Design of High Precision Temperature Measurement System based on Labview

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***Abstract*—Using the LabVIEW software platform, a high precision temperature measuring device is designed based on the principle of the thermocouple. The system uses the STM32 MCU as the main control chip, using AD7076 analog digital converter. The converter has 8 channel, synchronous sampling, and bipolar input. Improving the precision of temperature measurement by cold end compensation, fitting and other measures. The test results show that, the device temperature measurement precision can reach ±0.1 ℃, has the advantages of small size, high precision, and reliable performance, this high precision temperature measurement can be widely used in industrial production.**

***Keywords*—LabVIEW; AD7076; thermocouple; cold end temperature compensation; Temperature measurement**

I. Introduction

In the industrial production process, temperature is one of the important parameters to measure and control. The conventional temperature measurement method is influenced by the external factors such as emissivity, distance, dust and water vapor,also the measurement error is large. The thermocouple is widely used in the temperature measurement; it has the advantages of simple structure, convenient manufacture, wide measuring range, high precision, small inertia and output signals for transmission and many other advantages. In addition, the thermocouple is a kind of active sensor measurement, and it is not required external power supply and very easy to use, so it is often used to measure the surface temperature of solid and liquid or gas stove. The thermocouple can be used to measure -200 to 1600 ℃ temperature range, and even some thermocouple can measure temperatures above 2000℃.So the thermocouple is one of the most widely used temperature sensor. The temperature measured by thermocouple compensation is a traditional method, effective, the majority of technical staff has accumulated rich experience in the actual measurement.

Virtual instrument measurement technology is becoming more and more important in the field of measurement and control. Virtual instrument can make full use of computer, storage, display and other intelligent functions, through the software, fitting or interpolation correction to solve the cold side and nonlinear compensation. So it is a new topic in the field of temperature measurement that how to combine the thermocouple temperature measurement with the LabVIEW virtual instrument technology. In this paper, the National Instrument Corporation (NI) LabVIEW virtual instrument development platform for thermocouple temperature measurement system with high accuracy and greater application value.

II. The Measurement Principle and System Composition

A. The Principle of Temperature Measurement

The temperature measuring system based on thermocouple middle temperature law is the theoretical basis. In the thermocouple cold end potential relationship, the following formula:

$$E_{AB}(t,t_0) = E_{AB}(t,t_1) + E_{AB}(t_1,t_0) \tag{1}$$

In the formula, the measured temperature is t , the reference temperature is t_0 , the cold end temperature is t_1. In order to facilitate the calculation of the thermocouple indexing table inquiries, we take t_0 as the reference temperature is above 0℃, the formula can be simplified to:

$$E_{AB}(t,0) = E_{AB}(t,t_1) + E_{AB}(t_1,0) \tag{2}$$

When the cold end temperature $E_{AB}(t,0)$ is 0 ℃ , thermocouple output. When the cold end temperature $E_{AB}(t,t_1)$ is t_1 ℃, thermocouple output. $E_{AB}(t_1,0)$ is the cold end compensation potential. In the formula, $E_{AB}(t,t_1)$ can be directly detected from the thermocouple output. When we get the cold end temperature t_1 , $E_{AB}(t_1,0)$ can be

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calculated by dividing table, thus $E_{AB}(t,0)$ can be calculated. After completing the cold end voltage compensation, measured temperature can be converted by indexing table.

B. Automatic Temperature Measuring System

The structure of the system mainly includes temperature measurement, signal conditioning, data acquisition and AD conversion and PC platform. Among them, the system adopts K type thermocouple to complete temperature measurement, data acquisition and AD conversion using AD7606-F4, MCU control device is used in the design of STMicroelectronics STM32F106VET6, it is a 32 bit microprocessor ARM based on Cortex-M3 kernel.

The structure of component temperature measurement system diagram as shown in figure 1.

