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# DESIGN ON ADμC812 SCM BASED MULTICHANNEL TEMPERATURE INTEGRATION INTELLIGENT INSTRUMENT

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### ARTICLE DETAILS

### **ABSTRACT**

#### Article History:

Received 26 June 2018 Accepted 2 July 2018 Available online 1 August 2018 This paper introduces the design of intelligent temperature meter based on high precision data acquisition chip  $AD\mu C812$ . The realization methods of key technical such as linearization, scaling and digital filtering in the design of temperature sensor are described. This paper has reference value for the design of single chip integrated intelligent instrument.

### **KEYWORDS**

Intelligent industrial testing instrument, Linearization dispose, Mark degree transformation, Digital filtering.

### 1. INTRODUCTION

With the rapid development of computer technology and the continuous improvement of chip integration, more and more on-chip systems are applied to the design of intelligent industrial instrumentation. In the main design scheme, the integrated microprocessors, A/D and D/A analog channels, and reference sources on chip collection system chips is used to design industrial control instruments, which has the advantages of small volume, low cost [1]. Moreover, as the hardware integration is in the chip, which can not only reduce the later debugging time and debugging cycle, but also effectively improve the anti-interference ability of the system, which has a high-performance price ratio. Representative products of onchip data acquisition system include ADuC812, ADC8051F350 and so on. The ADuC812 used in this paper is an integrated analog collection on-chip system produced by ADI company in the United States, the system has the characteristics of fast speed and high precision, as well as low price, wide application and strong environmental adaptability, therefore, it is very suitable for real-time acquisition and temperature acquisition system [2].

# 2. HARDWARE DESIGN OF MULTICHANNEL INTELLIGENT THERMOMETER

The core processor of this system is called ADµC812 microchip. According to the practical application of the intelligent thermometer, the whole system is divided into 7 functional blocks: system reset, temperature collection, data display (LED), temperature adjustment, serial communication (RS232), data processing, upper control computer, the overall hardware composition is shown in Figure 1. The principle of this design is: the sensor will transform the collected temperature change to the corresponding electrical parameters [3]. After the amplification, maintenance, conditioning and A/D sampling via analog acquisition channel, the voltage data corresponding to the electrical parameters can be obtained. The data processing unit converts the corresponding voltage data into the temperature data collected by each channel by look-up table or function method and sends the data to the display module and then sends it to the serial communication module [4]. It is hence sent to the computer by communication module in real time. After the upper computer gets the data, it is displayed on the monitoring interface. Moreover, the single chip can also make up a temperature closed loop control system by the temperature sensor, the DA analog control interface and the peripheral temperature control execution equipment.

# 2.1 Performance characteristics of ADµC812 chip

ADuC812 is a data acquisition system based on the complete data acquisition channel, 12-bit A/D and MCU produced by ADI, USA, and its block diagram is shown in Figure 2. The internal resources of the chip mainly include:

- 8K byte flash / erasure program memory, 640-byte flash / erasure data memory and 256 byte data SRAM support programmable, 8051 compatible kernel;
- Precision reference voltage source (440ppm/°C);
- Standard UART serial input / output port, watchdog circuit and power monitoring function;
- Clock oscillator frequency≤16MHz;
- 32 programmable I/O lines provided for multiprocessor interfaces and I/O extensions;
- ADC direct memory access controller and internal temperature

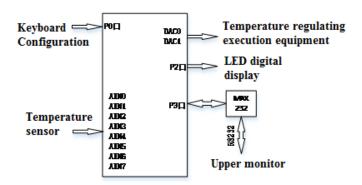


Figure 1: Hardware composition diagram of intelligent temperature control instrument based on ADμC812 kernel

