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MICROPROCESSOR MEASURER WITH THERMORESISTIVE SENSOR

B. Mamikonyan, Kh. Mamikonyan

Gyumri Branch of State Engineering University of Armenia, M. Mkrtchyan st., 2,
Gyumri, 377503, Republic of Armenia. Tel: (37441) 3-68-32, fax: (37441) 3-15-28.
E-mail of authors: bomam@yandex.ru
mamikonyan@yandex.ru

Abstract

MICROPROCESSOR MEASURER WITH THERMORESISTIVE SENSOR

B. M. Mamikonyan, Kh. B. Mamikonyan

In paper it is described the microprocessor measurer of resistance increase of thermoresistive sensors (S), where the method of errors digital compensation (EDC) is applied, which have either linear and non-linear character. The measurer is assigned for technological process temperature measuring with application of platinum thermoresistor of Pt100 graduation. In main range from +30 to +50 ^{0}C the device provides the temperature measuring with error, not exceeding ± 0,1 ^{0}C.

Keywords: measuring, sensor, thermoresistor, signal, code, temperature, error.

Анотація

МІКРОПРОЦЕСОРНИЙ ВИМІРЮВАЧ З ТЕРМОРЕЗИСТИВНИМ СЕНСОРОМ

Б. М. Маміконян, Х. Б. Маміконян

У статті описаний мікропроцесорний вимірювач збільшення опору терморезистивних сенсорів, у якому використовується метод цифрової компенсації похибок, що мають як лінійний, так і нелінійний характер. Вимірювач призначений для виміру температури технологічного процесу з застосуванням платинового терморезистора градуювання Pt100. В основному діапазоні від +30 до +50 ^{o}C прилад забезпечує вимір температури з похибкою, що не перевищує ± 0,1 ^{o}C.

Ключові слова: вимір, сенсор, терморезистор, сигнал, код, температура, похибка.

Аннотация

МИКРОПРОЦЕССОРНЫЙ ИЗМЕРИТЕЛЬ С ТЕРМОРЕЗИСТИВНЫМ СЕНСОРОМ

Б. М. Мамиконян, Х. Б. Мамиконян

В статье описан микропроцессорный измеритель приращения сопротивления терморезистивных сенсоров, в котором используется метод цифровой компенсации погрешностей, имеющих как линейный, так и нелинейный характер. Измеритель предназначен для измерения температуры технологического процесса с применением платинового терморезистора градуировки Pt100. В основном диапазоне от +30 до +50 °С прибор обеспечивает измерение температуры с погрешностью, не превышающей ± 0,1 °С.

Ключевые слова: измерение, сенсор, терморезистор, сигнал, код, температура, погрешность.

Measuring devices (MD), working with sensors, are one of the most important components of information-measuring systems and systems of automatization. They are called to receive from the sensors the output signals or the output parameters and to convert them into the signals, convenient for transmission by connection channels and further processing. The progress in sensors application technique for physical values measuring extensively depends on progress in these MD development. Therefore, the MD perfection on the base of modern electronic components, the raising of their accuracy, reliability, and error stability is the important and actual task.

In this paper it is described the microprocessor measurer of "SEUA-70" type, meant for technological process temperature measuring. As sensor it is used the industrial platinum thermoconverter of resistance (TC) of Pt100 graduation (resistor R_X in fig.1). As r_1, r_2, r_3, r_4 are lettered the resistance of TC connecting wires. The measuring circuit (MCi) contents also the power source (E, r), comparison resistor R_c, operational amplifier (OA) for opposed current creation.

In working conditions the real conversion characteristic of measuring device (MD) differs from the nominal because of errors availability. The lasts are appeared either as a result of external factors impact (environment temperature, noises, etc.), and unstability of MD parameters itself. In general case MCi and analog-digital converter (ADC) have linear conversion function, therefore the real output value of MD, considering the errors, can be presented as

$$A = K(1+\gamma_s)\Delta R_x + \Delta^o = K(1+\gamma_s)(R_x - R_c) + \Delta^o, \qquad (1)$$

where $K = I_0 K_A$ — nominal (graduated) value of conversion coefficient of MCi with ADC; K_A — conversion coefficient of ADC; $\gamma_s = \Delta K / K$ — the relative value of multiplicative error; Δ^o — absolute value of additive error.