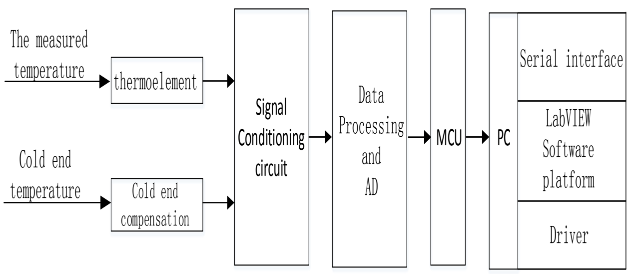

Fig. 1. Structure temperature measurement system

1) Temperature Sensor Selection

The thermocouple as the temperature sensor, which has the advantages of simple structure, easy manufacture, convenient use, high accuracy, in situ measurement and remote measurement, temperature measurement has been widely used in industrial measurement and control system, therefore, this design uses K type thermocouple as temperature measuring element. At the same time, the system uses the Pt100 sensor as the cold end compensating element.

2) The AD Module and Signal Conditioning

Thermocouple sensor signal input differential signal conditioning module, through the amplifier input AD7606, as shown in figure 2.

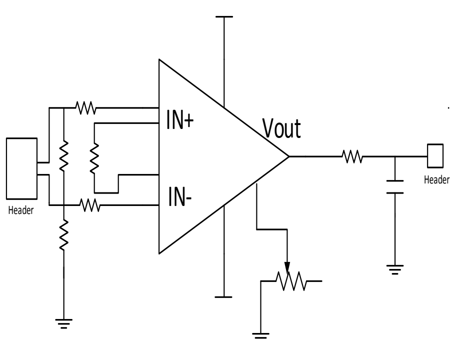

Fig. 2. Signal amplifying circuit

AD7606 synchronous sampling analog-to-digital data acquisition system 16 (DAS), it has respectively 8, 6, 4 acquisition channels. It has on-chip analog input clamp protection, two anti-aliasing filters, track and hold amplifier, 16 bit charge redistribution successive approximation ADC kernel, digital filter, 2.5V reference voltage source and buffer, high speed serial and parallel interface.

In the internal signal conditioning circuit in AD7606, it already contains a low noise, high input impedance signal conditioning circuit, the equivalent input impedance is completely independent of the sampling rate and fixed 1Mohm. At the same time the input terminal integrated with 40dB anti-aliasing filter stack suppression is simplified, the previous design, no longer need the external drive and filter circuit. Therefore, the two signal transformer output can be directly connected to the AD7606, as shown in figure 3.

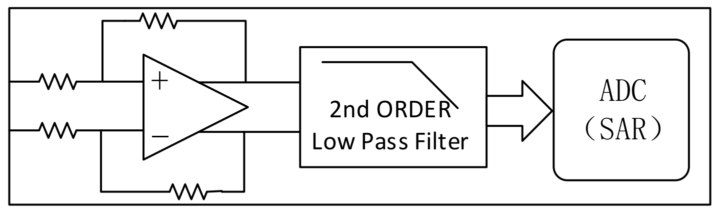

Fig. 3. AD7606 structure design

III. THE SOFTWARE OPERATION PLATFORM SYSTEM

The system of virtual instrument technology is based on LabVIEW software. The communication between the PC and the hardware is realized through the serial port. It is the core of software design personalized through the shortcut of the LabVIEW language to achieve the collection, analysis, computing, display and storage. To be able to adapt to the specific requirements of different users, and can continuously adjust the program according to the change of environment or hardware, improvement and optimization of test system, to meet the user's requirements. The use of the software interface as shown in figure 4.

