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SH2 Series

V/F Control for Induction Motor Using SH7137

Introduction

This application note is shown how to use the MTU2 of the SH7137 to do the sinusoidal pulse width modulation (SPWM).The SPWM is the popular driving method for industrial motor (IM).We use the V/F control method to set the speed and voltage commands.

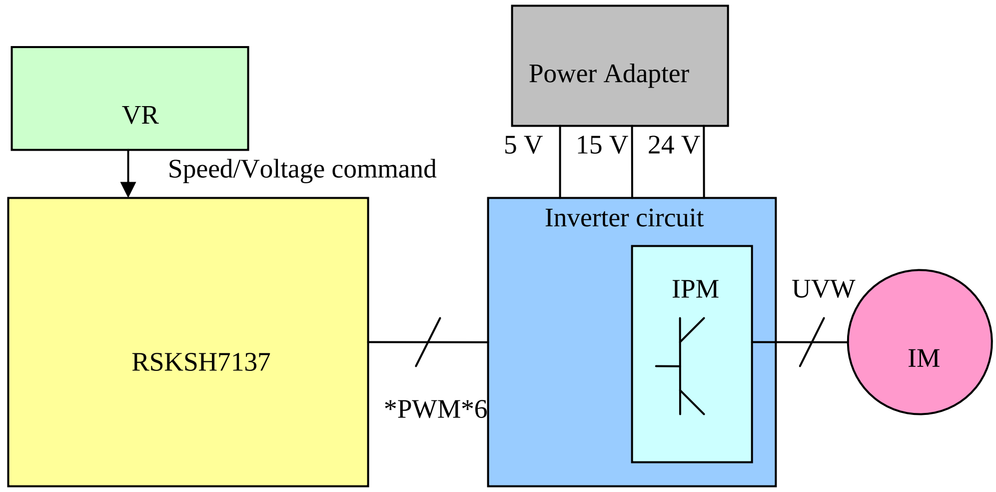
Target Device

The target device is SH2 series.

Contents

1. The Configuration of The System

The configuration of the system is shown in Figure 1. RSK27137 generates the different PWM output according by MTU2 or MTU2S. The three phase sinusoidal waveforms are generated after the PWM signals drive the Inverter board. The system is open loop system without any feedback signal to monitor the actual speed of the IM.



PWM : There are two konds of the hardware configuration.

(a) MTU2: PE9(TIOC3B), PE10(TIOC3D), PE11(TIOC4A), PE12(TIOC4B),PE13(TIOC4C),PE14(TIOC4D)
(b) MTU2S: PE16(TIOC3BS),PE17(TIOC3DS), PE18(TIOC4AS),PE19(TIOC4BS),PE20(TIOC4CS), PE21(TIOC4DS). MTU2S can not work with E10A .User need to program the code to flash memory directly when using MTU2S.

Figure 1 the configuration of the system

2. Hardware Specification

2.1 IM Specification

The specification of the motor which is used in this sample code is shown in Table1.

Table1 Motor specification

Item	Specification
Motor Type	Three phase AC Induction motor
Watt	90 Watt
V (Y Connection)	30 Volt
Rated speed	1300 RPM

2.2 Inverter Circuit

The specification of the inverter which is used in this sample code is shown in Table1.The pin connection with RSK is shown Figure 2. According to the hardware setting the PWM signal output pins are selected.

Table 2 Inverter circuit

Item	Specification
DC Bus	24 ~ 155 Volt
Current	Maximum 3A
Input Voltage for IPM module	5 and 15 Volt
IPM Module	MITSUBISHI ELETRIC PS21964-4

