THERMOPHYSICAL MEASUREMENTS

COPPER AND PLATINUM THERMAL RESISTANCE CONVERTERS FOR TEMPERATURE MEASUREMENTS TO 200°C

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UDC 536.531:621.317.3

Copper and platinum resistance thermal converters are compared by the criterion of minimum theoretically attainable error when they function as part of transducers with optimized parameters.

Resistive and thermoelectric converters are among the most widely used temperature-measuring instruments. Copper and platinum resistance thermal converters, (CRTCs) and (PRTCs), are used at temperatures up to 200°C, both for direct measurement of the temperature as part of measuring transducers and in compensators to compensate for the influence of variations of the temperature of the free ends (cold junctions) of thermal converters. Copper thermal converters are highly stable and reproducible characteristics, but unlike their platinum counterparts, the temperature dependence of their electrical resistance is nonlinear. The resistance measurements are always indirect and require an additional energy source; they measure the current or voltage, which depend functionally on the resistance (and, hence, on the temperature) of the thermal converter as well as on the design of the converter, in the given case either a measuring transducer or a compensator.

It is of interest, therefore, to compare the capabilities of CRTCs and PRTCs by the criterion of the minimum attainable error when they work as part of relatively simple, frequently used transducers and by an appropriate choice of circuit parameters ensure a nearly linear output characteristic or a curvilinear one with a positive first derivative, i.e., a characteristic that is close to the static conversion characteristics of thermal converters.

Schematic diagrams of the converters are shown in Fig. 1. The diagram of Fig. 1a was considered in [1-2], that of Fig. 1b in [2, 3], and that of c in [4, 5], but here we provide for standardization of the signal by the lower limit of measurement in the next stage, the adder, thus facilitating practical adjustment of the circuit. The load resistance of all the converters (the input resistance of the next amplifier adder stage) is assumed to be much higher than the output resistance of the converter and its influence can be ignored.

The dependence of the output voltage \( U(\theta) \) of the converter with the circuit a on the temperature of the thermal converter has the form

\[
U(\theta) = \frac{E}{1 + n} \left( W(\theta) - 1 \right) \left\{ \frac{1}{mW(\theta) + n} + \frac{n}{p(n + 1)} + \frac{1}{1 + n} \right\}^{-1};
\]  

that with circuit b,

\[
U(\theta) = E \left( W(\theta) - 1 \right) \left( W^2(\theta) + W(\theta) \left\{ \frac{1}{m} + 1 \right\} + \frac{n + \frac{1}{n}}{m + \frac{1}{n}} + 1 \right)^{-1};
\]

Translated from Izmeritel'naya Tekhnika, No. 4, pp. 30-32, April, 1997.

0543-1972/97/4004-0339$18.00  ©1997 Plenum Publishing Corporation
that with circuit c, 

\[ U(\theta) = \frac{E}{I} W(\theta) \left\{ 1 - W(\theta) \left[ \frac{K-1}{n} \right] \right\}^{-1}. \]  

(3)

where \( E \) is the stabilized supply voltage, \( K \) is the gain of the differential amplifier, \( W(\theta) \) are the standardization values of the ratios of the thermal converter resistance for any operating temperature and its resistance \( R_0 \) at 0°C, and \( k, l, m, n, p \) are constant coefficients.

The sum of the squares of the given values of the converter output voltages (given by a linear function or the static conversion characteristic of the thermal converter) and the values calculated from Eqs. (1)-(3) are taken to be the objective function. We thus have an optimization problem for minimization of that function, which can be solved on a computer using a nonlinear programming method [6, 7]. In the search for the optimum, the coefficients \( k, l, m, n, p \) are independent variables, with a limitation: they must be greater than zero. It is also understood that the current through the thermal converter is limited.