SOFIA, 2012 VOLUME 6, NUMBER 1 ISSN 1314-0078

ANNUAL JOURNAL

OF

ELECTRONICS

Technical University of Sofia

Faculty of Electronic
Engineering and Technologies

ANNUAL JOURNAL OF ELECTRONICS

The Journal is issued by the FACULTY OF ELECTRONIC ENGINEERING AND TECHNOLOGIES, TECHNICAL UNIVERSITY of SOFIA, BULGARIA.

The Journal includes the selected papers from the International Scientific Conference Electronics ‘12, held on 19 – 21 September 2012 in Sozopol, Bulgaria.

SOFIA, 2012 VOLUME 6, NUMBER 1 ISSN 1314-0078

ANNUAL JOURNAL

OF

ELECTRONICS

Technical University of Sofia

Faculty of Electronic
Engineering and Technologies

ANNUAL JOURNAL OF ELECTRONICS

The Journal is issued by the FACULTY OF ELECTRONIC ENGINEERING AND TECHNOLOGIES, TECHNICAL UNIVERSITY of SOFIA, BULGARIA.

The Journal includes the selected papers from the International Scientific Conference Electronics ‘12, held on 19 – 21 September 2012 in Sozopol, Bulgaria.

CONTENTS

BOOK 1

INDEX

Resistor Temperature Coefficients Extraction Using myDAQ

Georgi Todorov Nikolov and Boyanka Marinova Nikolova

Abstract - **Resistor temperature coefficients, play an important role in electronic circuits design and sizing, where often the worst case operating condition dictates the design. This paper describes method for direct measurement of the temperature coefficients of the resistor using low cost module myDAQ and possibility of virtual instrumentation. The main objective of present work is to demonstrate how with virtual instrumentation can be solved some difficult engineering problems such as temperature coefficients measurement and model parameters extraction.**

Keywords – **LabVIEW, myDAQ, resistor temperature coefficients, SPICE simulation**

I. Introduction

For the design of electronic devices and instruments, designers select passive components with specific base parameters' values. This values dependents on the length, cross sectional area of the material they are made from. The quoted value of however is actually given at a particular temperature, because the temperature of the component also affects its value [1].

For this reason, designers also must make sure the parameter value doesn't change too much when the temperature changes. The change in resistance or capacitance due to a change in temperature is normally quite small over a particular temperature range. This is because the manufacturer has chosen a material having a characteristics not greatly influenced by temperature. However, to ensure parameter change is minimized, designers measure and calculate the change in component value for a change in temperature value and obtain the temperature coefficients. Further this temperature coefficients can be used to predict behaivior of the component versus temperature changes using simulation procedures.

In this work a general applicable method for direct extraction of the resistor temperature coefficients is presented. For temperature sensing element a platinum resistive temperature detector is choosen. As measurement device is selected National Instrument's myDAQ, which is modular device with USB connection to the computer platform. One of the benefits of using National Instruments boards is the availability of DAQmx drivers for the measurement hardware. The other benefit is that myDAQ is part of National Instruments circuits teaching solution. The circuits teaching solution is the complete platform of software, hardware, and courseware for educators to build student expertise through practical application in design, prototyping, and testing of electronic circuits [4]. In this environment, students should be able to compare the results of a simulated and real measured data in the same time.

[1]Georgi Nikolov is from the Faculty of Electronic Engineering and Technologies at Technical University of Sofia, 8 Kl. Ohridski Blvd, Sofia 1000, Bulgaria, E-mail: gnikolov@tu-sofia.bg.

[2]Boyanka Nikolova is from the Faculty of Telecommunications at Technical University of Sofia, 8 Kl. Ohridski Blvd, Sofia 1000, Bulgaria. E-mail: bnikol@tu-sofia.bg.

II. Resistor Temperature Coefficients

By definition the temperature coefficient *TCX* is the relative change of a physical property *X* by changing the temperature *T*. Therefore [1]:

$$TCX = \frac{dX}{X.dT}, \text{ °C}^{-1} \text{ or K}^{-1}. \quad (1)$$

For the linear temperature dependences, *TCX* is constant and the physical property can be calculated by:

$$X(T) = X(T_{ref})(1 + TCX.\Delta T), \quad (2)$$

where T_{ref} is the reference temperature, and ΔT is the difference between T and T_{ref}.

