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Control Design of Stepper Motor based on Single Chip Microcomputer

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Abstract

With the development of intelligent control technology and power electronic technology, stepper motor controller has become an important part of automation device. Under the same motor conditions, the stepper motor responds faster, starts, stops, and shifts more easily, with smaller errors and better followability. Based on the above factors, this control system is mostly used in the fields of automation control and machinery. The stepper motor control system in this paper is designed based on the MK60DN512VLL10 single-chip microcomputer. The software programming is flexible, the degree of freedom is large, and the arithmetic operation function is strong.

Keywords

Single Chip Microcomputer; Stepper Motor; Closed-loop Control.

1. Introduction

In recent years, the development of automatic control system has promoted the development of stepper motor control system. As the research of stepper motor system gradually matures, the control of stepper motor has also received more and more attention. Due to the urgent needs of the market, there are higher requirements, so the control technology of stepper motors is also constantly improving and progressing in the research process.

The main function of the stepper motor in control is as an executive element, that is, if you give a pulse signal, the motor will rotate an angle, that is, the corresponding linear displacement and angular displacement are replaced by the pulse signal. It is because of this characteristic, so that the stepper motor is distinguished from other motors. Through the above description, we can easily know that the stepper motor is controlled by the pulse signal, so the speed of the motor is also controlled by the signal frequency. In view of these characteristics, it is easy to think of applying the single-chip microcomputer to the control of the stepper motor, and it is very convenient for the single-chip microcomputer to control the pulse, so this control method is favored by everyone. The stepper motor control system in this paper is designed based on MK60DN512VLL10 single-chip microcomputer. It has the advantages of flexible software programming, large degree of freedom, strong arithmetic operation function, and various algorithms and logic control can be realized by software programming.

2. Hardware Design

2.1 System Hardware Composition

The system adopts MK60DN512VLL10 single-chip microcomputer as the core control unit, and integrates downloading, debugging and peripheral interface circuits on this basis, forming a complete debugging control circuit. The hardware part of the system mainly includes the main control unit module, the power supply module, the encoder speed measurement module, the motor drive module, the OLED display module, and the control module.

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2.2 Design of Each Module of the System

2.2.1 Main Control Unit Module

This design uses the MK60DN512VLL10 microcontroller as the control chip. The MK60DN512VLL10 microcontroller is a 32-bit microcontroller that can run at a maximum operating clock frequency of 100MHz. Not only in teaching and learning, but also doing simple projects on a daily basis. It also has a wide range of uses in application fields such as high-end electrical products.

The main features of this microcontroller are as follows:

-Voltage range: 1.71V~3.6V.

-Up to 128KB of RAM.

- Two 16-bit SAR analog-to-digital converters (ADCs).

- 2 12-bit digital-to-analog converters (DACs).

- Multiple low-power modes to optimize power based on application needs.

- 16-bit low-power timer.

- 16-channel DMA controller supporting up to 63 request sources.

- Periodic interrupt timer.

-Real Time Clock.

- Memory protection unit with multi-master protection.

2.2.2 Power Module

The main power supply of the system hardware is provided by a battery with an output voltage of 7.2V. In the whole system, since different modules require different current and voltage values, the battery cannot directly supply power to each module. The operating voltage of the MOS driver is 7-12V, which can be directly powered by a 7.2V nickel-cadmium battery, while the microcontroller MK60DN512VLL10, OLED liquid crystal, etc. all require a voltage of 5V, and the encoder needs a voltage of 3.3V to work stably, so the power supply voltage is passed through LM2940 voltage regulator chip and LM1117 voltage regulator chip are used for voltage regulation. Each module works within its own working voltage range, and the entire system can run normally.

2.2.3 Motor Drive Module

One of the main sources of power for the stepping motor is the drive. If the motor needs to respond quickly and in time, the drive needs to respond in time. Therefore, this design adopts MOS drive, which provides a solid guarantee for the rapidity of the motor. MOS driver is a dual H-bridge chip, which is a unipolar voltage driver device. It can quickly respond to the instructions of the single-chip microcomputer; the input impedance is high, and it will not cause distortion due to the weak input signal, which is in line with the characteristics of the output signal of the single-chip microcomputer; good thermal stability, it can continue to work without overheating and failure.

2.2.4 Encoder Speed Measurement Module

The 512-line photoelectric encoder is used in this design. The so-called 512-line encoder means that in order to obtain 512 pulse signals, the encoder needs to be rotated once. It is calculated that a pulse needs to be rotated by 0.70°. The quadrature decoding function of the K60 microcontroller is used to collect the number of pulses, and then the real-time speed can be calculated according to the program cycle. After writing down the data, clear the pulse number and wait for the next program cycle. In this way, the encoder speed measurement task is completed.