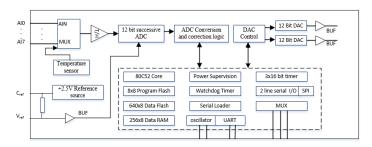


Figure 2: Functional block diagram of ADμC812

ADuC812 contains a significant reference source for the on-chip acquisition system, on the one hand, the reference source, to a certain extent, determines the effective range of the input voltage of the chip on the chip; on the other hand, the reference source affects the accuracy of the A/D sampling [5]. The reference source of ADuC812 can either use an internal reference source or an external reference source. The reference supply voltage of the internal configuration of ADuC812 is 2.5V. If the internal reference power is used, the input voltage range of the measured temperature sensor must be 0 to +2.5V. And, external reference source can be also applied to improve the precision and range of the reference source, at this time, the external reference source is introduced by Vref port, and the measured input voltage range is at 0V  $\sim$  Vref.

AD mu C812 chips have the features of low low power consumption, and strong environmental adaptability, all these make it adapt to general industrial environments (operating temperature range: -40 to +85 °C). The A/D of ADµC812 also has automatic calibration function, the factory determines the calibration coefficient of A/D when A/D is out of the factory and is stored inside the chip. In normal work, when the system is powered on, the system will download the time calibration coefficient to ADC to ensure the accuracy of the ADC. Moreover, the electrical parameters collected from the ADµC812 chip temperature sensor are directly proportional to the actual temperature parameters, therefore, the temperature values measured by the temperature meter can be guaranteed with accuracy.

# 2.2 Temperature sensor

The temperature sensor in this system can be divided into two parts: first, an internal temperature sensor built in the AD microchip, which is mainly used to measure the temperature inside the chip; second, a temperature sensor used to measure external temperature signals [6]. At present, applied industrial temperature sensors include thermal resistance sensor, thermocouple sensor, PN junction temperature sensor, thermistor sensor and integrated temperature sensor. Each type has its own characteristics, among them, thermocouple is mainly applied in temperature measurement environment with large range of industrial temperature measurement and high dynamic characteristic requirements, however, it is necessary to compensate the cold end, and the design and realization of the circuit are more complicated. Thermal resistance and thermistor are mainly used in temperature measurement environments with small range of industry and temperature measurement and low dynamic characteristic requirements, and, the electric bridge can be used to adjust the front end, and the circuit is simpler than that of thermocouple. Digital integrated temperature sensor is a temperature sensor appearing in recent years. It can directly digitize the temperature, and because of internal correction, it has high accuracy. Considering that the system is mainly used for granary system, the digital integrated temperature sensor is selected finally, while the analog temperature acquisition channel is retained, then the temperature can be measured by DC bridge and thermal resistance sensor.

Based on the above considerations, the system selects the DS18B20 temperature sensor of DALLAS company in the United States, the sensor has the characteristics of digital integration, and has a unique single line interface, when the DS18B20 is connected with the microprocessor, it only needs one line to realize the two-way communication between the microprocessor and the DS18B20. The connection is easy, and the performance is high.

The main features of DS18B20: Measuring range at -55°C $\sim$ +125°C, 9 $\sim$ 12-bit programmable resolution, single line (I2C) bus communication, various power supply modes supported, supported power supply of the sensor by the data line through the parasitic power supply, the connection mode of the parasitic power supply circuit is shown in Figure 3.

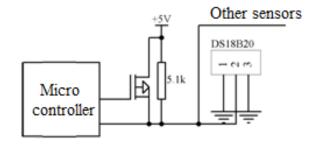
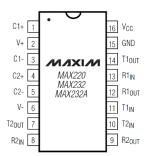


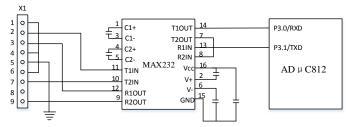
Figure 3: DS18B20 parasitic power supply connection

