Thermocouple-based Temperature Sensing System for Chemical Cell Inside Micro UAV Device

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Abstract. Environmental temperature of UAV system is crucial for chemical cell component inside. Once the temperature of this chemical cell is over 259 °C and keeps more than 20 min, the high thermal accumulation would result in an explosion, which seriously damage the whole UAV system. Therefore, we develop a micro temperature sensing system for monitoring the temperature of chemical cell thermally influenced by UAV device deployed in a 300 °C temperature environment, which is quite useful for insensitive munitions and UAV safety enhancement technologies.

1. Introduction

In the process control of industrial production, temperature is an important parameter. Thermocouple is one of the most widely used temperature sensors in engineering, its main characteristic is that the range of temperature measurement is wide, the performance is stable, the structure is simple and the dynamic response is well enough, it also easy to automatic control and centralized control and remotely transmit 4-20mA electrical signals. So, the thermocouple is important in temperature measurement. But because of the nonlinear relationship between the thermoelectric potential and the temperature of thermocouple, the complexity of display and processing is increase, and also with the development of industry and automation, the requirement of temperature accuracy is much higher. In modern industrial sites, thermocouples are commonly used to test high temperatures, and test results sent to the main control unit. Because the thermoelectric potential of the thermocouple is nonlinear with temperature, the thermocouple must be linearized to maintain the accuracy of the test.

The work environment is very important for all kinds of instruments or equipment to perform best and operate normally, One of the most important physical quantities in environmental factors is temperature. Thermocouple is one of the most widely used temperature sensors in Engineering. The utility model of thermocouple has the advantages of simple structure, convenient operation, well accuracy, small thermal inertia, good stability and reproducibility, wide temperature measuring range, etc. It is suitable for remote transmission, automatic recording and centralized control of signals, so it is important in temperature monitoring.

The main content of this work is using 89C52 single chip as the controller, K type thermocouple as the temperature sensor. The exclusive A/D converter of thermocouple and the 5-industrial bit liquid crystal display HJ1602A formed the digital temperature monitoring system. Thermocouple acquisition
temperature signal through signal conditioning, uses the A/D convertor to the microcontroller, and display the temperature in HJ1602A.

2. Design and Methods

Figure 1 shows thermal simulation of a chemical cell model in finite element analysis (FEA). The transient temperature of chemical cell is shown in figure 2, while the boundary temperature condition is set as 300 ℃ at the surface of UAV device. After 20 min elapsed, the temperature of chemical cell is heated up to 80 ℃, which is still quite lower than that of the threshold value.

![Figure 1. Thermal simulated UAV system using FEA.](image1)

**Figure 2.** Varied temperature of the chemical cell

In the field of control, C52 Series MCU controller with better stability, faster and more accurate calculation accuracy is undoubtedly one of the goals that people pursue, the digital sensor and SCM can be organically linked, sensors need to collect the required information and make it digital. The microcontroller can process it directly so as to realize the interactive control between them. Secondly, because of the strong core control ability of the MCU, overlapping the auxiliary circuit, and then get the practical development system is necessary.

The working environment to achieve the best performance, whether the normal operation is very important for a variety of instruments or equipment, and a very important physical quantity of environmental factors is temperature, thermocouple temperature sensor engineering is one of the most widely used, it has the advantages of simple structure, convenient use, accuracy, small thermal inertia, stability and reproducibility good temperature, wide measuring range. It is also suitable for remote transmission, automatic recording and centralized control of signals, and plays an important role in temperature measurement. With the development of electronic information technology, new material and automation technology, sensor technology has also been changing with each passing day. SCM and automatic control system have been widely used in many fields.
We are no longer limited to analog signals collected from the environment, but to consider how to obtain the processing of digital signals, so the Wen Min devices, A/D converters and memory are integrated together to form a digital sensor. In the field of control, it has better stability, C52 Series MCU control faster and more accurate calculation accuracy is one of the goals that people pursue, it brings convenience is not negative, while the digital sensor and single chip to connect sensors to collect required information, and the digital, so SCM can be processed directly, so as to realize the interactive control. Secondly, because of the strong core control ability of the MCU, we can overlap the auxiliary circuit, and then get the practical development system. The temperature measurement system can adopt this mode. At present, the accuracy and convenience of measurement are getting higher and higher. If we start with micro controller technology, it will be a good solution to this problem.

The feature of this scheme is that the AT89S52 is a low-power, high-performance CMOS 8 bit microcontroller with 8K in system programmable Flash memory. The AT89S52 is manufactured using Atmel's high-density nonvolatile memory technology, fully compatible with industrial 80C51 products, instructions, and pins. The on-chip Flash allows program memory to be programmable in the system and also suitable for conventional programming. On a single chip, the AT89S52 has a smart 8 bit CPU and programmable Flash in the system, enabling AT89S52 to provide high flexibility and ultra efficient solutions for many embedded control applications. MAX6675 is a high-precision integrated chip. It is small in size and does not need any other peripheral circuits. It greatly reduces the components and I/O connections in the circuit, thus simplifying the system structure.

