To our customers,

Old Company Name in Catalogs and Other Documents

On April 1st, 2010, NEC Electronics Corporation merged with Renesas Technology Corporation, and Renesas Electronics Corporation took over all the business of both companies. Therefore, although the old company name remains in this document, it is a valid Renesas Electronics document. We appreciate your understanding.

Renesas Electronics website: http://www.renesas.com

April 1st, 2010
Renesas Electronics Corporation

Issued by: Renesas Electronics Corporation (http://www.renesas.com)

Send any inquiries to http://www.renesas.com/inquiry.

RENESAS

Notice

1. 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.
2. 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.
3. You should not alter, modify, copy, or otherwise misappropriate any Renesas Electronics product, whether in whole or in part.
4. 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.
5. 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.
6. 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.
7. 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.
8. 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.
9. 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.
10. 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.
11. This document may not be reproduced or duplicated, in any form, in whole or in part, without prior written consent of Renesas Electronics.
12. 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.

R32C/118

Six Step Method for Brushless DC Motor based on R32C/118

Introduction

This application note is shown how to use R32C/118 to drive brushless DC motor (BLDCM) using the three phase timer module. The characteristic of the driver is using six step method and balanced PWM outputs to make the same switching loss on high side and low side IGBTs. The LED will be flashing to show that the system is working.

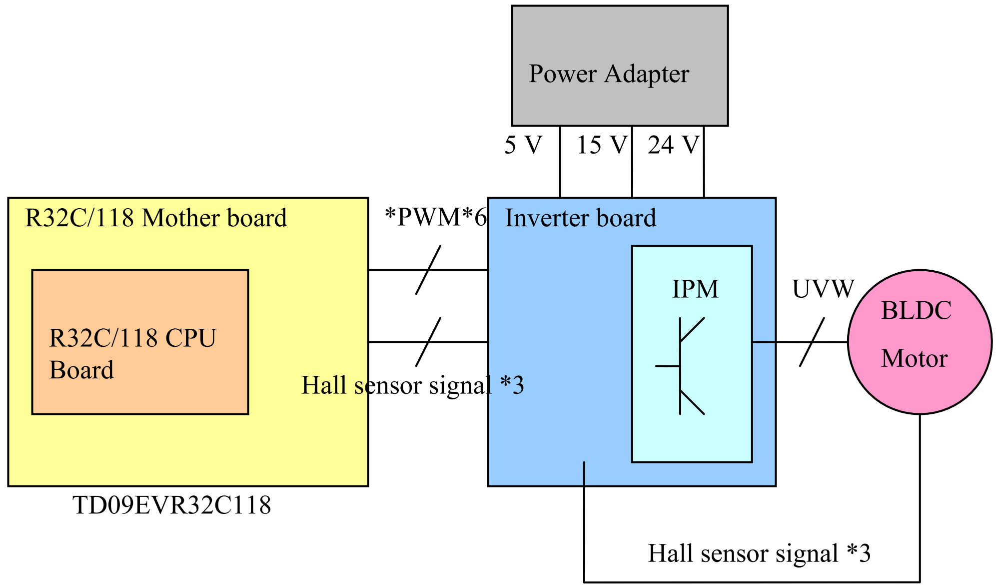
Target Device

The target device is the R32C/100 Series.

Contents

1. The Configuration of the system

The configuration of the system is shown in Figure 1. R32C/118 EVB generates the different PWM output according to the hall sensor signals. The three phase signals are generated after the PWM signals drive the Inverter board.



* PWM : U(P80),_U(P81),V(P72),_V(P73),W(P74),_W(P75)

Figure 1 the configuration of the system

2. Hardware Specification

2.1 Brushless DC Motor Specification

The specification of the motor used in this document is shown in Table1 and Figure1. The shape of N2341S014 is shown in Figure 2. The number of the pole in this motor is 2. It is a kind motor of distributed wiring so that the back-EMF waveform of the motor is sinusoidal wave. However, the trapezoidal waveform still can be used to drive this motor and the method is shown in the following.

Table1 Motor specification

Model	N2341S014(PITTMAN® ELCOM ST™)
Number of Pole	2(1 pair)
Sensor:	Hall sensor : U V W Encoder : 500 CPR, A , B , Z
Voltage	24 Volt

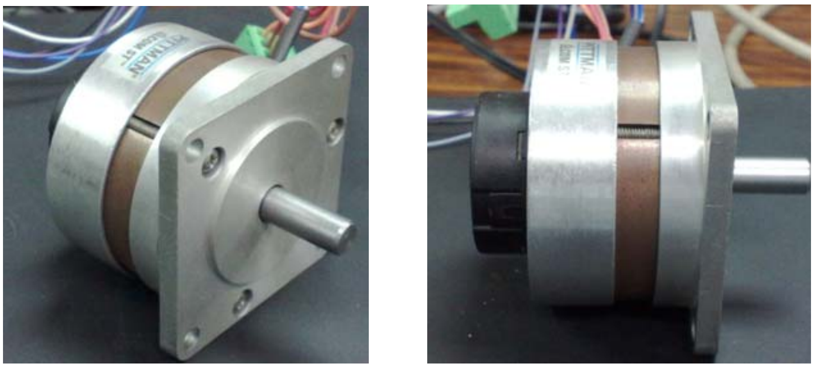


Figure 2 N2341S014

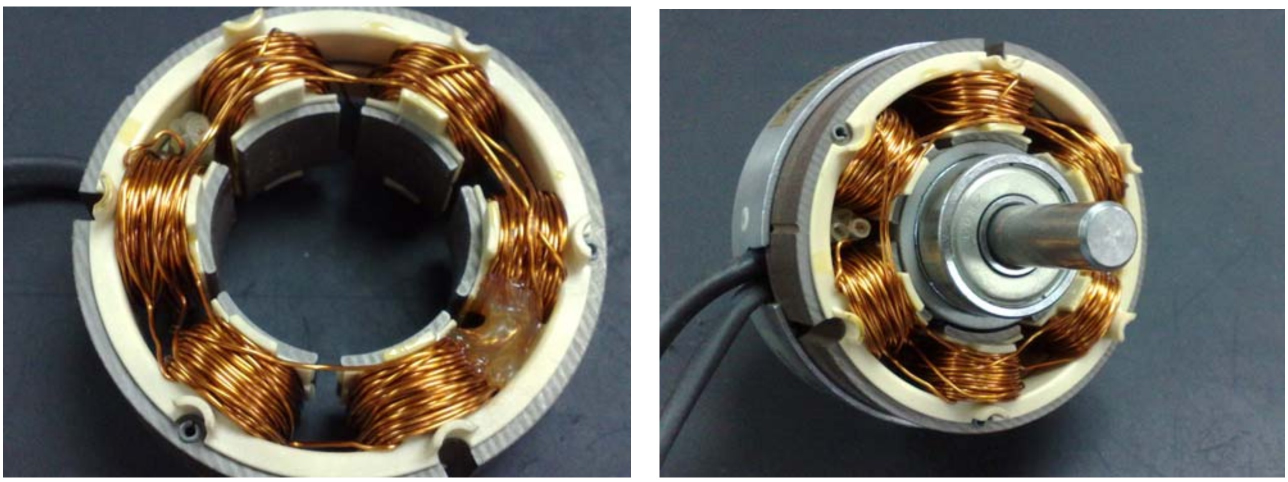


Figure 3 The structure of N2341S014

2.2 The relationship of the hall sensor signals and the Back-EMF

We need to know the relationship between hall sensor signals and the Back-EMF at each phase. A simple method to get this relationship is shown in this paper.

The direction of torque will be decided by the phase delay between Back-EMF and the current into motor. The phase delay should be zero if the rotor rotates in clockwise. However the phase delay should be 180 degree if the rotor will rotate in counter clockwise. Figure 4 shows the phase between inputs current I and Back-EMF.

