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DESIGN AND IMPLEMENTATION OF HIGH POWER DENSITY MOTOR DRIVE

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Abstract:-
Based on the demand of low-voltage, small-size and high-current motor drive in the vehicle-mounted servo system, the low-voltage and high power density motor drive, which used TMS320F2812 of TI as the control unit, Incremental encoder and small-value, high-power sensor resistor as motor speed and current acquisition unit, low-voltage and high power density MOSFET as driving unit, was designed and implemented. The hardware of driving system was introduced in details, and then the designs of high-density PCB, structure and technology, with relevant speed control of nested segment and parameters testing procedures, were employed to improve the driver integration and reliability. A DC servo motor with a rated current of 20 amps is used as a test motor. The experimental results indicate that the driving system has the advantages of high steady-state accuracy and stable load response.

Keywords: - *high power density; TMS320F2812; the design of high density PCB; DC servo motor*

INTRODUCTION

Modern motor servo system was first applied to the aerospace and military fields, and later gradually into the industrial, civilian areas. According to the survey, in the field of special industrial control of low-voltage environment such as vehicle-mounted, due to its harsh environment and high system integration, products are often required to have better environmental adaptability and smaller space occupation ratio, while similar motor drive products are generally used domestically Therefore, the design of such motor drives can help to break the foreign technology blockade and increase the localization rate of our country's automated equipment systems.

In view of the above situation, this paper designed and implemented a TI-based TMS320F2812 as the main control unit, the incremental encoder and the sampling resistor for the signal acquisition unit, the MOSFET power driver unit low-power high-density motor driver, and the structure Compact design and the corresponding thermal design. The drive has the characteristics of high steady precision, simple and compact structure, stable and reliable operation.

1. System control theory

This test motor selection DC servo motor, DC motor speed n is expressed as:

$$n = (U - IR)/(K\Phi)$$

Where: U-armature voltage, I-armature current, R-armature resistance, Φ -flux per pole, K-constant related to the motor structure.

In this paper, the control method of regulating voltage and speed is adopted, and the widely used pulse width modulation (PWM) converter (or DC chopper) is used to control the motor armature voltage to realize a large range of smooth speed regulation.

The system control scheme uses two control loops, namely speed loop and current loop, all adopt PI regulator.

2. System hardware design

System hardware includes the main control unit, signal detection unit, power drive unit and hardware fault protection unit, as shown below

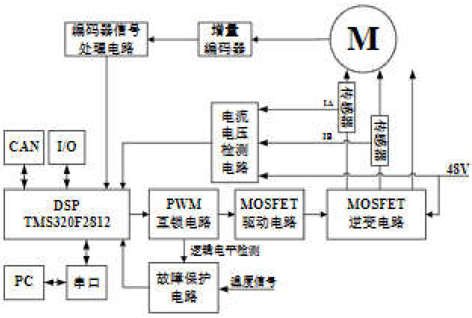

Figure 1 system hardware structure

2.1 Master unit

The main control unit includes DSP signal processor circuit and logic interlock circuit.

DSP processor chip selection TI's TMS320F2812 as a controller, the high-speed performance of the series DSP to enable it to handle multiple channels of data to achieve multi-channel control conversion. The main completion of the command to accept, a variety of signal acquisition, PWM signal generation, output torque control, speed tracking control, fault handling and other tasks, is the core of the whole system.

Logic processing circuit to achieve the main logic level PWM output interlock to protect the MOSFET inverter circuit.

2.2 Signal detection unit

In order to realize the drive control of the DC motor, it is necessary to detect the DC bus voltage, the motor armature current, the rotation speed and the angle of the rotor. Mainly include motor armature current sampling circuit, DC bus voltage sampling circuit, analogy signal input and digital I / O signal interface circuit. Conditioning circuit for a variety of digital analog input and output signals for normalization, digital processing into the DSP.

2.2.1 Motor phase current detection circuit Motor armature current detection circuit through the low-resistance sampling resistor 5mΩ / 2W phase current partial pressure acquisition, and then input to the DSP after op amp feedback current loop closed-loop operations. The current detection circuit implementation is as follows:

System design Rated sampling current 20A, the resistance of the voltage divider to 0.1V, 28.2A overload sampling current, the resistor divider 0.141V, the current sampling chip IR2175S output frequency of 130 kHz, duty cycle PWM wave into the corresponding DSP corresponding The CAP port to sample the PWM wave duty cycle to reflect the current phase current size. Which IR2175S rated input 260mV ~ +260 mV, the output PWM duty cycle of about 9% to 91%, and over-current signal / OC. Power supply MOSFET driver chip bootstrap capacitor supply.

