Demonstration of the NTC Ceramic Application for Temperature Measurement and Control Using the LabVIEW-Based Measurement System

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Abatract

In the present paper, $ZnO+0.01SnO_2$ ceramics were prepared using a standard ceramic method. We present the NTC ceramic application for temperature measurement and control using the LabVIEW-based measurement system. The measured resistance of the sample at room temperature was about 6.5 kΩ. The electrical resistance versus temperature of the sample was measured. The negative temperature coefficient of resistance of the sample was -1.018 %/°C. This sample showed NTC effect and exhibited NTC resistor, indicating their potential application as temperature sensor with low cost. It can be used as temperature sensor by using the NTC effect . The measured temperature (T) varies with voltage drop across the sample (Vs), as shown in the eq^n, $T = -6.125V_s^2 - 29.336V_s + 109$. The self-heating of the sensor was negligible. The sensitivity of temperature measurement provides 3°C resolution. The experimental setup and technical aspects for oven temperature control system was presented. The apparatus described here was suitable for controlling oven in constant temperature room and operated on the principle of supplying a constant input energy that was maintained by alternately raising and lowering the input voltage between two limits. This apparatus was simple, easily obtained, and allowed of temperature control within very close limits. The aim of this paper was to introduce a system developed for measuring sample resistance versus temperature using a procedure based on virtual instrumentation. The measurements and processing of the data were made using LP connector, a DAQ data acquisition card, computer and LabVIEW program. The system was able to store and display the data. This prepared system can, in addition, be used for oven temperature control testing. $ZnO+0.01SnO_2$ sample can be used as temperature measurement and control sensor. LM335 was used for calibration for measure temperature using $ZnO+0.01SnO_2$ sample. The operation of this sample for temperature control will use the comparison result between the measured temperature (T) and setpoint temperature (Tset). This result will control the operation of relay and solid state relay. The input power to the electric oven was controlled by solid state relay and using LabVIEW program. So, the oven temperature control system using $ZnO+0.01SnO_2$ temperature sensor and LabVIEW-based masurement system was successfully constructed and tested. This system can be used in the temperature range of 30°C to 100°C. The system has been put into operation this year and all its units have functioned well.

Key words : temperature sensor , temperature measurement and control sensor , LabVIEW

Introduction

Some properties of matter are strongly temperature dependent so that, if properly exploited, they may be sucessfully used for temperature measurements and controls.[5] Resistance changes with temperature of some ceramics were already used for temperature controls, and devices using such magnetic sensors were reported in the past. The interest for temperature sensors is due to their high rate of change of resistivity with temperature. Negative temperature coefficient (NTC) thermistors are semiconducting ceramics. Resistance R measured at room temperature provides the resistivity $\rho=RA/L$ with A the metallized surface and L the thickness when components have a cylindrical disc shape. Their resistivity varies exponentially with temperature, as shown in the following Arrhenius equation:

$$\rho=\rho_o exp(B/T) \qquad (1)$$

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where ρ_o is the resistivity of the material at infinite temperature, T is the absolute temperature, and B is the constant, sometimes called the coefficient of temperature sensitivity. Thermistor sensitivity is defined by :

$$\alpha=(1/\rho)(d\rho/dT)=-B/T^2 \qquad (2)$$

A thermostat is a device for regulating the temperature of a system so that the system's temperature is maintained near a desired setpoint temperature. The thermostat does this by controlling the flow of heat energy into or out of the system. That is, the thermostat switches heating or cooling devices on or off as needed to maintain the correct temperature. The thermostat can be constructed in many ways and use a variety of sensors to measure the temperature. The output of the sensor then controls the heating or cooling of the oven. Common sensors include electronic thermistor, electrical thermocouple and LM335. These may then control the heating or cooling apparatus using electrical signal. A number of laboratory measurements require a constant and uniform ambient temperature.

A common characteristic of the mentioned data acquisition systems is the use of data loggers or microcontrollers for measuring and acquiring the signals and transmitting them to a PC through serial port RS-232.[1,3]

The present investigation reports on the results obtained on $ZnO+0.01SnO_2$ such as temperature sensor and an application of this in a device for oven temperature control in the range of 30-100°C. The functioning of the equipment was based on the so-called virtual instrumentation and the programs were developed using LabVIEW. The data were transmitted and stored in a computer through data acquisition board. The monitoring variables were processed and displayed in the computer screen using virtual instruments developed with LabVIEW.