### 2.3 RS232 interface circuit

The ADµC812 SCM chip is equipped with a RS232C standard full duplex communication interface, the communication between the upper monitor computer and the single chip microcomputer is realized through the serial port RS232. The serial communication module of the system uses the MAX232 chip, and the pin arrangement diagram of the DIP/SOP package is shown in Figure 4 (a). AD mu C812 forms a RS232 communication interface through the external connection P3.0 and P3.1 and MAX232 chips. The concrete schematic diagram is shown in Figure 4 (b), as seen from it, through pins C1+, C1- and V+, the switch from voltage +5V to +10V can be realized, by pins C2+, C2- and V-, the switch from voltage +10V to -10V can be realized. The pin 10, 11, 7 and 14 constitute a data transmission channel, and pins 9, 12, 8 and 13 constitute another data transmission channel. Pins 10 and 11 will transform the data sent from an external device port X1 and then send it to P3.0/RXD of ADµC812 via chip pin 14. However, in contrary to the data transmission process of the previous channel, the data sent by the P3.1/TXD of AD mu C812 will be received by pins 8 and 13, after conversion by circuit processing, it will be sent to MCU peripherals RS232 communication port X1 via pins 9 and 12.



(a) MAX232 pin arrangement



(b) Chip circuit connection between MAX232 and ADµC812SCM

**Figure 4:** Communication realization circuit of MAX232 pin and AD / C812 serial port

# 2.4 Reset circuit

Meanwhile, the multichannel intelligent thermometer is designed with a reset button. When the system initiates or the operator presses the reset button, the thermometer will automatically complete the reset process. The external reset circuit of the system is shown in Figure 4, the reset button K1 is set with normally open contact, the system VCC serves as a power supply for the reset circuit. When the MCU system is powered on, capacitor C1 starts the charging process, due to the series of resistance R1

and capacitor C1, the capacitance C1 is equivalent to a short circuit in the charge state. The voltage at both ends can be considered zero and the voltage of the resistance R1 is VCC at both ends. At this time, the RESET voltage of the reset pin of AD mu C812 is "0", that is, low level, and the single chip system is reset. After booting, the capacitor C1finishes charging, it can be considered a circuit breaker, the voltage value at both ends of the capacitor is VCC, the reset pin RESET voltage is high level, then the reset process ends up. When the microcontroller starts running, and the manual reset button K1 is pressed, the two contacts of K1 are connected. After the short circuit of the capacitor C1, it is discharged through K1, the reset pin RESET is low voltage, and the AD mu C812 finishes reset. When the reset button K1 is released, the capacitor C1 is charged, thus repeating the above process.

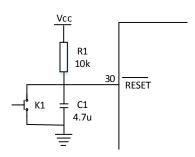


Figure 5: External reset circuit of ADμC812

# 2.5 Anti-interference design of hardware

Electromagnetic interference (EMI) is regarded as an important issue in the design of instrument hardware, which is directly related to the accuracy and reliability of the instrument. In order to improve the anti-interference ability of hardware, many factors are considered in this paper, such as anti-jamming of power supply system, anti-jamming of process channel and anti-jamming of PCB. As including analog circuit and digital circuit, the design of on-chip system requires considering the interference between analog and digital circuit parts, so as to avoid mutual disturbance between digital signal, analog signal, and big error in collecting data, to this end, the system adopts the following measures to resist electromagnetic interference:

The noise of power supply will affect the accuracy of the system. The power transformer uses a small leakage type R transformer, and its output voltage ripple is small (usually at mV magnitude), and its output is further filtered by large capacitor.

The analog and digital sources are independent of each other, so as to prevent digital signals from interfering with analog signals to lead to large errors in data acquisition

The intelligent thermometer system shields the interference by using the shielding box to prevent most of the electromagnetic interference from the outside world. In the shielding box, the power, digital circuit and analog circuit are separated to reduce the interference between the circuits.

# 3. SOFTWARE DESIGN

C language has the features of good portability, high quality of code and high execution efficiency. The multichannel intelligent temperature thermometer uses C language as its programming language.

