

# Temperature Monitoring System

Serghei ZAVRAJNYI, Iurie TIRON, Andrei GRIȚCO, Andrei STALBE, Iurie NICA  
 Institute of Electronics Engineering and Nanotechnologies "Dumitru Ghițu"  
 Chisinau, MD 2028R.. Moldova, e-mail: tehmed@iieti.asm.md

**Abstract** – The multichannel temperature probe for studying the behavior of thermal fields is described in this article. As temperature sensors used Chromel - Alumel thermocouples. Thermoelectric each thermocouple (from 11mV to 13mV) increased its own amplifier to output voltage from 0 to 5 V corresponds to a temperature ranging from 0 to 50oC. The optimal solution for this case was the use of two-stage amplifier based on low-noise operational amplifiers. Data converting, data collection and data transfer to PC is based on ATMEGA16 microprocessor company Atmel. Signals from the amplifier module used for the analog inputs of microprocessor. The microprocessor receives the amplified analog signals from each thermocouple, converts them and transmits the data according to the protocol USART to the PC. USART pins are connected to the MAX232 and ADM 485 transceivers. The system operates in accordance with the software application that is based on data received from the COM port allows it to control the temperature of the object at certain points, as well as using mathematical interpolation procedure to determine the temperature at other points of a predetermined extended region. Multichannel temperature probe allows us to observe thermal fields in the temperature range 0 ° C ... 50 ° C up to 0.1 ° C.

## I. INTRODUCTION

Bellow is described one variant of multi-channel measuring device of physical values, intended for use in various complexes of equipment for scientific research or control different processes. It is able to communicate with the devices within same complex, through RS232 and RS485 standards. Setting up for measure the physical values is performed by replacing the sensors and the corresponding correction function, stored in the microcontroller memory of the multichannel meter. In this article, the device is considered as multi-channel temperature measuring instrument for studying the behavior of thermal fields in the amount of physical bodies, part of the research method of local hyperthermia of malignant neoplasms.

As it is known that, one of the possible ways to combat the cancer can serve the destruction of malignant tumor cells with local overheating. Possibility of exercising of this method is associated with the fact that, during the heating of the body over 43 - 44 °C, is observed the destruction of tumor cells while healthy are more stable to heat tissue preserve the viability up to 50 °C.

Thus, it is strictly necessary to respect the two major limitations: on the one hand, overheating should not exceed the boundaries of viability of normal cells, on the other - the temperature of the tissues should exceed 43 °C, because insufficient heating only stimulates the growth of the tumors. As can be seen, acceptable treatment range of temperatures is narrow, about 5 °C. This imposes certain requirements on temperature measurement accuracy - better than 0.1 °C. To prevent localisation of the disease affected tissues in a region with temperatures below 44 °C, is necessary to monitor the heat dissipation and dynamics of its distribution, based on simultaneous measurements of temperature in several specific locations in the overheated region. Under these requirements has been designed the described multi-channel temperature meter.

## II. TEMPERATURE MONITORING SYSTEM

The temperature monitoring system is intended to monitor the temperature values in control points and construction of the temperature field. The system consists of the following functional levels:

- Temperature transducers
- The data acquisition and transmission system
- Temperature monitoring software

The system has 8 channels of temperature monitoring.

### 2.1 Temperature transducers

Temperature transducers are thermocouples of chromel-alumel type, which have coefficient of thermal sensitivity of 40 μV/°C.

Thermocouples conductors are protected by a Teflon hose.

