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Optical-Electronic Monitoring System of Biomedical Indicators

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The work is devoted to the development of medical systems for monitoring biomedical indicators. The problem of developing a universal hardware software-controlled control system for the diagnosis of biological objects is solved. The main requirements for such a system are a wide range of functionality for combining different methods of measurement transformation and compliance with modern trends in the development of microelectronic sensors. Given the requirements for modern microcircuitry, in particular for sensing devices of the Internet of Things, the signal path of the sensors is implemented on the basis of PSoC family 5LP Family Cypress. Approbation of the developed system is carried out in the course of research of character of optical radiation in the course of measurement of biomedical indicators.

Keywords: optoelectronic system, multiparameter analysis, monitoring of indicators, microcontroller unit.

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Introduction and problem statement

The use of information support in medical practice is becoming increasingly important. For today in her arsenal of such applications there are mainly three types of systems – display system of medical information, system information of monitoring patients and alert system on dangerous changes of vital biomedical indicators. First are graphically reflect the basic characteristics of health in real time, that is the time chart (ECG, EEG, plethysmography etc.) [1]. The second allow to get the doctor information based on results prolonged observation chosen change biomedical parameters for individual patient [2, 3]. Third create an informative signal (acoustic, light, etc) on dangerous changes in individual biomedical indicators [4].

However, those systems do not always allow the doctor who conducts a medical procedure, intervene in its course. But intervention may be extremely necessary especially at the work of the doctor in an interactive mode. The intervention of the doctor directly during the treatment may be in cases of early termination of the procedure if it is sufficient or the appearance of its adverse effects on the patient. The purpose of the intervention may also be the need for repeat the procedure when its effect is insufficient or need operative correct settings of procedure regime. Appropriate in

these cases are hardware tips for the doctor, is visual designs of medical decisions or automatic termination, continuation or correction. For this purpose, continuous monitoring of as many biomedical indicators of the patient receiving the treatment as possible is effective. This necessitates continuous analysis of many signals simultaneously and automates their processing with visualization of decisions or actions [5].

The doctor, as a person who makes decisions, makes it the solution to the shortage of basic data and essential a priori indeterminacy, based on their qualifications, experience and intuition. Thus, the decision wrong decision (medical error) at the stage of diagnosis and at the stage of treatment can have disastrous consequences for the patient. In order to prevent the wrong decisions needed new system of continuous monitoring of the treatment process that enable the doctor to see the patient in real time, and take rapid decisions.

Analysis of information sources was found that existing systems are used in most one-parameter monitoring does not ensure uniqueness in the process of message. The solution to this problem is to use multiparameter monitoring during the treatment procedure.

Of particular interest to medical practice represents information technology-aided selection signals change their priority during the procedure of formation of the

basis of the optimal solution. One promising solution to this problem is the development of new principles of implementation capabilities of modern high-performance microcontrollers and specialized software in software-driven medical-diagnostic devices.

The paper, based on the use of information technology elements helper attempt to implement such approaches for development of software-driven medical-diagnostic devices.

I. Information multiparameter analysis

Signals significant number of patient-controlled parameters processed in a matrix on a flexible hardware algorithm using the method of expert evaluations. The task of optimizing the distribution of hardware and software resources caused the need to choose new circuit solutions and the development of this microcontroller unit and optoelectronic monitoring system diagnostic and treatment process.

The basis of the microcontroller is a powerful microprocessor with Harvard architecture, which controls the operation of the digital and analog blocks, surrounding devices. The digital part consists of four eight-bit internal blocks PSoC and interface modules of user which are used for connecting external devices - keyboard, display, power audio signal, PC. The analog part consists of six indoor units which allows to use feature analog-to-digital and digital-to-analog conversion, amplification, programmable gain, pulse width modulation, detection, comparison, multiplexing and correlation. Processing of input information carried out under the control of embedded software which used by to store energy-volatile memory (EEPROM and Flash). To store of intermediate results during processing used an internal random-access memory (RAM).

Work of the system is in continuous signal analysis unit primary transducers embedded in the algorithm of the microcontroller. The obtained results transmitted to the processing unit in the display and PC software for further analysis.

The value of the controlled current can be set by software. In case of exceeding these values is automatically cut-off the power, and a message on the PC.

Information on the range of input voltages U_{min} - U_{max} , the threshold value of the protection current, voltage and step change in read current value displayed in the dialog window treatment. Addition possible set automatic selection step changes in stress. The information in the table formed, which exported to MS Office Excel to construct the corresponding graphic dependences.