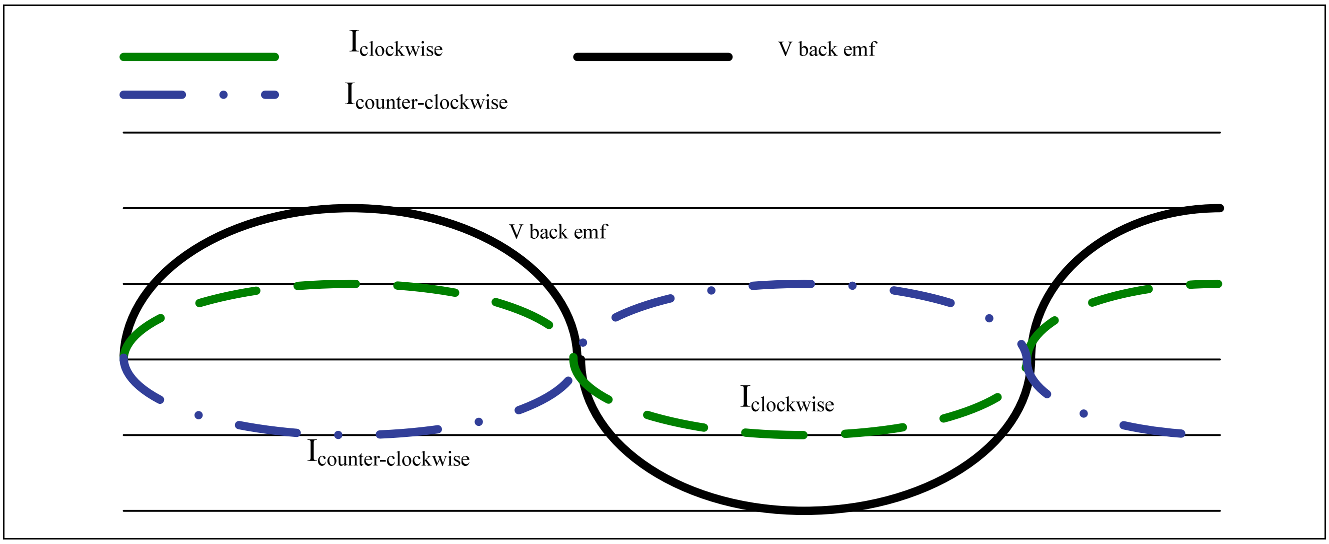


Figure 4 Current phase between Back-EMF and input current

Figure 5 shows the example how to measure the Back-EMF from motor. The voltage of the Back-EMF will be scaled by the rotating speed of the rotor. It will be larger in high speed than in the low speed. We can get the relationship between Back-EMF and sensor signals if we measure those signals simultaneously. Then we can make the switching table to drive the motor according to the measurement result.

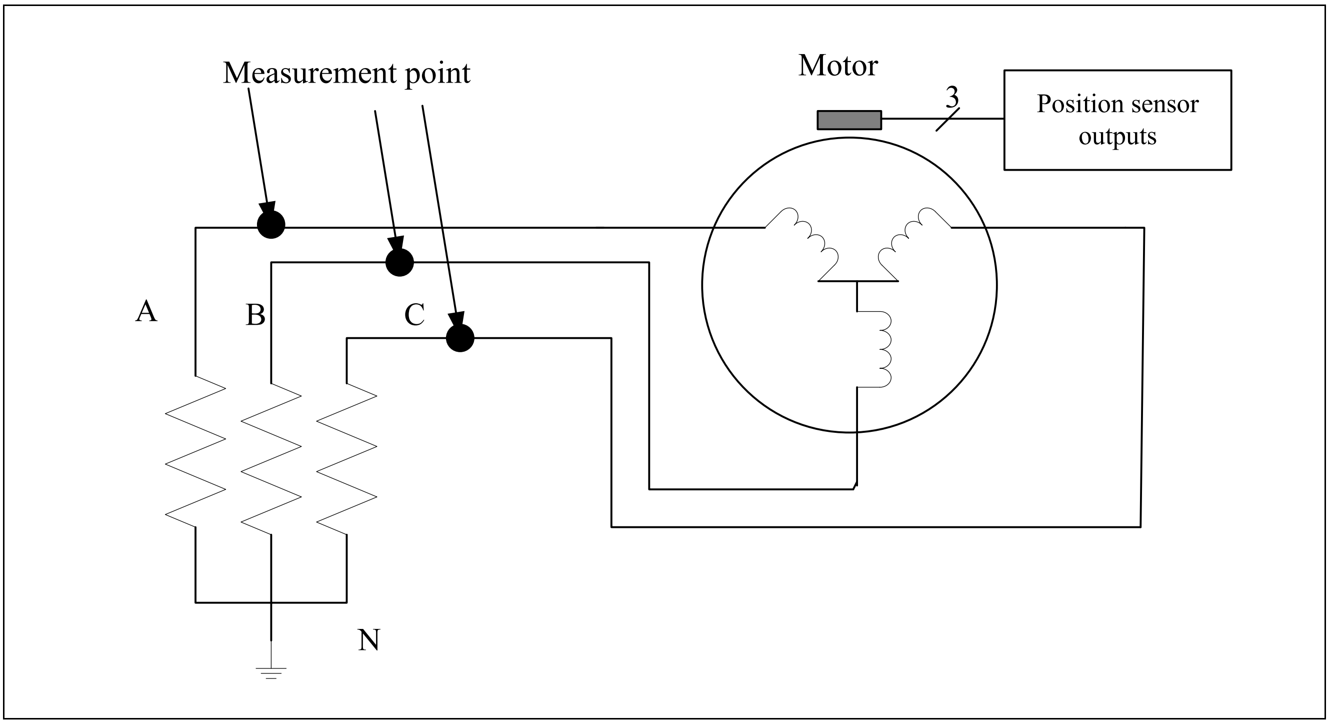


Figure 5 Measurement for the Back-EMF of the motor

Figure 6 can be got by rotating the rotor smoothly. It will be unstable waveform if the rotating speed is not constant. Figure 7 can be got according to Figure6.The unit of X axis is electrical phase. The switching table can be made by the result of Figure 7.

