Calibration of a nominal 10 kOhm standard resistor

The resistance of a four terminal standard resistor is determined by direct substitution using a long scale digital multimeter (7½digit DMM) on its resistance range, and a calibrated four terminal standard resistor of the same nominal value as the item to be calibrated as reference standard. The resistors are immersed in a well stirred oil bath operating at a temperature of 23 °C monitored by a centrally placed mercury-in-glass thermometer.

The resistors are allowed to stabilise before the measurement. The four terminal connectors of each resistor are connected in turn to the terminals of the DMM. It is determined that the measuring current on the 10 kOhm range of the DMM of 100 µA is sufficiently low not to cause any appreciable self-heating of the resistors. The measuring procedure used also ensures that the effects of external leakage resistances on the result of measurement can be considered to be insignificant.

Model Equation:

$$R_X = (R_S + \delta R_D + \delta R_{TS}) \times r_C \times r - \delta R_{TX}$$

List of Quantities:

Quantity	Unit	Definition
R_X	Ω	resistance of the unknown resistor
R_S	Ω	resistance of the reference
δR_D	Ω	change of the resistance of the reference since its last calibration due to drift
δR_{TS}	Ω	temperature related resistance deviation of the reference
r_C		correction factor for parasitic voltages and instrument resolution
r		$=R_{iX}/R_{iS}$ ratio of the indicated resistance for the unknown resistor and the reference resistor
δR_{TX}	Ω	temperature-related resistance deviation of the unknown resistor

R_S:
Type B normal distribution
Value: 10000.053 Ω
Expanded Uncertainty: $5 \cdot 10^{-3}$ Ω
Coverage Factor: 2

REFERENCE STANDARD: The calibration certificate for the reference standard gives a resistance value of 10000,053 Ohm ±5 mΩ (coverage factor k = 2) at the specified reference temperature of 23 °C.

δR_D:
Type B rectangular distribution
Value: $+20 \cdot 10^{-3}$ Ω
Halfwidth of Limits: $10 \cdot 10^{-3}$ Ω

DRIFT OF THE STANDARD: The drift of the resistance of the reference resistor since its last calibration is estimated from its calibration history to be +20 mΩ with deviations within ±10 mΩ.

δR_{TS}:
Type B rectangular distribution
Value: 0 Ω
Halfwidth of Limits: $2.75 \cdot 10^{-3}$ Ω

TEMPERATURE CORRECTION: The temperature of the oil bath is monitored with a calibrated thermometer to be 23.00 °C. Deviations from this value have been estimated to be within ±0.055 K, including temperature gradients in the oil bath. Thus the known value $5.0 \cdot 10^{-6}$ K^{-1} of the temperature coefficient (TC) of the reference resitor gives limits ±2,75 mΩ for the deviation from its resistance value according to calibration, due to a possible deviation from the operating temperature.

r_C: Type B triangular distribution
Value: 1.0
Halfwidth of Limits: $1.0 \cdot 10^{-6}$

RESISTANCE MEASUREMENTS: Since the same DMM is used to observe both and the uncertainty contributions are correlated but the effect is to reduce the uncertainty and it is only necessary to consider the relative difference in the resistance readings due to systematic effects such as parasitic voltages and instrument resolution, which are estimated to have limits of ±0,5E-6 for each reading. The distribution resulting for the ratio r_C is triangular with expectation 1,000 000 0 and limits ±1,0E-6.

r: Type A
Method of observation: Direct
Number of observations: 5

No.	Observation
1	1.0000104
2	1.0000107
3	1.0000106
4	1.0000103
5	1.0000105

Arithmetic Mean: 1.00001050000
Standard Deviation: $160 \cdot 10^{-9}$
Standard Uncertainty: $70.71 \cdot 10^{-9}$
Degrees of Freedom: 4

δR_{TX}: Type B rectangular distribution
Value: 0 Ω
Halfwidth of Limits: $5.5 \cdot 10^{-3}$ Ω

TEMPERATURE CORRECTION: The temperature of the oil bath is monitored with a calibrated thermometer to be 23.00 °C. Deviations from this value have been estimated to be within ±0.055 K, including temperature gradients in the oil bath. From the manufacturor 10.0·10-6 $K^{-1,}$ thus the resistance variations of the unknown resitor due to a temperature variation is estimated to be within ±5,5 mΩ

Uncertainty Budgets:

R_X: resistance of the unknown resistor

Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
R_S	10000.053000 Ω	$2.500 \cdot 10^{-3}$ Ω	normal	1.0	$2.5 \cdot 10^{-3}$ Ω	9.0 %
δR_D	0.020000 Ω	$5.774 \cdot 10^{-3}$ Ω	rectangular	1.0	$5.8 \cdot 10^{-3}$ Ω	48.1 %
δR_{TS}	0.0 Ω	$1.588 \cdot 10^{-3}$ Ω	rectangular	1.0	$1.6 \cdot 10^{-3}$ Ω	3.6 %
r_C	1.0000000000	$408.2 \cdot 10^{-9}$	triangular	10000	$4.1 \cdot 10^{-3}$ Ω	24.0 %
r	1.00001050000	$70.71 \cdot 10^{-9}$	normal	10000	$710 \cdot 10^{-6}$ Ω	0.7 %
δR_{TX}	0.0 Ω	$3.175 \cdot 10^{-3}$ Ω	rectangular	-1.0	$-3.2 \cdot 10^{-3}$ Ω	14.5 %
R_X	10000.178001 Ω	$8.328 \cdot 10^{-3}$ Ω				

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
R_X	10000.178 Ω	0.017 Ω	2.00	95% (t-table 95.45%)