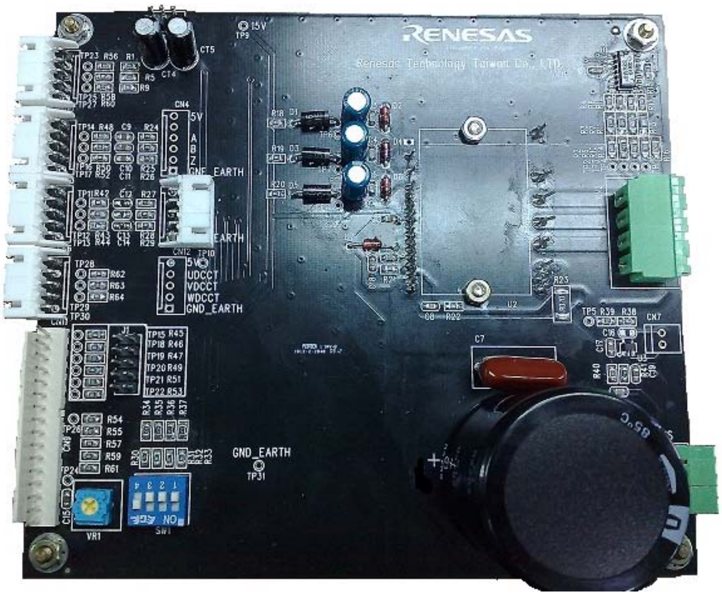
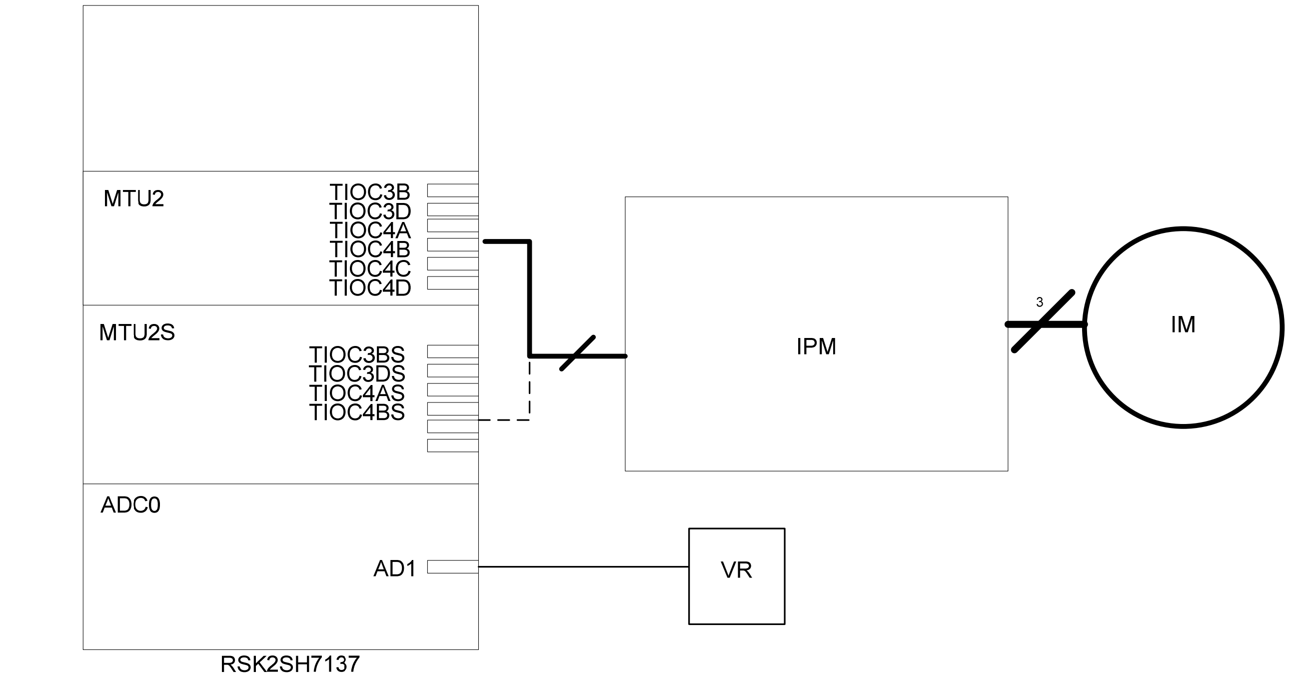


Figure 1 Reference inverter circuit



* MTU2 and MTU2S can be selected for PWM signals

Figure 2 Pin connectors of the system

3. Software Specification

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

Table 2 Software specification

Control method	V/F control
Rotor position detection	None (open loop)
Carrier frequency	20KHz
PWM method	Sinusoidal Pulse Width Modulation (SPWM)

3.1 Sinusoidal pulse Width Modulation (SPWM)

The voltage command which is sinusoidal wave can generate SPWM signals. The positive output and negative output are complement. Therefore, dead time control is necessary for SPWM. Figure 3 explains the PWM outputs of the SPWM.