2.2.2 DC bus voltage and current sampling circuit
The driver can convert the DC voltage at the DC bus to a voltage of 0-3V through the method of dividing the resistance by a large resistance and input it to the AD port of the DSP through the first-order active filter circuit.

2.2.3 Motor speed and angle measurement circuit
Motor speed and angle measurement circuit maximum output 5V / 200mA power supply, speed feedback sensor for the standard 5V differential incremental signal interface, the signal label is CHA +, CHA-, CHB +, CHB-, INDEX +, INDEX-, where INDEX signal for the motor Zero judgment, the incremental signal through the level conversion circuit input to the DSP chip, and for the motor angle of the precise determination and correction. In this paper, T method to make the difference between the motor angle in order to achieve the determination of motor speed.

2.3 Power drive unit
The power drive unit adopts the current mainstream linear PWM drive method. This method can realize the four-quadrant operation of the motor and is suitable for motor position control, speed control and torque control, and can be applied to AC motors and brushless DC motors.

The driver input voltage is DC7.559V.MOSFET rated voltage = input DC voltage + regenerative braking voltage increase + surge voltage + design margin, generally consider the MOSFET rated voltage control in the bus voltage 1.5-2 times. System bus voltage up to 60V, so the rated voltage of the MOSFET is at least 90V.The driver has a rated current of 20A and an overcurrent of 28.2A, so a MOSFET with a drain current of 60A or more can be used with sufficient heat dissipation. Therefore, the model number is selected as Infineon's BSC060N10NS3 MOSFET with source-drain resistance the voltage is 100V and the drain current is 90A.

MOSFET driver chip selection TI's LM5101 driver chip.LM5101 gate drive voltage output range of 9V ~ 14V, with under-voltage protection of hardware, unprotected output, which drives the upper and lower edges and the total delay time is less than 66ns. Inverter circuit diagram as shown below

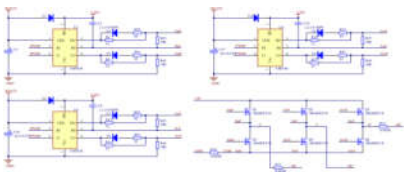

Figure 2 inverter circuit diagram

The PWM control signal for the control MOSFET is generated by the DSP at a frequency of 10 kHz and is logically protected before being directly input to the LM5101 and outputting a 12V level PWM wave control MOSFET to drive the motor.

2.4 Fault protection unit
Fault protection unit includes PWM logic protection circuit, brake protection output, over-temperature protection circuit.

2.4.1 PWM logic protection circuit
As the power MOSFET core input signal, PWM wave output must ensure that the MOSFET does not exist through the bridge through the signal, so we drive the front-end input logic design logic circuit, the circuit output signal sent to the tri-state gate chip To protect the PWM signal, the other way into the DSP's GPIO port for detecting error signals. If there is a logic error, set the PWM output signal directly and output the alarm signal. The schematic diagram is as follows:

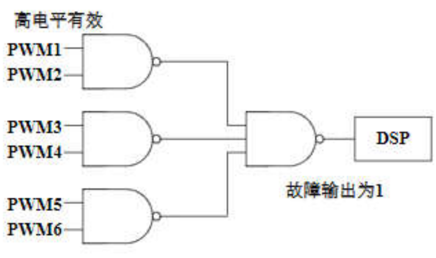

Figure 3 fault protection logic diagram

2.4.2 Brake protection output circuit

Motor braking, due to the motor feed can easily lead to the DC bus voltage increases, if the impact voltage is too high can easily lead to system protection or damage to other devices, so reserved in the drive design of the feed-in resistance output contact Point signal, at the same time, design the corresponding voltage comparator on the hardware, release the brake feedback to the motor quickly from the hardware, prevent the bus voltage from rising rapidly.

2.4.3 Over-temperature and other protection

Using LM26 temperature control chip as a temperature sensor, the output temperature signal and over-temperature level signal.

Operation error, over speed, bus overvoltage and undervoltage, speed feedback fault, communication fault are detected by software. The calculation error is the program to detect the key data variables, error code when overflow garbled value; over-speed, overvoltage and undervoltage bus program for the motor speed and DC bus voltage detection and processing; speed feedback Fault for the program to detect the speed of non-normal processing error; communication fault detection by timing connection method to deal with the normal or not.

