Smart Resistance Thermometer Sensor Based on C8051F350

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Abstract **— A Smart resistance thermometer sensor is designed to overcome the shortages of the traditional ones, and Con-form to the world development trend of the sensor market. According to the constitutions of this Smart sensor and its application coverage, those parts with good -application and low-cost were chosen to constitute this sensor on the basis of full consideration of the linkage among every part. The whole testing system were controlled and processed by C8051F350 single-chip, it could measure precise temperature by PT100 resistance thermometer and circumstance temperature for temperature compensating automatically and simultane-ously, it also could amplify signals to convert analog signals to digital ones, and display results automatically by analysing and processing information. Furthermore, it could auto-compensate self-check, and spot communicate.**

Keywords—C8051F350 single-chip; PT100 resistance thermometer; Regulators source; Communication interface.

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1 Introduction

Temperature is one of important parameters in common industrial production process. Physical change and chemical reactions in the automatic production process are closely related to temperature. Therefore, the accuracy of the temperature measu-rement has a direct impact on product quality and efficiency. With the development electronic techno-logy, temperature sensors used for the temperature measurement in the the international market are rapidly developing from analog type to digital type, integration to inteligence. Properties, such as small size, low power, high reliability of temperature needed are obtained from experiment data in the laboratory.

2 Hardware design

The system is controlled by C8051F350 single-chip. Analog signal collected by PT100 resistance thermometer sensor is disposed by signal conditioning circuit and then converted to matching binary number, which is deposited in ADC registers after suppress noise interference by signal magnified and sampling. The DS1820 is used to measure the ambient temperature for the temperature compensation. The system communicates with the sensors are more and more attracting attentions. In this article, We use the PT100 resistance thermometer, a C8051F350 single-chip, and some peripheral circuits build a precise temperature acquisition system, To achieve highly-precise temperature acquisition with some low-cost chip and components. The system has some simple peripheral circuits, and hardware maintenance and software upgrade is easily realized.

3 System composition

Smart resistance thermometer sensor system is shown in Fig.1.

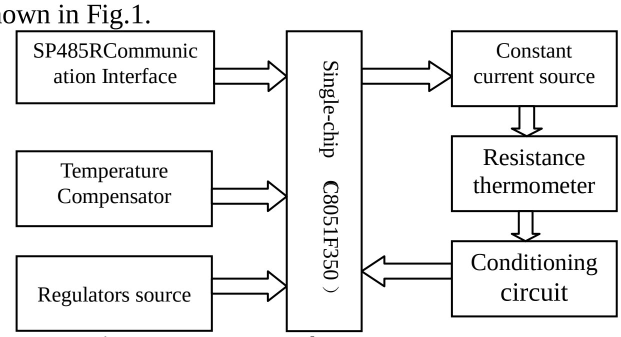

Fig. 1 Smart resistance thermometer sensor

An external circuit design achieves providing a stable power supply voltage for the single-chip. And then a constant current signal provided by single-chip’s IDA sends to PT100 resistance thermometer sensor as a power incentive. The analog signal responsing change of PT100 resistance value is sended to the C8051F350 single-chip which can process informations, such as magnify, alignment. Meanwhile, Real time localed temperature collections through by DS1820 are used for temperature compensated rectify, while single-chip communicates with the host computer through the RS485 interface. A variety of data required by temperature compensation algorithm

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host computer after information analysis and processing through the RS485 interface. -Smart pressure sensor circuit schematic diagram is shown as Fig. 2.

3.1 Choice of single-chip control

The system uses C8051F350 single chip control. It has the following characteristics:

- The C8051F350 include a fully differential, 24 bits Sigma Delta Analog to Digital Converter (ADC) with on-chip calibration capabilities. A Programmable Gain Amplifier (PGA) is included, with eight gain settings up to 128. An internal 2.5 V reference is available. Two independent decimation filter can be programmed to a sampling rate of 1KHZ.
- Apipelined architecture and high speed CIP-51 microcontroller core, it has a peak throughput of 50 MIPS.
- Precision programmable 24.5 MHz internal oscillator.
- The use of lock-in amplifier: Modulator will be used to make DC signals or slow-varying spectrum frequency modulation moved to further enlarge to avoid the impact of noise.
- Two 8-bit Current Output DACs; 8 kB of on-chip Flash memory, 768 bytes of on-chip RAM; Four general-purpose 16-bit timers; On-chip power-on reset, VDD monitor, and temperature sensor; In the system, full-speed, non-intrusive debug interface (on-chip).
- Cross-sensitivity of the coupling.

