

**НАУКОВІ ТА ПРАКТИЧНІ ПРОБЛЕМИ ВИРОБНИЦТВА
ПРИЛАДІВ ТА СИСТЕМ**

DOI: 10.20535/1970.71(1).2026.361877

UDC 536.531

**METHOD OF COMPENSATING THE INFLUENCE OF THERMISTOR POWER
ON ITS SELF-HEATING TEMPERATURE***Sergey N. Matvienko, Grigoriy S. Tymchyk**National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine**E-mail: s.matvienko@kpi.ua*

The work is devoted to the improvement of systems and devices for measuring the thermal conductivity coefficient of substances and materials and for determining the composition of substances based on their thermal conductivity using the direct thermistor self-heating method. The influence of the thermistor's power dissipation on the accuracy of measuring its self-heating temperature is analyzed. To compensate for this influence, a data processing algorithm for the measurement of the thermistor's self-heating temperature has been developed. The effectiveness of the proposed method and the developed algorithm was evaluated using a mathematical model implemented in MATLAB Simulink. A structural-functional synthesis of the thermistor self-heating temperature measurement system was performed, which comprises the following modules and subsystems: a module simulating the thermal processes occurring during thermistor heating, an electrical schematic of the measurement channel, and the subsystems of the proposed data processing algorithm. Structural-functional schemes of software subsystems for implementing the compensation algorithm to mitigate the effect of thermistor power on its self-heating temperature have been developed and justified. The measurement channel schematic has been designed and substantiated. An algorithm for compensating the effect of thermistor power on the accuracy of self-heating temperature measurement is proposed. Implementation of the proposed compensation algorithm for the effect of thermistor power on its self-heating temperature enables high measurement accuracy (up to 0.06 K RMS) and significantly simplifies both the measurement data processing procedure and the calibration procedure of the devices.

Keywords: *accuracy enhancement; direct thermistor self-heating method; NTC thermistor; MATLAB Simulink.*

Introduction

The direct thermistor self-heating method is used for measuring thermophysical properties of investigated substances and materials [1 – 5], for determining the composition of substances based on their thermal conductivity coefficient [2 – 7], in medical and biological applications [8], and for quality control of thermistor probe manufacturing [9]. It can also be employed in systems and devices for determining material moisture content, as part of an anemometer for measuring fluid or gas flow velocity, for liquid level detection in tanks, and other applications. This method is one of the simple and effective techniques for measuring thermophysical characteristics, providing sufficiently accurate measurements and being suitable for field use.

The direct thermistor self-heating method uses NTC thermistors – thermistors with a negative temperature coefficient. These are temperature-sensitive semiconductor resistors whose resistance decreases with increasing temperature. The method exploits the self-heating phenomenon of an NTC thermistor when an electric current flows through it [10]. Based on the measured self-heating temperature of the thermistor in the surrounding medium, the

thermophysical characteristics of the investigated substances and materials, as well as their composition and moisture content, are determined.

A number of factors influence the accuracy of measuring the thermistor's self-heating temperature by the specified method [2, 7]. These factors lead to increased measurement error, complicate the data analysis procedure, and the calibration process of the device. To compensate for the effects of destabilizing factors, reduce measurement error, and determine optimal data processing algorithms, there is a need for preliminary mathematical modeling of such devices and systems. Works [2, 7] note that one of the destabilizing factors is the dependence of thermistor power on its temperature.

The aim of this work is to synthesize the structure of a thermistor self-heating temperature measurement system and to determine the optimal algorithm for compensating for the influence of thermistor power variation as a function of the temperature of the test samples. This enables achieving high measurement accuracy (up to 0.06 K (RMS)) and significantly simplifies both the measurement data processing procedure and the device calibration procedure.

Review of the current state and development prospects of systems using the direct thermistor self-heating method

The dependence of the electrical resistance of an NTC thermistor on temperature is nonlinear and is described by the following expression [11]:

$$R_T = R_N \times e^{B \times \left(\frac{1}{T} - \frac{1}{T_N} \right)}. \quad (1)$$

Where, ΔT is the resistance of the NTC thermistor at temperature T (in K); R_{TN} is the resistance of the NTC thermistor at the nominal temperature T_N (in K); T , T_N are the absolute temperatures in K; and B is the material-dependent constant in K.

To linearize the temperature characteristic of an NTC thermistor over a limited working temperature range, circuit-based techniques are used, primarily employing passive correction networks [12-14]. To extend the operating temperature range, digital linearization methods are applied [12-14]. These are implemented either through software or by using analog-to-digital circuits to generate a linear signal.

The application of the direct thermistor self-heating method for measuring thermophysical properties has been examined in works [1 – 5]. The essence of the method lies in measuring the difference between the thermistor temperature at the beginning and at the end of a heating pulse. In practice, a measurement bridge is used in which one arm of the bridge – the thermistor, is supplied with a heating voltage pulse for a defined period of time. The instantaneous thermistor temperature is recorded both at the beginning and at the end of the pulse. The initial temperature corresponds to the ambient temperature, and the difference between these values constitutes the thermistor's self-heating temperature.

For an ideal model of a spherical thermistor sensor of radius r with perfect thermal conductivity, assuming that the thermistor is surrounded by the test material, the thermistor self-heating temperature is given by [15]:

$$\Delta T = \frac{P_{th}}{4\pi r \lambda} + \Delta T_G + \Delta T_R, \quad (2)$$

Where, ΔT is the thermistor self-heating temperature; λ is the thermal conductivity of the surrounding medium, $W/(m \cdot K)$; P_{th} is the thermistor's power dissipation, W ; r is the thermistor radius, m ; ΔT_G is the temperature shift due to the internal thermal gradient within the thermistor, K ; ΔT_R is the temperature shift caused by the thermal contact resistance between the thermistor and the medium, K .

Factors influencing the accuracy of thermistor self-heating temperature measurement using the direct self-heating method are discussed in [2, 7, 16], including the effect of thermistor power variation with respect to the temperature of the test samples [7, 16].

In works [7, 16], in order to increase measurement accuracy, it is proposed to perform measurements at a constant temperature of the test sample maintained in a thermostat, or to use multiple calibration tables for different ambient temperatures. However, this complicates the data processing algorithm and the device calibration procedure. In the present work, a compensation mechanism for the influence of thermistor power on its self-heating temperature is proposed by introducing a correction to the measured self-heating temperature as a function of the thermistor's power dissipation.