At first approach logic functions can be viewed as a process of manipulating information, and could be presented certain information signals, such as X_1, \dots, X_K . In this approach, the input signals are primary and logical reasoning - secondary. According to Bayes' formula as a measure of the reliability of conclusions about the effectiveness either efficiency or inefficiency of medical procedures probability $P(Y_j/X_i)$ in a recurrent form:

$$P(Y_j/X_1, \dots, X_K) = P(Y_j/X_1, \dots, X_{K-1}) \frac{P(X_K/Y_j)}{P(X_K)}$$

If the analysis one of the two available options, and provided that $P(Y_1) = P(Y_2)$, valid for statistically independent features are:

$$\frac{P(Y_1/X_1, \dots, X_K)}{P(Y_2/X_1, \dots, X_K)} = \prod_{i=1}^K \frac{P(X_i/Y_1)}{P(X_i/Y_2)}$$

or after the logarithm in arecurrent form:

$$u_K = u_{K-1} + \ln z_K$$

Decision rule in this case is as equation isolating rule:

$$u_K \geq 0 \rightarrow X \in Y_1,$$

$$u_K < 0 \rightarrow X \in Y_2.$$

Together with equation isolating rule is interpreted as follows: if, after consideration of another parameter the signal of sign magnitude u_K has not changed, there are grounds for termination of the analysis.

The peculiarity of the proposed algorithm is determining of one of three test signals, dynamics changing the parameters which are the most severe. Monitoring the progress of medical procedures based on analysis of the dynamics of the dominant signal X_i for which at each time interval is determined by its change ΔX_i and the average value and its absolute value passed for all time intervals. For each time interval is checked value and dynamics of change at exceeding standards emerging critical reports critical state - Y_K on the input signal X_i [6]. In addition, for each time interval is checking the total length of the procedure and in case of exceeding the preset time in the absence of dynamics parameters of the dominant signal formed message Y_{NE} the ineffectiveness of treatments.

Provided reduction of the dynamics of the dominant signal to a level that is described by the values a and b , which define the acceptable limits of the scope method Wald, formed message about the successful completion of the medical procedure.

In the event of emergencies formed a disturbing message about the need for an immediate cessation treatment. The dataset is stored in a database that is used in the design of similar devices.

The proposed algorithm is implemented based microcontroller family of PSoC, flexible architecture which provides high performance processing and analysis of information signals.

II. Optical-electronic monitoring system

Given the requirements for modern micro circuitry, in particular for sensing devices of the Internet of Things, the signal path of the system is implemented on the basis of PSoC family 5LP Family Cypress Semiconductor Corporation [7]. The structure of PSoC includes nodes of digital and analog systems, nodes of the microprocessor, matrices of volatile and non-volatile memory, system resources, as well as nodes of programming and power management. The basis of digital nodes is a matrix of universal digital blocks, specialized digital blocks, in particular for the implementation of interfaces, timers, pulse-width modulators and more. Analog nodes of PSoC are blocks on switching capacitors and blocks with

continuous signal conversion, in particular: operational amplifiers, comparators, reference voltage sources on the principle of a forbidden zone, analog multiplexers, etc. The nodes are connected by a software-configured network of signal lines (Fig. 1).

The defining components of the PSoC5 system, on the basis of which the signal converter is implemented (Fig. 2), are: digital-to-analog converter (VDAC8), synthesis generator (Wave DAC8), Timer, control

register (Control Reg), frequency divider (Freq. Divider), multifunction mixer (Mixer), operational amplifiers (Opamp), programmable Gain Amplifier (PGA) amplifier, analog multiplexer (AMux), analog-to-digital converters (ADC) based converters based on delta-sigma modulator (DelSig) and sequential approximation register (SAR). The CapSense CSD component was used to implement capacitive input sensors, and the temperature sensors used the components of the measurement transformation

