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THE SERVO-CONTROL TECHNOLOGY OF MULTI-DOF ROBOT BASED ON CANBUS

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ABSTRACT

A study for servo-control technology of multi-DOF robot is proposed, the structure of control system and principle of servo driver circuits for DC motor with low inertia presented. The experiment results are reported, indicates that the position tracking performance of motor meets the dynamic specifications of control system using modified PID algorithm. The servo-control technology based on CAN bus offers high potential in multi-DOF robot control applications due to its advantages of low cost, simple structure and high reliability.

KEYWORDS

Multi-DOF robot, Servo-control, DC motor with low inertia, Improved PID control, Position tracking, CAN bus.

1. INTRODUCTION

There have been important advances in robotics research over the past several years, the research has been expanding in new area: medical service, education, entertainment, exploration, bioengineering and disaster relief, etc., as well as traditional industry and defense [1,2].

Multi-DOF servo-control is a research focus of robot control technology, it has been attracting a great deal of attention. There exist representative two types of robot servo-control system, hydraulic and electrical servo-control system [3]. Hydraulic servo-control system is often used to drive high-power engineering robot, while electrical servo-control system is especially applicable in driving low-power robot. However, the high prices of servo-motor which is the power component of electrical servo-control robot, is disadvantage to robotics study and application [4]. In this paper, research on multi-DOF robot servo-control technology is proposed. The structure of servo-control system for multi-DOF robot is presented, DC motor servo-driver is designed based on C8051F500 in cost effective way.

2. PRINCIPLE

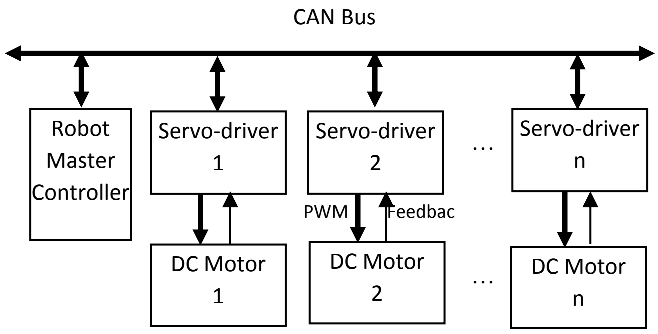

Figure 1: Shematic of the proposed design of the servo-control system

Figure 1 illustrates the schematic structure of the multi-DOF robot servo-control system based on CANbus, which consists of a robot master controller, n servo-drivers, n DC torque motors, where n is determined by DOF. Servo drivers receive instructions from master controller through a CAN bus, relevant driver generates PWM driving signal, position information of robot mechanisms from detectors is fed back to the driver.

3. DESIGN OF SERVO DRIVER

Servo driver is a key element of the servo-control system, it receives and analyses the instructions from master controller, then generates bipolar PWM driving signal for the DC motors and accomplishes detection on position and speed of motor through a photoelectric encoder. Figure 2 illustrates the schematic structure of the servo driver. The driver consists of a C8051F500 which is used as the controller, a PWM converter, a power drive circuit, a displacement detection and feedback circuit, a CAN bus interface circuit.

4. PWM Converter Circuit

C8051F500 is used for controlling the PWM convert, it generates three types of control signals, shown in Figure 3, where Q+ is the controlling signal for rotation in forward direction, Q- is for reverse rotation, both operational level is low. The signals will be processed by converter which is shown in Figure 3, before they are transmitted to the power driver circuit. Figure 4 shows the output controlling signal waveforms of the converter.

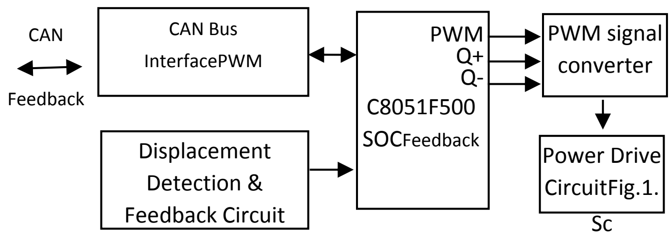

Figure 2: Structure of servo driver

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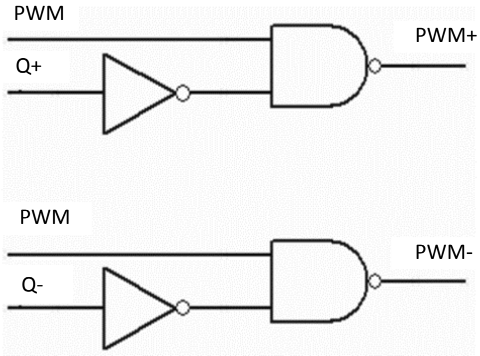