Materials and Experimental Procedures

Sample Preparation

The materials were prepared by the standard ceramic technique using reagent grade raw oxides. High purity ZnO and SnO_2 powders were used. Preparation sample composition was $ZnO+0.01SnO_2$. The powders were weighed and mixed in a mortar and a mixer for 10 min. 1 wt.% of an organic binder (PVA) was added and they were then pressed at 265 MPa into 12 mm diameter and about 2.5 mm height cylindrical pellets. The pellets were fired at 1200°C with the furnace heating rate at about 5°C/min for 4 h. The opposite sites of the fired pellets were coated with a silver paste and the components were fired at 120°C for 15 min.
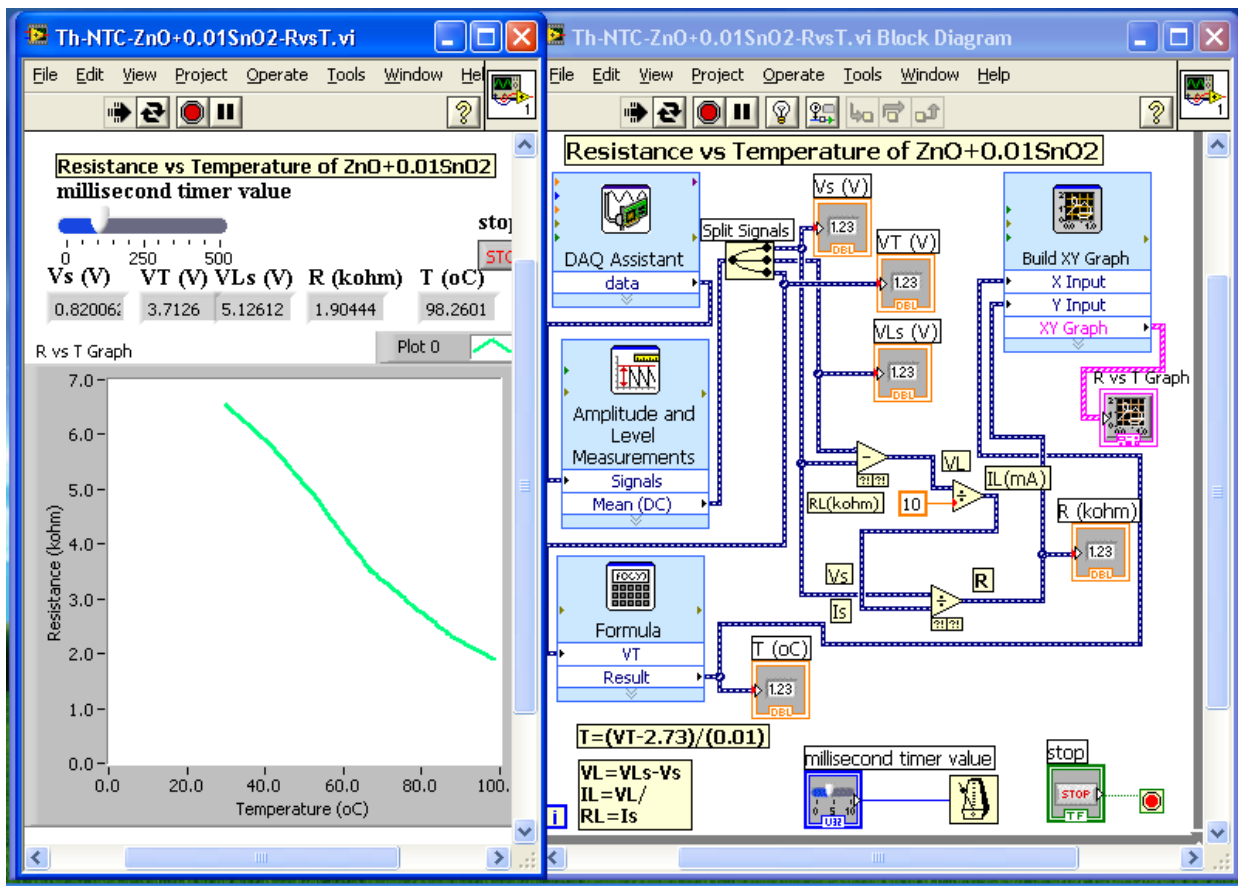
Resistance Versus Temperature Measurement

Experiment setup for resistance vs temperature of NTC sample with LabVIEW is shown in Figure 1. Front Panel and Block diagram for resistance vs temperature of NTC sample with LabVIEW is shown in Figure 2. The used sample was $ZnO+0.01SnO_2$. The load resistance (RL)
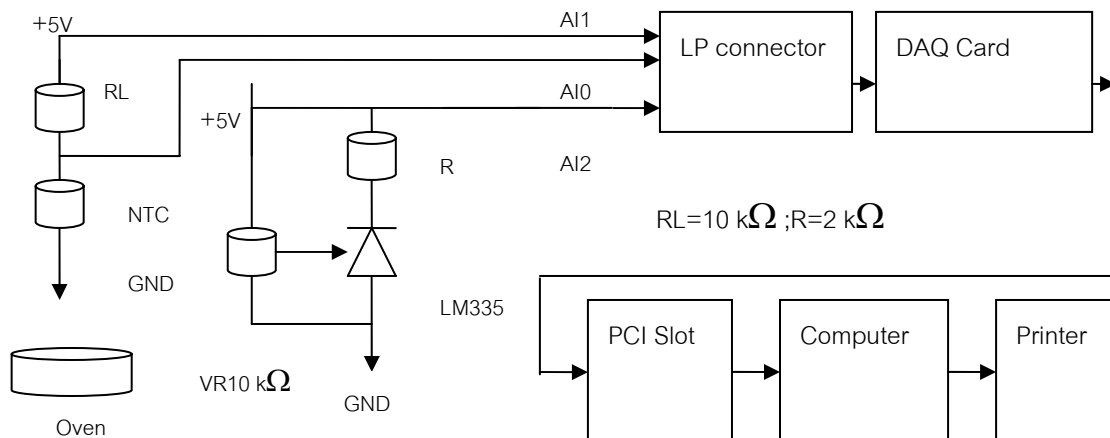
Figure 1. Experiment setup for resistance vs temperature of NTC sample with LabVIEW.

