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A Control System of Laser Temperature Based on the TEC

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Abstract: *Temperature plays an important role to the laser, the temperature control system based on TEC is implemented, which uses MAX1978 chip controlled by MCU to heat and cool the laser by adjusting the direction and magnitude of TEC driving current, and designs the optimal control process of PID controller, so that the working environment temperature of the laser can reach the predetermined value quickly and accurately. This system provides a small volume, high precision and convenient operation for the temperature control of laser.*

Keywords: *Temperature control system, TEC. MAX 1978, STM32F103, PID*

1. Introduction

Semiconductor laser plays an irreplaceable role in military, medical, communication and other fields because of its high efficiency, small size, light weight and low price. Temperature is an important factor that determines whether the laser can work stably. The wavelength and power of light will change correspondingly with the change of temperature, and its change coefficient is about 0.1 nm/°C [5]. With the increase of temperature, the output power decreases and the noise increases. Therefore, it is necessary to accurately control the working temperature of the laser. Through investigation and research, we find that there is not a suitable product that can meet the precise, fast and efficient control of laser temperature. This paper mainly introduces a laser temperature control system based on TEC semiconductor [1]. According to the high-precision temperature control chip MAX1978 [3, 4], the laser is heated or cooled by adjusting the magnitude and direction of TEC driving current, and the working temperature of the laser is accurately controlled. MCU is used to control DAC to adjust the preset temperature range of the system.

2. System Working Principle

The working principle of the temperature control system is as follows. The laser is heated or cooled by adjusting the magnitude and direction of TEC driving current by high precision temperature control chip MAX1978. NTC [9] is used as the temperature sensor to feedback the temperature signal of the laser, and the differential signal of preset temperature signal and feedback temperature signal is provided to MAX1978 chip for differential amplification through H bridge, so as to adjust the driving direction and magnitude of TEC current and form a closed-loop temperature control system. The system MCU presets the temperature value through keyboard, and displays the current system temperature in real time through LED digital tube. The system workflow is shown in Figure 1:

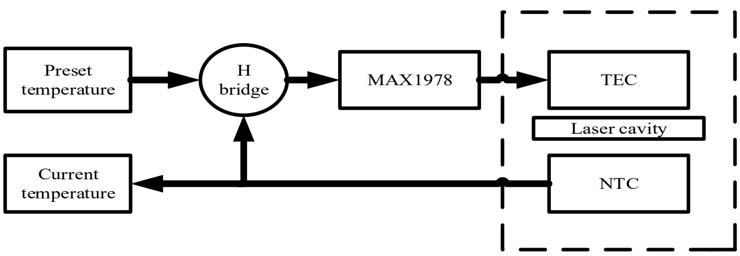

Figure 1: Schematic diagram of system operation

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2.1. Working Principle of Thermoelectric Cooler (TEC)

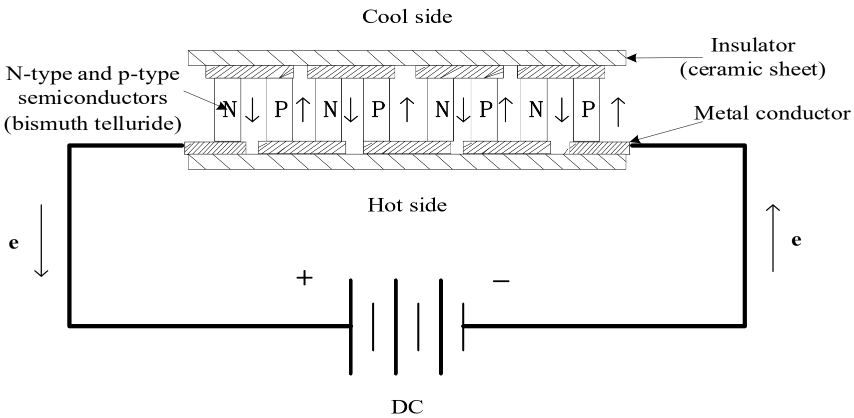

Figure 2: Schematic diagram of TEC

Thermoelectric Cooler is made of Peltier effect of semiconductor materials. The so-called Peltier effect refers to the phenomenon that when a direct current flows through a galvanic couple composed of N-type and P-type semiconductor materials, one end absorbs heat and the other end releases heat. The TEC comprises a number of P-type and N-type pairs (groups) connected together by electrodes and sandwiched between two ceramic electrodes; When a current flows through TEC, the heat generated by the current will be transferred from one side of TEC to the other, resulting in "hot end" and "cold end" on TEC [6], which is the heating and cooling principle of TEC, shown in Figure 2.

TEC has two working states, namely, maximum refrigeration/heating capacity state and maximum refrigeration/heating efficiency state. Expression:

$$Q_C = ST_c - \frac{1}{2}I^2R - K\Delta T \tag{1}$$

QC is the cooling/heating amount, I is the loop current, S is the Saibel coefficient of the material, K is the thermal conductivity of the semiconductor, R is the resistance of the cooler / heater, △ T is the temperature difference between cold and hot ends, TC is the cold end temperature, and Th is the hot end temperature [2].

