A Low-intensity Laser Control System Design

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Abstract

Laser-assisted therapy has a good therapeutic effect on specific symptoms in clinical and experimental applications. This paper proposes a low-intensity laser control system design scheme, which is divided into operation unit, control unit and work unit. The main control unit is based on the STM32F407ZGT6 chip design, the operating unit uses a 10.1-inch serial screen, and the working unit consists of 8 low-intensity laser generators. The system can control the power, frequency and working time of 8 laser generators at the same time, and has the function of automatically saving working parameters when the power is turned off.

Keywords: single chip microcomputer, laser, pulse width modulation, power failure protection

1. Introduction

In recent years, laser diagnosis and treatment have achieved a mass of successful applications in the field of medicine [1]. This treatment has many advantages, such as non-invasive, short treatment time and low risk [2]. These characteristics make laser physiotherapy technology very popular.

Low-intensity laser physiotherapy equipment has high requirements for performance, especially the accuracy of control signals. It also requires products with good safety and reliability. In terms of function, for different needs, different laser sources are needed for treatment. How to control multiple laser generators to work together at the same time is a difficult point.

Based on the above discussion, this design is optimized for the precise control of multiple light sources. The design of laser physiotherapy apparatus proposed in this article can control eight laser generators to work at the same time.

In order to ensure the reliability, the parameters manually set in this design can be saved in real time. This way can avoid the loss of the set parameters after the power is cut off due to an emergency. When the device is powered on again, the system can be set to the working parameters of the laser generator soon.

2. The Hardware Structure

The final control effect achieved by the laser controller is closely related to each functional module. According to the hardware structure, the laser physiotherapy instrument can be divided into the following three parts: operation unit, control unit and working unit, which is shown in Fig 1.

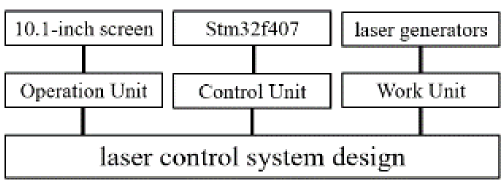

Fig.1 System structure diagram

The operating unit consists of a 10.1-inch touch screen and an emergency stop button. The control unit integrates the main control chip, signal output interface, power supply module and buzzer on a PCB board. The working unit is composed of a laser drive circuit and a laser generator.

The PCB board is designed to reduce circuit complexity and improve the practicability of the device. For a qualified product, the PCB design can directly affect its performance. The design of the PCB board is shown in Fig.2.

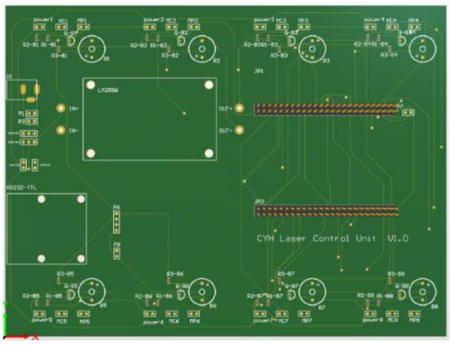

Fig.2. The designed PCB board

2.1. Capacitive touch screen

The DWIN serial capacitive touch screen is used as the data input terminal. Its creen resolution is 1024*600 pixels, and the ideal working power supply is 12V, 1A. The operating temperature is between -20°C and 70°C. The DWIN capacitive touch screen is shown in Fig.3.

Fig.3. Front and back of the DWIN screen

The screen supports RS232 and TTL two serial port modes for communication, and its corresponding working voltages are 12V and 5V respectively. In order to match the working voltage of the single-chip microcomputer, the TTL communication mechanism is adopted in this design. The communication data format is 16-bit hexadecimal characters, and the data format is shown in Fig.4.

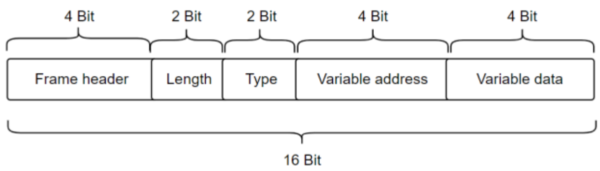

Fig.4. Serial communication data format

2.2. Eemergency module

In order to deal with possible unexpected situations, an emergency stop button is added. The emergency stop button used in this design is a double-in and double-out type, which is usually used to connect the power supply line and the grounding line.