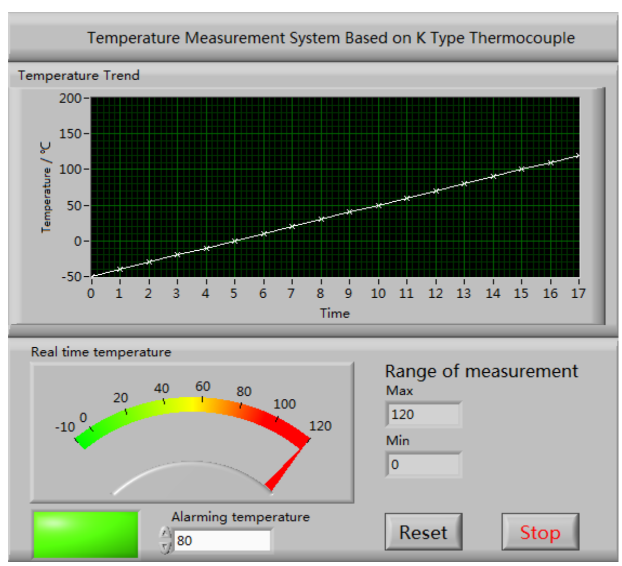

Fig. 4. Program interface

The key issue is the difficulty lies in the design of a full-featured, easy to use, stable performance and friendly interface of the thermocouple temperature testing system. Conversion of voltage signal to the hardware through the verification, determine the voltage is beyond the optimum range, this is because the voltage table temperature is within a certain range, if beyond this range, the accuracy of the thermocouple will not be guaranteed, the measurement is meaningless.

Because of the change of potential temperature K type thermocouple is nonlinear, and the nonlinear lead resistance and other factors, led to the thermocouple output values are deviation from the actual temperature value. Therefore, in order to improve the measurement precision, the data were piecewise linear processing, so as to realize the nonlinear error of the thermocouple calibration. In the temperature range of -100 ℃ ~600 ℃ ~-20 ℃ , divided into -100 -20 ℃ ~0 ℃, 0 ℃ ~300 ℃, 300 ℃ ~600 ℃ by piecewise linear fitting, temperature and thermoelectric potential relationship model, the script and the formula module provided by NI, for the preparation of the formula node module, as shown in figure 5.

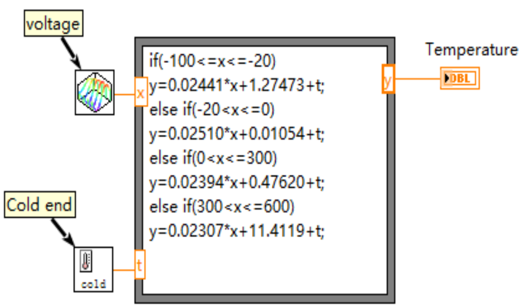

Fig. 5. Relationship between temperature and thermo emf

IV. Test Results and Analysis

TABLE I. Result and Error of Thermocouple Temperature Measurement

The output voltage value (mV)	**The thermostatic bath temperature (℃)**	**Fitting temperature conversion (℃)**	**Measurement error (℃)**
-2.909	-50	-49.937	0.063
-1.036	0	0.015	0.015
0.984	50	50.047	0.047
3.071	100	99.981	-0.019
5.159	150	150.036	0.036
7.248	200	199.926	-0.074
9.337	250	249.944	-0.056
11.423	300	299.953	-0.047
13.509	350	350.083	0.083
15.67	400	399.937	-0.063
17.842	450	450.049	0.049
20.011	500	500.072	0.072

a. The thermostatic bath temperature and analysis

When the cold and hot end voltage data acquisition, floating due to electromagnetic interference or zero drift will cause the voltage, thus showing the temperature values constantly beating, which will lead to a decline in the accuracy of measurement, therefore, paper collected 100 voltage value in 0.1s time, through software programming to solve it the arithmetic mean of the mean, as the sampling results, then the subsequent calculation. This effectively inhibited the beat voltage value, and the accuracy of the measurement results have been better guarantee.

The thermocouple temperature sensor placed in the thermostat, set the temperature of -50 ℃ and the initial test, the thermostat changes with every 50 ℃, the temperature stability, began testing. Experiment results and error as shown in table 1. The results show that the temperature measurement of the temperature measuring device, the absolute error is less than 0.1 ℃, high precision. Have a good practical value in need of high precision temperature measurement.

V. Conclusion

This paper describes the design of a high precision temperature measuring device based on K type thermocouple. Compared with the traditional temperature measuring methods, the device has the advantages of simple circuit structure, high accuracy, good stability. The device can meet the temperature test in the hot test process needs, also has a good prospect in high pressure, high impact and other harsh environments.

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