Development of two-axis translation stage control system based on STC8A8K64S4A12

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Abstract: Based on STC8A8K64S4A12 microcontroller and LabVIEW[1] software, the two-axis translation stage control system is designed. The two-axis translation stage is applied to a plane plotter, and the two rails are placed at right angles to form a horizontal motion mechanism. The two-axis controller consists of STC8A8K64S4A12 microcontroller control board and TMC5160 stepper motor driver[2], which realizes independent control of the two-axis translation stage. At the same time, PC software is designed, which can be connected to the two-axis controller through network interface or serial communication interface. The two-axis translation stage is controlled by a PC or a laptop. Repeated test experiments were carried out on the system. The experimental results show that the system has high reliability and control precision, and the horizontal displacement control accuracy is 0.01 mm.

1. Introduction

With the rapid development of computer technology, numerical control technology and software research, the development of plotters has entered a new stage. A computer with high-speed processing of large amounts of data is equipped with a high-precision drawing machine to form a new computer graphics system. At present, a variety of drawing systems are emerging one after another, and the functions realized are also blooming. Various plotter systems are inseparable from the translation stage [3]; industrially, the translation stage is used to control various CNC machine tools, production machines, and large frame instruments; in the aerospace field, the translation stage is in the field of optical research. Various semi-physical simulation studies and tests play a key role.

The design content of the translation stage control system includes hardware and software design. The stability of software and hardware operation is directly related to the realization of the translation control function and the reliability of the precision. The two-axis translation stage of this paper is self-developed and used in the plotter control system. It is placed at right angles by two linear guides, which constitutes the XY two axes of the plotter. The Y axis is fixed on the platform and the X axis is in Y. The axis is controlled by the Y-axis to move linearly. The drawing brush is fixed at the end of the X-axis slide. The steering brush controls the lifting and lowering of the brush. The open-loop control of the translation stage XY axis can be set under the speed. The functions of jog, absolute positioning, zeroing, stopping, drawing straight lines, arcs, DEMO circles and real-time status display, horizontal XY two-axis horizontal displacement repeat positioning accuracy of 0.01mm.

2. Structural design of the control system

The system is mainly composed of the following three parts:

(1) PC software platform of the host computer: realizes the human-computer interaction function, sets the motor driver operating parameters, completes the response of the user operation command, and displays the status information of the two-axis motion position and speed in real time.

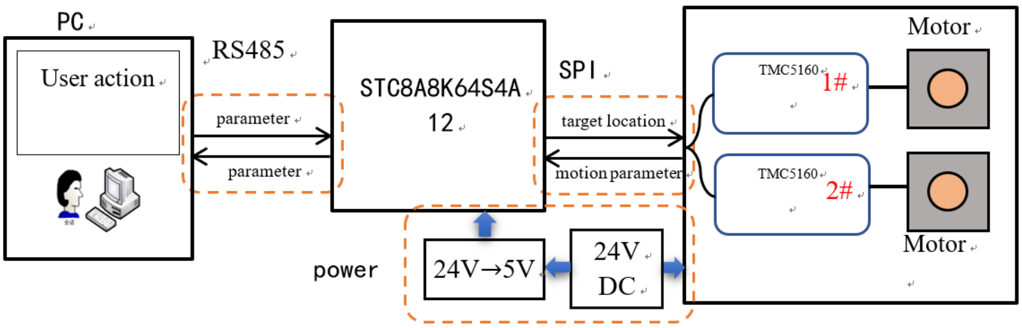

Fig.1 Two-axis translation stage control system overall structure block diagram

(2) Lower machine controller: STC8A8K64S4A12 MCU as the main control board. The TMC5160 driver chip is used as the drive control board. In this control system[4], the drive control board is the core drive part of the translation stage control system. The MCU control board receives and parses the upper computer control commands, and the drive control board executes all the stepper motor control logics. The related algorithm does not require software to control the motor. It only needs to provide the target position, and then sends a control signal to drive the two-axis translation stage [5].

(3) Stepping motor system: The actuator of the two-axis translation stage control system cooperates with the linear bearing movement by means of belt, optical axis and other transmission mechanisms, and the XY axis moves according to the received control command to drive the translation stage to run smoothly.