For quantities that vary polynomially, exponentially or logarithmically with temperature, it can be used more than one temperature coefficients for a useful approximation for a certain range of temperatures.

The temperature coefficient of resistance is a number used to predict how the resistance of a material changes with changes in temperature. The electronic manufacturer has chosen a materials with low temperature coefficient and so the resistor has a low temperature coefficient as well. Therefore the change in resistance due to a change in temperature is normally quite small over a particular temperature range. This change in value is normally quoted in parts per million (ppm).

The change in value of a resistor with changing temperature is not very dependent on changes in the dimensions of the component as it expands or contracts due to temperature changes. It is due mainly to a change in the resistivity of the material caused by the activity of the atoms of which the material is made.

A resistor's temperature behavior can be precise described using its temperature coefficients $TC1$ and $TC2$, which are derived from the Taylor Series expansion around the nominal temperature T_{ref} [2]:

$$R(T) = R(T_{ref})\left[1 + TC1(T - T_{ref}) + TC2(T - T_{ref})^2\right]. \quad (3)$$

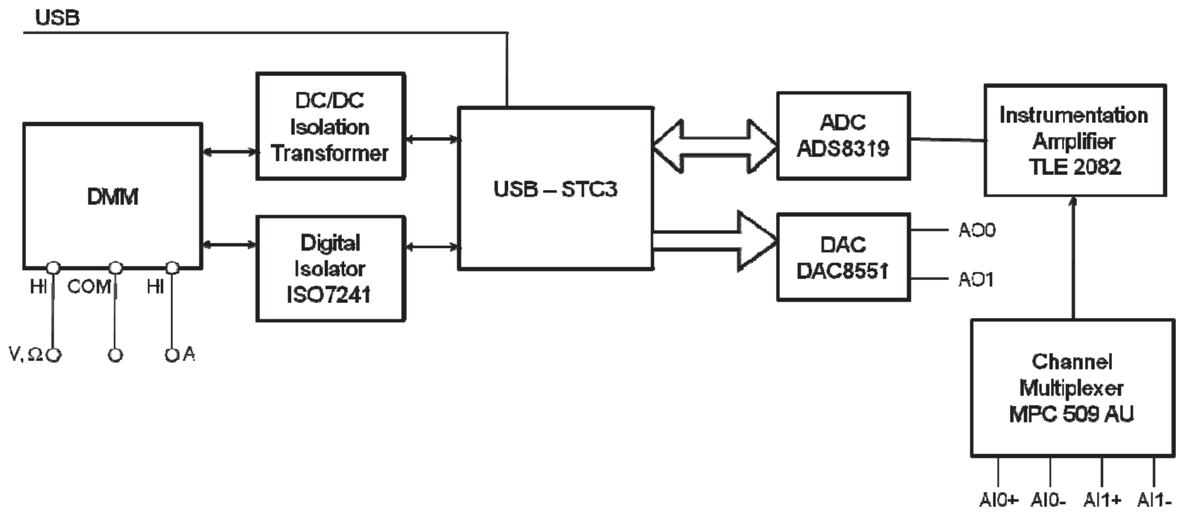

Fig. 1. The part of myDAQ subsystems

III. MyDAQ

National Instruments myDAQ is a portable data acquisition device that uses LabVIEW based software. The myDAQ is designed primary for students, allowing them to measure and analyze real-world signals. This portable data acquisition system is ideal for exploring electronics and taking sensor measurements and offers an affordable and accessible way for students to make electrical measurements, control electronics systems, and experience the world through instrumentation [4, 5]. Within a single plug-and-play USB device, the myDAQ combines portability with a suite of number of the most commonly used instruments in the educational laboratory. Integrated circuits supplied by Texas Instruments form the power and analog modules of myDAQ. In the Figure 1 is shown the arrangement and function of the part of myDAQ subsystems.

The ADS8319 is 16-bit analog-to-digital converter. Device includes a capacitor based, successive approximation ADC with inherent sample and hold. The ADS8319 unipolar single-ended input range supports an input swing V to V_{ref}. Device operation is optimized for very low power operation. This feature makes it attractive for lower speed applications.

The TLE2082 is JFET-input operational amplifier. It has wide supply-voltage rails up to ±19 V. On-chip zener trimming of offset voltage yields greater accuracy in dc-coupled applications. This makes this amplifier good suited for interfacing with high-impedance sensors or very low level ac signals.

