Design of Multi-angle Motion Control System for The Servo

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Abstract: The servo is mainly used in the control system where the angle is constantly changing. In order to realize the multi-angle motion control of the servo, the pulse width modulation (Pulse Width Modulation, PWM) is used as the mechanism and combined with Proteus software for simulation analysis. In the Proteus environment, the AT89C52 chip is used as the control core, and two different buttons are used to control the forward and reverse rotation of the servo. The rotation angle of the servo can be changed according to the number of button closures. In order to see the results of steering and angle changes of the servo more clearly, a combination of nixie tubes and light-emitting diodes (LEDs) is used to present it. The experimental simulation results show that the servo can meet the requirements to achieve multi-angle motion.

1. Introduction

As a kind of actuator\textsuperscript{[1]}, the servo has been widely used in the fields of car model, airplane model, robot and so on in recent years. For example, the joints of robots, the rudder surface of unmanned aerial vehicles, and the transformation of missile attitude all require the servo signals to drive\textsuperscript{[2]}. Therefore, it is very important to study the movement of the servo. According to the power source, the servo can be divided into three types: electric, pneumatic and hydraulic. Due to the simple structure and large output power of the electric servo, this type of the servo was selected for this study. In view of the better processing technology, lower cost, and strong anti-pollution ability of the PWM servo\textsuperscript{[3]}, the current PWM control is still the mainstream method of steering gear drive, and this control method is widely used by many scholars.

In this paper, the program of pwm wave generation is written by Keil software, and a hardware platform is built in Proteus software to realize multi-angle motion control of the servo. Compared with the servo movement in other documents, this article presents the result of its movement through the intuitive experience of the nixie tube and LEDs in the Proteus environment, and has obtained correct and effective experimental results.

2. The principle of the servo control

2.1. Principle of the servo control

2.1.1. Structure and working principle of the servo
Electric servo is mainly composed of motor, coupling, position sensor, reducer, etc, and the essence of steering gear is a position (angle) servo driver[4].

The servo works by transmitting signals through a control line, driving the motor through its internal circuit board and transmitting power to the swing arm through the deceleration gears, while the position sensors feed back into the arm position to determine whether positioning has been reached. It is not difficult to see from the working principle of the servo that it is a typical closed-loop feedback system.

2.1.2. pwm control of the servo

As shown in Figure 1 below, there are usually three leads on the outside of the servo.

![Fig.1 Schematic diagram of the standard servo leads](image)

In the servo system, the control signal enters the modulation chip by the internal channel of the receiver to obtain the DC bias voltage. Its internal reference circuit produces a reference signal with a period of 20ms and a width of 1.5 ms, and obtains a voltage difference output by comparing the voltage obtained from the DC offset voltage with that of the potentiometer. Finally, the positive and negative outputs of the voltage difference are fed to the driving chip to determine the steering gear’s positive or negative inversion. When the motor gains a certain speed, the reducer will drive the potentiometer to turn, causing the voltage difference to change to 0. The motor will stop rotating at this point.

This paper uses pwm signal to control the rotational motion of the servo. When the duty ratio of pwm waves changes, the position of the servo changes accordingly, as shown in figure 2 below.

![Fig.2 The relationship between the servo output angle and PWM width](image)

It can be seen from Fig.2 that the rudder is at the initial position of 0 degrees when the pulse width is 0.5 ms. When the pulse width is 1 ms, the servo moves to a 45-degree position. When the pulse width is 1.5 ms, the steering gear moves to 90 degrees. When the pulse width is 2 ms, the servo moves to a position of 135 degrees. At a pulse width of 2.5 ms, the servo moves to a position of 180 degrees.

3. System design

3.1. Hardware design

The hardware platform of the system is built in Proteus software, and the hardware circuit mainly consists of 5 parts: servo wiring part; crystal vibration circuit; luminescent diode groups; nixie tube display section; keystroke group. The main control chips of the hardware circuits are AT89C51, U2 and U3 are 74HC573 latches, the nixie tubes are model 7SEG-MAPX4-CC, and the five LEDs are
exactly the same. P1\(^1\) in I/O of AT89C51 is connected to the signal control line of the servo and conveys pwm waves to it. P1\(^3\) ~ P1\(^7\) is respectively connected with the 5 LED D1 ~ D5. The eight I/O ports of P0 are connected with the D0 ~ D7 of U2 and U3 respectively. The key group includes K1 and K2. The oscilloscope in the hardware circuit is used to display pwm, the details of which are shown in Figure 3 below.

