Hardware Design of Brushless DC Motor System Based on DSP28335

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Abstract

This article selects TI's TMS320F28335 floating-point digital signal processor as the main controller, and designs the overall block diagram of the hardware circuit of the brushless DC motor speed control system. Including power supply design, speed detection circuit design, current detection circuit design, rotor position detection circuit design, and power drive circuit design, etc. The article gives the overall design of the system, analyzes the working principle of the brushless DC motor, and proposes the design strategy of the drive circuit and the control circuit. The basic structure, working principle and design method of the system are described. The paper also makes a detailed analysis of the hardware control principle and circuit design, as well as various software modules (including position signal detection, fault protection interrupt handling, etc.).

Keywords

DSP, Brushless DC Motor(BLDCM) , Hardware.

1. Introduction

Brushless DC motors replace mechanical commutation methods with electronic commutation. Because of its simple structure, reliable operation, no excitation loss and other characteristics, and is not subject to mechanical commutation restrictions, easy to achieve large capacity, high speed, so widely used in all walks of life.

The TMS320F28335 DSP is a 32-bit floating point digital signal controller. Compared with the traditional fixed-point DSP, the controller can perform more complex floating-point operations, can save code execution time, improve the system's response speed, and provide advantages for the advanced control theory and the realization of complex control algorithms. Support greatly improves system flexibility, accuracy, and control performance [1].

The power drive module of the brushless DC motor speed control system adopts Mitsubishi's intelligent power module (IPM), and the model number is PSS30S71F6. The intelligent power module integrates a three-phase AC/DC inverter, a high-low side driver chip, a temperature sensor and control power supply low-voltage protection (UV), short-circuit protection (SC), and a built-in bootstrap diode with a current limiting resistor. It is suitable for low power motor control system with AC voltage between 100V~240V, or DC motor with voltage below 400V. And it has the advantages of low price and short development time.

2. Motor control principle

In order to clearly explain the commutation principle of the brushless DC motor, the three-phase star full-control bridge circuit will be taken as an example to explain the commutation signals of the Hall position sensor described above.

A three-phase bridge type Y-connected motor has two phases conducting at any time under ideal conditions to form a current path. The Hall sensor outputs 6 states during one revolution of the motor rotor.

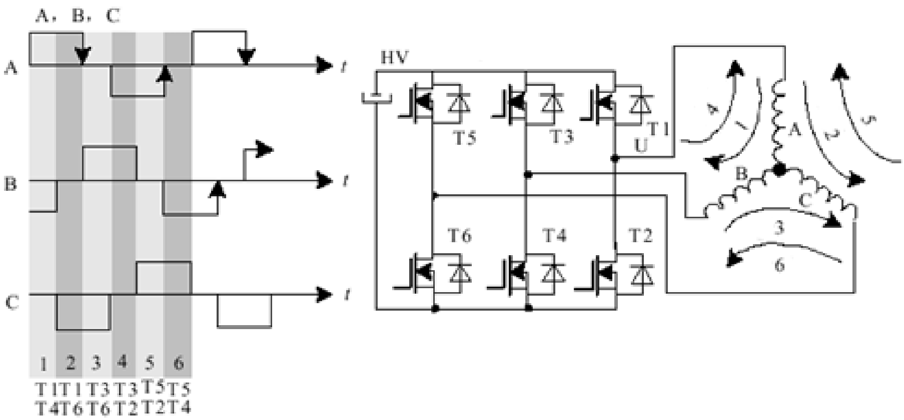

Figure 1. Three-phase star full-control bridge circuit and current waveform diagram

Table 1. Correspondence table for conducting power tube and stator synthesis magnetic potential

Stator magnetic potential	Fa1	Fa2	Fa3	Fa4	Fa5	Fa6
Conductive power tube	T6T1	T1T2	T2T3	T3T4	T4T5	T5T6

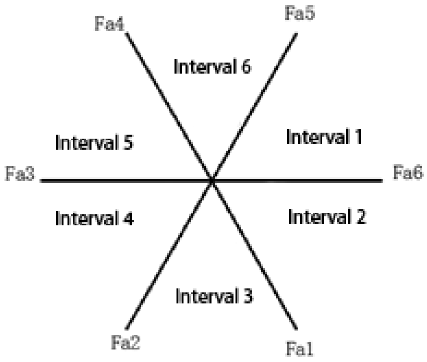

Figure 2. Stator magnetic potential vector diagram

Take the inverter bridge in Fig. 2 as an example. T6 and T1 are turned on in position sensor output state 1, T1 and T2 are turned on in state 2, T2 and T3 are turned on in state 3, and T3 and T4 are turned on in state 4. 5 T4 and TS turn on, state 6 turns on TS and T6, as shown in Table 1. Each state lasts for π/3 electrical degrees, so that it is spatially divided into six intervals, as shown in Fig. 2. The corresponding rotor rotates in the corresponding interval. The waveform diagram in Fig. 1 is the power tube in Table 1 Switching logic diagram of three-phase winding conduction.