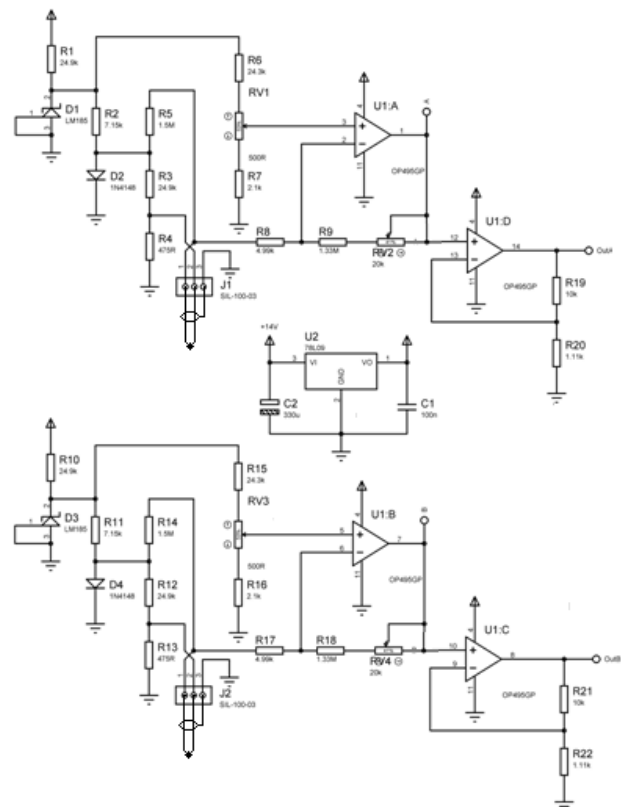


Fig. 1 Principal scheme of a signal amplification module from thermocouple

The hose is covered with a mesh shield. The screen, in addition to the useful signal protective function from noise, serve as mechanical support, offering increased mechanical strength conductors. The own low consumption of operational amplifiers, 150µA, allows realization of an amplifier system which is powered from an independent source such as a galvanic cell. Cold junction of the thermocouple are inside of the isothermal block with a compensaty diode.

In order to achieve amplification of the thermocouple signal, in the temperature range of 0 °C - 50 °C, the output voltage 0mV - 5000mV, is necessary to increase the amplification factor up to 10V. Optimal solution for this case was serial adding of a another amplification stage based on operational amplifiers. Because integrated circuit have four operational amplifiers, reasonable solution is to make two parallel analogue channels on a single PCB board. Developed module has its own voltage stabilizer to avoid the influence of supply and the digital circuits noise. Principal

scheme of a two channel thermocouple signal amplifier module is shown in Figure 1.

### 2.2 The data acquisition and transmission system

The data acquisition and data transmission system to PC is realized based on ATMEGA16 microprocessor, from ATMEL company. The signals from the amplifier modules are applied to the analog inputs of the microprocessor. The microprocessor reads the values achieved on each analog pin, converts them and transmits digital data via USART module to the computer. The device consists of four modules of 2 amplifier channel each. USART pins are connected to the MAX232 and ADM485 transceivers via 74HC4016 digital keys. This type of connection offers selectable data transmission serial interface. With 74HC4016 keys can choose the RS232 or RS485 interface. Principal scheme of data acquisition and data transmission module is shown in Figure 2.