Figure 3: Schematic of PWM converter circuit

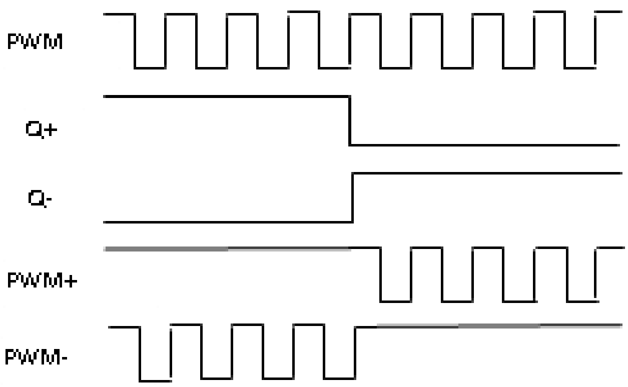

Figure 4: Signal waveforms from PWM converter

5. POWER DRIVE CIRCUIT

Figure 5 illustrates the schematic structure of the power drive circuit, PWM+ and PWM- are PWM signals for controlling rotation direction of motor. Q5 and Q6 are used to switch the Level of PWM+ and PWM- from 5V to 12V and provide anti-phase signal. Q1and Q2 are controlled by U4(IR2111), provide positive half-bridge driving signal, OUT+ in Figure 5. And Q3 and Q4 provide the negative half-bridge signal, OUT- in Figure 5. Output current is associated with the characteristics of Q1, Q2, Q3 and Q4. R10 is sampling resistance, by which driving current for motor can be detected.

The output signal waveforms of power drive circuit are shown in Fig.6. OUT+ and OUT- are designed in differential output way, used to control the rotation direction and velocity of the DC motor. A LC passive filter can be introduced in the circuit, connected to OUT+ and OUT-, will improve the stationary of motor. The circuit parameters can be determined by bandwidth which is based on system dynamic characteristics [5].