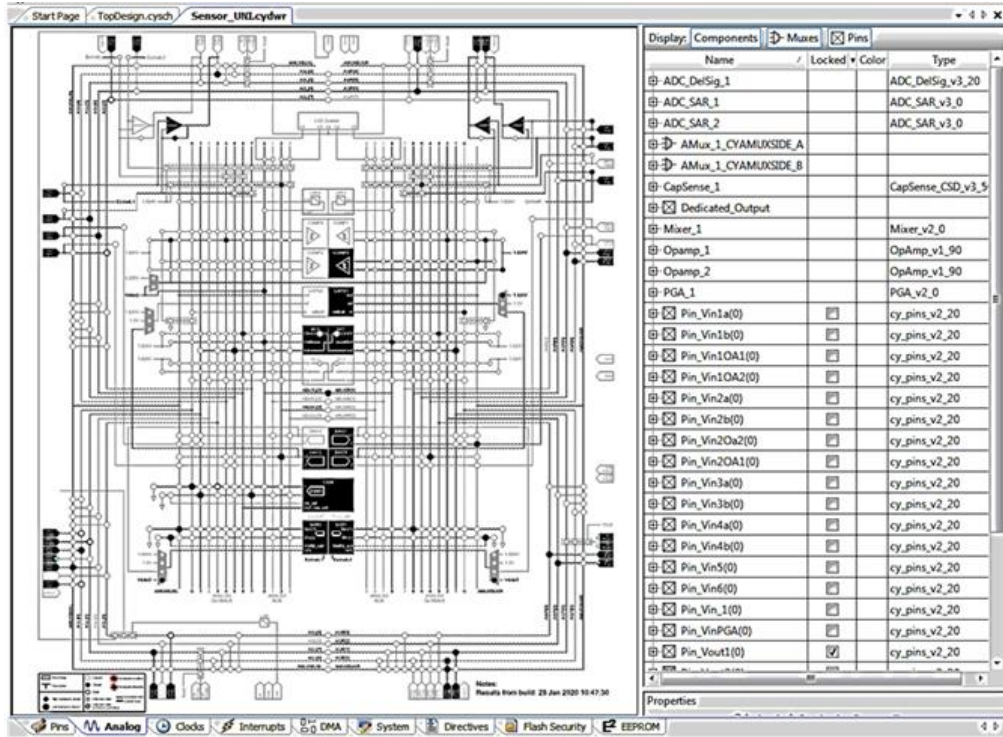


Fig. 1. The software configuration to network of signal lines.

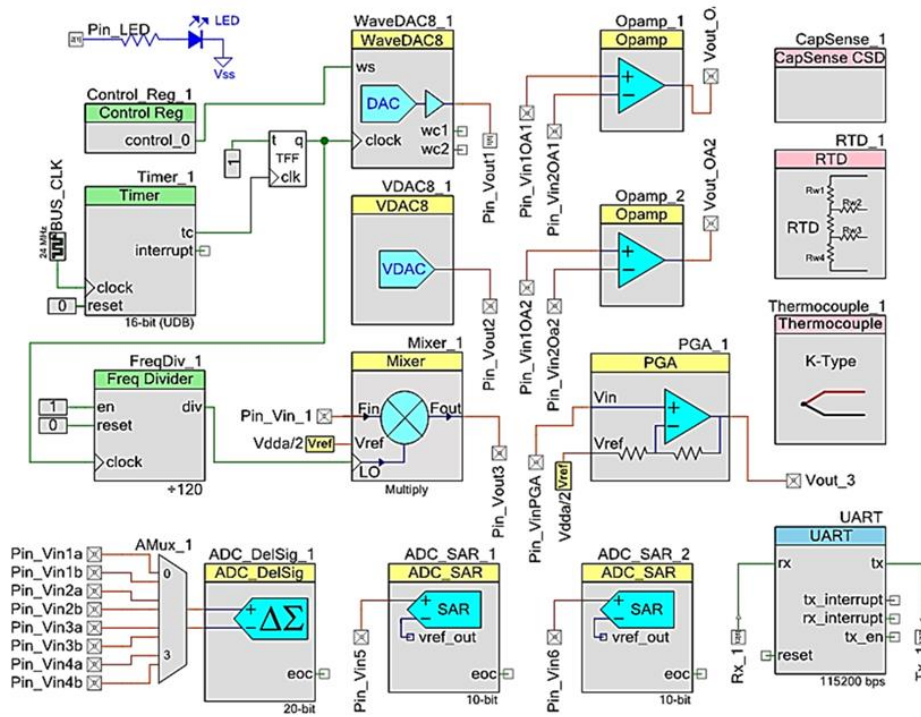


Fig. 2. Implementation of the signal converter on PSoC.

on thermistors (RTD) and Thermocouple.