3 System software design

3.1 System main program design

System software development environment using TI's dedicated DSP development software CCS5.4.0.
After the main program completes the system initialization, the system executes the system self-check and fault indication circularly, and executes the system control closed-loop algorithm, system input / output, speed monitoring, current and voltage monitoring, fault protection and other functions in the interrupt main program. Interrupt the main program flow chart as shown below

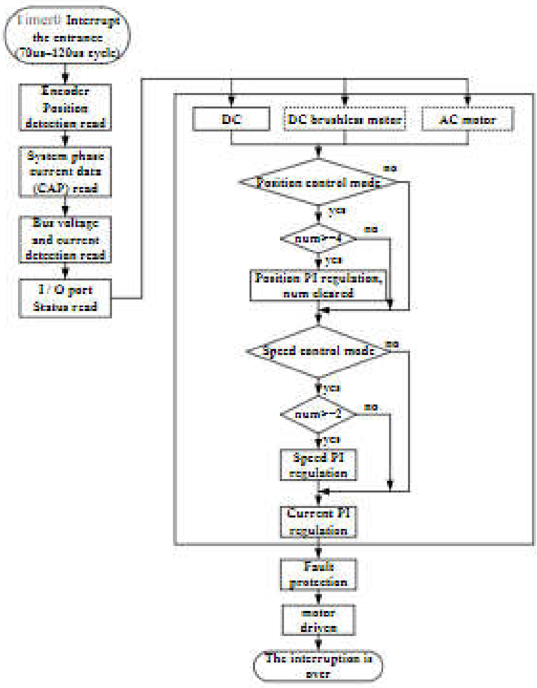

Figure 4 system software flow chart

3.2 Speed nested segmentation control

The system adjusts the parameters of the speed loop according to the expert experience by using the nested piecewise look-up table technique, that is, firstly, the first segment is given according to the given speed and the feedback speed, and then the first segment is given in each segment The difference between the speed and the feedback speed is further divided once, which not only ensures the smooth operation of high speed and low speed, but also responds to the load disturbances promptly and quickly.

In all the sub-sections, the speed conversion buffer technology is used at the sub-section limit points, that is, the buffer section is set between the two sections of speed adjustment sections, the speed adjustment parameters entering the buffer section continue the adjustment parameters before entering the buffer, This makes the speed switching point into a speed switching interval, which avoids the unstable regulation caused by the frequent switching of the adjusting parameters in the two speed ranges.

The rated motor speed of the test motor selected in this paper is 3000 r / min. The specific adjusting parameters are shown in Table 1 Show:

Table 1 Parameter Segment Table

Feedback speed / Given speed	<10r/min	60~200 r/min	>300 r/min
<10 r/min	P1	P2	P3
60~200 r/min	P2	P2	P3
>300 r/min	P3	P3	P3

The corresponding parameter values of P1 in Table 1 are Kp = 0.06, Ki = 0.05, and P2 and P3 need to be further segmented. The specific parameter values are shown in Table 2: Table 2 Parameter Table

Table 2 Parameter Table

Given and feedback speed difference	<20 r/min	>40 r/min
P2parameter	Kp=0.06 Ki =0.03	Kp=0.06 Ki =0.01
P3parameter	Kp=0.06 Ki =0.006	Kp=0.06 Ki =0.003

3.3 System parameter testing program design

3.3.1 Phase current detection

Captures rising and falling edges through the CAP unit in the EVA, resulting in CAPINT1 and CAPINT2 external capture interrupts. The CAP interrupt routine calculates the time difference between two interrupts. The magnitude of the difference is proportional to the duty cycle of the PWM wave output from IR2175S (which converts the currents of U and V phases into PWM waves), thus determining the phase the size of the current. Interrupt processing flow as shown below.

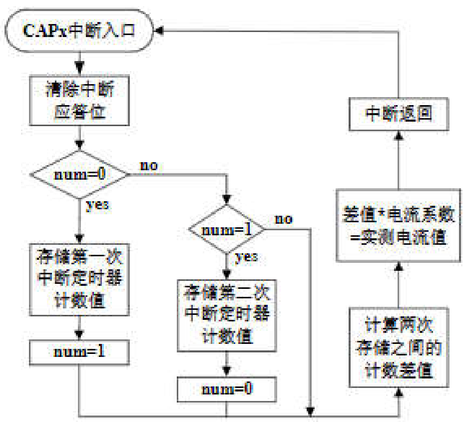

Figure 5 CAP interrupt program flow chart

3.3.2 Other parameters detection

Obtain the motor speed and angle information through the QEP module in the EVB. Through the AD module to obtain the external bus voltage, current analog quantity corresponding to the digital.

