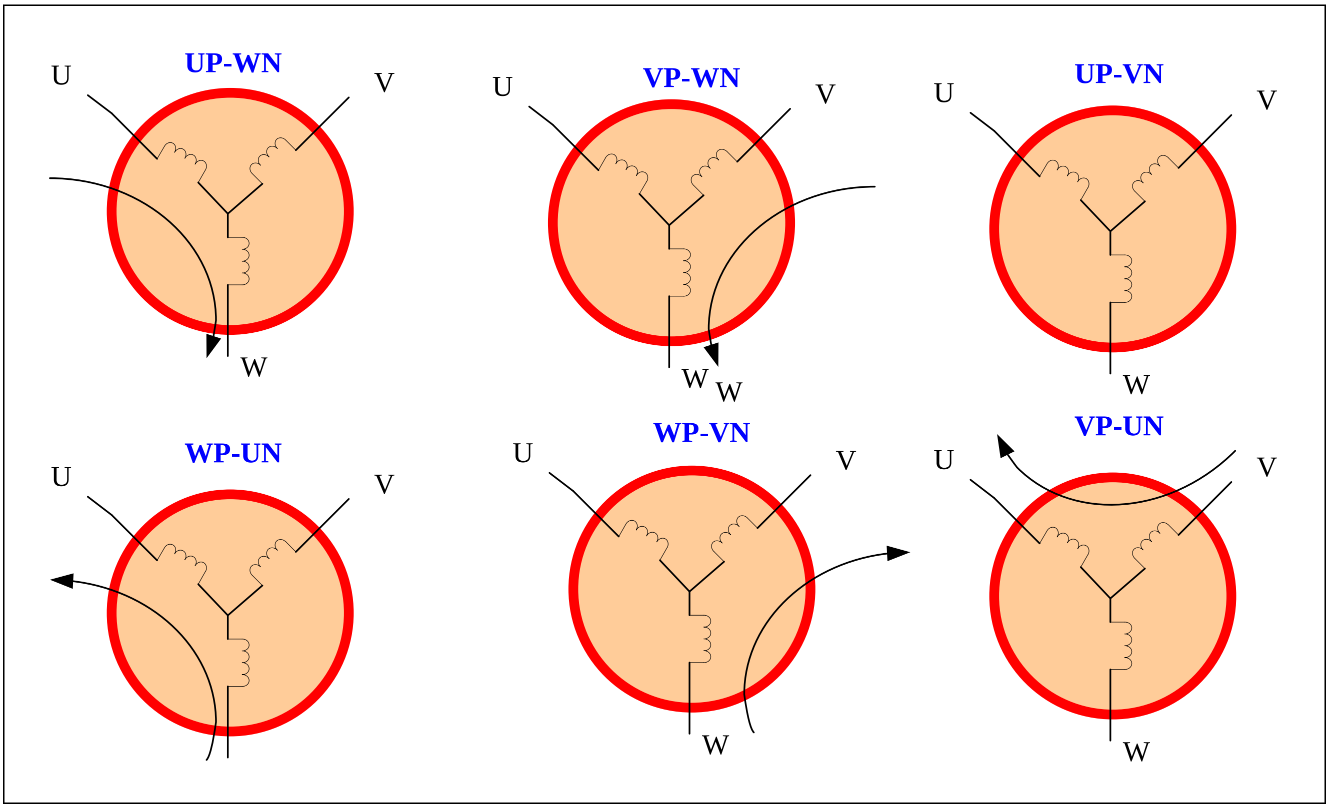


Figure 5 Current follow of each status

3.2 Program following chart

The program following charts are shown from Figure 6 to Figure 11

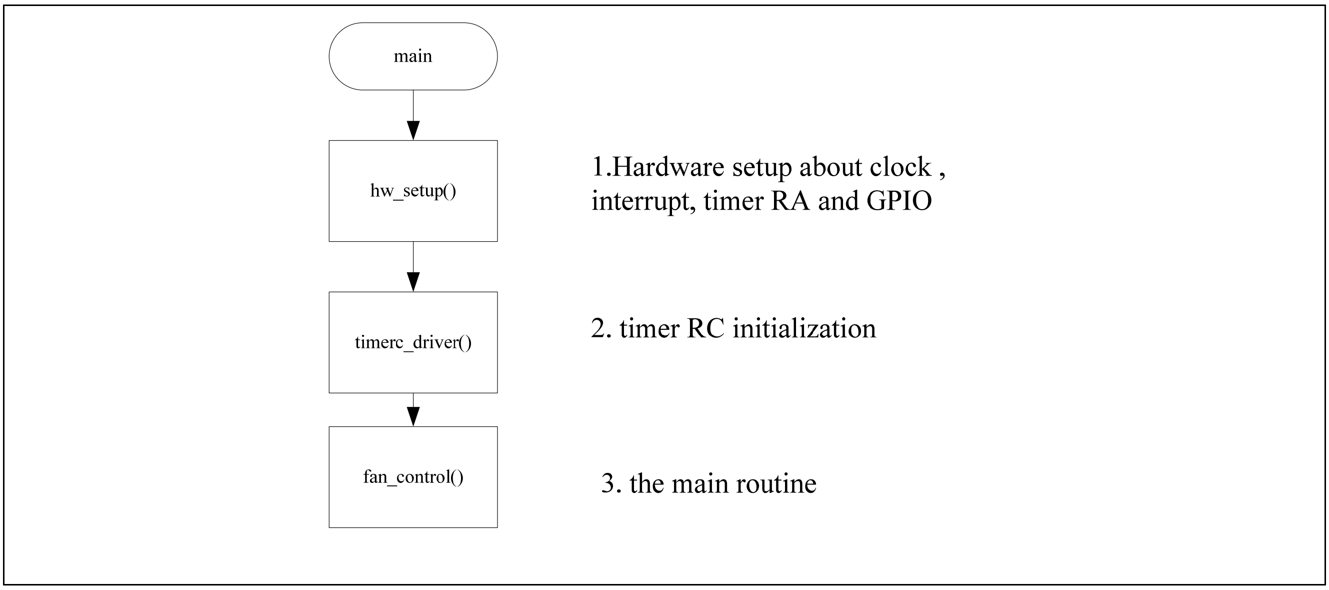
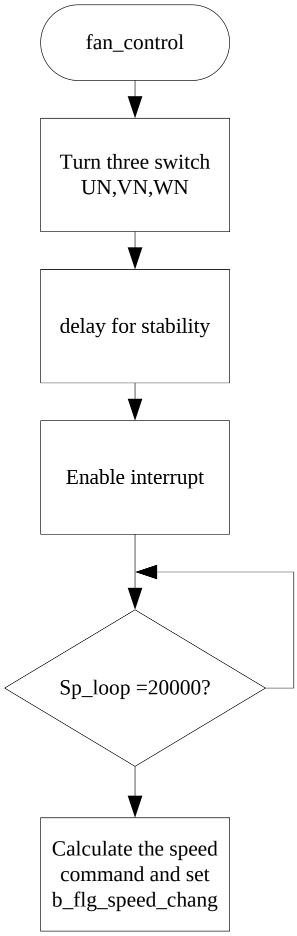


Figure 6 System operation procession



1. Turn on the switches (UN, VN ,WN) to release the electric charge of the wires

2. call delay time for step1

3. enable the interrupt system

4. calculate the speed command once every second and setup the flag for change the compare register

