Fuzzy-PID based heating control system

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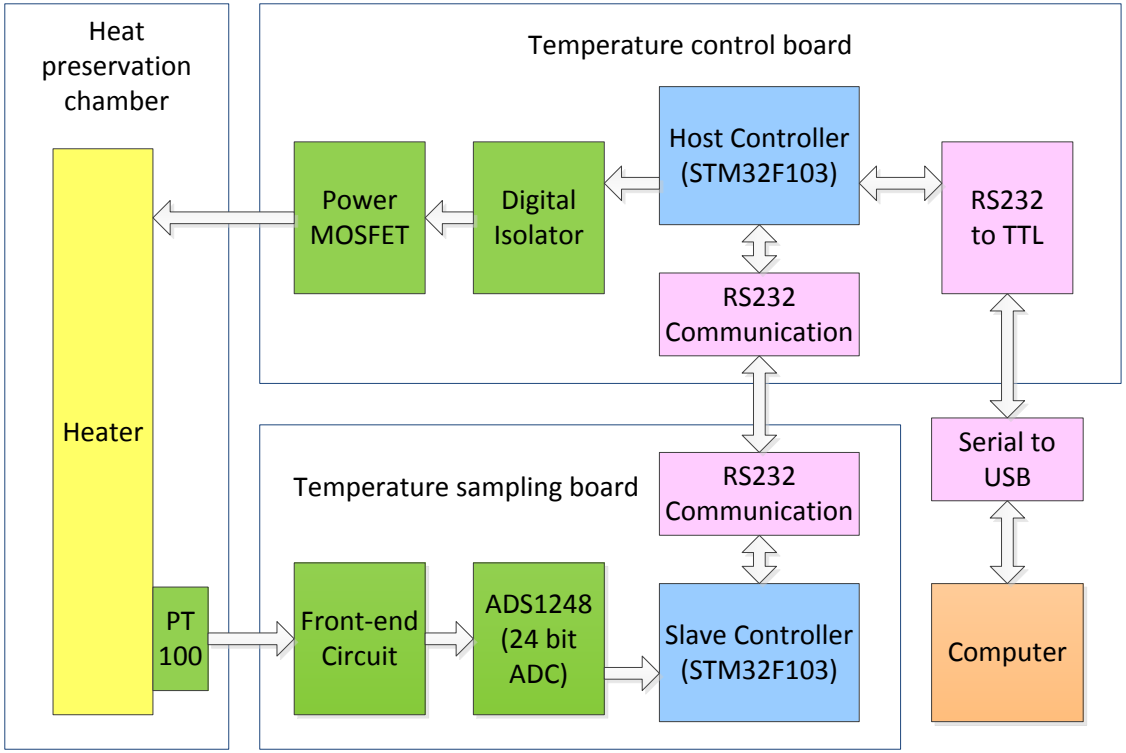