2.2.5 OLED Liquid Crystal Display Module

OLED liquid crystal display refers to organic electroluminescent diodes. This kind of diode can emit light by itself, which is a function that most diodes do not have, so it does not need a backlight; secondly, the thickness of this display module is extremely thin, only about 2mm, which is much lighter than the 1602 display screen, and it is very easy to use. Convenience, at the same time, the

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excellence is not only reflected in the size, but also far ahead in the response speed, which can be said to be the biggest advantage of this liquid crystal display.

3. The Overall Idea of the System

3.1 Main Program Design

The basic task of the main program is to control the entire DC servo motor control system, so that each module can coordinate with each other to complete the process of speed regulation together. The specific process is that the single-chip microcomputer sets the target speed of the stepping motor, accelerates the rotation, decelerates the rotation, and controls the forward and reverse rotation, as well as a series of adjustments to the precise operation. The main program block diagram of the system is shown in the figure.

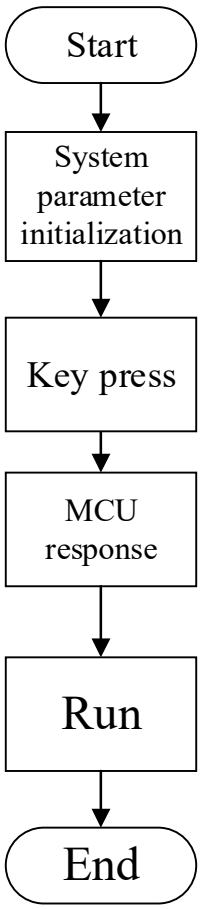

Figure 1. main program block diagram

3.2 System Programming

The system programming is divided into the following modules: initialization module, interrupt speed acquisition module, speed PID control module, drive motor control module.

(1) MCU initialization module: I/O module, timer module, PWM module, liquid crystal display module.

(2) Interrupt speed acquisition module: The PIT timer is used to time the program period of 10ms, and the pulses collected by the encoder are transmitted to the single-chip microcomputer every 10ms and cleared.

(3) Speed PID control module: using incremental PI control. The deviation between the current speed and the target speed is calculated and converted into PWM according to the formula.

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(4) Drive motor control module: According to the PWM calculated by PID, the motor speed is controlled by driving to quickly reach the target speed. Achieve ideal speed control.

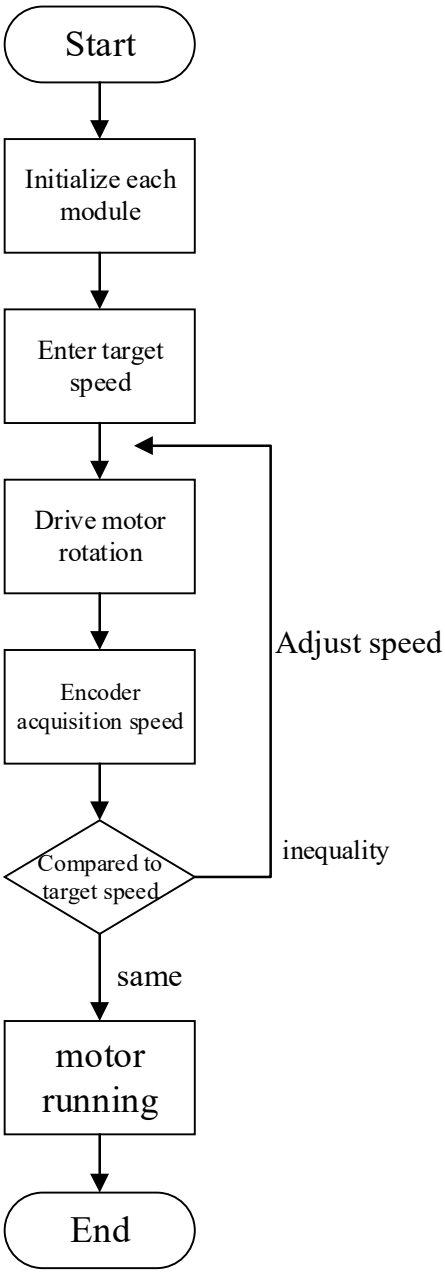

Figure 2. overall system flow chart

3.3 Each Control Module of the System

3.3.1 PIT Timer

First of all, the cycle of the single-chip microcomputer running the program should be measured, and a test IO port level flip should be written at the end of the while, so that each time the program runs, the IO port level will flip once, and the system can be seen through the oscilloscope. It takes about 6ms to run the program once, so the program cycle can be timed to 10ms, so that each program can run fully. At the same time, the period is 10ms, which will also facilitate the calculation of the speed.