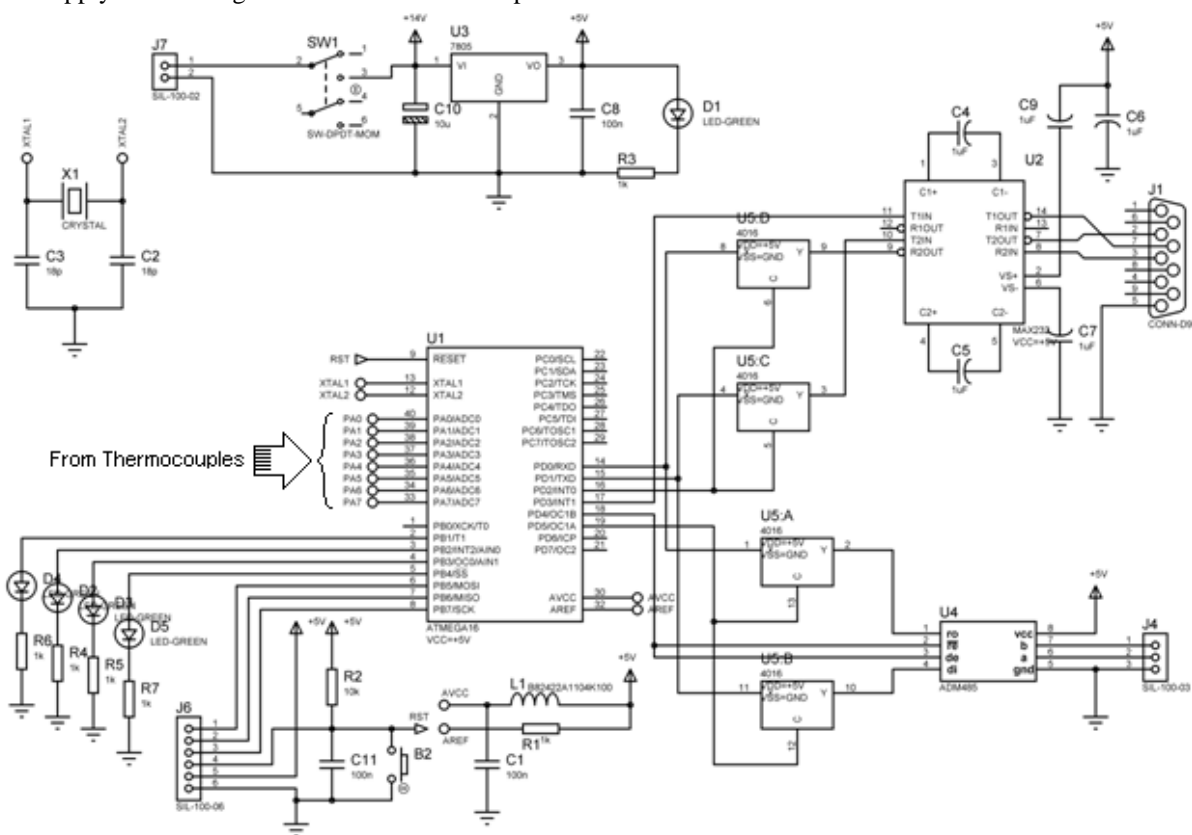


Fig. 2. Principal scheme of the data acquisition and transmission module

### 2.3 The data exchange packet format

Package for data exchange between PC and data acquisition system is composed of two bytes. In the first

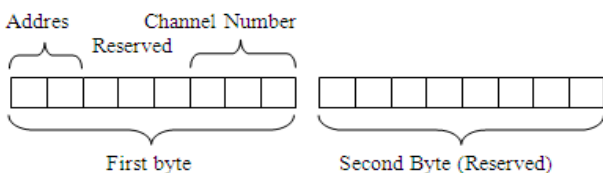


Fig. 3. Data exchange packet format.

byte, the two most significant bits contain the peripheral system address that is addressed computer. Three the least significant bits indicate the channel number on which the temperature is to be read. The remaining three bits and bit

field in the second byte is reserved.

The program consists in initialization section of the peripheral equipment involved in data collection process (ADC and USART unit) and data transmission section. Block - diagram of the microprocessor program shown in appendix A.

### 2.4 Temperature Monitoring System.

The system represents a software application, which, based on data obtained from the COM port, allows monitoring the temperature of the studied objects at the procedure determines the temperature on a previously defined domain. The domains on which is determined the temperature field can have multiple configurations: Irregular, Linear, Rectangle, Sector, Radial, and Cross