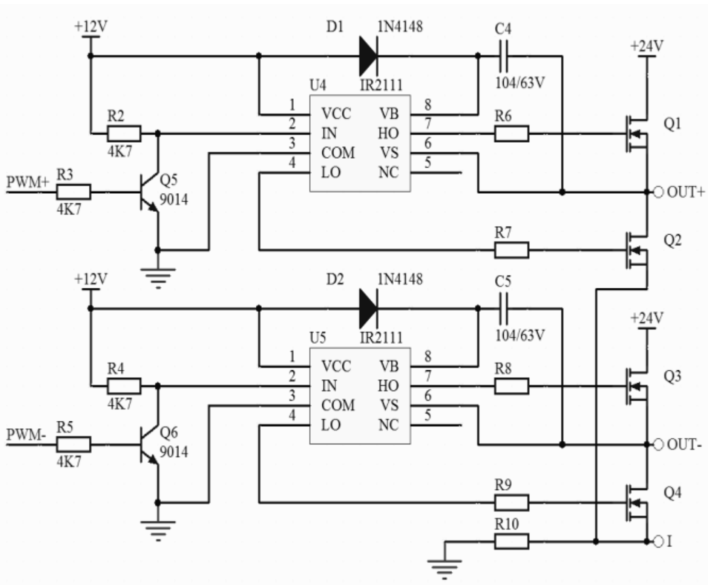

Figure 5: Schematic of power drive circuit converter

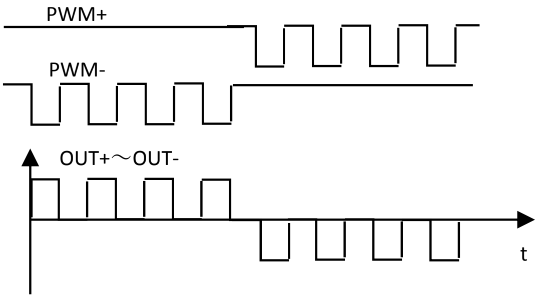

Figure 6: Output signal waveforms of power drive circuit

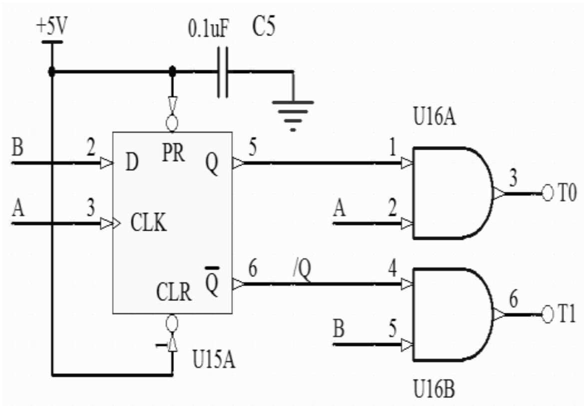

Figure 7: Schematic of displacement detection circuit

6. DISPLACEMENT DETECTION CIRCUIT

A displacement detection circuit is designed in the system, displacement data is fed back to the controller. In this work, a photoelectric encoder circuit is used as shown in Figure 7. Compared with traditional method of quadruple frequency, the proposed circuit offers high precision, rapid response, simple structure, and the control logic is easy to be implemented. A and B provide pulse signal as same frequency and quadrature phase. U15A is positive edge triggered D-type flip-flop, U16A and U16B are AND gate circuit. As motor rotates in the forward direction, A leads B, Q produces low level signal, $\bar{Q}$ produces high level signal, T0 produces low level signal and T1 produces pulse signal. When motor rotates in backward direction, B leads A, $\bar{Q}$ produces low level signal, Q produces high level signal, T0 produces pulse signal and T1 produces low level signal. Count value of T0 and T1 is transmitted to the microcontroller, based on which the rotate velocity and angle is obtained.

7. CAN INTERFACE CIRCUIT

CAN bus is used in the system to realize data communication between master controller and servo drivers. There is an integrated CAN controller in C8051F500 [6]. In this work, the CAN interface is designed by CTM1050T, which is a magneto electric isolation CAN transceivers. The schematic of interface circuit is shown in Figure 8, CRXD connects the CANRX of C8051F500, and CTXD connects the CANTX of C8051F500, CAN_H and CAN_L is the data interface of CAN bus, CANG is left unconnected. The design method which is proposed in Figure 8, compared with traditional way, DC-DC module and photo coupler are unnecessary. The circuit can offer simple structure, small size, high reliability and low fault rate [7].

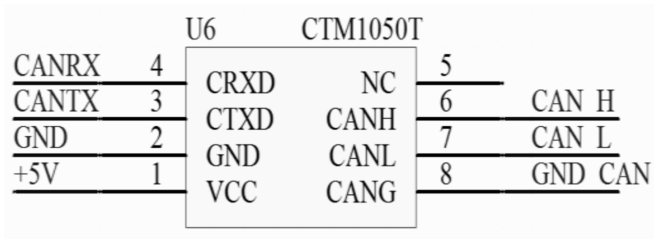

Figure 8: Schematic of CAN interface circuit

Table 1: Interface protocol adopted in system

No	Identification	Media	Message ID	Rate	Interval	Source	Destination	Meaning
1	CCI_01	Twisted-pair	0CFF0021	1MHz	5ms	Master controller	Servo Driver	Instruction
2	CCI_02	Twisted-pair	18FFDC01	1MHz	5ms	Servo driver	Master controller	Position information of servo driver
3	CCI_03	Twisted-pair	18FFDD01	1MHz	50ms	Servo driver	Master controller	Status information of Servo driver

Table 2: Extended frame format (150bits, maximum)

		Arbitration Field (64bits)					Control Field (6 bits)			Data Field	CRC Field			
Name	SOF	ID	SRR	IDE	Extended ID	RTR	r0	r1	DLC	Data	CRC	CRC separator	ACK	EOF
Bit	1	11	1	1	18	1	1	1	4	64	15	1	2	7

Table 3: J1939 protocol format

Name	PRIORITY	R (Reserved)	DP (Data Page)	PDU FORMAT	PDU SPECIFIC	SOURCE ADDRESS	DATA FIELD
Bit	3	1	1	8	8	8	64

8. CAN COMMUNICATION PROTOCOL

Communication protocol consists of interface protocol between CAN modules, data frame format and protocol format [8]. The interface protocol used in system proposed is given in Table 1, extended frame format is given in Table 2, protocol format of J1939 in Table 3.

