www.s2is.org
International Journal on Smart Sensing and Intelligent Systems
ISSN 1178-5608

LabVIEW Based Characterization and Optimization of Thermal Sensors

Nasrin Afsarimanesh and Pathan Zaheer Ahmed
University of Pune
Pune, India
Email: afsarimanesh@yahoo.com, zabk@rediffmail.com

Submitted: Oct. 1, 2011 ***Accepted: Nov. 20, 2011*** ***Published: Dec. 6, 2011***

Abstract*- Reliable operation of a transducer carries a great importance while choosing it for a particular application.This project report characterization of thermistor, and RTD in detail. Thermal transducers are widely used transducers in most of the industrial and scientific instrumentation. These transducers of different types and parameters are commercially available in the market by different manufacturers. The manufactures need to test large volume for specifying the parameters of these devices. More over this test would serve as feedback for quality assurance and production schedule. Moreover any upgradation in processing technology proposed by the research and development activities has to be evaluated before launching in to the production. On the other hand the users of such transducers would need to test the critical parameters before they use it in a specific application. The LabVIEW software, its example and LabVIEW based characterization setup reported here offer reliable high speed solution with flexibility in the form of software adjustment for performing different test suitable to both categories such as manufacturers and the users.

Index terms*:* LabVIEW, Transdcer, RTD, Thermistor, AD590, Sampling and Optimization

1. INTRODUCTION

Any measurement system comprises the areas of detection, acquisition, control and analysis of data. The accuracy of the detection parameter depends upon: the type of transducers implied and considers being the heart of instrument and playing a key role. During the last four decades the technologies gives a number of sensors for number of physical variables and also miniaturize the size of sensors.

In past few years due to the advancement in technology the LabVIEW are available in the market with less cost, powerful and easy to use. It is now possible with relatively small expenditure to produce a system that will take the data quickly processes it and displays the results and / or control the process. Thus now days LabVIEW based experimental setup has become new trend. The lab view software and associated circuit put together offers, an easy to built, versatile enough setup. The figure 1 shows a lab view based system interface to sensor and associated analog circuit for data conditioning, analysis, display and control.

The primary objective of process control is to control physical parameter such as temperature, pressure, flow rate, level, force, light intensity and so on. As these parameter can change either spontaneously or because of external influences, we must constantly provide corrective action to keep these parameters constant or within the specified range.

To control process parameter, we must know the value of that parameter and hence it is necessary to measure that parameter. A transducer is a device that performs the initial measurement and energy conversion of a process parameter into analogous electrical or pneumatic information. Many times further transformation or signal conditioning may be required to complete the measurement function.

In practice very often it is required to measure various physical quantities such as velocity, acceleration, pressure, temperature etc. an electronic instrumentation system consist of a number of components which together are used to perform a measurement. An instrumentation system consists of three major elements input device, signal conditioning circuit and output device.

The input quantity for most instrumentation system is non electrical in order to use electrical methods and techniques for measurement the non electrical quantity is converted into proportional electrical signal by a device called “transducer”.

Temperature is the most often-measured environmental quantity. This might be expected since most physical, electronic, chemical, mechanical, and biological systems are affected by temperature. Some processes work well only within a narrow range of temperatures; certain chemical reactions, biological processes, and even electronic circuits perform best within limited temperature ranges [1-9].

2. Classification of Thermal sensors

In this section we will describe different types of sensors for measurement of temperatures.

2.1 RTDs

Resistance Temperature Detectors (RTDs) are wire wound and thin film devices that measure temperature because of the physical principle of the positive temperature coefficient of electrical resistance of metals. The hotter they become, the larger or higher the value of their electrical resistance [10-14]. They are most popular, nearly linear over a wide range of temperatures and some small enough to have response times of a fraction of a second. They are among the most precise temperature sensors available with resolution and measurement uncertainties of ± 0.1°C. Usually they are provided encapsulated in probes for temperature sensing and measurement with an external indicator, controller or transmitter, or enclosed inside other devices where they measure temperature as a part of the device's function, such as a temperature controller or precision thermostat.

RTDs can be made economically in copper and nickel, but the latter have restricted ranges because of non-linearities and wire oxidation problems in the case of copper. Platinum is the preferred material for precision measurement because in its pure form the temperature coefficient of resistance is nearly linear; enough so that temperature measurements with precision of ± 0.1°C can be readily achieved. All RTDs used in precise temperature measurements are made of platinum and therefore sometimes called PRTs. The advantages of RTDs include stable output for long period of time, simplicity of recalibration and accurate readings over relatively narrow temperature spans. Their disadvantages, compared to the thermocouples, are: smaller overall temperature range, higher initial cost and less rugged in high vibration environments. They are active devices requiring an electrical current to produce a voltage drop across the sensor that can be then measured by a calibrated read-out device.

