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Development of a Wind Tunnel Control System for Accurate Position Regulation

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Abstract:

This system uses the STM32F103C8T6 microcontroller to control and display the height of a table tennis ball in real-time. It consists of several key components including a microcontroller system, a driving device, an ultrasonic ranging circuit, a key circuit, and a display circuit. The system allows users to select the working mode, measures the distance to the ball using an ultrasonic module, and employs a closed-loop control system for precise height regulation. Key functionalities include the control of a DC motor by the microcontroller to manipulate the ball's position with wind force, and the use of Proportional-Integral-Derivative (PID) control for accurate height adjustment. The system's design is straightforward, which facilitates understanding and implementation, and it provides a high control accuracy and a real-time display of measurements. This setup effectively demonstrates the practical application of the STM32F103C8T6 microcontroller in controlling and monitoring a dynamic object like a table tennis ball.

Keywords:

Design, wind, system.

1. Introduction

Wind tunnel is the most effective and commonly used tool for aerodynamic experiments. Its working principle is to generate and control the air flow manually. It is a kind of pipe like equipment used to measure the effect on the aircraft and observe the physical phenomenon. It is mainly used to simulate the gas flow around the aircraft. In this paper, a wind tunnel control system based on stm32f103c8t6 single-chip microcomputer is designed. The single-chip microcomputer realizes the adjustment and control of the speed of DC fan through PWM, while the experimental table tennis of the simulation aircraft is monitored and fed back its position through ultrasonic wave in real time. The position information and position time are displayed by LCD.

2. Design function and scheme design

2.1 Design function

1. Place the small ball at the bottom of the tube, control the small ball to reach the BC section upward within 5 seconds after starting, and maintain it for more than 5 seconds.

2. When the small ball is maintained in BC section, cover the air inlet of the fan with cardboard, and keep the small ball in BC section.

3. Take the coordinates of point C as 0cm and point B as 10cm; use the keyboard to set the height position of the ball (unit: cm). After starting, make the ball stably at the specified height for more than 3 seconds, and the fluctuation shall not exceed ±1cm.

4. Display the height position of the ball and the timing of the ball's maintenance status in a proper way in real time.

5. Place the small ball at the bottom of the tube, and control the small ball to reach the a end of the top of the tube upward within 5 seconds after starting, without jumping away, and maintain for more

than 5 seconds.

6. Place the ball at the bottom of the tube, and control the ball to complete the following movement within 30 seconds after starting: up to ab section and maintain for 3-5 seconds, down to CD section and maintain for 3-5 seconds, up to ab section and maintain for 3-5 seconds, down to CD section and maintain for 3-5 seconds, and then rush out the tube upward.

7. When the fan stops, put the small ball into the wind tunnel from the a end by hand. After the small ball enters the wind tunnel, the system will start automatically to control the drop of the small ball to no more than D point, and then maintain it at BC section for more than 5 seconds.

2.2 Scheme design

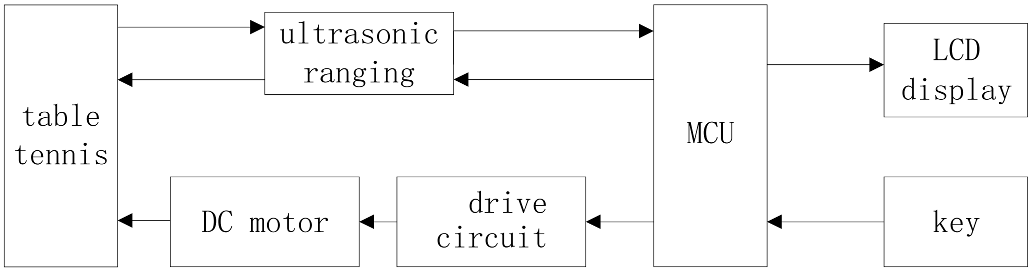

Figure 1 System block diagram

The system block diagram is shown in Figure 1. After power on, press the key, the single-chip microcomputer detects the key information and works according to the set working mode. The single-chip microcomputer sends the information to the ultrasonic sensor, which feeds back the measurement data to the single-chip microcomputer. After analyzing the data, the single-chip microcomputer generates a PWM signal and sends it to the drive circuit to control the speed of the motor so as to control the wind speed and then the height of the small ball. The same as At the same time, MCU controls LCD to display height position and maintenance time in real time.