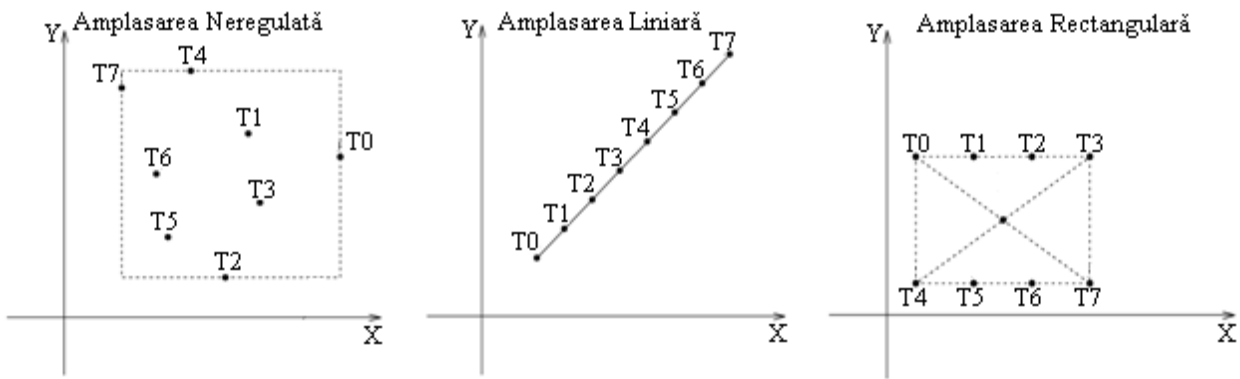


Fig 4a Amplasarea termocupurilor: Neregulată, într-o singură linie, Rectangulară

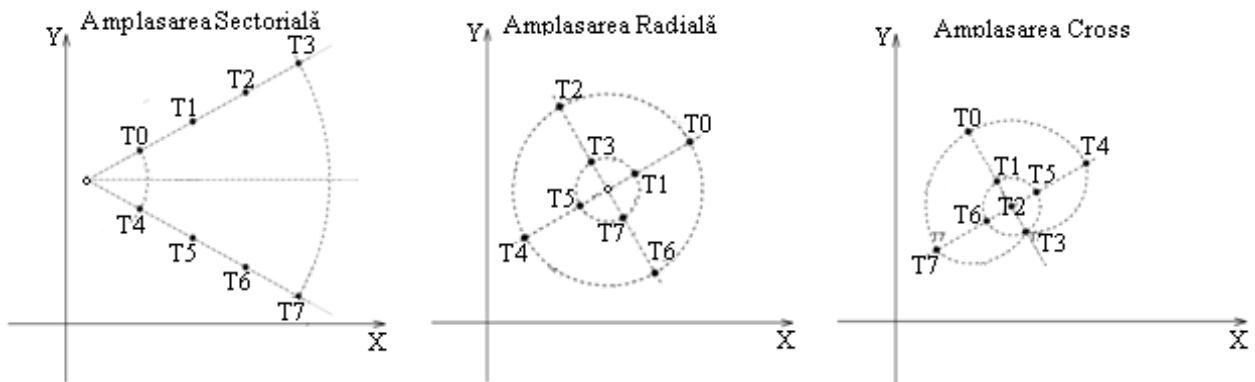


Fig 4b Amplasarea termocupurilor: Sectorială, Radială, Cross

The program consists from functions for processing the events from the main window of graphic elements, another large group of functions are mathematical and graphical processing functions. We will focus, more detailed, on the last ones, giving them a greater interest.

- **Bicubic interpolation.** Represents an extension of one-dimensional cubic interpolation used for interpolation of two variables function, which values are known from a regular grid of points. The interpolated surface is smoother compared to bilinear interpolation algorithms or "Nearest-Neighbor interpolation". Mathematical relations for the interpolation method are presented below

$$p(x, y) = \sum_{i=0}^3 \sum_{j=0}^3 a_{ij} x^i y^j \quad (1)$$

$$p(t) = \frac{1}{2} [1 \quad t \quad t^2 \quad t^3] \begin{bmatrix} 0 & 2 & 0 & 0 \\ -1 & 0 & 1 & 0 \\ 2 & -5 & 4 & -1 \\ -1 & 3 & -3 & 1 \end{bmatrix} \begin{bmatrix} a_{-1} \\ a_0 \\ a_1 \\ a_2 \end{bmatrix} \quad (2)$$

