Using Sensor Networks for Assessing Work Conditions

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ABSTRACT: *The sensor network that we studied the observation of the indicators in the workplace for an evaluation of work conditions. We have given the two models of measuring the temperature change. The models given for other conditions of the workplace are used in the studied sensor networks.*

Keywords: Smart sensor, Smart sensor network, LabView

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1. Introduction

Globally, there is a steady increase in the attention that is paid to the health and the safety of the employees. Good working conditions are part of the motivating factors for them. [1]. Humans' efficiency is influenced by temperature, amount of heat and ventilation, humidity, air movement, atmospheric pressure, quantity and quality of light, noise, concentration of CO2 and CO, magnetic field, vibration accelerations. Comfort is a feeling, we all instinctively seek. If the surroundings provide proper conditions, one is able to work more, without getting tired quickly and recover from fatigue faster.

The wide variety of sensors, the advances in microelectromechanical systems integration and wireless communications are a prerequisite for the rapid development of technology in the field of sensor networks and their mass deployment in practice [2], [3]. The aim of this paper is to develop a smart sensor network which allows the monitoring of the environment in the workplace.

2. Parameters for Evaluation the Environment in the Workplace

To achieve the maximum in the workplace the application of ergonomic criteria is needed. Business owners have responsibilities regarding health and safety of their employees. The requirements for the evaluation of the different working environment parameters are described in [4], [5], [6]. The parameters shown in table 1, are objects of the proposed study.

Parameter	Border values for comfortable area	
	min	max
Temperature [ºC]	18	24
Humidity [%]	40	60
Intensity of light [lux]	250	1000
Noise [dB]	50	80

Table1. Border Values for the Parameters of the Workplace

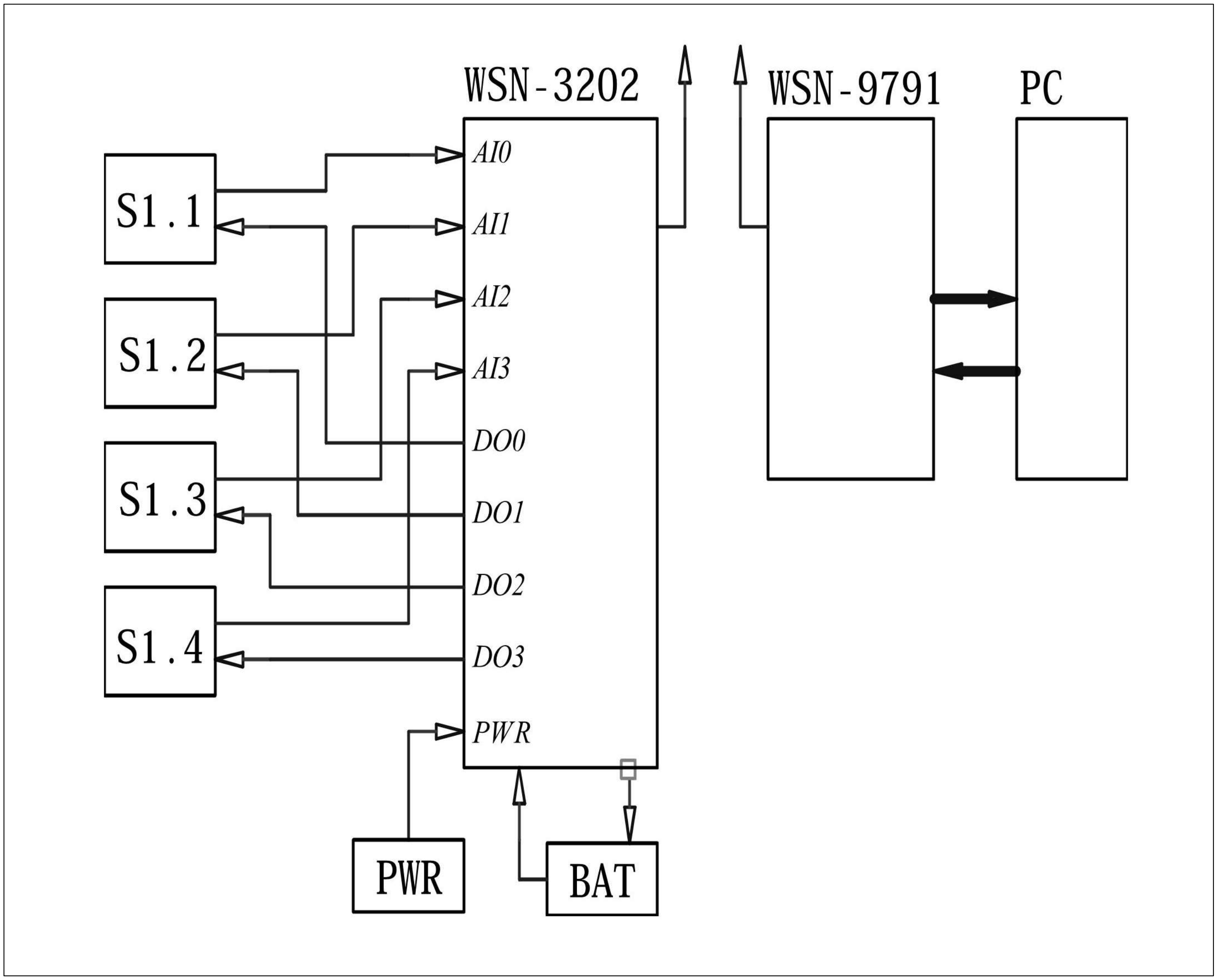
3. Schematic Diagram of Smart Sensor System for Ergonomic Assessment of Working Environment