In order to realize the feedback of the emergency stop signal, this design connects the ground terminal interface to the IO port of the single-chip microcomputer. The power supply line end interface is connected to the working unit. The emergency stop button is shown in Fig.5.

Fig.5. Emergency button

2.3. Main control unit

The main control unit includes a control chip, a power supply circuit and a signal output interface. The control chip model is STM32F407ZGT6. The chip adopts a 32-bit Corte-M4 CPU with FPU, the main frequency is up to 168MHZ, and it is equipped with 140 IO ports with terminal functions. The chip has 1MB of Flash memory and 192+4KB RAM. The equipped 17 timers can well meet the requirement of multi-channel PWM signal output [3]. Other related features are as follows:

- Up to 15 communication interfaces, including 6x USARTs running at up to 11.25 Mbit/s, 3x SPI running at up to 45 Mbit/s, 3x I²C, 2x CAN, SDIO
- Analog: two 12-bit DACs, three 12-bit ADCs reaching 2.4 MSPS or 7.2 MSPS in interleaved mode
- Operating Voltage 2.0V ~ 3.6V.
- Operating temperature range: -40 ºC ~ 105 ºC.

The design of the main control chip is shown in Fig.6.

Fig.6. STM32F407ZGT6 chip

2.4. Working unit

The working unit is composed of a laser drive module and a laser module. The laser drive module is shown in Fig.7.

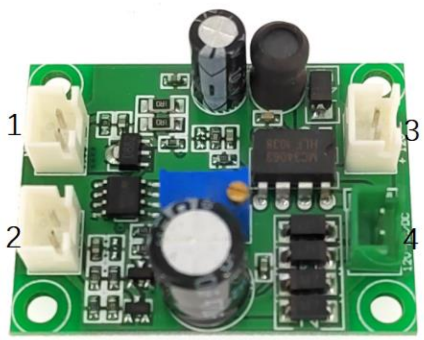

Fig.7. Laser drive module

The laser driver module has four interfaces, the interface 1 is the laser output terminal, the interface 2 is the signal input terminal, and the interfaces 3 and 4 are the power ports. By controlling the signal input of the laser drive module, the power and frequency of the laser output can be adjusted.

The wavelength of the laser source used in this design is 650±20nm. This light source has a wide range of applications in the field of biomedicine. Its working parameters are as follows:

- Operating temperature range: -10 ºC ~ 50ºC.
- Operating voltage: 10~12V
- Operating current: <200mA
- Laser Safety: Class IIIB

The laser generation module is shown in Fig.8.

Fig.8. Laser generation module

3. System Circuit Module Design

This system adopts the STM32407ZGT6 core board, which is equipped with the smallest circuit system of single-chip microcomputer and the download and debug interface.

Therefore, when designing the circuit, only need to consider the signal output interface circuit, voltage conversion circuit and buzzer drive circuit. This kind of scheme is more convenient in design, so as to realize the design of PCB quickly.

3.1. Voltage conversion circuit design

The voltage conversion circuit converts the 12V DC input from the power adapter into 5V DC through the LM2596 module.

LM2596 is a switch type step-down chip, usually is a step-down circuit with a constant voltage output. The chip samples the output voltage value through a resistor and inputs to the chip's feedback terminal. The output voltage can be changed by changing the resistance of the resistor. The schematic diagram of the power circuit design is shown in Fig 9.

