The engine temperature real-time monitoring instrument based on Microcontroller

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Abstract. temperature measurement instrument is based on thermocouple, with AT89C51 single chip as kernel. Dedicated chip max6675K for cold junction compensation of thermocouple is adopted to perform cold junction compensation to K-type thermocouple and to perform amplification, AD conversion and digital processing to input signal from T- and T+ end of K-type thermocouple. It is transmitted to single chip by passing through spi serial port. Convert into ROM address after operation processing of single chip. Practical temperature value will be calculated by twice table-finding method and relevant procedure will be called to transmit the temperature value to 4 common-anode LED nixie tube display or outrange alarm. Software of temperature instrument of this thermocouple is compiled with C language and modular construction design is adopted.

Introduction

Temperature is physical parameter reflecting cold and hot state of object and measurement to temperature is widely applied in many fields, such as metallurgical industry, chemical industry production, electric power engineering, machine manufacturing and food processing, national defense and scientific research etc. There is strict requirement to detection speed of temperature at some special occasions. For example, when temperature of suction air of automobile engine is measured, it is required that thermal response time should be less than 1s. It is required that temperature measurement of main engine of space shuttle should be finished within 0.4s and so on. Therefore someone puts forward the thought of rapid temperature measurement aimed at above problems.

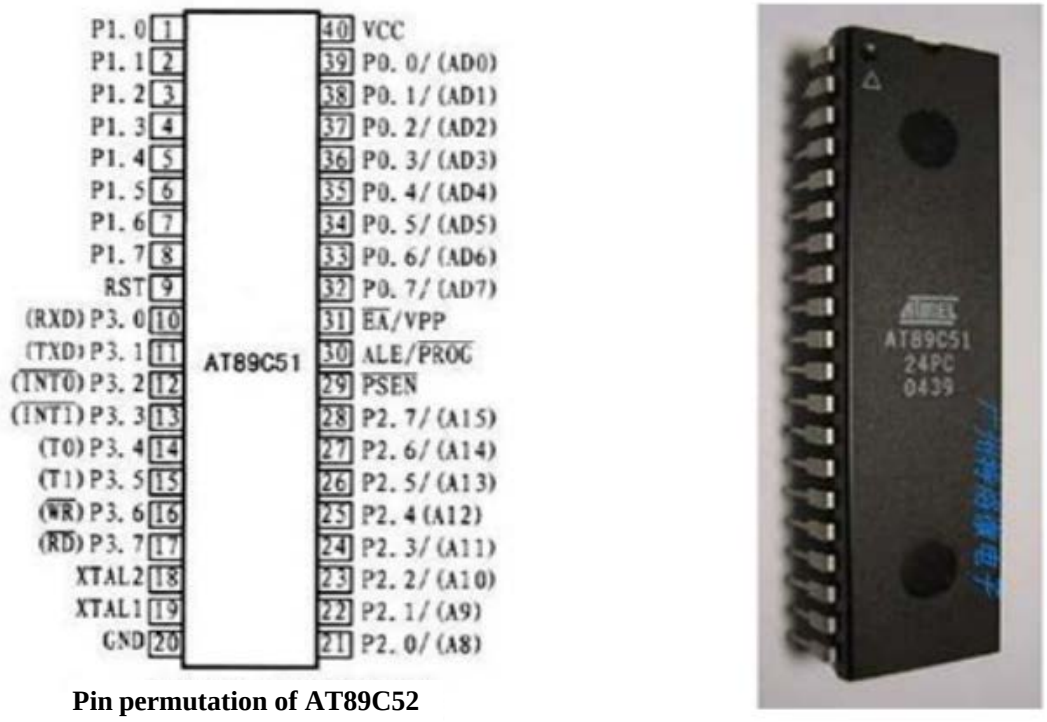
Sensors used for temperature measurement usually include thermal resistance temperature sensor, thermistor, thermocouple, semiconductor temperature sensor etc. Ordinary temperature measurement of these commonly-used temperature sensors can meet problem of response speed. Temperature sensor which is commonly used in industry with relatively high accuracy includes platinum thermistor, semiconductor temperature sensor etc. When platinum thermistor is used for temperature measurement, several seconds are required at least, so when temperature sensor is used, the problem that response to gas temperature changing is relatively slow usually exists. If common method is applied, it is difficult to measure features, such as large range, good repeatability and high accuracy etc., but response is not fast. Especially when rapid temperature measurement is performed to gas, there is great impact on accuracy of system.

System design

System hardware mainly includes thermocouple temperature collection circuit, MAX6675 temperature processing circuit, 89C51 singlechip control circuit, outrange alarm circuit and nixie tube display Nixie tube.

