The use of unmatched thermistors for the measurement of temperature difference under varying ambient conditions

Thermistors are temperature dependent resistances obeying approximately the law

$$R = A\,e^{b/T} \tag{1}$$

where R is the resistance, T the absolute temperature and A and b constants varying from one thermistor to another.

One convenient application for two thermistors is to measure temperature difference independently of ambient temperature (as, for example, in the determination of the wet-bulb depression in hygrometry). Such a measurement presents two problems. First, due to the exponential relationship between resistance and temperature as expressed in equation (1), the change of resistance with respect to temperature dR/dT depends in magnitude on the absolute value of T and hence on the ambient temperature. Secondly, there is a wide variation in the constants A and b for thermistors of the same nominal type and hence each of the two thermistors would exhibit a different dependence of dR/dT on T.

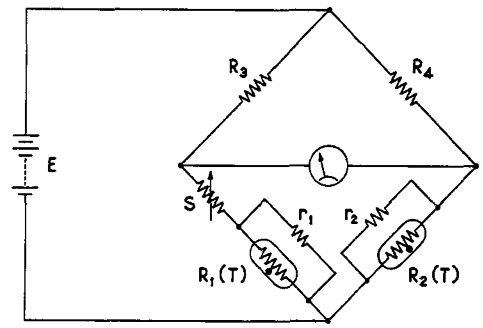
We have overcome these problems by using an electrical network in which any two thermistors of the same basic type may be employed. The resistance–temperature characteristics of each of the two thermistors is first linearized by connecting a non-temperature-sensitive resistance in parallel. Farhi and Groves (1961) recommend the shunt to have a resistance equal to that of the thermistor at the mid-point of the temperature range over which linearization is required. We have found that a more accurate linearization may be obtained using a different value for the shunt resistance. If the formula for the temperature dependence of the parallel combination of thermistor and resistance is expanded in a Taylor series and the term involving the second differential coefficient equated to zero, one obtains

$$r = R_T \frac{(b - 2T)}{(b + 2T)} \tag{2}$$

where r is the value of the shunt resistance, R_T the thermistor resistance at temperature T, and b the exponent in equation (1). A practical example of such a parallel combination exhibited a linear dependence on temperature with an error of 0·5% over a temperature range of 50 degc and of 0·05% over a range of 18 degc.

For comparison, when r was chosen to be equal to R_T in the middle of the temperature range, the error in linearization was about 2% for a 50 deg range and 0·3% for an 18 deg range.

In general, each of the two parallel combinations will have a different resistance and temperature sensitivity. To equalize the difference in resistance (at a given temperature) a resistance is connected in series with one of the parallel combinations. The different temperature sensitivities may be compensated for by passing constant currents through each, of values such that the same potential variation per unit of temperature change occurs across each of them. A constant current supply may be approximated in the usual way by a fairly high voltage supply with large series resistance. This can be achieved in a Wheatstone bridge configuration with a detector of high input impedance, as shown in the figure.



When this bridge is balanced with both thermistors at the same temperature it will remain balanced at any other temperature within the range of linearization provided the temperature of both thermistors remain equal.

The linearity of output of the bridge with respect to temperature difference depends on the ratio of the dropping resistors to the parallel combinations. This is best illustrated by an example. If thermistor R_2 is 2000 ohms at 25° c and $b = 3000$, then according to equation (2) $r_2 = 1433$ ohms. For this combination the change of resistance for a temperature change from 45° c to 5° c is 455 ohms. Thus, if the corresponding arm (R_4) in the bridge is made 45 500 ohms, the current through the parallel combination will only change by about 1% as its temperature changes from 45° c to 5° c. Hence, the potential drop across the parallel combination will be proportional to its resistance within an error of 1% and the output of the bridge linear to about 1%.

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Note added in proof: Since submission of this Letter to the Editor our attention has been drawn to a note appearing in the May issue of this *Journal* by Godin (1962), in which the problem of matching thermistors for the measurement of temperature differences is discussed. This note and the present one represent two different solutions of the same problem.

Farhi, S., and Groves, S., 1961, *Trans Amer. Inst. Elect. Engrs, Comm. Elect., No.* 55, 246.
Godin, M. C., 1962, *J. Sci. Instrum.*, **39**, 241