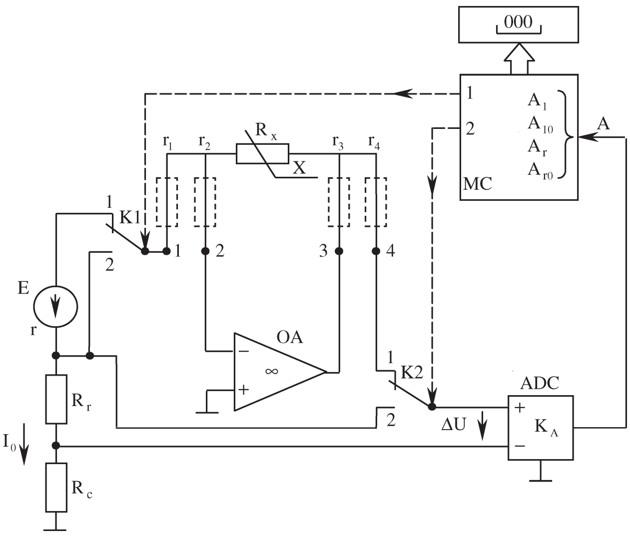

Fig.1. Flowchart of "SEUA-70" measurer

EDC method provides for separate measuring of resistance R_X and destabilizing factors [1]. With this aim in MD additionally are entered the programming microcontroller (MC), electronic switches K1 and K2 and resistor R_r for formation of reference signal. At the entry MC the coding values of measuring variables are coming, and on the exits 1 and 2 the signals for switches position control are emitted, depending on which on the exit of ADC the various digital codes are forming.

The measuring is conducted in four steps at different positions of switches.

1. Step 1: $K1=1$, $K2=1$ — in this position of switches the real value of MD signal is measured. Measuring result:

$$A_1 = K(1+\gamma_s)(R_x - R_c) + \Delta_1^o .$$

2. Step 2: $K1=1$, $K2=1$ — MCi supply is switched off: the additive component of error in signal A_1 is measured:

$$A_{10} = \Delta_1^o .$$

3. Step 3: $K1=1$, $K2=2$ — the output signal of MD is measured at the exit feeding instead of ΔR_x of known reference resistance $R_r \le \Delta R_{x\max}$. Measuring result:

$$A_r = K(1+\gamma_s)R_r + \Delta_r^0$$

where Δ_r^0 — additive component of error in signal A_r, which differs from Δ_1^o because of scheme MCi peculiarities, while coefficient $K(1+\gamma_s)$ value remains the same at steps 1 and 3.

4. Step 4: $K1=1$, $K2=2$ — MCi supply is switched off; the additive component of error in signal A_r is measured. Measured result:

$$A_{ro} = \Delta_r^o .$$

MC processes the signals and measuring parameter calculation according to algorithm

$$A_p = \frac{A_1 - A_{1o}}{A_r - A_{ro}} = \frac{R_x - R_c}{R_r}, \qquad (2)$$

in result of which the additive and multiplicative errors are excluded, and the measuring accuracy is determined only by accuracy and stability of resistors R_c and R_r resistance. Therefore, it is possible to conduct the comparison resistors R_c and R_r with more stability and thereby essentially to decrease the requirements to all other elements of device.

The variation of ADC conversion coefficient and frequency of MC clock generator do not affect on measuring exactness: it requires only from ADC the high linearity of conversion characteristics. The switches are beyond the bounds of formation of measuring and reference signals, owing to which their resistance in open and closed positions do not impact on measuring result. This important advantage of developed scematics allows creating of unified measurers of temperature with use of TC of other graduation and other values of R_0, owing to switching possibility of comparison and reference resistors chain.

Formula (2) presents, that there is an possibility to correct the initial scale mark by resistance adjustment R_c (adjustment of zero), and the final scale mark — by R_r (adjustment of sensibility).

The switches are fulfilled on 74HC4052AP chip, ADC is fulfilled on AD7705BN chip, which includes sigma-delta converter and two preliminary amplifiers with differential entries and changeable (by program) coefficients of amplification in the range of 1 to 128; ADC digit is 16 bit, non-linearity — 0,003%. ADC conversion time is chosen equal to 20 ms, measuring cycle is 1sec.

