Proceedings of the 29th Chinese Control Conference
July 29-31, 2010, Beijing, China

Intelligent Control and Implementation of a New Type Constant Temperature and Humidity Box*

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Abstract: This paper focuses on the hardware and software design method of a new type of high efficient temperature and humidity testing cabinet. As the hardware core is based on the STC12C5620AD MCU, the entire hardware system is simpler and more reliable. By using the box inside the environmental cycle and using adjust channel of the atmospheric environment, the system efficiency is greatly improved, while energy-saving effect is remarkable. By adopting expert PID control algorithm and using hardware and software compensation measures, the system dynamic and static quality and control precision is further improved. Furthermore, the use of intelligent terminal as input and output device, which is simpler to operate , meets the different needs of consumers.

Key words: Constant Temperature and Humidity Box, STC12C5620AD, Intelligent Control, Intelligent Terminal, Double-loop Structure

1 INTRODUCTION

Temperature and humidity instrument of measure and control plays an increasingly important role in many fields (e.g., industry, agriculture, health care and science research), thus it is more widely applied and its performance is required higher and higher. Based on past experiences, the paper eliminates the traditional design of which AT89C52 MCU is the core of measurement and control, uses an advanced, high-performance, and self-bring AD conversion STC12C5620AD MCU, adopts expert PID control algorithm to design PID Controller, and through carefully research, design and adjustment develops a high efficient constant temperature and humidity box, which has the advantages of high performance-price ratio, good durability and fast response compared with the traditional one [1]. To be more convenient, intelligent terminal is used as input and output device.

2 HARDWARE DESIGN

Constant temperature and humidity box is composed of box and control system of which MCU is the core device. By controlling solenoid valves and humidifiers through system software, the box maintains stable temperature and humidity.

2.1 Hardware Design of the Control System

The hardware is showed as Fig 1. A high-performance STC12C5620AD MCU with 8051 kernel is used as the core of measurement and control [2]. In addition the system also includes sensors, signal conditioning circuits, intelligent terminal, micro-printer, and output control equipment (including heater, refrigerator, humidifier, dryer, and environmental control valve), etc.

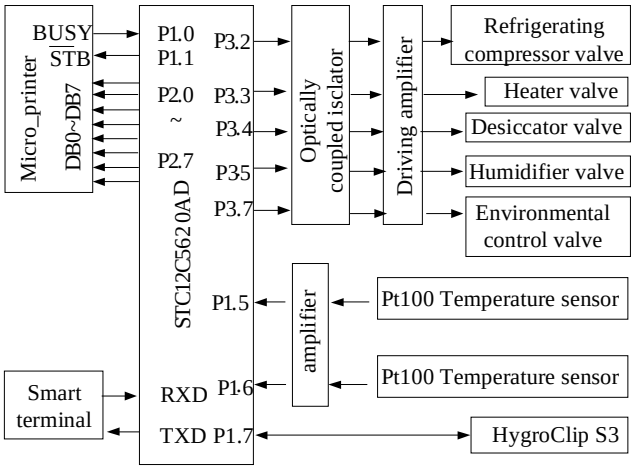

Fig. 1 the system hardware block diagram of temperature and humidify measuring and control

- CPU

  To be the circuit board smallest, a 28-pin package STC Series of STC12C5620AD MCU is used. The chip with 20KB Flash memory has online system programming of ISP & IAP function and a watchdog timer WTD. The MCU has 23-bit I/O port (P1、P2、P3), of which port 3 has no pin P3.6 and port 1 also serves 8-way 10-bit AD conversion. The system makes fully use of the internal resources of MCU without expanding AD conversion and watchdog circuit, which makes relatively big system become very simple. The system interface circuit

[1] *Development of temperature and humidity test box, Hebei Province Department of Education, topic ID: 20042002

design is simple and clear. The input sensor signal is three-bit in which 2-way Pt100 platinum resistance uses the 2-way input port of AD conversion. Besides port 3 pins P3.0 to P3.1 are connected to intelligent terminal, the residual 5 pins are the output port to control the equipment. Port 2 are the data port and port 1 pins P1.0 to P1.1 are the state and strobe signal of micro printer respectively.