The purpose of this paper is to present the results of designing smart sensors to operate under the management of a smart sensor network.

A system for collecting data from smart sensors, based on a wireless sensor network, including node NI WSN-3202 and Gateway (Gateway) NI WSN-9791. It is run by a PC using specialized software LabVIEW - Figure 1.

Figure 1. System for data collection

A functional diagram of the proposed sensor network is displayed on figure 2. The information is obtained from the smart sensors S1.1 to S1.4, for tracking changes on 4 major environmental parameters - temperature, humidity, noise and light. Signals enter from the sensors' outputs to the analog inputs AI0 ÷ AI4 of the node. The inclusion of each of the sensors is performed by control signals coming from one of the digital outputs DO0 ÷ DO3 of the node.



S1.1 ÷ **S1.4** – sensors (temperature, humidity,noise, light);

PWR – battery power supply for the sensors;

WSN-3202 – node; **“** - battery power supply for the node;

WSN-9791 – gateway;

Figure 2. Functional scheme of the system collecting data

The output of the sensors used, is a constant voltage varying within the limits set by the limit input voltages to the analog inputs of the used node - max ± 10 V. Since the use of "smart sensors", the requirement of independent battery power has been met, for the sensors' power in digital output sensor (PWR) and the power of the node (VAT).

From a wide variety, were selected sensors, the output of which is a constant tension in the specified limits:

- temperature sensor type - TC1047A [7], the output voltage which is a linear function of temperature - amend from 0, 1 V to 1, 7 V with temperature changes from -40 to +120 ° C (Figure 3); very low power consumption (max 60µA) at a supply voltage of 2, 5 to 5, 5 V.

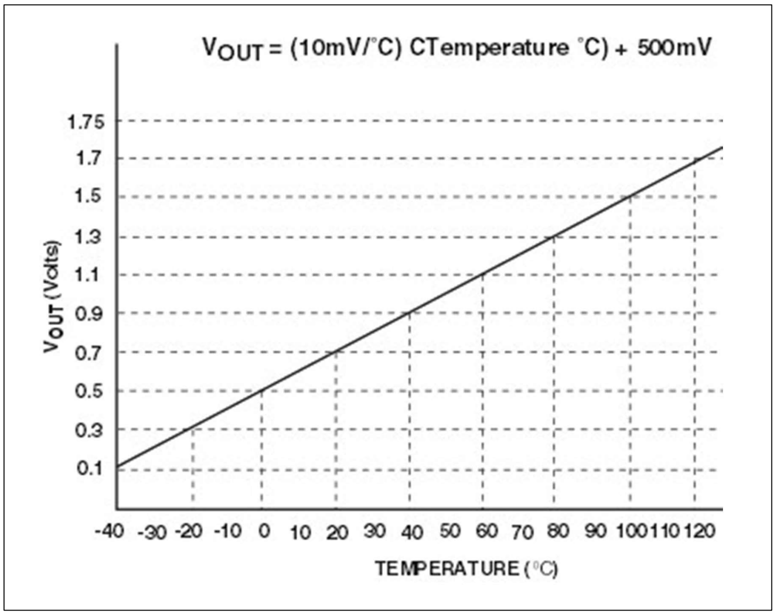


Figure 3. Dependence $U_{out} = \varphi\,(T)$ for TC1047A

- humidity sensor - HCH-1000 [8], the capacity of which varies linearly from 300pF to 360pF, when modifying the relative humidity RH from 0 to 100%.

