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Design of FDM Printer Controller Detection System

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***Abstract*—Fused Deposition Modeling (FDM) 3D printing technology is the main way of 3D printing. In order to ensure that the FDM printer can maintain normal and stable operation for a long time, the design of the FDM printer controller detection system is of great significance. System design is divided into two parts: hardware design and software design. The hardware design firstly realizes the real-time detection of the current, voltage values of the FDM printer controller and the program-controlled power supply, and can alarm over-voltage and cut off the circuit. Secondly, it realizes temperature control, printing, unlocking and zero-crossing of the printer's nozzle, and State detection of switch and other status. Finally, the system can output the on and off pulse of the FDM printer and the pulse is adjustable. The part of software design realizes the display of each state quantity, current quantity and voltage quantity waveform. The system works normally in test and meets the requirements for use, which is of great significance to the service life and performance optimization of printers.**

Keywords—FDM printer, Controller, component, Detection Systems

I. INTRODUCTION

3D printing is the ideal model for digital manufacturing with the ability to print 3D digital models directly into the final product. From design to manufacturing, the intermediate process is greatly reduced. Compared with traditional manufacturing methods, 3D printing has the following three advantages: Product complexity and diversification having nothing to do with cost, zero-skill manufacturing and personalized customization [1]. And 3D printing has the characteristics of rapid manufacturing, personalized manufacturing, and green manufacturing. It also has been widely used in developed countries and used in many high-end fields such as military weapons research, development, aerospace precision, medical equipment [2] and so on [2]. After years of development, 3D printing technology can be divided into the following accumulation technologies according to process technology [4]: Fused Deposition Modeling (FDM) [5],6], Selective Lase Sintering (SLS) [6], Stereoligthgraphy (SLA) [8], Laminated Object Manufacturing (LOM) [9]. Because other methods are more difficult in technology application and require higher equipment costs compared with FDM, FDM is the main way of 3D printing. In order to ensure that the FDM printer can maintain normal and stable operation for a long time, it is of great significance to design the FDM printer cont-roller detection system.

The design of FDM printer controller detection system adopts automatic detection technology. Automatic detection technology is one of the important technical means in modern science and technology and modern production which is an important part of information technology and many activities such as scientific experiments and industrial processes are based on automatic detection of parameters [10]. The FDM printer controller detection system designed in this paper is based on the STM32F103ZET6 chip and is supplemented by peripheral circuits to realize the detection and control of the status of the FDM printer controller. The results of the system are displayed through the software interface.

II. OVERALL SYSTEM DESIGN

According to the specific requirements of the FDM printer controller, the main performance indicators of the detection system design are the followings:

First, the system can output an adjustable DC voltage of 0-50V in real time and cut off the output when it is above 34V. The system's power supply data and the start and end of the power supply time can be displayed and saved.

Second, the system can provide the default 80ms±10ms pulse command and the maximum current is 180mA. At the same time, the system can manually send 70-500ms adjustable pulse command and the manual mode sends a pulse command at a time.

Third, the system can detect the output voltage status of the FDM printer controller, the temperature control, printing, unlocking, zero-crossing, switch, etc in a high and low mode, and the voltage and status values can be displayed and saved.

Fourth, the system software control interface can display the status of each state and the amount of current and voltage which can also send pulse commands and turn the system on and off.

For the system performance index requirements, the overall system design block diagram is shown in Fig.1.

FDM printer controller detection system works as the next: After the system is powered, the output voltage and operating current of the power supply must be detected first, and the overvoltage alarm protection function is implemented to achieve safe and stable operation of the equipment. Then the MCU outputs the default 80±10ms pulse command, and the embedded processor detects the power supply data and state quantity of the nozzle temperature control, printing, unlocking, zero crossing, switch and so on, and transmits the data which is displayed and saved in the host computer to the host computer through the serial port. Finally, through the software, the data of the power supply in the host computer, the state quantity, the time when the power starts and stops supply the power are displayed. And the software has an overpressure alarm, and the power supply function is restored after the circuit is cut off and the voltage is adjusted.

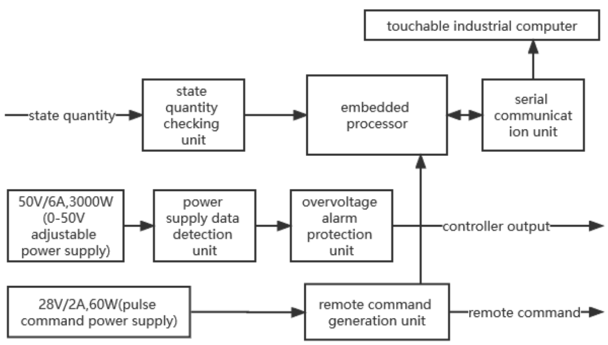

Fig. 1. System overall design block diagram

III. System Hardware Design

FDM printer controller detection system equipment hardware mainly includes main control unit, power supply data detection unit, overvoltage protection unit, remote control command generation unit, status quantity detection unit, serial communication unit, equipment power supply unit, FDM printer controller output voltage detection, etc.

