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The Application of PMSM in Motor Drive Control System of patrol Robot

Guangjun Yuan[1], Runsheng Guo[2], Jiyuan Sun[3]and Zhenxiong Zhou[4]*

[1234]*School of Electric and Information Engineering Beihua University*
[1]*E-mail:ygj791223@163.com,* [2]*E-mail: 1518443606@qq.com,* [3]*E-mail: dick780818@163.com,* [4]*E-mail: 742884852@qq.com*

Abstract

In order to reduce the power consumption, and enhance the drive ability of robot, the PMSM is adopted in the drive system of patrol robot. The PMSM need a more efficient and cheaper drive system of patrol robot. The hardware platform of drive system of patrol robot based on the MC9S12XS128 is designed, the three-phase inverter is set up based on the BTS7960, PMSM is controlled by vector control algorithm, the three closed-loop control of position, velocity and current is realized. The experiment shows that actual current of axis q traces the setting value fast, and dynamic response of velocity is fast, and the trace of velocity in the steady state is stable, and the position loop is stable.

Keywords*: Microcontroller of free-scale, PMSM, Servo system, Patrol Robot*

1. Introduction

The fire, under the storage rack, can be detected by the fireproofing robot of warehouse is more *handy* than the fix detector [1]. A drive motor with high safety, low energy consumption and fast response is needed by the robot, in order to fit for the complicated and flammable environment. PMSM can meet this requirement primly.

Because there is no field winding in the rotor, the performance of PMSM is higher than other motors. The efficient rare earth permanent magnet materials excitation is adopted to reduce the volume and the weight of the motor effectively, and realize the higher output torque, and reduce the rotational inertia of the rotor obviously. Therefore, the PMSM is widely used in the high performance alternating current servo drive system [2-4]. With the development of the efficient inverter, digital signal controller, high performance servo motor and control theory, it is inescapable tendency that the alternating current servo system replaces the direct current servo system.

PMSM is adopted in the patrol robot to reduce the power consumption of robot and enhance the drive capability of robot. Therefore, the key problem of this article is how to control the PMSM efficiently. Furthermore, TMS320LF2407 is applied in the reference [2] which is more expensive and more difficult nowadays. The MOSFET circuit, over current detect circuit, over voltage detect circuit and *etc*. are applied in reference [12] which is instability. The MCU of Freescale and the BTS7960 are adopted in the system to solve the problem above, and the vector control algorithm is adopted in the system to improve the efficiency of the control system of the PMSM.

2. Position Servo Control Strategy

Following a series of assumption of the ideal model of the motor, after a series of derivation, the mathematical model of PMSM, under synchronous rotation of rotor and d and q coordinate system, is acquired [5-6].

The equation of the voltage and magnetic linkage of rotor is:

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$$\begin{cases} u_{sd} = R_s i_{sd} + p\Psi_{sd} - \Psi_{sq}\omega_r \\ u_{sq} = R_s i_{sq} + p\Psi_{sq} + \Psi_{sd}\omega_r \\ \Psi_{sd} = L_d i_{sd} + \Psi_{fs} \\ \Psi_{sq} = L_q i_{sq} \end{cases} \quad (1)$$

In the equation (1), u_{sd} is voltage of axis d, u_{sq} is voltage of axis q, i_{sd} is current of axis d, i_{sq} is current of axis q, L_d is inductance of axis d of rotor, L_q is inductance of axis q of rotor, R_s is resistance of rotor, ω_r is angular velocity of rotor, $\omega_r=n_p\omega_m$, n_p is the number of pole pairs of motor, ω_m revolving speed of rotor, Ψ_{fs} is magnetic linkage which is a part of excitation magnetic linkage of rotor, and pass through the stator winding, p is differential operator.

Equation of electromagnetic torque is:

$$T_e = 3n_p\left[\Psi_{fs} i_{sq} + (L_d - L_q) i_{sq} i_{sd}\right]/2 \quad (2)$$

Equation of motion of motor is:

$$T_e - T_L = Jd\omega_m / dt + B_m\omega_m \quad (3$$

In the equation (3), B_m is friction coefficient, J is rotational inertia of motor, T_L is load torque.