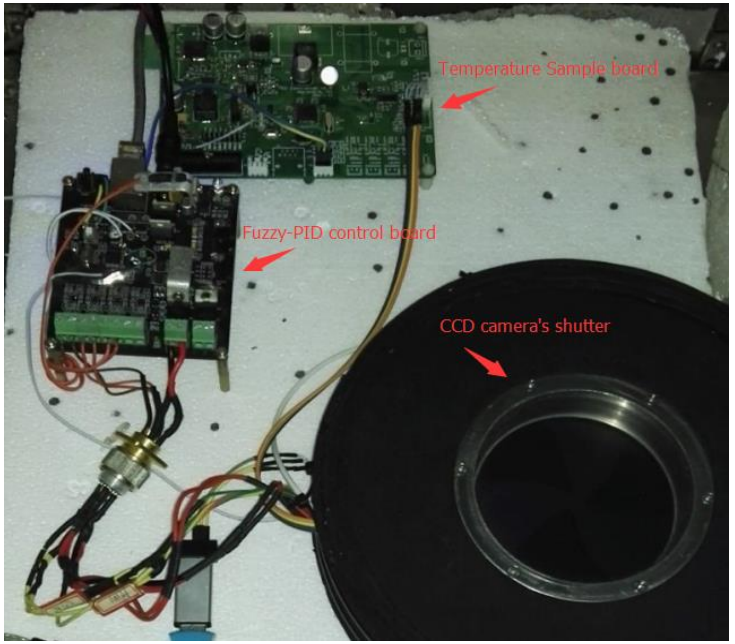

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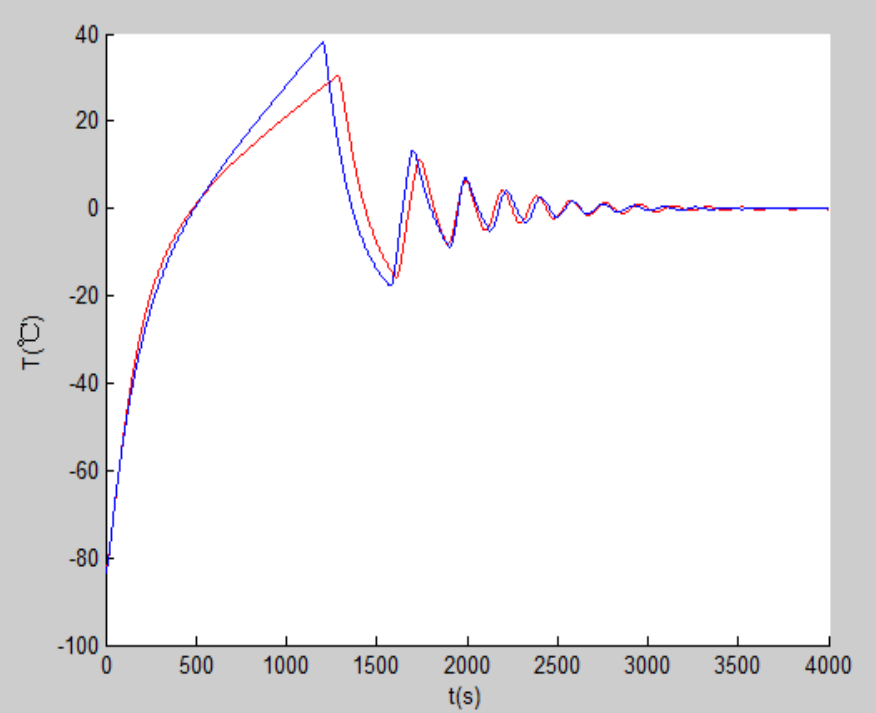

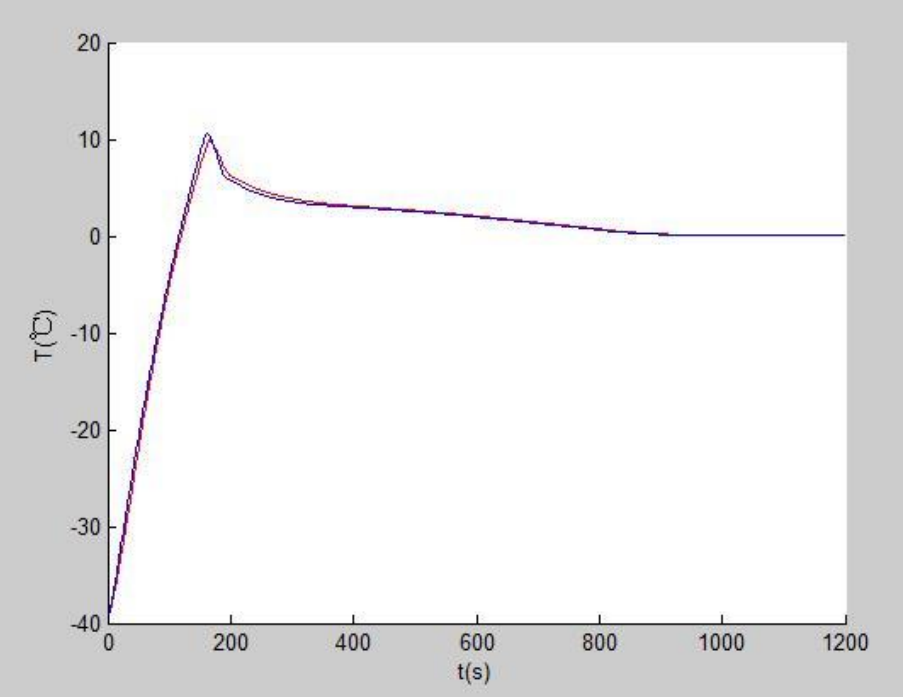

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Fuzzy-PID based heating control system

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Introduction

Heating Mode

Algorithm design

Algorithm design

Test Result

1.Introduction

Many scientific devices have been used in Antarctic, and some parts of the device cannot run at the low temperature as low as -80 degree Celcius such as a mechanical shutter in a scientific CCD camera[1][2]. In such a condition, a heating system should be designed to satisfy the temperature requirement. For a CCD camera, we designed a heater system for the shutter including a heat-hold shutter house, temperature sensors, heater, a control board based on STM32F103[5] heater driver and temperature sensor sampling, a control software in the computer

Conventional PID has several problems, such as overshot, low efficiency, poor environmental adaptability [3]. The fuzzy controller has a good control performance in multivariable, dynamic, nonlinear system. We get the temperature control system model, then simulation the whole system with the MATLAB's tools, and finally design a self-adapting Fuzzy-PID controller.