Thermocouple adopts thermocouple of which the graduated no. is K. It is directly connected to MAX6675 chip by twisted-pair to reduce interference of external signal. MAX6675 chip transmits data through SPI serial interface. 89C51 singlechip is adopted to control temperature conversion chip MAX6675 with cold junction compensation. The system design has feature of alarm. When temperature measured is lower than 0 degree centigrade or higher than 400 degree centigrade, alarm circuit will alarm. As for display circuit, 89C51 singlechip controls 4 common-anode nixie tube through latch. Nixie tube work needs to be controlled by relatively large electric current with PNP audion of which the type is 8550. When measured temperature is within prescribed limit, it can be rapidly displayed through nixie tube.

MCU is control core of entire system. Because of convenience of port of temperature measurement system, AT89C51 type singlechip produced by American ATMEL Company is chosen after entire system is considered comprehensively. The instrument is manufactured by adopting ATMEL high density nonvolatile store manufacturing technology, being compatible with MCS-51 instruction set and output pins of industrial standard. Because multifunction 8-bit CPU and flash memory are integrated within single chip, AT89C51 of ATMEL is a kind of microcontroller with high efficiency. Its appearance pin is as shown in Fig. 1:



Pin permutation of AT89C52

Fig.1 Appearance Pin Figure of AT89C51

AT89C51 provides following criterion functions[12]: flash memory of 4k byte, repeated erasure of 100 times, interior RAM of 128 byte, four 8-bit parallel I/O ports, two 16-bit timing/counter, one 5-vector two-stage interrupt structure, one full duplex serial communication port, inside oscillator and clock circuit. At the same time, AT89C51 can be reduced to static state

logic operation of 0hz and supports power-saving work pattern and idle mode optional to two kinds of software to stop CPU work, but it allows RAM, timer/counter, serial communication port and interrupt system to work sequentially. Save content in RAM by the way of power down, but oscillator stops working and work of all other components is forbidden until next hardware is restored.

AT89C51 has 4 bidirectional 8-bit parallel I/O ports, respectively are P0~P3. There are total 32 port lines. Each bit of port consists of latch, output driver and input buffer. Port registers of P0~P3 belong to special function register series. As for four ports, address can be located by byte as well as by bit, of which P0 port is drain open circuit, when it is used as output, pull-up resistor should be added. P3 port can be used as ordinary I/O port and it can also be used as specific function pin. Although there is only one serial port interface at 51 singlechip, but as for its I/O port, address can be located by byte as well as by bit. In practical application, we can realize transmission of every kind of data by simulating time-order character of different buses.

At inside of AT89C51 singlechip, there is a serial communication port of full duplex with powerful function. Its serial port has four kinds of working modes which respectively are synchronous communication mode, 8-bit asynchronous reception and transmission, 9-bit asynchronous reception and transmission (specific baud rate), 9-bit asynchronous reception and transmission (timer-control baud rate). It has two reception and transmission buffers which are independent in physics, and they can transmit and receive data simultaneously. Baud rate can be controlled by timer in software setting chip. When serial port finishes reception and transmission of 1B, they can send interrupt request.

As for control circuit in this paper, AT89C51 is chosen to control peripheral circuit. Its interface circuit is as shown in Fig.2. Because AT89C51 does not have SPI Bus Interface, interface to MAX6675 is realized by adopting method of simulating SPI bus in the design, of which P1.0 simulates data input end of SPI and is connected to SO, P1.1 simulates serial clock signal of SPI and is connected to SCK, and P1.2 simulates slave selection end of SPI and is connected to CS. Mainframe of circuit is AT89C51 and slave is MAX6675. P2.0 of singlechip is used to control outrange alarm of system. P2.4, P2.5, P2.6, and P2.7 and P0 port of singlechip control bit code and segment code of nixie tube through corresponding circuit. System transmits serial clock to MAX6675 through P1.1 of AT89C51. P1.0 is used to receive serial temperature data outputted by MAX6675. Low level outputted by P1.2 performs zero setting to that of MAX6675 for gate of work of MAX6675. The system is equipped with 4-bit nixie tube display. Decimal point is set at the rear of tens. Measurable temperature is 0~400℃ and resolution ratio is 0.25℃.