In theory, any metal could be used to measure temperature. The metal selected should have a high melting point and an ability to withstand the effects of corrosion. Platinum has therefore become the metal of choice for RTDs. Its desirable characteristics include chemical stability, availability in a pure form, and electrical properties that are highly reproducible.

Platinum RTDs are made of either IEC/DIN grade platinum or reference grade platinum. The difference lies in the purity of the platinum. The IEC/DIN standard is pure platinum that is intentionally contaminated with other platinum group metals. The reference grade platinum is made from 99.999+ % pure platinum. Both probes will read 100Ω at 0°C, but at 100°C the DIN grade platinum RTD will read 138.5Ω and the reference grade will read 139.24Ω in RdF's maxiumum performance strain-free assemblies. International committees have been established to develop standard curves for RTDs. Only platinum RTDs have an international standard.

2.2 THERMISTORS

Thermistors are special solid temperature sensors that behave like temperature-sensitive electrical resistors [15-17]. Broadly, these are of two types, NTC-negative temperature coefficient thermistors and PTC-positive temperature coefficient thermistors. NTC are used mostly in temperature sensing [18-20], while PTC used mostly in electric current control [21-23].

Temperature sensors are mostly very small bits of special material that exhibit more than just temperature sensitivity. They are highly sensitive and have very reproducible resistance vs. temperature properties. During the last 70 years or so, only ceramic materials was employed for production of NTC thermistors. In 2003, Si and Ge high temperature NTC thermistors were developed with better performance than any ceramic NTC thermistors. Thermistors, since they can be very small, are used inside many other devices as temperature sensing probes for commerce, science and industry. Some of those novel digital medical thermometers that get stuck in one's mouth by a nurse with an electronic display in her other hand are based on thermistor sensors. Thermistors typically work over a relatively small temperature range, compared to other temperature sensors, and can be very accurate and precise within that range.

Most manufacturers will specify alpha and beta, and the R tolerance at the ambient temperature. Beta is temperature dependent, and is specified between two temperature points, and can be used to calculate Temperature between the specified temperatures, with a rated accuracy. For example, for a beta specified between 25 and 85 it will often be denoted as $B_{25/85}$. Alpha the temperature coefficient is often denoted as TCR on datasheets. Alpha is negative for NTC thermistors and positive for PTC thermistors.

2.3 AD590

The AD590 is a three terminal integrated circuit temperature transducer that produces an output current proportional to absolute temperature. For supply voltages between +4v and +30v the device acts as a high impedance constant current regulator passing 1uA/k. The AD590 should be used in any temperature sensing application below +150 degree C in which conventional electrical temperature sensors are currently employed. The AD590 is particularly useful in remote sensing applications. The device is insensitive to voltage drops over long lines due to its high impedance current output.

3. EXPERIMENTAL SET-UP

The block diagram representation of the experimental set-up is shown in Figure 1. The figures 2 to 4 show the pictures of the experimental set up for the characterization of the sensors.

