Design and implementation of laser marking machine control system

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Abstract. The laser marking control system based on STM32 microprocessor is designed. Combined with the advantages of high efficiency and low cost of embedded control system, the overall scheme design is described and the peripheral hardware and the underlying driver are analyzed and designed. The microprocessor controls the switch of the laser by receiving the marking data sent by the upper computer via USB, and at the same time, the simulated galvanometer control protocol (XY2-100) controls the scanning of the galvanometer. SDRAM is used to enhance the data storage and processing capacity of the microprocessor. In order to improve the security and reliability of data, symmetric encryption algorithm is designed. After testing, the designed system meets the requirement of actual marking precision and has good practical value.

1. Introduction

With the development of laser technology, laser marking machine, as a kind of laser processing technology, has been increasingly prominent in the industrial field. The application of laser marking machine can be seen everywhere in our life, such as electronic components, integrated circuits, auto parts, which are printed on the products through laser marking. Laser marking is to hit the laser beam on the workpiece to make the surface of the workpiece gasification, melting and other physical and chemical changes, so as to leave text, pattern etched marks on the surface of the workpiece. Based on USB bus speed, high stability, support hot plug and the advantages of the STM32 processing ability, the advantages of low cost, easy extension, we design a laser marking control card. The upper computer sends the marking data to the microprocessor, after receiving the data will be temporarily stored in SDRAM, data according to the received marking data to complete the X-Y galvanometer control, laser control and so on [1].

2. Whole scheme design

Figure 1 is the system structure diagram of laser marking machine. The laser marking machine mainly consists of computer, controller, laser, galvanometer scanning system and power supply. The computer is the upper part of the laser marking machine system, which mainly completes the processing of graphics. The controller mainly processes the data sent by the computer, so as to control the laser and galvanometer, and finally complete the marking of the graph. The laser is mainly used to produce high energy density laser which is passed into the galvanometer to be scanned during marking. Two orthogonal motors are placed inside the galvanometer system, and a reflector is placed on each
motor [2]. The operation of the two motors is controlled quickly and accurately to deflect the mirror and change the propagation path of the laser. The power supply provides power for the whole laser marking machine hardware.

3. Hardware design

3.1 USB interface controlled circuit
The design of USB interface circuit uses CH340 chip. It is a USB bus transfer chip, which can realize USB to serial port. The microprocessor communicates with the computer through the chip, as shown in Figure 2. CH340 is powered by 5V voltage and the crystal oscillator frequency is 12MHz. TXD and RXD are the sending end and receiving end of the serial port interface, which are respectively connected to STM32-RXD and STM32-TXD terminals of STM32 serial port, which correspond to PA9 and PA10. The USB interface circuit is shown in Figure 2.

3.2 SRAM memory circuit
STM32 contains FSMC (flexible static memory controller). By setting the controller, the memory can be expanded directly without adding too many external devices. FSMC is a new memory expansion technology integrated with STM32 series microcontrollers. It makes it very convenient for STM32 to expand external memory, and can expand different types of memory according to different actual needs. The SRAM chip model of this system is IS61WV102416BLL of ISSI company. It is a 1024k × 16bit SRAM for external expansion. It can store 16m data. Its working voltage is 3.3V. The address interface and data interface of the chip can be directly connected with STM32, and the chip is completely static operation without clock and refresh [3].

3.3 Laser control
The system uses the Ruike pulse laser, which has the advantages of low energy consumption, suitable
for laboratory or outdoor operation, and can be directly embedded in the user's equipment. The laser can emit 1060 ~ 1085nm pulse laser, which is controlled by industrial laser standard interface. The laser needs 24V DC power supply. There is a main oscillator inside the laser. After the oscillator generates pulses, it is amplified by the power amplifier, and then the output power is 20W. The main oscillator and power amplifier are set and controlled by the user through the DB25 interface. The internal structure of the laser is shown in Figure 3.

![Figure 3. Internal structure of laser](image)

### 3.4 Control of galvanometer system

The data transmission between galvanometer scanning control system and microprocessor follows XY2-100 protocol, which can send 20 bits of valid data at a rate of 2Mbit / s. The protocol includes four channels of differential signals: SENDCK (clock signal), SYNC (synchronous signal), CHANNELX (X-Channel signal), CHANNELY (Y-channel signal). The data sequence diagram is shown in Figure 4.

![Figure 4. XY2-100 sequence diagram](image)

In this design, the differential chip AM26C32 is used to transform the four channel control signals of the microprocessor to obtain the differential signals needed by the galvanometer scanning system. An AM26C32 chip contains four channels of differential signals, which just meets the design requirements. Clock signal, synchronous signal, X-Channel signal and Y-channel signal are respectively connected to the I / O of STM32. After AM26C32 conversion, they are connected to DB15 connector and connected to galvanometer through DB15 [4]. The control circuit is shown in Figure 5.
4. **Software design**

4.1 **Software design of lower computer**

When the system is powered on, STM32 is initialized first, including STM32 system clock, serial port and FSMC. Initial configuration of SRAM, galvanometer scanning system module and laser control module. After the connection between the controller and the host computer is established, the user can send data to the controller through the upper computer, and the controller will make corresponding processing after receiving the data. In this program design, there are two types of data from the upper computer, one is the system marking parameters, the other is the marking data. The controller will judge when receiving the data. If it is the system marking parameter, the controller will configure the galvanometer scanning system and laser according to the user's requirements; if it is the marking data, the controller will process and store the data in the external SRAM. After the data is sent, processed and stored, the controller will transfer the data from the SRAM The marking data is read and sent to the galvanometer scanning system and the laser to start marking until a marking pattern is completed [5]. The software design flow chart of the lower computer is shown in Figure 6.

![Figure 5. Control circuit of galvanometer scanning system](image-url)
4.2 Software design of upper computer

In Visual Studio 2019, select the Windows Forms application program, insert the required control, and modify the name, size and other properties of the control. The effect of the upper computer interface is shown in Figure 7. The software of laser marking host computer mainly includes two parts. The left side is the image display interface, which is mainly used to display the marking graphics; the right side is the parameter setting interface, which mainly includes the conventional operation of laser marking, such as loading marking content, adjusting laser parameters and controlling laser marking progress [6].
4.3 Design of symmetric encryption algorithm

In the process of laser marking, the upper computer and microprocessor often need to transmit data. In order to improve the security and reliability of data, it is necessary to encrypt the data. Advanced Encryption Standard (AES), also known as Rijndael encryption method, is a block encryption standard adopted by the federal government of the United States. The marking data sent by the upper computer is encrypted into ciphertext by AES encryption function, and transmitted to the microprocessor through USB. The microprocessor decrypts the ciphertext into the original marking data through AES decryption function [7]. The specific encryption process is shown in Figure 8.

![Figure 7. Effect drawing of upper computer interface](image)

![Figure 8. Specific encryption process](image)

5. Conclusions

This system combines STM32 and USB high-speed bus to design a high-speed and high-precision laser marking control system. The hardware, software and symmetric encryption algorithm are designed. The USB laser marking control system based on STM32 makes full use of STM32’s internal resources and can reduce the download amount of marking data. The application of symmetric encryption algorithm improves the security of the system and effectively ensures the reliability of the transmission data.

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