Figure 7 Fan control routine

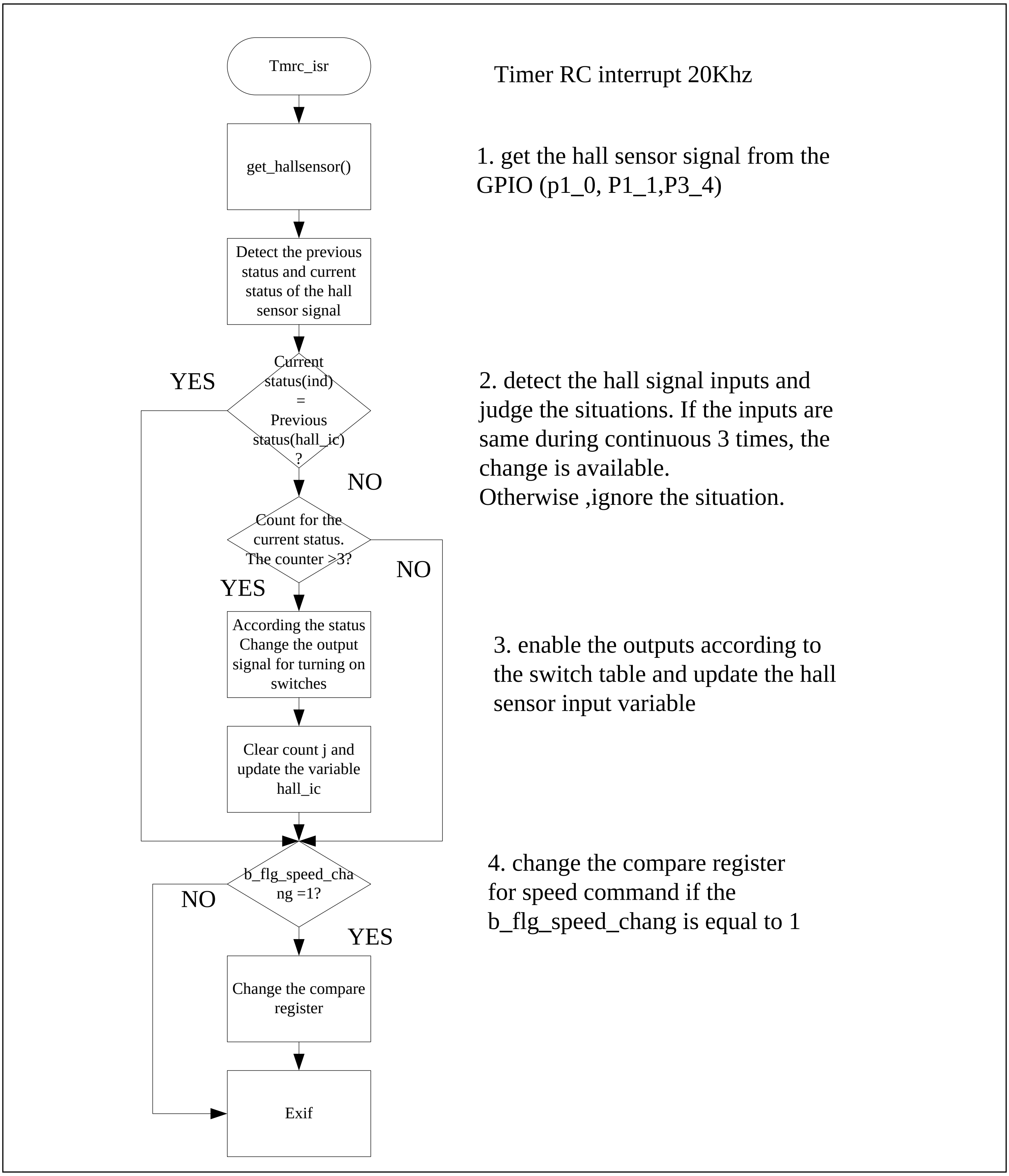


Figure 8 Timer RC interrupt service routine

