Design and Implementation of the Servo Control System Based on DSP

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Abstract

To enhance the tracking accuracy of servo control system of a testing platform, the AC servo control system digital controller based on DSP is designed, and the structure and the working principle of the system are introduced in this article. For system hardware, TMS320F28335 is the control core, and for the software, complex control strategy of PID control and feed-forward control is adopted. The testing result shows that the control of the system is effective.

Keywords: DSP, AC servo motor, PID, Feed-forward control, CAN

The AC servo system has many advantages such as strong overloading ability, large output torque, high reliability and good maintainability. So it has been widely applied in various automatization domains (Bai, 2009), especially in the occasions with high precision and response. Taking one certain testing platform servo control system as the application background, the composing and working principle of the AC servo control system are researched in this paper, and the hardware controller of the system is designed based on DSP. Because of numerous unknown influencing factors of the system, the open-loop transfer function of the system is distinguished by the step response method, then the complex control strategy based on the PID control and the feed-forward control is discussed.

1. System composing

As seen in Figure 1, the structure of the system is composed by tester, DSP controller, motor driver, AC motor, reducer, load and encoder. The AC motor and the motor driver are the executing agency of the system, the reducer is to reduce the speed of the motor to required range, the photoelectric encoder could measure the position of the motor and output the information by the RS485 interface, the DSP based on the TMS320F28335 is the hardware controller of the system and it communicates with the tester by CAN interface.

2. Hardware design

In this paper, the hardware core of the controller adopted new floating point DSP of TI, TMS320F28335, and the main frequency of this chip could achieve 150MHz, with strong computation ability and abundant peripherals. It largely simplifies the peripheral circuit design of the hardware system and more suitable for the hardware development in the movement control domain (Texas Instrument, 2008). As indicated in Figure 2, the DSP peripherals used in this design include SCI, CAN, and extended DA output unit.

The SCIA peripheral module of DSP is configured as RS485 interface for receiving the photoelectric encoder data and the transceiver chip is MAX485. The GPI01 of DSP is used to control the transmitting and receiving timing of RS485, the output difference signal is terminated with 120 Ω resistors in parallel by jumper wire.

CAN transceiver used CTM8251AT which integrated with devices such as transmitter, receiver and isolating circuit. Therefore, it made the design of CAN serial communication very easily. The CAN2.0B protocol is adopted and the communication speed is 500kbps. Jumper wire between pins CANH and CANL is selected and a 120 Ω resistance is connected in parallel to minimize signal reflections on the differential bus.

AD Company's chip AD669 is used for DA output unit, and its logic control pins L1, CS and LDAC are respectively allocated to DSP ports of GPIO40, GPIO41 and GPIO42, as shown in Figure 3.The data bus D15~D0 of AD669 are linked with the data bus XD15~XD0 of DSP, respectively.

3. Software design

3.1 System model

The system is controlled by three loops, i.e. position loop, speed loop and current loop. The parameters of the speed controller and the current controller have been adjusted well when they leave the factory, as illustrated in Figure 4. Because of the existence of some nonlinear factors such as friction in the engineering, the system could not been modeled exactly, so the step response method is adopted to obtain the system model. To simplify analysis, the model structure of the system is considered by the second order underdamped system (Cheng, 2004) and the controlled object model of the system is $G(s)=\frac{K}{s(Ts+1)}$.

3.2 Controller design

After the system model is simplified, the position controller is designed. In theory, when the system is a continuous system, and if the transfer function product between the feed-forward part and the plant is 1, the system output could exactly trace the system input without error, but it is very difficult to realize the complete tracing (Sun, 2008). As Figure 5 shows, the control strategies incorporate PID control with the feed-forward control to enhance the tracing precision of the system. The output of feed-forward control is $u_f(s)=r(s)/G_p(s)$, and the output of PID control is $u_c(s)=G_c(s)*e(s)=k_p(1+1/(T_I s)+T_D s)*e(s)$, thus the total output controlling variable is $u(t)= u_c(t)+ u_f(t)$. Where, k_p is the proportional coefficient, T_I is the integration time constant, and T_D is the differential time constant. The parameter adjustment of the PID controller is based on human experiences.

3.3 Program flow

The program flow of the system is shown in Figure 6, the DSP loads program in Flash to the interior RAM after the system is electrified and begins to execute the program. First the variables and the function are initialized, then in the function of main, the DSP, SCI, CAN and system interrupts are initialized, after that the program will enter into a 4ms timer cycle. In this cycle, the position information of the rotary transformer will be collected, and the system receives the tester's instructions and PID parameters by CAN Bus, computes and outputs the control voltage to servo motor driver, if necessary it could also feedback the current state information to the tester by CAN Bus.