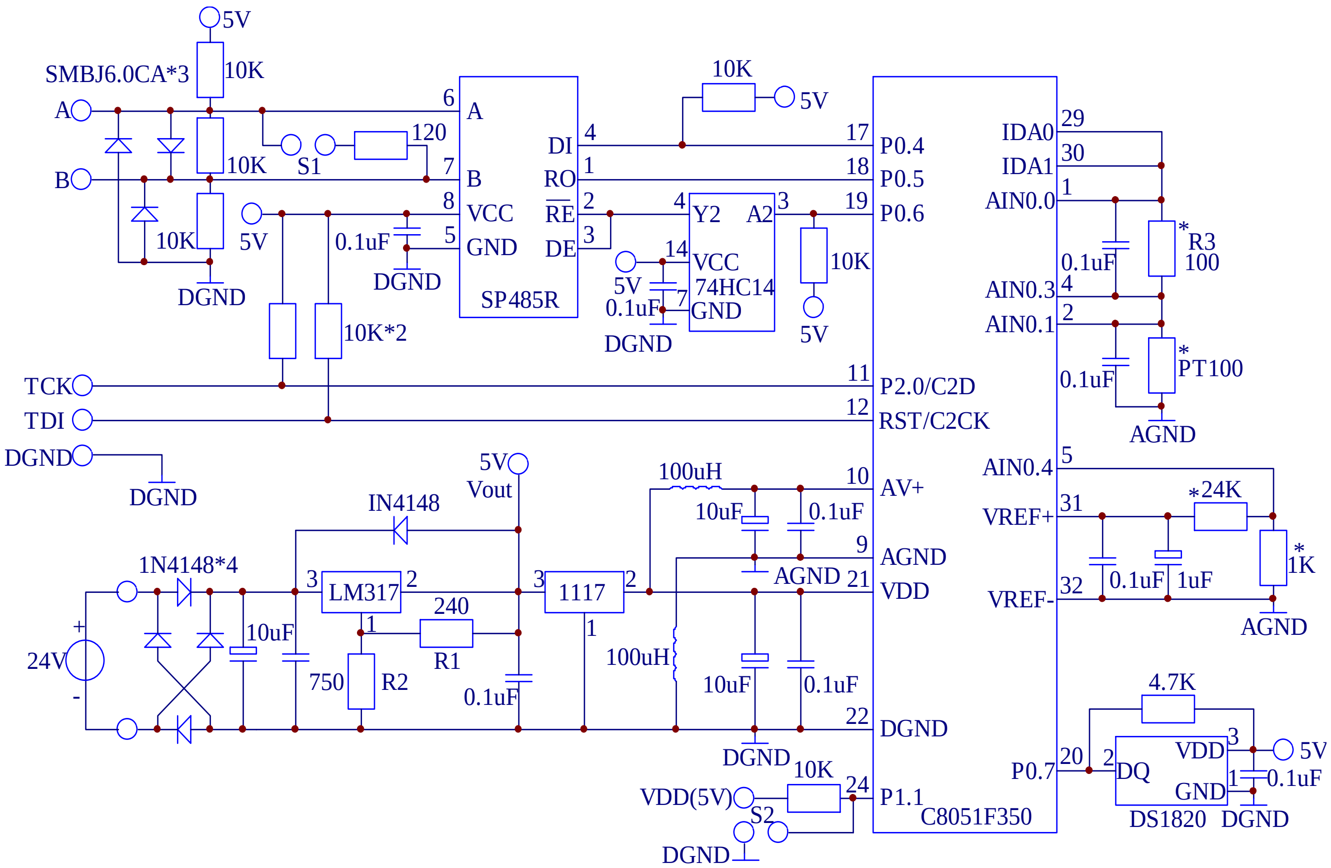

Fig. 2 Smart pressure sensor

3.2 Design of voltage regulator

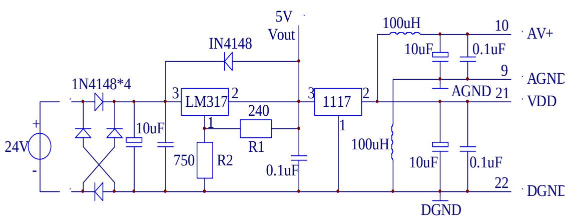

Fig. 3 Smart pressure sensor's voltage regulator

As shown as Fig.3, the circuit provides stable voltage power. Four diodes neering by 24v are used to avoid error voltage source connection. LM317 is a 3-terminal positive voltage regulator, one pin is voltage input(positive voltage), one is voltage output (load), and the last one is adjust(an adjustable resistor for the size of output). Input and output pin-to-ground need filter capacitor to be taken.The output voltage:

$$V_{out} = 1.25(1 + R_2 / R_1) \quad (1)$$

AMS1117 is a 3-terminal voltage output regulator which supplies stabe voltage power as 3.3V for C8051F350 MCU VDD pin to promise its normal operation. The role of indu-ctances is useing to prevent high frequency of the digital circuits to interfere analog circuits. In addition, the capacitor next to the power is used for input rectifier.

3.3 Choice of resistance thermometer sensor

- Platinum (Pt) resistance value varies when temperature varies with good reproducibility and stability, The sensor using physical properties of platinum is called of platinum resistance temperature sensor. PT100 resistance temperature sensor is a commonly one whose zero resistance is 100Ω and resistance change rate is 0.3851 Ω / ℃. PT100 resistance temperature sensor which is most commonly used as a temperature detector in the range of the low temperature (-200 ~ 650 ℃) has high precision, good stability and wide temperature range applications. PT100 sensor's temperature / resistance character is shown as the following equation.