If the salient pole effect of magnetic circuit is ignored, then $L_d=L_q$. From the equation of electromagnetic torque (2) above, the maximum torque can be acquired while the included angle between i_s and axis d is 90°. Meanwhile:

$$T_e - T_L = Jd\omega_m / dt + B_m\omega_m \quad (4)$$

The conclusion can be made from above that the torque can be controlled via the control of i_{sq} to realize linear zed control of torque of PMSM, just like controlling the direct current motor, as long as maintain the i_s be perpendicular to axis d [7].

Topology of the PMSM servo control system, basing on the rotor field oriented, is shown in Figure 1.

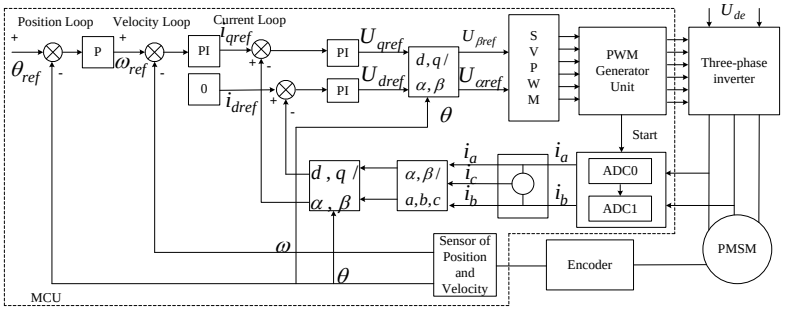

Figure 1. Topology of the PMSM Servo Control System

3. The Design of Hardware of System

The hardware of the system is mainly composed by six parts, PMSM, MCU, position and velocity detect circuit, main power component, drive circuit and D/A converter circuit. The circuits of the main unit will be introduced.

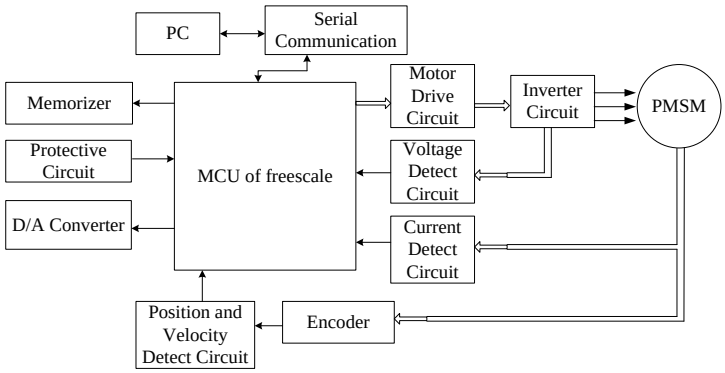

Figure 2. Topology of Hardware System

3.1. MCU

MC9S12XS128, MCU of Freescale, is adopted in system. The performance of this MCU can meet the requirement of the drive system of the patrol robot, and this MCU is cheaper than the TMS320LF2812.

The core operating frequency of MC9S12XS128 could reach 100MHz. The main function modules of MC9S12XS128 are inner memorizer, inner phase-locked loop module, SCI serial communication interface, SPI and MSCAN communication interface, 8 channels I/O compare timer module, 16 channels A/D converter module, 8 channels PWM [8-9].

3.2. Inverter Circuit

Three-phase fully-controlled bridge is adopted in the main circuit, the method of pair wise break over. The BTS7960B is used to build the three-phase fully-controlled bridge [10-11].

The BTS7960 is a fully integrated high current half bridge for motor drive applications. It is part of the Novalith IC^{TM} family containing one p-channel high side MOSFET and one n-channel low side MOSFET with an integrated driver IC in one package. Due to the p-channel high side switch, the need for a charge pump is eliminated thus minimizing EMI. Interfacing to a microcontroller is made easy by the integrated driver IC which features logic level inputs, diagnosis with current sense, slew rate adjustment, dead time generation and protection against high temperature, high voltage, low voltage, high current and short circuit. The BTS7960 provides a cost optimized solution for protected high current PWM motor drives with very low board space consumption [12].

There are three BTS7960Bs is used in the control system of patrol robot, as shown in Figure 3, the output of BTS7960Bs are connected to phase u, phase v and phase W separately in order to drive PMSM.