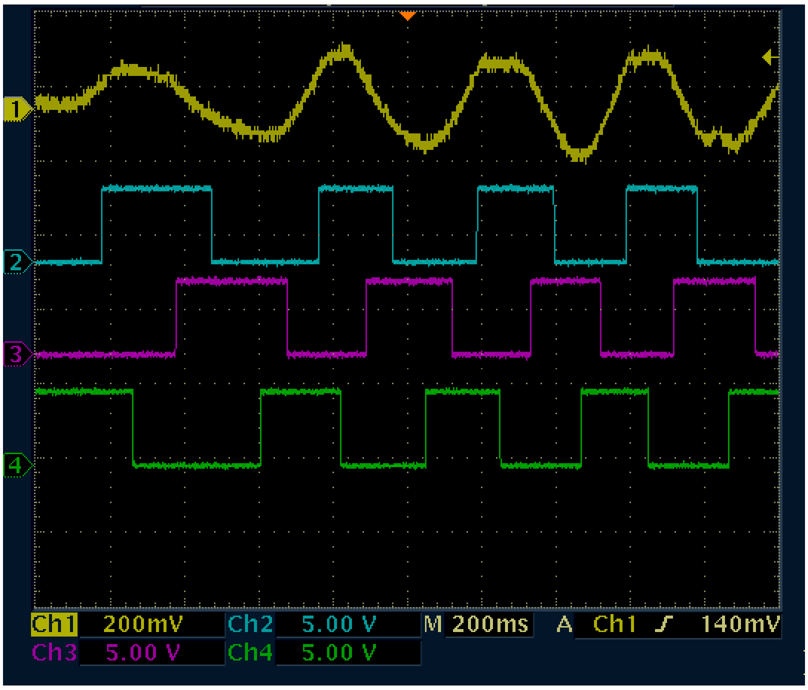


Figure 6 The Back-EMF and Hall sensor signals from scope

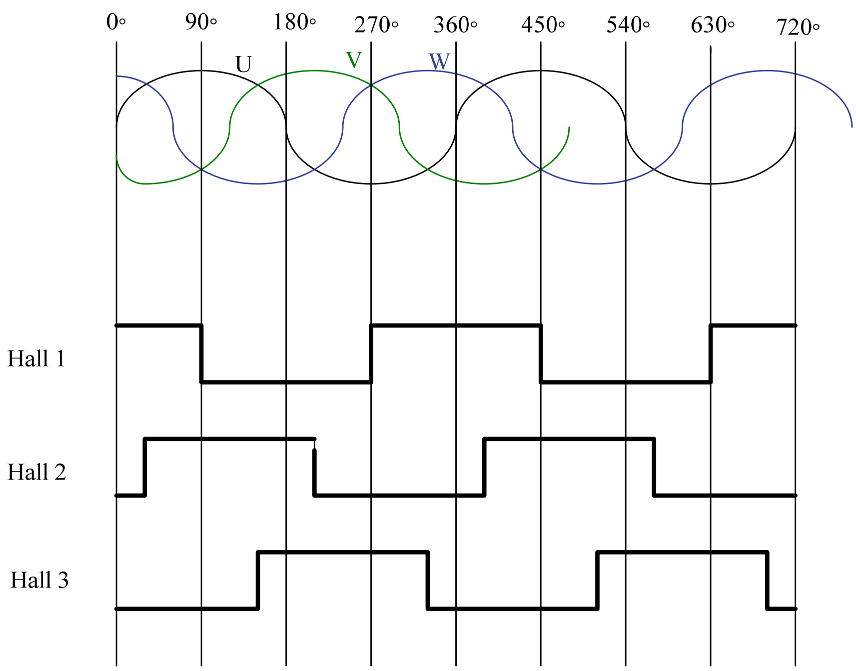


Figure 7 The signal follow chart between position sensor and the Back-EMF

2.3 Construct the switching table

How to use trapezoidal waveform to drive the motor which is the type of the distributed winding is shown in Figure 8. The blue line is the Back-EMF of the motor and the red line is the driving voltage. The simple model of the system is shown in Figure 9. In the Eq1 it explains how to get the value of the input current i. However it is just a brief expansion because of ignoring the real complex model .The trapezoidal can not fully match to sinusoidal waveform so that the torque will not be a constant .The noise and torque ripper will be larger in using trapezoidal waveform than sinusoidal waveform for distributed winding.

$$i = \frac{Vout - E}{r} \qquad \text{Eq.1}$$

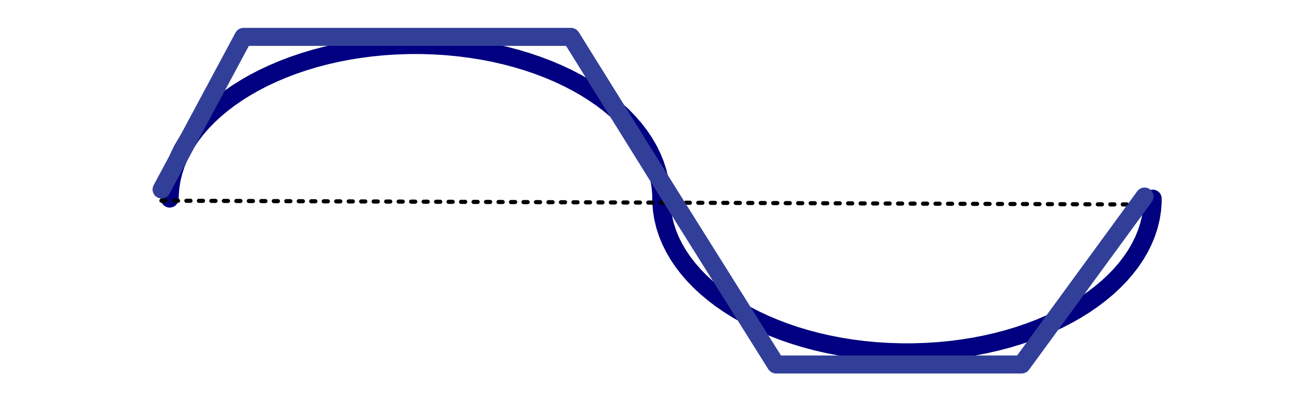


Figure 8 Use trapezoidal waveform to replace sinusoidal waveform

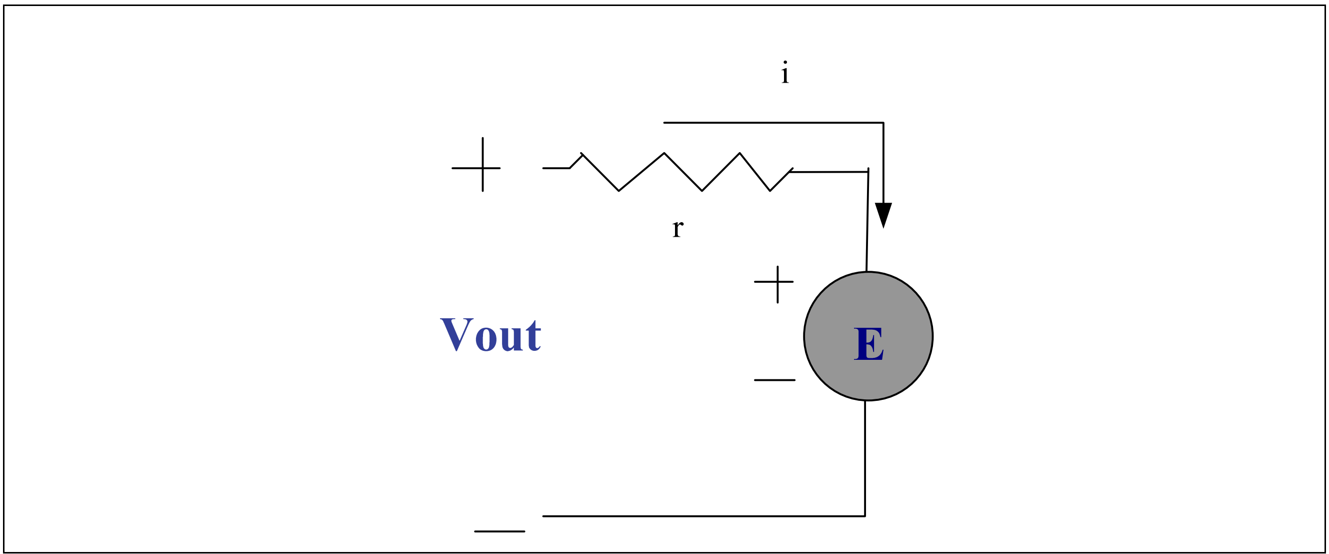
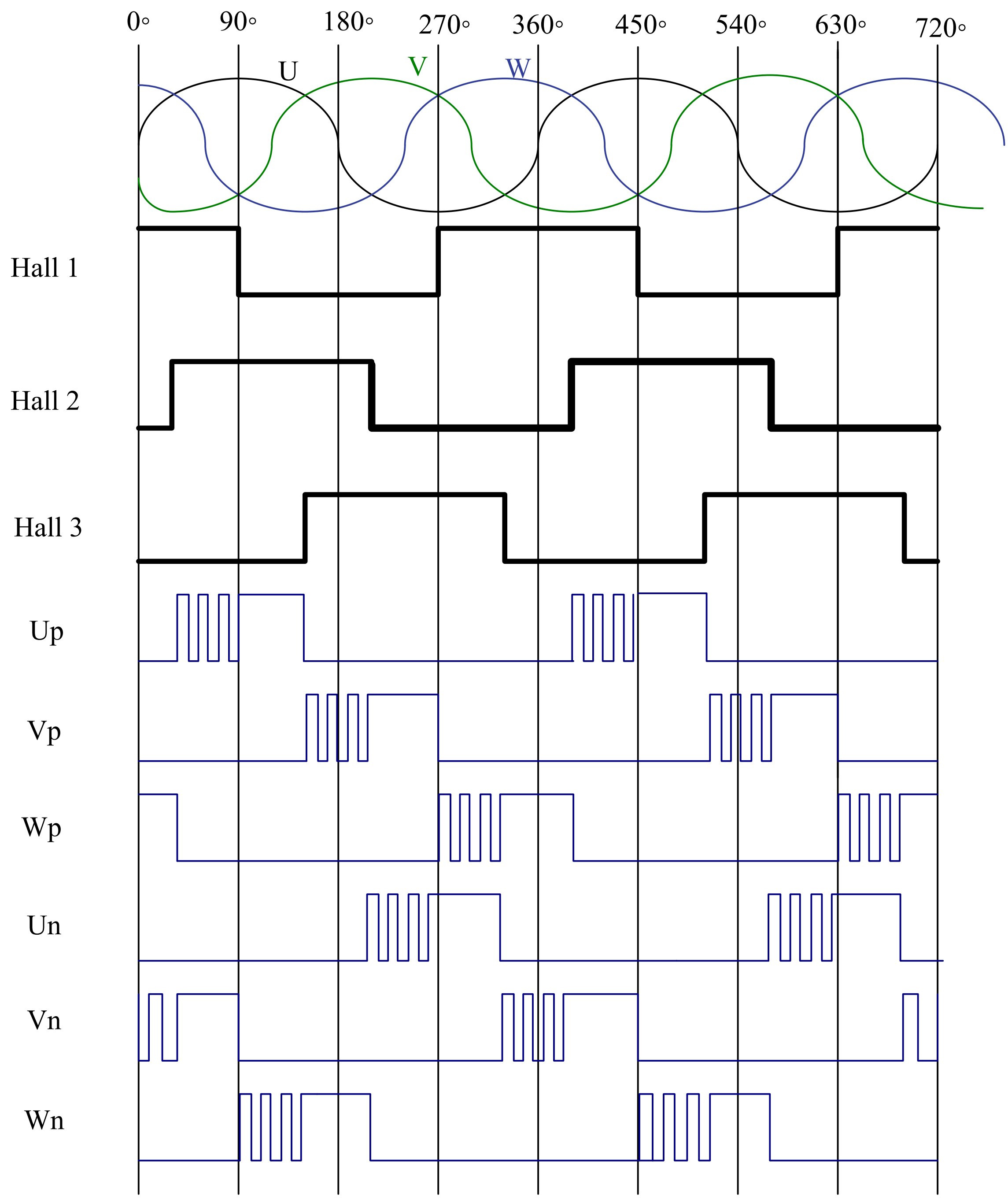