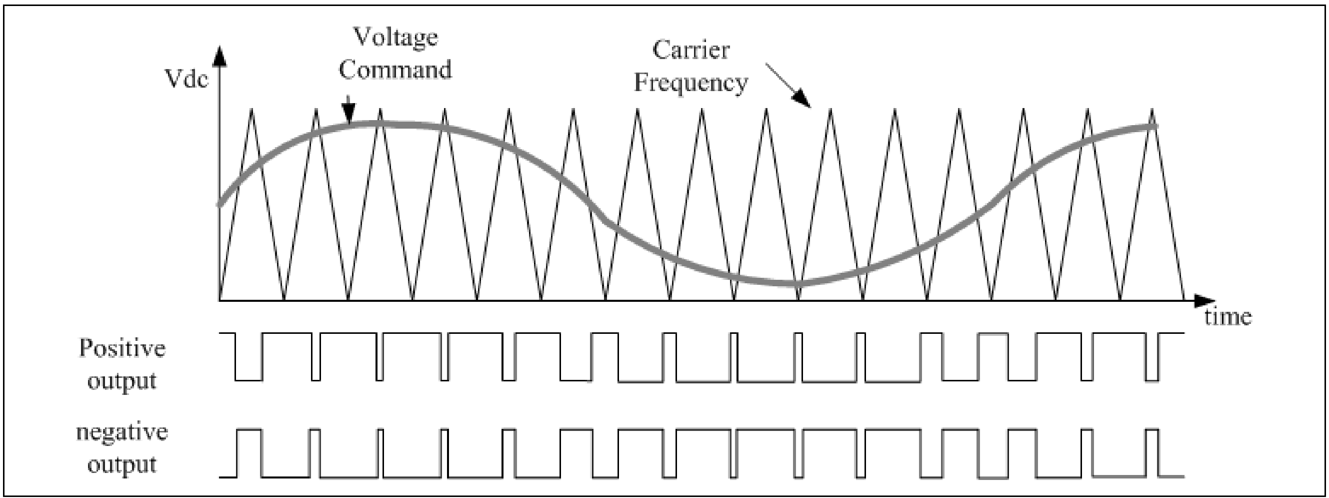


Figure 3 Sinusoidal PWM

This sample code shows how to use MTU2 or MTU2S to generate the SPWM signal. Complementary mode is used. The maximum source clocks of MTU2 and MTU2S are different. The maximum source clock of MTU2 is 40 MHz and another is 80 MHz. In this sample the MTU2 or MTU2S can be selected by definition.

If EN_MTU2 is set, system will use MTU2. On the other hand, system will use MTU2S. However debugging is unable when using MTU2S module.

```
/*****************************************************************************
Macro Defines
*****************************************************************************/
/* define for module */
#define EN_MTU2   1               /* enable MTU2  */
```

Figure 4 selection of the MTU2 and MTU2S(main.h file)

Figure 5 show the complementary mode operation of MTU2 and MTU2S. Each phase has positive output and negative output. Dead time is inserted within the transition between turning-on and turning -off of the PWM signal. There are four register and four buffer register in the module.

The specification of the SPWM can be setup in main.h. Figure 6 shows the items. CARR is the carrier frequency of the PWM. DEAD_TIME_SET is the period of dead time and unit is μs. The default setting of the carrier frequency is 20 KHz.

The PWM duty cycle calculation is according to eq2.

Value of the duty cycle variation = volt_cmd x sin θ (θ = 0 degree to 360 degree) ---------------- eq2

Therefore, TGRD_3, TGRC_4 and TGRD_4 setting can be calculation as following:

TGRD_3 = TCDR /2 - volt_cmd x sin θ
TGRC_4 = TCDR /2 - volt_cmd x sin(θ + 120)
TGRD_4 = TCDR /2 - volt_cmd x sin(θ + 240)

In order to compensate the loss which is cased by dead time, the calculations are changed as following:

TGRD_3 = TCDR /2 - volt_cmd x sin θ + Dead Time value /2
TGRC_4 = TCDR /2 - volt_cmd x sin(θ + 120) + Dead_Time value /2
TGRD_4 = TCDR /2 - volt_cmd x sin(θ + 240) + Dead_Time value/2

The output angle θ is shifted forward every carrier period.

