BIPM Capacity Building & Knowledge Transfer Programme

2018 BIPM - TÜBİTAK UME Project Placement

REPORT

Project Name	High DC resistance measurement using Wheatston Bridge
Description	Develop an automatic adapted Wheatstone bridge for high DC resistance measurement
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Motivation & Introduction

The purpose of the project is to measure high DC resistance values in the range of MΩ to TΩ, with the goal of extending the range of EMI's laboratory in DC resistance measurements above 1 GΩ, thereby meeting high demand from customers for higher DC resistance values. In order to perform measurements of high DC resistors, a system is needed to deal with low current measurement and manage leakage current. A Wheatstone bridge provides a system that measures high DC resistance values under computer control, reducing the amount of operating time required and the human effort with no degradation of the measurements uncertainties. For high DC resistance, the Wheatstone bridge is constructed with a guarding circuit and special cables to reduce errors resulting from leakage current.

Research

The project started by reading through articles and training documents related to high DC resistance measurements and Wheatstone bridge and analyzing the main circuit of the bridge as shown in Figure 1.

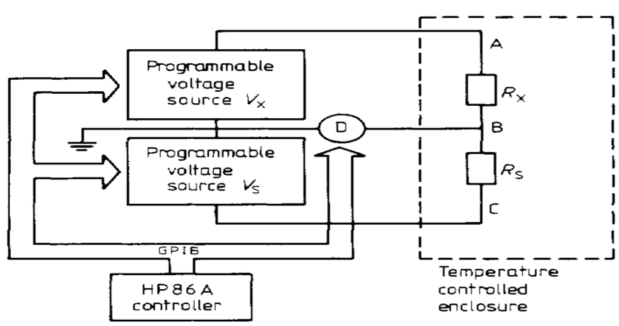

Figure 1:Wheatstone bridge

The purpose of the circuit illustrated in Figure 1 is to measure Rx, which is the unknown resistor, by using R_s which is a known standard reference resistor using two voltage sources.

To get the value of the unknown resistor R_x, the bridge needs to be balanced by changing the voltage sources value until the detector (D) indicates a zero value. By balancing the bridge, the equation $V_x/V_s = R_x/R_s$ can be used to calculate R_x. The resistors are in a controlled temperature and humidity bath.

One of the important challenges with high resistance measurements is that the measurements are made using a low current. Therefore, some improvement was made to the circuit to reduce leakage current by guarding the circuit.

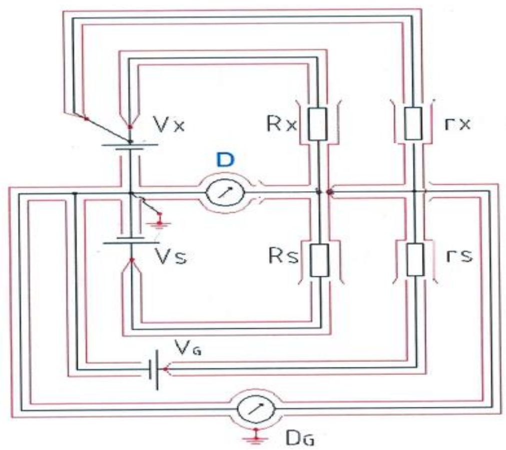

Figure 2: Adapted Wheatstone bridge

As shown in figure 2, there are additional resistors, a voltage source and a current detector. The purpose of this equipment is to remove leakage current from the connection between R_x and R_s. In addition, the cable shields from voltage sources were connected to the source output to prevent leakage as well. The thermal EMF was taken into consideration by executing the measurement in both negative and positive. A low noise cable is used to get a better and more stable result and a section of the project focused on the low noise cable and how to terminate this cable with suitable adapters to connect it to the equipment.

The next step in the project was to understand how to build the bridge circuit and how to connect all the equipment.

From this point onward, the bridge was made ready for use for the measurements. Initially the bridge was operated manually to get more of an understanding of the bridge and the process of balancing the bridge. In addition, the settling time was measured, which is the time required for the resistor to stabilize after supplying the voltage.

Then, the software programming of the set-up was studied in order to learn how to program each piece of equipment to perform the measurement, balance the bridge, calibrate the calibrator using a DMM and obtain the result. Finally, the uncertainty budget was drafted to determine all the uncertainty contribution within the system.

Lectures were given on the international aspect of metrology in which it was explained that the metrology provides measurements that are stable, comparable and coherent. The world economy, society and citizens depend on the international “quality infrastructure” which depends on metrology. Quality infrastructure is an element to support the economic development by ensuring effective operation of local markets and allowing access to foreign market by reduction of Technical Barriers to Trade (TBTS) through an internationally recognized metrology institute.

To provide mutual recognition of calibration CPIM MRA was created. Under the CIPM MRA, the calibration and measurement capabilities (CMCs) of signatory NMIs are the fundamental object of mutual recognition. In addition, CIPM MRA requires that all signatory NMIs establish and maintain an appropriate Quality System (QS). Consultative Committees of the CIPM (CCs), the Regional Metrology Organizations (RMOs) and the BIPM are responsible for carrying out the key and supplementary comparisons. Key and Supplemental comparisons provide evidence of the equivalence of NMI measurement capabilities.

Metrology institute can get recognition either through accreditation or through RMOs. The process to get the CMCs approved through RMOs is to submit CMCs for intra-regional review to be reviewed by TC-RMO then TC chair, upload it to JCRB for inter-review by other RMOs and after been approved it will be published in Appendix C of the KCDB.

Conclusions and Future Work

To conclude, the main purpose in this project was to learn how to build and operate a Wheatstone bridge to measure high DC resistance values along with some important techniques to ensure highly accurate results with low uncertainties. With the knowledge gained through my studies, I will produce a project plan to develop the capabilities at EMI for measurements of high DC resistance values, participate in an inter-laboratory comparison and submit CMCs.

Acknowledgements

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