- **Noise sensor** - SPM0404LE5H-QB-38342 , sensitivity - 38 dB, S / N ratio 62 dB, bandwidth.

- **A light sensor** - OPT101 [9] of the output voltage which is a linear function of the light intensity, a sensitivity of 0.45 / W (at 650 nm).

Output signal from the temperature and light sensor are constant voltages. This simplifies their connection to the analog inputs of the node. In this case, the use of buffer amplifiers is enough to decrease the disturbances of the connection cables. The output signal of the noise sensor is varying voltage, which has to be converted in constant voltage.

The connection of the capacitive humidity sensor to the designed sensor network requires additional conversion, in order to provide constant voltage to the input of the node.

4. Development of Smart Temperature Sensor

To monitor the change in temperature of the environment with the proposed smart sensor system, the execution of the following two steps is required.

Firstly, the deviation of the characteristic from figure 3, has to be shifted and scaled so that the indication of the system is directly shown in Celsius' degree. Secondly, to ensure the signalization when the temperature reaches values in uncomfortable area.

For realization of these two steps in this paper, two methods are suggested – circuit solution (design of a transducer) and software design with Labview (in this case sensor TC1047A is directly connected to the smart sensor system using the node NI

WSN-3202)

4.1. Circuit design
To obtain a DC voltage proportional to the temperature, a transducer is designed, a simulated diagram of which is shown in Figure 4.

