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INFORMATIONAL MEASURING SYSTEM WITH WIRELESS DATA TRANSFERRING FOR SENSORS OF PHYSICAL VALUES

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Abstract: At the stage of designing, the prototype of a multifunctional computer-aided informational measuring system with wireless data transferring with the use of various sensors of physical values was developed, and experimental investigations of such a system for revealing the possibilities of correct work with the sensors industrially produced, as well as sensors and converters of physical quantities developed at the Laboratory of sensor electronics of the Department of Semiconductor Electronics of Lviv Polytechnic National University as a part of a current research project were carried out.

Key words: monitoring systems, sensor, informational measuring system, thread-like crystals.

1. Introduction

The modern development of the informational measuring systems is characterized by wide usage of measuring converters of different physical values into electrical signals convenient for their further processing and transferring to large distances. Sensors are the primary part of measuring converters in the informational measuring system and to a great extent determine its metrological characteristics. Among the great variety of sensors produced at industrial enterprises, the tensoresistive or thermoresistive sensors based on resistive nano- and microelectromechanical systems prevail due to their multifunction nature while measuring pressure, temperature, mechanical deformation and movement, acceleration etc., as well as simple development of measuring circuits, high technological effectiveness, reliability and adaptability while being compiled with the converters of analogue signals to frequency, code or digit. Their usage improves structure, elementary components, measuring and processing algorithms. To each kind of sensors certain secondary measuring converters suit, whose construction features depend on certain tasks and objectives of information processing.

Developing all modern basic systems for monitoring of technically complicated objects is based on the principles providing the ability to adaptation to the monitoring of objects of national economy (hydroelectric power structures, bridges, thermal power stations, buildings etc.) [1].

The constituent parts of the monitoring systems can be located either in the same building, or at the considerable distance of one another. For the interaction of the system elements it is necessary to use different communication channels: cable lines, radio channels, satellite channels. At the same time, in the boundaries of one physical channel different interfaces exist.

Nowadays, the combination of networks of different topology is not a serious problem, since interface converters are used for this process. More serious is the issue occurring at the interaction of different producers at the level of data transfer. Producers of modern equipment do not have a single link protocol for the industrial networks [2, 3]. The most widespread data communications protocol is MODBUS, but at the same time, many producers use link protocols of in-house design. If the realization of a certain link protocol is not a difficulty for an experienced programmer, the application of a variety of them in the same system dramatically increases the time and cost of the design. Moreover, not all of the protocols provide the complete reliability of the data transfer.

The development of new and more perfect informational measuring devices requires a system approach to the analysis and development of measuring converters as the part of the informational measuring system.

Today, the great variety of devices and platforms for controlling and monitoring the physical processes exists. They cover the separate information on the development of the control systems and display it in the form convenient for further usage and investigations. However, they are almost inaccessible for mass users apart from profile engineers, other professionals or local R&D institutions, which is the most considerable drawback of them.

At the development stage, the task of designing the layout of multifunctional computer-aided informational measuring system with wireless data transferring and with the use of the sensors of physical values was set. It implied the experimental investigations of such a system for revealing the possibility of its correct work with industrially produced sensors, as well as with the sensors and convertors of physical values developed at the Laboratory of sensor electronics of the Department of Semiconductor Electronics of Lviv Polytechnic National University during the current research project.