*Demonstration of the NTC Ceramic Application for Temperature Measurement
and Control Using the LabVIEW-Based Measurement System*

Figure 2.   Front Panel and Block Diagram for resistance vs temperature of NTC sample with LabVIEW.

was 10 kΩ. Heat source was an electric oven. The equipment was developed using LP connector, a DAQ data acquisition card, computer and LabVIEW program commercially supplied by National Instruments Corporation (http://www.ni.com). When the program started, the main menu of the LabVIEW came to screen. Users were expected to creat the Front Panel and Block Diagram and set the properties of virtual devices and virtual instruments. The principle of operation was an electronic load connected in series with the sample as voltage divider. This load resistor-ceramic sample voltage divider was used to supply voltage as input to the LP connector and DAQ card. This card was used to capture the V_s and V_{Ls} signals generated in this voltage divider. Current from 5 V dc power supply flowed through a load resistor (RL) of 10 kΩ and sample resistance (Rs). Voltage drop across Rs and RL+Rs were Vs and VLs. oltage (VT) was generated using temperature sensor (LM335) for sample temperature measuring. Voltage Vs, VLs and VT were transmitted to AI0,

AI1 and AI2 of LP connector, DAQ Card, PCI slot and computer, respectively. DAQ Assistant worked by receiving voltage Vs, VLs and VT from LP connector and transmitted through DAQ Card into computer. Vs and VLs were transmitted to Amplitude and Level Measurements for Mean (DC) measuring. Split signal splited Vs, VLs and VT.   For resistance determination, Vs and VLs were transmitted to Substract for VL=VLs-Vs. Load current (IL) was calculated with IL=VL/RL. Sample current (Is) and load current (Is=IL) were equal.   Sample resistance (R) was calculated with R=Vs/Is.   Resistance value (R) was displayed with Numeric Indicator.   Voltage (VT) was transformed to be temperature (T) with Formula and T=(VT-2.73)/(0.01).   Temperature value (T) was shown with Numeric Indicator. Temperature (T) and Resistance (R) of the sample were transmitted to X Input and Y Input of Build XY Graph for displaying R vs. T graph.   The sample was heated in oven.   The program was run to show the result. The Front Panel and Block Diagram were saved in computer and printed with printer.   The computer will control the entire measurement process.
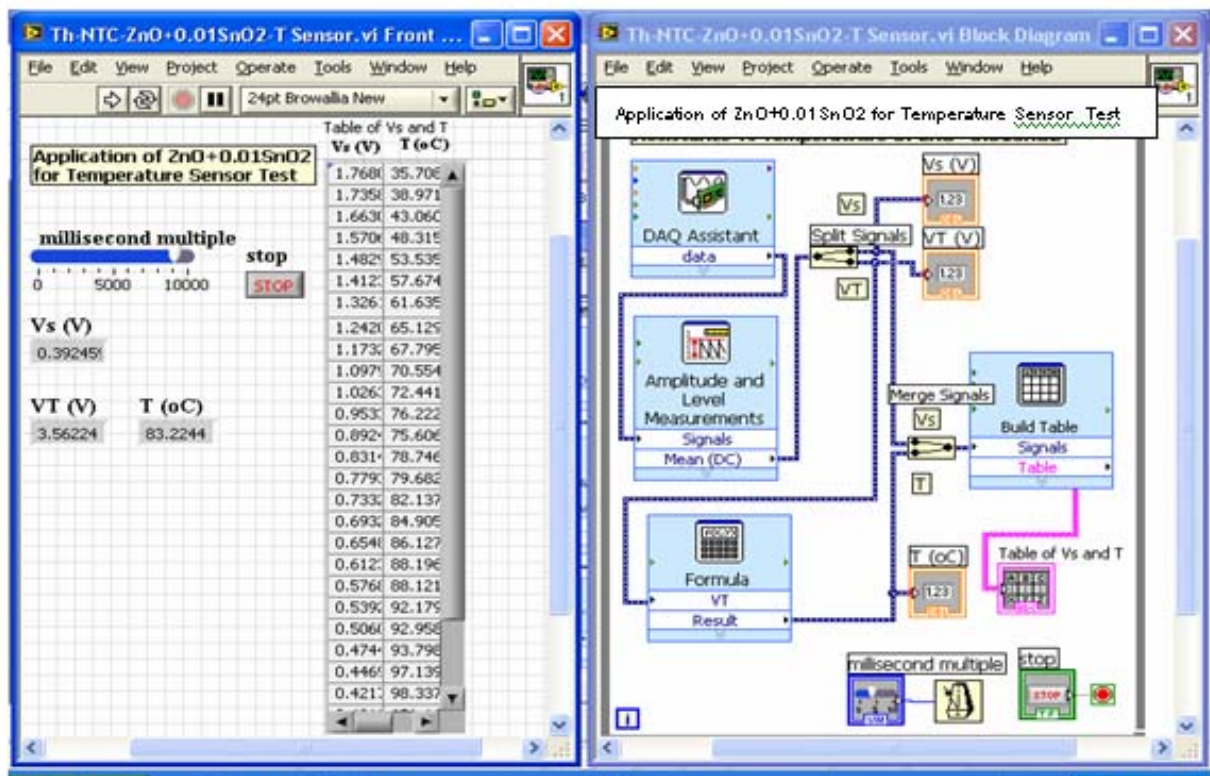
The Determinaton for Temperature from LM335 (T) Versus Voltage Drop Across the ZnO+0.01SnO₂ Sample (T vs Vs)

