Design of Automatic Controller System for Three Axis 3D Printing Platform

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Abstract. With the development of society and the continuous improvement of the level of automation, automatic three-dimensional work platform is more and more popular, but now the three-dimensional work platform has a single function, and the waste of capacity is a serious problem. Therefore, this paper uses STM32F429 MCU to design a set of replaceable working position of the three axis control platform. The design of the table with replaceable work head, by identifying the ID on the head, change the control mode, enhance the functional diversity of the three-axis platform. In addition, in order to improve the universality of the system, the platform has many external communication interfaces, visual man-machine interface and LAN network communication functions.

Keywords: Three axis 3D system; Controller system; Mechanical arm.

1. Introduction
In recent years, 3D printers and automatic welding machine have developed rapidly, almost realizing comprehensive applications in most fields and playing an active role in various high-end fields [1]. In 3D printing industry and electronic industry started late in China, most only for education teaching and many individual enthusiasts, but has been developing rapidly in the field of circuit design, cutting-edge level can compare a shoulder completely large technology such as the United States, in the aspect of hardware processing has a worldwide market, so domestic of engraving machine, glue machine, CNC milling machine and other mechanical demand is also big. Therefore, in the field of processing, China continues to pursue intelligent process.

No matter at home or abroad, there is no attempt to integrate multiple triaxial systems under the same production process into a relatively portable triaxial platform. All the intelligence is only to improve the convenience of using a single platform, foreign CNC milling machine has tried to replace the mode of multi-function cutter head, but it is still not separated from the single platform single function of the working mode. Under this premise, this paper combines a variety of three-axis equipment in the same production process onto the same portable three-axis platform, and functions in different production processes can also be transformed by simply changing the work head, which greatly improves the initiative of the industry.
2. Overall System Design

The overall scheme of this paper is mainly composed of power supply part, SCM, memory part, power down storage part, stepper motor drive circuit, detection circuit, video signal transmission circuit, IIC and SPI communication circuit, wireless transmission circuit, TTL to USB and high-speed CAN external communication interface and Ethernet data transmission interface [2]. Three external A4988 driver chips are used to drive the three-axis motion, and two pairs of interfaces are left for expansion into five axis to meet the requirements of high-precision engraving machine [3]. FPC40 is used to connect the capacitive touch screen as a visual interactive port.

The main reason why the traditional three-axis platform cannot achieve true multi-function is that the control modes of various three-axis platforms cannot be unified, and the core algorithms of different motion modes differ greatly, which makes it difficult to integrate into the same platform [4]. Paper work in each segment on joining the ID attribute, change jobs after cutting head, the system will automatically detect the current working segment ID, determine th e control algorithm for ID after the system will automatically switch to the mode matching with the ID of the cutting tools, it needs to be stored at the same time a variety of control algorithm in the system, and usually using three axis controller chip capacity is insufficient, This paper studies STM32F429IIT6 as the core [5].

3. The Hardware Design

The hardware system of paper consists of five main parts, including core control part, data storage part, motor drive part, data communication part, disp lay part. Because SDRAM and LVDS converter frequency and signal synchronization and stability requirements are high, so we develop our own special main control board.

Paper circuit schematic diagram is mainly composed of MAIN, JTAG, MCUBASE, POWER, USB&USART, MEMORY, LCD, M_DRIVE, LED&BEEP, ETHERNET eight parts. Among them, MAIN, MCUBASE, POWER, JTAG and are the core control part, MEMORY is the data storage part, M_DRIVE is the motor drive part, USB&USART and ETHERNET are the data communication part, LCD and LED &BEEP are the display part.

3.1. Core Control

The core control circuit is mainly composed of power supply part, STM32F429IIT6 and its basic peripheral circuit and program burn debugging port. In order to ensure the stable operation of the main control chip, paper uses a large number of filter capacitors, so that each of the 15 power supply pins of STM32F429IIT6 has more than one filter capacitor to eliminate power fluctuation. At the same time, it is equipped with on-board standby power supply and RC1220 button battery, which can supply power to the internal RTC when there is no off-board power supply, so as to ensure that the RTC still works normally after VDD power failure.