The MPC509AU is a 4-channel differential multiplexer. Analog input voltages may exceed either power supply voltage without disturbing the signal path of other channels. These features make the MPC509A ideal for use in systems where the analog signals originate from external equipment or separately powered sources.

In general, the myDAQ provides two differential analog inputs, two analog outputs, eight digital inputs and outputs, audio input and output, DC power supplies, and digital multimeter (DMM) functions [4]. The DMM provides the functions for measuring voltage (DC and AC), current (DC and AC), resistance, and diode voltage drop. It is important to notice that DMM measurements are software-timed, so update rates are affected by the load on the computer and USB activity.

IV. Experimental Setup

A. Hardware Design

The idea how to investigate resistor's temperature behavior using myDAQ is illustrated in fig. 2. In order to measure continuous temperature close up investigated resistor a resistance temperature detector (RTD) is used. Resistance temperature detectors rely on the principle that the resistance of a metal increases with temperature. When made of platinum and when specified to have a resistance of 100 Ω at 0°C, they are known as Pt100. Each RTD requires the data acquisition hardware to provide a constant current source. The current flows through the RTD and the voltage drop over the RTD is measured. Using Ohms law the value of the resistance of the RTD can be calculated.

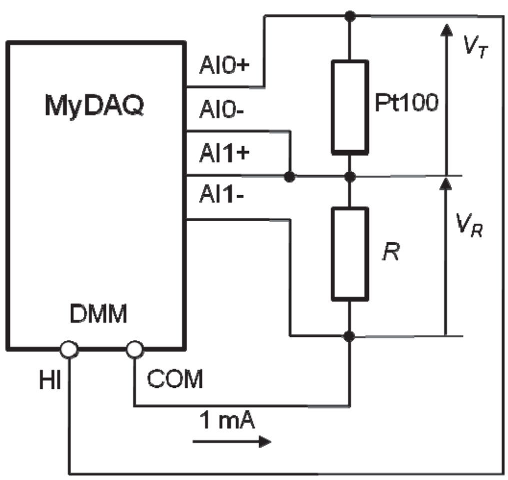

Fig. 2. Experimental setup

The capability of digital multimeter (DMM) build in myDAQ to produce reference current is used in presented circuit. The Pt100 is wired in a circuit as a resistor. It requires a positive input on one side and a negative input on the other side. As can be seen in the figure resistors are arranged in a chain, so the current has only one path to take. The current is the same through each resistor. The total resistance of the circuit is found by simply adding up the resistance values of the individual resistors. When the current is passed through the resistive devices it produce a voltages that can be sensed by a data acquisition system. The level of each voltage output signal will depend directly on the resistance and magnitude of the current excitation source.

Because myDAQ analog inputs have large input impedance (10 GΩ), any voltage dropped across the main current-carrying wires will not be measured by the DAQ analog inputs, and so do not factor into the resistance calculation at all. In such a way the measurement method introduced in this work avoids errors caused by wire resistance.

B. Software Design

In order to be controlled with LabVIEW, myDAQ requires ELVISmx and DAQmx software drivers. Block diagram of introduced system for resistor‘s temperature behaviour investigation is shown in Fig. 3. The base DAQmx functions are used to control the measurement process. In the upper part of the block diagram are placed functions for DMM control. The DMM is configured for 2-wire resistance measurement with 1 mA internal exitation current. For this measurement task, result is not needed and Read function absent. In lower part of the figure are placed functions for analog inputs control. Virtual analog channels are implemented by Create Channel function. Synchronization and timing are managed by Timing and Start Task functions. Inside the while loop on the left is the Read function. This function acquired measured data and it's configured to read multiple value from multiple channels each time it executes. All of the code inside the While Loop continues to run until the Stop button is pressed on the front panel. The Wait function delays execution of the while loop to every 100 ms. At the end of the data flow the DAQmx Clear Task function and Simple Error Handler are placed.

Once a measurable voltage signals have been obtained these signals must be converted to actual units of temperature and resistance respectivly.