3. Hardware system design

3.1. STC8A8K64S4A12 micropro-Cessor

STC's single-clock/machine-cycle (1T) microcontroller is a high-speed/low-power/new generation 8051enhanced microcont-roller ultra-high-speed 8051 core (1T), which is about 12 times faster than the traditional 8051. The instruction code is fully compatible with the traditional 8051, 20 interrupt sources, 4 levels of interrupt priority. On-chip integration of rich resources 64K bytes of Flash space, 64K bytes of RAM, external crystal oscillator (4MHz-33MHz), eight sets of enhanced PWM, five 16-bit timers, one ultra-high-speed ADC, support for 12 bits Precision, 15-channel analog-to-digital conversion, high speed. Three SPI interfaces mean up to three motors can be controlled.

3.2. TMC5160 stepper motor driver chip

The TMC5160 is a high-power stepper motor control driver chip with a serial communication interface that supports two-phase stepper motors, combining a flexible ramp generator for automatic target positioning with the industry's most advanced stepper motor driver. High dynamic, high torque motor drive with external transistors. TRINAMICs' advanced spreadCycle and stealthChop choppers provide absolute noise-free operation and maximum efficiency and optimum motor torque control. High integration, energy efficiency and small form factor make system miniaturization and performance scalable, enabling cost-effective solutions. With higher voltage and higher motor current, coil current up to 20A, voltage range 8-60V.

3.3. Drive circuit design[6]

This driver circuit is designed with a minimum of external components. Eight MOSFETs are selected according to the driving current and driving voltage required for the two-phase stepping motor. The eight signals of the TMC5160 output HA1, HA2, HB1, HB2, LA1, LA2, LB1, and LB2 are connected to the MOS drive tube to form a typical H-bridge drive circuit diagram. BMA1, BMA2, BMB1, and BMB2 are the output terminals of the AO4606 drive tube, which are respectively connected to the two-phase winding of the stepping motor. The drive circuit sets the motor coil current through two sampling resistors. The power supply filter uses a low ESR capacitor. For best performance, the minimum coil current near the power bridge is 100μF / ampere. Considering the high power supply voltage of 48V, the internal gate voltage regulator and the internal 5V regulator have considerable power consumption. When the MOSFET gate charge is high, the chopper frequency is high, or the system clock frequency is greater than 12MHz, it is itself. Power consumption increases the chip temperature and will significantly lower the temperature protection threshold. Therefore, in order to reduce power consumption, the drive gate voltage is externally connected in this design. The TMC5160 driver board is connected to the microcontroller as shown:

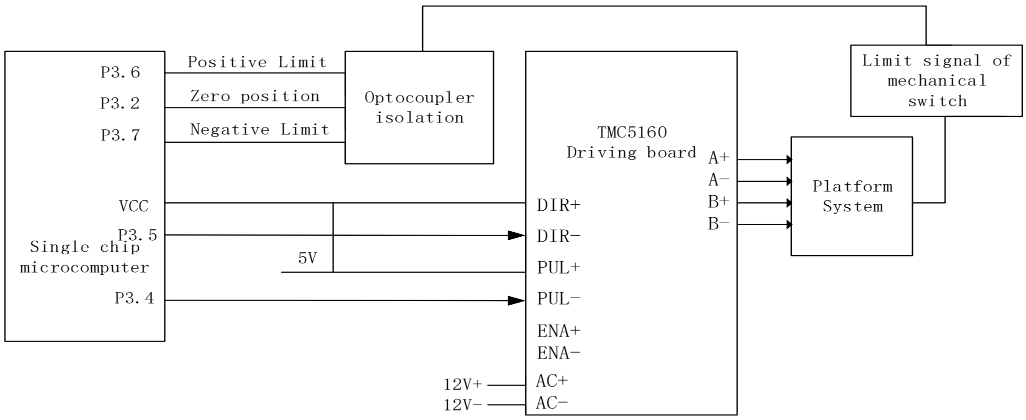

Fig.2 Driver port connection diagram

(1)A stepping motor [7]is an actuator that converts electrical pulses into angular displacement. When the stepper driver receives a pulse signal, it drives the stepper motor to rotate a fixed angle (called the "step angle") in a set direction, and its rotation is performed step by step at a fixed angle. The angular displacement can be controlled by controlling the number of pulses to achieve the purpose of accurate positioning. At the same time, the speed and acceleration of the motor rotation can be controlled by controlling the pulse frequency, thereby achieving the purpose of speed regulation. The stepping motor can be used as a special motor for control, and it is widely used in various open-loop control because it has no accumulation error (100% accuracy).