$$b_{-1} = p(t_x, a_{(-1,-1)}, a_{(0,-1)}, a_{(1,-1)}, a_{(2,-1)}) \quad (3)$$

$$b_0 = p(t_x, a_{(-1,0)}, a_{(0,0)}, a_{(1,0)}, a_{(2,0)}) \quad (4)$$

$$b_1 = p(t_x, a_{(-1,1)}, a_{(0,1)}, a_{(1,1)}, a_{(2,1)}) \quad (5)$$

$$b_2 = p(t_x, a_{(-1,2)}, a_{(0,2)}, a_{(1,2)}, a_{(2,2)}) \quad (6)$$

$$p(x, y) = p(t_y, b_{-1}, b_0, b_1, b_2) \quad (7)$$

- **Ponderable interpolation.** Represents an interpolation method which allows the construction of a surface based on control points which are positioned irregular. In determining the function value in a particular point, each control point contributes in an inversely proportional

measure with the distance to the calculated point at a certain power. Power exponent determines the smoothing degree of the surface.

Also known as Shepard method (1968). Mathematical relationships of this method are:

$$F(x, y) = \sum_{i=1}^n w_i f_i$$

$$w_i = \frac{h_i^{-p}}{\sum_{j=1}^n h_j^{-p}}$$

$$h_i = \sqrt{(x - x_i)^2 + (y - y_i)^2}$$

where  $f_i(x_i, y_i)$  is the function value in the control point,  $h_i$  – the distance between the calculated point and the control point,  $w_i$  – weight value for that control point.

The algorithm presented above is used to construct a surface on a field where the control points are placed irregularly. Power parameter  $p$  takes the value of 2.8, chosen experimentally, providing a convenient smoothing of the surface.

- Point representation in Cartesian and cylindrical coordinates. Depending on the type of the domain on which is defined the temperatures field, is more convenient to process data in Cartesian or cylindrical coordinates. The interpolation occurs in Cartesian coordinates for irregular, linear and rectangular areas type. For sectorial, Cross and radial areas type the interpolation is carried out in cylindrical coordinates. The built field is visualized only in Cartesian coordinates

Allows you to visualize the temperature field interpolated on the basis control points in real-time control. The observed surface will have the height of the Z coordinate, and the point value will be proportional to the temperature at that point. On the right side of the image is displayed the colors ramp fieacare correlated with the the temperature for each color. Temperature of 0 ° C corresponds the black color,

temperature 50 ° C corresponds white color. At the bottom side of the picture are presented the control tools of the three-dimensional image: rotation around the axes x, y, z, vertical and horizontal image displacement, separated scaling on x-y, and z. Using the checkbox "Solid Surface" we choose the type of the viewed surface of temperatures field: as a continuous surface form or in a grid form