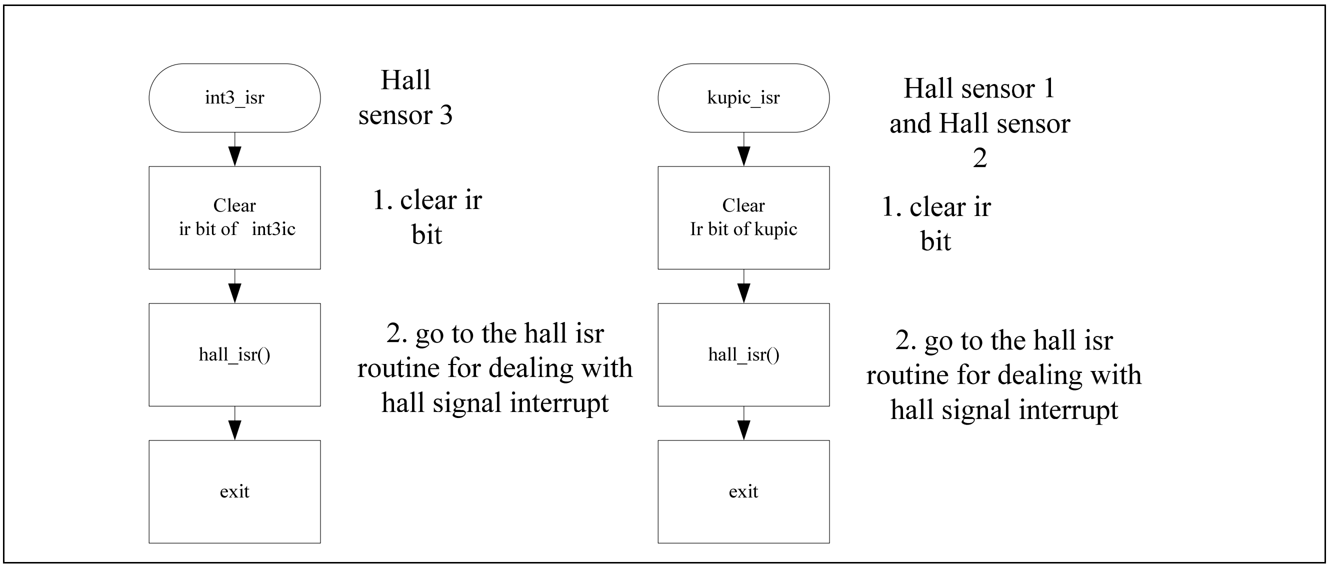


Figure 9 Hall sensor signal interrupt routine

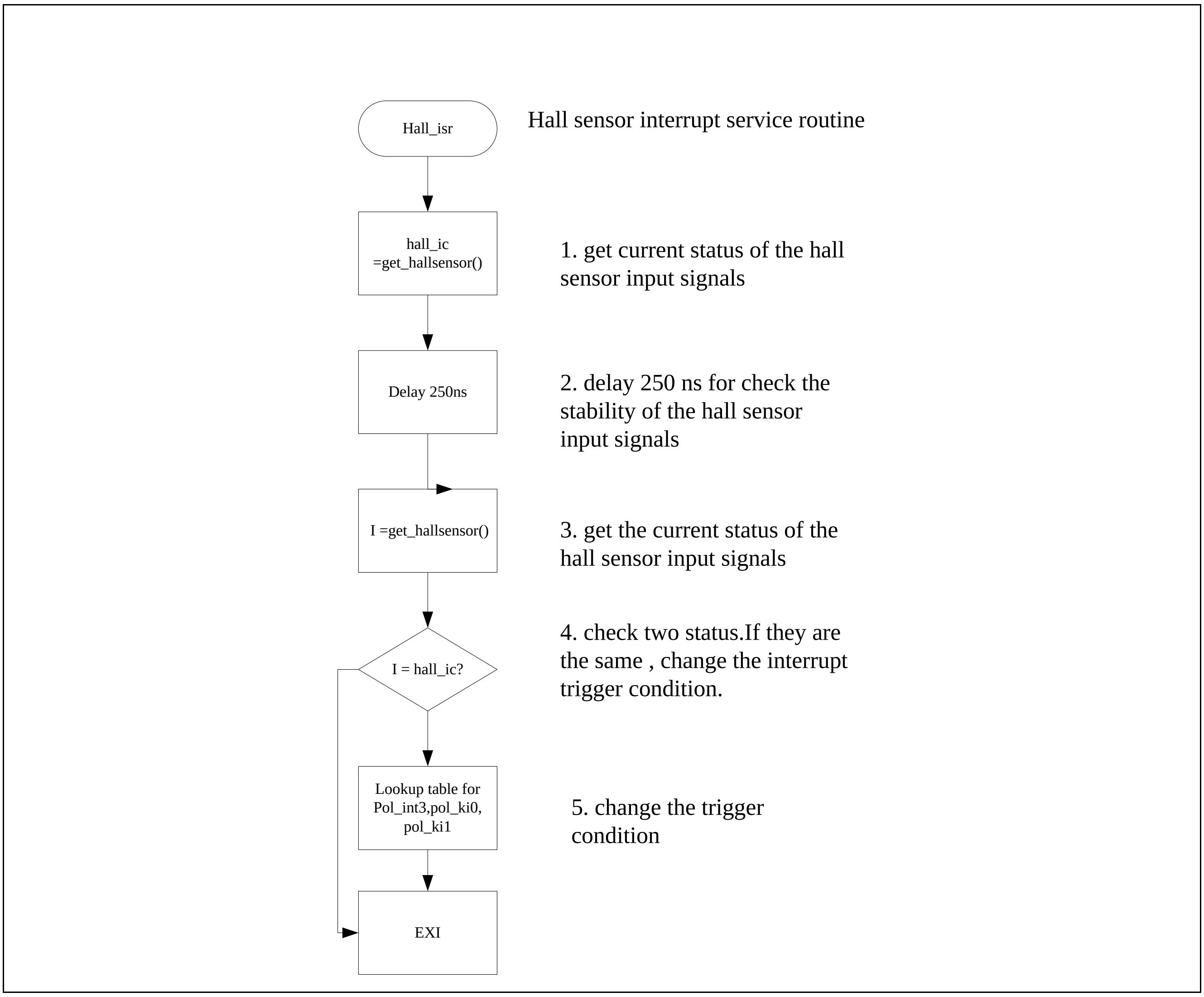