Output angle = Previous output angle + $\Delta\theta$
$\Delta\theta$ = size of the angular shift per 100 μs (10 KHz)

The scale factor of the $\Delta\theta$ is 64.

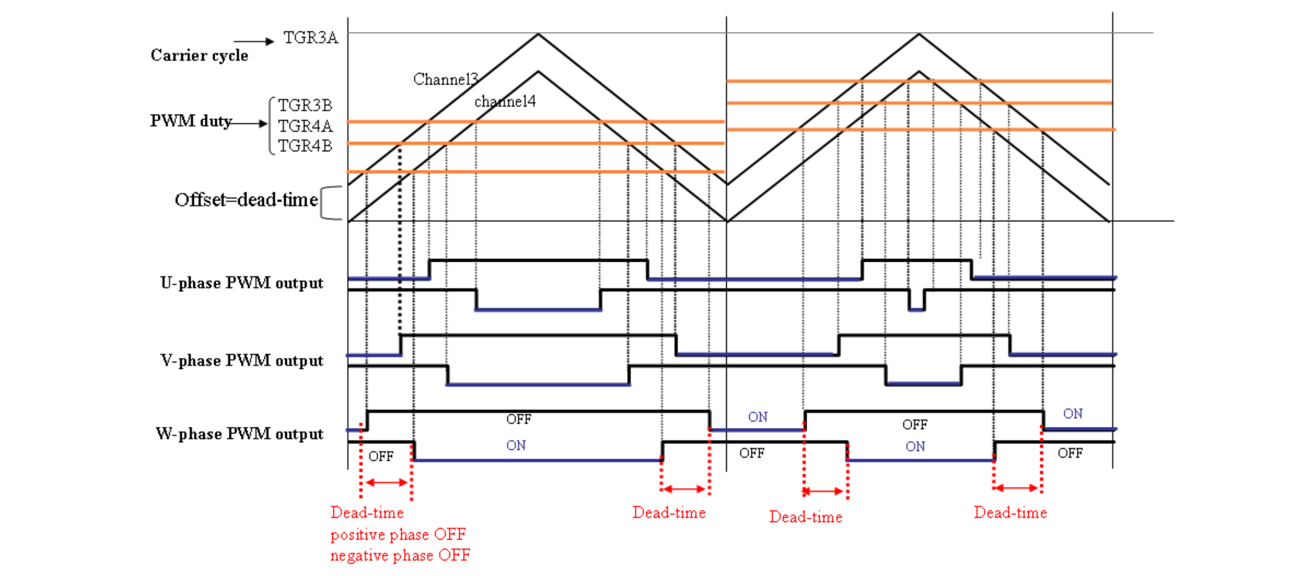


Figure 5 Complementary mode of MTU2 and MTU2S

```
/******************************************************************************
Symbol Definition
******************************************************************************/
#define CARR  15000                      /* carrier frequency Hz*/
#if(EN_MTU2)
    #define Clock   40000000              /* MTU2 use */
#else
    #define Clock   80000000               /* MTU2S use */
#endif

#define C_CYCLE     ((unsigned long) Clock /(2*CARR))
#define C_CYCLE_2   C_CYCLE/2
#define DEAD_TIME_SET  3                 /* usec */
#define DEAD_TIME   ((unsigned short) 3*(Clock /1000000))
                            /* dead time 3us                    */
                            /* DEAD_TIME = 240    */

#define PUL_CYCLE   (C_CYCLE+DEAD_TIME) /* One-half of carrier period + Dead time */

#define PUL_DUTY75  (unsigned short) C_CYCLE_2           /* Duty ratio 90% set */
#define PUL_DUTY25  (unsigned short) C_CYCLE+C_CYCLE_2    /* Duty ratio 10% set */
```

