Development of Embedded Practice Platform for Control System Based on ARM

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***Abstract*—This paper uses an industrial control product as a teaching platform, the necessary foundation of theoretical teaching and practical exercises which is combined, so that students quickly grasp the embedded industrial control system software and hardware, the basics of the system hardware and software analysis, circuit testing, and has strong ability to application. It can improve students on the practical aspects of the initiative and enthusiasm by courses. Improve the requirements of the course on the basis of the original experiment, the validation and repeated cross-experiment is deleted, which is contributed to save hours and improve efficiency. Due to the application of advanced processing technology, so it can reduce the distance of the school teaching and social applications.**

Keywords- Embedded System; Industrial Control; ARM; Teaching Platform.

I. INTRODUCTION

In order to increase students' awareness of the overall system and meet the needs of the community, we combine the more community ARM processor to process the quantities of industrial process control and control objects then give the industrial process control by image shown.

From the system design to late programming and control algorithms explaining to students, so as more abstract theoretical knowledge converted to concrete practical link. It can broaden students' ideas and achieve to the theories consolidation, enhancing students' Interest of learning. It combines the boring theory with interesting experiments to improve the abilities of students [1].

It can develop students ' practical competent and the ability of innovate by learning. We can avoid the creation of a separate and independent credit to guarantee students seriously weighing experimental courses in mechanism and develop students' practical competent and the ability of innovate .It also enable students to face the problem of independent thinking and develop their own problem-solving abilities. Most of the original teaching labs for validation experiments are completed under the guidance of the experiment instructions and teachers. It has been constrained by the ideas and personality of the students and is not helpful to the students' creative ability [2]. By integration and optimization of practice teaching, It can break the previous validation experiments based teaching model to improve the requirements in the original experiment based on the deletion of some validation and repeated cross-experiment, saving hours, and improve efficiency. It is possible to collect large amounts of data and understand the development of the industry. By purchase of some related components to build a system to complete the design and implementation to improve the students' practical aspects of the initiative and enthusiasm.

II. HARDWARE DESIGN BASED ON ARM EMBEDDED CONTROL SYSTEM

This paper presents a industrial control the actual products as teaching platform, By combing the necessary basic theory of teaching with a lot of practice session, it can enable students to quickly grasp the system hardware and software analysis of embedded industrial control systems and make the system hardware and software analysis [3], circuit testing to be true and has a strong comprehensive ability.

The system microprocessor core is based on STM32f103 [4], The temperature acquainted by the temperature sensor. Through refrigeration and heating equipment, control temperature and combine with PID algorithms and PWM control to make the stability of the system running. The system hardware structure diagram is shown below. a stable supply of electricity demand is provided by power management module and reset circuit module for the entire system, while protecting the security of the system's hardware; temperature sampling circuit and the signal acquisition circuit make analog signal acquisition to be true; The temperature control circuit and signal control circuit complete digital signal processing and intelligent control; storage module and 485 transmission module achieve data storage and transmission of the signal; heating and cooling module complete temperature control of the accused object.

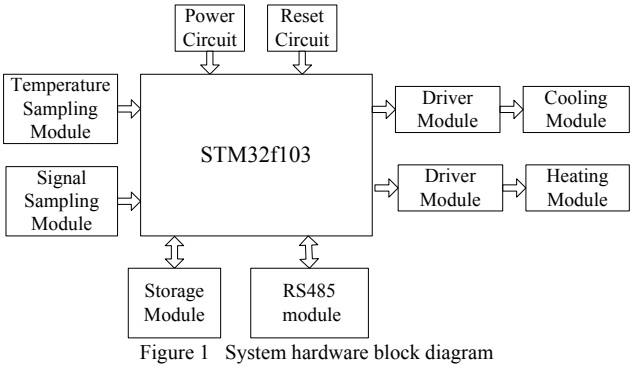

Figure 1 System hardware block diagram

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A. *STM32f103 microprocessor*

According to the design applications, user demand, the degree of difficulty to cost development, a suitable selection of the ARM processor is the key to system design. The STM32 family performance is divided into two different series: STM32F103 the "Enhanced" series and STM32F101 "Basic" series. The two series have built-in flash 32k to 128k and the clock frequency is 72 MHZ. Executing from Flash, STM32 consumes only 36mA and become the lowest power consumption in the 32-bit market, which is equivalent 0.5mA/Mhz. In the performance, STM32 series of processing speed is 30% faster than the other based on ARM7TDMI products. in other words, if the same processing performance, STM32 products with power consumption 75% is lower than the level of product. Using the new kernel Thumb 2 instruction set, designers can put the code capacity reduced by 45%, almost reducing the application software required memory capacity half [5-7].

B. *Temperature sampling circuit design*

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This article uses the temperature sensor of DS18B20. When testing temperature, DS18B20l direct output digital temperature signal by 12 digital quantity way to a line bus way serial transmission to the microprocessor, and at the same time it also can transfer CRC check code. It's strong anti-interference ability and also solves some problems of the traditional analog signal remote in temperature control system. Such as the lead error compensation problem, multipoint measurement switching error problem, amplifying circuit zero beautiful shift error problem, and other technical problems, it also can achieve higher measurement temperature [8] The temperature measurement ranged in -10 ~ + 85 and pulsed power ranged in 3.0 ~ 5.5 V circuit shown in figure 2.