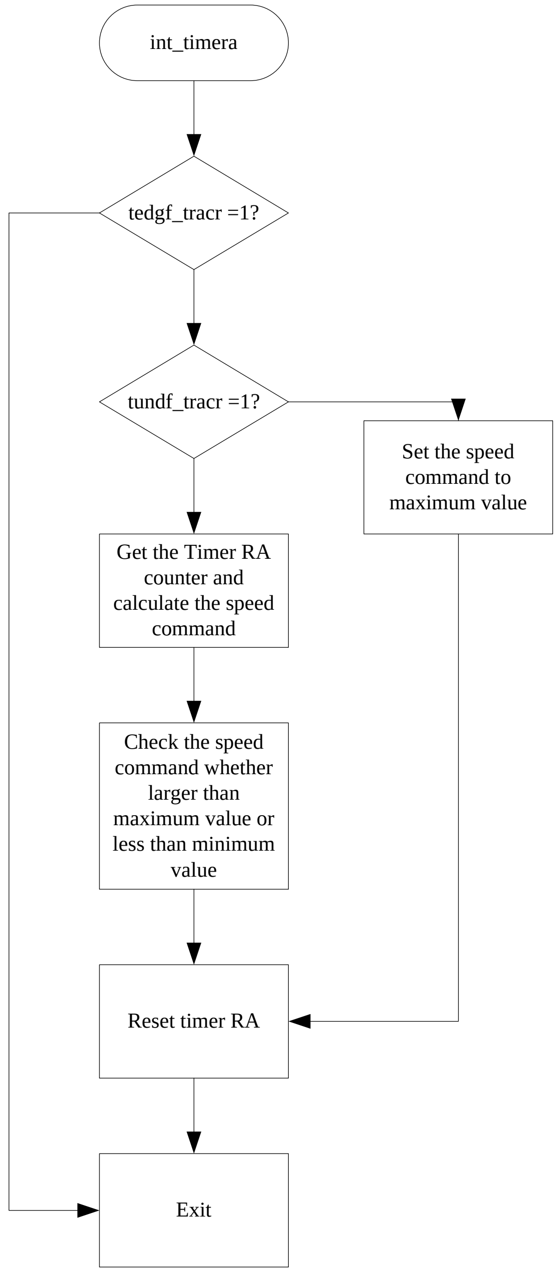


Figure10 Hall ISR



Timer RA
pulse period measurement mode

1. check the active edge trigger flag.