Figure 6 The settings of PWM (main.h file)

3.2 V/F Control

The induction motor speed is controlled by the driving frequency and slip. The equation can be explained as the following. The "S" is the slip and "p" is the numbers of pole in the motor. ω1 is the driving frequency and ωm is the speed of the motor.

$$\omega_m = \frac{1}{p}(1 - S)\omega_1 \quad \text{-- (eq.1)}$$

There two methods for change the driving frequency ω1: One is V/F control and another is vector control. V/F control is to change the output voltage and the driving frequency ω1 at the same time. The main magnetic flux will not be changed with frequency because the ratio of the output voltage and driving frequency is constant. Figure 7 shows the operation of the V/F control. Voltage to frequency ratio is constant when the driving frequency is beyond the frate and the torque will be the constant because of the constant excitation current. If the driving frequency is above the frate and the output voltage is the maximum value, the torque will reduce and not be easy to control. In this sample code the driving frequency will be beyond the rate frequency according to the specification of the motor.

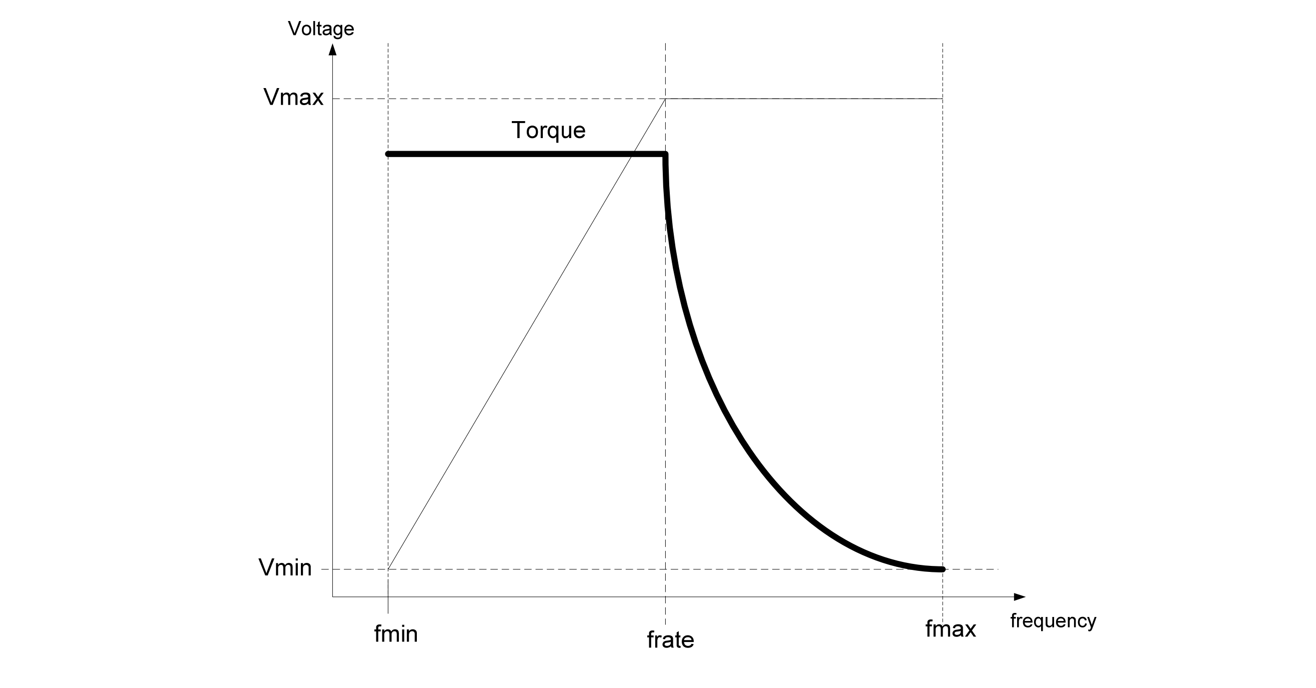


Figure 7 V/F Control

The V/F control command can be adjust by the various register. The operation of the V/F control is shown in Figure 8. The maximum frequency is set to 50Hz and minimum is set to 10Hz. The maximum voltage command is set to 1000.