Figure 9 The driving voltage and Back-EMF

By turning on the switch during 120 degrees of a half electrical cycle, the trapezoidal waveform can be constructed. A total electrical phase can be divided into six zones. Each zone is 60 degrees. There are always two switches turned on at each zone. This method is called “six step method”, “120 degrees driving method” or “trapezoidal waveform driving” etc.

Figure 10 shows the switching table according to Figure 7. Each PWM signal is output during 120 degrees at a electrical period. The signal is chopping at the first 60 degrees and then full opening at the last 60 degrees. This method is called balanced PWM output which means the both positive and negative signal are chopping. The IGBTs which are for the one phase will consume the same switching loss. The life cycle of the IGBT can be extended.



U: U phase back-emf V : V phase back-emf   W : W phase back-emf

Hall1 : Hall sensor 1   Hall2 : Hall sensor 2 Hall3: Hall sensor 3

Up : PWM output for positive phase of U   Wp : PWM output for the positive phase of W

Un : PWM output for negtive phase of U   Wn : PWM output for the negtive phase of W

Vp : PWM output for positive phase of V

Vn : PWM output for negtive phase of V

Figure 10 six-step switching table

3. Software Specification

The software specification of the sample code is shown on the Table 2.

Table 2 Software specification

Control method	Six-Step method (120-degree commutation using trapezoidal waves)
Rotor position detection	Detecting by hall sensors
Carrier frequency	20KHz
PWM method	Balanced PWM method (chopping at high side and low side)

The positive phase and negative phase will be chopping at each turned-on period. We called this balanced pwm method in Figure 11. There is the same switching loss for the IGBTs or MOSFETs of the inverter at high side and low side. The method is also useful to reduce the ripper of the torque.

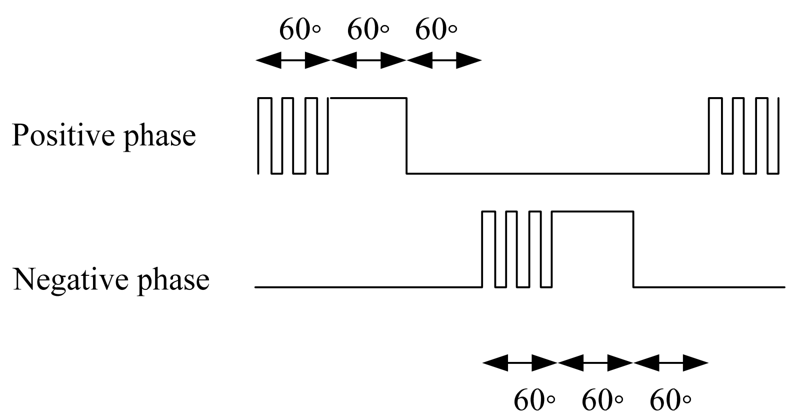


Figure 11 Balanced PWM method

4. Program follow chart

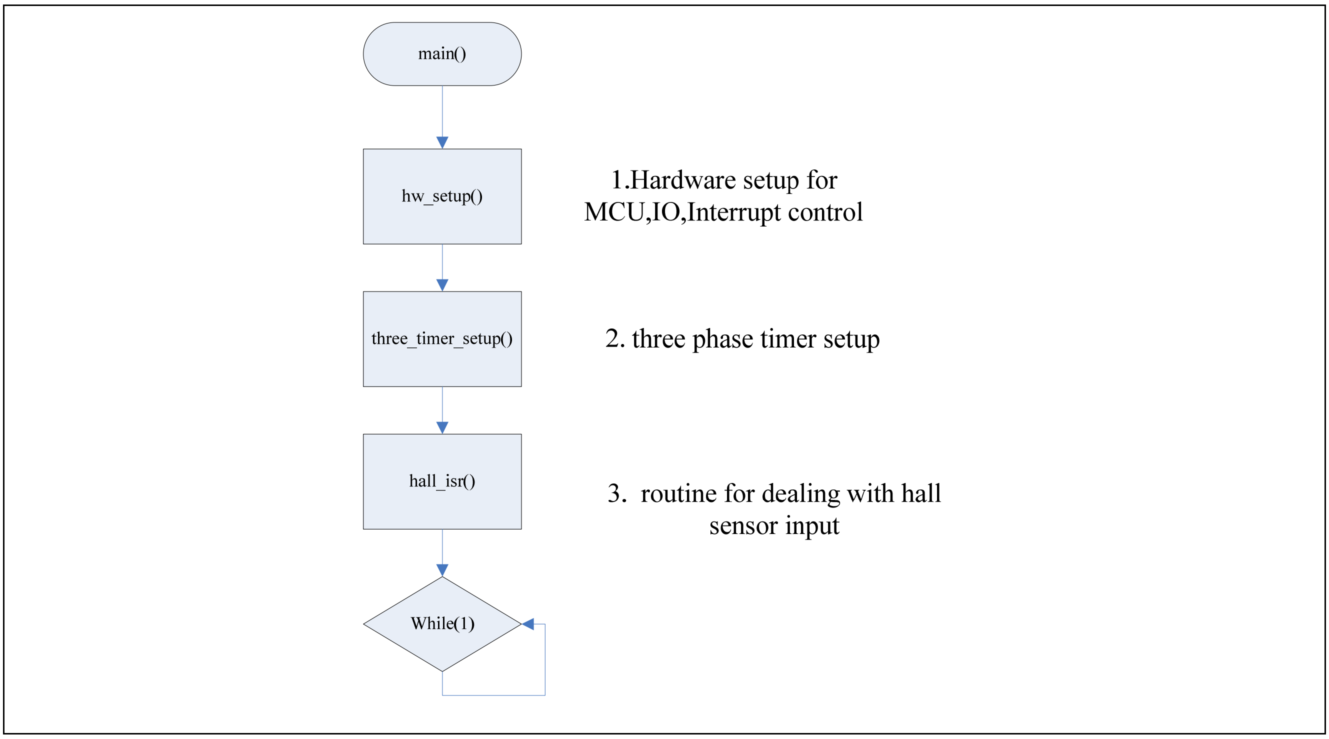


Figure 12 Program follow chart of main( )