As is known [7], the power dissipation of a thermistor when connected in a measurement bridge reaches its maximum when the bridge is balanced, i.e., when the thermistor resistance (at the nominal ambient temperature T_N) equals the resistance of the fixed resistors in the bridge [16]. In the present work, for comparison, the case is considered where the nominal ambient temperature T_N equals the midpoint of the ambient temperature range in which measurements are performed. In this case, with an increase in ambient temperature, thermistor power increases at the beginning of the heating pulse and decreases at the end of the pulse.

Thus, the literature analysis shows that to improve the accuracy, reliability, and effectiveness of devices for measuring the thermal conductivity coefficient of substances and materials or determining composition based on thermal conductivity using the direct thermistor self-heating method, it is necessary to compensate for the influence of thermistor power variation. This can be achieved by introducing a corrective function defined through mathematical modeling.

Structural-functional synthesis of the thermistor self-heating temperature measurement system

The development of the compensation algorithm for the influence of thermistor power on its self-heating temperature and the analysis of the algorithm's effectiveness in this work were carried out using a mathematical model in MATLAB Simulink. MATLAB Simulink is an optimal tool for modeling such devices and systems, as it allows concurrent simulation of both heat transfer processes from the thermistor into the surrounding medium and the electrical circuits of the measurement channel with mathematical data processing.

A thermistor with the following characteristics was selected for modeling: thermistor resistance at 25 °C (298 K) - $R_{25} = 2000 \Omega$; B-coefficient $B_{25/50} = 3450 K$; Thermal time Constant $\tau = 6 S$; Maximum power Dissipation, $P_{max} = 51 mW$; Heat dissipation $\delta = 0,6 (mW/^\circ C)$.

In the simulation, the ambient temperature range was from 303 K to 323 K (from +30 °C to +50 °C). According to practical research reported in [2], for a

thermistor with similar characteristics, the self-heating temperature range is between 12 K to 22 K.

The developed mathematical model in MATLAB Simulink is shown in Fig. 1.

It consists of a thermal process simulation module for heat propagation from the thermistor into the surrounding medium, implemented using the general method of thermal-electric system analysis — the thermal resistance network method (“*Thermal model*”); an electrical model of the measurement channel (“*Sensor interfacing circuit + Amplifier + ADC*”); and measurement data processing software modules “*Subsystem T0*”, “*Subsystem T1*,” and the “*Correction subsystem*”.

For modeling the behavior of the NTC thermistor in MATLAB Simulink, the “*Thermistor*” model is

used. The thermistor R_{th} is connected as one arm of a Wheatstone bridge R_1, R_2, R_3, R_{th} in the “*Sensor interfacing circuit*.” The resistance values of resistors R_1, R_2, R_3 (1120 Ω) are selected such that the Wheatstone bridge is balanced at the midpoint of the ambient temperature range, 313 K (+40 °C). In this case, the thermistor’s power dissipation reaches its maximum at a thermistor temperature of 313 K. The bridge arms R_1-R_3 та $R_2- R_{th}$ are connected via switches $S1$ and $S2$, respectively, either to the “*Voltage Source*” model or to ground (0 V). The blocks “*Repeating Sequence 1*” and “*Repeating Sequence 2*” actuate switches $S1$ i $S2$ at the appropriate times, thereby forming an electrical reference voltage pulse applied to the measurement bridge.

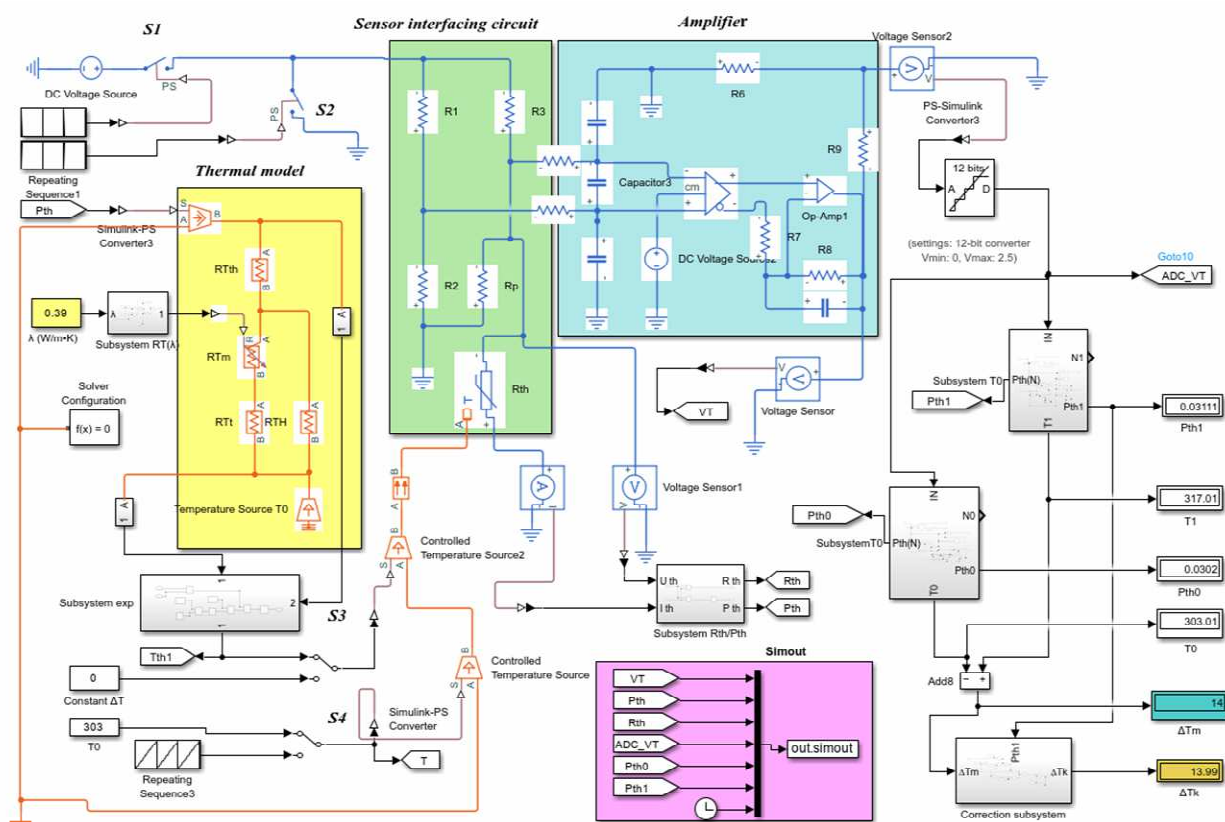


Fig.1. Model in the MATLAB Simulink environment for developing an algorithm to compensate for the influence of thermistor power on its self-heating temperature and analyzing the effectiveness of the developed algorithm when using the direct thermistor heating method

