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Research Paper

Measurement of thermometer using automated system

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Abstract

Calibration of thermometers is time- consuming process that requires short-term temperature stability during multiple measurements at given temperature points. In most laboratories, thermometer calibration process is not automated, requiring the presence of the laboratory assistant during the calibration and for the subsequent calculation of the measurement uncertainty. In this paper, an automated system for calibration of thermometers is presented. The system enables the entire calibration process to be computer driven, after setting calibration parameters. The details are presented on an example of a furnace for temperatures up to 1 000 ° C. The review of the metrology software is given

Keywords: *Calibration/Thermometers/Metrology/ Automated Measurement And Control System/ Software For Process Automation.*

1. Introduction

Thermometer calibration process is time-consuming. Typical calibration lasts for several hours. For that reason, temperature calibration laboratories develop systems for partial or complete calibration process automation [1]. At Faculty of Technical Sciences, University of Novi Sad, an automated system for thermometer calibration has been developed. This system comprises furnace with programmable temperature setting and control, system multimeter, programmable selector switch with low thermo-electromotive force and computer with Lab VIEW software for process control [2]. Developed a new method to executing such a thermometer, with some preliminary results carried about a minimal value of 0.2 K measurement sensitivity errors and maximal of 0.5 K measurement sensitivity errors are validated in [5]. A self-calibration method for the elimination of measurement errors when measuring low temperatures affected by thermal gradients in thermopile-based infrared thermometry system are executed and reported to reduce the measurement error to within ±1°C within 5 s of an extreme thermal shock are presented in [6]. High precision (3.7 mK) temperature sensor has been calibrated and tested using standard calibrated equipment's. It indicates high sensitivity of 3.7 (± 0.2) mK and can be applied where high accuracy in temperature measurements is essential [7]. A dual-calibration technique to develop the matching accuracy of digital-to-analog converter components and increase nonlinearity induced static errors in a current-steering thermometer digital-to-analog converter[8].To design of an infrared (IR) thermometry system for measuring temperature in domestic induction stoves and the results are implemented for frying temperature measurements (140 °C-180 °C) and verified in the cooking range from 120 °C to 200 °C for cookware made of various materials[9]. In the paper, the details of this system will be given.

2. Thermometer Calibration System

The automated system for calibration of thermometers can be used for a large number of temperature baths and furnaces that have a computer interface [3]. This paper describes a system for Compared to manual calibration, the automated system brings a number of improvements as listed below:

- Elimination of the human influence in the process of calibration (laboratory assistant only sets the initial requirements for the calibration, after that the measurement and control system takes control of the calibration process,
- The measurement results are automatically stored in the database,
- Processing of the results, measurement uncertainty evaluation and report generation on completed calibration is carried out automatically.

Laboratory system for calibration of thermometers uses the comparative method – it compares the temperature measured by a standard thermometer with a temperature measured by a thermometer under test [4]. It consists of:

- Personal computer with LabVIEW,
- System multimeter - at least 6.5 digit resolution, for voltage and resistance measurement,
- Programmable selector switch (multiplexer)
- Furnace with system for temperature control with computer interface,
- Standard thermometer.

In Figure 1, block diagram of this system is shown.

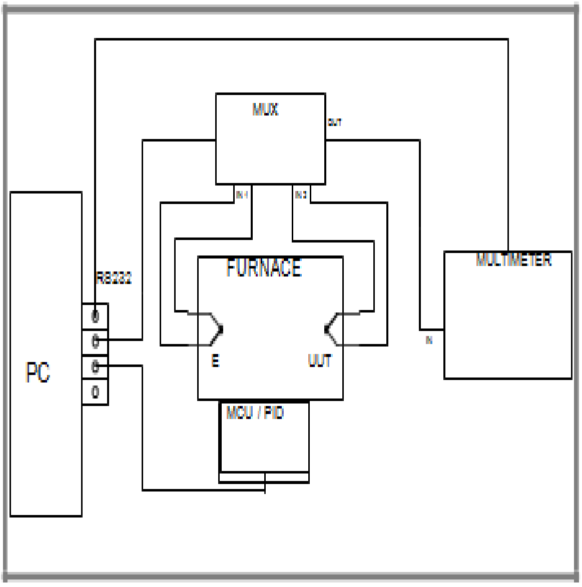


Fig. 1: Block diagram of the calibration system

3. Furnace

Figure 2 shows a block diagram of the subsystem for furnace operation management:

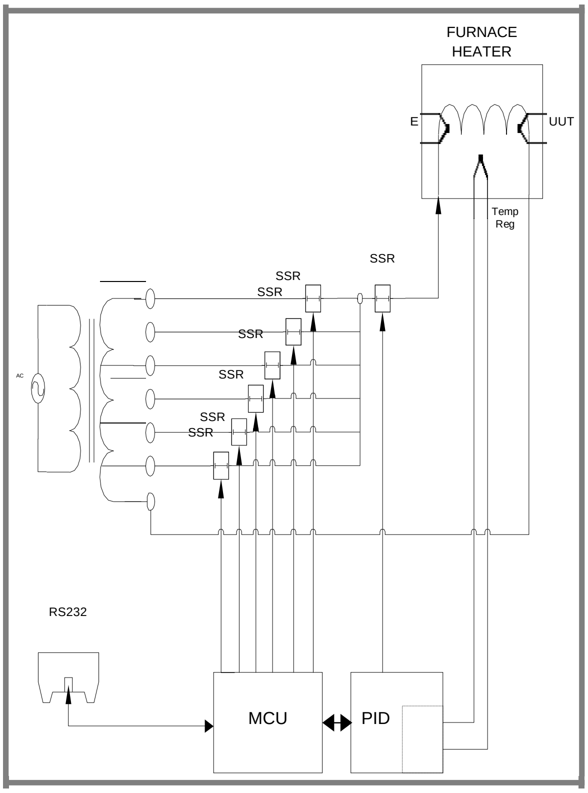


Fig. 2: Block diagram of the furnace control system

- microcontroller subsystem (MCU),
- PID controller,
- Group of "solid state" relays (SSR)
- Toroidal transformer with multiple terminals.

As shown in Figure 2, MCU subsystem is directly connected to PC via RS232 port. At the very beginning of a calibration process, microcontroller unit receives relevant calibration data (temperature range, number of calibration points and also temperature step between the two adjacent points) from the PC software. Based on these data, MCU turns on appropriate SSR which connects one of transformer terminals to the SSR controlled by PID. The purpose of this mode of operation is to provide the lowest possible voltage to the heater inside of the furnace, but still enough to achieve the specified temperature. Due to the furnace architecture and characteristics of the PID regulator with ON/OFF control output, time constants are large and without this additional possibility to control the heater power it would be very difficult to maintain stable temperature during the measurement.

After the system reaches the next temperature given in calibration plan, (after this temperature is stable in defined period of time), the measurement process starts. The same procedure applies to all other points of calibration. At the end of calibration process, the furnace power is turned off and computer calculates all data for the calibration report and generates the report.

The PID regulator parameters have been theoretically considered and experimentally tested. The parameters were chosen to minimize both the time needed to achieve the next temperature point and temperature variations at the given temperature. Measurements and furnace validation shows that such chosen regulator parameters provides the most effective way of keeping the temperature stable during a specified time interval. Temperature variations are in range of ±50 mK for lower calibration temperatures (25 °C – 400 °C), and in the range of ±200 mK for higher calibration temperatures (400 °C – 1 000 °C).

4. Software for the Automation of Thermometer Calibration Process

Software for the automation of thermometer calibration process is implemented in Lab VIEW environment. Its main functions are:

- User interface to set the configuration parameters,
- Initialization of all parts of the system,
- System multimeter and programmable selector control to collect the measurement results from a system multimeter according to pre-programmed calibration procedure,
- Data processing and calculation of measurement uncertainty,
- Report generation on the thermometer calibration and
- Archiving of the reports and raw data (results).

Figure 3 shows the front panel of the Lab VIEW application.