In the power supply part, the design adopts a two-stage step-down power supply scheme from 12V to 5V and then to 3.3V. The first-stage step-down part uses RT8289 switch voltage regulator with high stability and large overcurrent. In addition, a filter capacitor group is added at the 12V access end to filter out voltage fluctuations, and a transient suppression diode SMBJ13A is connected in parallel to prevent surges and lightning strikes. The 5V output terminal has a parallel decoupling capacitor to enhance the voltage stability of the power supply. The second stage step-down part adopts AMS1117-3.3. The 3.3V voltage after this chip will power the core control part, data storage part, motor drive part and data communication part in addition to the display part. Considering that the full power consumption of these four parts will cause the current to slightly exceed the maximum operating current of AMS1117-3.3, BL8072Ctri33 with the same package and pin definition as AMS1117-3.3 is prepared as a spare replacement component in this design. The circuit schematic diagram of two-stage step-down power supply scheme is shown in Figure 1.
3.2. Data Storage
The data storage part consists of an EEPROM 24LC64, an SDRAM MT48LC16M16A2, an SPI serial flash memory EN25F80 and NAND flash memory K9F1G08U0A. NAND Flash is used to store large data volume drawing model files, SDRAM is used as the extended memory of CPU for real-time data processing, and SPI Flash and EEPROM are used to store some system setting parameters. The sub-schematic diagram of data storage is shown in Figure 2. Since the SRAM of STM32F429IIT6 chip is not enough to support the canvas space required by LTDC maximum 1024*768 resolution, we choose MT48LC16M16A2 as the external memory of the canvas space required by LTDC display driver, and the remaining space is used as dynamic video memory. MT48LC16M16A2 is a 16-bit 256Mbit high speed SDRAM, the data throughput speed theoretically fully meets the requirements of the highest resolution smooth operation of dynamic pictures. In order to
ensure the stability of chip data transmission, MT48LC16M16A2 and the main control chip STM32F429IIT6 placed adjacent, each power supply pin is equipped with bypass capacitor to reduce power clutter interference, and the data line is surrounded by the ground plane. At the same time, a matching resistor is placed near the pin of the main control chip to reduce the reflection of high-speed signals and minimize interference. NAND Flash is a storage chip for parallel transmission. The data transmission speed is fast enough to avoid data waiting gap during system operation, which can make the overall system run more smoothly. Therefore, we use the fixed chip NAND Flash K9F1G08U0A to store data.

3.3. Motor Drive
The motor drive part is composed of three sets of single drive control signal outputs, one set of extended control signal outputs, one NMOS brake motor drive circuit and three limit detection signal inputs. The sub-schematic diagram of the motor drive circuit is shown in Figure 3.

The output of the drive signal uses three 8pin sockets, externally connected to the A4988 stepper motor drive board. The high-precision control of the stepper motor is completed after the signal is subdivided. The extended drive signal also uses an 8pin socket for external connection, which can be used for off-chip key connection or expanded to 5 axis, for higher precision control schemes.

For safety considerations, this design uses a stepper motor with brakes in the z-axis moving part. When an unexpected power failure occurs in the work, the brake motor can quickly lock the brake disc and the load carried on the motor to prevent the danger of falling. Therefore, a set of brake driving circuit is designed by using IRF3205NMOS tube to ensure that the brake disc keeps releasing when the power on works normally, and the brake can be stopped quickly without control signal when the power is off. Hardware control is used to ensure the timeliness of the brake. In addition, the limit detection signal input part adopts 3PIN socket, connected with external pull-up resistance, and compatible photoelectric switch and micro switch as the limit signal input end, which is convenient for the system to return the three axes to the limit origin at the same time.