3.4 Fault protection

For common faults in system operation, we designed over current, overload, over temperature, over voltage, under voltage, over speed and possible software operation errors in software protection. When the corresponding software fault occurs or there is a hardware fault signal Input, in the DSP software by setting all the PWM output pin low, so that the level of the input to the MOSFET all set low to shield the PWM signal and CAN or RS232 interface through the relevant fault feedback to the host computer.

4 Technological design

Drive high power density, small size, so the PCB to be high-density wiring, based on actual engineering experience we have taken the following EMC design:

（1） during wiring, care should be taken to avoid interference between the signals of the high-frequency signal lines and the communication lines and to ensure that the single-point beads are connected between the driving ground and the controlling ground to reduce the interference between the electric signals.

（2） MOSFET driver chip, bootstrap capacitor, current sampling chip should be followed by close arrangement to ensure the stability of floating power supply. Conditions allow the increase of 10uF and 0.1uF bus filter capacitor to improve the stability of the input power and output power

Taking full account of product volume and heat dissipation requirements, we carry out the structural design as shown in the following figure. The overall structure of the product is designed as two layers. The upper control board and the lower power board are connected and fixed through the pins. Above the power board, two MOSFETs are mounted on the two parallel lines. The bottom of the power board is designed with two 7mm wide heat-dissipating welding electrodes. The heat conducting welding electrodes pass through the multi-layer copper-clad heat conduction inside the printed board,

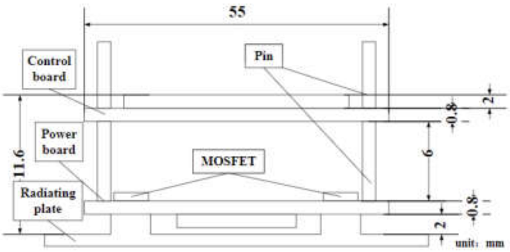

Figure 6 drive structure

The way of welding is welded with the boss of the bottom heat sink.

The drive housing is box-shaped on the heatsink by injection molding. The shell, the control board and the power board each reserved 2 2mm potting port, the assembly of the first two upper and lower plate through the pin welding connection, and then with the bottom of the heat sink welding connection, and finally card plastic case, the assembly is complete, Glue processing, enhance the components of the anti-shock vibration characteristics and cooling effect.

5 Performance and functional test analysis

DC servo motor parameters used in the test: rated power 1.1kW, rated speed 3000r / min, the maximum current of 28.6A, the maximum torque 3.5N_m, and operating voltage 48V. When the system is running, the power supply input is 48V DC voltage, the PWM switching frequency is 10kHz, the dead time is 2us, the given speed is 3000r / min, the speed loop PI adjustment cycle is 1ms, the current loop PI adjustment cycle is 100us. The test data is collected through the serial port.

The bit rate is set to 115.2kbps.

The motor with light load conditions, the given speed 2100r / min and then given -3000r / min, given and response curve as shown below, can be seen from the figure drive response speed command steady, steady-state error <1.5%

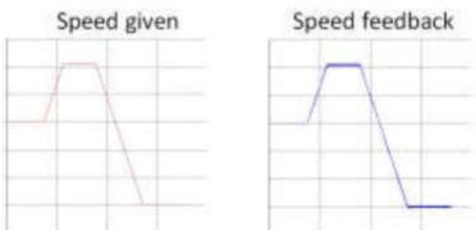

Figure 7 speed response curve

Motor at rated voltage and rated speed, and gradually increase the motor load until the maximum drive design capacity of 20A, the experimental characteristic curve is shown below, indicating that the drive hardware meets the design specifications, the maximum power of 960W, and the size of the length and width dimensions of only 55mm × 42mm × 12 mm.

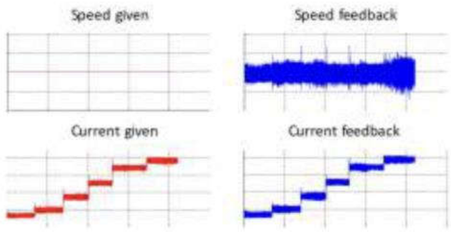

Figure 8 load response curve

The above test data show that the system has good dynamic and static control performance and reliable load capacity. The system has a certain fault error handling function, tested to overload, over speed, PWM signal through, DC bus overvoltage and undervoltage and software operations and other failures to respond correctly.

6 Conclusion

The actual experiment and operation results show that the drive is stable and reliable, with high power density and load carrying ability, and has certain error handling functions. The control board and power board are designed Independently to better increase the system integration and system dynamic and static performance good. The system is designed to be used in the servo system of a small vehicle-mounted radar turntable. The electrical test results show that the system runs smoothly and reliably with high precision. The protection functions are reasonable and effective to eat the performance requirements of the turret system for motor speed regulation and servo control.

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