the Design of Motor Precision Positioning System Based on STM32 Single Chip Microcomputer

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Abstract. Aiming at the problem that the positioning accuracy of the motor is not high when the electric hoist vertical lifting industrial material is working, the PC + motion control card + digital AC servo motor positioning cost is too high. The system uses the STM32F103 core controller + incremental photoelectric encoder control scheme, which can locate the position of the material tray accurately. The test results show that the system has the characteristics of high positioning accuracy, stable operation and low cost, The average error is within 0.2mm, it has a certain guiding significance for industrial measurement, automatic control, electrical transmission and other fields of application.

1. Introduction
In the electric hoist vertical lifting industrial materials operations, we commonly used the limit device to the motor rotation of the limit position to locate, limit device is made of the rope device, the limit bar baffle, motor, breaker and other parts. The plate is installed in the limit position where the tray needs to be stopped, that is, when the tray is running to the limit position, the guide rope will push the stop levers and the breaker contact to disconnect, thus cutted off the motor and stopping the motor in the limit position [1 -2]. This program has high requirements for the limit device, any part of the limit device damage or improper installation will constitute a security risk, the other limiter can not protect the motor positioning accuracy, the use of the process often occurs due to motor over Turn, so that the lifting equipment damage, serious will lead to decoupling, roof and other major security incidents. In order to improve the accuracy of the motor and the stability of the system, the control scheme for the high-performance PC + motion control card + digital AC servo motor is used to locate the motor accurately. For example, SINAMICS S120 is produced by Siemens Electric Transmission Co, Ltd. Drive control system, which is designed by Wu Qinbin the teacher in School of Mechanical Engineering and Automation and other teachers that is based on FM351 positioning module rotary table full closed-loop positioning control system [3-4]. Although the above system has a high positioning accuracy, smooth operation characteristics, but compared with the limit device positioning program, the early need for greater cost investment. The author designs a high precision and low cost motor positioning system which is based on STM32 controller for industrial lift operation. The system adopts STM32F103 core controller + incremental photoelectric encoder control scheme, through the STM32 encoder interface to the encoder A, B phase pulse to count, and according to the count value and A, B phase difference to calculate the current motor steady-state speed and material tray position, the continuous room temperature aging performance test, the system positioning accuracy is up to 0.2mm, it has been applied to the wine factory grapple positioning project.
2. Motor Precise Positioning Strategy

The initial strokes of the system are calibrated to calculate the number of pulses corresponding to the total displacement of the material run. Then, the encoder A and B phases are sampled according to the parameters. The motor running direction is judged in real time and the motor rotor is calculated from the initial position rotate the number of count pulses generated, and finally determine the material running position.

2.1. Encoder Configuration

The TIM4_CH2 channel acquisition encoder phase A input, TIMX_SMCR SMS position is 011, select the encoder mode 3, the counter on the TI1FP1 and TI2FP2 edge In the TIM4_CCER register, set the CC1P and CC2P bits in the TIM4_CCMR register, select the TI1 and TI2 polarity, filter the IC1F and IC2F bits of the appropriate TIM4_CCMR according to the filter factor setting algorithm. Set the CEN = 1 of TIM4_CR1 to start the counter captures encoder pulse [5].

2.2. Data Definition

To prevent overflow, the program uses two variables to store the number of edge pulses generated by the encoder rotation, which are the number of count pulse spills and the motor rotor rotation angle count pulse. If the encoder rotates a week to generate a pulse, the A and B phase input pulse using both sides of the simultaneous counting, the timer counter TIM4_CNT value is \( V_{\text{cnt}} \), the motor rotor rotation angle is \( \theta \), it can be obtained that (1):

\[
\theta = V_{\text{cnt}} \times \frac{(4 \times X_{\text{pulse}}) \times 360^\circ}{V_{\text{arr}}}
\]

(1)