When current flows through the thermistor, it gradually heats up; thus, the thermistor temperature at the beginning of the pulse differs from that at the end. The temperature difference between the initial and final values depends on the thermistor’s power dissipation and the thermophysical properties of the surrounding medium. The bridge output voltage imbalance is amplified in the “*Amplifier*” module, providing the required gain G for the bridge imbalance voltage. The amplified instantaneous voltage is converted into a digital code N by a 12-bit ADC

(“*Idealized ADC quantizer*”). Due to the nonlinearity of the thermistor’s $R(T)$ characteristic and the nonlinear transfer functions of the Wheatstone bridge and the differential amplifier, the relationship between the ADC output code and temperature, $N(T)$ is also nonlinear.

The software subsystems “*Subsystem T0*” and “*Subsystem T1*” record the thermistor temperature values T_0 at the beginning of the electrical pulse and T_1 at its end, respectively. The difference $T_0 - T_1$ is then computed, which corresponds to the thermistor

self-heating temperature ΔT_{th} . Similarly, the instantaneous thermistor power dissipation at the beginning P_{th0} and at the end P_{th1} of the pulse is computed by the software subsystems “Subsystem T0” and “Subsystem T1,” and their difference $P_{th1} - P_{th0} = \Delta P_{th}$ is recorded.

The instantaneous thermistor temperature is determined using a precomputed lookup function $T=f(N)$, where T is the current temperature and N is the ADC output code. This function, in the form of a table, is implemented in “Subsystem T0” and “Subsystem T1” and is generated during the simulation. To obtain this table, in the settings dialog of the “Repeating Sequence T” block, the required ambient temperature range is set, and the corresponding ADC output value N from the “Idealized ADC quantizer” is recorded.

The instantaneous thermistor power dissipation is calculated using the following formula:

$$P_{th} = U_{th} \times I_{th} = \left(\frac{R2 \times U_{ref1} - k_N \times N}{R1 + R2} - k_N \times N \right) \times \left(\frac{U_{ref1} G - \frac{R2 \times U_{ref1} - k_N \times N}{R1 + R2} - k_N \times N}{G \times R3} \right). \quad (3)$$

Where, P_{thN} is power dissipation of the thermistor, W; U_{th} is the voltage across the thermistor, V; I_{th} is current flowing through the thermistor, A; $R1$, $R2$, $R3$ are resistances of the corresponding resistors of the Wheatstone bridge, Ω ; G is the gain of the amplifier (“Amplifier”); N is digital output value of the ADC; k_N is the slope coefficient of the linearized characteristic $U=f(N)$, V; U_{ref1} is the voltage of the thermistor heating pulse, V.

The modeling of the heat transfer process from the thermistor to the surrounding environment is performed using equivalent thermal resistance component blocks (“Thermal Resistor”) for each layer, starting from the heat flux source (the thermistor) and extending to the ambient environment. To simplify the model, the thermistor is assumed to have the shape of an ideal sphere with a radius of $r1=0,4$ mm, enclosed in an epoxy resin coating with a radius of $r2=1,3$. The thermistor is immersed in the investigated medium with a radius of $r2=5,0$ mm. The ambient temperature range is from 303 K to 313 K (from 30 °C to 40 °C). The thermal conductivity coefficient λ of the investigated substance varies from 0.07 W/(m·K) to 1.2 W/(m·K). The thermistor has an epoxy resin coating with a thermal conductivity of $\lambda=0,4$ W/(m·K).

In the model, the thermal resistance value is formed as a function of the specified thermal conductivity coefficient using the “Subsystem $R_T(\lambda)$ ”

block for each layer, according to the formula for determining the thermal resistance of a spherical surface [17]:

$$R_{Tm}(\lambda) = \frac{1}{4 \times \pi \times \lambda} \left(\frac{1}{r_{\min}} - \frac{1}{r_{\max}} \right) = \frac{1}{4 \times \pi \times \lambda} \left(\frac{r_{\max} - r_{\min}}{r_{\min} \times r_{\max}} \right), \quad \text{W/K}, \quad (4)$$

Where, λ is the thermal conductivity coefficient of the medium surrounding the thermistor, W/(m·K); r_{\min} is minimum radius of the spherical layer of the surrounding medium volume, m; r_{\max} is the maximum radius of the spherical layer of the surrounding medium volume, m.

The calculated value of the thermal resistance of the thermistor coating with a radius of $r2=1,3$ mm is $R_{Tth}=344.5$ W/K. The calculated value of the thermal resistance of the thermistor surrounding medium, R_{Tm} , for the thermal conductivity coefficient in the range from 0.07 W/(m·K) to 1.2 W/(m·K), varies accordingly from 453 W/K to 37 W/K. In addition, the thermal resistance of the thermistor probe structure is taken into account in the model and is equal to R_{Th} , W/K.

The input parameters for determining the thermistor self-heating temperature are the thermal conductivity of the surrounding medium λ , W/(m·K), and the thermistor power dissipation P_{th} , W. Depending on the thermal conductivity coefficient of the surrounding medium λ , the software module “Subsystem $RT(\lambda)$ ” determines the thermal resistance of the surrounding medium R_{Tm} . For this purpose, the current value of the thermistor power dissipation P_{th} , which is measured directly on the thermistor, is used.

The “Thermal model” module calculates the thermistor self-heating temperature during the thermistor heating pulse as a function of its power dissipation. During the heating pulse, the time dependence of the thermistor temperature is close to exponential. In the model, this dependence is generated using the software module “Subsystem exp” based on the specified thermistor heating time constant, the thermal time constant τ .

