DC Verses AC Technology

History: The DC Current Comparator Principle was developed in the late 1960's. The technology was later commercialized as a manual device for both resistance and temperature measurements. In 1987, Measurements International enhanced the DC Technology in the 6010B bridge. MIL has become the premier manufacturer of DC Metrology products, for the majority of National Laboratories around the world, for use in Resistance and Temperature measurement applications. The ability to measure resistance ratio accurately is key to both resistance and thermometry measurements. In the 6010, the ratio between an unknown resistance and a known reference resistor is measured using the DC Comparator. The resistance of the unknown resistor is calculated by multiplying the comparator ratio times the reference resistance value. The uncertainty of the measurement is calculated using the RSS of the standard deviation of the measurement and the reference resistance uncertainty.

In terms of performance over the last few decades, DC technology was used as the primary measurement exclusively and AC was chosen for its automation, as it was the first technology automated. However, DC was still used as the technique of choice for all those involved with the most accurate measurements.

The Direct Current Comparator: The DCC Comparator operates with its magnetic core at zero flux. Using two-core magnetic modulation techniques to detect ampere-turn balance, it can be used for direct current ratio measurements. Except for the two-core detector, the configuration is essentially the same as the ratio transformer in the AC Bridge. And unlike the AC Bridge, no compensation winding is required for the direct current comparator. The DC Technology consists of a binary wound current transformer with a detector winding, a primary and secondary winding. A secondary or slave current source is slaved to the master current source by the detector or feedback winding in the comparator.

In the DCC Comparator, the current circuits are magnetically coupled and no current is present in the potential leads, lead resistance is not a problem. On the other hand, ac bridges are concerned with the amount of inductance and capacitance that are created by changing lead lengths and this can cause an error in the reading. This phenomena is described in a paper titled

"INFLUENCE OF CONNECTING CABLES ON THE MEASUREMENT UNCERTAINTY IN CALIBRATION OF RESISTANCE THERMOMETERS" presented at CPEM 2000 in Sydney Australia by Jovan Bojkovski, Franc Bergeli, Igor Pusnik and Janko Drnovsek from the University of Ljubljana in Slovenia.

Two identical magnetic cores are used and by suitable connection of the windings on each core the odd harmonic components cancel one another and only the even harmonics remain. The modulation or sensing cores control the modulation frequency, thereby reducing the effects caused by temperature variation in the DC comparator in obtaining the highest accuracy and stability. The resistance of the measurement is defined as the voltage difference between the potential terminals divided by the currents passing through the current terminals. Measuring the current ratio when the voltages across the resistors are equal compares the resistors. Since the ampere turn ratio in the current comparator depends only on the turn's ratio, turns cannot be lost or gained, this represents a fundamental measurement standard and the error can be defined, for temperature applications, as $e = e_p$.

Where e_p = ratio error

In comparison to AC Bridges, DC bridges depend on a smaller number of components to achieve their performance, the inherent stability coming from the DC Comparator, which is not subject to temperature variations or warm up. An outstanding feature of the DC Comparator is that switch contact and other parasitic resistances; capacitance or inductance does not affect the winding turns or bridge measurement. As a result, self-calibration of the turns can be performed to less than 0.01 PPM. The corrections are small enough that they do not have to be added to the measurement to achieve this performance. Under microprocessor control, these values can be printed out over the IEEE488 bus for history monitoring of the bridge. The DC Bridge has a maximum ratio of 13:1, which allows the user to calibrate a 25Ω PRT over its full range using a 10Ω standard resistor, utilizing more of the bridge range with increased resolution.

Elimination of thermal & electrochemical EMFs: Reversing the current source and averaging the two results eliminates the effect of thermal electromotive forces on the measurement. The current is reversed every few seconds to eliminate truly static thermal and electrochemical EMFs and any changes that occur during the measurement time. Selections of timing associated to DC Current reversal gives the end user control of the reversing rate to eliminate polarization in the PRT, a phenomenon that exists when using the AC bridges.

The following paper was presented by Dr. Piero Marcarino at Tempmeko 99', held at NMi in Delft, The Netherlands. The paper can also be found in the Tempmeko 99' proceedings issued December 1, 1999, editors M.J. deGroot and J.F. Dubbeldam and at mintl.com under technical papers.. It is reproduced with permission from the owner and publisher, NMi.

CALIBRATION OF SPRTs IN THE SUB-RANGE BETWEEN THE TRIPLE POINT OF Hg AND THE MELTING POINT OF Ga

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Speed of response: When using AC Bridges, most temperature laboratories take their readings at 0.1 Hz. This is equivalent to a 5-second reversal rate on the DC Bridge. As the MI DC Bridge requires no "auto-zero" or "self calibrate" cycles during the measurement, continuous temperature measurement can be made. This means that the measurement time and consequently the throughput of any calibration system are much better. This is particularly important when a bridge is used with a scanner to multiplex around a number of probes or resistors.

No warm up time: The heart of the DC Bridge is a current comparator, which provides inherent stability and is not susceptible to temperature variations. There is no warm up time and it can be used immediately after turn on.

AC Technology: AC Technology is limited to a ratio of 1.4:1. And from the fundamentals of physics, the AC signal is comprised of two components, the in-phase and quadrature errors and thus two uncertainties.

The error of the AC comparator e $= e_p + je_q$

Where e_p, e_q = in-phase and quadrature components of the complex error e., each having an uncertainty = u_p and u_q respectively. AC technology has a faster response as it runs at 30 or 70 Hz. However, the PRT responds slowly during stabilization, so speed is not an important issue in all measurements.

Are there any disadvantages of AC bridges? There are several

- The Cost
- AC Technology is more complicated
- Errors in measurement due to various lead lengths
- Errors in measurement due to polarization in the PRT
- Complex error with two components of uncertainty
- Does not cover the full range of resistance measurements
- Almost impossible to calibrate

Are there any disadvantages of DC bridges? There is only one; the DC Bridge is not as fast as the AC Bridge in following drastic changes in temperature but it is quite evident that the measurement speed is the same for 99% of all temperature measurements. AC bridges were the first automated temperature bridges and are visible in the standards laboratories around the world. However, it is becoming increasingly evident that the DCC Technology from MI, now that it is automated, is becoming the device of choice for the temperature metrologists, the inherent stability of DC with the corresponding measurement confidence offers the customer significant benefits.

Advantages of DC Technology include its simplicity and therefore cost, no special resistors are required. Both AC and DC resistors can be used and a full set of standard resistors can be calibrated to primary levels for absolute measurements. DC technology has better overall performance for both temperature and resistance measurements.