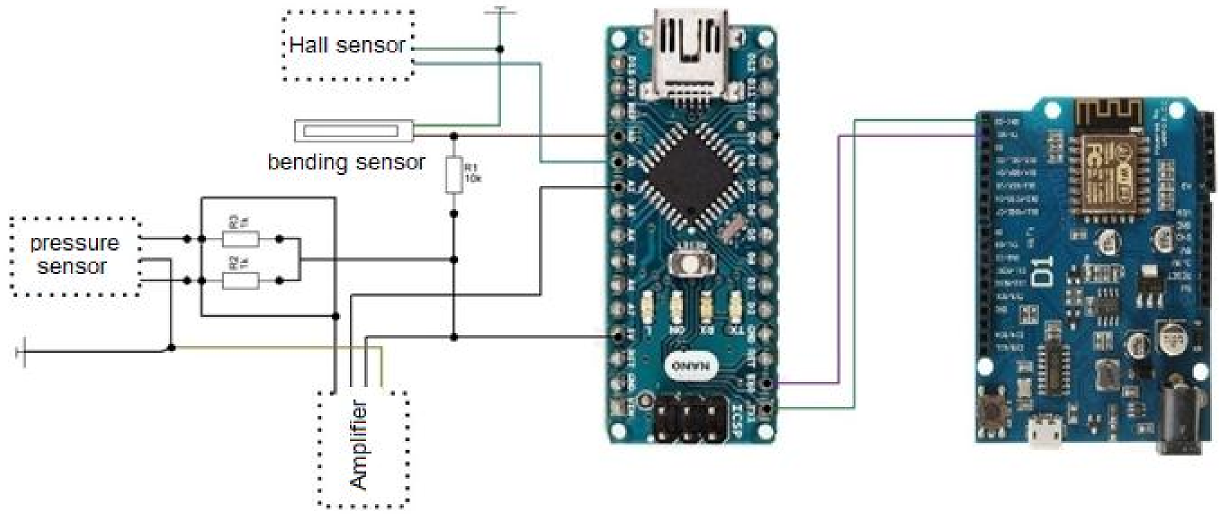


Fig.1. Flowchart of informational measuring programmed system with the use of the sensors of physical values

For the development of the informational measuring system, the platform on the Arduino basis was used. The main advantage of the platform is being a tool for designing electronic devices which closely interact with physical environment, contrary to simulations on personal computers, which cannot move beyond the virtual boundaries. For designing and using the sensors, the Arduino platform has a variety of circuit boards and their modifications, which can be used as the basis for the development of automatized systems. They differ in size, embedded memory, the number of analogue and digital inputs and outputs, microcontroller capacity and dimensions. A typical RS-232 interface can be found practically in every personal computer. RS-232 is a typical interface which meets the standard including electrical, physical and mechanical characteristics and provides the connection between the computer and its periphery for the realization of serial communication. It is a "point-to-point" interface and can work at small distances with speed up to 20 Kbps [4].

Many projects use modules of the ESP type, for example, in the well-known modern development spheres as "internet of things", "smart house" or intellectual systems for home automatization etc. This type has such modifications as ESP-01, ESP-02, ESP-03, ESP-04, ESP-05, ESP-06, ESP-07, ESP-08, ESP-09 and ESP-10 [5].

Therefore, the Arduino platform is the best for the development of compact devices and automatized systems, has some advantages comparing with other platforms, that is, unified equipment, high interchangeability of the components, stable characteristics, wide collection of typical communication interfaces and design simplicity.

As the network module for data transferring, the microchip esp8266 with TCP/IP stack support was chosen, which can be used for the development of the web-service of full value, together with its most wide-spread circuit board WeMosD1 R1, which is convenient and easy to use. The board can be easily reprogrammed since it is supported by the USB interface [6].

An application on the phone acts as a server which starts up and waits for a client (WiFi board). Being started up, the board adjusts the WiFi client at connecting to the network. After the client being connected, the server receives data which are processed, and the result is shown on the screen. If the client is not connected or data is not output to the screen, a proper message appears saying that a chosen sensor is inaccessible. The board identifies the server by the port number through which the data transfer is done and by a telephone IP. The data on the WiFi network should be known before the client settings are done. This can be further realized using the simplest outer peripheral devices, or, if the list of networks is provided, the module will search for the accessible ones and connect to them automatically. A bluetooth module can be also used, and in this case the preliminary settings can be provided from the application software.

The software for the microcontroller can be found in the integrated environment Arduino IDE, which allows easy downloading all necessary libraries for operations with the circuit board. The analysis of working in such an environment showed its low operation speed and lack of some tools necessary for work with the microcontroller, so it is not very convenient under the continuous work conditions. Therefore, in practice, an Atmel Studio platform is used, which is based on the professional development environment for C++ programming language. This platform provides all necessary tools regarding modern environment for working with the microcontroller.

For the experiments three sensors of physical values with different operation principles developed at Lviv

Polytechnic National University were chosen, in particular, the sensor of hydrostatic pressure on the basis of thread-like crystals GaSb and multifunctional sensor for measuring temperature, deformation and magnetic field. The flowchart of the developed system is shown in Figure 1.