To determine the algorithm for compensating the influence of thermistor power dissipation on its self-heating temperature within the ambient temperature range from 303 K to 333 K, it's first necessary to select an optimal gain of the “Amplifier” such that it corresponds to the full range of digital values at the ADC output, taking into account the maximum thermistor self-heating temperature. This range must correspond to the full ADC output code range from 0 to 4096. Next, the functions $U=f(N)$ and $T=f(N)$ are obtained through modeling. From the function $U=f(N)$, the slope coefficient of the linearized

characteristic k_N is calculated, while the function $T=f(N)$, represented in tabular form, is used by the software subsystems “Subsystem T0” and “Subsystem T1”. The value of k_N is used by “Subsystem T0” and “Subsystem T1” to calculate the current thermistor power dissipation P_{thN} .

Using the model, the correspondence between the calculated current thermistor power dissipation P_{thN} and the power dissipation P_{th} measured directly at the thermistor is verified. Figure 2 shows the result of this comparison.

To determine the algorithm for compensating the influence of thermistor power dissipation on its self-heating temperature within the ambient temperature range from 303 K to 333 K, the thermistor self-heating temperature ΔT is further measured, along with the instantaneous thermistor power dissipation at the beginning of the heating pulse P_{th0} and at its end P_{th1} . The difference between these values, ΔP_{th} , is also determined.

Figure 3 presents comparative plots of the dependencies ΔT , ΔP_{th} and ΔT , P_{th1} as functions of the ambient temperature T_0 .

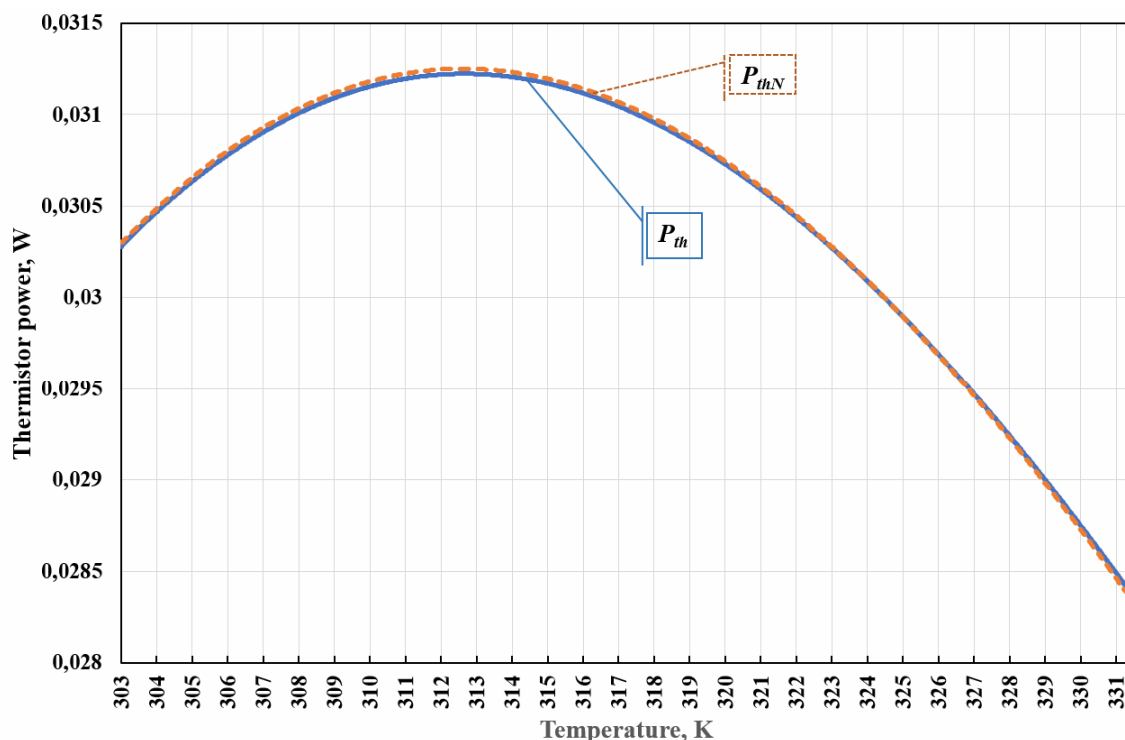


Fig. 2. Comparison of the current value of the thermistor P_{thN} dissipation power calculated by the software subsystems “Subsystem T0” and “Subsystem T1” with the value measured directly on the thermistor P_{th}

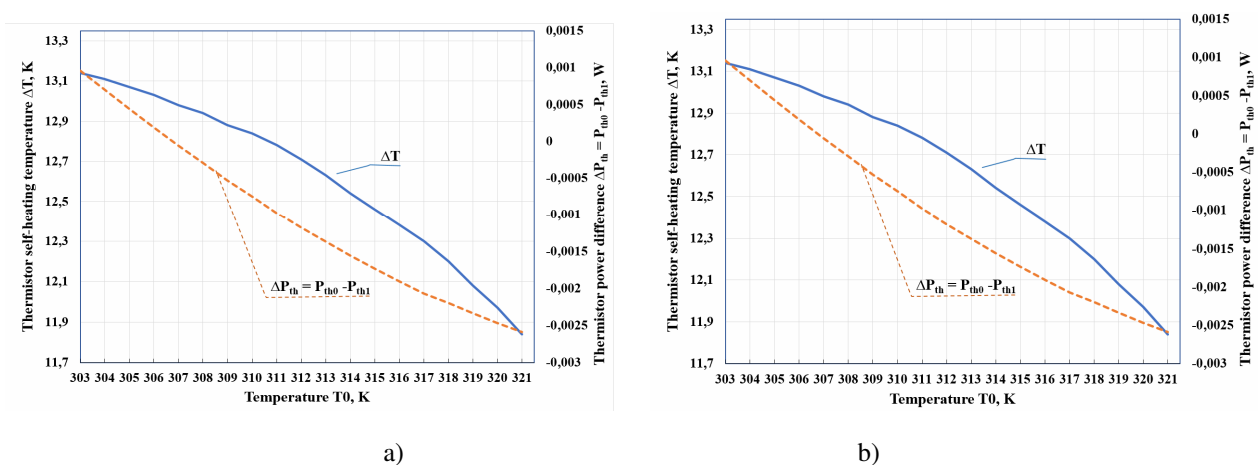


Fig. 3. Graphs of dependence of ΔT , ΔP_{th} and ΔT , P_{th1} on the ambient temperature T_0 : a) ΔT and ΔP_{th} ; b) ΔT and P_{th1}

As can be seen from the graphs, to compensate for the influence of thermistor power dissipation on its self-heating temperature, it is advisable to use the instantaneous thermistor power dissipation at the end of the heating pulse, P_{thI} . This is because, as the ambient temperature increases from 303 K to 323 K, the thermistor self-heating temperature ΔT decreases proportionally to the thermistor power dissipation P_{thI} .