The signal coming from the Pt100 is converted to a temperature using the polynomial equation from the Pt100 specifications and the Callendar-Van Dusen equation [1]. For T > 0°C, the quadratic formula can be used to solve for temperature as a function of measured resistance with the result:

$$T_R = \frac{-R_0 A + \sqrt{R_0^2 A^2 - 4R_0 B(R_0 - R_T)}}{2R_0 B}. \tag{4}$$

where R_T is resistance at temperature T(°C), R_0 is resistance at 0°C, T is temperature in °C, and the Callendar-Van Dusen constants A and B are obtained from actual resistance measurements. Common Callendar-Van Dusen constant values for Pt100 that are used in this investigation are: $A = 3.908.10^{-3}$; $B = -5.775.10^{-7}$.

This equation is solved in LabVIEW using Formula node. Finally, it output the result to a file using Write To Spreadsheet File function.

V. RESULTS AND SIMULATION

The approach for temperature measurement of resistance described above is implemented for metal film resistor with nominal value of 100 Ω.

Once the all resistance and temperature data is obtained and saved in file, this data can be manipulate with LabVIEW Regressin Solver function [3]. When starting the function a dialog window is opened urged the user to select the type of regression analyses to best fit the experimental data points to some equation. Regression is a process of constructing a mathematical function that has the best fit to a series of data points. This technique acts to minimize the sum of the squares deviations of the experimental values from values calculated using some theoretical equation. Solving the regression equation is difficult task but by using capability of virtual instrumentation in this development solving the regression equation is quite easy.

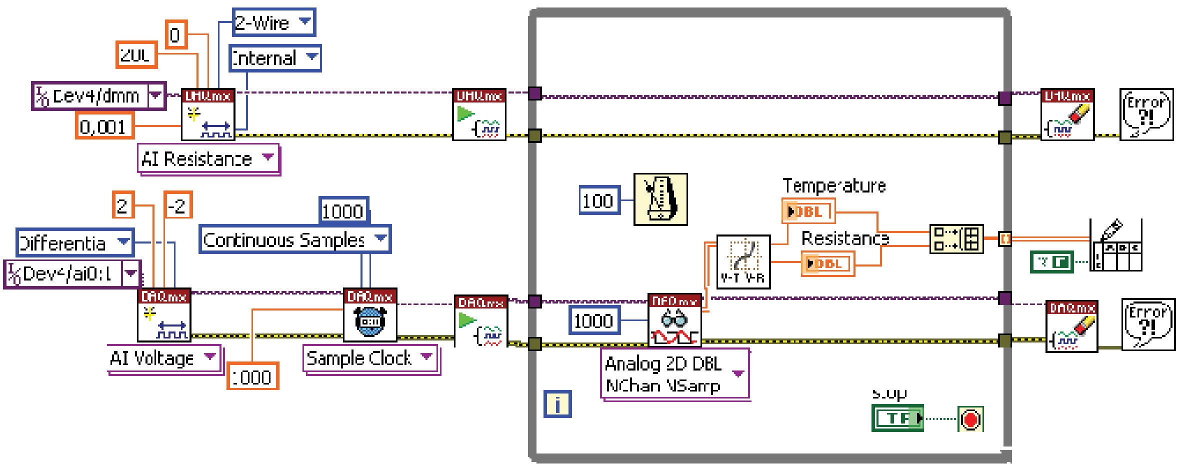

Fig. 3. Block diagram of the presented system

For this purpose the LabVIEW function called "Regression solver" is used with slight adaptation. The dialog window of regression solver is shown on the Fig. 4.

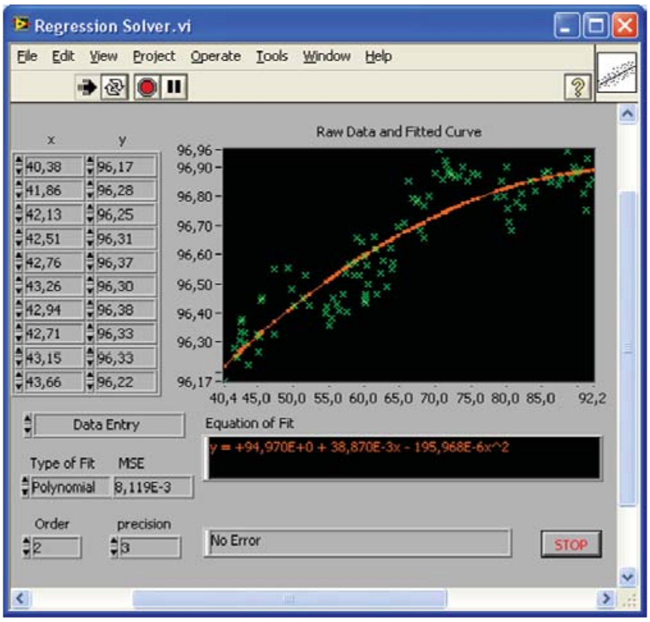

Fig. 4. The dialog window of regression solver

As can be seen from the figure acquired data is well described with the second degree polynomial equation:

$$y = a + b.x + c.x^2 \,. \qquad (5)$$

where a = 94.97, b = 38.87.10^{-3} and c = 195.968.10^{-6}.