Experiment setup for the determination of temperature from LM335 (T) versus voltage drop across the $ZnO+0.01SnO_2$ sample (T vs Vs) with LabVIEW is shown in Figure 1. Front Panel and Block Diagram for displaying temperature from LM335 versus voltage drop across the $ZnO+0.01SnO_2$ sample (T vs Vs) with LabVIEW is shown in Figure 3. The relation of true temperature from LM335 from computer screen (T)
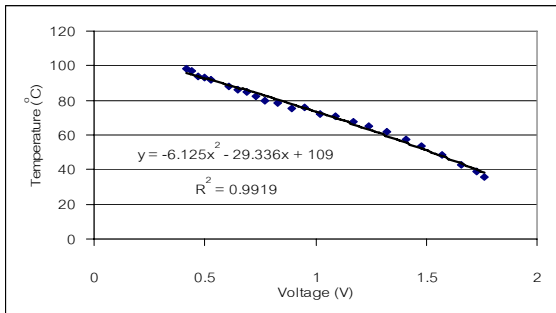
and voltage drop across sample ($ZnO+0.01SnO_2$) (V) were displayed using Build Table. This program was RUN. The T=f(Vs) curve and the equation were written using EXCEL Figure 4. The resultant equation was $T = -6.125V_s^2 - 29.336V_s + 109$.

Temperature Measurement Using the ZnO+0.01SnO₂ Sample

Front Panel and Block Diagram for temperature measurement using the $ZnO+0.01SnO_2$ sample is shown in Figure 5. The relation of
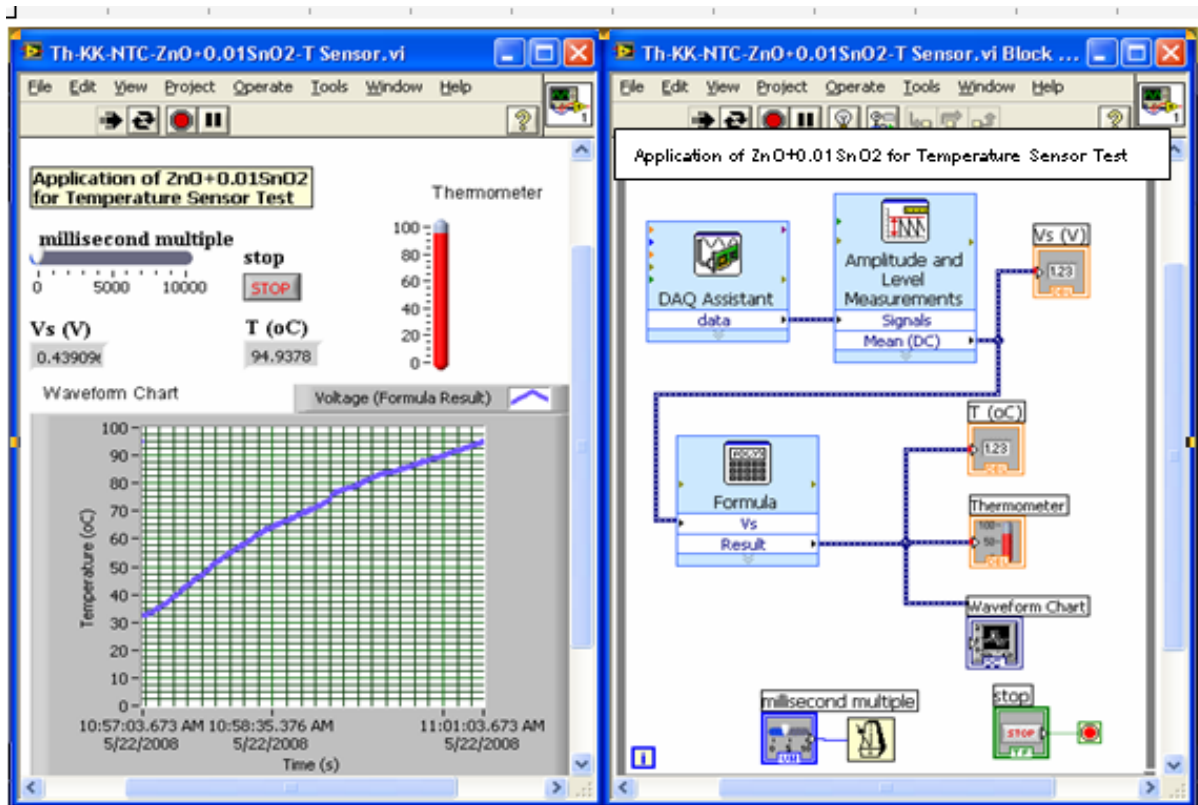