4. System testing

Figure 7 shows the sinusoidal response and error curves of the position loop of the system, with a given amplitude of 40^0 and frequency of 1Hz. Figure 8 is the step response and error curves of the system position loop, with a step value of 60^0. From the curves in the Figure, the controller designed in this paper could follow the reference signal well and satisfy the performance requirements of the system.

5. Conclusions

The step response method is used to distinguish the opening-loop transfer function of the system, which could simplify the design difficulty of the system controller. The position servo controller based on the high-performance DSP could largely enhance the running speed of the control algorithm, and improve the following precision of the system better. The testing results show that this controller is feasible and effective, and could meet the performance requirements of the system.

References

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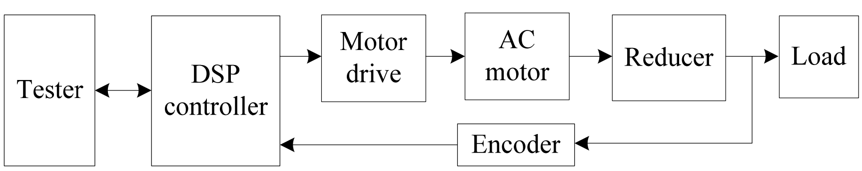

Figure 1. System Composing

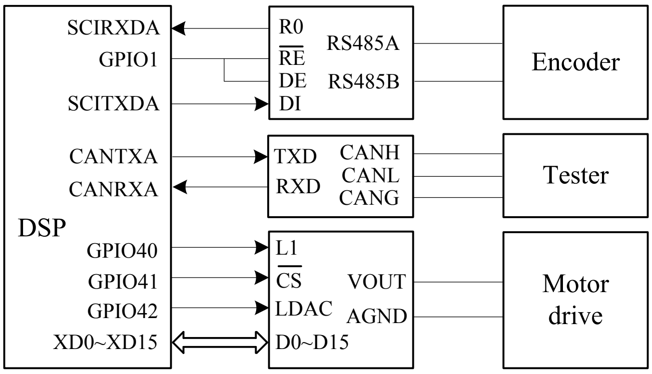

Figure 2. Block Diagram of System Hardware

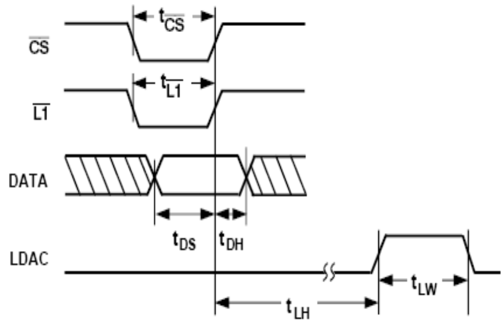

Figure 3. AD669 Level Triggered Timing Diagram

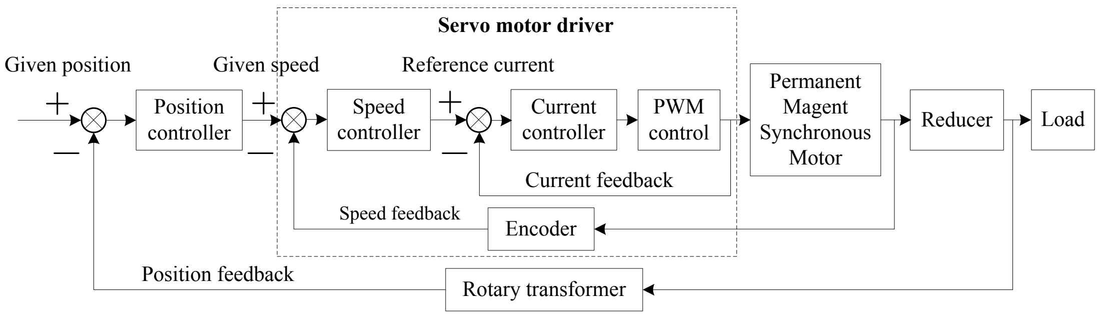

Figure 4. Structured Chart of System Control Model

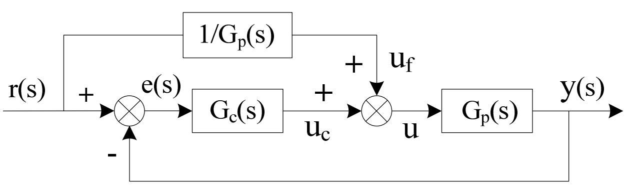

Figure 5. System Control Structure

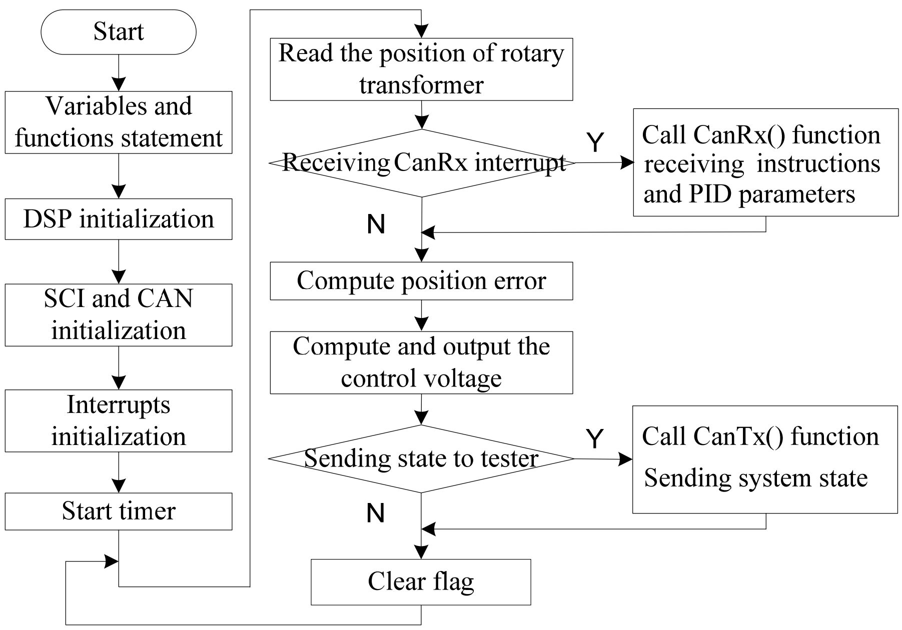

Figure 6. System Program Flow

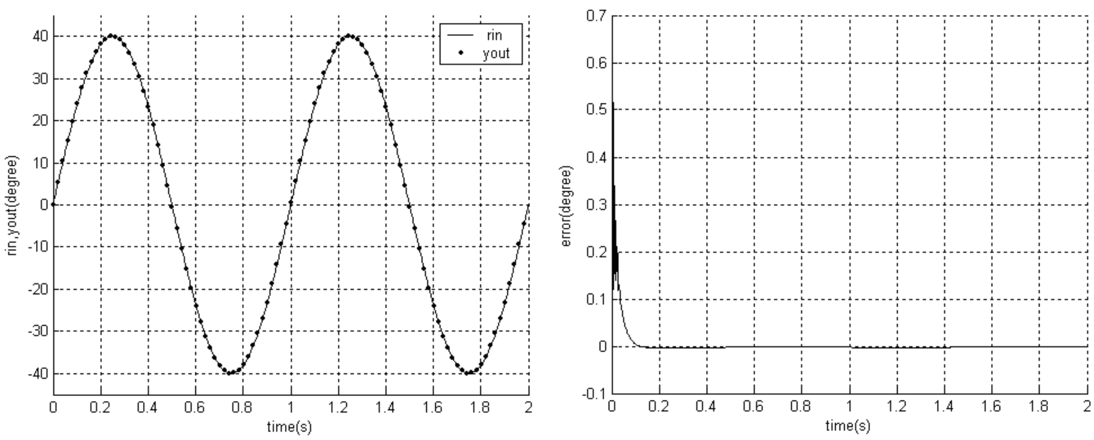

Figure 7. System Sinusoidal Response and Error Curves

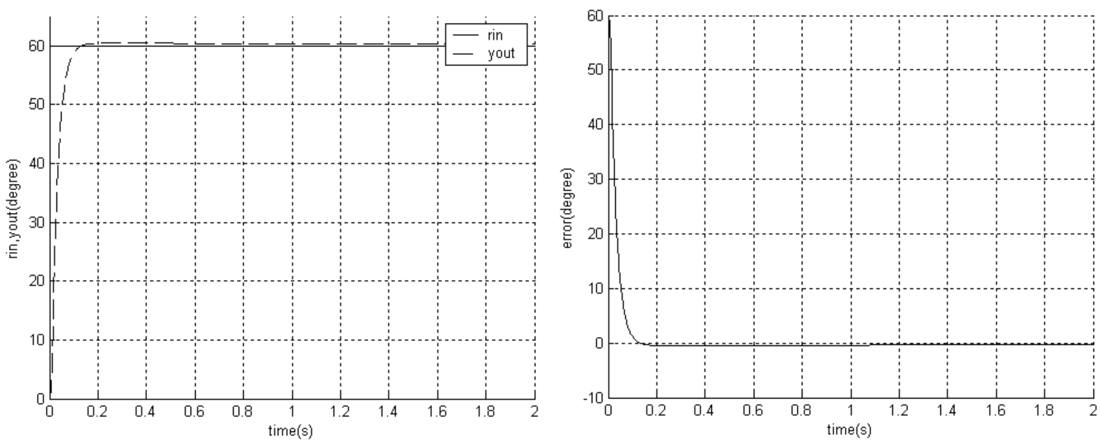

Figure 8. System Step Response and Error Curves