The main functions of the program include initialization, system self-checking, fault diagnosis, sensor value reading, temperature PID adjustment, RS232 serial port data communication, and judgement according to the current system settings, and execution of corresponding programs according to the judgement results. The program also realizes the current sensor reading and the system status display in turn, and it can also enter the system man-machine dialogue interface to set up the functional modules of the system. Setting contents include: system settings, password settings, time and timing settings, custom control of upper and lower limits, terminal settings, terminal queries. For the purpose of making the master controller more real-time, the system is embedded with a  $\mu C/OS$  II embedding operating system.

#### 3.1 Tasks in the application system

For the purpose of simplifying the design and debugging of the intelligent temperature instrument software, this paper uses the task mechanism to realize the function of the user based on the  $\mu C/OS$  II embedded operating system. The so-called task mechanism is the decomposition of the functions to be decomposed into multiple independent functional modules, each of which corresponds to a small task state. The tasks in the C/OS II operating system are divided into system tasks and user tasks, the system task is provided by the operating system, the user task is realized by the program task written by the user, and the function modules of the main controller are all user tasks.

The ADµC812 chip has only one CPU. At any time, there is only one specific task occupying CPU. The task in the  $\mu\text{C}/\text{OS}$  II operation system has different states according to different operation conditions. The transformation of the task state is shown in Figure 5. It can be seen that the program execution states include interrupting execution state, task running state, idle wait state, ready state, and system dormancy state.

After the main program is started, it enters the waiting state, and the system is judged into the ready state according to the self-inspection state of the temperature instrument and the operation condition of the task. Since any task module must run after necessary conditions met, the main program can't go directly to the running state across the ready state. It can only enter the ready state after the operation condition is available, and then switch from the ready state to the running state.

When CPU is in operation state, it can receive interrupt requests of processing system and suspend the operation taskto run the interrupt task, and then continue the interrupted task after the interrupt task is processed. When the run task is completed, it can be transferred to the waiting state, ready state, or dormant state.

The task with its task code not given to the operating system management is called a dormant task, the instrument system will switch to the dormant state after the system receives the dormant instruction, the dormant task will enter a ready state once a new task control block is configured.

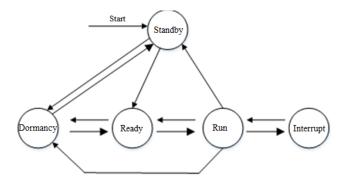


Figure 6: Master program task state conversion diagram

### 3.2 Asynchronous serial communication protocol

Serial communication includes asynchronous communication and synchronous communication. The difference between the two is that when using asynchronous communication, the transmitter and receiver often use their own clock signals, while synchronous communication requires the sending and receiving terminals to use the same clock to control. In contrast, asynchronous communication is slightly slower than synchronous communication at speed, but the interface design is simpler than synchronous communication, and the requirement for communication timing is not so strict, so it is easier to implement. In this system, the asynchronous communication mode is chosen because the requirement on the control of time sequence is not high.

Asynchronous serial communication is the transmission of information in character units, since the transmission between characters is completely asynchronous, so the interval between two adjacent characters is arbitrary, and each frame information of asynchronous serial

communication consists of 4 parts: 1-bit starting bit,  $5\sim8$ -bit data bit, 1 bit even-odd check bit, and  $1\sim2$  bit stop bit. The starting position is defined as a low level of 0, the stop bit is specified as a high level of 1, and the data bit is a valid message to be transmitted. When there is no data transmission on the communication line, it is in the logical "1" idle state, when starts sending data, the sender first sends out a logical "0" low level start bit, the receiving device detects the starting position and begins to receive the data bit, data bits begin to transmit from the lowest level, when the data transmission is completed, the sending device sends even-odd check bit, the even-odd check bit is used for the finite error detection, and the stop bit is the end mark of a character data. After 1 frame data transmission is completed, the communication line is in a logical "1" idle state.

In serial communication settings, because the bit length of a character is limited, the required clock and sending clock shall be close to each other, and the baud rate reflects the data bits transmitted between the sending and receiving sides per second during asynchronous communication. Two indicators, baud rate and the character frame format, can be set by the user according to the actual needs.