2. Heating Mode

The transfer function of H(t) is the model of the target.

$$T(t) = P(t)*H(t)$$

(t is time, P(t) is the heating power, T(t) is the output of the target.)

With the Ident tools of MATLAB, we can get the model of the target from these data. Then, we can use the Simulink to simulate the model, and evaluate its correctness.

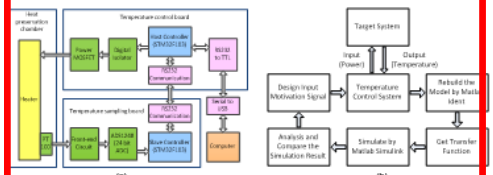

Fig.1 The Heater system and test process.

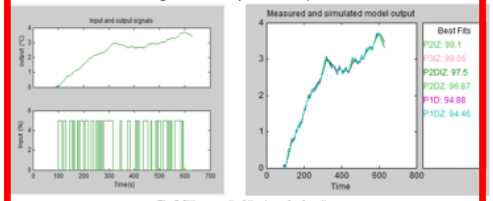

Fig.2 fitting result of the transfer function.

The P2IZ(second-order system with integral and zero) type of ident model has the fits as high as 98.1%. And we can get the best fits as the model, it is shown as follows:

$$G(s)=K*\frac{1+Tz*s}{s(1+Tp1*s)(1+Tp2*s)}$$

(K=0.00059453, Tp1=179.59, Tp2=5.9418, Tz=1850.6)

3. Algorithm design

As is shown in Fig.3, the deviation value e(t), between the input signal r(t) who represents the target temperature and the feedback signal c(t) which is the current sample of the space temperature, is applied by two modules. One is the fuzzy controller, the other one is the variance ratio of e(t) that is then used by the fuzzy controller. The function of the fuzzy controller is to compute the parameters' modification values like, which are used to automatic correct the initial parameter of the PID controller as KP, KI, KD. And via the parameters, the PID controller calculates the control value u(t) output to controlled object. Afterward the feedback signal is attained again to generate the close loop control.

Fig.3 The structure of the fuzzy-PID control algorithm.

The module of the Fuzzy-PID controller and the process of the heating system is shown as Fig.4. With the transfer function of target system (eg. H(x)), we can build a simulation system in the Simulink tool. The structure is shown as Fig.5.

Fig.4 The process of Fuzzy-PID logic.

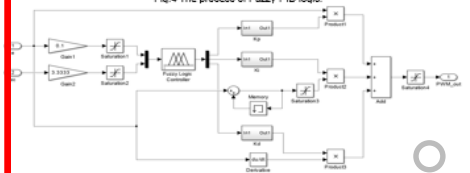

Fig.5 The simulation of Subsystem of Fuzzy-PID logic in Simulink tool. (In this figure, Gain1、Gain2 is quantification facto, it changes according to the actual temperature variation range. Saturation is used to ensure all the value in the domain of discourse.)

We get the fuzzy output according to the e and ec, and composition the final output by PID logic. After simulation, we translate the MATLAB program into C program, then download it into control board. The target system's temperature is get by the temperature sampling board.

4. TEST RESULT

We design a fuzzy-PID algorithm control board based on STM32F103[5], and a high precision temperature sampling board based on ADS1248 (24bit,∑-△ ADC).

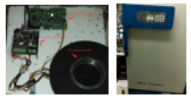

Fig.6 Temperature controller and freezer

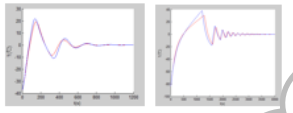

Fig.7 The simulation and experiment result of conventional PID in -40℃ and –80℃. (The blue line represents the simulation result, the red line represents experiment result.)

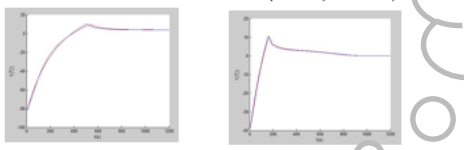

Fig.8 The simulation and experiment result of fuzzy-PID in -40℃ and -80℃.

When using Fuzzy-PID control, the heating target system has a lower temperature overshoot and it takes the system shorter time to be stable. In addition, Fuzzy-PID control has a strong adaptability in different environments, the performance of temperature regulation is stable.

By measuring the transfer function of the heating target system, the accuracy of the simulation results is greatly improved, and the guiding significance of the simulation is more obvious.

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