- Control Circuit

  The system controls the drives including compressor-driven refrigeration, electric heating wire, molecular sieve dehumidifier, ultrasonic humidifier, environmental regulator valve, and so on. Output control circuit is composed of interface circuit, zero-crossing triggering SCR output control circuit, and so on. By using the collected data to convert and calculate, the system employs expert PID control algorithm to automatically adjust the inner temperature and humidity of the box..

- Sensor

System detects the temperature ranging from -30℃ to +80℃ and the humidity ranging from 20 to 100 %RH. Because of its good temperature linearity and repeatability, Pt100 is widely used to deliver the benchmarks and standards of temperature, and it is currently the best kind of temperature sensor. To measure the temperature and humidity accurately, four-wire Pt-resistance temperature sensor is used to measure temperature, and dry and wet bulb thermometer method is used to measure humidity.

Based on the principle that the temperature of wet-bulb can be measured [3] when its surface water evaporates in stable and enough large wind, wet and dry bulb detects humidity. According to psychrometer equation (1), the water vapor pressure is deduced, and relative humidity and dew point temperature are calculated. Equation (2) calculates relative humidity *U*

$$e = e(t_w) - \mathrm{A} \times \mathrm{P} \times (t_a - t_w) \qquad (1)$$

$$U = \frac{e(t_w)}{e(t_a)} \times 100\% \qquad (2)$$

e——Water vapor pressure

U——Relative humidity

ta、*tw*——Dry bulb and wet bulb temperature

e(*ta*)——Saturation vapor pressure corresponding to dry-bulb temperature

e(*tw*)——Saturation vapor pressure corresponding to wet-bulb temperature

P—— Value of the local atmospheric pressure

A——Psychrometer coefficient

From 0℃ to +80℃, collected data about dry bulb and wet bulb temperature is processed by amplifying circuit. And then it is introduced into MCU by pins P1.5 to P1.6 for AD converting. By calculated, the air temperature and humidity of measured area is determined.

To resolve the problem that humidity in low-temperature from-30℃ to 0℃ can not be detected through dry and wet bulb method, the system adopts sectional measurement by using HygroClip S3 (single-wire digital temperature and humidity sensor) from ROTRONIC CORP SWISS [4]. The device is widely used in temperature and humidity measurement and control occasions such as electronic equipment, environmental test box, high-precision environmental control, etc because of its miniaturization, low power, high performance, high anti-interference ability and easy coordination with microprocessor. The sensor's data line is connected to P1.7 to realize the digital measurement of air temperature and humidity. It has following main technical indexes: humidity: 0-100%RH, temperature: -40℃~+80℃; precision: ±1.5%RH （0~100%RH, 23℃±2℃）, ±0.3℃.

- Input and output circuit

  System uses intelligent terminal equipment of LJD-ZU070 as human-computer interaction, which makes operation simple and convenient. Through LJD-ZU070, identification mode is set to detect thermometer and hygrometer point by point according to test procedures. It is back to standby state until the whole process is finished. Modes can also be set according to actual demands to measure arbitrary value of temperature and humidity. Measurement in different modes may need to stay for some time at a certain stable point of temperature and humidity for some reasons to do "pause" operation.

2.2 Structure Design of Box

The box is composed of the upper and lower part, its cross-section of the form of a square wipe angle. Because the system's hardware and software design are based on modular structure, the box can be taken apart, and then measurement and control part can also be used independently as a portable instrument, which means its application is expanded.

The upper box is a well-sealed temperature and humidity part, and the lower box supports the upper part and is equipped with the solenoid valve, ultrasonic humidity generator, liquid container, drying box, and measurement and control system. It can achieve high precise, stable and uniform effects to obtain a good dynamic and static quality. Apart from using software measures like expert PID control, the system is benefited form the use of a unique box structure of the inner and outer double circulation system which increases atmospheric control channels, and is also benefited from secondary isothermal technology. As long as the object's temperature and humidity is different from that of the environment, environmental adjustment is firstly implemented to reduce overshoot, respond fast, and save energy. System adopts secondary isothermal technology. By directly heated or cooled, the liquid circles in the liquid cabinet through the pipelines in the upper box, and thus its temperature is measured by temperature sensor pre-arranged in the upper box, which overcomes the air fluctuation generated by direct heating or cooling, resulting to better control effects of PID.