If the current count pulse overflow times is \( N_{\text{overflow}} \), the automatic reload counter TIM4_ARR value is \( V_{\text{arr}} \), the current motor rotor deviation from the initial position of the rotation of the count pulse is \( C_{\text{cur.pulse}} \), so we can generated by the formula (2):

\[
C_{\text{cur.pulse}} = N_{\text{overflow}} \times V_{\text{arr}} + V_{\text{cnt}}
\]

(2)

2.3. Algorithm Implementation

When the system is running for the first time, we must calibrated the initial stroke distance of the material pallet at first to determine the total number of pulses corresponding to the distance between the highest point and the lowest point. The specific positioning method is to lift the tray to the lowest point, The number of count pulse overflow and the motor rotor rotation angle count pulse value are cleared, and then the tray is raised to the highest point. During the tray lifting process, the system always records the rotary encoder A and B phase input pulse. When the tray is raised to the highest point, Record the count pulse overflow count and the counter value at this time, and calculate the total count pulse value of the motor rotor deviation from the initial position rotation according to the equation (2), that is, the count pulse value corresponding to the total stroke distance of the material tray and record it in the storage unit. Set the initial total travel distance as \( D_{\text{total}} \), the total travel distance corresponding to the count pulse value is \( C_{\text{tot.pulse}} \), then the tray at a certain time from the vertex of the vertical distance difference is \( D_{\text{cur.position}} \), so we can obtained by (3):

\[
D_{\text{cur.position}} = D_{\text{total}} - \frac{C_{\text{cur.pulse}}}{C_{\text{tot.pulse}}} \times D_{\text{total}}
\]

(3)

The counter TIM4_CNT always counts the captured encoder A and B phase input pulses as the tray runs along the total stroke path. Reference[6] gives the specific counting principle. When the count reaches the TIM4_ARR preset value it will produce an overflow, then the program needs to store the number of pulse overflow count value of the variable to modify the principle of modification which is based on the motor rotor rotation direction, if the motor clockwise rotation, the material tray to do lifting. If the motor rotates counterclockwise, the material tray is subjected to descent motion. The count pulse overflow is decremented by 1, and the direction of rotation of the motor can be determined according to the DIR bit in TIM4_CR1 [6]. The overflow judgment can be made. The interrupt event is triggered by the STM32 update. The motor deceleration to stop needs to have a certain buffer time,
so the material tray is close to the pole when need to advance the brake, the brake is called the critical point of braking, the critical point and the total stroke between the poles are known as the critical area. When the microcontroller detects the tray to run to the critical area, immediately through the IO port to the upper controller to send a message, so that the controller sends a brake signal to the motor. In order to increase system security, the microcontroller sends a message at the same time, also controls the industrial field alarm device to start, so that the site workers to take emergency braking measures. Motor positioning main program flow is shown in Figure 1, count pulse overflow update interrupt flow shown in Figure 2.

3. System Implementation

3.1. Hardware Design

System hardware part is made of the main control circuit, power management module circuit, alarm light drive circuit, pulse acquisition module circuit, data storage module circuit and display terminal. The main control circuit is the control core of the whole system. It is composed of the minimum system and the on-chip basic IO peripherals composed of STM32F103ZET6 chip with high performance, low cost and low power consumption which is based on ARM Cortex-M3 core architecture. It is responsible for counting the input pulse of the encoder. The motor rotation direction, speed and material running position data processing, tray operation to the critical area when the microcontroller through the RS485 protocol to the host controller to send the motor to stop the command to control the industrial field sound and light alarm, real-time and monitoring stations to communicate. Power management module circuit by the TI company BQ24295 PMU battery management chip and peripheral circuit components, responsible for system power supply, voltage conversion, charge and discharge management. Alarm light drives circuit consists of NPN transistor and enhanced P-channel FET structure of the amplifier circuit, through the microcontroller PB0 mouth issued PWM pulse signal control rated voltage of 12V alarm light flashing alarm, see Figure 3. Pulse acquisition module consists of Jie Te Shi 600 line incremental photoelectric rotary encoder, level
conversion circuit, STM32 encoder interface circuit, the encoder through the coupling and hoist motor connection, the output A, B, Z phase pulse by the level Conversion circuit to STM32 level signal sent to the TIM4_CH2 and TIM4_CH1 timer channel, which level conversion circuit by the beads, pull-up resistor and build FET, responsible for the encoder output 5V level signal and transformed it into STM32 which can be normal work of the 3.3V level signal, see Figure 4.