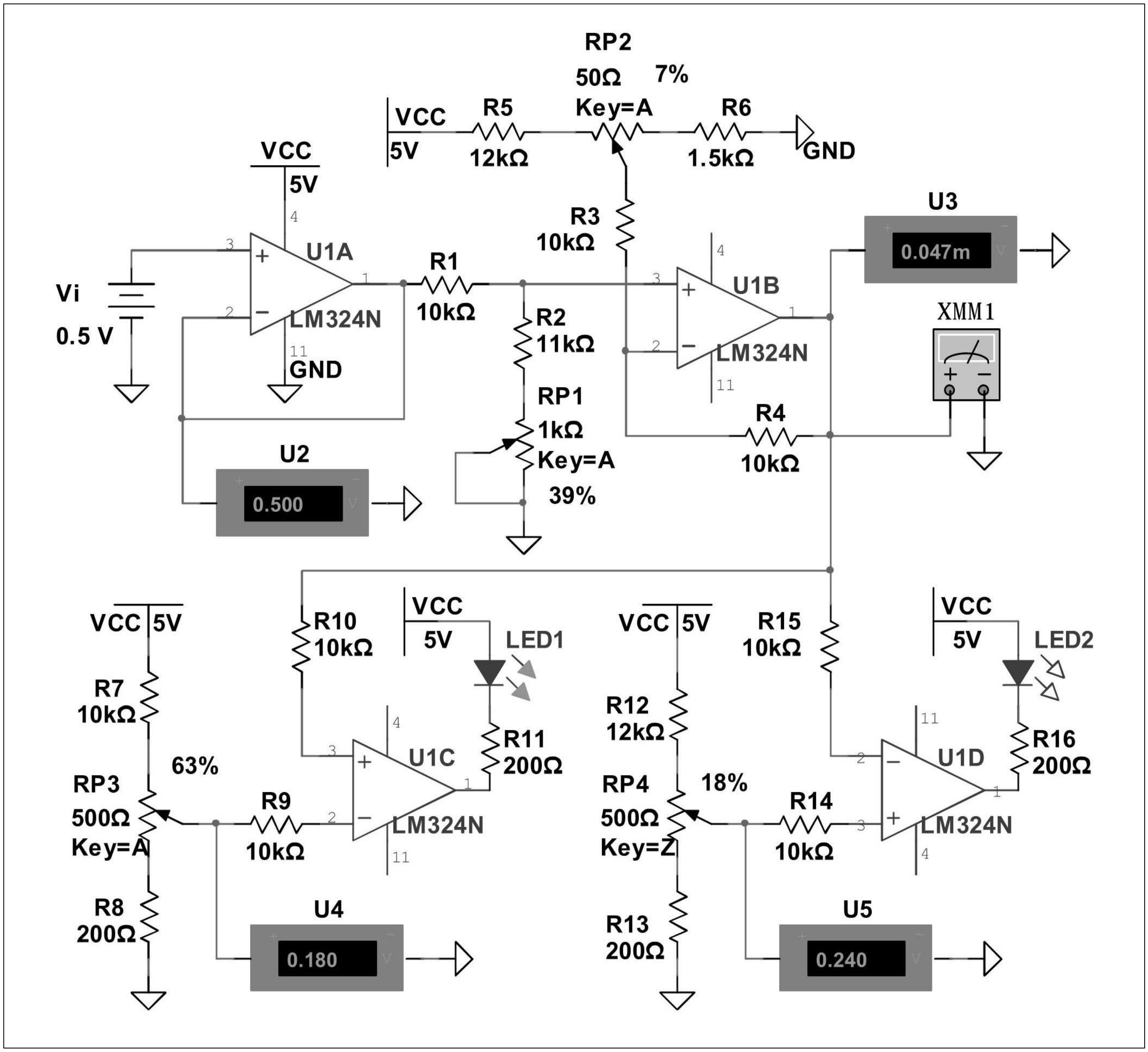


Figure 4. Circuit design of temperature transducer

For the proposed realization integrated circuit LM324 is used. It packs 4 Op-Amps - with very low power consumption (less than 1,2 mA), at a supply voltage 5V.

Temperature sensor in this scheme is replaced with a source of constant voltage Vi, which during the study of the pattern varies between 0,5 V and 1,5 V. These values correspond to a change in the output voltage of the sensor with change in temperature from 0 to 100 ° C.

With the op amp U1A and U1V, the change in the input voltage Vi is converted to output change from 0 V to 1 V. The voltage on the input is fed through a buffer amplifier filled with op amp U1A through the voltage divider R_1, R_2, RP_2 to the non-inverting input of the second op amp U1B. To the inverting input of U1B is submitted reference voltage from the divider R5, RP1, R6, which sets the "offset" of the output voltage so that the output voltage can be obtained at 0V input voltage Vi = 0,5 V. The output voltage of the intensifier, filled with U1B, is determined by the expression:

$$Vout = V_1 \frac{R_2 + RP_1}{R_1 + R_2 + RP_1} \cdot \left(1 + \frac{R_4}{R_3}\right) - Vcc \frac{R_6 (b.RP_2)}{R_5 + R_6 + RP_2} \quad (1)$$

where, *b* is the portion of the potentiometer RP2, between the slider and the terminal connected to R4.

After setting the zero indication of output, the input voltage is Vi = 1, 5 V with potentiometer RP1 that adjusts the output voltage to be 1V. Actions, by settings, of the zero indication and the maximum (1V) is repeated several times until the desired contrast values are achieved, with accuracy to within 0.1%.

The dependence of the output voltage from the specified input range of variation nd the change of the relative error d are shown in Table 2.

t [°C]	0	25	50	75	100
Ui [V]	0,5	0,75	1	1,25	1,5
Uo [V]	0,0465	250,088	500,13	750,171	1,0
δ [%]	0,0465	0,0352	0,026	0,0228	0

Table 2. Dependence $Uo = \varphi(Ui)$

Research results of the scheme show that it can measure the temperature from 0 to 100 º C at a relative error less than 0.05%.

The second part of the scheme includes comparators implemented with U1C and U1D. Include the output of U1C LED LED1 (blue) lights up when the output voltage of U1V = 0,18 V, corresponding to the set min temperature 18 ° C.

Include output U1D LED LED2 (red) lights up when the output voltage of U1V ≥ 0, 24 V, corresponding to the set max temperature of 24 ° C.

4.2. Software design with LabVIEW

There is a second embodiment of signal conversion from the output of the pattern, by using the potential of the programming environment LabVIEW. A developed block diagram of the voltage converter from the output of the temperature sensor and a comparator responsive to the limit value of the temperature is shown in Figure 5.