2. Characteristics of the sensors of hydrostatic pressure with tensoresistors based on thread-like GaSb crystals

For measuring high pressure reaching values of hundreds of megapascal, the sensor of hydrostatic pressure is used, which does not require a complex construction of springy elements, since the pressure passes through liquid directly to the sensitive element of the sensor [7]. The results of calibration of the sensor are shown in Figure 2. Measurements were carried out at the current value of 1 mA through the sensitive element. From graphs provided it can be concluded that the circuits converting the change of resistance into the output signal of the sensors, depending on the exploiting conditions, require temperature compensation of the resistance and tensosensitivity.

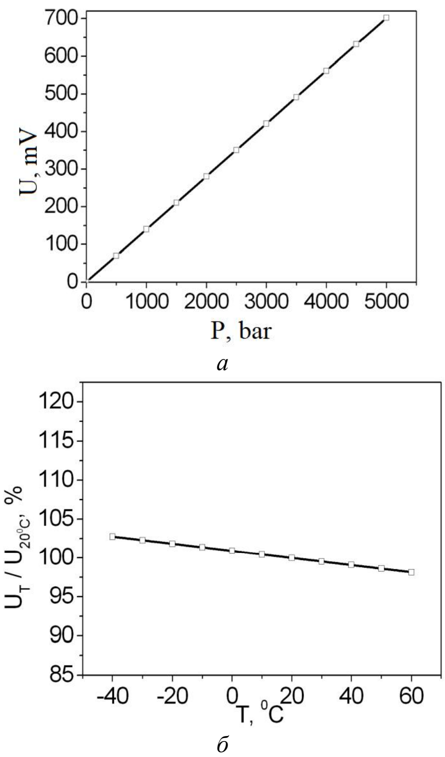


Fig.2. Output signal of the sensor of hydrostatic pressure (a) and its temperature dependency (b).

3. Multifunctional sensor for measuring temperature, deformation and magnetic field.

The design of multifunctional sensor, where the sensor for measuring temperature was realized on the basis of thread-like Si crystals of n-type conductivity, and sensors for measuring deformation and magnetic field were made on the basis of thread-like Ge crystals of p-type and n-type conductivity, correspondingly, was developed [8]. This design allows providing the temperature compensation of tensosensitivity and temperature dependency of sensitivity to the magnetic field.

In Figure 3, output signals of the deformation sensor (Fig. 3a) and magnetic field sensor (Fig. 3b), created on the basis of thread-like Ge crystals of p-type and n-type conductivity, correspondingly, and the temperature sensor on the basis of thread-like Si crystals of p-type conductivity are given.

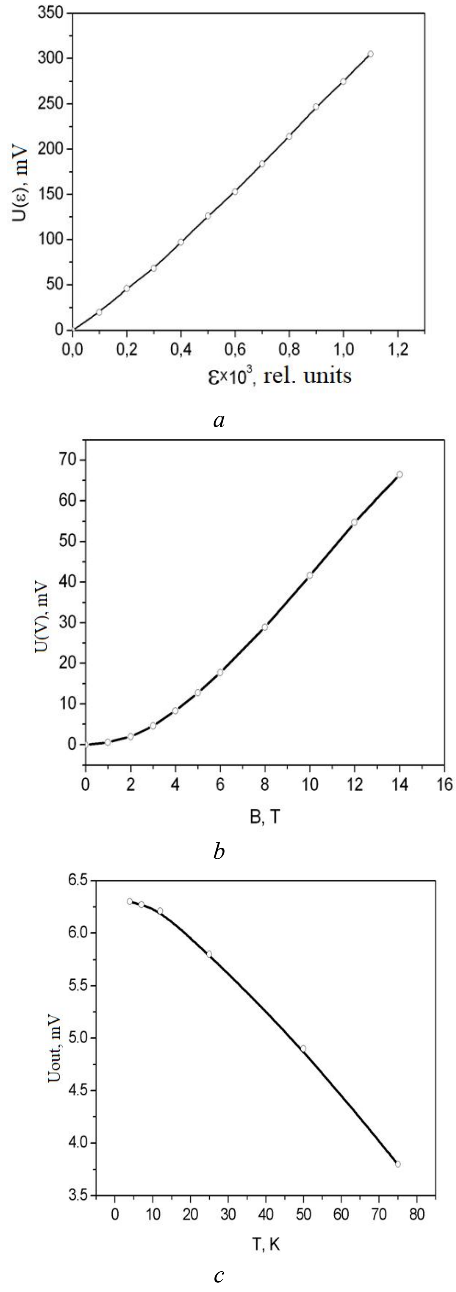
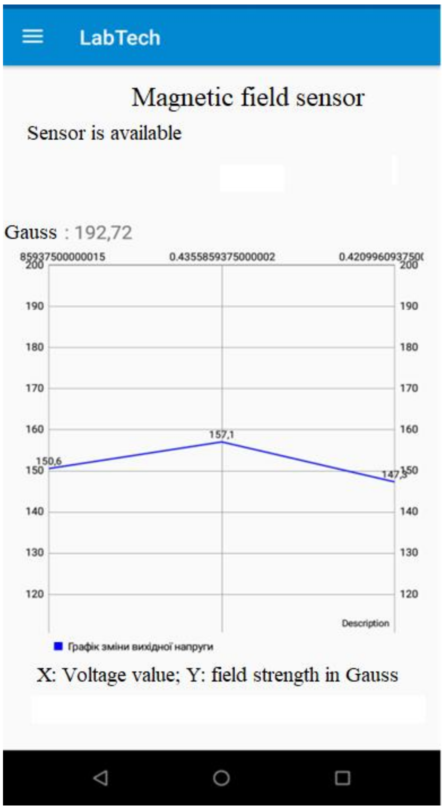