Figure 1: Sensor characterization block diagram

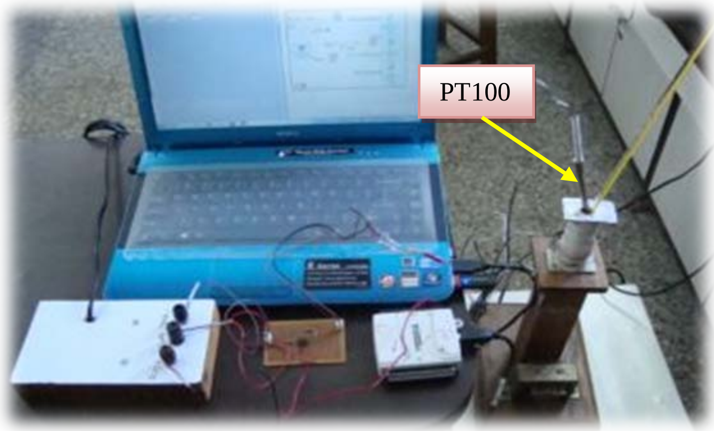

Figure 2: PT100 characterization set up

Figure 3: Thermistor charactrization set up

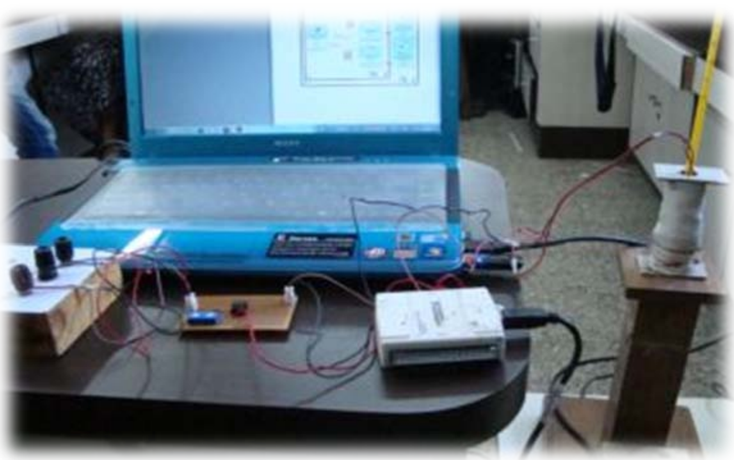

Figure 4: AD590 as a thermocouple

4. CHARACTERIZATION OF SENSORS

Figure 5 shows the signal conditioning circuit for PT100. It consists of potential divider arrangement comprising of resistor R4 and PT100.

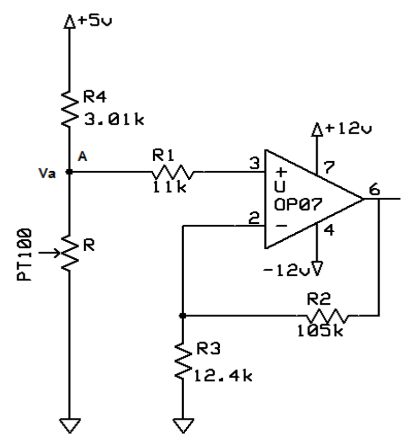

Figure 5: Signal Conditioning circuit for RTD(PT100)

As temperature changes resistance of PT100 changes that in turn produces changing voltage Va at point A. This voltage Va is then amplified using non-inverting amplifier whose gain is controlled using resistors R2 and R3. The voltage Va produced is applied to non-inverting terminal of op-amp via resistor R1.

Figure6 shows signal conditioning circuit for thermistor which is a simple voltage divider circuit. As temperature changes, resistance of thermistor changes that in turn output voltage will change.

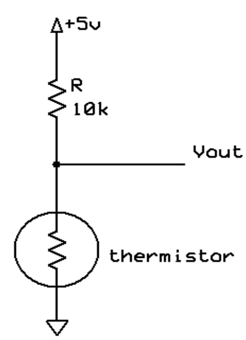

Figure 6: Thermistor signal conditioning circuit

In this work AD590 temperature sensor has been used as a thermometer which is shown in the

Figure 7. The output voltage of the circuit is directly proportional to the temperature.

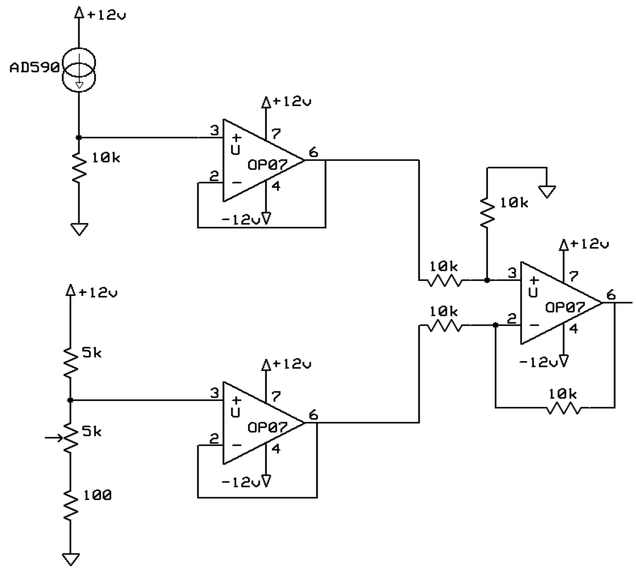

Figure 7: AD590 as a thermocouple

Figures 8 and 9 show the temperature vs voltage according to figures 5 and 6, respectively. It can be seen that PT100 is a positive temperature coefficient; with an increase in temperature there is an increase in voltage (resistance), this is the ideal characteristics of PT100.