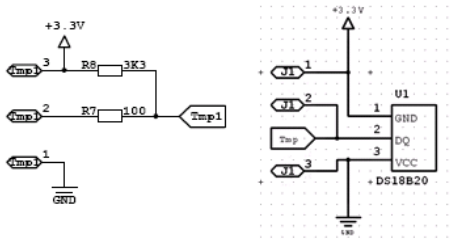

Figure 2 Temperature sampling circuit

C. *Heating and cooling module drive circuit design*

Through the PWM wave to control the CtrlT2 tube feet on or off and the control system temperature. The specific circuit as shown in figure 3, when CtrlT2 pin for low electric, through the inverter U2 make N-channel MOS tube Q2 to control the switch of control circuit, which is equivalent to the electronic switch. When G is conduction, due to the gate of VGS > 0, the two stages of D and S conducting voltage pull is zero, forming pressure difference on both ends in R3. (R3 for copper clad layer) When Even to the circuit board to be heated; The CtrlT2 is high, passing U2 cannot make Q2 work, so the system is not heating. LD2 is heating display lamp for copper clad layer. Heating method is wiring cloth into intensive U-shaped structure in ordinary PCB board that equivalent to the entire plate apply copper. In the above conductivity is full of silica gel and place it under steel plate. This method makes preliminary temperature area, test area, and sample region uniform heating. by a large number of experiments prove that copper clad method heating affections is better than heating bar .

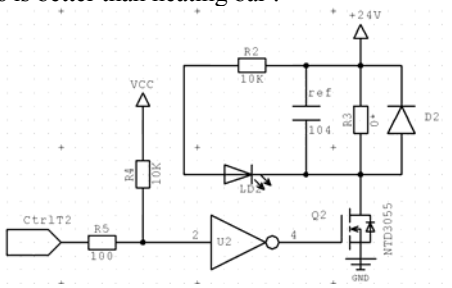

Figure 3 Heating and cooling module drive control module

D. *RS485 communication module*

Tcp1 tubes used in the design of foot control SP3485e enabled, using UART transmission data, need to send information, we will Tcp1 for a high level, 485 as the sender, and then send data, data from the input pin 4, 6 and 7 pin output, including 7 pin output signal of; When data is sent after the completion, Tcp1 pin must be set to low level waiting for receiving data, SP3485 as a receiver. Signals from 6 or 7 pin input pin, pin 1 export. RS485 interface using the difference of transmission, have certain ability to resist common-mode interference, but when the common-mode voltage more than the limit of the RS485 receiver receive voltage, namely greater than + 12v or less than 7v, the receiver can't normal work, serious and even burned chips and equipment. Circuit diagram as shown in figure 4.

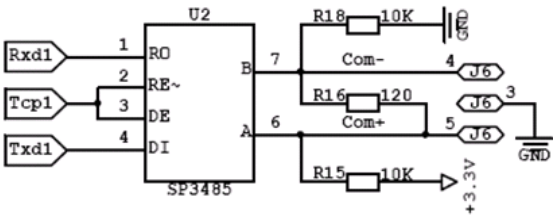

Figure 4 RS485 communication module

E. *Power module*

Power supply circuit is the foundation of the whole system，that provides the foundation for the system normal work of energy and has the extremely important position.

After the voltage conversion chip, we can designs a few groups of different circuits needed power signal, which mainly can be divided into 3.3 V, 5 V power supply network. the above power supply voltage Demand the rectifier bridge converting ac input voltage 24 v dc voltage, and then through the filter input power supply chip U8 (LM2596_5V) to convert the voltage to + 5 v dc. The circuit also need to use + 3.3V power supply voltage, which used the power conversion chip AS1117-3 v3 chip. 5 V power supply network as shown in figure 6, 3.3 V power supply network as shown in figure 7. General AS1117 have 1.5 V, 2.5 V, 2.85 V, 3.0 V, 3.3 V, 5.0 V, output voltage, and the output voltage can be adjusted through the resistance value.

III. SOFTWARE DESIGN OF THE CONTROL SYSTEM OF EMBEDDED CONTROL SYSTEM BASED ON ARM

This design mainly use incremental PID algorithm to realize closed-loop control. In the temperature real-time control, the setting of PID controller parameters is the core content of control system design, According to the characteristics of the controlled process to determine the size of K_p, Ti and Td, In this design, The PID controller is to be adjusted according to the proportional, integral and derivative terms of the desired temperature value and the actual value of modulated quantity. This controller does not require precise mathematical model, and the system has the following advantages: simple algorithm design, robustness, high reliability. This temperature control system use the incremental PID control algorithm.

$$\Delta U= u(k)-u(k-1)=K_p[e(k) -e(k-1)] + K_i*e(k) +K_d[e(k) – 2e(k-1) – e(k-2)] \quad (1)$$

The $K_i= K_p*T/T_i$, $K_d =K_p*T_d/T$， u(k) is the k-th output of regulator, e(k) is the deviation of the given value and the feedback value.