Seibel coefficient S is used to express the potential generated at the input when there is a temperature difference between the two sides of TEC. The expression is:

$$S_{MT_h} = s1 \cdot T_h + \frac{s2 \cdot T_h^{\ 2}}{2} + \frac{s3 \cdot T_h^{\ 3}}{3} + \frac{s4 \cdot T_h^{\ 4}}{4} \tag{2}$$

$$S_{MT_c} = s1 \cdot T_c + \frac{s2 \cdot T_c^{\ 2}}{2} + \frac{s3 \cdot T_c^{\ 3}}{3} + \frac{s4 \cdot T_c^{\ 4}}{4} \tag{3}$$

$$S_M = \frac{S_{MT_h} - S_{MT_c}}{T_h - T_c} \tag{4}$$

SMTh is the Seibel coefficient of hot surface, SMTC is the Seibel coefficient of cold surface, Tc is the cold end temperature, Th is the hot end temperature, SM is the Seibel coefficient of device model, and Si is the constant coefficient of TEC temperature polynomial.

2.2. Working Principle and Characteristics of MAX1978

MAX1978 is the latest monolithic integrated temperature control chip introduced by Maxim Company, which integrates FET and thermal control circuit on the chip and reduces peripheral devices. The internal operating frequency of the control chip can be selected. Ultra-low drift chopper amplifier can maintain temperature stability of 0.001°C. Independent current limiting and voltage limiting setting circuits provide protection for TEC and chip [7].

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MAX1978 working priciple: A PID controller is constructed by integrated on-chip instrumentation amplifier and high-precision integral amplifier [10]. The amplifier can be externally connected with thermistors such as NTC or PTC. By comparing the voltage value of thermistors such as NTC or PTC with the voltage value converted from the set temperature, the direction and magnitude of current passing through TEC are controlled by differential amplification, thus accurately controlling the temperature, shown in Figure 3.

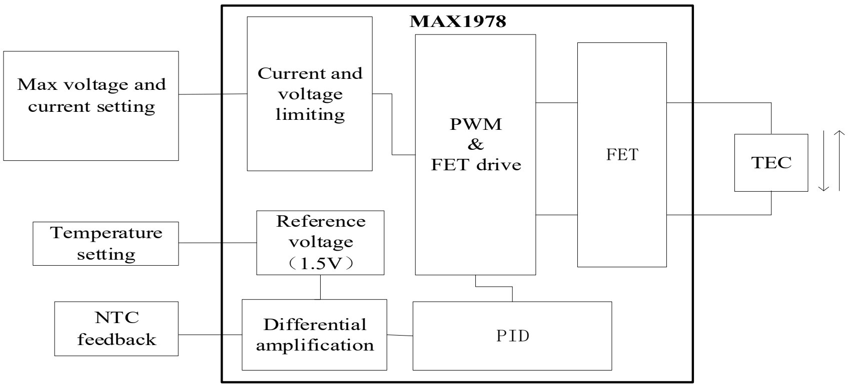

Figure 3: Block diagram of MAX1978 working principle

3. System Hardware Circuit Design

The MCU of this system selects STM32F103VCT6, a 32bit MCU of ST Company. This MCU integrates various high-performance peripheral interfaces, such as internal integration of A/D module and D/A module, which can be used in this system, which not only improves the complexity of operation, but also reduces the system design cost.

MAX1978 and its peripheral circuits are the core circuits of the system, which mainly realize the functions of controlling the current magnitude and direction of TEC, temperature compensation and temperature alarm of PID, etc [11]. Based on the typical application circuit in the chip manual, the circuit is improved, and the LED is used to alarm the condition of low or higher temperature, and the internal working frequency of the chip can be adjusted manually. The switch is used to control the working state of the chip. MAX1978 and its peripheral circuits are shown in Figure 4.

