LOW-TEMPERATURE RTD CALIBRATION SYSTEM*

K. Kozlowski[a,b], H. Malinowski[a,c], D. Dabrowski[a,d]
K. Malinowski[e], K. Roslon[a,d]

[a]Joint Institute for Nuclear Research, Joliot-Curie 6, Dubna, Russia
[b]Nicolaus Copernicus University, Gagarina 11, Toruń, Poland
[c]Electrotechnical Institute, Pożaryskiego 28, Warszawa, Poland
[d]Warsaw University of Technology, Plac Politechniki 1, Warszawa, Poland
[e]Lublin University of Technology, Nadbystrzycka 38D, Lublin, Poland

(Received July 11, 2016)

The design of a calibration system for resistance temperature detectors (RTD) will be presented. The project was optimized for the high-accuracy calibration in the cryogenic temperatures. The system is based on the 18-bit ADC with an internal MUX and 35 input channels for the calibrated resistors and referential sources. The project will be used in the preparation of the NICA temperature monitoring system.

DOI:10.5506/APhysPolBSupp.9.251

1. Introduction

The development of an experiment based on the cryogenic technologies always requires a precise temperature monitoring system. A very important part of those systems are the temperature sensors themselves. They have to meet a number of requirements for a proper measurement, which are different for every type of cryogenic installations, its purpose and temperature range. The sensors used in the JINR nuclotron system are resistance temperature detectors (RTD). Carbon-based resistors were used because of a very high resistance increase in the systems operational temperature range. The same type is planned to be used in the NICA experiment for the temperature monitoring of the booster, collider and the detectors. The design presented below will be used for preparing those sensors for the experiment applications.

* Presented at the NICA Days 2015 Conference associated with WPCF 2015: XI Workshop on Particle Correlations and Femtoscopy, Warszawa, Poland, November 3–7, 2015.

2. Motivations

The difference in the cost of the calibrated and non-calibrated RTD is always significant. This interval is getting even bigger for RTDs calibrated in the range required for the monitoring of superconductivity-based systems. That was the motivation behind the construction of a first RTD calibration system used in the Laboratory of High Energy Physics (LHE) during the construction of the nuclotron system.

The development of the nuclotron and the construction of the new elements of the system to contribute to the project NICA required a number of sensors at the level of 4–5 k. Calibration of this amount of RTDs with the existing calibration system would take several years, and involve a constant human supervision.

3. Early assumptions

The main purpose of the new system construction was the improvement in the amount of sensors calibrated daily (in order to make the amount required by NICA possible). The new design was also an opportunity to make other changes. New system was supposed to have a higher measurement resolution and make an operator involvement as limited as possible. Other important design element was the possibility of switching between the different calibration modes (different calibration range, amount of calibration points and equipment).

4. Problems and solutions

4.1. Seebeck effect reduction

The temperature amplitude between different parts of the measurement circuit of the device can go up to 300 K depending on the room temperature. This amplitude indicates a possibility of a thermoelectric effect (Seebeck effect in this particular case) influence on the measurement. To eliminate this influence, PCB with a set of analog keys DG303 [1] was included in the measurement circuit. This allowed for the change of the current flow polarization in the circuit. The output resistance data is calculated based on those two measurements.

4.2. Current fluctuations

The output resistance data of the calibration system is being calculated based on the voltage and current measurement. Any current fluctuation or changes affect the results directly. To minimalize this error, not only a stabilized current source was used, but also a current measurement circuit was added.

4.3. Temperature coefficient of the electronic components impact on the measurement

The high accuracy of the measurement requires the minimization of the impact of the electronic components temperature coefficients. The amplification value of the instrumental amplifiers INA 121P [2], that were used for the project, is set by a resistance attached to the component. This makes this system very sensitive to any temperature changes due to the resistance temperature characteristic of those resistors. As a result, the amplification is changing with the device temperature. The problem was solved by stabilizing the temperature inside of the device. For this purpose, one of the channels of the Lakeshore 336 [3] was used.

5. Hardware

5.1. The measurement circuit

The measured resistors are connected serially to the current sources with additional outputs between every two resistors. This makes measurement of the voltage drop on a single resistor possible.

A PCB with DG 303 [1] analog keys is responsible for switching between two current sources (which are built in the ADC system) and for changing the current polarization in the circuit.

