

A comparison of cryogenic current comparator resistance bridges and quantised Hall resistance standards at NPL

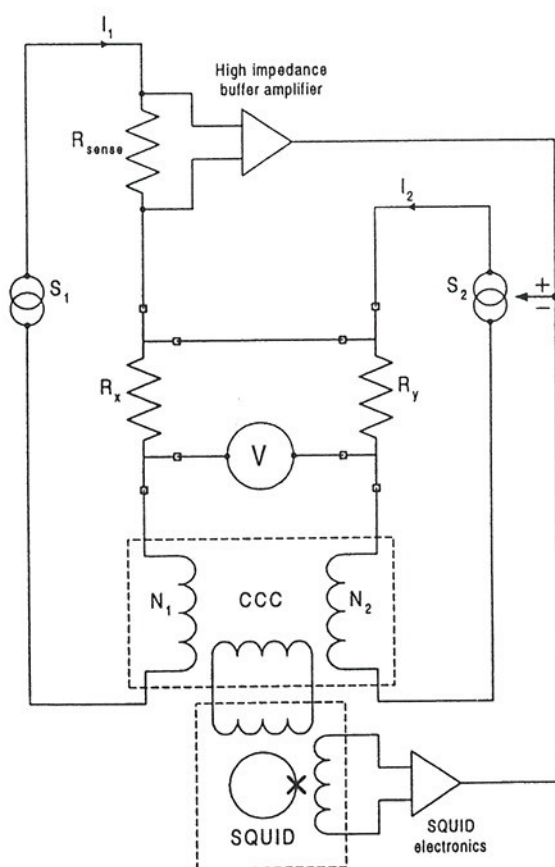
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Introduction

For over ten years, routine resistance calibrations in the range $1\ \Omega$ to $10\ \text{k}\Omega$ have been carried out at NPL using an automated resistance bridge based around a cryogenic current comparator (CCC) [1]. A further CCC bridge has provided traceability for all measurements to the quantised Hall resistance (QHR) since the adoption of the internationally agreed value of the von Klitzing constant, R_{K-90} , in 1990. Oxford Instruments have produced a commercial CCC bridge based on the NPL design which can be combined with a quantum Hall primary standard to provide a complete resistance measurement system. This paper describes the results of a side by side comparison of the Oxford Instruments and NPL CCC bridges and independent QHR systems carried out at NPL in July 1999.

Tests

The CCC bridges are capable of 1:1, 10:1 and 100:1 ratio measurements on resistors from $1\ \Omega$ to $10\ \text{k}\Omega$, as well as measurements of $100\ \Omega$ resistors against the QHR $i=2$ and $i=4$ plateaux. Figure 1 shows the operating principle of the CCC bridge.



The winding ratio, $N_1:N_2$, provides a precise current ratio via a SQUID detector used in a servo loop. A voltage null detector then senses any deviation of R_x and R_y from the ratio $N_1:N_2$.

The system supplied for testing by Oxford Instruments also included a QHR system, consisting of a 14 tesla magnet with a ^3He refrigeration insert capable of maintaining a QHR sample at a temperature of 300 mK for several hours, along with a selection of QHR samples.

Several room temperature resistance standards were chosen, which were either already maintained in thermostated enclosures, or were allowed to stabilise in an oil bath. Three different $100\ \Omega$ standards were measured on both systems against both the $i=2$ and $i=4$ QHR plateaux. One of these $100\ \Omega$ standards was subsequently

used as a reference for 10:1 measurements to 10 Ω and 1 k Ω and 100:1 measurements to 1 Ω and 10 k Ω .

Results

The results of these tests are presented below, with all values expressed in terms of R_{K-90} . Each value represents a measurement of between 5 and 10 minutes, with a maximum measurement power of 1 mW in the smaller resistor. The figures in brackets give the type A uncertainty (1σ) for each measurement.

Ratio	NPL System	Oxford Instruments System	Oxford Instruments - NPL
100 Ω : $i=4$ ^(a)	100.000 555 91(55) Ω	100.000 555 46(33) Ω	-0.0045(64) ppm
100 Ω : $i=4$ ^(b)	99.998 839 69(46) Ω	99.998 838 83(45) Ω	-0.0086(64) ppm
100 Ω : $i=4$ ^(c)	99.998 837 83(65) Ω	99.998 837 13(48) Ω	-0.0070(81) ppm
100 Ω : $i=2$ ^(a)	100.000 556 46(56) Ω	100.000 556 05(79) Ω	-0.0041(97) ppm
100 Ω : $i=2$ ^(b)	99.998 838 96(16) Ω	99.998 839 81(96) Ω	+0.0085(97) ppm
100 Ω : $i=2$ ^(c)	99.998 838 57(61) Ω	99.998 837 73(105) Ω	-0.0084(121) ppm
100 Ω : 100 Ω	99.998 112 33(08) Ω	99.998 112 27(03) Ω	-0.0006(09) ppm
100 Ω : 10 Ω	9.999 893 002(18) Ω	9.999 892 941(06) Ω	-0.0061(19) ppm
100 Ω : 1 Ω	1.000 011 237 2(26) Ω	1.000 011 239 8(55) Ω	+0.0026(61) ppm
100 Ω : 1 k Ω	1.000 015 229 4(14) k Ω	1.000 015 223 3(11) k Ω	-0.0061(18) ppm
100 Ω : 10 k Ω	10.000 071 646(66) k Ω	10.000 071 570(57) k Ω	-0.0076(87) ppm

The type B uncertainty for measurements made on the NPL CCC is estimated to be 0.005 ppm (this figure is arrived at by self consistency checks such as comparing two 10:1 measurements against a 100:1 measurement, and from the results of international intercomparisons).

Conclusions

The results above show that in all cases, the difference between the NPL and Oxford Instruments systems is less than 1×10^{-8} and that a few differences are slightly larger than the RSS combination of the type B and the two type A uncertainty contributions (as should be expected for uncertainties at the 1σ level). For all ratios, the resolution (type A uncertainty) of both CCC bridges is at least 1×10^{-8} for a measurement of less than 10 minute duration at 1 mW.

References

- [1] Williams, J.M. and Hartland, A.: 'An automated cryogenic current comparator resistance ratio bridge'. IEEE Trans. Instrum. Meas., 1991, vol. 40, pp.267-270