Figure 3. Front Panel and Block Diagram for temperature from LM335 (T) versus voltage drop across the $ZnO+0.01SnO_2$ sample (T vs Vs).

Figure 4. The relationship for temperature from LM335 (T) versus voltage drop across the $ZnO+0.01SnO_2$ sample (T vs Vs).

$T = -6.125V_s^2 - 29.336V_s + 109$ was written into Formula for transforming the voltage across the sample (Vs) to be the oven temperature (T). So, the $ZnO+0.01SnO_2$ sample can be operated as temperature sensor for measuring the oven temperature. The oven temperature value is displayed using Numeric Indicator and The T vs. t curve is displayed using Waveform Chart.
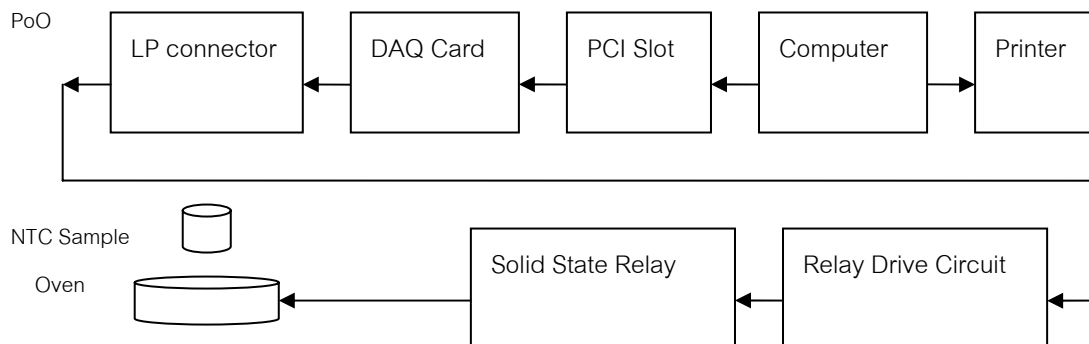
Figure 5. Front Panel and Block Diagram for temperature measurement using the ZnO+0.01SnO$_2$ sample.

Relay On-off Control Test

The experiment setup for Relay ON-OFF control is shown in Figure 6. Front Panel and Block Diagram for relay on-off control is shown in Figure 7. For Loop and Greater were used for generating the 5 V and 0 V. DAQ Assistant was used for transmitting the 5 V and 0 V out from computer to relay drive circuit. Voltage supplying to solid state relay was controlled using switch 3-5. Solid state relay was used to control voltage flowing through oven heating element.

NTC Temperature Sensor Application for Oven Temperature Control

Experiment setup for NTC temperature sensor application for oven temperature control with LabVIEW is shown in Figure 8. Front Panel and Block diagram for NTC temperature sensor application for oven temperature control with LabVIEW is shown as Figure 9. The used sample was ZnO+0.01SnO$_2$. The load resistance (RL) was 10 kΩ. Heat source was an electric oven. The equipment was developed using LP connector, a