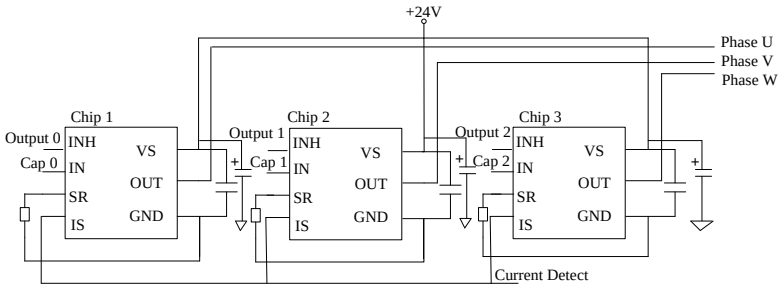

Figure 3. Drive Circuit of PMSM

3.3. Sampling Circuit

There are many ways to detect current. The CS040G, electromagnetic isolation hall current sensor, is adopted to detect current. The range of measurement of primary current of CS040G is -20A to 20A, and corresponding secondary output voltage is -1V to 1V which do not fit for the range of direct signal, 0 to 5V. That direct signal is the requirement signal of the A/D converter of the MC9S12XS128. Therefore, the signal, outputted by the sensor, must be magnified through the voltage amplifying circuit.

Voltage amplifying circuit of the sampling channel adopts the LM324, operational amplifier, and peripheral component to build summator, and the input signal of the summator is output voltage of hall's component Uis, the reference voltage signal of voltage amplifying Uref, and the output signal of the summator is voltage signal Uiso, Uiso=1.5（Uis+Uref）.

The range of signal Uis is -1V to 1V, Uref=1V, therefore, Uis is ensured to be positive. Using low pass filtering circuit, built by resistance and capacitor, switch interference is eliminated. Input of A/D converter of MC9S12XS128 is clamping protected through a connect diode to 5V.

3.4. D/A Converter Circuit

For the convenience of observation of intermediate variable in the process of debugging of motor, the hardware of drive system of the patrol robot increases the D/A converter circuit. At present there are two methods of D/A output. Method one adopts software PWM, the digital value is output through I/O ports, and connected to a simple RC low pass filter in order to acquire analog signal. Method one cannot fit for the high frequent signal. Method two is using independent D/A converter. This method is fit for both low frequency and high frequency, but the price of this method is higher than the other one. To synthesize each kind of situation, method two is adopted.

D/A converter circuit is composed by TLC5620 and bipolar output circuit. The TLC5620 and TLC5620I are quadruple 8-bit voltage output digital-to-analog converters with buffered reference inputs (high impedance). TLC5620 can be operated by controlling the four ports: DATA, CLK, LDAC and LOAD. DATA is the serial data input port. DATA is connected to the port MOSI of SPI of the MC9S12XS128, and CLK is connected to the port SPCLK of SPI of the MC9S12XS128. At falling edge of every clock period data input from DATA port. The LOAD is always at a high logic level in the input process of data until the process is ended, after that the state of LOAD is cleared, and the digital value is converted into analog value. The LDAC keeps low logic level in the experiment.

4. Experiment Research

The parameters of the PMSM used in the experiment are listed below: nominal voltage is 36V, rated current is 7.6A, rated speed is 3000min-1, rated power is 200W, number of pole-pairs is 4, d-axis inductance is 0.162mH, q-axis inductance is 0.142mH, stator resistance is 0.215Ω, magnetic linkage of stator side reacted by rotor is 0.012405 Wb. The precision of encoder is 1000 line. In order to verify the feasibility of the design of hardware system, the servo control software is written for the experiment research, the flow chart of software is shown in Figure 4. Software is written in C language.

Control period of system is 40μs. A/D conversion is triggered under the PWM and then enters the program into periodic interruption. After the sample signal was disposed, the new control signal of PWM is made by the program.