Figure 3 alarm light drive circuit  Figure 4 Level conversion circuit

The data storage module selects the AT24C256 chip, which supports the IIC bus protocol with 256K bits. The WP, SCL and SDA pins are connected to the PB1, PB10 and PB11 pins of the microcontroller. The total number of pulses and the total number of pulses rotor deviation from the initial position rotation angles count pulse value. The display terminal is made by the installation of serial port debugging software composed of the upper PC, it is responsible for real-time display of motor status and tray operation information, the system hardware block diagram is shown in Figure 5.

Figure 5 system hardware block diagram

3.2. Software Design
The system software business logics includes the system initialization service, the counting acquisition service, the critical area judgment business, the alarm business, the storage data business, the positioning business, the charge and discharge standby business, the watchdog business, use the software engineering thought and divided it into the driver layer, the device layer, and the business logic layer. The system business process is as follows: After the system starts the self-test, including according to the current power supply mode intelligent switch normal mode or low power mode, and the peripheral communication is normal, the initial total distance measurement to determine the normal; self-test after the initial configuration. Including system clock, external interrupt and interrupt priority, timer mode, STM32 IO port, RS485 serial port communication, ethernet interface
communication, EEPROM storage communication protocol, window watchdog start. After the configuration is completed, the electric hoist began to improve the material operation, in the material tray lift operation of the whole process, STM32 microcontroller real-time encoder A, B phase input pulse count, count the current count pulse overflow times and motor rotor rotation angle count pulse. And the vertical distance difference between the two ends of the material tray is calculated according to the precise positioning algorithm of the motor. If the test tray is running to the critical area, the brake controller of the upper controller is informed immediately and the alarm lamp is flashing. Workers can observe the motor status and pallet operation information about the monitoring station, and can re-calibrate the total stroke distance between the interactive key.

4. Performance Test
Test environment selected from the weight of 10T MD1 wire rope electric hoist, the rated speed of 1400r/min, the rated motor capacity of 13kW, the hoist hanging through a hook which is weight about 2T trailer, lifting height of 9m, lifting speed for the 8m/min, respectively, from the total stroke of the lowest point and the highest point of the vertical distance of 0.6m as the alarm critical point, but also as the system measurement point 1 and measurement points 2, the encoder using Jie Te Shi 600 line A, B Incremental photoelectric encoders, that is, a revolution can produce 2400 pulses. The experimental results show that the system can work continuously under normal temperature and permanent magnetic environment, and the experimental results show that the system can operate normally at room temperature, and the temperature of the test point 1 and the test point 2 and the actual position are measured. Positioning accuracy is always within 0.2mm. The test results are shown in Table 1.

Table 1 system performance test table

| Running time(hour) | Rotation speed(r/min) | Point 1 average error(mm) | Point 2 average error(mm) |
|-------------------|----------------------|---------------------------|---------------------------|
| 36                | 800                  | 0.091                     | 0.091                     |
| 36                | 1000                 | 0.114                     | 0.115                     |
| 36                | 1400                 | 0.118                     | 0.117                     |
| 72                | 800                  | 0.119                     | 0.118                     |
| 72                | 1000                 | 0.122                     | 0.122                     |
| 72                | 1400                 | 0.143                     | 0.144                     |

5. Conclusion
The test results show that the STM32-based motor precision positioning system is more secure and reliable in dealing with the problem of motor positioning than the limit device positioning scheme. Compared with the high cost performance PC and the motion control card + Digital AC servo motor control program, the case before the total investment is less than a thousand dollars, the cost is more affordable, easier maintenance. The system has been successfully applied to the winery grapple positioning project, the annual economic benefits for enterprises to bring hundreds of thousands of dollars, the use of motor precision positioning program for industrial measurement, automatic control, electrical transmission and other fields have a certain guiding significance and reference value.

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