- -200<t<0℃
- $$R_t = R_0[1 + At + Bt^2 + C(t-100)t^3] \tag{2}$$
- 0<t<650℃

$$R_t = R_0(1 + At + Bt^2) \tag{3}$$

- R_t : resistance value at t℃
- R_0 : resistance value at 0℃

3.4 Communication Interface and protocol

- The system achieves single-chip communicating with the host computer through SP485R communication interface[3]. SP485R are pin-to-pin equivalent with our existing SP485 product and contain enhancements such as higher ESD tolerance and high receiver input impedance. Allows over 400 transceivers on a transmission line; Half-duplex config-uration consistant with industry standard pinout;–7V to +12V common mode inputvoltage range; Low power consu-mption(250mW); Separate driver and receiver enable. 74HC14 is an inverter outputing the TTL electric level. Two resistors named R3 and R4 are used as pull-up ones. The deisign of SP485R communication interface is shown as Fig.4.

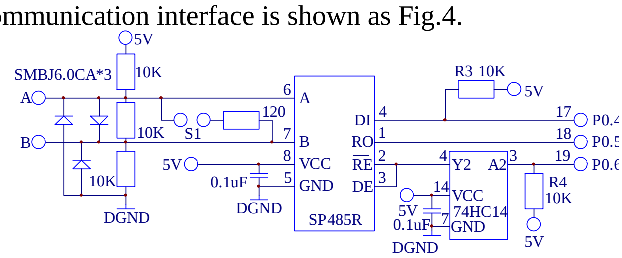

Fig. 4 Communication Interface

- Data communication uses modbus communication protocol which is the main one completing communication from the master station to slave one by UARTS. Physical layer uses RS485 or RS232. Transfer rate can be up to 115kbps and be accessed (addressing) a master station and up to 247 slaves in theory. There are two serial modbus transfer modes, ASCII and RTU. Users should select the same communication mode and serial port communication parameters (Baud rate, parity, etc.) for the all devices on the modbus bus. This design uses RTU communication mode. The format of each byte is shown as Table 1.

