Thermo Tank Temperature Control System Based On STM32

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Abstract – **This paper introduced a thermo tank temperature control system based on STM32. Firstly, the temperature acquisition is realized by the high-precision electrical bridge based on constant current source. Then the augmented PID algorithm realized by software is adopted. Butterworth filter is used to convert the output PWM of STM32 to current signal which is used to control the semiconductor control rectifier to adjust the temperature. Calibration check and practical application both indicated that the system was reliable, high-precision, practicable and could meet reality needs.**

Key words – *STM32*; *thermo tank*; *temperature acquisition*; *PID*

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1 Introduction

Thermo tank can be divided into low temperature thermo tank and high temperature thermo tank according to temperature range. Heating control thermo tank is one kind of high temperature thermo tank and has a wide range of applications in industrial, medical and scientific areas. As some special thermo tank control systems require high precision in temperature acquisition and control, the system designed in this paper can measure temperatures from 16 ℃ to 80 ℃ and its precision is superior to ±0.05 ℃. AS ARM is gradually occupying the microelectronics market for its powerful function and low cost, it is of important practical significance and value to design a temperature control system based on ARM with high precision, simple structure and low cost.

2 Basic control principles of thermo tank

In this system, temperature acquisition of the inner thermo tank is realized by using platinum resistance as temperature sensor and bridge circuit based on constant current source. Then compare the actual temperature with the temperature set by touch screen. By using augmented PID algorithm to adjust, STM32 outputs 16-bit PWM signals. Then convert PWM signal to voltage signal to control the conduction angle of Semiconductor Control Rectifier (SCR) which controls the heating tubes. System control principle is shown in Fig.1.

Considering the system accuracy and stability requirements, features of this system include: powerful and high-speed ARM STM32F103 as the controller, augmented PID algorithm, and full use of on-chip resources of microcomputer such as ADC, USART and 16-bit PWM output for great control accuracy.

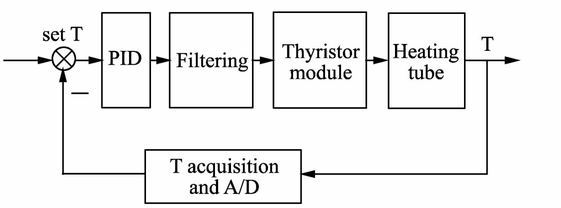

Fig.1 System control principle

3 Hardware design

This system includes temperature acquisition bridge circuit, STM32F103, color LCD touch screen control circuit, filtering circuit and SCR. In addition, the system has a good man-machine interaction function and can realize real-time monitoring and control by using 5.6 inches color LCD and touch screen. Temperature control system structure is shown in Fig.2.

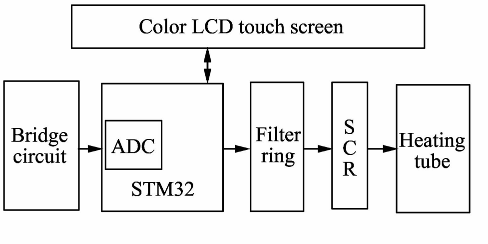

Fig.2 System structure

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3.1 Temperature acquisition and A/D conversion

Among the thermal resistance temperature sensors, platinum resistance, with advantages as high precision, stable performance, corrosion resistance and easy to use, is the ideal temperature acquisition component widely used in industrial environments and control systems. As the temperature acquisition range is 16 ℃ ~ 80 ℃, Pt1000 is chosen as temperature sensor, which resistance changes with temperature according to certain rules and has good high precision and stable performance.

Unbalanced bridge measurement is typical in detect circuits using platinum resistance as temperature sensors[1]. However, the nonlinearity between platinum resistance and temperature and nonlinearity of unbalanced bridge lead to acquisition error, thus we improved the temperature acquisition bridge circuit. Use constant current source to power the bridge, connect the two bridge arms with precise operational amplifier that is low noise and low temperature drift, use 4DH2 to constitute constant current source circuit which outputs 0.5 A current, thus the current in platinum resistance is equal to constant current source.

The ADC of STM32F103 is used to convert analog voltage of temperature into digital signal. The 12-bit ADC is a successive approximation analog-to-digital converter and has the function of self-calibration. A/D conversion of each channel can be performed in single, continuous, scan or discontinuous mode, and in this system we use continuous mode. The result of the ADC is stored in right-aligned 16-bit data register which improves the conversion speed. In addition, the analog watchdog feature allows the application to detect if the input voltage goes outside the user-defined high or low thresholds.

3.2 TM32F103 on-chip resources

TM32F103 can work in − 40 ℃ ~ 105 ℃ and this meets the requirements of industrial environment. It incorporates the high performance ARM Cortex[Tm]-M3 32-bit RISC core operating at a 72 MHz frequency, high speed embedded memories (Flash memory up to 128 Kbytes and SRAM up to 20 Kbytes) to store data and program, and an extensive range of enhanced I/Os, most of which have alternate functions and peripherals connected to two APB buses. It has three general purpose 16-bit timers plus two watchdogs, as well as standard and advanced communication interface USART used to communicate with LCD[2]. More importantly, it offers two 12-bit ADCs with 1 μs conversion speed which make it suit for fast acquisition and fast processing. It is one of the important reasons for this system to choose TM32F103 as the core controller.

3.3 Filtering and conversion circuits

In order to realize the convention from PWM signal to analog output, we use the second order low pass filter to filter out the high frequency components and keep DC component and changing duty cycle of PWM signal so that the analog voltage output is got then. Fig.3 shows the designed Butterworth filter. After filtering, convert PWM signal to 0 ~ 2.5 V to control thyristor conduction angle[3]. Thus we realized the precise control of heating temperature.