To determine the correction function, measurements of the dependencies of ΔT and P_{thI} on the ambient temperature T_0 are performed in the range

from 303 K to 323 K with a step of 1 K, for ΔT values ranging from 12 K to 22 K. By selecting the thermal conductivity coefficient λ of the surrounding medium within the range from 0.05 W/(m·K) to 1.2 W/(m·K) at an ambient temperature of $T_0 = 303$ K, the values of ΔT in the range from 12 K to 22 K with a step of 1 K are established. The selected values of λ are listed in the table 1.

Figure 4 shows graphs of the dependence of the self-heating temperature of the thermistor on its power P_{thI} , constructed according to research data.

Table 1. Thermistor self-heating temperature ΔT as a function of the thermal conductivity coefficient λ of the surrounding medium at an ambient temperature of $T_0 = 303$ K.

$\Delta T, K$	12	13	14	15	16	17	18	19	20	21	22
$\lambda, W/(m \cdot K)$	1,11	0,587	0,39	0,2857	0,2217	0,1778	0,146	0,122	0,1032	0,08789	0,07539

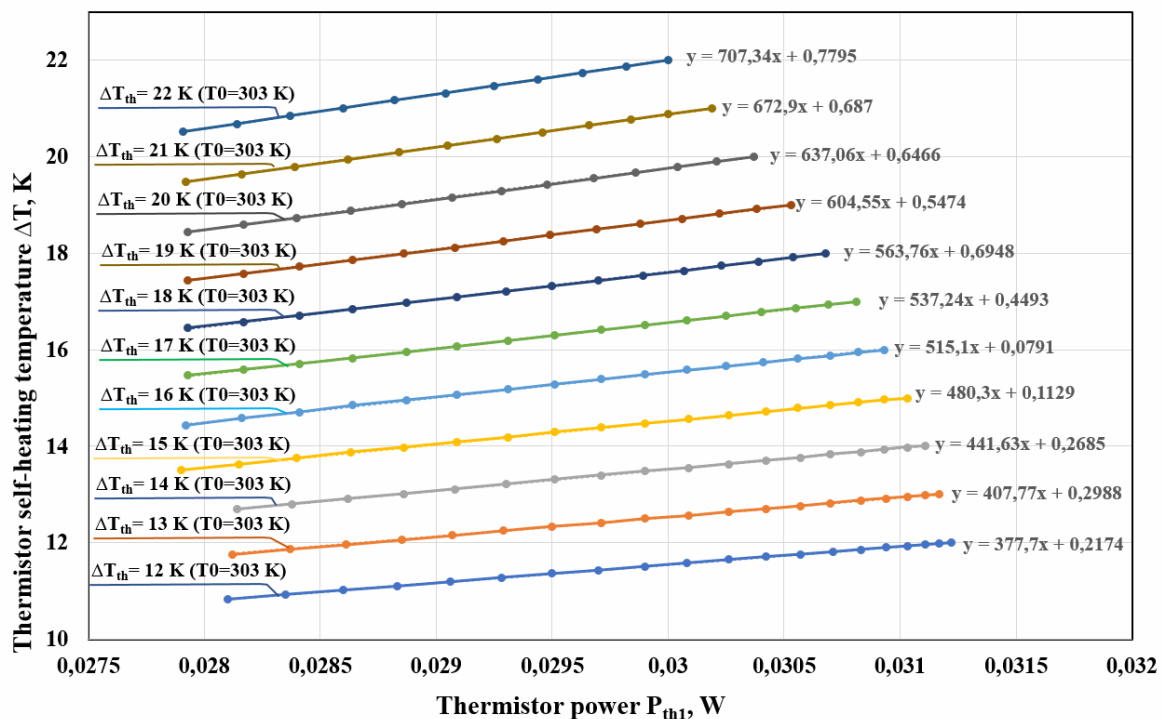


Fig. 4. Graphs of the dependence of the self-heating temperature of the thermistor ΔT on its power P_{thI} , constructed according to research data.

Thus, the graphs indicate that the dependence of the thermistor self-heating temperature increment ΔT on its power P_{thI} is close to linear when the thermal conductivity coefficient of the surrounding medium is constant. If this coefficient varies, both the proportionality coefficient and the intercept of the function also change linearly.

To compensate for the influence of thermistor power on its self-heating temperature, a correction in the form of a linear function should be added to the measured value of the thermistor self-heating temperature:

$$\Delta T_k = \Delta T_m + k_p \times \Delta P_{thI} + C_p \quad (5)$$

Where, ΔT_k is corrected value of ΔT_m , K; ΔT_m is the

measured value of the thermistor self-heating temperature, K; k_p is the proportionality coefficient (slope of the linear function describing the dependence $\Delta T = f(P_{thI})$, K/W; C_p is the intercept of the linear function $\Delta T_m = f(P_{thI})$, K; $\Delta P_{thI} = P_{thN} - P_{thI}$ is the difference between the nominal thermistor power P_{thI} and the instantaneous thermistor power at the end of the heating pulse P_{thN} , W.

With an increase in the thermistor self-heating temperature ΔT_m , both the proportionality coefficient k_p and the intercept C_p of the function $\Delta T_m = f(P_{thI})$ increase. Figure 5 presents the dependences of k_p and C_p on the value of ΔT .