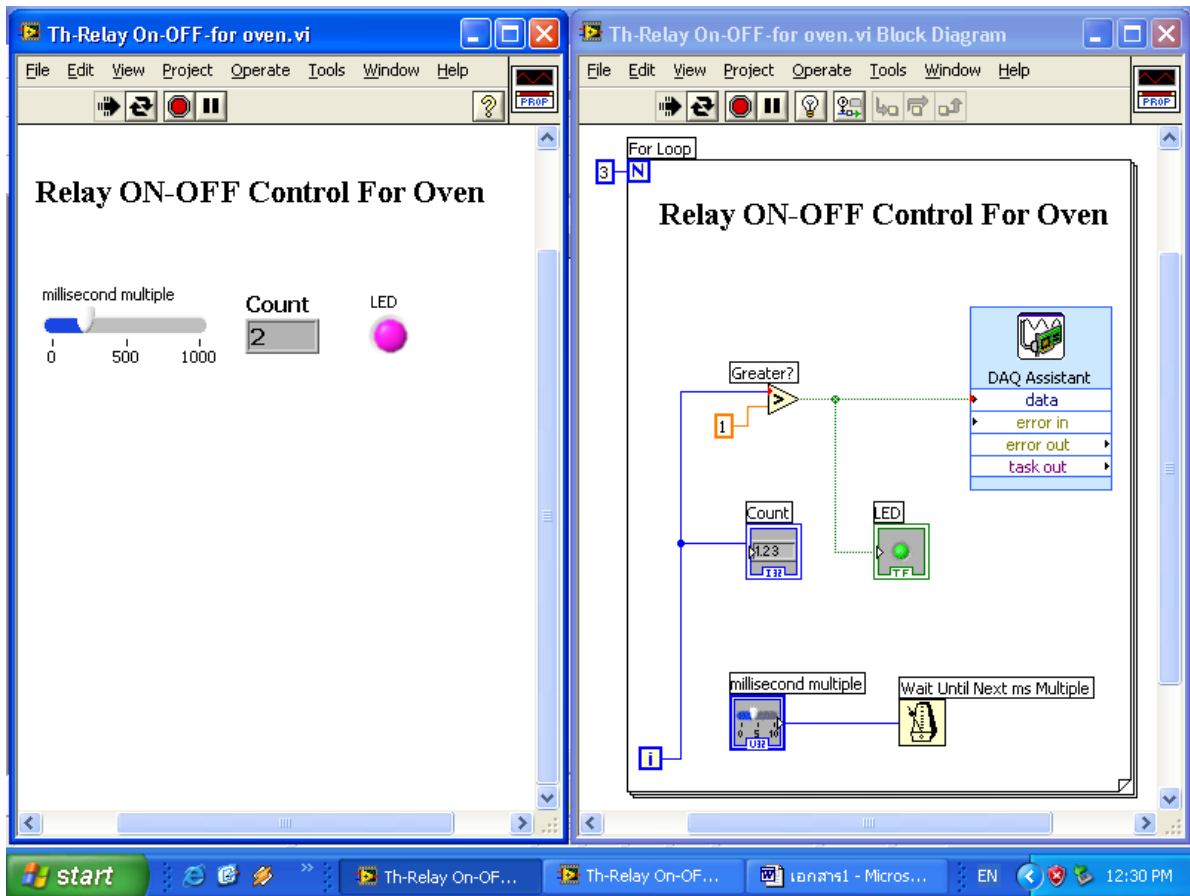**Figure 6**. The experiment setup for Relay ON-OFF control.