3 SOFTWARE DESIGN

3.1 Control Method

Existing products, which want to realize the constant temperature control at low temperatures, need to run the compressor full power at full speed (because the compressor does not allow frequent start), and then adjust PID with the heater to maintain constant temperature, which leads to undoubted facts including more energy consumption, big noise and reduced service life. However, this system takes fully advantage of digital control of MCU and uses expert PID frequency modulation to control cooling capacity to achieve the aim of constant temperature. It overcomes the deficiency of exiting products, improves product quality, and has obvious energy-saving effect.

To overcome the drawbacks of traditional PID algorithm which is easy to overshoot and some other anti-overshoot algorithm whose transition is too long, to achieve the aim of constant temperature and humidity box without overshoot, and to further improve dynamic and static quality, the system adopts temperature and humidity control system which is based on expert PID algorithm. Control block diagram of humidity is showed as Fig. 2. Based on classic PID control algorithm, the essence of expert control algorithm is a variety of knowledge including controlled objects and the control law. The knowledge is employed to design controller through an intelligent way [5]. Namely, according to the errors and error change, different control rules are chosen to design PID parameters and PID controller

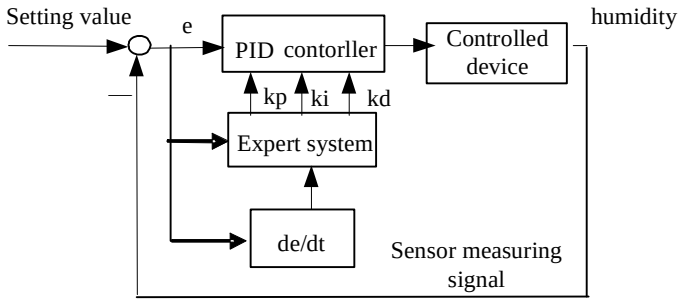

Fig.2: the expert PID system block diagram of humidity control

with variable structure by using expert experiences.

The controller design of this system is showed as followed. Two error bounds are set as ML and MS, and ML is bigger than MS. K1 is gain coefficient bigger than 1. K2 is inhibition coefficient bigger than 0 and smaller than 2. ε is any small positive number. Then the designed expert PID control has following rules: (1) Before reaching stability, if the overshoot is too large and the requirement of accurate transition time is not high, the system can appropriately increase proportional band to overcome the overshoot. (2) To speed up the arrival time of stability, the system can allow a small amount of overshoot and appropriately reduces proportional band. (3) When the measured values slowly fluctuate up and down around set value, the system can appropriately increase the integration time or proportional band. (4) When the measured values frequently fluctuate up and down around set value, the system can appropriately reduce the differential time.

Experiences have proved expert PID controller's step response curve without overshoot and adjusting time is much shorter than routine PID.

3.2 Programming

The system application programs using modular structure are compatible with the hardware configuration. The emphasis and difficulty of the software lies in the dynamic process of creating a stable temperature and humidity environment. According to site-specific conditions, the main program coordinates with subprograms of various hardware configurations to form a complete system measure and control program