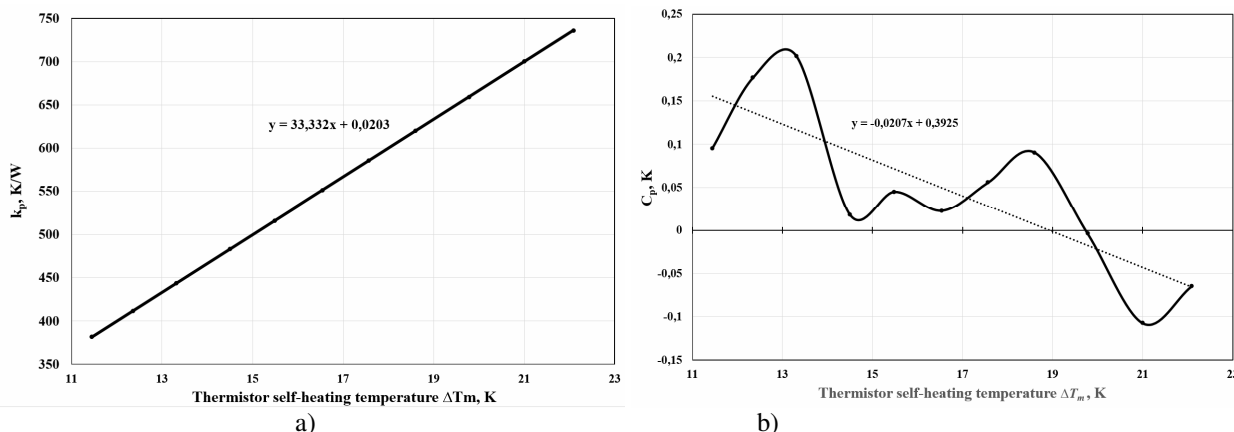


Fig.5. Graphs of the dependences of k_p and C_p on the thermistor self-heating temperature ΔT_m .

Considering that k_p and C_p depend on the value of ΔT_m equation (5) can be rewritten as:

$$\Delta T_k = \Delta T_m + (k_{pT} \times \Delta T_m + C_{pT}) \times (P_{thN} - P_{th1}) - (k_{cT} \times \Delta T_m + C_{cT}) \cdot (6)$$

Where, k_{pT} , k_{cT} are proportionality coefficients (slopes of the linear functions $k_p = f(\Delta T_m)$ and $C_p = f(\Delta T_m)$, K/W; C_{pT} , C_{cT} are the intercepts of the functions $k_{pT} = f(\Delta T_m)$ and $C_p = f(\Delta T_m)$, respectively.

The initial values of ΔT_m were obtained by selecting the thermal conductivity coefficient λ of the surrounding medium at $T_0 = 303$ K in the range from 12 K to 22 K with a step of 1 K. To ensure that for the

average thermistor power $P_{thN} = 0,03$ W the corrected value ΔT_k matches the measured values ΔT_m at ambient temperature $T_0 = 303$ K, the following correction should be applied to equation (6):

$$\Delta T_{kN} = K_{TN} \times \Delta T_k + C_{TN} \cdot (7)$$

Where, ΔT_{kN} is corrected value of ΔT_k corresponding to ΔT_k at $T_0 = 303$ K; K_{TN} , C_{TN} is proportionality coefficient and the intercept of the function $\Delta T_{m(303)} = f(\Delta T_{k(0.03)})$, where $\Delta T_{k(0.03)}$ - the value of ΔT_k at the average power $P_{thN} = 0,03$ W, and $\Delta T_{m(303)}$ is the measured value of ΔT_m at ambient temperature $T_0 = 303$ K.

The values of k_{pT} , k_{cT} , C_{pT} , and C_{cT} (Table 2) are determined using the graphs constructed from simulation data shown in Fig. 6 and Fig. 7.

Table 2. Values of the coefficients k_{pT} , k_{cT} , C_{pT} and C_{cT} of the correction function for ΔT_m relative to the average thermistor power $P_{thN} = 0,03$ W.

Coefficient	k_{pT} , 1/W	k_{cT}	C_{pT} , K/W	C_{cT} , K	K_{TN} ,	C_{TN} , K
Value	33,332	-0,0207	0,0203	0,3925	0.9399	1.4101

$T_0 = 303$ K on the value of ΔT_k at the average thermistor power $P_{thN} = 0,03$ W, obtained from simulation

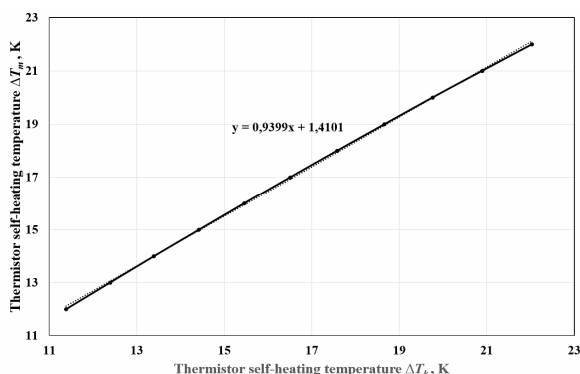


Fig. 6. Dependence of the measured value ΔT_m at ambient temperature $T_0 = 303$ K on the value of ΔT_k at the average thermistor power $P_{thN} = 0,03$ W, obtained from simulation

To compensate for the influence of thermistor power on its self-heating temperature according to the developed algorithm, linear functions are used. However, both the thermistor and the “Sensor interfacing circuit” exhibit nonlinear transfer characteristics, which necessitates correction using a polynomial function.

Figure 7 shows the dependence of the error of the average corrected value ΔT_{kN} relative to the measured value ΔT_m at ambient temperature $T_0 = 303$ K.

The measurement error of the thermistor self-heating temperature can be reduced by applying a correction using a polynomial function:

$$\Delta T_{kor} = \Delta T_{kN} + A_{nl} \times \Delta T_{kN}^2 + B_{nl} \times \Delta T_{kN} + C_{nl} \cdot (8)$$

Where, ΔT_{kor} is the value of ΔT_{kN} with corrected using the polynomial function, A_{nl} , B_{nl} , C_{nl} are the coefficients of the polynomial function.

The result of applying the developed correction algorithm, compared with the measured values ΔT_m is

shown in Figure 8.

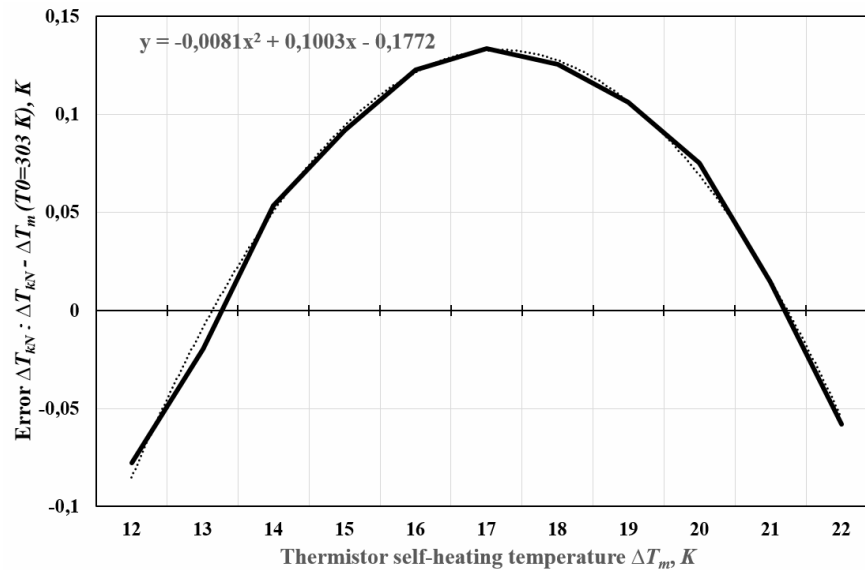


Fig.7. Error of the average corrected value ΔT_{kn} relative to the measured value ΔT_m at ambient temperature $T_0 = 303$ K