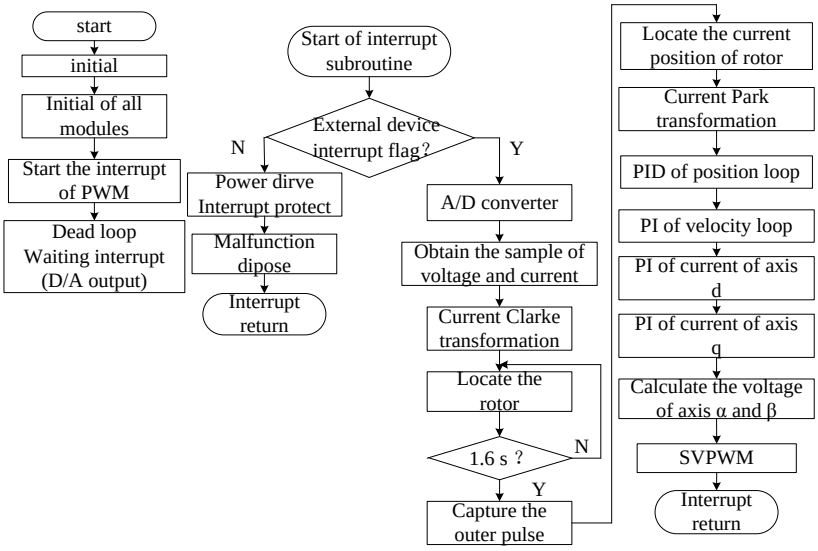

Figure 4. The Main Flow Chart of Software

5. Conclusions

1. The program of vector control algorithm is running on the MC9S12XS128 stability. Therefore MC9S12XS128 can replace TMS320LF2407 as the core of patrol robot.
2. The current loop can maintain the proper function. Therefore, BTS7960B can replace the drive circuit built by independent components, and the right signal can be fed back by BTS7960B precisely.

The time of velocity response and position response is short. Therefore, using PMSM as the drive motor, the drive abilities and mobile abilities of patrol robots are enhanced and power consume is reduced.

Acknowledgments

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References

[1] Z. He and D. Han, “Fire Fighting of Multi Storied Factory Building Warehouse”, science and technology of firefighting, vol. 32, (**2013**), pp.81-83.
[2] R. Chen, B. Kou and S. Cheng, “AC servo motor and control”, China Machine Press, Beijing, (**2008**).
[3] Q. Cheng, Y. Cheng and Yi. Wang, “Development of AC motor control stratergy”, Power System Protection and Control, vol.39, (**2011**), pp.145-154.
[4] C. Wang, J. Xia and Y. Sun, “Control technique of Modern motor”, Beijing: China Machine Press, Beijing, (**2009)**.
[5] J. Zou and Y. Zhu, “Dynamic Characteristic in Permanent Magnet AC Synchronous Servo Motor Position Servo System Based on Compound Feedforward Control”, electric machines and control application, vol.38, (**2013**), pp.29-32.
[6] F. Morel, J. M. Retif and L.S. Xuefang, “Permanent Magnet Synchronous Machine Hybrid Torque Control”, IEEE Trans. on Industrial Electronics, vol.55, (**2008**) , pp.1756 - 1761.
[7] H. Chen, Y. Wang and J. Zhou, “System Model Identification of permanent Magnet Synchronous Motor”, Small and Special Electrical Machines, vol.41, (**2013**), pp.7-10.
[8] G. Yuan and J. Sun, “The microcontroller of free-scale applying in control system of explosion-proof vehicle”, Application of Electronic and Technique, vol.38, (**2012)**, pp.41-43.

[9] S. Shi, M. Sun and S. Shi, "Design of Intelligent Tracking Car Based on MC9S12XS128", Automation and Instrumentation, vol.4, **(2012)**, pp.50-53.
[10] T. Shi, L. Liu and H. Wang, "Sliding Mode Variable Structure Control for Matrix Converter Fed Permanent Magnet Synchronous Motor Drive System", Transactions China Electro Technical Society, vol.25, (**2010**), pp.54-60.
[11] X. Wen, X. Yen and Z. Zhang, "Unified Space Vector PWM Implementation Method for Three-Phase Inverters", Transactions China Electro Technical Society, vol.24, (**2009)**, pp.87-93.
[12] J. Chen, S. Yang and J. Wang, "New Design and Realization of the Motor Driver Circuit for the Intelligent Car", Electronics Quality, vol.9, **(2011)**, pp.32-34.

Authors

Guangjun Yuan, she is a Lecture in Beihua University of Electric &Information Engineering, China. Her research interests are automatic control Technologies and power electronic technologies.