A. Master Unit

The main control unit mainly refers to the overall control unit with the touch control industrial computer as the main control terminal. The embedded processor controlled by each unit is also listed in the main control unit for unified introduction. The two complement each other, making the whole system more complete and stable.

This paper selects Advantech's touch-sensitive display industrial computer with LCD screen with 50,000 hours of LED backlight life. The front panel LED visually indicates the operating status. The industrial computer has an RS-232 interface, an RS-232/422/485 port, two Ethernet interfaces and two USB interfaces to meet the design requirements.

The embedded processor selects STM32F103ZET6 single-chip microcomputer whose working frequency can reach 72MHz, which has 512K bytes of flash memory storage space, 48K program running memory space, 3 SPI communication interfaces. The single-chip can meet Design requirements whose working temperature range -40°C~85°C, especially the requirements of the device for the I/O port of the microcomputer.

B. Power Supply Data Detection Unit

The device power supply data detecting unit is divided into two parts, the first part is the device power supply voltage detecting part; the second part is the equipment power supply working current detecting part. Since the range of the supply voltage is 0~50V, a proportional resistor network circuit can be designed so that the ratio of the two resistors is 1:9 and the voltage of 0~50V can be divided into 0~5V then connected to the AD. The measured data is sent to the MCU for analysis and calculation to obtain the supply voltage.

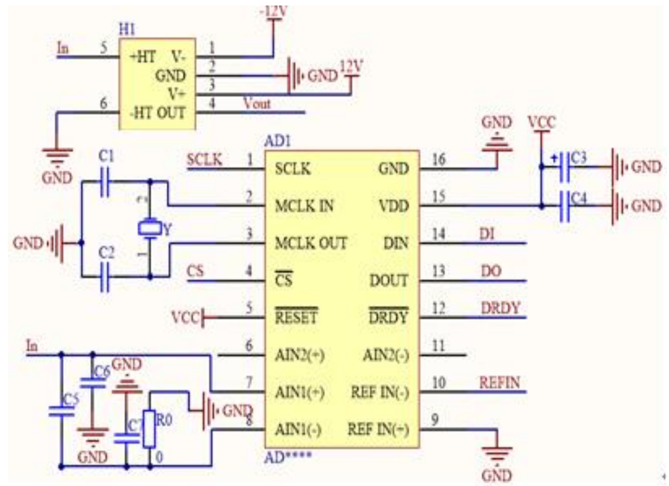

Fig. 2. Schematic diagram of the power supply data detection circuit

The current detection part uses a Hall linear current sensor, which can achieve the purpose of less interference and high precision. This sensor has a built-in precision low-bias linear Hall sensor circuit with low noise, fast response time and high output sensitivity. The sensor can convert the amount of current input from the +HT pin into amount of voltage that output from the OUT pin which has linear relationship with the current, and then use the AD to collect the voltage. The MCU calculates the current value according to the voltage value. The schematic diagram of the data power supply detection circuit is shown in Fig. 2.

C. Controller Output Voltage State and State Quantity Detecting Unit

Because the normal working voltage of the controller is 28V DC and the voltage fluctuation range is 24V-33V, in order to protect the controller, an overvoltage alarm protection circuit should be added to the front of the controller output voltage state detection unit to ensure the controller voltage output in the range of 24V ~ 33V DC. If the FDM printer controller detects that the system device output voltage is greater than or equal to 34V, the device will overpressure alarm and cut off the output. If the FDM printer controller detects that the system device output voltage is less than 24V, the device will prompt the device to undervoltage output. At this time, the user can control the output voltage of the device through the system software operation interface. Fig. 3 is a block diagram of the overvoltage alarm protection circuit.

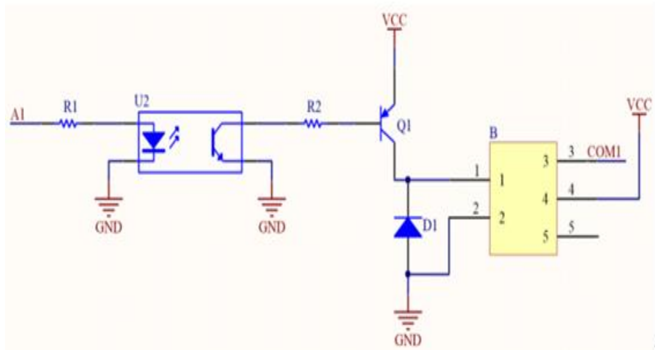

Fig. 3. Optocoupler isolation overvoltage protection circuit diagram

Overpressure alarm protection circuit consists of optocoupler and relay. When the microcomputer detects overvoltage, it will cause one pin of the MCU to output a high level and then turn on the optocoupler so that the relay is turned on to achieve the purpose of cutting off the circuit. Optocoupler is added to the circuit. The optocoupler isolates the input and output electrical signals, and has the characteristics of one-way transmission of signals, the complete electrical isolation between the input and output terminals, strong anti-interference ability, etc.