Table 1: RTD temperature Vs voltage

Temperature(^{0} C)	Voltage (V)
30	300mv
35	350mv
40	400mv
45	440mv
50	490mv
55	540mv
60	585mv
65	640mv
70	690mv
75	745mv
80	790mv
85	840mv

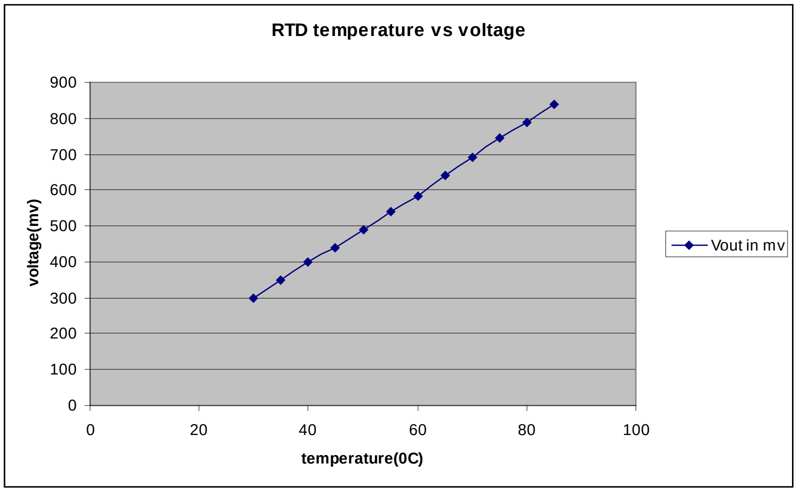

Figure 8: RTD temperature Vs voltage

Table 2: Thermistor temperature Vs voltage

Temperature(^{0} C)	Voltage (V)
40	3.65
45	3.45
50	3.21
55	3.02
60	2.75
65	2.52
70	2.32
75	2.10

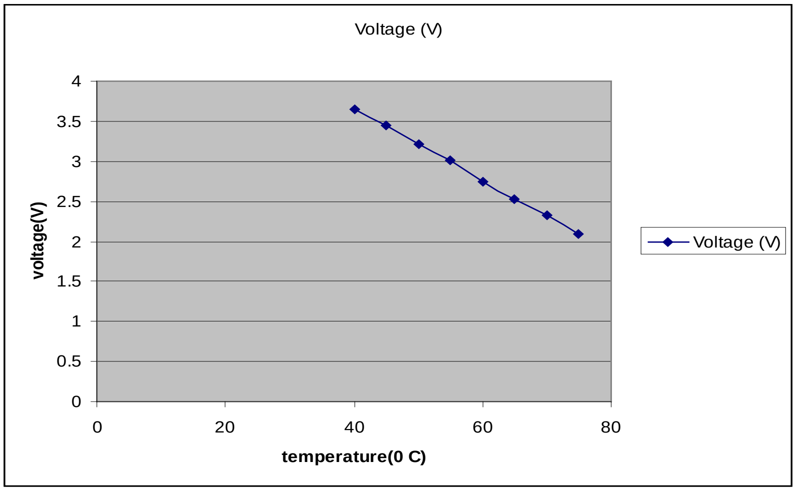

Figure 9: Thermistor temperature Vs voltage

5. SAMPLING AND OPTIMIZATION

Table 3 summarizes the number of samples, sampling frequency and delay for RTD and Thermistor. With variation in the number of samples, sampling frequency and delay, it's observed that the best result in terms of linearity, repeatability of RTD is obtained with 50/10k/10sec, and with Thermistor is obtained with 50/10k/1sec as shown in Figures 10 and 11.