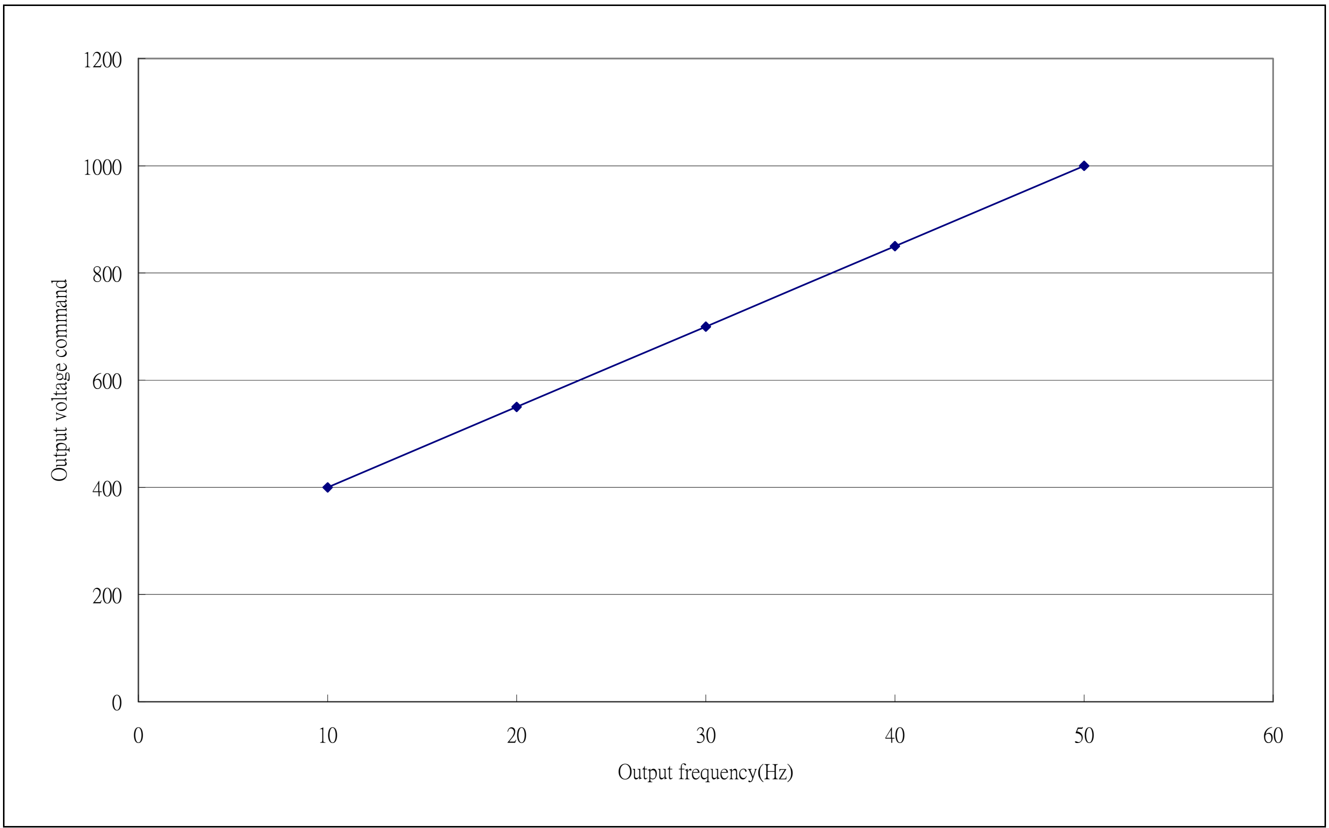


Figure 8 V/F Control Table

3.3 Motor Control

The block diagram of the sample code is shown in the Figure 9.The output frequency is got from adc every 0.5 sec and calculate the shift angle and the voltage command every 10 ms. The calculation of the output angle and the three phase output PWM duty is every 100 μs(10KHz).