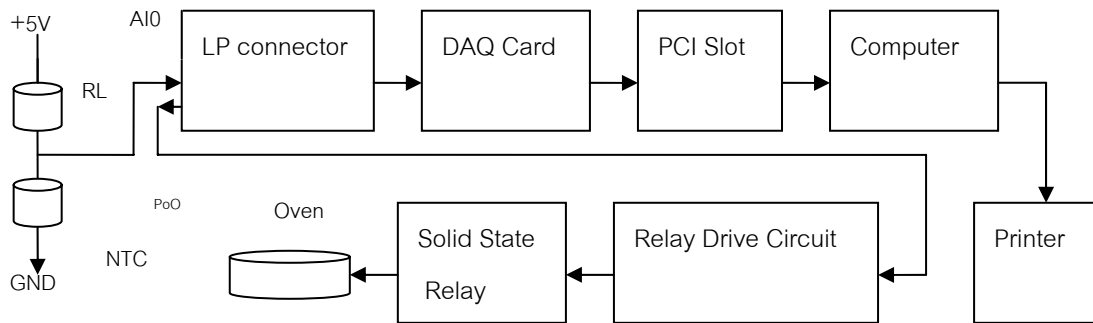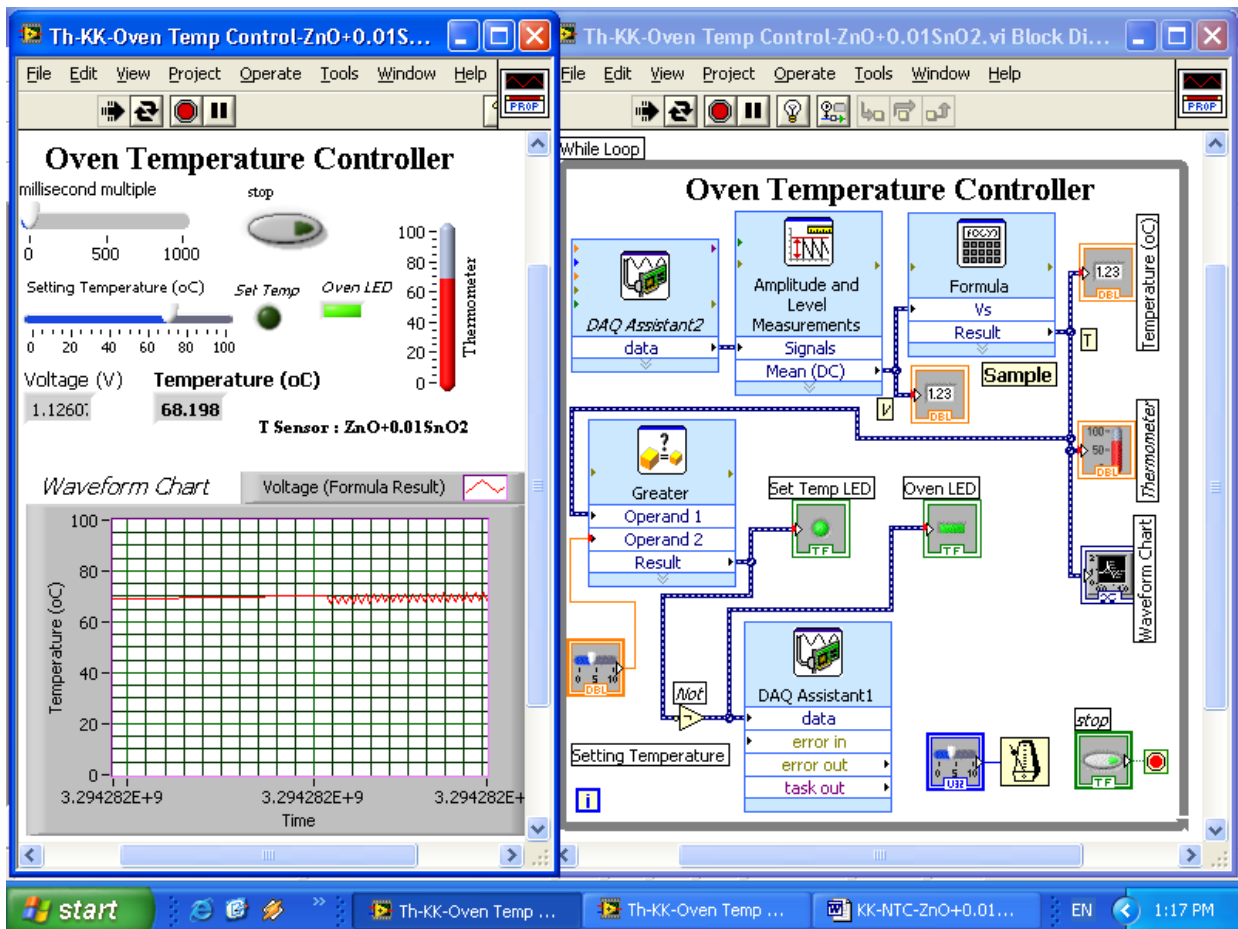**Figure 7**. Front Panel and Block Diagram for relay on-off control.

Figure 8. Experiment setup for NTC temperature sensor application for oven temperature control with LabVIEW.

Figure 9. Front Panel and Block diagram for NTC temperature sensor application for oven temperature control with LabVIEW.

DAQ data acquisition card, computer and LabVIEW program commercially supplied by National Instruments Corporation.[4] When the program started, the main menu of the LabVIEW came to screen. Users were expected to creat the Front Panel and Block Diagram and set the properties of virtual devices and virtual instruments. The principle of operation was an electronic load connected in series with the sample as voltage divider. This load resistor-ceramic sample voltage divider was used to supply voltage as input to the LP connector and DAQ card. This card was used to capture the V_s signals generated in this voltage divider. Current from 5 V dc power supply flowed through a load resistor (RL) of 10 kΩ and sample resistance (Rs). Voltage drop across Rs was Vs. Voltage Vs was transmitted to AI0 of LP connector, DAQ Card, PCI slot and computer, respectively. DAQ Assistant2 worked by receiving voltage Vs from LP connector and transmitted

through DAQ Card into computer. Vs and VLs were transmitted to Amplitude and Level Measurements for Mean (DC) measuring. The oven temperature (T) was calculated from the equation of T = $-6.125V_s^2$ - $29.336V_s$+109 and using Formula. For temperature control, initially, oven was cool, oven temperature (T) was transmitted to Operand 1 of Greater and setting temperature (Tset) was transmitted to Operand 2 of Greater. The oven temperature (T) was less than the setting temperature (Tset). The result (5V) from Greater was transmitted to Not gate. Set Temp LED was dark. Oven LED was light. The voltage from Not gate was transmitted to DAQ Assistant1. DAQ Assistant1 will control for transmitting the 0 V to relay drive circuit, switch 3-5 was opened. Solid state relay electrically conducted, the electric current of 220 V flowed through oven heating element. Oven temperature increased. Finally, when the oven was heated, the oven temperature (T) was

greater than setting temperature (Tset). The result (0V) from Greater was transmitted to Not gate. Set Temp LED was light. Oven LED was dark. The voltage from Not gate was transmitted to DAQ Assistant1. DAQ Assistant1 controlled for transmitting the 5 V to relay drive circuit, switch 3-5 was closed. Solid state relay did not electrically conducted, the electric current of 220 V can not flow through oven heating element. Oven temperature decreased. When this operation was repeated, the oven temperature was controlled successfully. The oven temperature value (T) was displayed with Numeric Indicator. The oven temperature versus time curve was displayed using Waveform Chart. Program was run to show the result. Print Screen button was used for transferring picture of T vs. t curve onto working area of Microsoft Word and was saved in text file. Front Panel and Block Diagram were saved in computer and printed with printer. The computer will control the entire measurement process. This was done in order to control the temperature of the electric oven.