The block diagram of the optoelectronic system of continuous monitoring of the treatment and diagnostic process is presented in Fig. 3. The main elements of the structure are: temperature sensor (X1) photoelectric converters (X2-X3), operational amplifiers (AMP1-AMP3), filters (SF1-SF3), analog multiplexer (MUX), reference voltage source, digital-to-analog converter (ADC), built-in memory (RAM, data and program memory), microprocessor core (MCU) and peripheral interfaces – CapSense, LCD-driver, PMW, USB. The photoelectric converter is implemented on the basis of a sensitive broadband converter BPW-21 from Vishay [8]. This converter in combination with a transimpedance signal amplifier provides the formation of an output

signal sufficient for software analysis and further processing by the microcontroller unit.

The configuration of the signal path and its outputs in the housing CY8C5888LTI-LP097 are shown in Fig. 4. Control circuits of measuring circuits and signal transmission are carried out using the universal serial UART interface.

PSoC components are configured and dynamically programmed using API (Application Programming Interface) functions. The basic software PSoC Creator was used to configure the internal elements of the microcontroller [9]. The program allows the user to build arbitrary input conversion functions using existing internal logic blocks, which is optimal for the implementation of specialized flexible algorithms. A

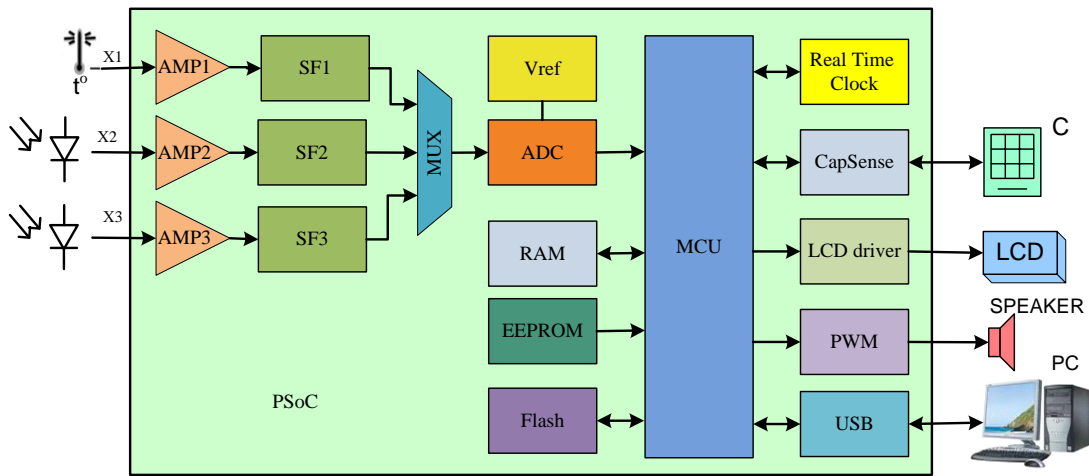


Fig. 3. Block diagram of the optoelectronic system of continuous monitoring.