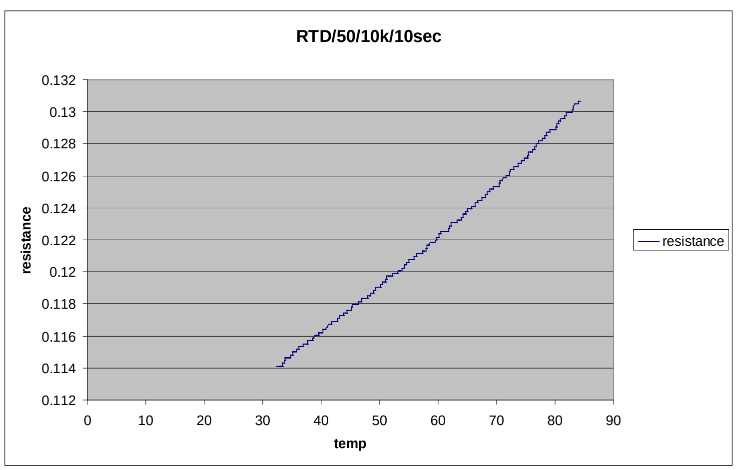

Figure 10: RTD resistance vs. temperature

Table 3: Sampling of RTD and Thermistor

Sr. NO	**No. of Samples**	**Sampling Frequency**	**Delay**
1	10	10K	1 Sec
2	10	10K	5 Sec
3	10	10K	10 Sec
4	10	15K	1 Sec
5	10	15K	5 Sec
6	10	15K	10 Sec
7	10	20K	1 Sec
8	10	20K	5 Sec
9	10	20K	10 Sec
10	50	10K	1 Sec
11	50	10K	5 Sec
12	50	10K	10 Sec
13	50	15K	1 Sec
14	50	15K	5 Sec
15	50	15K	10 Sec
16	50	20K	1 Sec
17	50	20K	5 Sec
18	50	20K	10 Sec

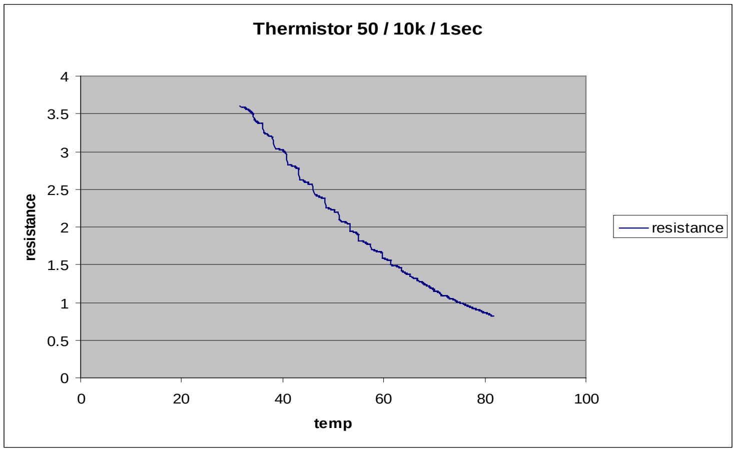

Figure 11: Thermistor resistance vs. temperature

6. CONCLUSION

The PT100 is a positive temperature coefficient; with an increase in temperature there as an increase in resistance this is the ideal characteristics of PT100. As per the output observed it is as per PTC. The ideal characteristics and outputs taken are compared both are approximately same as cold region.

The NTC thermistor is negative temperature coefficient; with an increase in temperature there as a decrease in resistance this is the ideal characteristics of NTC thermistor. As per the output observed it is as per NTC. The ideal characteristics and outputs taken are compared both are approximately same.

The value of Alpha, and R_0 from the experimentation and observation for RTD is 0.385% and 97.127 K ohms, respectively and for thermistor the value of Alpha, Beta and R_0 are -2.06%, 2558.634 K and 9.523471 K Ohms, respectively which are almost same as the real values.

7. REFERENCES

[1] Yoshihito Kurazumi, Tadahiro Tsuchikawa, Jin Ishii, Kenta Fukagawa, Yoshiaki Yamato and Naoki Matsubara, “Radiative and convective heat transfer coefficients of the human body in natural convection,” Building and Environment, Volume 43, Issue 12, 2008, pp. 2142-2153.

[2] İbrahim Gülseren and John N. Coupland, "Ultrasonic properties of partially frozen sucrose solutions," Journal of Food Engineering, Volume 89, Issue 3, 2008, pp. 330-335.

[3] Shinji Miyata, Bernd-Robert Höhn, Klaus Michaelis and Oliver Kreil, "Experimental investigation of temperature rise in elliptical EHL contacts," Tribology International, Volume 41, Issue 11, 2008, pp. 1074-1082.

[4] P. Sazama, H. Jirglová and J. Dědeček, "Ag-ZSM-5 zeolite as high-temperature water-vapor sensor material," Materials Letters, Volume 62, Issue 7, 2008, pp. 4239-4241.

[5] Bharathi Bai J. Basu and N. Vasantharajan, "Temperature dependence of the luminescence lifetime of a europium complex immobilized in different polymer matrices," Journal of Luminescence, Volume 128, Issue 10, 2008, pp. 1701-1708.

[6] Jianwei Shen and Yonghang Shen, "Investigation on the structural and spectral characteristics of deposited FBG stacks at elevated temperature," Sensors and Actuators A: Physical, Volume 147, Issue 1, 2008, pp. 99-103.