2. check the underflow flag. If underflow happen, the speed command is set to the maximum value.

3. get the Timer RA counter and calculate the speed command

4. check the speed command and make sure that is less than maximum value and larger than minimum value

5. reset timer RA and the counter

Figure 11 Timer RA interrupt service routine

4. Reference hardware circuit

The hardware circuits of BLDC FAN EVB are shown from Figure12 to Figure14.

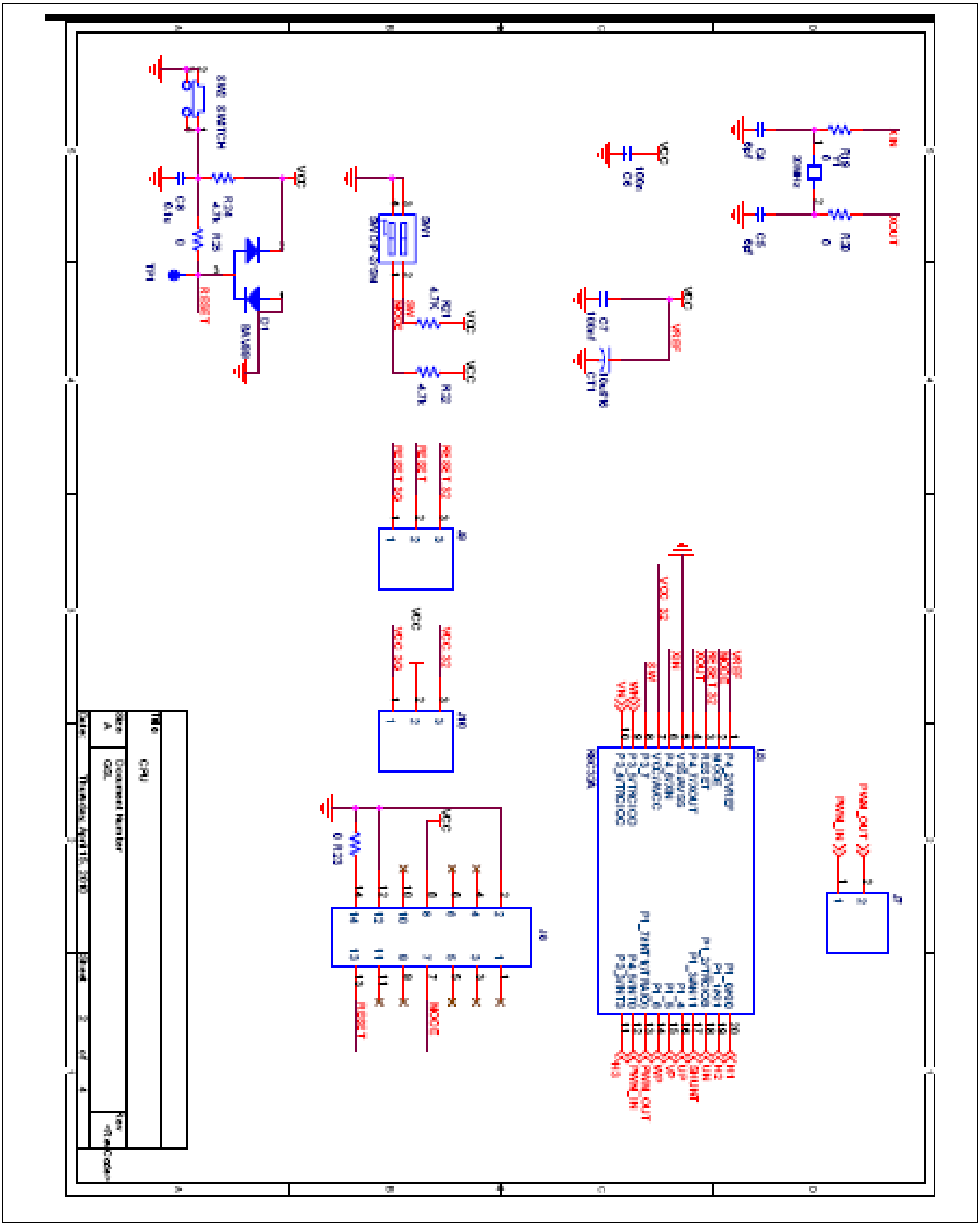


Figure 12 CPU circuit

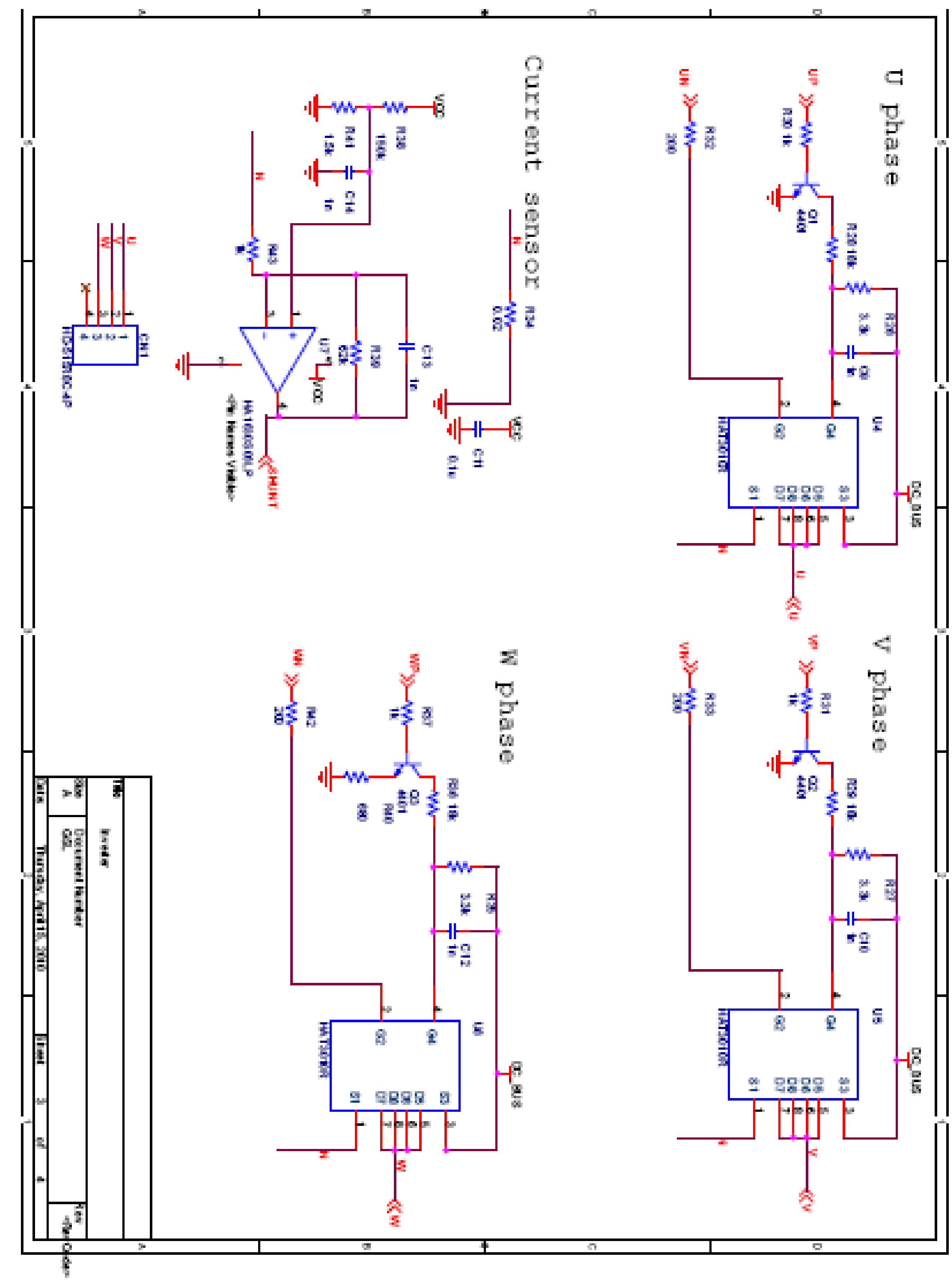


Figure 13 Inverter circuit

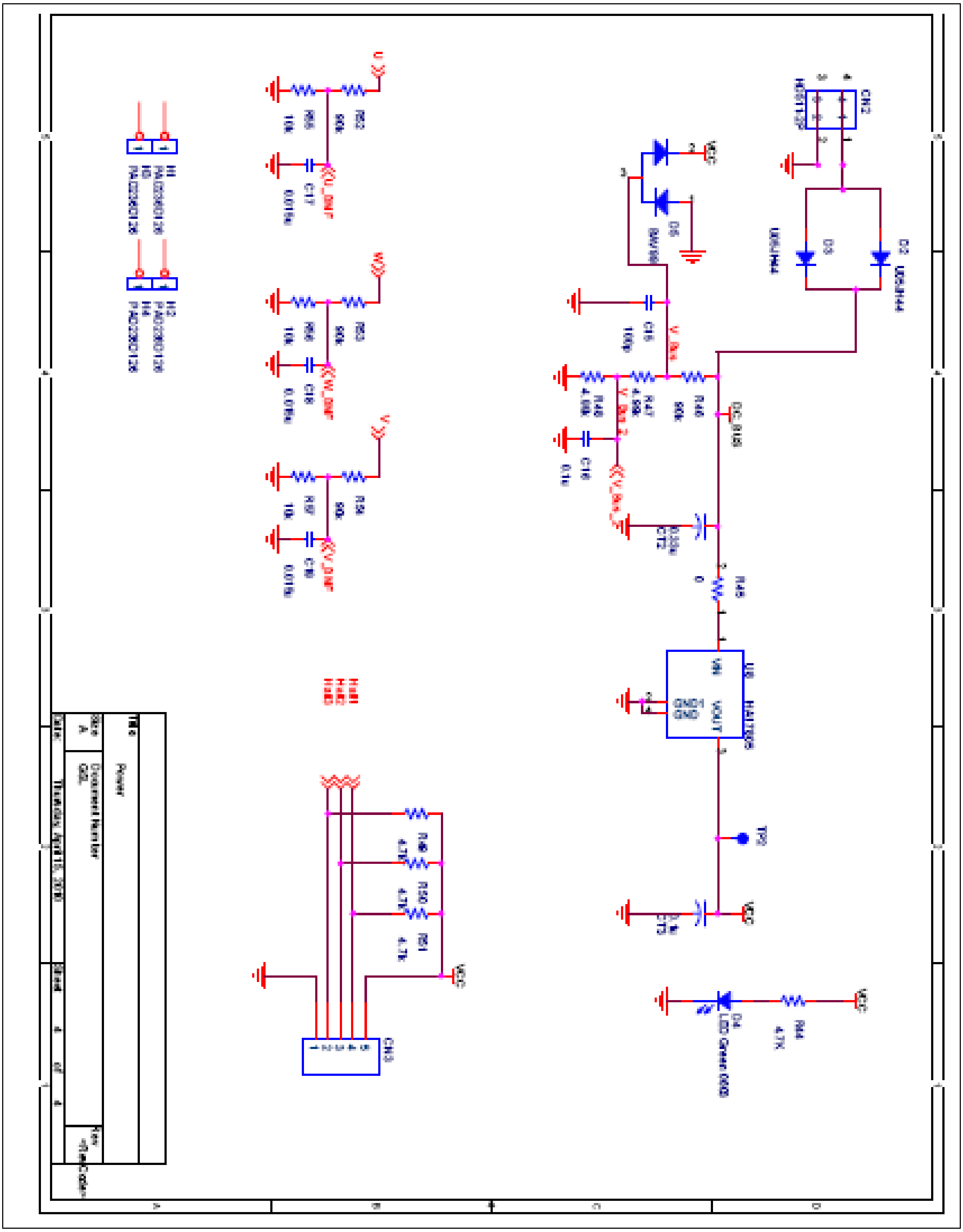


Figure 14 Power circuit

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Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	Apr.15.10	—	First edition issued

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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.
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