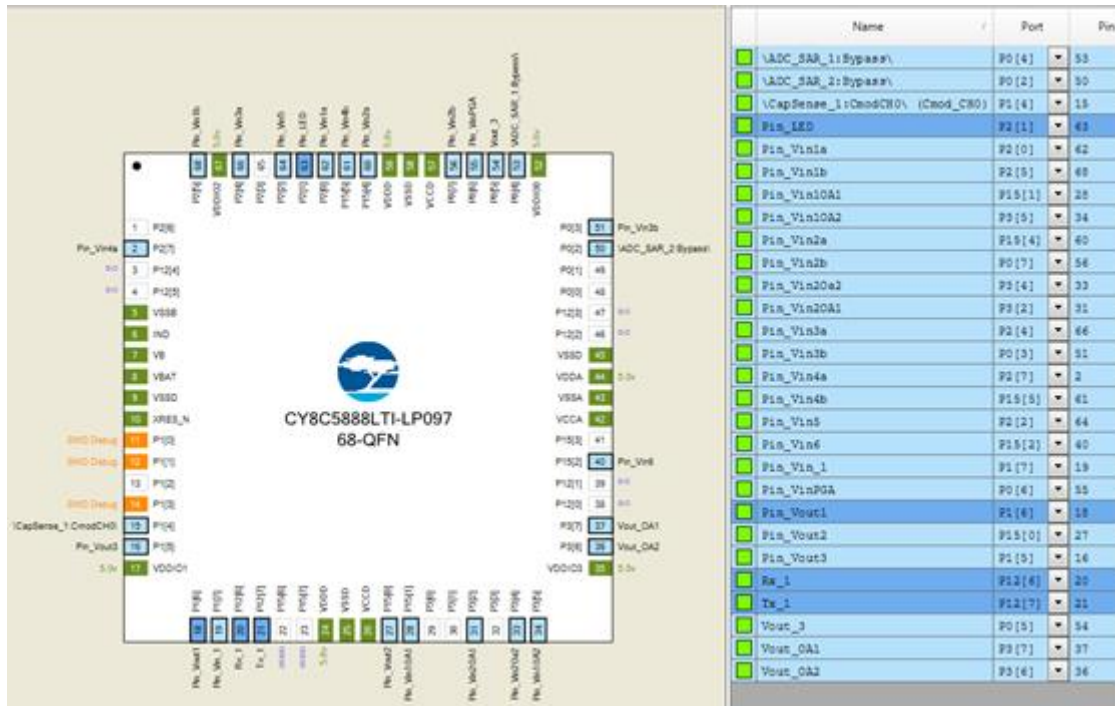


Fig. 4. Outputs of the signal converter on PSoC CY8C5888LTI-LP097.

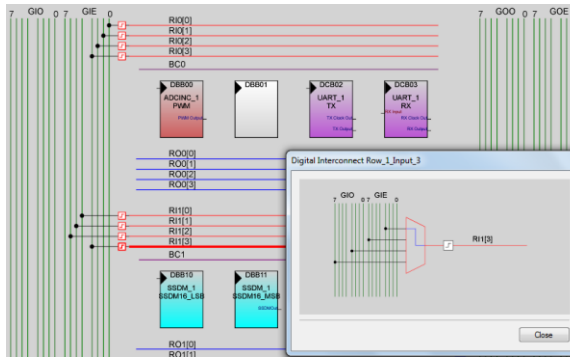


Fig. 5. A fragment of the implementation of the logical conversion function in the software PSoC Creator.

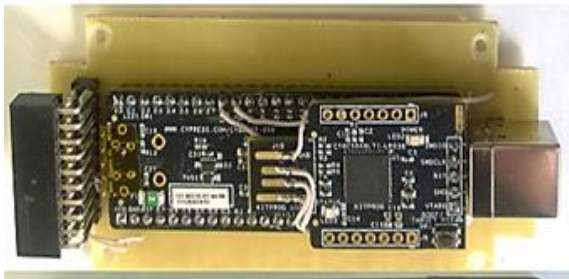


Fig. 6. Image of the layout of the optoelectronic system for monitoring the treatment and diagnostic process.

fragment of the implementation of the logical transformation function is presented in Fig. 5.

Based on the simulation results, a model of the hardware part of the system was created, the appearance of which is shown in Fig. 6.

The developed monitoring system provides

connection of three input sensors (with the possibility of expansion up to 8), the analysis time of the input signal is 100 μ s, the range of registration of optical radiation is 690 to 980 nm, information is exchanged via USB 2.0. The software provides a wide range of parameters, modes and strategies of therapy.

Conclusions

The structural and functional scheme of the microcontroller block of processing of sensory signals of the system of monitoring of treatment procedures with automated decision-making is developed. An algorithm of continuous monitoring system operation is proposed, which is the basis for the implementation of a new class of devices with the function of continuous automatic evaluation of the effectiveness of the treatment procedure. The operation of individual nodes is described and their operation is modeled in the Proteus software environment, the scheme and printed circuit board of the microcontroller control unit are developed, the internal configuration of the microcontroller is formed according to PSoC Designer and external ports are configured according to the device algorithm.

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Оптико-електронна система моніторингу біомедичних показників

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Робота присвячена питанням розроблення медичних систем моніторингу біомедичних показників. Вирішується задача розроблення універсальної апаратної програмно керованої системи контролю для діагностики біоб'єктів. Основними вимогами до такої системи є широка функціональність щодо поєднання різних методів вимірювального перетворення та відповідність сучасним тенденціям розвитку мікроелектронної сенсорики. Враховуючи вимоги до сучасної мікросхемотехніки, зокрема до сенсорних пристроїв Інтернету Речей, сигнальний тракт сенсорів реалізовано на основі PSoC сімейства 5LP Family Cypress. Апробація розробленої системи здійснена в процесі дослідження характеру оптичного випромінювання в процесі вимірювання біомедичних показників.

Ключові слова: оптико-електронна система, багатопараметричний аналіз, моніторинг показників, мікроконтролерний блок.