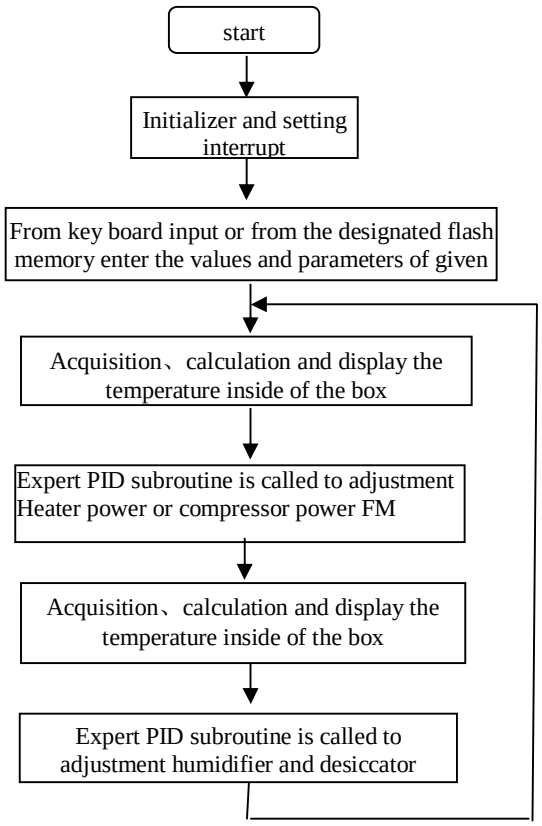

Fig. 3 the flow chart of main program

which achieves the determined functions. The flow chart of main program is showed as Figure 3. The sequential execution of the main program is following: (1) Initialization, which mainly includes opening stack, working mode of timer/counter, opening interrupts and setting priority level of interrupt. (2) Each initial parameter value of the given value and expert PID is sent to specified RAM cell by the keyboard or flash memory unit. (3) To measure and control, display, and call expert PID subprogram to adjust temperature and humidity in the box. (4) To repeat the third step to adjust circle detection.

The subprogram of expert PID algorithm is showed as Figure 4.

4 MAIN TECHNICAL INDEXES

Range of temperature: -30 °C~＋80 °C
Degree of temperature fluctuation: ≤ ±0.3 °C
Temperature detection precision: ≤ ±0.1 °C
Temperature control precision: ≤ ±0.4 °C
Range of humidity: 20~100%RH
Degree of humidity fluctuation: ≤ 1%RH
Humidity detection precision: ≤ 2%RH
Humidity control precision: ≤ 3%RH
Above technical indexes are actual measured values, which are more precise than those of existing products, because several following points are fully taken into consideration in the system design: (1) To make use of MCU self-bring AD to convert circuit, which reaches to 10-bit accuracy and has stronger anti-jamming capability. (2) To use platinum resistor of Pt100, which has very good linearity, repeatability and reliability. (3) To adopt standard resistor with high stability for comparison, which inhibits the temperature drift and time drift of the whole system. (4) To use amplifier of AD521 with high input impedance, low offset current and high common-mode rejection ratio and other characteristics.

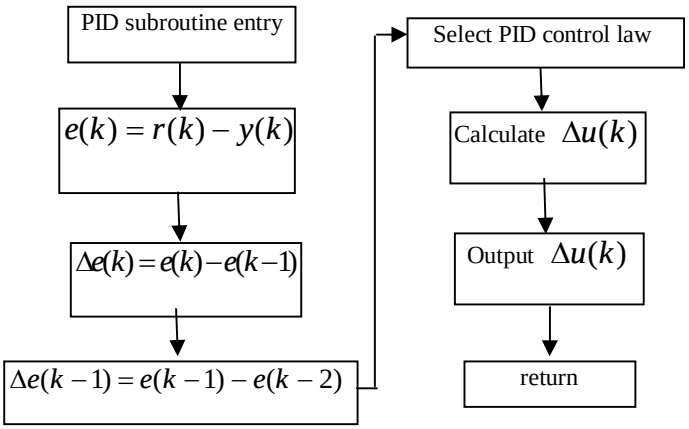

Fig.4 PID subprogram flow chart

Several points on how to improve the system's control precision and to reduce the degree of fluctuation are taken into consideration as follow: (1) The air in the box rationally flows to eliminate dead zone; (2) The secondary isothermal technology is taken to get over the fluctuation caused by direct heating and cooling, so expert PID is easier to control the system; (3) In addition to using an expert PID adjustment method to control the temperature and humidity, the system increases the atmospheric environmental adjust channel, which improves the system's response speed and efficiency, and has a significant energy-saving effect.

5 CONCIUSIONS

New type of constant temperature and humidity box in a real sense achieves the design of embedded MCU in measure and control system, and further improves products' performance-price ratio. Frequency modulation technique is applied in the refrigeration compressor to significantly improve the dynamic quality of refrigeration control because expert PID control method is directly used in refrigeration process. Based on this core technique, Tianjin Meteorological Instrument Factory (national key enterprise) produces DJM-10A humidity examination box, which has been widely used in strains culture rooms in which quality and production is greatly improved leading to good economic benefit. Consequently, this instrument can be greatly popularized.

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