3. System hardware design

3.1 Motor drive circuit

The driving circuit adopts optocoupler circuit, which makes the front and rear circuits isolated and prevents the rear circuit from affecting the normal operation of the front circuit. Due to the high power of the motor, the parallel shunt mode is adopted in the amplifying circuit, so as to reduce the heat generation of the circuit and prevent the device from burning out.

The amplifier adopts lm358, which includes two independent dual operational amplifiers with high gain and internal frequency compensation. It is suitable for single power supply with a wide range of power supply voltage, and also suitable for dual power supply working mode. Under the recommended working conditions, the power supply current is independent of the power supply voltage. Its application range includes sensor amplifier, DC gain module and all other occasions where operational amplifier can be used with single power supply.

The PWM signal generated by the single-chip microcomputer system is sent out and sent to the drive circuit to generate the drive signal and control the DC motor. The circuit is shown in Figure 2, mainly composed of optocoupler, four Ti lm358 and four NPN type triodes.

3.2 Key input circuit and LCD display circuit

3.2.1 y input circuit

As shown in Figure 3, the key circuit is mainly composed of four keys, from top to bottom are S5, S4, S3 and S2. Four keys constitute the setting of working mode, among which S5 is the delete key, S4 is the + 1 key, S3 is the - 1 key and S2 is the confirm key. The specified functions can be realized by selecting different working modes by pressing the key.

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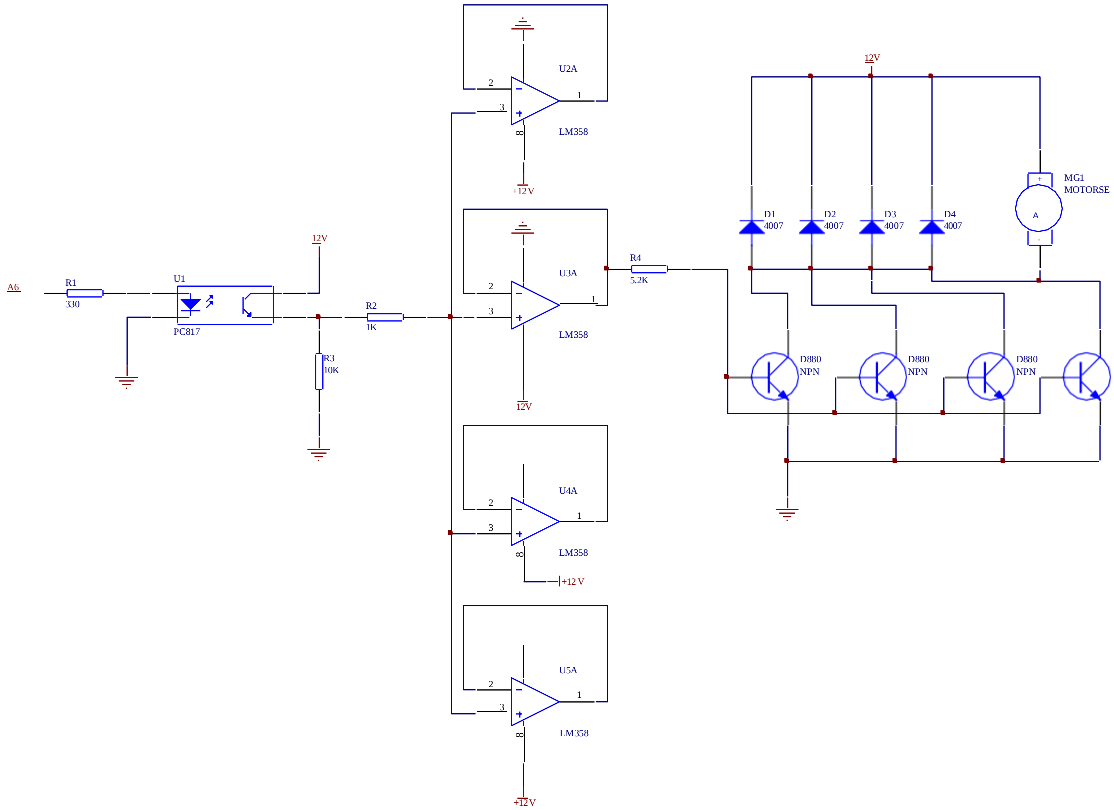