Tab.1 RTU mode features

Coding system		Hex
Number of bits per character	Start bit	One
	Data bit	Eight
	Parity bit	Zero or one
	Stop bit	One or two
Checksum		CRC

3.5 Temperature Compensator

- In the measurement process, the ambient temperature and the system's temperature changes will affect resistance thermometer sensor system measurement accuracy, the DS18B20 meet this requirement that sensor system needing temperature compensation to make the system measurement more accurate. The formula reflects changes in resistance with temperature:

$$R_t = R_0[1 + \alpha(t - t_0)] \tag{4}$$

- R_t , R_0 : resistance value at t℃, 0℃
- α : temperature coefficient of resistance (1/℃)
- t : temperature (℃)

4 Software design

- The software design of the system is used to promise data collected to be more accurate. Through software programming, the system can have nonlinear automatic correction function to eliminate the nonlinear error of the sensor to improve accuracy. Moreover, the software program can automatic zero and calibration to eliminate zero drift and sensitivity drift because of outside interference (such as ambient temperature) in real-time. The software procedure composed of PT100 resistance thermometer value calculation and temperature compensation procedure. The flowchart of procedure is shown as Fig.5.

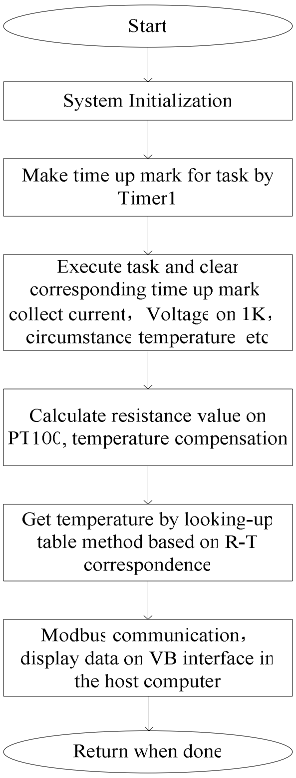

Fig. 5 Flowchart of procedure

- The system improves the accuracy of temperature though by increasing the measurement accuracy of PT100 resistance vlaue. However, because of hardware, there are some error between the resistance value of PT100 measured by micro-controller and the actual value, which requires us to collect a significant amount of laboratory data to polyfit between them. Through the operation, we can make the data curve getted by measurement to be closer to the actual resistance curve so as to improve accuracy of the measurement. Ten groups of the actual resistances and the measured ones are shown as table 2.

Tab.2 The comparison between actual resistances and measured ones

actual resistance	100.8	121.34	151.5	176.95	195.24
measured resistance	100.08	120.56	150.77	176.34	194.72
actual resistance	219.86	236.86	267.96	300.56	315.6
measured resistance	219.16	236.2	267.35	300.19	314.72

- Though by the Matlab 6.5, we can get the ployfit formula:

$$R_{PT} = 0.101091e^{-4}R_m{}^2 + 0.995393R_m + 1.134648 \quad (5)$$

- R_{PT} : The actual PT100 resistance vlaue.
- R_m : The PT100 resistance vlaue measured.
- After temperature compensation by least square method for PT100 resistance vlaue, we can get a highly precise temperature.

5 Conclusion

- The advantages of Smart PT100 resistance thermometer sensor system are low cost, small size, high accuracy, high reliability and simple use and convenient, etc. It can achieve temperature measurement self-tuning through by software programming in different temperature environments. And getting precise resistance value though by polynomial fitting method and calculating temperature compensation factor by least square method can get highly precise temperature. We can ensure that the accuracy is less than five thousandths by large amounts of laboratory data. This system uses modbus communication protocol to achieve single-chip communica-ting with the host computer through by SP485R communication interface, which helps form a wider scope and more sophisticated sensor control system, it has a very good market prospects.

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