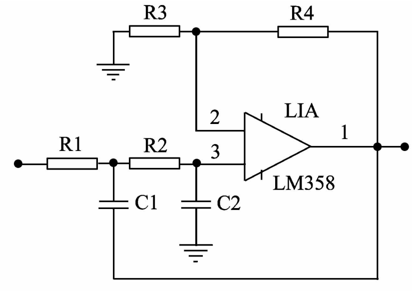

Fig.3 Butterworth filter

4 Software design

4.1 PID control algorithm

This system uses PID control algorithm which is a basic control method widely used in industrial process control. Augmented PID control algorithm[4] is

$$u_k - u_{k-1} = K_P(e_k - e_{k-1}) + K_1 e_k + K_D(e_k - 2e_{k-1} + e_{k-2}).$$

However, if this algorithm was used directly, it would generate a large overshoot and cause integral saturation easily when startup, stop or adjust substantially. In order to inhibit the emergence of this phenomenon, we use integral separation as an improvement.

Integral separation won′t work until actual temperature is approaching the settings. When it works, it can eliminate static error and improve precision[5]. Block diagram of integral separation PID is shown in Fig.4.

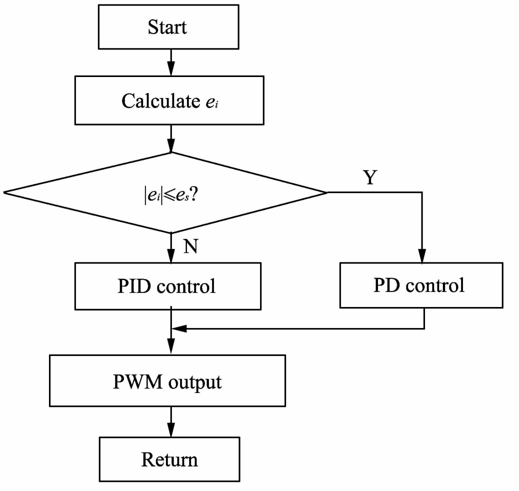

Fig.4 Integral separate PID algorithm block diagram

4.2 Touch screen software design

It makes human-computer interface much more friendly, more convenient and faster by using touch screen. Use dedicated control chip ADS7843 to connect AMT9532, four-wire resistive touch screen, with STM32F103, process the touch screen signals[6]. Touch screen's software design flow chart is shown in Fig.5.

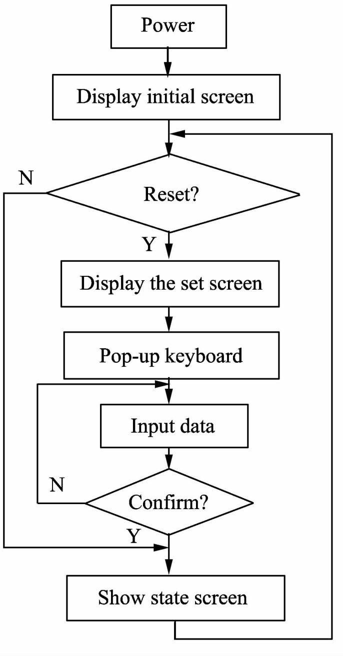

Fig. 5 Touch screen flow chart

5 Experimental results

Use standard thermometer with 0.001 ℃ precision as calibration to check the experimental results. Specific methods: set different temperatures within the appropriate range though touch screen, wait untill the temperatures shown in the LCD are stable, then calculate the errors based on the actual temperature of standard thermomete with formula:

$$\text{error} = |\text{set} - \text{actual}|/\text{set}.$$

The check results are shown in Tab.1.

Tab. 1 Calibration results

Set(℃)	Show(℃)	Actual(℃)	Error(‰)
16.00	15.98	15.977	0.2
30.00	30.00	29.988	0.4
40.00	40.01	40.009	0.2
50.00	50.00	50.014	0.3
60.00	60.01	60.011	0.2
70.00	69.97	70.020	0.3
80.00	79.98	80.037	0.5

6 Conclusion

By using 16-bit PWM output, simple filtering circuit, conversion circuit, software design and floating-point operations, this system realized 16-bit D/A Conversion which is very hard for common MCU to realize.

The system temperature range is 16 ℃ ~80 ℃ and the resolution of 16-bit control signal could reach to 1‰. The experimental results show that the system definitely can reach the control requirement that temperature accuracy is better than ±0.05 ℃. The application shows that this system has the real-time, flexible, stable high-precision, and low cost advantages, and can meet the industrial requirements of high accuracy, high stability and reliability.

References

[1] Zhaojun Li, Ping Ji, Xiaoguang Lou, 2007. Design of high precision temperature control system. *Electronic Measurement Technology*. (2): 146-148.

[2] STMicroelectronics Corporation, 2007. STM32F103XX Datasheet.

[3] Dayong Xia, Xiaohui Zhou, Zeng Zhao, Bofeng Chen, Endian Hu, 2007. Temperature control system of single-chip of model MCS-51. *Industrial Instrumentation & Automation*, (1): 43-47.

[4] Lin Wu, Enping Lou, Dongqing Hou, Liang Xu, 2006. Wireless temperature and humidity control system based on PID arithmetic. *Chinese Journal of Scientific Instrument*, 27(21): 619-620.

[5] Yan Zhao, Guangzhi Yang, 2006. Automatic measuring system in constant temperature for oxygen content based on singlechip. *Chinese Journal of Scientific Instrument*, s1.

[6] Songmei Zhang, Junkai Liang, Longji Liu, 2008. Design of thermo tank temperature control system based on C8051F. *Electronic Measurement Technology*, 31(9): 147-149.