9. PID ALGORITHM

The differential forward PID and incomplete derivation PID is jointly applied, control model is defined as a function of the error, by equation 1 [9].

$$MV = K_P \; e + \frac{1}{T_i s} e + \frac{T_d s}{1 + \frac{T_d}{M} s} SP] \quad (1)$$

Where is the error (difference between set value and the measured value), SP is the set value, is the proportional constant [10]. SP is used as derivative constant, that can improve differential forward PID and offer better response characteristic. After discretization, equation 1 can be represented as difference equation 2 [11].

$$MV_k = K_P (SP_k - PV_k + \frac{T}{Ti} \sum_{j=0}^{k} (SP_j - PV_j) + SP_{Dk}) \quad (2)$$

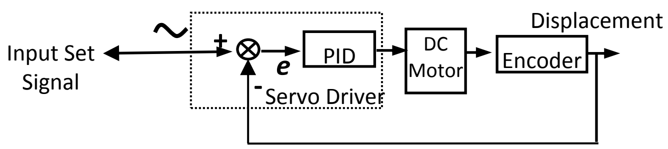

Figure 9: Schematic of experimental system circuit

Where $SP_K - PV_K$ is e_k, $\frac{T}{Ti} \sum_{j=0}^{k} (SP_j - PV_j)$ is the Kth time integral of error, SP_{DK} is the Kth time difference result of set value, SP_{DK} and $SP_{D\ (K-1)}$ can be achieved by equation 3 using recursive method, $SP_{D0} = 0$ [12].

$$SP_{Dk} (1 + \frac{0.1 T_d}{T}) = \frac{T_d}{T} (SP_k - SP_{k\;1}) + \frac{0.1 \cdot T_d}{T} SP_{D(k-1)} \quad (3)$$

The control algorithm can be adjusted as needed. If the controlled object has a higher control demand on speed than precision, the integral term should be used carefully, and the derivative term can play a more important role in the algorithm by increasing the coefficient [13]. In contrast, the integral coefficient should be increased, when the control precision is the primary target. Integral separation method is used, integral term is operating din dependently, controller will clear the integral term once error crossing zero. Using integral separation method, the static control precision of hydraulic servo system can be improved, and rapid response can be obtained. The integral term is limited to maximum value in case integral saturation happens [14].

10. PID ALGORITHM

Figure 9 presents a schematic view of the experimental system. A servo controller is linked into the control loop of torque motor with low inertia, PC gives the input signal via CAN bus, CAN communication is defined with a Baud Rate of 1Mbps, transmission time interval of 5ms. The digital displacement information is send to PC through CAN bus, the photoelectric encoder produces 10,000 pulses per revolution [15].

Based on the experimental results of step response, a set of control parameter are selected for test, where $K_P = 10$, $T_I = 10{,}000ms$, $T_D = 10ms$, $T = 10ms$. Sinusoidal input set signal is given by PC via CAN bus (range from -30º to +30º, frequency of 3.3Hz and 6.6Hz). Based on the experimental angle displacement data, the tracking performance curve is plotted with MATLAB, shown in Figure 10 and Figure 11 (the blue is experimental curve, the red is input curve).