Fig.3. Output signal of multifunctional sensor: a) deformation; b) magnetic field; c) temperature.

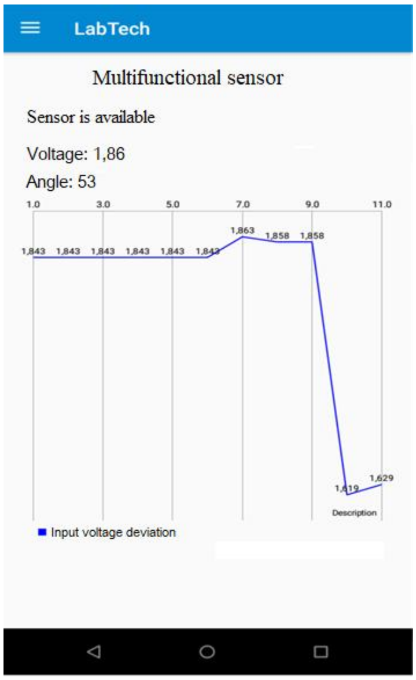
As it is shown in Fig.3a, at the temperature of 70 K the output signal of the deformation sensor on the basis of thread-like Ge crystals of p-type with deformation level of $1{,}2\times10^3$ relative units reaches 300 mV. For the magnetic field sensor on the basis of thread-like Ge crystals of n-type conductivity at the same temperature and the magnetic field induction of 14 T the output signal equals 65 mV. The output signal of the temperature sensor on the basis of thread-like Si crystals of p-type conductivity is used for the correction of temperature errors at the range of 4,2 ÷ 70 K.

For the convenience of operation with the developed informational measuring system on the basis of the converters of physical values the full software code for the application being installed on the smartphone is created.

In Figure 4, the interface of developed application software during the measurement of physical values by the informational measuring system containing three above mentioned sensors is shown.



a



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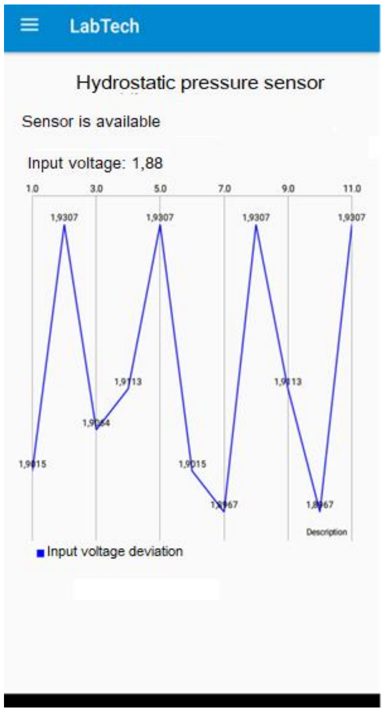

c

Fig.4. Interface of the developed application on the smartphone screen during the measurement of physical values by the informational measuring system containing three different sensors: a – magnetic field sensor; b – deformation sensor; c - hydrostatic pressure sensor.