Results and Discussion

Temperature Sensor

The tested sample was $ZnO+0.01SnO_2$. The measured sample resistance versus temperature at room temperature using the LabVIEW-based measurement system is shown in Figures 1 and 2. As revealed in these figures, the resistance of the sample at room temperature was 6.5 kΩ. When temperature increased, sample resistance decreased in the range of 30-100°C. So, the sample exhibited NTC resistor, indicating their potential application as temperature sensor with low cost. Under thermal radiation, electron–hole pairs were created, the sample behaved NTC property. The calculated negative temperature coefficient of resistance (α) was calculated using the expression : $\alpha = (1/R)(dR/dT)$; $\alpha = (1/R1)(R_2-R_1)/(T_2-T_1) \times 100$; $\alpha = -1.018$ %/°C, where R_2 and R_1 were the sample resistance at temperature of T_2 and T_1, respectively. So, the calculated negative temperature coefficient of resistance of the sample was -1.018 %/°C. Comparison between this value and the reported value by Moulson (α= -1 to -7 %/°C) showed that this $ZnO+0.01SnO_2$ sample was in NTC thermistor group.[5] The application of NTC ceramics for temperature sensor application was studied by measuring the temperature versus

voltage drop across load resistor (Figures 3 and 4). The measured temperature (T) varies with voltage drop across the sample (Vs), as shown in the equation: $T= -6.125V_s^2 - 29.336V_s+109$. The self-heating of the sensor was negligible. The sensitivity of temperature measurement provides 3°C resolution. So, this sample can be used as temperature sensor by using this NTC effect. Ceramic sample was used by Dipika, Saha for measuring in the temperature range of 50–150°C using $Mn_xFe_{1-x})_2O_3$ sample.[2] So, this present paper describes the application of NTC ceramics in a similar range of temperature that is reported by Dipika, Saha.

NTC Temperature Sensor for Oven Temperature Control System

Front Panel and Block Diagram for temperature measurement using the $ZnO+0.01SnO_2$ sample is shown in Figure 5. The experiment setup for Relay ON-OFF control is shown in Figure 6. Front Panel and Block Diagram for relay on-off control is shown in Figure 7. The experiment setup was prepared for NTC temperature sensor for oven temperature control and is shown in Figure 8.

Front Panel and Block Diagram for oven temperature control is shown in Figure 9. We present the NTC ceramic application for temperature measurement and control using the LabVIEW-based measurement system. From this figure, temperature control corresponded to on-off techniques using solid state relay and the LabVIEW-based measurement system. Voltage supply from source to oven was controlled by solid state relay using the $ZnO+0.01SnO_2$ temperature sensor. So, this sample can be used as temperature measurement and control sensor in the range of 30-100°C. This system will be used for other experiments in the future.

Conclusions

1) In conclusion, $ZnO+0.01SnO_2$ pellets fabricated by standard ceramic techniques have disc-shaped form. These samples exhibited thermal response and were found to be suitable for NTC thermistor applications over a 30-100°C temperature range.

2) The low cost temperature control system was made up of relay drive circuit, solid-

state relay, temperature sensor ($ZnO+0.01SnO_2$), LP connector, a DAQ data acquisition card, computer and LabVIEW program. The solid-state circuitry ensures accurate operation of this system.

3) An automatic, low cost data acquisition system for monitoring and controlling the temperature has been developed using a procedure based on virtual instrumentation. It measures and displays graphics of the results. The proposed equipment was used for processing, displaying and storing the collected data.

4) This test has conducted from May 2008 and indicated that the equipment developed was suitable for controlling the oven temperature. This experimental work was carried out at the Physics Department, Faculty of Science, Prince of Songkla University, Thailand. The work presented was part of a research project and in the near future will be used for further tests.

Acknowledgements

References

1. Barney, George C. 1988. *Intelligence Instrumentation : Microprocessor Applications in Measurement and Control.* 2nd ed. New York : Prentica Hall : 467.

2. Dipika, Saha. 2002. Preparation of bixbyite phase $(Mn_xFe_{1-x})_2O_3$ for NTC thermistor applications. *Mater. Lett*. **55(6)** : 403-406.

3. Forero, N. 2006. Development of a monitoring system for a PV solar plant. *Energy Conversion and Management.* **47(15-16)** : 2329-2336.

4. Http://www.ni.com, 1993-2001. *LabVIEW IM Basic I. Introduction Course Manual.* National Instruments Corporation.

5. Moulson, A.J. and Herbert, J.M. 1990. *Electroceramics.* London : Chapman & Hall :