The temperature coefficients $TC1$ and $TC2$ can be practically define using polynomial curve fitting procedure. Comparing equations (3) and (5), and assuming that T_{ref} = 0°C the coefficients are obtained as follows:

$$R(T_{ref}) = a, \quad TC1 = \frac{b}{R(T_{ref})}, \quad TC2 = \frac{c}{R(T_{ref})}. \qquad (6)$$

The values for the temperature components according to (6) are $R(T_{ref})$ = 94.97 Ω with coefficients of resistance $TC1$ = 0.4093.10^{-3} 1/°C and $TC2$ = -2.06347.10^{-6} 1/°C^2.

In order to complete the coefficients extraction process, obtained values are established in Multisim resistor model. Fig. 5 illustrates the simulation results of the temperature vs. resistance characteristic of metal film resistor, using the SPICE simulator. The error of the model is formed only from the accuracy of the curve fitting, because the characteristic is described by mathematical polynomial equation.

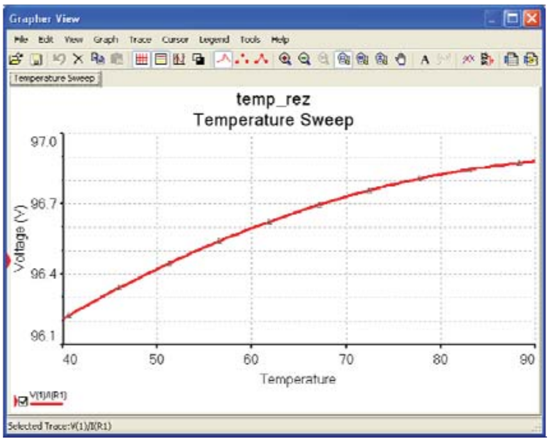

Fig. 5. The results of temperature simulation

VI. CONCLUSION

An approach to direct extraction of resistor temperature coefficients has been introduced in present paper. The aproach is applicable to any resistor with value between 100 ohms to 10 kohms. In order to build presented virtual system, the part of National Instruments circuits teaching solution platform has been used. It is integrated hardware and software that guides students through the engineering and design process from understanding circuit theory to developing and simulating designs to prototyping and validation. In presended work are included myDAQ for hardware and LabVIEW and Multisim for software. With the LabVIEW and myDAQ prototyping platforms, users and educators can quickly and easily develop their circuits and take measurements interactively in the laboratories using DAQmx instrumental drivers. On the other hand Multisim provides intuitive circuit design and SPICE simulation to help students explore circuit theory and investigate behavior of electronic compounents.

The presented approach can be applied for any electronic device with DAQs with reference current source to realize virtual system for temperature coefficients measurement. However to achieve better measurement accuracy the more precise current source and analog inputs must be used because in present development the accuracy and long term stability of these modules is not investigated.

ACKNOWLEDGEMENT

This investigation has been carried out in the framework of the research project 122ПД0041-07.

REFERENCES

[1] John G. Webster. *Electrical measurements, signal processing, and displays*, ISBN 0-8493-1733-9, CRC Press LLC, 2004.
[2] E. Dudek, M. Mosiadz, M. Orzepowski. *Uncertainties of resistors temperature coefficients*, Measurement Science Review, Volume 7, Section 1, No. 3, 2007.
[3] B. Nikolova, G. Nikolov. *Design, Development and Calibration of Virtual System for Relative Humidity Measurement*. Sensors & Transducers Journal, ISSN 1726-5479, Vol.93, Issue , 2008.
[4] National Instruments Corporation. *NI myDAQ User Guide and Specifications*, 2012.
[5] P. Blume. *The LabVIEW Style Book*, ISBN 0-13-145835-3, Pearson Education, 2007.