The developed system is universal, as it allows working with analogue and digital sensors of physical values (those being in full-scale production and in short-run production as well) without depending on the interface of their connection. Moreover, the system can process data from tem sensors simultaneously. The graphs of changing the physical quantities provide visual observations and further recording of certain physical phenomena. Due to the use of the Arduino platform, a considerably compact size, efficiency and productivity of the system has been achieved.

4. Conclusions

Summing up the findings of the research, it should be noted that the informational measuring system developed during this project can be useful either for scientific investigations, or for institutions and enterprises dealing with monitoring and diagnostics of specialized sensor systems measuring deformation of construction materials, protection systems, intellectual systems of automatization of thermal power engineering etc. Moreover, the developed informational measuring system can be applied to creating robotic systems, automobile production, biomedicine, virtual reality, “smart city” systems. There is no such a system existing nowadays.

References

[1] Tsapko M.P. *Measuring information systems: structures and algorithms, circuit design*: Tutorial for universities. - M.: Energoatomizdat, 1985, 439 p. (Russian)

[2] Naumann G., Meiling W., Shcherbina A. *Standard Interfaces for Measuring Technology* ,Translated from German, M., 1982. (Russian)

[3] N.I. Gorelikov, A.N. Domaratsky, S.N. Domaratsky et al *Interface for Programmable Devices in Experimental Automation Systems* , Moscow: Nauka, 1981, 262 p. (Russian)

[4] Serial Protocols Compared / John Patrick // Embeded, ttps://www.embedded.com/design/connectivity/4023975/Serial-Protocols-Compared, 2002.

[5] *WiFi Module - ESP8266 Description*, Official documentation, SparkFun Electronics, 2019. https://nurdspace.nl/ESP8266

[6] *The USB bridging solution specialists*, Application Note, Future Technology Devices International Ltd, 2015.https://www.ftdichip.cn/Corporate/Press/FTDI%20Chip%20Product%20Brochure.pdf

[7] Druzhinin, A. A., Khoverko, Y. M., Kutrakov, A. P., Liakh-Kaguy, N. S., & Yatsukhnenko, S. Y. Sensitive element of multifunctional sensor for measuring temperature, strain and magnetic field induction, *Technology and design in electronic equipmen*t, Vol. 6, Pp. 42-45, 2017

[8] Druzhinin, A. A., Maryamova, I. I., Kutrakov, A. P., & Lyakh-Kahuy, N. S. Hydrostatic pressure sensor based on gallium antimonide microcrystals. *Technology and design in electronic equipment*, Vol. 4, 19-23, 2015 (Russian)

ІНФОРМАЦІЙНО-ВИМІРЮВАЛЬНА СИСТЕМА З БЕЗДРОТОВИМ ПЕРЕДАВАННЯМ ДАНИХ ДЛЯ СЕНСОРІВ ФІЗИЧНИХ ВЕЛИЧИН

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На етапі конструкторських робіт розроблено макет багатофункційної програмно-автоматизованої інформаційно-вимірювальної системи з бездротовим передаванням даних з використанням різноманітних датчиків фізичних величин та проведено експериментальні випробування такої системи з метою виявлення можливості коректної роботи з датчиками як промислового виробництва, так і сенсорами та перетворювачами фізичних величин, розроблених у лабораторії сенсорної електроніки кафедри напівпровідникової електроніки НУ “Львівська політехніка” у поточному науково-дослідному проекті зокрема.

Anatoliy Druzhinin – D. Sc., professor, Head of the Department of Semiconductor Electronics at the Institute of Telecommunications, Radioelectronics and Electronic Engineering, Lviv Polytechnic National University, Ukraine. He is also the winner of Ukrainian State Prize in Science and Technology (2011), Honored Research Worker of Science and Technology of Ukraine. The main scientific activities of prof. A. Druzhinin include: theoretical and experimental study of strain-induced effects in silicon, germanium and their solid solutions whiskers. Prof. Druzhynin has authored more than 140 scientific publications indexed in scientometric databases in Scopus and Web of Science and more than 50 invention certificates and patents. Under his supervision 6 DSc and 11 PhD degrees in technical science were obtained.

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