Figure 2 driver circuit

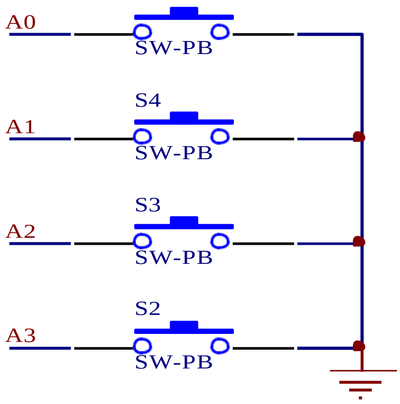

Figure 3 key input circuit

3.3 Ultrasonic sensor circuit

The circuit of ultrasonic sensor is as shown in Figure 5. The trig pin and echo pin of ultrasonic sensor are respectively connected with the A7 and A8 of single chip microcomputer. The single chip microcomputer sends signals to the ultrasonic transmitter for transmission. When the sent signals meet the ping-pong ball, they are reflected back and received by the ultrasonic receiver, and then sent to the single chip microcomputer. The single chip microcomputer for the time of transmitting and receiving signals and in the air The current table tennis position is calculated by the propagation speed of.

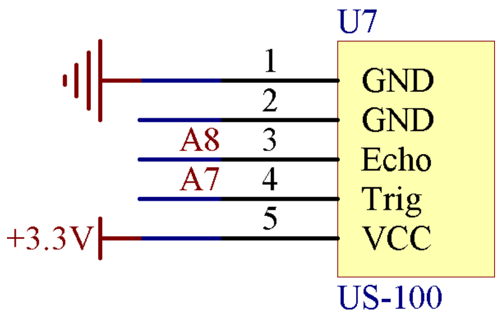

Figure 5 Ultrasonic sensor circuit

4. Software design

The single-chip microcomputer collects the information of the key input circuit to make it work in the corresponding function mode. After the single-chip microcomputer controls the ultrasonic transmitter to transmit the signal, the ultrasonic receiver sends the received signal to the single-chip microcomputer. The single-chip microcomputer calculates the distance, analyzes the current situation, realizes the PID control, and generates the corresponding PWM signal to the drive circuit. At the same time, the single-chip microcomputer also outputs the current position. Information on altitude and maintenance time.