![Fig.3. System schematic diagram](image)

The rotation of the servo will change closely with the change of PWM wave duty ratio, and the MCU can realize a change in the pulse width microsecond level, so the control precision is higher. As the single-chip microcomputer is a digital system, its working mode is decided by the program only, so the control program is used to control the steering gear by controlling the signal line, the external interference is small and the system has high reliability.

### 3.2. Software design

The system’s software program is written in the software Keil, language environment based on C language, using the timer T0 in MCU and combined with interrupt service to complete the time control. Set the angle flag variable jd in the program, which corresponds to the pulse width shown in Table 1 below.

| The angle marker jd | Pulse width (ms) |
|---------------------|-----------------|
| 1                   | 0.5             |
| 2                   | 1               |
| 3                   | 1.5             |
| 4                   | 2               |
| 5                   | 2.5             |
From the relationship between the rudder output angle and the width of PWM in Fig. 2, it is not difficult to find the relationships among the angle marker \( jd \), pulse width, and actuator output angles, as shown in Table 2 below.

**Table 2** The relationship between \( jd \), pulse width and the servo output angle

| The angle marker \( jd \) | Pulse width (ms) | Output angles of the servo |
|--------------------------|------------------|---------------------------|
| 1                        | 0.5              | 0°                        |
| 2                        | 1                | 45°                       |
| 3                        | 1.5              | 90°                       |
| 4                        | 2                | 135°                      |
| 5                        | 2.5              | 180°                      |

In the program, the corresponding relationship between rudder output angle and LEDs D1~D5 and the nixie tube is as follows: when servo angle is 0 degrees, experimental phenomenon is the LED D1 light up and other die out. When the servo angle is 45 degrees, the experimental phenomenon is the LED D2 light other extinguishing, and the digital tube shows the number 045. When the servo angle is 90 degrees, the experimental phenomenon is the LED D3 light other extinguish, the nixie tube shows the number 090. When the servo angle is 135 degrees, the experimental phenomenon is LED D4 light other extinction, and the nixie tube shows the number 135. When the servo angle is 180 degrees, the experimental phenomenon is the LED D5 light other extinguishes, and the nixie tube shows the number 180.

This system is to change the value of the angle flag \( jd \) by pressing the key. K2 is the angle increase button, K1 is the angle decrease button, the button K2 (or K1) is closed once, and the value of the angle flag \( jd \) increases by 1 (or subtracts 1). The C programming flow of the servo is shown in Figure 4 below.

![Fig. 4 Program flow chart](image-url)
4. Simulation results

After the program is downloaded, proceed to the Proteus simulation experiment. At the beginning, the servo is in the initial state. According to the program design, the predicted experimental phenomenon at this time is that the LED D1 is on and the other LEDs are off, and the nixi tube displays the number 000. The simulation results of the software Proteus are shown in Figure 5 below.

![Figure 5](image1.png)

Fig.5 Experimental phenomenon in the initial state of the servo

When the button K2 is pressed, the angle flag jd will increase by 1. It can be seen from Table 2 that the rotation angle of the steering gear is 45° at this time. Combined with the program designed, the predicted experimental phenomenon is that the LED D2 is on and the other is off, and the digital tube displays numbers is 045. The simulation results of Proteus software are shown in Figure 6 below.

![Figure 6](image2.png)

Fig.6 Experimental phenomenon when the steering gear rotates 45°

When the buttons K1 and K2 are operated respectively, the angle flag jd changes accordingly, and the actual results of the software Proteus simulation experiment are consistent with the predicted results of the program. The specific relationship is shown in Table 3 below.

| The output angles of the servo | The brightness of the LEDs | The number displayed by the nixie tube |
|-------------------------------|----------------------------|--------------------------------------|
| 0°                            | the LED D1 is on and the other is off | 000                                  |
| 45°                           | the LED D2 is on and the other is off | 045                                  |
| 90°                           | the LED D3 is on and the other is off | 090                                  |
| 135°                          | the LED D4 is on and the other is off | 135                                  |
| 180°                          | the LED D5 is on and the other is off | 180                                  |

Table 3 The relationship between the output angle of the servo and the brightness of the LEDs and the number displayed by the nixie tube
When the pwm duty cycle is 10%, that is, the pulse width is 2ms, the display waveform of the oscilloscope in Proteus is shown in Figure 7.

![Fig.7 pwm waveform](image)

5. Conclusions
This article builds a hardware platform based on Proteus software, and writes a simulation program through Keil software. The rotation position of the servo is presented in the order of light-emitting diodes and nixie tube display numbers. The method adopted in this article is more intuitive and clearer than directly observing the movement of the servo. The final experimental results show that the system designed in this paper can realize the multi-angle motion control of the servo, and the experimental phenomenon is intuitive and clear.

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