It can be seen in figure 6 the temperature's indicators. Input voltage is fed to the input AI0 of the node (from Figure 2). Its value is reported by the program indicator AI.

The current value of the temperature is recorded simultaneously with the two indicators "Temperature [° C]" - digital and analog. The transformation of the input voltage varies from 0, 5 V to 1,5 V, in the indicator from 0 ° C to 100 ° C, is carried out by successively using the functions "-" and "x".

Thus was prepared the indicator:

$$Y = (X - 0,5).100\ [\%] \quad (2)$$

where $X\,[V]$ is the value of the input voltage.

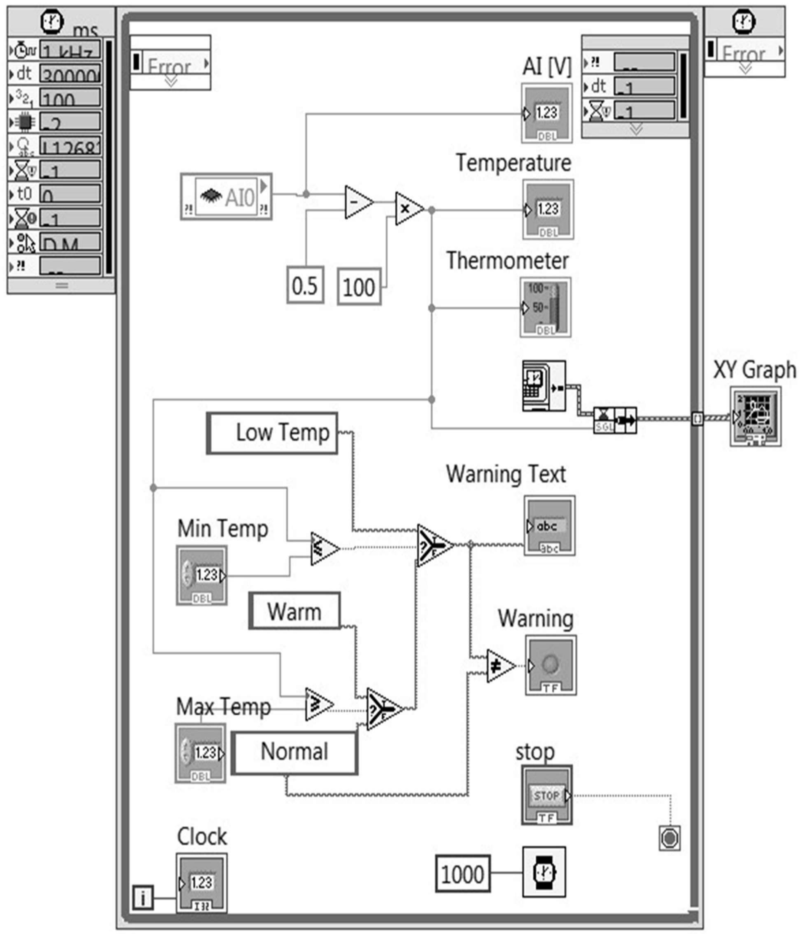


Figure 5. Block diagram of the measuring system

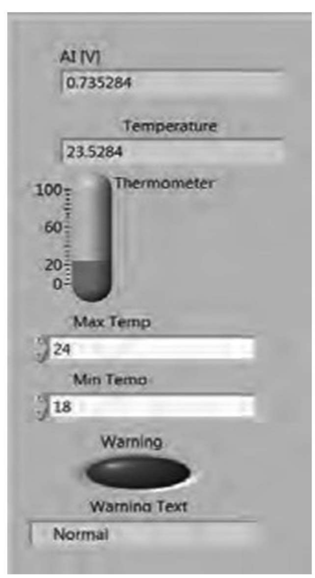


Figure 6. View of the front panel

Coefficients "0.5" and "100" are set in the respective blocks.

The second part of the scheme includes two comparators, connected to the output. They compare the current value for the temperatures with the minimal and the maximal, determined by the comfort area. The Time Loop function is used to regulate the interval between measurements. XY Graph shows the temperature's changes in time. In this case, there have been made 20 measurements, 5 minutes apart. A fake maximum is made to demonstrate the reaction of the sensor and the activation of the alarm for high temperatures.

The TC1047A sensor is directly connected to the input AI0 of the node.