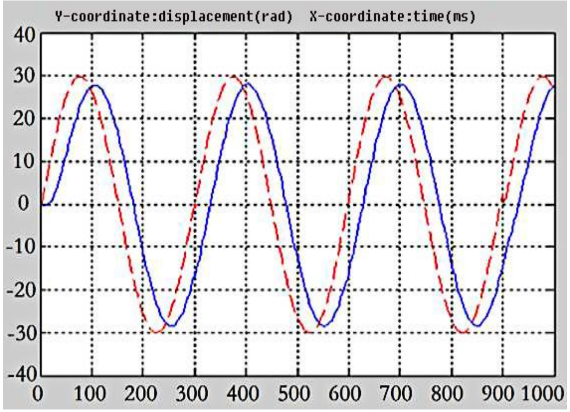

Figure 10: Tracking characteristics curve (3.3 Hz*)*

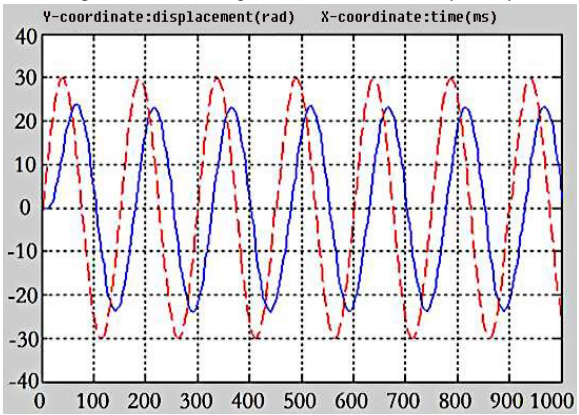

Figure 11: Tracking characteristics curve (6.6Hz)

The experimental data shows that motor can track the preset position, there exists a 20ms delay. As the experimental frequency increases, the actual range decreases. The amplitude-frequency characteristic is analyzed, result shows that the system has a cut-off frequency as 7Hz.

11. CONCLUSIONS

A design of servo control system for multi-DOF robot is proposed, CAN bus is used to accomplish the data exchange between master controller and servo-drivers. The system is cost-effective with a simple structure, has potential in practical applications as control system for low-power robot. The experimental scheme and data can be used as reference in similar research and application on motor control.

REFERENCES

[1] Tan, M., Wang, S. 2013. Research Progress on Robotics. Acta Automatica Sinica, 39 (7), 963 – 972.

[2] Wang, T., Tao, Y., Chen, Y. 2012. Research Status and Development Trend of Serve Robot Technology. Scientia Sinica (Informationis), 42 (9), 1049-1066.

[3] Zhang, Z., Zhao, D., Chen, T. 2007. Design of The Master-Slave System and Research on Bilateral Servo Control System of Tele-Operated Manipulation Robots. IEEE International Conference on Automation and Lofistics, 913–917.

[4] Ai, X., Ji, H., Zhang, Y. 2010. Design of Inverter Power Based on System-On-Chip Mcu Of C8051f410. Control and Instruments in Chemical Industry, 37 (8), 63 – 65.

[5] Zhou, Z., Li, T., Takahashi, T., Al, E. 2004. Fpga Realization of a High-Performance Servo Controller for Pmsm. Applied Power Electronics Conference and Exposition, 1604-1609.

[6] Bao, G., Ji, S., Zhang, L. 2003. Can Fieldbus Technology. Journal of Zhejiang University of Technology, 31 (2), 58–66.

[7] Luo, Y. 2002. Design of Electric Servo Control System Based on Can bus. Unpublished Doctoral Dissertation, Northwestern Polytechnical University.

[8] Zhang, X., Song, X., Cao, J. 2016. Research on Simulation of Network Control System Based on Can Bus. Computer Technology and Development, (7), 192 – 195.

[9] Ai, X., Yang, X., Zhai, Y. 2008. Design of Field-Bus Controller Based on Soc C8051f060. Control and Instruments in Chemical Industry, 5 (4), 67 – 71.

[10] Wang, G., Liu, N., Xie, C. 2008. Dsp-Based Digital Pid Servo Control System Design. Microcomputer Information, 24 (7), 90–92.

[11] Yang, Y. 2006. Research on Control Strategy of Hydraulic Servo System with Multi Degree of Freedom. Unpublished Doctoral Dissertation, Central South University.

[12] Terrence, L., Blevins. 2012. Pid Advances in Industrial Control. Ifac Proceedings, 453.

[13] Valery, D., Yurkevich, D. 2012. Subbaram Naidu. Educational Issues of PI-PID Controllers. IFAC Proceedings, 4511.

[14] Zanoli, S.M., Barchiesi, D., Astolfi, G. 2012. Head Pressure Minimization of A Visbreaking Column Through An Advanced Pid Controllers Architecture. Ifac Proceedings, 453.

[15] Zhou, Z. 2004. Development of Servo Control System for Four Joint Robot. Unpublished Doctoral Dissertation, Central South University.

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