After the overvoltage protection circuit, the output voltage state of the controller can actually be measured by the controller output voltage state detection circuit. The controller output voltage detecting unit measures the output voltage of the controller by using a comparator circuit. The signal outputted by the circuit is sent to the MCU for identification. If it is high, the controller has no output. On the other hand if the MCU recognizes the low level, the controller has an output with a voltage value of 28V.

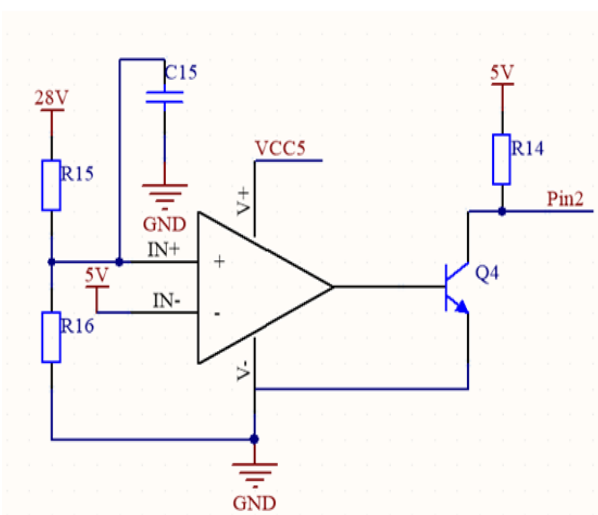

Fig. 4. Controller voltage detection circuit

The state quantity detecting unit is also composed of a voltage comparison circuit and a single chip microcomputer which compares the temperature control, printing, unlocking and zero-crossing state quantity voltage signals of the connected nozzles with the reference. The comparison result signal is sent to the single chip microcomputer for identification. If the MCU recognizes as low level, the state quantity is high level; if the MCU recognizes high level, the state quantity is low level. The schematic diagram of the state quantity detection circuit is the same as in Fig.4.

D. Remote Command Generation Unit

The function of the remote command generation unit is to realize the output of the default 80ms±10ms pulse command. The pulse can be adjusted from 70~500ms. The command form is the OC gate open collector with a maximum current of 180mA. According to the above design requirements, this design uses the design circuit and the single-chip controller to achieve the pulse command. With the single-chip microcomputer, the pulse command of outputting 80ms±10ms can be realized more accurately. Also the command can be adjusted within the range of 70~500ms. The pulse command generation circuit is shown in Fig.5.

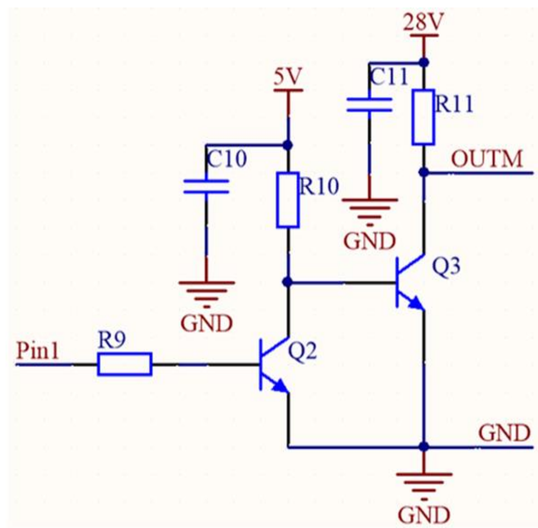

Fig. 5. Pulse command generation circuit

IV. System Software Design

The device uses a stable and reliable Windows 7 operating system as a program running platform and the software design is based on the C/C++ software platform .

For the FDM printer controller detection system, the upper computer of the system needs to communicate with the lower computer of the system in real time and receive the real-time monitoring data sent by the lower computer of the system. In order to meet the above communication requirements, the system software uses serial ports for communication.

First, the upper computer of the system establishes a stable communication connection with the lower computer and receives the detection data sent by the lower computer. Then the upper computer performs verification processing on the detected data transmitted from the lower computer. After the data verification is successful, the correctly received monitoring data will be parsed and processed through the built-in software of the upper computer. If the data verification is unsuccessful, the system will again request the lower computer to send the monitoring data to the upper computer.

