Binary voltage divider for verifying DC voltage linearity of calibrators and digital multimeters
Diviseur de tension binaire pour vérification de la linéarité de la tension continue sur des calibrateurs et des multimètres numériques

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This paper reviews the difficulties and limitations of verifying the performance and linearity of the DCV function on high performance calibrators and voltmeters. The general recommended metrology guidelines, such as the EURAMET cg-15, recommend verifying for performance and linearity at 5 different points within the instrument's setting for higher performance instrumentation. Usually they are at 10%, 30% 50%, 70% and 90% of a given operating range. Plus several additional points are used for verifying reverse or negative polarity voltage operating performance.

With existing dividers verification can readily be done at decade points using 10:1 and 100:1 dividers and 10 volt reference standards. However, verification of non decade ratios is not readily possible (for example the desired 10%, 30%, 50%, 70% and 90% of scale operating points.). Traditional metrology instrumentation with variable ratio capabilities, such as Kelvin-Varley dividers, fall short in satisfying the uncertainty requirements needed for these high performance instruments. As a solution the OEM manufactures of calibrators and voltmeters recommend techniques using built in internal instrument checks (problematic to traditional metrology philosophy). Alternatively, they use external measurement techniques with very high performance techniques, such as Josephson Junction voltage systems, or highly characterized standards for comparison measurements. The OEM's laboratories can readily utilize such techniques due to the speciality of their work. However, these techniques are not practical nor easily done in other labs which must support traceability not only of such special instruments but are also required to support a wider metrology instrumentation workload. As a result, other laboratories might not be able to perform the recommended number of tests that are deemed acceptable by good metrology practice.

This presentation offers techniques which can perform such tests at the required uncertainties using commercially available instrumentation. This includes example results of such testing with the resulting measurement uncertainties.

The metrology process uses the 10 V Binary Voltage Divider (BVD), an range extender to perform measurements to voltages, as high as 1200 V. It is also fully automated for maintenance of the DC voltage scale across the full range of both positive and negative voltage polarities with very good uncertainties. The paper also discusses the self calibration techniques used in the Binary Voltage Divider (BVD). It is based on Cutkosky principle for fully automated maintenance of the voltage scale. It is best used through comparison to a traceable 10 V standard of other various test voltages down to effectively zero. It is also scalable up to a maximum of 1200V.

The BVD offers a range of verification of effectively 25 bits with performance to <0.01 ppm in both the positive and negative polarities. It is considered ideal for checking the linearity of up to 8 ½ digit voltage sources and also used for testing DVMs up to 8 ½ digit of measurement performance. This satisfies the recommendation for acceptable metrology practice of performance verification within the operating range of such instrumentation.

In order to document performance in this paper and demonstrate proper function and necessary metrology characteristics of this selected solution, all self-characterization procedures and standardization procedures were made at both polarities and results were compared. An extensive series of experiments and measurements were made together and the uncertainties support verifying both the linearity and the specific values required when calibrating with these instruments which are also summarized in this paper.

The enhanced performance of the DCC Current Comparator using AccuBridge Technology
La performance améliorée du comparateur de courant DCC avec la technologie AccuBridge

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Key Words / Mots Clés : Direct Current Comparator (DCC), AccuBridge®, ratio error, improved partial turn technology, ampere turns, variable slave turns, turns calibration, voltage balancing, and PID controller

The Quantum Hall effect (QHE) or primary resistance standard provides a universal representation of the unit of resistance which depends on the elementary charge e and the Planck constant h. The quantum resistance standard can be reproduced with a relatively low uncertainty using the traditional GaAs silicon sample. If the measurements on a QHE are implemented according to specific technical guidelines and the sample is at a temperature of 1.2 K in an 8 tesla magnetic field, uncertainties as low as few parts in 10-9 can be achieved. Quantum Hall resistors (QHRs) have a defined value (RH) of 25,812.807 Ω on step i = 1, with appropriate sub-multiples of this value on other steps. Such resistors are used as representations of the ohm in national laboratories of many countries, where it is common practice to compare these primary resistance standards on a regular basis with a set of thermally stabilized wire resistors.

These Quantum Hall resistance measurements are typically carried out using either resistance ratio bridges equipped with the cryogenic current comparator bridge (CCCB) or the room temperature direct current comparator (DCC) where the performance of each relies on the magnetic flux sensitivity. Binary wound current comparators are used in both which makes them easy to calibrate. Calibrations of wire resistors in terms of the QHE can also be carried out with similarly low uncertainties. Nevertheless there are difficulties associated with implementing a CCCB, amongst these the necessity to cool the coil with liquid helium.

Over the last five years the DCC bridge, which is another application of the same connection technique as the CCCB, provides an effective solution for measuring the QHR with a relative ratio uncertainty below two parts in 10-8. However the DCC ratio bridge development has been hindered by this inherent ratio error of the direct current comparator. By improving on the technologies around the DCC, as described in this paper both the specific technical guidelines used firstly to verify the GaAs sample and the reduction of the inherent ratio error in the range of 0.01 ppm to 0.005 ppm can be achieved.

Verification of the ratio accuracy is now becoming comparable with the technology in the (CCCB). The new DCCB ratio bridge, with its fast measurement algorithms also make it ideal for measurements using Graphene samples.
Automatic balancing of the DCCB facilitates a new Nano measurement operation of the bridge for more accurate resistance measurements of both the QHR value and laboratory standards.