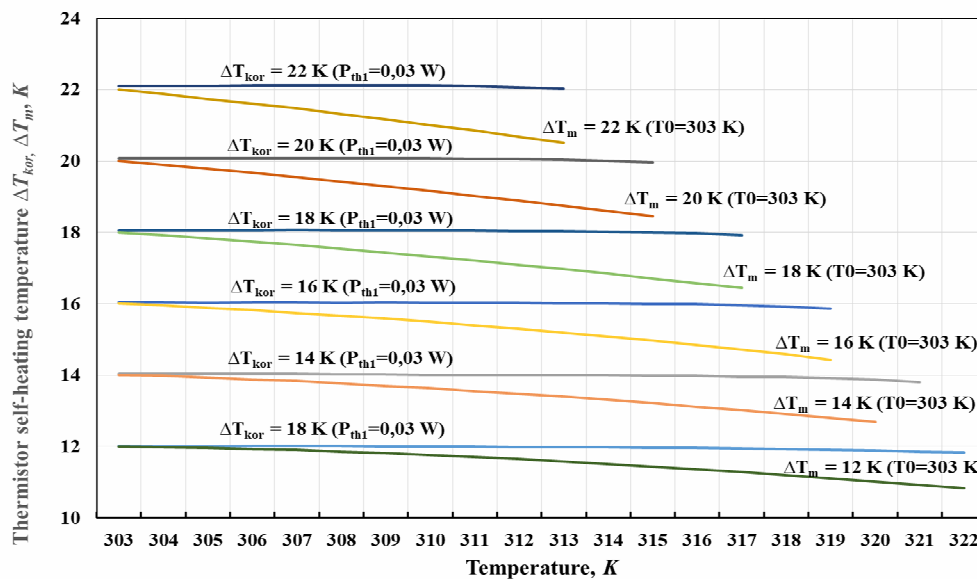


Fig. 8. Corrected values of $\Delta T - \Delta T_{kor}$ obtained using the developed correction algorithm compared with the measured values ΔT_m .

When applying the developed correction method, the root mean square (RMS) error of the thermistor self-heating temperature ΔT_{kn} obtained from simulation was 0.081 K, while the corrected values ΔT_{kor} yielded an RMS error of 0.053 K.

Thus, the application of the developed algorithm for compensating the influence of thermistor power on its self-heating temperature allows achieving a measurement RMS error of no more than $\delta = 0,06$ K, which confirms the effectiveness of the proposed method.

Conclusions

An analysis of scientific publications and development prospects of systems for measuring thermophysical properties of substances and materials has shown that one of the simple and effective measurement methods is the direct thermistor heating method. However, such a system requires further improvement to ensure the required measurement accuracy. One of the factors affecting measurement accuracy is the variation of thermistor power during heating.

This paper proposes and substantiates an

algorithm for compensating the influence of thermistor power on its self-heating temperature. To verify the effectiveness of the proposed algorithm, a device model was developed in the MATLAB Simulink environment. The model includes a module for simulating thermal processes of heat transfer from the thermistor to the surrounding medium, models of the electrical circuitry of the measurement channel, and software modules for measurement data processing. Using this model, an algorithm for correcting the measured value of the thermistor self-heating temperature as a function of its power was determined. It was established that the instantaneous thermistor power at the end of the heating pulse is an appropriate correction parameter.

A simulation of the thermistor self-heating temperature measurement system was performed to develop an optimal correction algorithm and to verify its effectiveness. Structural and functional schemes of the software modules for measurement data processing and the measurement data correction module were developed and justified.

Implementation of the proposed algorithm ensures high accuracy of thermistor self-heating temperature measurement with an RMS error not exceeding 0.06 K, enables extension of the ambient temperature range over which measurements can be performed, and significantly simplifies the calibration procedure of devices and systems.

Further research using the proposed algorithm will focus on verifying its effectiveness in devices and systems for measuring thermophysical properties of substances and materials, as well as on determining the composition of substances based on their thermal conductivity.