As can be seen from the above, each power tube turns on π/3 electrical angles during one cycle. The inverter bridge is a lateral commutation mode. The stator windings conduct each π/3 electrical angle positively and negatively every cycle, and the positive and negative current intervals are π/3 electrical degrees. At any time, the stator has two phase windings energized and generates stator magnetomotive force. As the rotor position signal changes, the stator composite magnetomotive force takes π/3 as the step, the stepwise rotation, the rotor magnetic field in the stator magnetomotive force Under the effect of synchronous rotation [2].

3. Hardware circuit design

Based on the analysis of brushless DC motor control system, the design of high-performance and practical digital control system of brushless DC motor based on TMS320F28335 is carried out, and the hardware structure of the control system is shown. Among them, TMS320F28335 captures the unit, captures the pulse signal on the rotor position sensor of the electrical machinery, calculates the rotor position, and outputs the appropriate driving logic level to the intelligent power module, then drives the electrical machinery to rotate by it. The TMS320F28335 calculates the current speed of the motor based on the width of the captured Hall position sensor pulse signal. After comparing with the set speed of the motor, it generates a speed deviation signal. The deviation signal generates a current reference through PI regulation; the given reference is compared with the actual current again to generate a current deviation signal, and an appropriate PWM signal is generated by the PI algorithm to control the rotation speed of the motor. TMS320F28335 uses the A/D and I/O ports to collect the motor's speed setting value and the start/stop, forward/reverse, and braking commands of the motor to control the motor's running status. The intelligent power module can complete the motor's over-current and low voltage. Fault protection such as abnormal drive timing.

3.1 System rectifier circuit design.

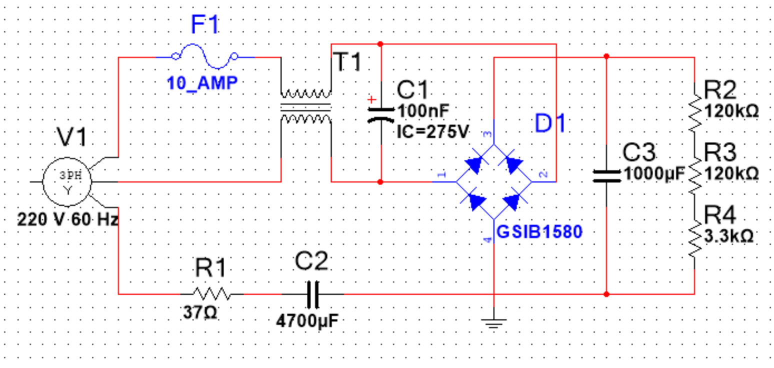

Figure 3. Rectifier circuit

The power of the selected motor used in this project is 300W, rated voltage is 220V, and rated current is 1.6A. Then need to use single-phase bridge rectifier module, use single-phase rectifier module GSIB1580, rectifier circuit shown in Figure 3.