# 3.3 Scale transformation processing of temperature acquisition system

After electrical signal of the temperature sensor is amplified by the 12-bit temperature acquisition system of the ADuC812 single chip microcomputer and the AD conversion, it becomes the 0000H to 0FFFH digital quantity. This digital signal is a dimensionless binary number, which needs to be reduced to a temperature value with dimension at °C, the specific scaling transformation process is implemented by the software program. There are various algorithms for scaling transformation, considering the function relationship between the measured parameters and the dimensionless number, the linear interpolation method is selected for the scale transformation of the thermometer, the basic idea is to replace the value of the function y=f(x) by using the N section of the n+1 interpolation node, the specific mathematical formula represents the scale transformation of the temperature acquisition system as follows:

$$y_i = y_k + \frac{y_{k+1} - y_k}{x_{k+1} - x_k} \times (x_i - x_k)$$
(1)

When the detection value Xi is determined, the Xi interval is determined by the look-up table, then based on the calculated coefficient term, it is substituted to the interpolation formula to get the value of y.

By using linear interpolation, as long as the number of segments is fine enough, the accuracy of computation can be achieved, but it will increase the memory capacity. Therefore, under the premise of accuracy, we choose fewer segments to reduce the number of calibration points and improve the speed of operation.

# 3.4 Realization of digital filtering

The main purpose of adding digital filtering is to overcome the random interference signal and improve the measurement accuracy. In actual industrial situations, the changes in the temperature of the measured objects are generally relatively slow, arithmetic mean filtering can be used for the interference introduced in the process of signal acquisition, the concrete realization method is to carry on the continuous multiple diversity, the arithmetic average of the sample value is used as the temperature value at that time, the formula for the arithmetic average value filtering algorithm is shown in (2). When number N of samples selected by arithmetic average filtering is larger, the better the degree of smoothness of the signal will be, but the reaction lag is more serious when the temperature changes quickly; When number N of samples selected by arithmetic average filtering is smaller, although the response to temperature changes is very fast, the effect of interference suppression is poor. The comprehensive effect of filtering is better when the N value is about 10 during the design of the intelligent thermometer.

$$X = (X_1 + X_2 + X_3 + \bullet \bullet \bullet + X_N)/N \tag{2}$$

Wherein: X1, X2, X3—XN are temperature values of continuous N sampling, X is the filter value.

## 3.5 Realization of temperature control

The intelligent thermometer not only has the function of temperature detection, but also has the ability to control the temperature closed loop through the analog output of control electric heater. The temperature control has the characteristic of time delay. The conventional PID control is often used in temperature control because of its simple and practical structure. The principle of specific temperature control is: the intelligent temperature instrument compares the actual temperature of the acquisition system with the target temperature set by the instrument, and uses proportional, integral and differential options to control the error e. The proportion control parameter P mainly produces the control effect on the output input error signal of the system at the fastest speed by proportionate relation, in order to reduce the error. In integral control, the output of the controller is proportional to the integral of the input error signal, with the introduction of integral term, the control static difference can be eliminated in the steady state, but with the introduced inertia link at the same time, system reaction lags behind. The differential term is mainly to improve the dynamic characteristics and stability of the control system. It combines the proportional and proportional integral control to form the temperature PD control algorithm or the PID control algorithm. The discrete formula of the PID control algorithm is as follows:

$$U_{k} = K_{p}e_{k} + K_{i}\sum_{i=0}^{k} e_{i} + K_{d}(e_{k} - e_{k-1})$$
(3)

### 4. CONCLUSION

For the purpose of adapting to the needs of multifunctional, miniaturized and intelligent development on industrial instruments, this paper introduces a software and hardware design scheme using on chip collection system chip for the design of industrial control instrument. And, it explores the key technical problems including algorithms of linearization and scaling, interference filtering and temperature adjustment and their and implementations encountered in the design. The design scheme proposed in this paper is small in size and low in cost, and as hardware integration in the chip, it can not only reduce the time of debugging and debugging, but also improve the cost performance of the product.

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