References

- [1] H. Zhang, S. Cheng, L. He, A. Zhang, Y. Zheng та D. Gao, "Determination of Thermal Conductivity of Biomaterials in the Temperature Range 233–313K Using a Tiny Detector Made of a Self-Heated Thermistor", *Cell Preservation Technol.*, v. 1, № 2, pp. 141–147, june 2002. DOI: 10.1089/153834402320882647
- [2] G. Tymchik, S. Matvienko, et al. "Improving the way of determination substances thermal physical characteristics by direct heating thermistor method", *PRZEGLAD ELEKTROTECHNICZNY*, iss. 1, № 4, pp. 123–128, apr. 2019. DOI: 10.15199/48.2019.04.21
- [3] C. Ould-Lahoucine, H. Sakashita та T. Kumada, "A method for measuring thermal conductivity of liquids and powders with a thermistor probe", *Int. Commun. Heat Mass Transfer*, v. 30, № 4, pp. 445–454, may 2003. DOI: 10.1016/s0735-1933(03)00073-3
- [4] N. M. Kharalkar, L. J. Hayes та J. W. Valvano, "Pulse-power integrated-decay technique for the measurement of thermal conductivity", *Meas. Sci. Technol.*, v. 19, № 7, pp. 075104, june 2008. DOI:10.1088/0957-0233/19/7/075104
- [5] J. D. Brionizio, A. d. F. Orlando та G. Bonnier, "Characterization of a spherical heat source for measuring thermal conductivity and water content of ethanol and water mixtures", *Int. J. Metrol. Qual. Eng.*, v. 8, pp. 18, 2017. DOI: 10.1051/ijmqe/2017007
- [6] A. O. Guimarães, F. A. L. Machado, E. C. da Silva та A. M. Mansanares, "Thermal Effusivity and Thermal Conductivity of Biodiesel/Diesel and Alcohol/Water Mixtures", *Int. J. Thermophys.*, v. 33, № 10-11, pp. 1842–1847, aug. 2012. DOI: 10.1007/s10765-012-1280-3
- [7] E.-J. An, S.-S. Park, W.-G. Chun, Y.-C. Park, Y.-H. Jeon та N.-J. Kim, "A Comparative Study on the Thermal Conductivities and Viscosities of the Pure Water and Ethanol Carbon Nanofluids", *J. Korean Sol. Energy Soc.*, v. 32, spc3, pp. 213–219, june 2012. DOI: 10.7836/kjes.2012.32.spc3.213
- [8] G. Tymchik, S. Vysloukh, N. Tereshchenko та S. Matvienko, "Investigation Thermal Conductivity of Biological Materials by Direct Heating Thermistor Method", у *2018 IEEE 38th Int. Conf. Electron. Nanotechnol. (ELNANO)*, Kiev, 24–26 квіт. 2018. IEEE, 2018. DOI: 10.1109/ELNANO.2018.8477460
- [9] S. A. Rodríguez-Jiménez and L. A. Cárdenas-Robledo, "Leveraging the self-heating effect of an NTC thermistor to detect its minimum coverage by a dispensed paste in the mass production process of temperature sensors," *IJISSET – International Journal of Innovative Science, Engineering & Technology*, vol. 10, no. 4, Apr. 2023. [Online]. Available: https://ijisset.com/vol10/v10s4/IJISSET_V10_I4_11.pdf
- [10] G. M. F. van Gelder, "A Thermistor Based Method for Measurement of Thermal Conductivity and Thermal Diffusivity of Moist Food Materials at High Temperatures", dissertation, Va. Tech, 1997. [Online]. Available: <http://hdl.handle.net/10919/30286>
- [11] TDK Corporation - NTC Thermistor General Information - Technical Overview: [Online]. Available: https://product.tdk.com/system/files/dam/doc/product/sensor/ntc/ntc_element/general_tech_info/ntc_thermistor_general_technical_information_digest_en.pdf
- [12] S. Matvienko and G. Tymchik, "Analysis of circuit design methods for linearizing the temperature characteristics of ntc thermistors and the measurement channel characteristics", *KPI Sci. News*, v. 139, № 2, jul. 2025. DOI: 10.20535/kpissn.2025.2.331284
- [13] S. Matvienko та G. Tymchik, "Polynomial-based method for linearizing the temperature response of NTC thermistors", *System res. inf. technol.*, № 1, pp. 58–75, mar. 2026. DOI:10.20535/srit.2308-8893.2026.1.04
- [14] A. J. Lopez-Martin та A. Carlosena, "Sensor signal linearization techniques: A comparative

- analysis”, у *2013 IEEE 4th Latin Amer. Symp. Circuits Syst. (LASCAS)*, Cusco, 27 feb.–1 march. 2013. IEEE, 2013.
DOI: 10.1109/lascas.2013.6519013
- [15] J. D. Brionizio, A. d. F. Orlando та G. Bonnier, “Characterization of a spherical heat source for measuring thermal conductivity and water content of ethanol and water mixtures”, *Int. J. Metrol. Qual. Eng.*, v. 8, pp. 18, 2017.
DOI: 10.1051/ijmqe/2017007
- [16] G. S. Tymchik, A. M. Matvienko, M. F. Tereschenko та S. M. Matvienko, “Effect of the Convection Processes in Liquid on Thermal Conductivity Measurement Error by Direct Heating Thermistor Method”, *Res. Bull. Nat. Tech. Univ. Ukraine "Kyiv Politechnic Inst."*, № 5, pp. 110–122, oct. 2017.
DOI: 10.20535/1810-0546.2017.5.107938
- [17] CELSIA HEADQUARTERS -Fundamentals of Thermal Resistance, Beyond Plane Wall Conduction. [Online]. Available: <https://celsiainc.com/heat-sink-blog/fundamentals-of-thermal-resistance/>

УДК 536.531

С. М. Матвієнко, Г. С. Тимчик*Національний технічний університет України «Київський політехнічний інститут імені Ігоря Сікорського», Київ, Україна***МЕТОД КОМПЕНСАЦІЇ ВПЛИВУ ПОТУЖНОСТІ ТЕРМІСТОРА НА ТЕМПЕРАТУРУ ЙОГО САМОРОЗІГРІВУ**

Роботу присвячено вдосконаленню систем і пристроїв вимірювання коефіцієнта теплопровідності речовин і матеріалів, визначення складу речовин за їх теплопровідністю, що використовують метод прямого підігріву термістора. Розглянуто вплив потужності розсіювання термістора на точність вимірювання температури його саморозігріву. Для компенсації цього впливу розроблено алгоритм обробки даних вимірювання температури саморозігріву термістора. Оцінку ефективності запропонованого методу за розробленим алгоритмом виконано за допомогою розробленої математичної моделі в середовищі MATLAB Simulink. Виконано структурно-функціональний синтез системи вимірювання температури саморозігріву термістора, яка складається з таких модулів і підсистем: модуля імітації теплових процесів, що відбуваються при нагріванні термістора, електричної схеми вимірювального каналу та підсистем запропонованого алгоритму обробки даних вимірювань. Розроблено та обґрунтовано структурно-функціональні схеми програмних підсистем для реалізації алгоритму компенсації впливу потужності термістора на його температуру саморозігріву. Розроблено та обґрунтовано схему вимірювального каналу. Запропоновано алгоритм компенсації впливу потужності термістора на точність вимірювання температури його розігріву. Реалізація запропонованого алгоритму компенсації впливу потужності термістора на температуру його саморозігріву надає можливість забезпечувати високу точність вимірювання (до 0,06 К(RMS)) та значно спростити процедуру обробки даних вимірювання та процедуру градування пристроїв.

Ключові слова: підвищення точності; метод прямого підігріву термістора, NTC-термістор, MATLAB Simulink.

*Надійшла до редакції
02 лютого 2026 року*

*Рецензовано
12 березня 2026 року*



© 2026 Copyright for this paper by its authors.
Use permitted under Creative Commons License Attribution 4.0 International (CC BY 4.0).