3.2 Power Drive Circuit Design.

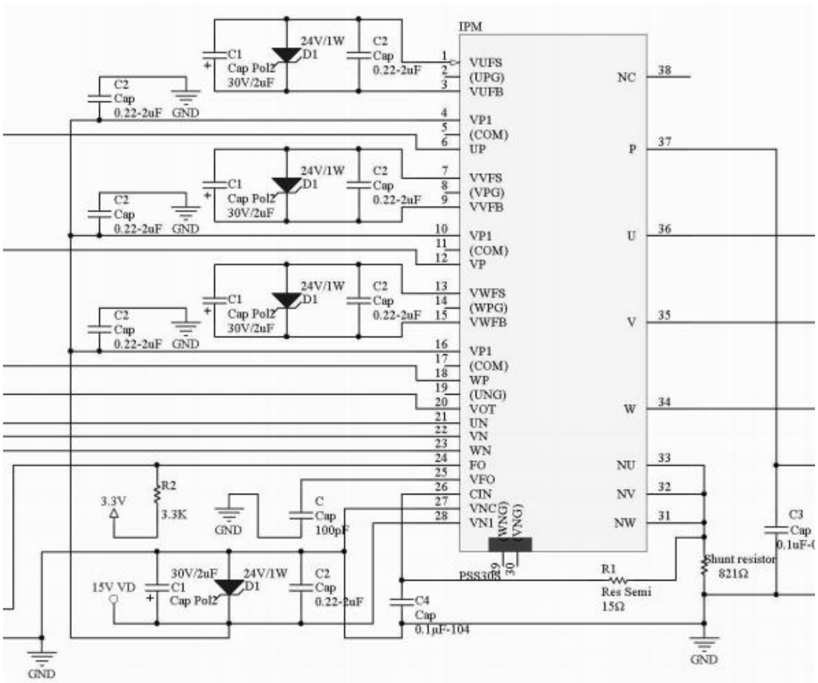

Figure 4. IPM peripheral circuit

The power drive part is an important part of the control system. In my design, Mitsubishi's PSS30S71F6 is used as the drive module. This smart power integrated circuit has better safety and reliability. As shown in Figure 4, the external circuit of the power driver chip. When designing a circuit, it is important to note that:

1). If control GND is connected with power GND by common broad pattern, it may cause malfunction by power GND fluctuation.It is recommended to connect control GND and power GND at only a point N1 (near the terminal of shunt resistor).

2). It is recommended to insert a Zener diode D1(24V/1W) between each pair of control supply terminals to prevent surge destruction.

3). To prevent surge destruction, the wiring between the smoothing capacitor and the P, N1 terminals should be as short as possible. Generally a 0.1-0.22μF snubber capacitor C3 between the P-N1 terminals is recommended.

4). The point D at which the wiring to CIN filter is divided should be near the terminal of shunt resistor. NU, NV, NW terminals should be connected at near NU, NV, NW terminals when it is used by one shunt operation. Low inductance SMD type with tight tolerance, temp-compensated type is recommended for shunt resistor [3].

3.3 Detection circuit design.

The reference speed of the brushless DC motor can be given through an external potentiometer, through the A/D conversion of the DSP, or through the external keyboard. For the measurement of the motor speed, usually through the speed measuring element, the speed measuring elements are divided into two categories: analog speed measuring elements and digital speed measuring elements [4].

There are two main roles of the position sensor: one is to detect the relative position of the stator and rotor of the motor and to provide the commutation signal of the phase winding of the motor; the other is to form the feedback link of the speed together with the controller.

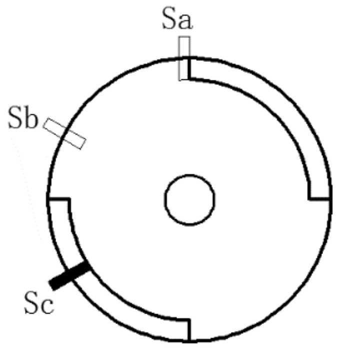

Figure 5. Position sensor arrangement

The brushless DC motor used in this project is equipped with a Hall element type position sensor. The sensor consists of a stationary part and a rotating part. The stationary part consists of a set of Hall elements and a permanent magnet block and is fixed on the motor frame. The rotating part is a shading plate with teeth and slots. (The number of teeth and slots are equal to the number of motor pole pairs, respectively). It is fixed on the motor shaft and rotates synchronously with the rotor. By shielding and not blocking the teeth of the shading plate, the Hall element generates high and low level signals, thereby providing rotor position information of the brushless DC motor. Figure 4 shows the position sensor installation[5].

3.4 Detection circuit design.

Phase current detection circuit shown in Figure 3.4, the phase current through the R64 and then amplified by the operational amplifier LM258P, sent to the DSP's AD conversion port. In order to prevent some high-frequency signal interference, the LM258P amplification output signal needs to be filtered and A/D converted.

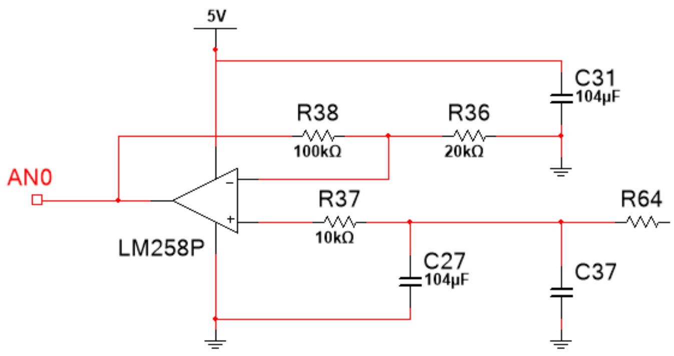

Figure 6. Phase current sampling circuit

4. Conclusion

This design is based on the TMS320F28335 brushless DC motor control system. The circuit outside the system is simple, the safety and reliability are good, and the cost is low. It is especially suitable for the control of low-power brushless DC motor. It has practical significance and broad market value.

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