Figure 3(a) demonstrates our proposed temperature monitoring system, including (b) STC89C52, (c) liquid crystal display and (d) power supply. The microcontroller can process it directly and realize the interactive control between them. Because of the strong core control ability of the MCU, overlapping the auxiliary circuit, and then get the practical development system is necessary. The system we designed is using 89C52 single chip as the controller, K type thermocouple as the temperature sensor. The system structure diagram is shown in figure 3(a). The exclusive A/D convertor of thermocouple and the 5-bit industrial liquid crystal display HJ1602A formed the digital temperature monitoring system. This system takes the single chip microcomputer as the control core, samples and amplifies the thermocouple electromotive force through the high precision A/D converter, and a certain algorithm is used in the microcontroller to realize the linearization of the thermocouple and display the corresponding measurement data through the LCD screen.
3. Experiment Results and Discussion

Our system uses AT89C52 as the microcontroller, uses MAX6675 as the temperature sensor, and temperature light crystal display. The whole system strives simple structure and well function. The use of temperature sensor MAX6675, thermocouple temperature measurement applications, complex linearization, cold end compensation, digital output and other problems focused on a chip to solve, the complex hardware and software design is simplified when the thermocouple temperature measurement scheme is applied to the embedded system field, therefore, the device is an ideal choice for the application of thermocouple temperature measurement in the field of embedded systems. With the rapid development of SCM technology, through the MCU control of the controlled object has become an important development direction in the future in the field of automatic control, current, voltage, temperature, pressure, flow, flow rate and switching capacity are mainly charged with common parameters. For example: in metallurgical industry, chemical industry, electric power engineering, paper industry, machinery and food processing and other fields, people need to all kinds of heating furnace, heat treatment furnace, furnace and boiler temperature detection and control. Using MCS-52 SCM to control the temperature, is not only easy to control, simple and flexible configuration advantages, and can greatly increase the temperature was charged with the technical indicators, which can greatly improve the quality and quantity of products. Therefore, the temperature control of single chip microcomputer is a problem that is often encountered in industrial production.

MAX6675 is a serial analog-to-digital converter K type thermocouple cold end compensation, linear correction, thermocouple break detection produced by American MAXIM company, it is the temperature resolution of 0.25 degrees, cold end compensation range is -20 to 80°C, the working voltage is 3 ~ 5.5V. This paper introduces the function characteristics, pin arrangement and operation sequence of MAX6675, and gives the interface circuit and programming design method of MAX6675 and 89C51. In the field of industrial temperature measurement and control, K thermocouple is widely used because of its good linearity, low cost and wide measuring range. But it often needs cold end compensation, and the circuit is more complex, debugging trouble. The K thermocouple serial analog to digital converter (MAX6675) produced by MAXIM can not only convert analog signals into 12-bit corresponding digital quantities, but also bring cold end compensation. The temperature resolving power is 0.25°C, which can satisfy most industrial applications. MAX6675 uses small size and good reliability SO-8 packaging.

The experimental setup is shown in figure 4. We employ a controllable hot plate as a source of thermal stimulation for UAV device and its chemical cell. The thermocouple is attached to the surface of chemical cell inside UAV device. The temperature data is shown in a display of temperature monitoring system. Figure 5 a tiny temperature difference between the set thermal value $T_s$ (black line) and real one $T_f$ (blue line) of a hot plate. Assuming the temperature of UAV surface is close to that of hot plate, the heat would transfer into the UAV body and thus chemical cell inside. A much temperature different between the chemical cell ($T_c$, red line) and UAV surface. When $T_f$ reaches 300 °C, $T_c$ is about 90 °C on a stable state. These results can give us a conclusion that present design of temperature monitoring system can work well for sensing temperature of chemical cell inside UAV device, and also
the chemical cell can hold a much lower temperature of 80 °C than that of thermal source of 300 °C within 20 min.

![Image of the experiment system design and result diagram](image)

**Figure 4.** Experiment system design and result diagram. (a) Experimental setup for heating fuse device and temperature monitoring, (b) Measured temperature of the chemical cell inside fuse device using a thermocouple

4. Conclusion

The main content of this work is using 89C52 single chip as the controller, K type thermocouple as the temperature sensor. The exclusive A/D convertor of thermocouple and the 5-industrial bit liquid crystal display HJ1602A formed the digital temperature monitoring system. Thermocouple acquisition temperature signal through signal conditioning, uses the A/D convertor to the microcontroller, and display the temperature in HJ1602A. This system takes the single chip microcomputer as the control core, samples and amplifies the thermocouple electromotive force through the high precision A/D converter, and a certain algorithm is used in the microcontroller to realize the linearization of the thermocouple and display the corresponding measurement data through the LCD screen.

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