Formula (1) is to calculate the Vref. The value of R1 in this circuit is fixed at 2.5KΩ, and the value of R2 is determined by the chip model. When the output voltage Vo is 5V, the resistance value of R2 is 7.6KΩ, then the reference voltage Vref is 1.24V.

$$Vref=Vo*R1/(R1+R2) \quad (1)$$

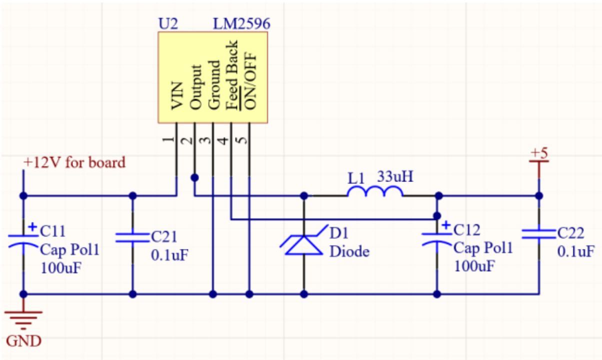

Fig.9. Schematic diagram of the power circuit

3.2. Design of buzzer drive circuit

For an active buzzer, the only thing to do is to input the drive level at the signal end and amplify the drive current through a transistor to make a sound.

Through the test, the actual working time of the buzzer is about 4.7V, and the working current is 30mA.

The schematic diagram of the buzzer drive circuit is shown in Fig.10. In the circuit, R1 and R3 play a current limiting role, and R2 is a pull-down resistor, which can improve the turn-off speed of the transistor.

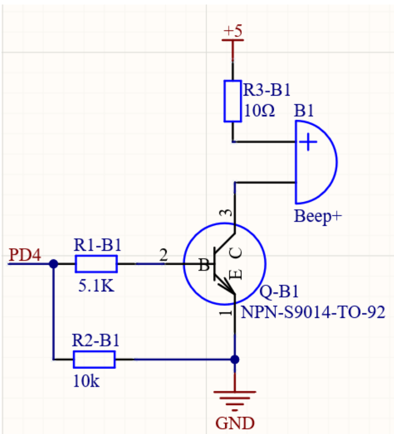

Fig.10. Schematic diagram of the buzzer drive circuit

4. The Functional Module

The various hardware modules of the system ensure the reliability of the system's implementation functions, and the control logic and interactive operations are completed by software codes.

After the system is powered on, enter the initial interface, and enter the preparation interface with a delay of three seconds after confirming to enter the system. At this time, the microcontroller will read the last set parameters and enter the ready state.

When the operator sets the parameters and confirms the work, the system will turn on the laser source and start timing. After the countdown time is over, the corresponding buzzer will give a reminder and turn off the laser. The system work flow chart is shown in Fig.11.

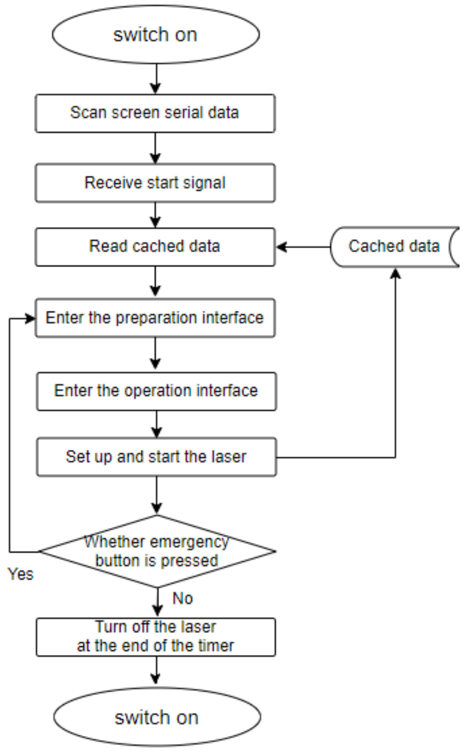

Fig.11. System work flow chart

5. Conclusion

Through testing, it can be concluded that this design can complete the work of controlling eight laser generators at the same time. In continuous mode, four-speed power adjustment can be achieved. In the pulse mode, the default working time is 30 minutes, and each laser generator has a separate timing channel, which can realize the time setting of 0-99 minutes. The default laser power is 50%, and the adjustable range of power is

0~100%. The default laser frequency is 50Hz, and the adjustable range is 1~1K Hz. When an emergency stop is needed, the emergency stop module can also respond quickly and save data.

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