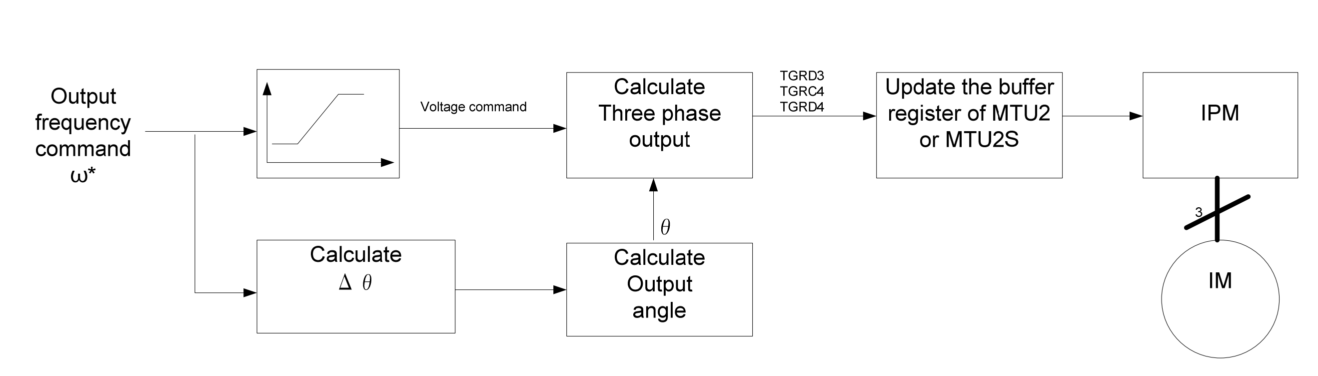


Figure 9 The block diagram of the motor control

The motor rotate with the constant speed during 2 sec. Then, the speed command is used for the speed control.

The operation is shown in the Figure 10.

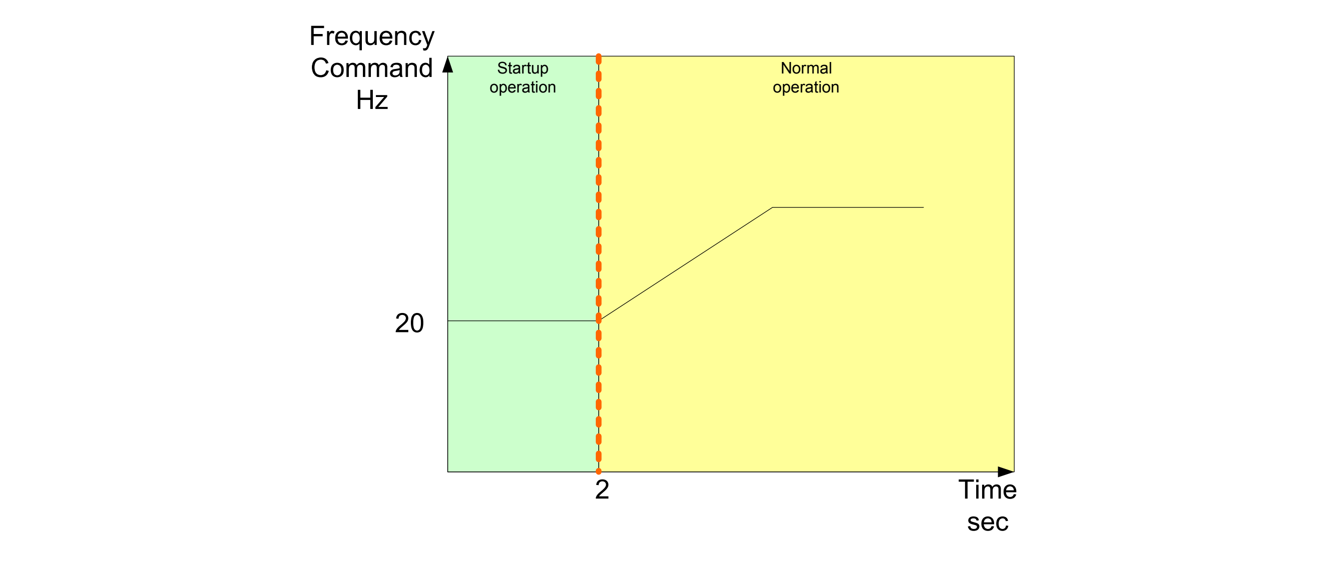


Figure 10 The startup processes of the motor Program follow chart

4. Reference Hardware

4.1 Reference Circuit of Inverter Circuit

The reference inverter circuit is shown in the Figure11. The IPM module is PS21964.