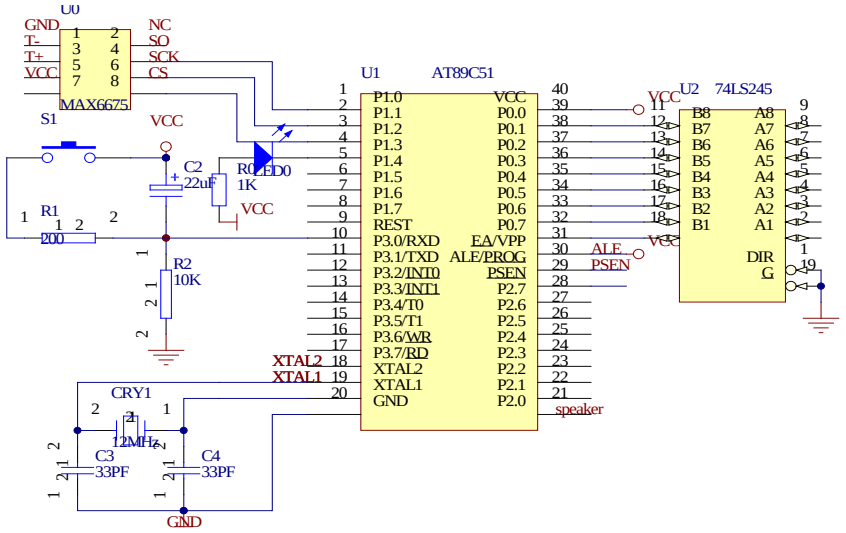


Fig.2 Control Circuit of Singlechip

Modules of temperature collection circuit include K-type thermocouple and circuit module consisting of max6675. Its schematic diagram of circuit is as shown in Fig.3. Function of thermocouple is to detect difference value of hot and cold junctions. Thermal node temperature of thermocouple changes in the range of 0℃～+l023.75℃. Cold junction is ambient temperature of circuit board where MAX6675 is installed and the temperature changes in the range of -20℃～+85℃. When there is temperature fluctuation at cold junction, MAX6675 can still accurately detect changing at hot junction. MAX6675 detects and adjusts ambient temperature variation by cold junction compensation. Interior circuit of this instrument sends diode voltage and thermocouple voltage to ADC to converse to calculate hot junction temperature of thermocouple. When cold junction of thermocouple is equal to temperature of chip, MAX6675 can gain the best measurement accuracy. Therefore in practical temperature measurement, heating instrument or element should be away from MAX6675, because it will cause cold junction error.

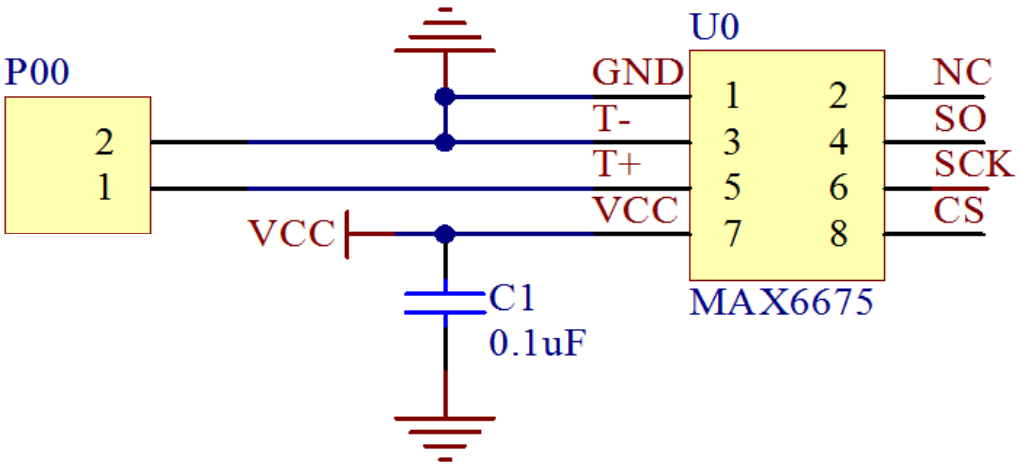


Fig.3 Schematic Diagram of Temperature Collection Switching Circuit

Conclusion

Relevant design is performed in this paper by adopting K-type thermocouple, dedicated digital conversion chip MAX6675 of K-type thermocouple and AT89C51 singlechip. MAX6675 integrates complicated linearization, cold junction compensation and digitization output etc. problems to one chip to solve about temperature measurement application of thermocouple, which simplifies complicated software and hardware design when temperature measurement scheme of thermocouple is applied to embedded system field. Therefore this instrument is ideal choice when temperature measurement scheme of thermocouple is applied to embedded system field. According to theory of fast algorithm and with software programming of AT89C51 singlechip, rapid temperature measurement is realized.

Reference

[1] Ying Liang, Wei Wu.(2014). Exploratory analysis of health-related quality of life among the empty-nest elderly in rural China: An empirical study in three economically developed cities in eastern China, Health and Quality of Life Outcomes, 12:59,1-16.

[2] Yang J, Lin Y, Gao Z, et al. Quality Index for Stereoscopic Images by Separately Evaluating Adding and Subtracting[J]. PloS one, 2015, 10(12): e0145800.

[3] Jiang D, Xu Z, Lv Z. A multicast delivery approach with minimum energy consumption for wireless multi-hop networks[J]. Telecommunication Systems, 2015: 1-12.

[4] Ying Liang, Peiyi Lu. (2014). Effect of occupational mobility and health status on life satisfaction of Chinese residents of different occupations: logistic diagonal mobility models analysis of cross-sectional data on eight Chinese provinces, International Journal for Equity in Health, 13:15, 1-14.