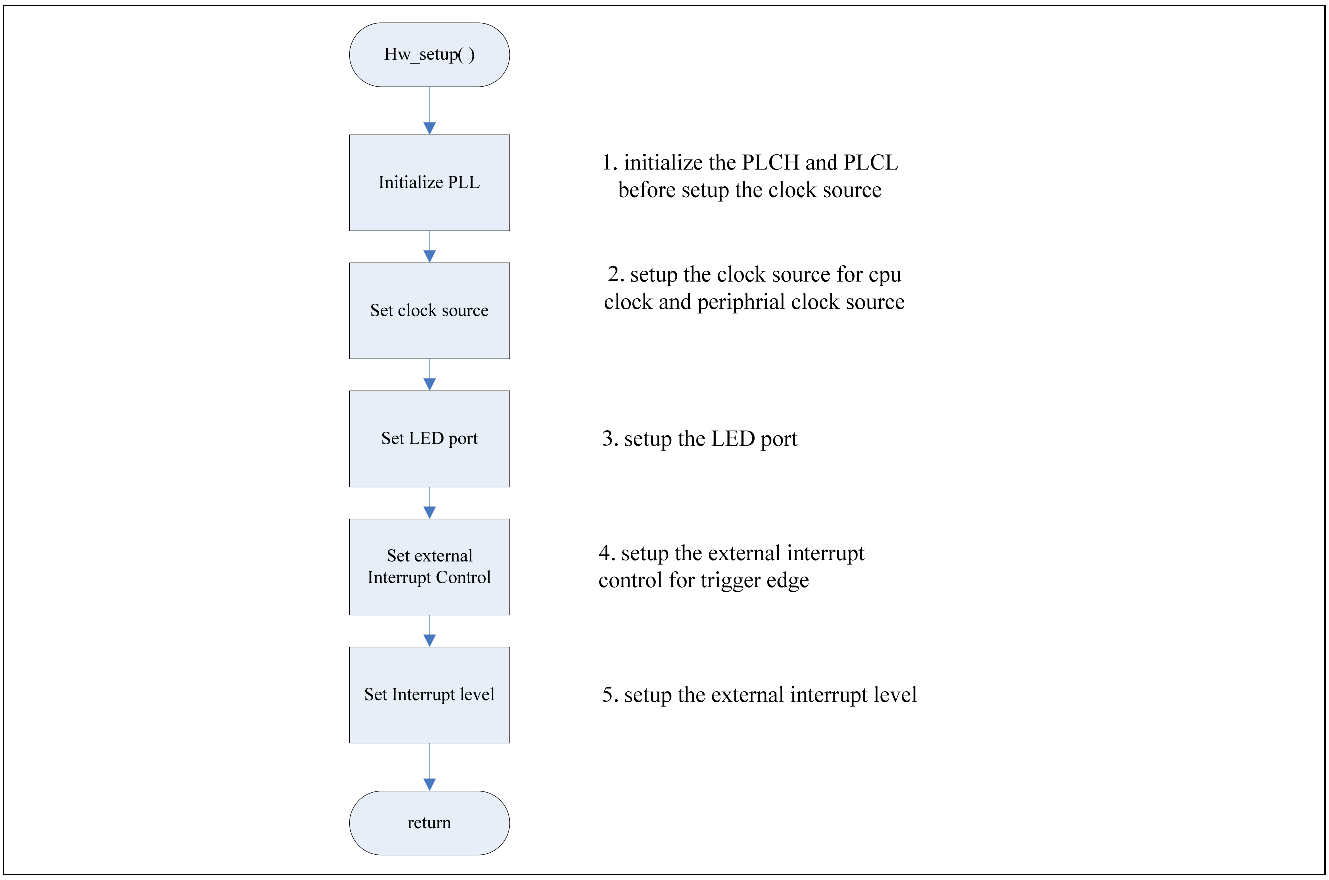


Figure 13 Program follow chart of hw_setup( )