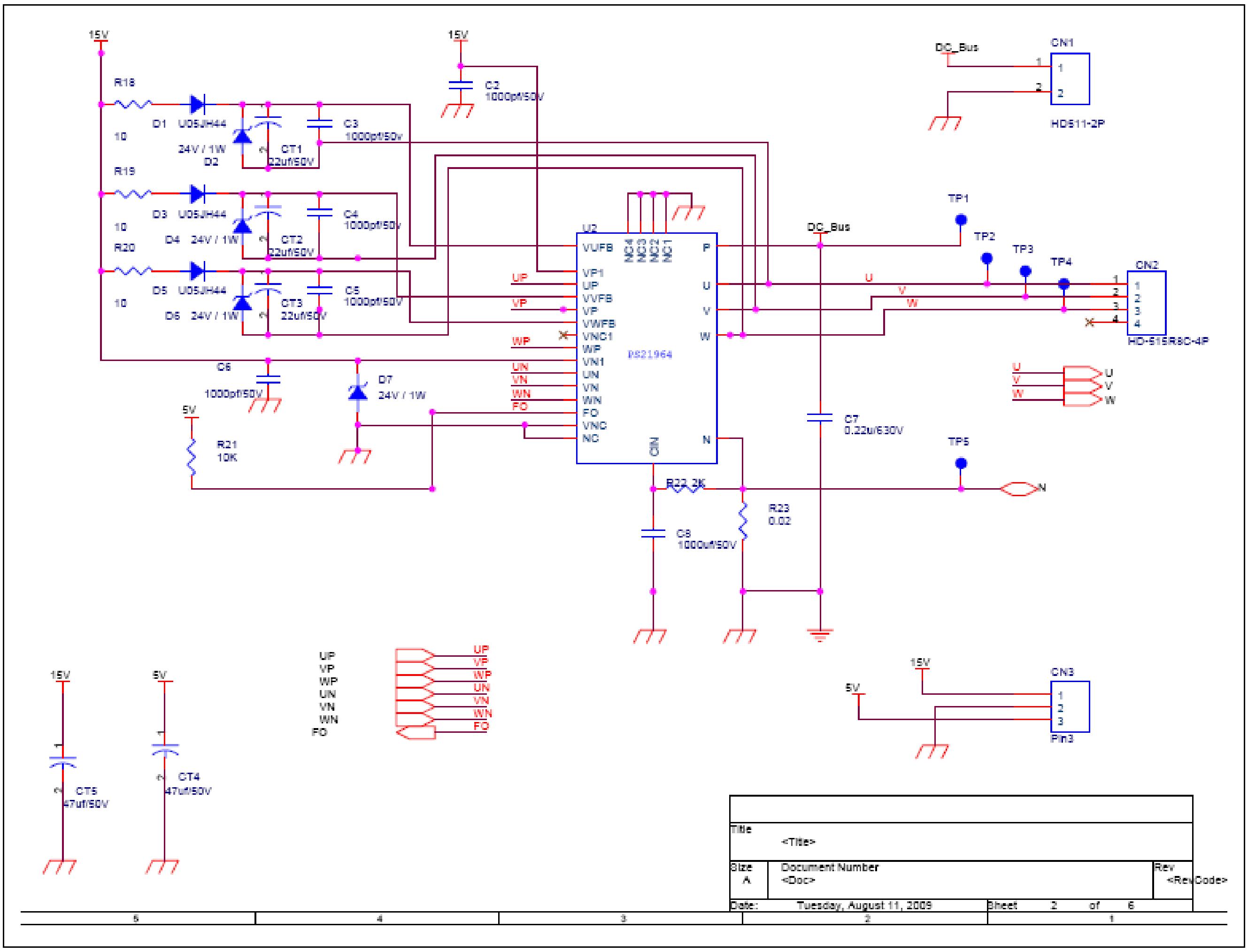


Figure 11 The reference inverter circuit

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