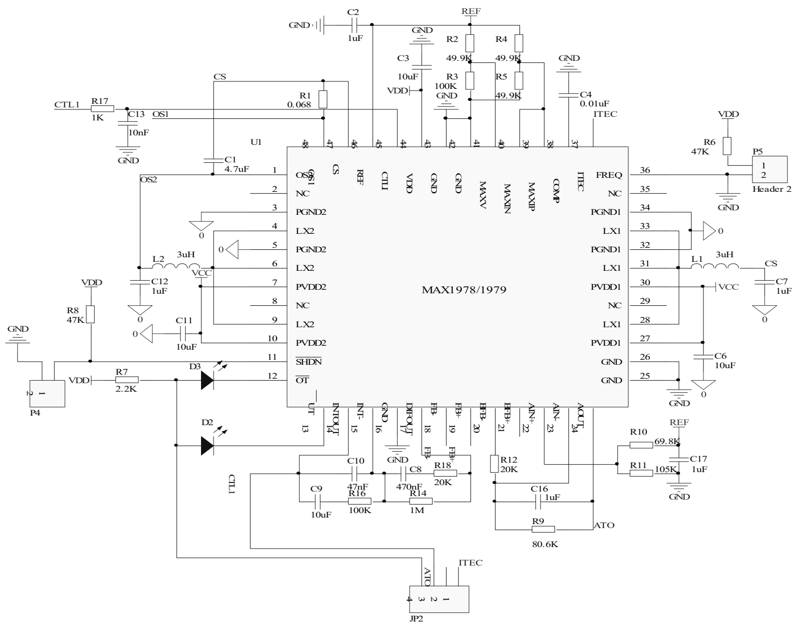

Figure 4: MAX1978 and the peripheral circuit

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4. System Software Design

The working environment temperature of the laser is set by keyboard, which is converted into corresponding voltage signal by single chip microcomputer and provided to MAX1978; The single chip microcomputer displays the current temperature value of the laser cavity in real time [8]. The flow of laser temperature control is shown in Figure 5.

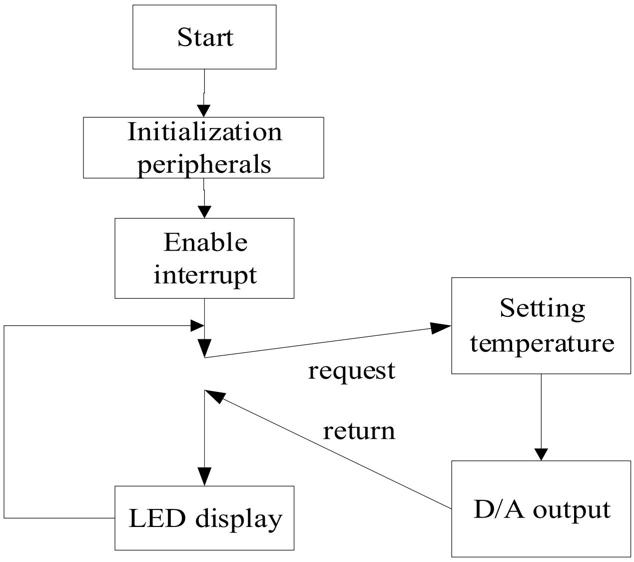

Figure 5: Software flow chart of laser temperature control

5. System Test

In the laboratory with the laser TEC and NTC interface, set temperature control system temperature value of 24°C, stable laser current, by observing the wavelength of the laser wavelength detector, we can see that the laser wavelength can quickly stabilize around 795nm, and fluctuation in the error range, Figure 6, 7.

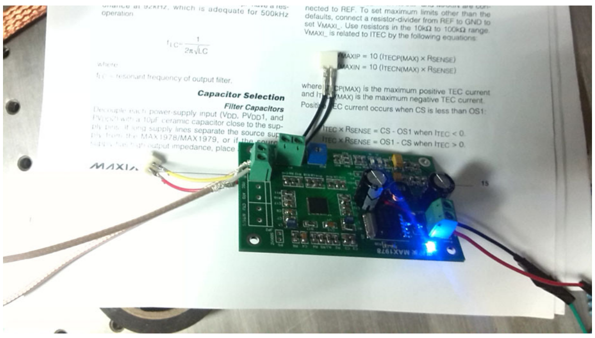

Figure 6: Actual connection between temperature control system and laser

Figure 7: Laser wavelength detector

The test results are shown in Figure 8 below:

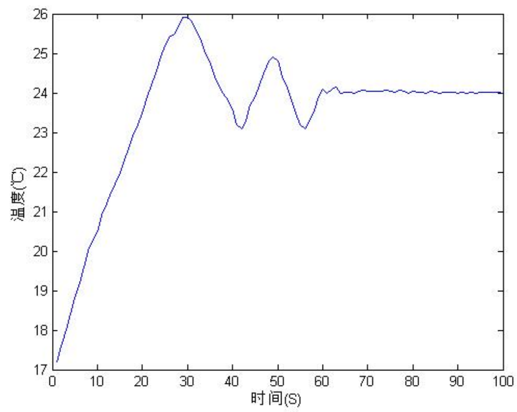

Figure 8: Temperature change curve in 100 seconds

Through the above experiments, we can see that the temperature control system can quickly stabilize near the set temperature value, and the temperature fluctuation is within the error range.

6. Conclusion

The system uses high-precision NTC as temperature sensor to measure temperature signal and TEC as actuator to cool / heat the laser. The voltage difference is measured by Wheatstone Bridge method to suppress temperature drift. MAX1978 chip provides differential amplification and TEC current drive for voltage difference signal. The temperature of the laser is set by MCU, the model of TEC in greenhouse is established, the wavelength of the laser is actually test, and the temperature stability is verified by collecting data, which achieves the expected effect.

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