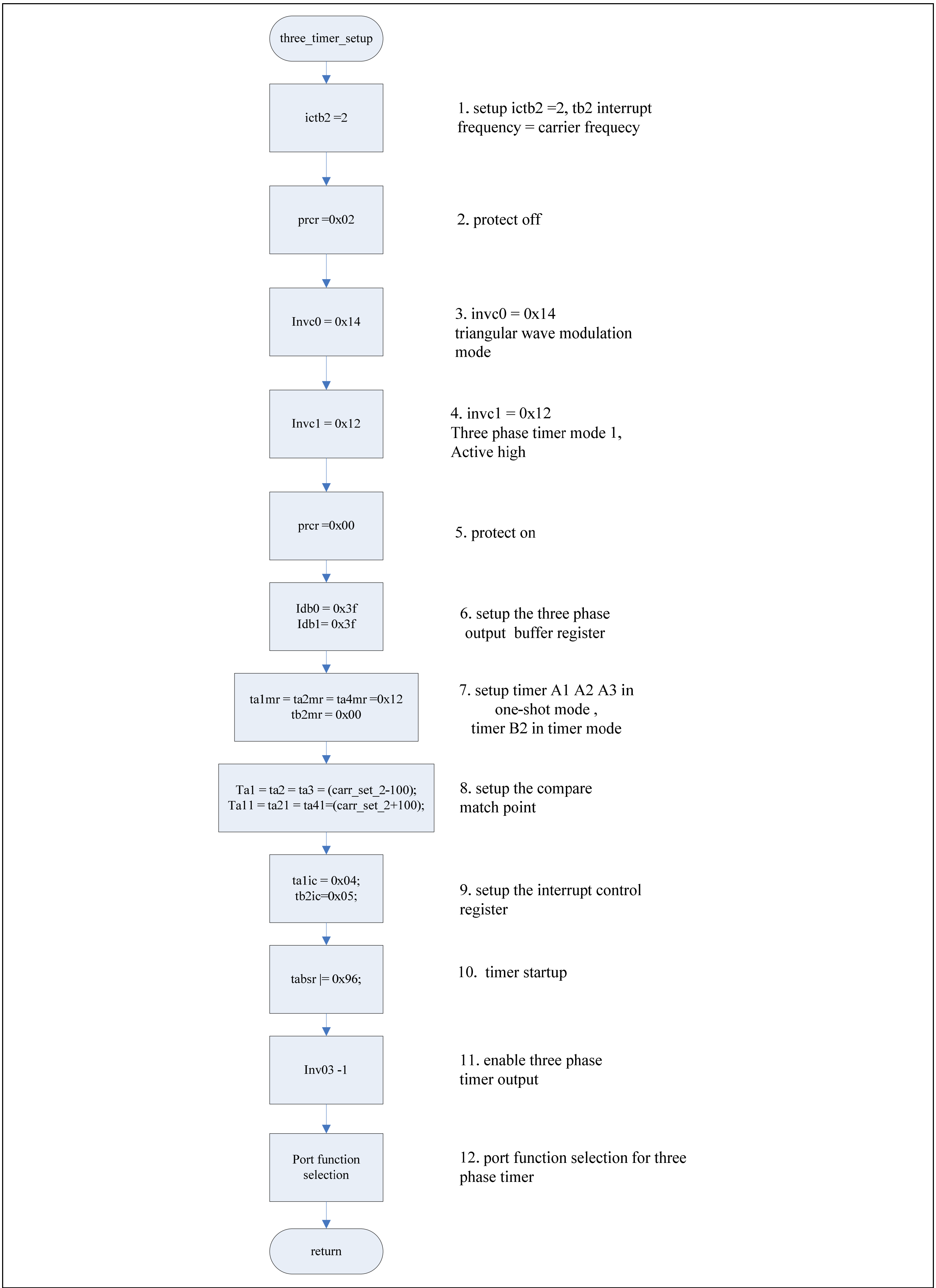


Figure 14 Program follow chart of three phase timer setup

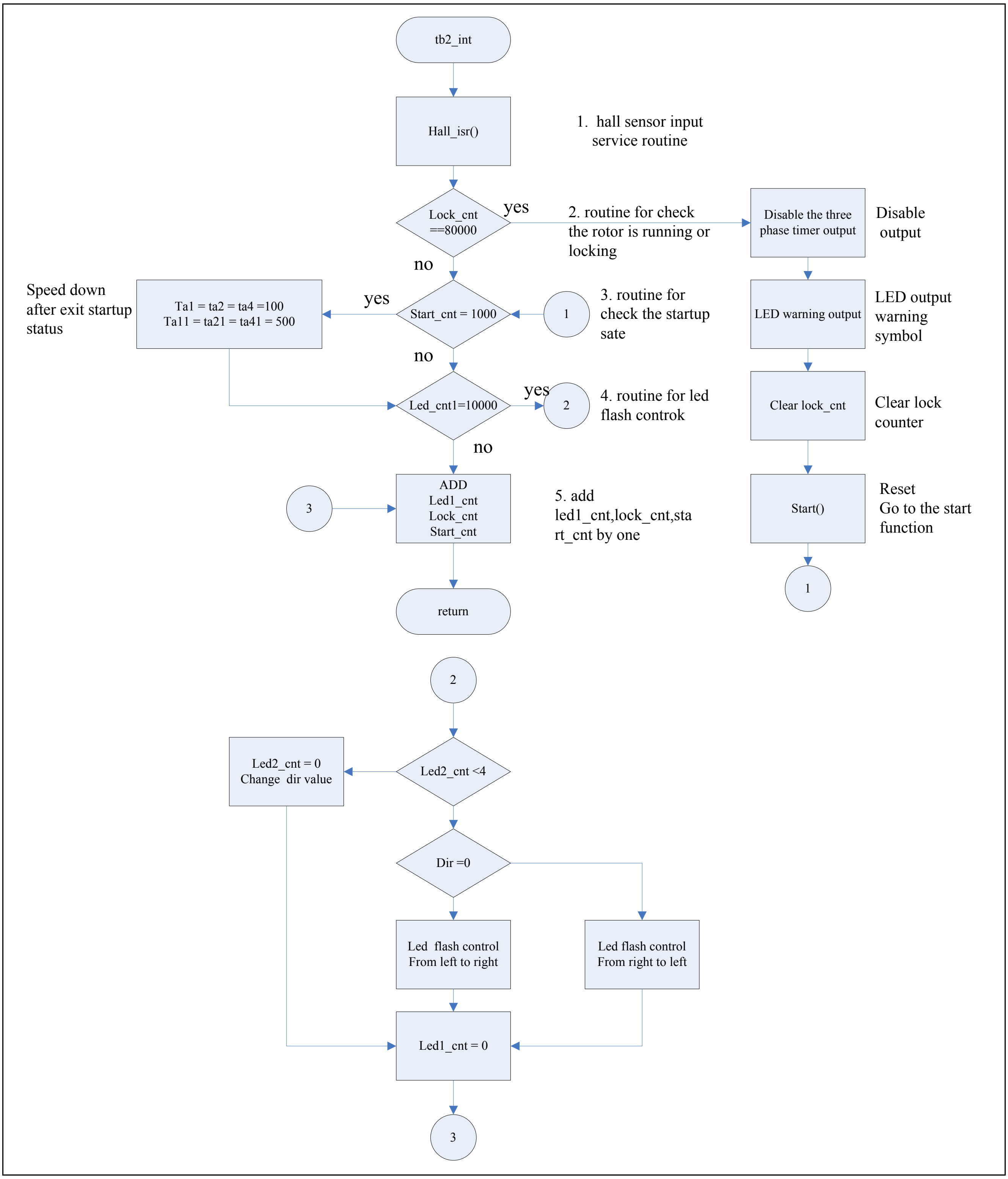


Figure 15 Program follow chart of tb2_int( )

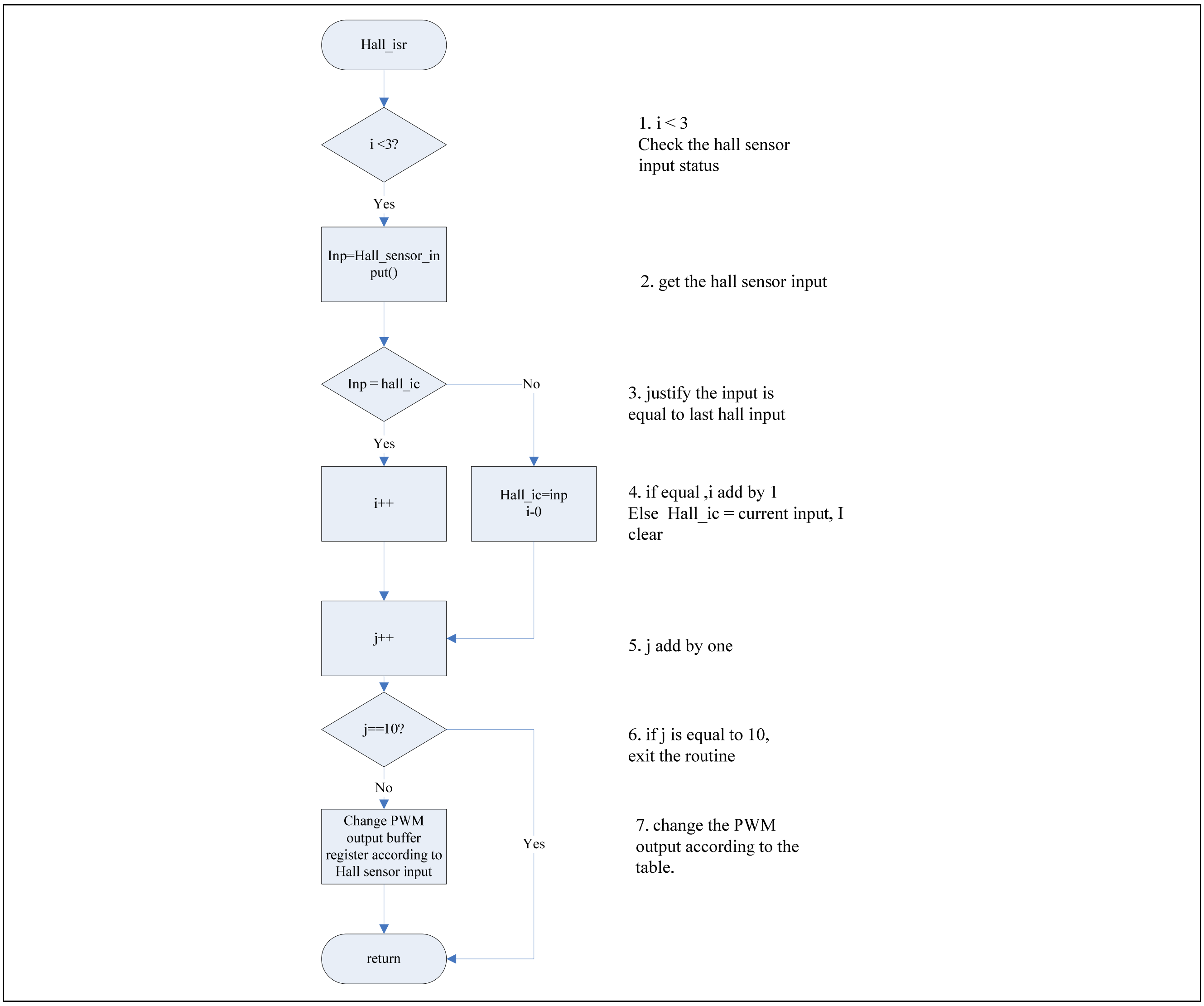


Figure 16 Program follow chart of hall_isr( )