Fig. 3: Lab VIEW application front panel

A. Software configuration

Lab VIEW application provides ability to set different communication parameters for all peripheral programmable devices (system multimeter, multiplexer and furnace controller). This enables system components to be connected to separate COMM ports or GPIB port. When software starts, these parameters are pre-settled on their default values, but it is up to operator to set those with regard to their own hardware configuration.
Software provides an operator with choice between the two different types of temperature probes: thermocouples or RTD thermometers. Depending on this choice, the program automatically sets an appropriate measured type (voltage or resistance) and measuring range of the system multimeter.
The next set of configuration parameters are intended for setting number of samples taken from each probe, and also overall number of cycles for entire calibration process.
Last, but maybe the most important input parameter is the algorithm of a calibration process. The choice is given to the operator, to select one of several predefined algorithm types. Each algorithm is designed as the best response to the calibration requirements of a particular type of a temperature probe. And, if an operator decides that existing algorithms do not suite calibration requirements, there is still an option to create his own, so called "User defined algorithm". This option is recently added to the calibration software, considering a variety of commercially available temperature probes.
When all parameters are configured, there is just one more important issue which requires the operator's attention, to choose a directory for software to save the calibration results. After that, operator "pushes" the START button and the process of calibration starts. The Lab VIEW application follows the calibration program and sets temperatures and takes measurement without the further need for operator presence.

5. Results

In Figure 4 a result of an experiment is shown. During this experiment, the temperature plan was to measure temperature in three temperature points, 200 °C (20 minutes), 400 °C (20 minutes) and 600 °C (until operator stops the process, to show the long-term stability of temperature regulation). Temperature was measured with two Pt25 PRT (Platinum Resistance Thermometer).
It is visible from the graph that the temperature rises 200 degrees in about 20-25 minutes and the PID regulator after that keeps the temperature stable until the next request for new temperature point.

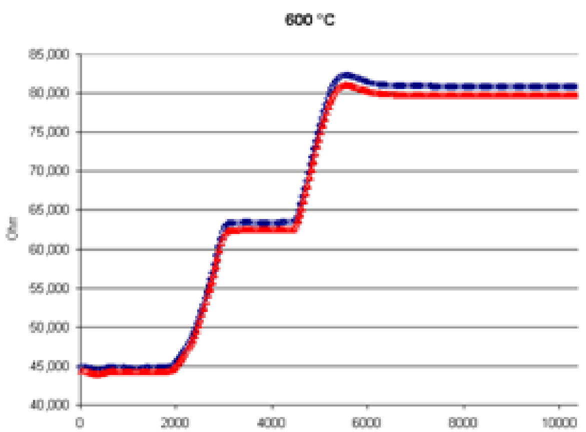
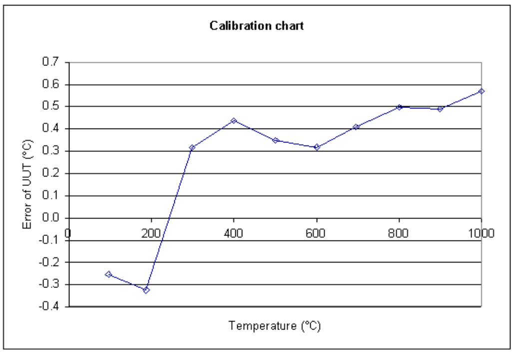


Fig. 4: Graphical representation of calibration results of two Pt25 temperature probes

The process of calibration will be similar to this graph. Data from at least two thermometers (one will be standard thermometer, the other will be unit under test – UUT) are collected during stable temperatures. Based on these results, after the calibration, the software generates a report in standard form for temperature calibration process.
Note: Data on the x-axis are proportional to the time of a measurement.
The Figure 5 shows an automatically generated report on the completed calibration. The report is given on example of calibration process in temperature range of 95 ° C – 1 000 ° C.

T_{cal} °C	T_{UUT} °C	Error of UUT °C	U °C
95.85	95.6	-0.3	0.15
186.92	186.6	-0.3	0.15
298.58	298.9	0.3	0.15
399.26	399.7	0.4	0.15
500.25	500.6	0.4	0.15
599.98	600.3	0.3	0.15
694.89	695.3	0.4	0.36
800.70	801.2	0.5	0.45
898.61	899.1	0.5	0.55
999.23	999.8	0.6	0.80

T_{cal} Temperature of calibration
T_{UUT} Reading of UUT
U Calibration uncertainty



The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor k = 2, which for a normal distribution corresponds to a coverage probability of approximately 95%. The standard uncertainty of measurement has been determined in accordance with Publication EA-4/02.

End of Certificate

Fig. 5: automatically generated report on the completed calibration.

6. Conclusion

This paper presents a system for automated thermometer calibration in a Laboratory for metrology. The system is developed in Lab VIEW environment. This system provides full control of calibration process and report generation with only initial assistance of laboratory staff. Results show that using this automated system time-consuming calibration process for thermometers can be done without full-time presence of laboratory staff.

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