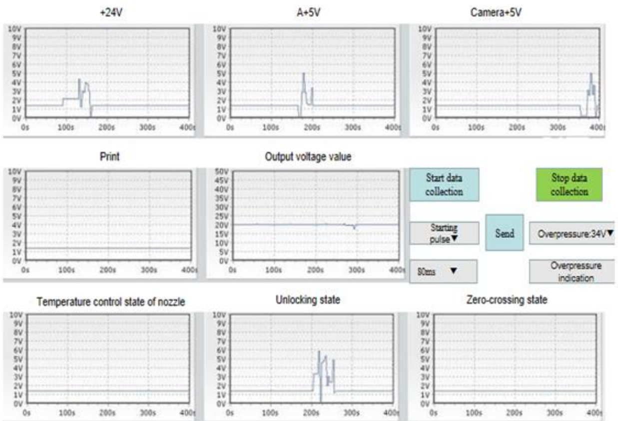

Fig. 6. Software interface

The FDM printer controller detection system software interface displays the value of the supply voltage and current in real time and the time to start and end the power supply. The operator can view the pulse command output port voltage waveform and controller output voltage waveform and voltage value by selecting different interfaces and adjust the power supply output voltage value by adjusting the software interface power output adjustment button. The system software interface is shown in Fig.6.

In the interface, the upper part shows the waveform of each measurement signal, while the lower four small squares indicate the measurement signal. If you want to view the port voltage signal waveform, click the second box. The small light in the second box will change green. When you don't want to see it, click on this box and the corresponding small light will turn red. The waveform display also supports simultaneous multi-signal waveform display for user-friendly simultaneous viewing and comparison of multiple signals. In the system software interface, the lower area is mainly divided into three parts. In the left are the display of the power supply data and the display area of the ground detection device which is displayed in real time by digital code as well as the overpressure alarm and the reset button after adjustment; In the middle are the command output port voltage value and the controller output voltage value; On the right are the power input adjustment, command output settings and the manual send command button.

Human-machine interface is friendliness, flexibility, functionality, clarity, consistency, reliability, and graphics to achieve adaptation and understanding of human capabilities and weaknesses, so that interactive activities meet the requirements of human cognition and behavioral factors, which gives full play to the strengths of both human and machine.

V. Test Results

A. Pulse Command Generation Test

After powering up the system, we send a pulse command using the pulse command setting value on the software, then measure the pulse width of the current command through the oscilloscope, in the end get the average date of 3 times. The obtained pulse command transmission test record table is shown in Table I.

TABLE I. Pulse Command Occurrence Test Table

	Setting values	**Measured value**	**Setting values**	**Measured value**
Startup puls (ms)	70.0	73.6	440.0	443.8
	100.0	100.4	470.0	470.0
	120.0	198.5	490.0	492.8
	130.0	128.6	500.0	501.5
Shutdown puls (ms)	70.0	70.8	440.0	440.5
	100.0	101.5	470.0	472.3
	120.0	125.8	490.0	490.0
	130.0	131.2	500.0	500.5

From the table, it can be calculated that the startup pulse error is about 1.201%, the shutdown pulse error is about 1.138%. So that the error is within the acceptable range.

B. Data Acquisition Test

After the system is powered on, making actual voltage which is outputted by DC regulated adjustable linear power supply act in the nozzle temperature control state, print the unlock state, zero-crossing state respectively, then recording the state voltage values on the software for 3 times, finally calculating the average. Similarly, adjusting the actual value of the power supply voltage, and then calculating average. The test record table is shown in Table II.

TABLE II. Data Acquisition Test Table

Nozzle temperature control state		**Print status**		**Unlocked state**		**Zero crossing status**		**Supply voltage**	
Actual value(V)	Collected value(V)	Actual value(V)	Collected value(V)	Actual value(V)	Collected value(V)	Actual value(V)	Collected value(V)	Actual value(V)	Collected value(V)
3.6	3.598	3.8	3.798	4.0	4.001	4.4	4.399	0	0
4.6	4.601	5.8	5.798	4.2	4.197	5.0	4.999	30.0	29.997
5.6	5.598	6.8	6.798	6.0	6.001	6.8	6.798	45.0	44.999
7.6	7.599	7.8	7.798	9.0	9.001	9.2	9.198	50.0	50.001

From the table, it can be calculated that the temperature control state error of the nozzle is about 0.32%, the printing state error is about 0.36%, the unlocking state error is about 0.31%, the zero-crossing state error is about 0.23% and the power supply voltage detection error is about 0.01%. The error is within acceptable limits.

VI. Conclusion

The FDM printer controller detection system of this paper realizes the detection of the output voltage and current of the program-controlled power supply and has an over-pressure alarm function. At the same time, the device can output remote control commands with a range of 70~500ms and waveforms, which can measure the voltage output by the controller and display multiple measurement data at the same time. This design fully meets the measurement requirements and functional requirements mentioned in the technical indicators.

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