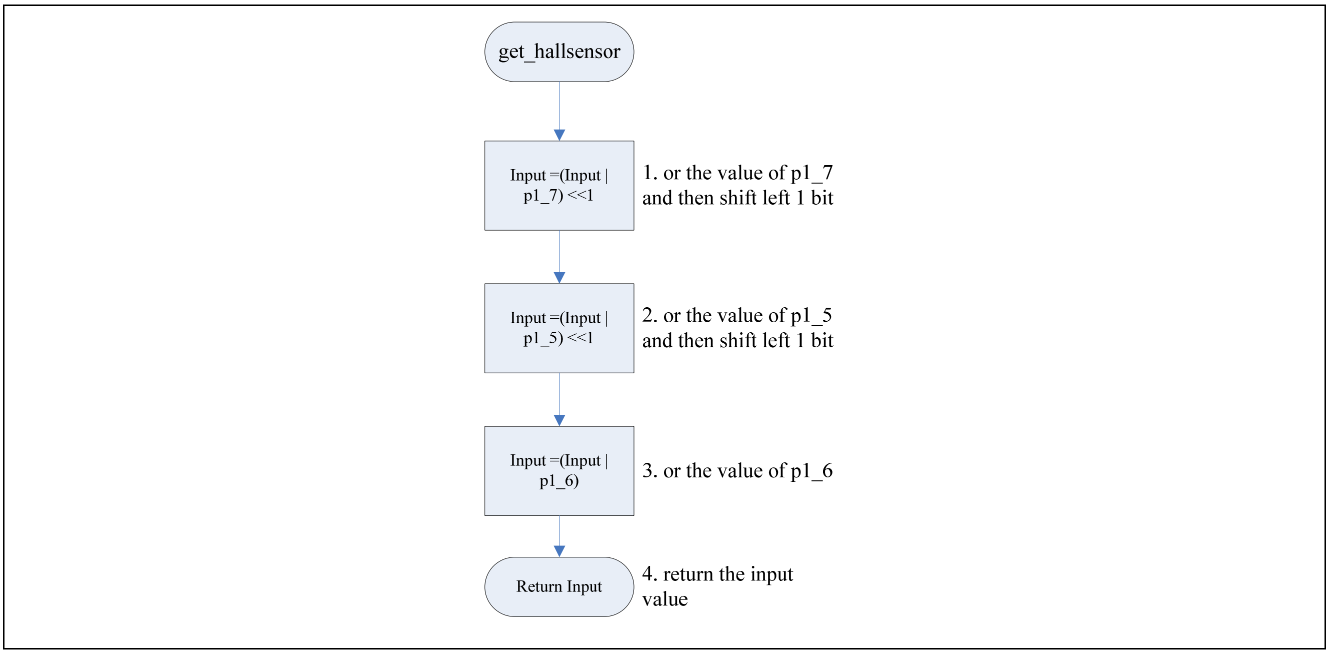


Figure 17 Program follow chart of get_hallsensor( )

5. Reference Hardware

The reference circuit of the inverter will be shown in this chapter. The connections are shown in Figure 18.

The six PWM outputs are connected to IPM and the hall sensor signals are feedback though the pulling-high circuit.

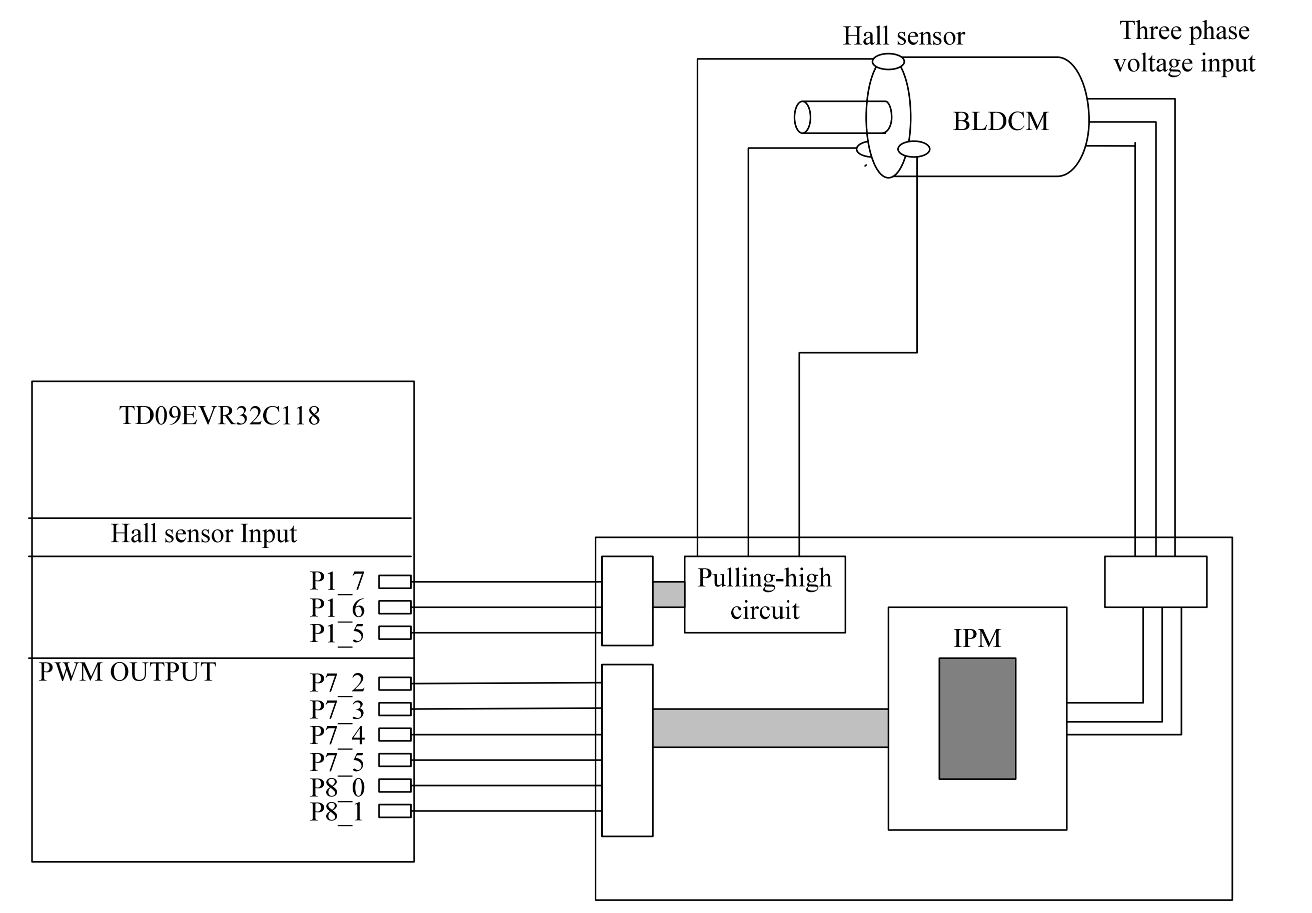


Figure 18 The hardware connection

5.1 Reference circuit of the pulling-high circuit for hall sensor input

The output stage of the hall sensors is open-drain and there are pulling-high circuit to supply the voltage to signals.

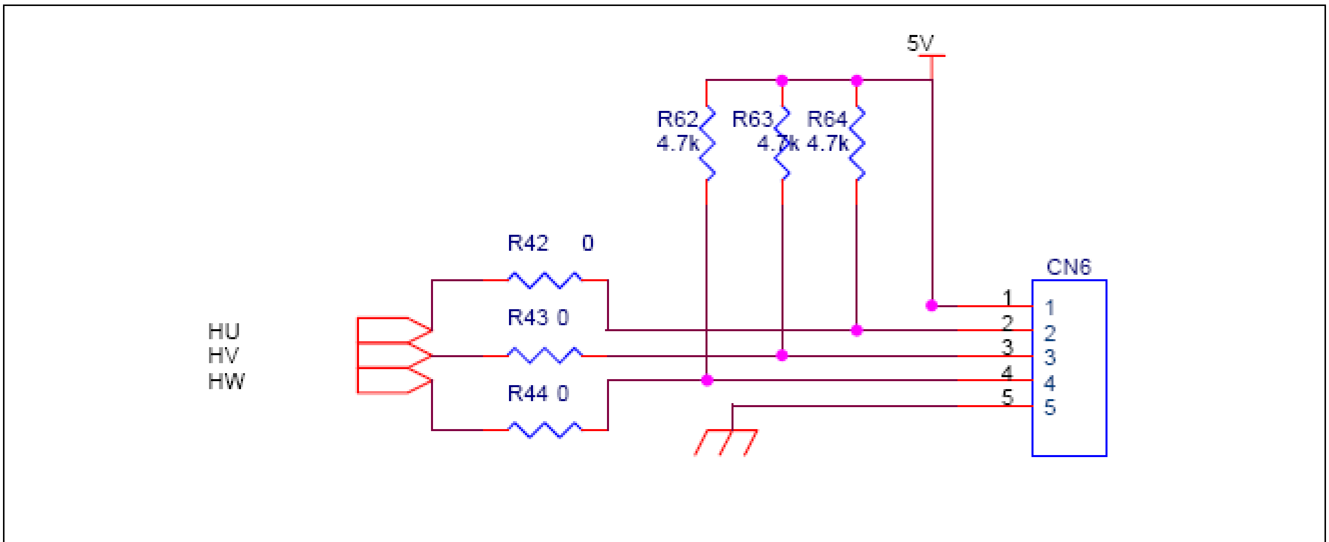


Figure 19 the pulling high circuit

5.2 Reference circuit of inverter circuit

The reference inverter circuit is shown in Figure 20. The IPM module is PS21964.