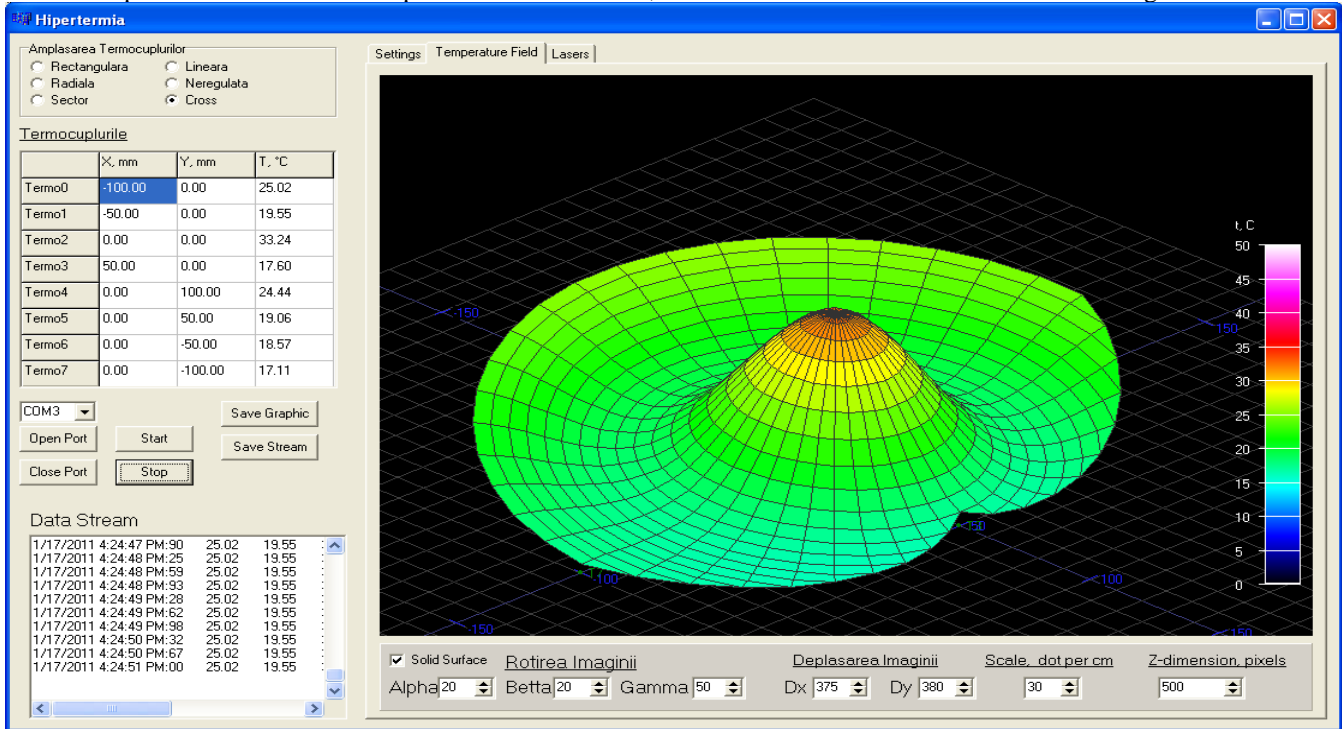


Fig. 5., „Temperature Field”

In the Figure 6 are represented graphs of the time dependency of the recorded signals by thermocouples in one experiment on the heating of the inner regions of a biological sample by the 808 nm infrared radiation.

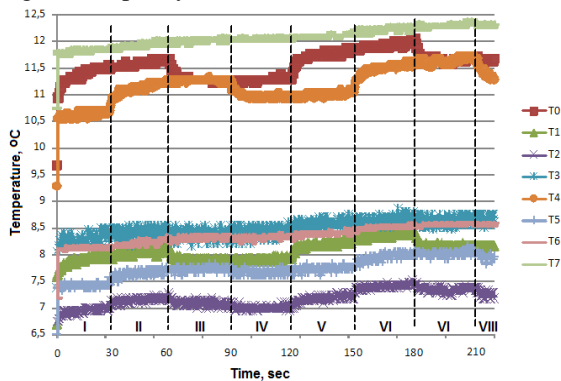


Fig. 6 Time dependence of the signals recorded by the thermocouples

Blurring curves determines the resolution of temperature meter,  $\sim \pm 0,05$  ° C, which is satisfactory when it is necessary to control the temperature with an accuracy of 0.1 ° C.

### III. CONCLUSIONS

The above-described multi-channel temperature meter, which allows to observe the thermal fields within the temperature range of 0 ° C... 50 ° C through the simultaneous measurement of temperature at several points on the studied area with a precision 0.1 ° C, is a options for

multi-channel measuring instrument of physical magnitudes designed for use in various sets of equipment for scientific researches or control of different processes. It is able to communicate with the hardware complex, in which is included, in the regime of serial code in a standard RS232 and RS485. This allows increasing the measurement channels by simply connecting to the installation of multiple measuring modules. Setting up the measurement of any physical value can be made by replacing the sensors and the corresponding tabulation of the correction function, stored in the controller memory of multichannel meter that will monitor several physical values.

### IV. ACKNOWLEDGMENTS

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