For the purposes of the project, a test is carried out, measuring the temperature in a teaching laboratory at the Technical University - Varna, with duration of 42 hours. The results are presented in Figure 7.

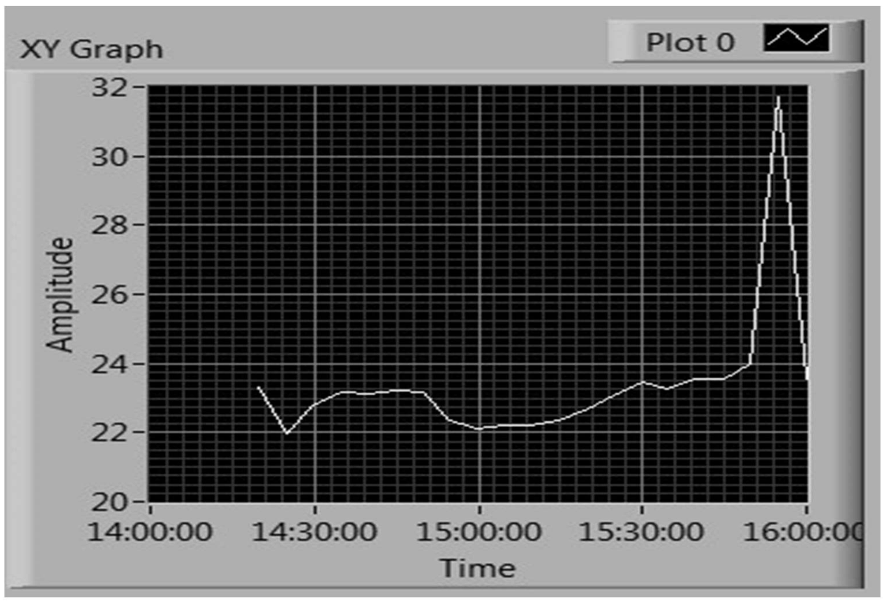


Figure 7. Variation of the room temperature

It can be noted that the change of temperature is approximately 2.5 ° C. The variation of the temperature is in norm according to the recommendations.

The flexibility of the design allows the sensor network to include more sensors and the relative ease of tracking changes and other environmental parameters.

5. Conclusion

This report presents the design of smart sensor network for ergonomic assessment of factors affecting the health and performance in the workplace. The proposed system allows four parameters of the environment to be overseen, in this case – temperature, humidity, light and noise.

In this paper, there is a detailed explanation only for measuring the change in the temperature. Two ways are developed and used. Firstly, a circuit design of a transducer, secondly, a sensor TC1047A connected to the smart sensor system using the node NI WSN-3202 and NI WSN-gateway 9791, under the management of the programming environment LabVIEW.

The other sensors can be connected to the node in accordance with the temperature one. Afterwards, the entire workplace environment can be monitored.

Acknowledgement

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References

[1] Въчинска С., „Здравословни работни места – насоки за оценка на риска по време на работа", Научни трудове на, 2011, Русенския университет, Том 50, Серия 1.2, Русе, 2011, стр..168- 173.

[2] Yick, J., Mukherjee, B., Ghosal, D. (2008). Wireless sensor network survey, *Computer Networks*, Vol. 52, Issue 12, pp. 2292-2330, August 2008.

[3] Ch. Buratti, M. Martalo, R. Verdone, G. Ferrari. *Sensor Networks with IEE* 802.15.4 Systems, Springer, 2011.

[4] Маркова В., М. Иванов, Проектиране на сензорна мрежа за ергономично изследване на лаборатория за интерактивно обучение в областта на техническите науки", Тр международен научен конгрес "50 години ТУ-Варна", Том Варна, България 2012.

[5] НАРЕДБА № 7 ДВ бр.43,13.05.2003г. за минималните изисквания за здравословни и безопасни условия на труд на работните места и при използване на работното оборудване.

[6] Acoustics — Declaration and verification of noise emission values of machinery and equipment EN ISO 4871:2009

[7] http://ww1.microchip.com/downloads/en/DeviceDoc/51483b.pdf http://www.engineeringtoolbox.com/light-level-rooms-d_708.html

[8] http://pdf1.alldatasheet.com/datasheetpdf/ view/230829/HONEYWELL/HCH-1000.html

[9] http://www.ti.com/lit/ds/symlink/opt101.pdf