For adjusting the measured signals to the required by the ADC system level, an conditioning PDB set was used. Those boards are based on Texas Instruments INA121P instrumental amplifiers. Every board contains 14 input channels with hardware programmable amplification.

The conditioning ADCs are connected to the LabJack U6-PRO ADC inputs. This ADC system [4] contains 14 analog inputs with the programmable resolution of 16 to 18 bit. It also contains an internal MUX and an additional sigma–delta ADC channel for more precise measurement (22 to 24 bit resolution), which was used for the current measurement. A LabJack extension card was used to increase the amount of inputs.

The LabJack ADC system is responsible for all of the control signals send to the PCD components and its programmable via the USB protocol.

5.2. The temperature control system

The LakeShore 336 [3] temperature driver is responsible for the temperature control inside the device and inside the cryostat where the measurement is taken. The temperature is measured by the use of a connector RTD sensors made out of platinum and germanium depending on which temperature range it is required at the particular moment. The temperature adjustments are taken by the use of two heaters (20 and 40 Ohm). The scheme of the measurement circuit and the heating system is presented in Fig. 1.

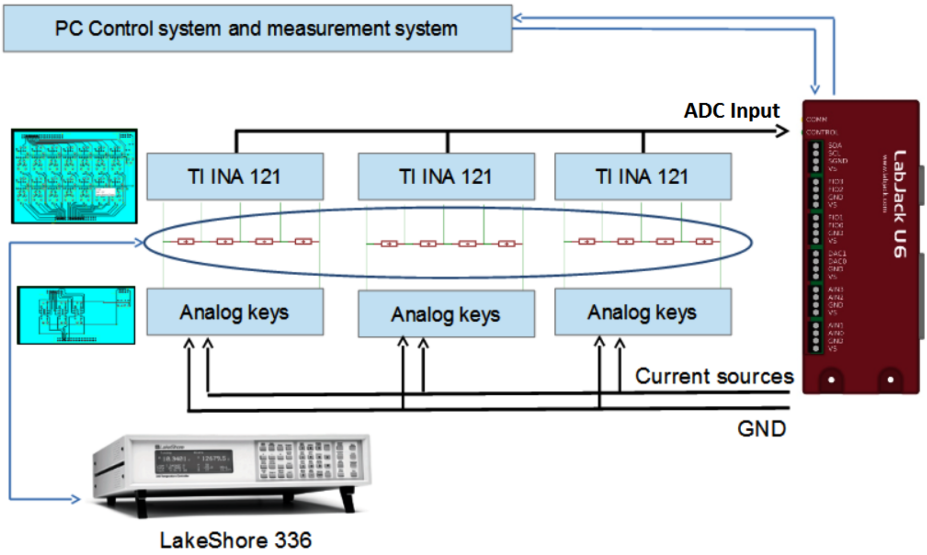


Fig. 1. The measurement circuit scheme.

6. Software

Presently, the software layer of the project is being developed. For the prototype version, a Python program was made for the hardware testing. The module architecture of the software allowed to control every aspect of the calibration process from every working station in the local network. Different modules of the configuration, measurement, data processing and data transfer are able to work independently after starting a mother program on the computer to coordinate the calibration process.

The first version of the software is not further developed due to a new LabView-based system being created.

7. Results and the projects status

The prototype of the system was developed and tested. It was fully operational and used for the calibration of about 1300 sensors in the 3-points calibration mode and about 100 sensors in the 30-points mode. The results are satisfying and gave an error of 0.002% while the measurement was taken in the liquid helium temperature and 0.007% in the temperature of liquid nitrogen. The error was calculated from the measurement data of a calibrated germanium resistors.

The proper testing calibration and output data analysis of the final version of the device is during the process. The main improvement of the final version will be a better temperature shielding of the device, which will improve the device temperature control and additional inputs.

REFERENCES

[1] Intersil Corporation, DG303 datasheet, Milpitas, USA, 1999.

[2] Texas Instruments, INA 121 P datasheet, Dallas, USA, 2015.

[3] LakeShore Cryotronics, Model 336 Manual, Westerville, USA, 2015.

[4] LabJack Corporation, U6 datasheet, Lakewood, USA.