[7] R. Van Nieuwenhove and L. Vermeeren, "Irradiation effects on temperature sensors for ITER application," Rev. Sci. Instrum., Volume 75, 2004, pp. 75.

[8] J. Sanjuán, A. Lobo, M. Nofrarias, J. Ramos Castro and P. J. Riu, "Thermal diagnostics front-end electronics for LISA Pathfinder," Rev. Sci. Instrum., Volume 78, 2007, pp. 104904.

[9] Andrew S. Farmer, David P. Fries, William Flannery and John Massini, "Hand-held thermal-regulating fluorometer," Rev. Sci. Instrum., Volume 76, 2005, pp. 115102.

[10] W. Prost, V. Khorenko, A.C. Mofor, S. Neumann, A. Poloczek, A. Matiss, A. Bakin, A. Schlachetzki and F.J. Tegude, "High performance III/V RTD and PIN diode on a silicon (001) substrate," Applied Physics A: Materials Science & Processing, Volume 87, Number 3, 2007.

[11] Jikwang Kim, Jongsung Kim, Younghwa Shin and Youngsoo Yoon, "A study on the fabrication of an RTD (resistance temperature detector) by using Pt thin film," Korean Journal of Chemical Engineering, Volume 18, Number 1, 2001.

[12] Sunit Kumar Sen, "An improved lead wire compensation technique for conventional two wire resistance temperature detectors (RTDs)," Measurement, Volume 39, Issue 5, (2006), pp. 477-480.

[13] Muhammad Imran and A. Bhattacharyya, "Thermal response of an on-chip assembly of RTD heaters, sputtered sample and microthermocouples," Sensors and Actuators A: Physical, Volume 121, Issue 2, 2005, pp. 306-320.

[14] L.R. Klopfenstein Jr., "Software linearization techniques for thermocouples, thermistors, and RTDs," ISA Transactions, Volume 33, Issue 3, 1994, pp. 293-305.

[15] Liang Dong, Ruifeng Yue and Litian Liu, "An uncooled microbolometer infrared detector based on poly-SiGe thermistor," Sensors and Actuators A: Physical, Volume 105, Issue 3, Volume 2003, pp. 286-292.

[16] Nitya Vittal, R.C. Aiyer, C.R. Aiyer, M.S. Setty, S.D. Phadke and R.N.Karekar, "Formulation of silver loaded manganite based thermistor paste and application of 18 percolation theory for sudden transition in conductance," J. Appl. Phys., Volume 64, 1988, pp. 5244.

[17] Nitya Vittal, G. Srinivasan, C.R. Aiyer and R.N. Karekar, "Correlation between X-ray diffraction studies and conductivity dependence of Ag loading in thick-film thermistors," J. Appl. Phys., Volume 68, 1990, pp. 1940.

[18] Shweta Jagtap, Sunit Rane, Suresh Gosavi and Dinesh Amalnerkar, "Preparation, characterization and electrical properties of spinel-type environment friendly thick film NTC thermistors," Journal of the European Ceramic Society, Volume 28, Issue 13, 2008, pp. 2501-2507.

[19] C. Molina, L. Victoria and J.A. Ibáñez, "Measurement of volume flow through a microporous membrane by a NTC thermistor miniature bead**,"** Rev. Sci. Instrum., Volume 65, 1994, pp. 2726.

[20] Xinyu Liu, Ying Luo and Xvqiong Li, "Electrical properties of BaTiO3-based NTC ceramics doped by BaBiO3 and Y2O3," Journal of Alloys and Compounds, Volume 459, Issues 1-2, 2008, pp. 45-50.

[21] M.A. Zubair and C. Leach, "The influence of cooling rate and SiO2 additions on the grain boundary structure of Mn-doped PTC thermistors," Journal of the European Ceramic Society, Volume 28, Issue 9, 2008, pp. 1845-1855.

[22] Markus Wegmann, Rolf Brönnimann, Frank Clemens and Thomas Graule, "Barium titanate-based PTCR thermistor fibers: Processing and properties," Sensors and Actuators A: Physical, Volume 135, Issue 2, 2007, pp. 394-404.

[23] Marko Hrovat, Darko Belavič, Jaroslaw Kita, Janez Holc, Jena Cilenšek, Leszek Golonka and Andrzej Dziedzic, "Thick-film PTC thermistors and LTCC structures: The dependence of the electrical and microstructural characteristics on the firing temperature," Journal of the European Ceramic Society, Volume 27, Issue 5, 2007, pp. 2237-2243.