With the above control algorithm, if the set values is 42 ℃, the software PID adjustment process is as follows:

1) If $U < U_{min}$, using the PWM control output high level , full-speed heating.
2) If $U > U_{max}$, using PWM control output low level, the heating was stopped.
3) If $U_{min} \leqslant U \leqslant U_{max}$, using the PID controller to control amount of adjustment. Then the temperature is between 40 ℃ to 45 ℃, Repeated cooling and warming process. Slowly adjusted so that the temperature value of the system to stabilize at around 42 ℃.
4) In the process of adjusting the PID controller, due to the limitation of actuators, control amount tend to be limited within a certain range, and the change is also limited in $| U | < U_{max}$, If the control outside the above range, there will be integral saturation, The actual amount of control will be the upper limit value U_{max} instead of calculating amount control.

So in the process of design, using the integral separation and Specific process are as follows:

1) According to the setting of the actual situation, setting the threshold $\varepsilon > 0$ which is suitable for system control.
2) If $| E (k)|> |\varepsilon |$, using PD control can prevent integral saturation and make the system response fast.
3) If $| e (k)| \leqslant |\varepsilon |$, using PID controller, which can guarantee the system regulation precision, we can give the integral term multiplied by coefficient β when write the formula of the Integral separation PID control, the size of β can be decided according to the size of the error .

Another essence of integral separation PID algorithm is to change the weight coefficient of the past error to control the amount, so according to effectiveness and cost of various improved integral algorithms, we choose the integral separation algorithm which is easy to implement and has good effect applied in our practical temperature control system.

IV. OVERALL DEBUGGING OF EMBEDDED CONTROL SYSTEMS BASED ON ARM

Hardware debugging occupies a very important position in the entire design process. Producing PCB plate and welding circuit board components based on the system task to complete the testing requirements, PCB line and part is more and more intensive. Modification the problem of system hardware design and welding in the testing process gradually, Debugging steps can be divided into: PCB bare board test, PCB welding circuit board examination, as well as the debugging process of the detection circuit, the specific steps are as follows:

1) PCB bare board inspection: pad flat is flat or not, there is no short circuit phenomenon between the lines, resistance welding complete, silk screen clean and tidy.
2) PCB welding plate should fist check the chip whether welding justice, non- reverse device , not accounted for solder between pin and chip whether mistakenly welding by eyes
3) When test with power-on, we should first touch the important components to ensure that there is no overheating phenomenon, and check the power supply module is normal or not, this include: crystals is normal, power supply chip is working properly.

V. CONCLUSION

This paper select temperature as an important parameter in the industry, because the temperature is one of the most important parameters in industrial production and scientific experiment, in the electronic, chemical industry, metallurgy, medicine, aviation and other fields, the parameter of temperature plays a very important role in the measurement of the products, preparation, analysis and many other aspects ,it affects the quality of many products and service life directly At the same time, there is no effective way to control the temperature of the sample will bring uncertainty to the industrial environment and bring difficulties to the analysis of the sample, So the research and design of high

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performance of the temperature control system has very important significance. The characteristics of its inherent hysteretic and vulnerable to outside interference will bring great difficulties to the control of temperature.

This project's innovation lies in integration optimization of the industrial control in the process of experiment teaching, that cultivate students' practical ability and innovation ability and avoid open alone, independent credit and on the mechanism to ensure the students seriously experiment course, break before by the verification experiment teaching mode, on the basis of original experiment to improve requirements, delete some verification and repeat cross experiment, saves hours, improve the efficiency. Due to the application in the society now more advanced processing technology, it narrow the distance of the school teaching and social application.

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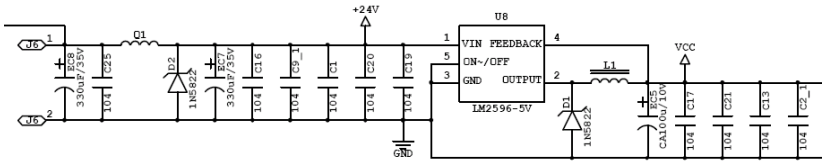

Figure 5 5V power conversion module

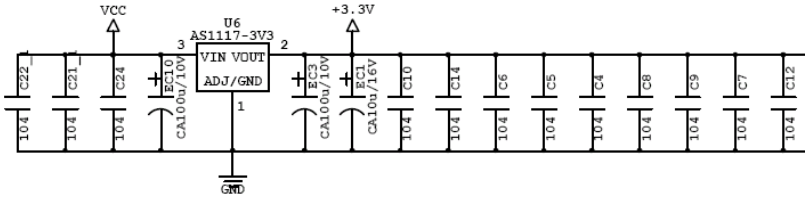

Figure 6 3.3V power conversion module

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