(2) PUL+: pulse signal input positive, PUL-: pulse signal input negative, control the speed of stepper motor, mainly controlled by changing the control pulse frequency. The step angle of all two-phase stepping motor of this system is 1.8°. Step, the motor needs 200 pulses per running. If the motor runs in half step, the motor needs 400 pulses. The maximum subdivision [8]value of the TMC5160 drive chip can reach 256 machines. Each operation requires 256*200=51200 pulses. That is to say: when subdivided into 256, the motor speed is 1rps, the frequency of the control pulse is 51200Hz, the motor speed is 2rps, and the control pulse frequency is 102400Hz. Using the subdivision technique to use 64 subdivisions for this design, the 1 pulse equivalent is 0.028125°.

(3) Enable signal ENA+(+5V), ENA-: Normally not connected to ENA+, ENA-, the system is enabled by default.

4. Software system design

The software design part is the soul of a control system. The quality of the system software design will directly affect the effect of the entire control system. Therefore, real-time, reliable software is an effective guarantee for the stable operation of the entire system.

4.1 PC software design

The software design of the system is divided into two levels

In order to ensure the correct interpretation of the instructions in the communication process between the upper computer and the lower computer and make the system have good maintainability, the control system customizes the communication protocol. The specific protocol format is shown in Figure 3:

AA	xx	xxxx	BB
Frame header	Instruction type 10 set the x-axis position 11 set the y-axis position	Instruction content X, Y axis actual coordinates	Terminator

Fig.3 Protocol instruction format

According to the functional I requirements of the host computer, the modular design concept is adopted, and its functional modules are as follows:

(1) Communication configuration module: Start the software initial interface for selecting the communication method and configuring the communication parameters.

(2) Control parameter setting module: The speed of the motion control system, the first phase acceleration, the second phase acceleration, the maximum acceleration, the subdivision number, the motion speed, etc. can be set.

(3) Control operation module: used to input user commands, send commands to the lower computer, control the turntable to perform related motion and motion status display. The control interface is shown in Figure 4:

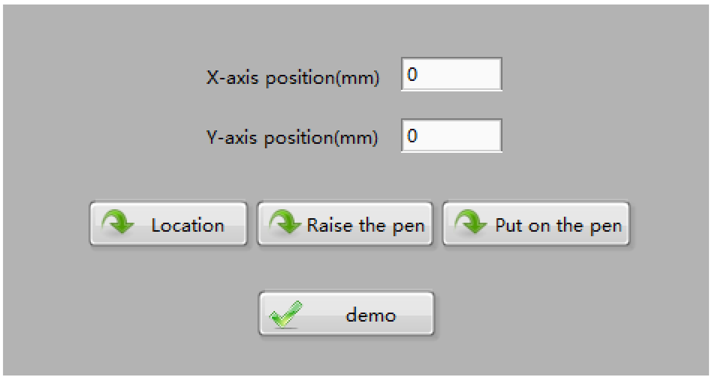

Fig.4 Functional interface

4.2.TMC5160 Configuration

For the TMC5160 initialization configuration, the configuration of the TMC5160 related registers is required. The TMC5160 has six related registers to be configured, which are GCONF, CHOPCONF,X_COMPARE,IHOLD_IRUN, TPWMTHRS, and RAMPMODE. Mainly configured with chopping coefficient, standing current, motion current, stop delay and switching speed. The number of bits in each register is not the same. Note that the address +0x80 is written to each register address. SPI has four kinds of timings. When configuring related registers, it is necessary to strictly follow the configuration timing to ensure the reliability of communication. In order to ensure the reliability of communication, it is necessary to follow strict configuration timing when performing related register configuration.