3.3.2 Encoder Acquisition Module

The encoder's acquisition of speed is very important, which is related to the accuracy of the entire system. Therefore, the collected data must remain accurate, otherwise it will affect the entire system. Just like this, the filtering method is used in the collection to filter out the wrong data and save the

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correct data. However, considering that filtering data will lead to data loss, while filtering out the wrong data, the previous data is supplemented, because the change between the two data is not very large, which greatly reduces the error.

3.3.3 Calculation of Rotational Speed

According to the data collected by the encoder, the system calculates the number of revolutions per minute of the DC servo motor according to the formula, and then displays it on the OLED LCD screen in real time.

3.3.4 Key Module

For the sudden input signal, the best way to deal with it is to use interrupt detection and then deal with it. The IO port interrupt of the MK60DN512VLL10 microcontroller can handle this situation, so the key is used to interrupt the IO port of the microcontroller, and the signal input that occurs at any time period during the system operation can make the CPU respond quickly and achieve the desired operation result.

3.3.5 PID Algorithm

There are positional PI and incremental PI in the PI control algorithm, and the incremental PI algorithm is used in this system. It is an increment for the positional PI, and the output value of the digital regulator is an increment. The output increment of the PI operation is the difference between the position values calculated by two adjacent samples, as shown in formula (1):

$$\Delta \mathrm{u(k)} = \mathrm{u(k)} - \mathrm{u(k-1)} \tag{1}$$

The output u(k) of the positional PI regulator is the full output, as shown in formula (2):

$$\mathrm{u(k)} = K_p \left[e(k) + \frac{T}{T_i} \sum_{j=0}^{k} T_e\,(j) \right] \tag{2}$$

From the above formula, it can be known that formula (3) is shown as:

$$\mathrm{u(k-1)} = K_p [e(k-1) + \frac{T}{T_i} \sum_{j=0}^{k-1} T_e(j)] \tag{3}$$

u(k) minus u(k-1) is shown in equation (4):

$$\Delta \mathrm{u(k)} = K_p [e(k) - e(k-1) + \frac{T}{T_i} e(k)] \tag{4}$$

The above formula is the incremental type of the PI control type, and its output represents the increment of the valve position, as shown in formula (5):

$$\mathrm{u}(k) = u(k-1) + \Delta u(k) \tag{5}$$

4. Conclusion and Analysis

After a series of designs, we have completed the speed regulation and forward and reverse control of the stepper motor. This paper mainly studies the control scheme of the single-chip microcomputer. The system adopts MK60DN512VLL10 single-chip microcomputer as the control chip, the MOS drive provides power, and the encoder is used as the speed feedback transposition to make the system closed-loop. As well as the assistance of independent buttons, LCD and other modules, the system is

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more complete and easy to control and observe. In terms of algorithm, PI control is adopted to realize the ideal speed of the stepper motor control system in the shortest time, and the stable and reliable continuous operation is realized.

All in all, the single-chip microcomputer is a widely used automatic speed control method for the stepping motor speed control system, and the closed-loop control is the basis for the accurate and stable operation of the system. With the passage of time, the single-chip microcomputer will become more and more perfect for the stepper motor control system, and it will be used in more and more life and production.

References

[1] Chen Yufei, He Wangyang, Wang Chenguang. Design of elevator control system based on single-chip microcomputer[J].Science and technology innovation, 2020(01):95-96.

[2] He Yikang, Pan Zaiping. Power Electronics Technology [M]. Beijing: Science Press,2019.

[3] Hua Chengying. Fundamentals of Digital Electronic Technology [M]. Beijing: Higher Education Press, 2018.

[4] Li Xiaolin. The principle and interface technology of single chip microcomputer [M]. Beijing: Electronic Industry Press, 2020.

[5] Liu Juan. Application of single-chip microcomputer in the design of stepper motor control system [J]. Digital Technology and Application, 2019,37(12):9+11.

[6] Liu Runze, Wang Xianlei. Design of a stepping motor operation controller [J]. Science and Technology Vision, 2019(16):16-17.

[7] Luo Zhiyuan, Zhang Youlong, Li Yaoxin. Simple stepper motor control system[J]. Mechanical and Electrical Engineering Technology, 2019,48(04):163-165.

[8] Tian Juan. Research on application technology and development of power electronics [M]. Beijing: Water Resources and Hydropower Press, 2019.

[9] Tian Qiushi, Zhao Peng. Design of stepper motor controller[J].China Science and Technology Information, 2019(14):69-71.