3.4. Data Communications
The data communication part consists of USB\&USART and ETHERNET, the former is serial communication extension, the latter is network communication. It includes a SET of USB to TTL circuit, a set of high-speed CAN bus circuit and a set of wireless transmission communication circuit. The USB to TTL part uses CH340G serial chip. It can be connected with a personal computer, and it is very convenient to transfer data or draw files to the main control board. At the same time, it can run and
debug the whole system through a serial port. It can be used with SWD online simulation to complete the function development faster. The CH340G used in this design needs external crystal oscillator to provide its working clock. Through the hardware circuit design, the chip can change the BOOT0 pin potential by itself, reset the master chip, and write the program through USB to serial port. In terms of CAN bus, since STM32F429IIT6 comes with its own CAN controller, there is no need to use additional CAN controller, so we only need to use a CAN transceiver. The high-speed CAN transceiver MCP2562FD is used in this design. CAN bus is used for multi-computer communication or data transmission between two devices. The external receiving and sending end are connected with TVS diode anti-surge burn chip, and then connected with common mode filter to ensure the stability of the signal into CAN transceiver, which is forwarded to the main control chip after level signal processing. LC12S wireless communication module is used for wireless transmission. Use 2.4g frequency band, transmit power 12dBm, transceiver integrated, for UART half duplex bidirectional transmission, more adjustable frequency segments. The wireless communication mainly develops the service for the follow-up expansion function, sends the information to the system remotely.

3.5. Display Part

The display part is composed of LCD and LED&BEEP, which mainly consists of an LVDS converter and its independent power supply, a group of LED indicators and a buzzer. The LED and buzzer use 3.3V power from the AMS1117/BL8072, while the LVDS converter uses 3.3V power from the RT9018A alone. In this paper, there is only one 8pin expansion jack on the main control board that can be used to connect the expansion keys, so this design places all the interactive functions on the visual TFT LCD screen. STM32F429IIT6 has an LTDC controller that can output RGB signals externally. This design adopts touch screen for internal information input, uses capacitive touch pad with the same size as display screen, is compatible with I2C and SPI dual bus, STM32F429IIT6 has strong performance, and touch screen basically has no delay in dynamic operation.

DS90C385A is a high-speed signal equipment, so it is close to the main control chip as far as possible in layout. When supplying power, a second-level buck module RT9018A is used to provide an independent 3.3V power supply. Each signal line is treated with equal length, and matching resistors are connected in series at the transmitting end to reduce signal reflection. The power supply pins are connected in parallel to the ground filter capacitor at the beginning to ensure the stability of the power level. In the lower left corner of the main control board, there are two LED lights for the system running status display, and the buzzer uses the basic triode drive circuit for the operation prompt and system alarm.

4. Run Test

Due to the actual production of the original scale required investment beyond the author's affordable range, so the same scale to make the demonstration model. The main control board is powered by 12V voltage, and the model four-wire binomal motor is powered by 12V independently. Mini USB serial port is connected to PC analog display screen, and three 8pin pins of motor drive part is connected to A4988 control board and then connected to three axial stepper motors. First, test the serial port part, connect the main control board and PC, send information to the main control board, if the circuit is normal, it will return normal feedback and send value test results as shown in Figure 4. Use the Serial command to store a variable into EEPROM and SPI Serial Flash, and then continue to read the variable by sending commands through the Serial port. After the storage is completed, the response signal is returned, and the response signal and variable value are returned after reading. The test result is shown in Figure 5. It indicates that some circuits of EEPROM and SPI Serial Flash are normal. Write data to SDRAM continuously, write a value every 8192 addresses and increase, write 2048 data continuously, theoretically should just write all the space, then read the data in turn and compare the size with the last data for verification, finally output the total space size, test results are shown in Figure 6. Test limit switch signal in circuit and stepper motor drive signal output circuit is normal, after power on to start stepping motor drive signal output and via a serial port to send normal sign, using the
oscilloscope to observe whether stepper motor drive signal output is normal, external input limit signals, immediately after receiving limit signal to stop the output of the stepper motor drive signal, And return the stop signal through the serial port. Test results are shown in Figure 5-7:

Figure 4. Serial communication. Figure 5. EEPROM and SPI Serial Flash. Figure 6. SDRAM.

Figure 7. Limit switch and step motor input and output circuit serial port test.

5. Conclusion
According to the system requirements, this paper selects the appropriate CPU and designs a set of stable two-stage step-down power module. Meanwhile, it designs independent primary or secondary power supply for special parts such as motor drive and video signal conversion to open a variety of communication ports to the outside world, which greatly expands the compatibility of this design. The use of external independent video memory to improve the ability to support high resolution display devices and improve the smoothness of the picture. After comprehensive testing, the operation test of each hardware module of the main control circuit board is completed, and the results are normal, which proves that the circuit of each module works normally and stably after the system is powered on. The reading results of virtual ID test tool head show normal.

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