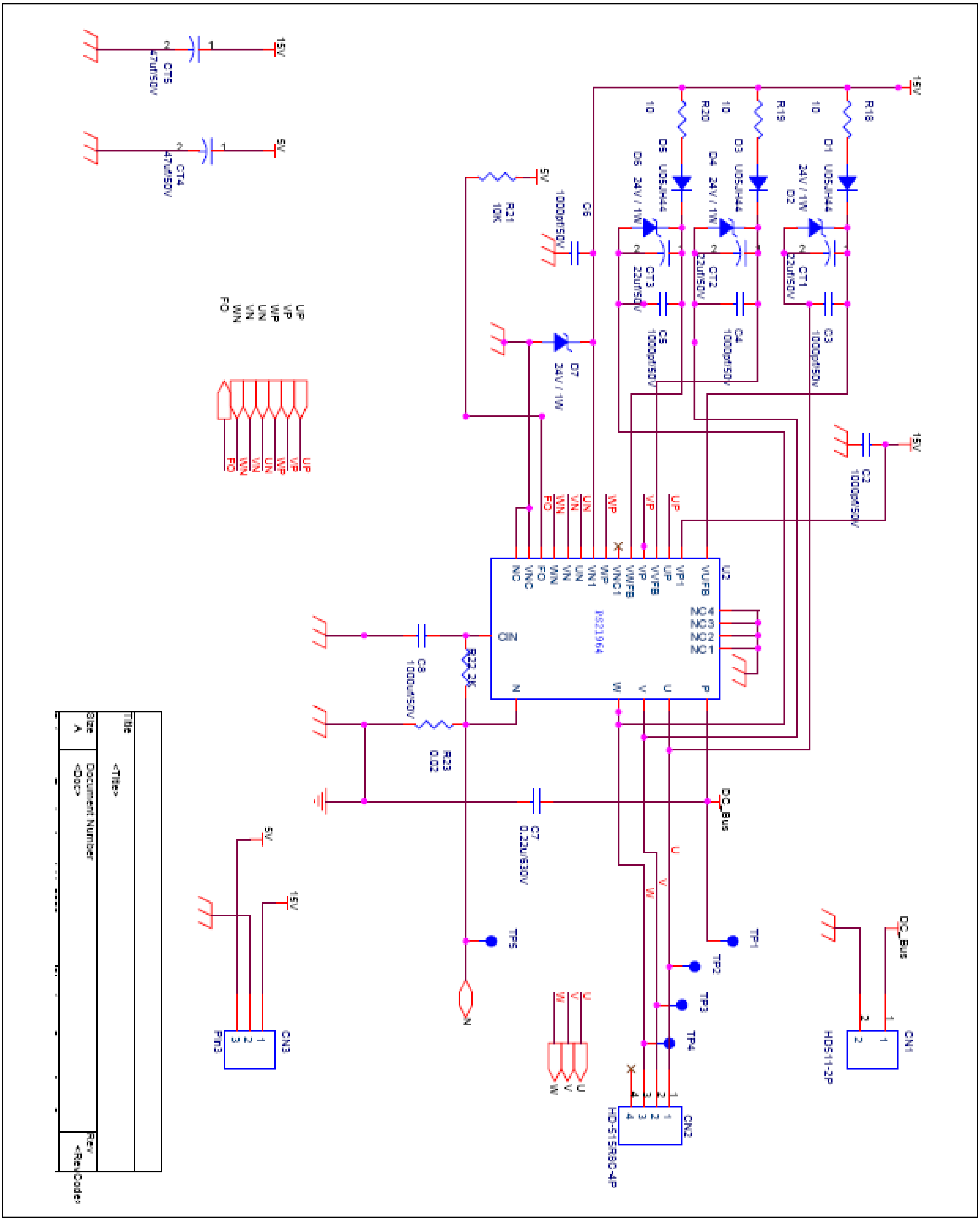


Figure 20 The reference inverter circuit

6. Website and Support

Renesas Technology Website
http://www.renesas.com/

Inquiries
http://www.renesas.com/inquiry
csc@renesas.com

Revision Record

Rev.	Date	Description	
		Page	Summary
1.00	Mar.31.10	—	First edition issued

Notes regarding these materials

1. This document is provided for reference purposes only so that Renesas customers may select the appropriate Renesas products for their use. Renesas neither makes warranties or representations with respect to the accuracy or completeness of the information contained in this document nor grants any license to any intellectual property rights or any other rights of Renesas or any third party with respect to the information in this document.
2. Renesas shall have no liability for damages or infringement of any intellectual property or other rights arising out of the use of any information in this document, including, but not limited to, product data, diagrams, charts, programs, algorithms, and application circuit examples.
3. You should not use the products or the technology described in this document for the purpose of military applications such as the development of weapons of mass destruction or for the purpose of any other military use. When exporting the products or technology described herein, you should follow the applicable export control laws and regulations, and procedures required by such laws and regulations.
4. All information included in this document such as product data, diagrams, charts, programs, algorithms, and application circuit examples, 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 products listed in this document, please confirm the latest product information with a Renesas sales office. Also, please pay regular and careful attention to additional and different information to be disclosed by Renesas such as that disclosed through our website. (http://www.renesas.com)
5. Renesas has used reasonable care in compiling the information included in this document, but Renesas assumes no liability whatsoever for any damages incurred as a result of errors or omissions in the information included in this document.
6. When using or otherwise relying on the information in this document, you should evaluate the information in light of the total system before deciding about the applicability of such information to the intended application. Renesas makes no representations, warranties or guaranties regarding the suitability of its products for any particular application and specifically disclaims any liability arising out of the application and use of the information in this document or Renesas products.
7. With the exception of products specified by Renesas as suitable for automobile applications, Renesas products are not designed, manufactured or tested for applications or otherwise in systems the failure or malfunction of which may cause a direct threat to human life or create a risk of human injury or which require especially high quality and reliability such as safety systems, or equipment or systems for transportation and traffic, healthcare, combustion control, aerospace and aeronautics, nuclear power, or undersea communication transmission. If you are considering the use of our products for such purposes, please contact a Renesas sales office beforehand. Renesas shall have no liability for damages arising out of the uses set forth above.
8. Notwithstanding the preceding paragraph, you should not use Renesas products for the purposes listed below:
   (1) artificial life support devices or systems
   (2) surgical implantations
   (3) healthcare intervention (e.g., excision, administration of medication, etc.)
   (4) any other purposes that pose a direct threat to human life
   Renesas shall have no liability for damages arising out of the uses set forth in the above and purchasers who elect to use Renesas products in any of the foregoing applications shall indemnify and hold harmless Renesas Technology Corp., its affiliated companies and their officers, directors, and employees against any and all damages arising out of such applications.
9. You should use the products described herein within the range specified by Renesas, especially with respect to the maximum rating, operating supply voltage range, movement power voltage range, heat radiation characteristics, installation and other product characteristics. Renesas shall have no liability for malfunctions or damages arising out of the use of Renesas products beyond such specified ranges.
10. Although Renesas endeavors to improve the quality and reliability of its products, IC products have specific characteristics such as the occurrence of failure at a certain rate and malfunctions under certain use conditions. Please be sure to implement safety measures to guard against the possibility of physical injury, and injury or damage caused by fire in the event of the failure of a Renesas 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 applicable measures. Among others, since the evaluation of microcomputer software alone is very difficult, please evaluate the safety of the final products or system manufactured by you.
11. In case Renesas products listed in this document are detached from the products to which the Renesas products are attached or affixed, the risk of accident such as swallowing by infants and small children is very high. You should implement safety measures so that Renesas products may not be easily detached from your products. Renesas shall have no liability for damages arising out of such detachment.
12. This document may not be reproduced or duplicated, in any form, in whole or in part, without prior written approval from Renesas.
13. Please contact a Renesas sales office if you have any questions regarding the information contained in this document, Renesas semiconductor products, or if you have any other inquiries.