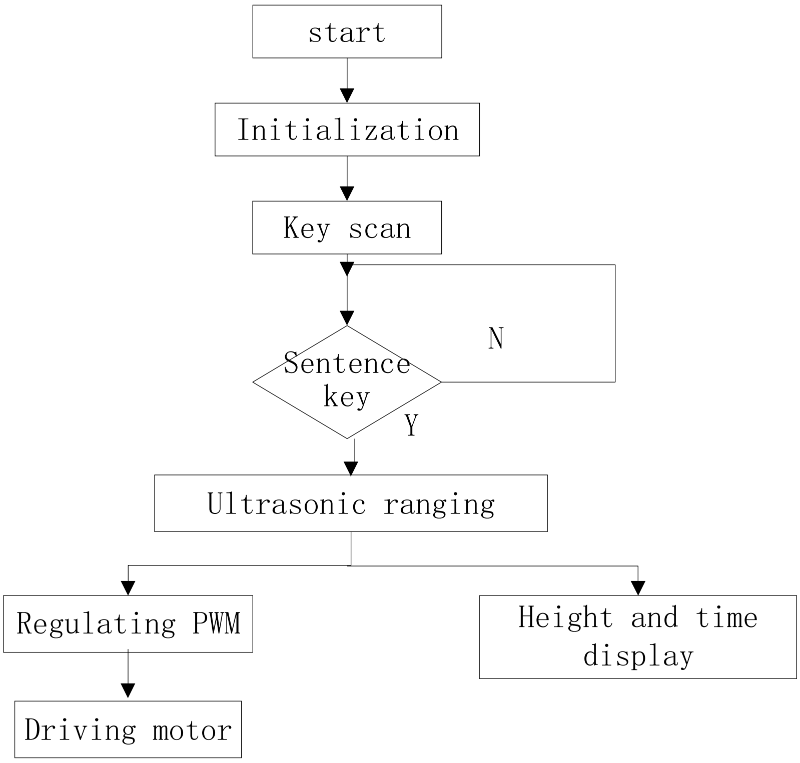

Figure 6 Procedure flow chart

5. Test

5.1 Table tennis height test

After the joint debugging of the system, two table tennis balls are used to set the height positions of 10cm, 25cm and 40cm respectively for testing. The test results are shown in Table 1.

Table I table tennis height position measurement (height in cm)

height	Table Tennis	The first time	The second time	The third time	The fourth time	The fifth time	mean value
10	Nail ball	12	9	10	13	8	10.4
	B ball	11	10	12	8	13	10.8
25	Nail ball	27	25	24	26	25	25.4
	B ball	25	26	26	25	25	25.4
40	Nail ball	40	39	40	40	40	39.8
	B ball	40	40	39	40	40	39.8

5.2 Function test

The system control is divided into mode 1 to mode 5. After the motor is started, press key 2 as mode 1 to realize the small ball starting for 5 seconds to reach BC section and maintain for 5 seconds; then cover one third with long cardboard and keep the small ball in BC section; press key 2 to continue to press key 2 as mode 2, and set the height with key, and maintain at the set height for more than 3 seconds; press key 2 to press the third as mode 3, and it will be small within 5 seconds after starting When the ball reaches the top of the tube, it does not jump away and lasts for more than 5 seconds; press the fourth button to set mode 4, and the ball moves many times in 30 seconds; press the fifth button to set mode 5, so as to put the ball from above, and the fan controls the ball to fall no more than D points. At the same time, LCD12864 liquid crystal display module is selected to monitor the height position of the small ball to the small ball and the maintenance time of the small ball in real time.

5.3 Test analysis and conclusion

By testing the different height of table tennis, it is found that table tennis is relatively difficult to control in the low position, with slightly lower accuracy. When it is set in the middle position and high position, the control effect is relatively good, and it can basically maintain at the set height, and the stability time is longer.

Using PID algorithm to control the height of table tennis, the adjustment of KP, Ki, KD three parameters is more important, it needs more experiments to achieve better results.

Conclusion

By employing the STM32F103C8T6 microcontroller to control a DC fan, this system achieves position control of a ball within a wind tunnel. To enhance understanding of the ball's position, an LCD display provides real-time position information, culminating in the comprehensive design of a wind tunnel control system. The system's performance is stable and reliable, with all design objectives and functional requirements successfully met.

The STM32F103C8T6 microcontroller serves as the central control unit, managing the operation of the DC fan to regulate the ball's position within the wind tunnel. An LCD display shows the current position of the ball in real time, allowing for immediate monitoring and adjustments. The system demonstrates stable performance, ensuring consistent control of the ball's position. All design criteria and functional requirements are fulfilled, indicating the system's completeness and effectiveness.

Overall, the system integrates precise control, real-time monitoring, and stable performance, showcasing a well-executed application of the STM32F103C8T6 microcontroller in a wind tunnel control system.

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