In measurer it is used programmable MC of AT89C51 type. Microcontroller parameters: digit — 8 bit, clock frequency — 12 MHz, capacity of program memory 4096 byte, capacity of operative memory 128 byte, command system MCS-51; MC work program is realized on ASSEMBLER language. For indication of temperature value the block of sevensegment indicators on LED of E20561-5-0-W type is used.

In concerned range of temperature the resistance of using platinum TC is connected to measured temperature t °C by interpolar equation [2]

$$R_x = R_0\left(1 + At + Bt^2\right), \qquad (3)$$

where $R_0 = 100$ Ohm — resistance value TC at $t = 0$ °C; constant coefficients A and B have values: $A = 3{,}9692 \cdot 10^{-3}\ ^oC^{-1}$; $B = -5{,}8290 \cdot 10^{-7}\ ^oC^{-2}$.

As conversion function (2) is linear, and the dependence R_x on measured temperature in accordance with equation (3) is non-linear, so the algorithm of numerical calculation MC foresees the calculation of measured temperature t by way of reverse formula conversion (3) with account of equation (2), resistances R_c, R_r, R_0 values and coefficients A, B. In result the necessity in scheme method of TC conversion characteristics linearization drops out, which at analog method of errors compensation requests the certain hardware costs and is realized with some residual error of non-linearity. The realized method of errors compensation allows to exclude the unstability impact of MCi supply current, to cut the requests to metrological characteristics of MD elements. Owing to acute reduction of additive errors it is supported the possibility to decrease the MCi supply current, which gives arise to overall size and supply unit mass decrease, to its operating regime easing. Owing to sensibility increase at the expense of additive errors decrease the range of measured temperature can be appreciably narrowed.

In experimental model of MD at value of measuring current $I_o = 5{,}1\ mA$ the output voltage $I_o = 5{,}1\ mA$ is variated on 2,0 mV at measured temperature variation on 1 °C, which is about 20 greater than thermocouple in analogical conditions. At this owing to EDC method application, TC turned out in pulse supply regime, and dispersed on it the mean power decrease by 4, amounted to 0,75 mW in total, at which the given error value of self-heating TC do not exceed 0,012% [3].

In the result of metrological research it is found, that in main range from +30° to +50 °C "SEUA-70" device provides the temperature measuring with error, not exceeding ± 0,1 °C. It can be used also for more extensive range of temperature measuring from +5 to +95 °C with error, not exceeding ± 0,2°C. Below the appearance of measurer is given (fig. 2).

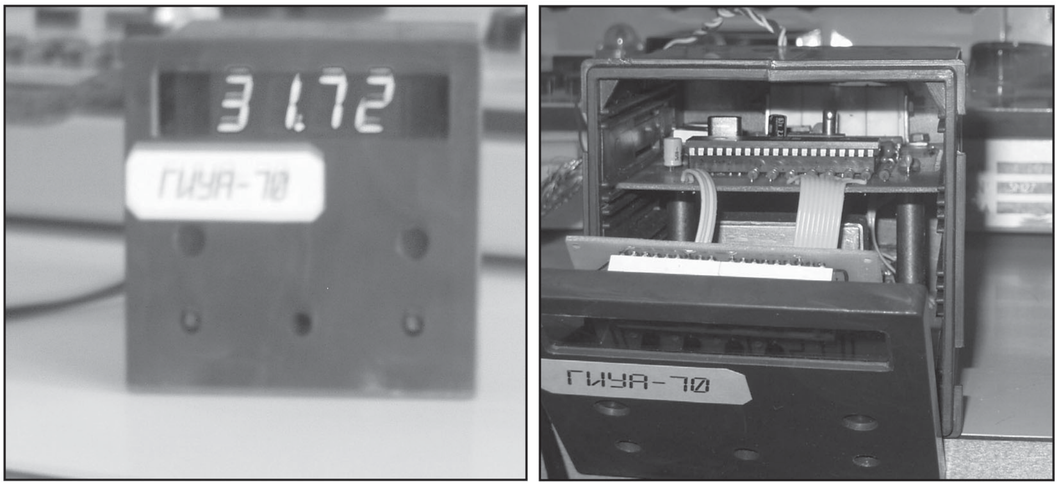

Fig.2. Appearance of "SEUA-70" measurer

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