Accurate High-Ohmic Resistance Measurement Techniques up to 1 PΩ

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Abstract **The two main measurement techniques for precision high-ohmic resistance measurements for values of 100 MΩ and above are presented and discussed, the current integration technique and the adapted Wheatstone bridge. In calibrations using these systems, the quality of high-ohmic resistance standards, especially their time constants, temperature and voltage dependence, often is limiting the final uncertainty that can be reached. Still, expanded uncertainties (k = 2) of only a few parts in 10^5 are achievable at the 1 TΩ level.**

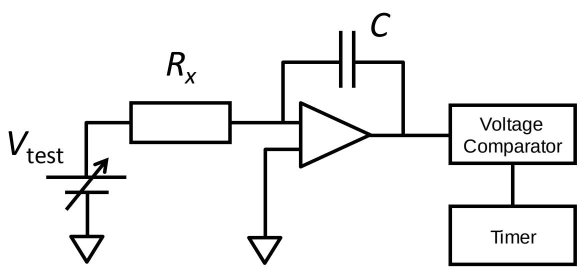
Current Integrating Teraohmmeter

Basic principle:

Charging a capacitor C by the current resulting from a test voltage V_{test} applied across the resistor R_x that needs to be measured.

From the linear output voltage ramp, R_x can be determined via:

$$R_x = -V_{test} / (C \cdot \Delta V/\Delta t)$$



Main advantage: Best for resistance transfer measurements and measurements of very high resistance, well into the PΩ range.

Uncertainty sources:

- Linearity of the $\Delta V/\Delta t$ ramp
- AC/DC difference and leakage of C
- Noise and stability
- Calibration of overall system (e.g. parasitic capacitance effects) using a lower-ohmic reference resistor R_s
- Incomplete compensation of input offset current and voltage
- Time base and voltage comparator errors.

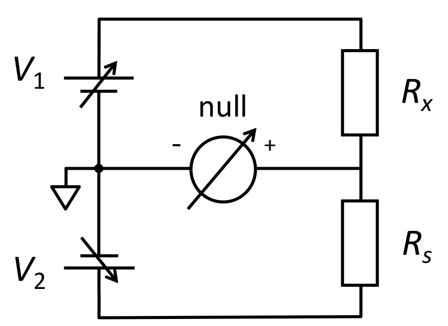
Adapted Wheatstone Bridge

Basic principle:

Balancing a Wheatstone-type bridge with two adjustable voltage sources in one arm of the bridge.

At balance, R_x can be directly determined from the voltage ratio via:

$$R_x = R_s \cdot (-V_1/V_2)$$



Main advantage: Lowest uncertainties, low sensitivity to leakage.

Uncertainty sources:

- Calibration of the voltage sources (voltage ratio)
- Noise and stability
- Reference resistor R_s
- Incomplete cancellation of offset voltages or offset currents (up to 100 GΩ, either voltage or current null detection can be used)

Nota bene: there is a big difference in final uncertainty statements made by NMIs for measurements of 1 TΩ and above, due to different estimations of the contribution of systematic effects, especially those related to the resistance standards.

Resistance standards

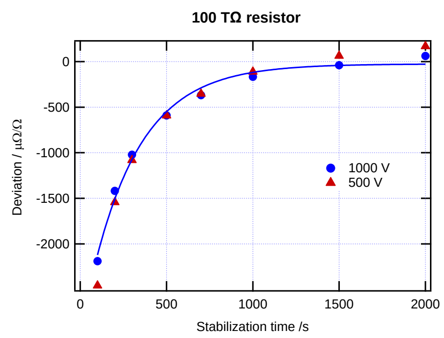
The performance of high-ohmic resistance standards is *critical* in achieving the best uncertainties in measurements using the current integration technique or the adapted Wheatstone bridge.

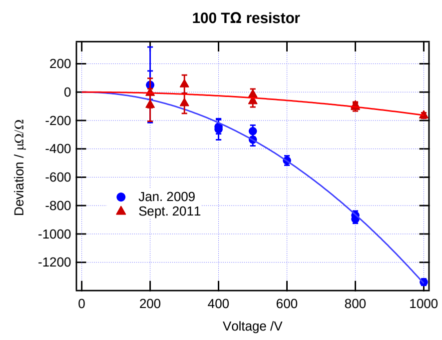
Influence factors:

- Voltage coefficient of resistance (VCR)
- Temperature coefficient of resistance (TCR)
- Relative humidity effects
- Long-term drift
- Short-term settling time
- Construction material properties, resistor configuration

The actual measurement method should take this into account via:

- Determination of the size of VCR and TCR effects
- Minimising relative humidity effects via hermetical sealing
- Minimise short-term settling times (material selection, coatings)
- Ensure sufficient waiting times in the measurement method



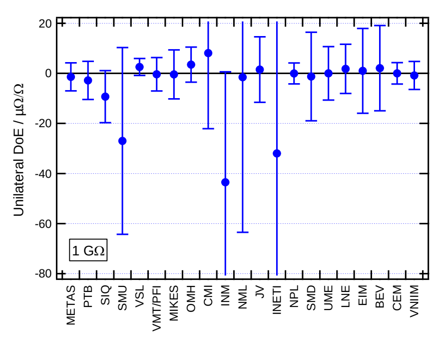


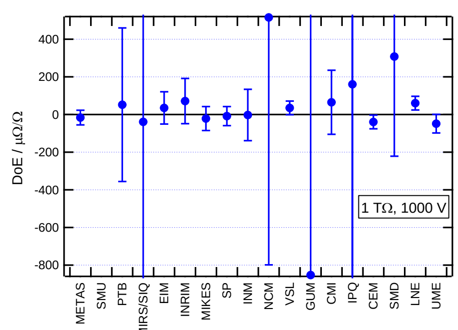
Summary

High-ohmic resistance measurements are relevant for calibration of electric isolation meters, low-conductivity meters, and electrometers. Both the current integration and the adapted Wheatstone bridge are suitable for high-ohmic calibrations at the highest level of accuracy.

Recent comparison results and best achieved uncertainties:

- Down to a few ppm at 1 GΩ (EURAMET.EM-K2)
- Around 20 ppm at 1 TΩ (EURAMET.EM-S32)





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