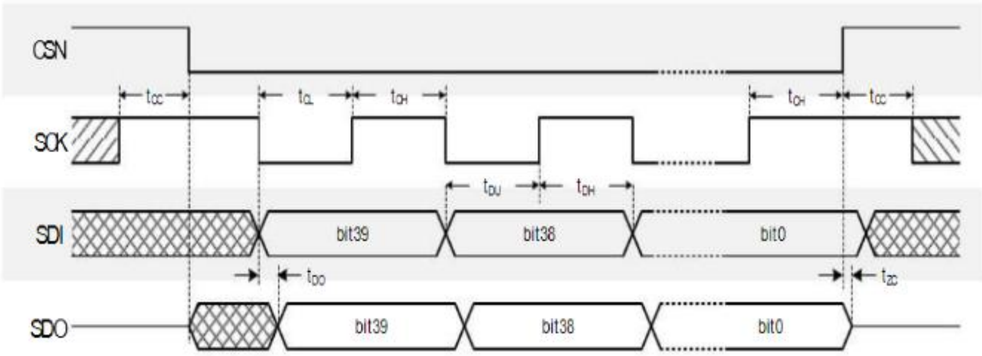

Fig.5 SPI configuration timing diagram

The minimum value of the SCK clock pulse must be set during communication. One clock transmits one data and sends 8 bits at a time. There are two kinds of initial state of the clock, and there are two kinds of positive and negative pulses. Therefore, to correctly select the mode, the selection error will cause the data to be misaligned, resulting in transmission failure. The CSN is used as a chip select terminal for selecting the ones that are used to drive multiple SPI devices. When setting the speed, the time conversion of speed and acceleration is to change the unit of parameter value into time unit. The time reference of speed: tv = 2^24 / f_{CLK} Time reference of acceleration ta2: ta2 = 2^41 / (f_{CLK}) 2 (f_{CLK} is the system clock frequency, 16MHz) The lower computer software also adopts the idea of modular programming, which is convenient for program debugging and later maintenance. The flow chart of the drive control system is shown in Figure6:

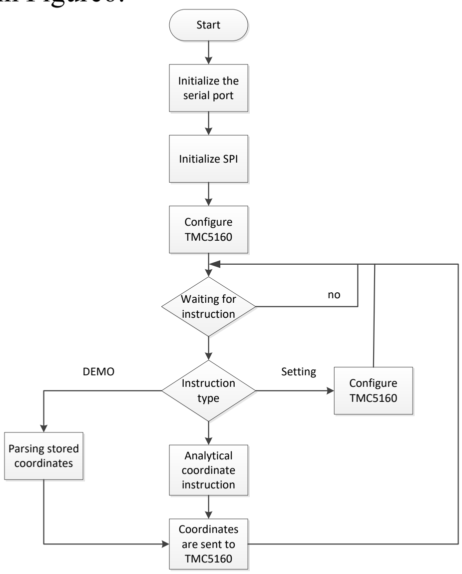

Fig.6 Drive control system program flow chart

The entire two-axis translation stage control system is controlled by the human-machine interface, and the control system first initializes the serial port and SPI. Configuration TMC5160 involves parameter setting, motion control, data processing, and setting interrupt processing in the microcontroller. When the control system is powered on, the system automatically searches for the absolute coordinate origin of the plotter system; then, according to the instruction type, the set target position is parsed, the driver is set to the position mode, and by reading the position value, the driver separately controls the XY axis. The two stepping motors send a corresponding number of pulses and frequencies; then the two-axis controlled translation stage moves the position, and the steering gear will complete the drawing instructions according to the actual task, including drawing straight lines, drawing arcs, DEMO circles. During operation, the system reads the running parameters of the two axes of the plotter in real time, and sets different interpolation functions and running speeds. After the drawing is completed, it will stop and return to the set coordinate origin; in order to prevent the occurrence of wire drawing, it needs to be in the single chip microcomputer. Set a certain delay, the servo should first raise a certain height, and then complete the reset operation. In this plotter, in order to further improve the control precision and achieve better control effect, we try to combine the pan-Boolean algebra [9] with the traditional PID algorithm, and apply the parameter self-tuning fuzzy PID controller [10] to the closed-loop control of the stepper motor. In the middle, and introduce a position feedback mechanism to achieve high stability and high precision control of the stepper motor.

5. Conclusion

The system is based on the upper computer for the industrial PC computer, the controller is programmed with STC8A8K64S4A12, and the intelligent drive chip TMC5160 is used for the plotter actuator for the first time. Under the principle of ensuring the same accuracy, a stepping motor instead of a servo motor was selected as the main drive motor. The control stepper motor meets the control requirements, and the replacement of the servo motor is realized, which greatly saves the cost. The software design uses Bresenham linear algorithm and circle drawing algorithm control. It can choose to send the position target directly in the position mode. The driver calculates the number of pulses according to the target position, drives the actuator action, and the subdivision microstep function in the TMC5160 driver chip. It can make the whole motion process smoother and smoother and smoother. At the same time, the motion control and driver chip TMC5160 can perform high-power stepping motor drive excellently. The built-in stall-Guard2TM function module can automatically change the current output to reduce power consumption according to the change of load, while maximizing the speed without losing step, guarantee The self-generated precision requires smoothing to reach the target position, which meets most of the mechanical work requirements, and can even replace some of the instruments using servo motors, which greatly reduces the product cost. The test results show that the two-axis positioning accuracy is 0.01mm, which has practical significance.

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