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Information Technology of Concept Design of Biosensors

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Abstract

Objectives: This paper expresses a new technology of conceptual design of biosensors. The technology is according to the energy-information patterns of various physical nature chains. **Methods**: The primary advantage of the conceptual design is that it concentrates the R & D in the desired direction and thus saves resources on the stage of the experimental phase. Also, knowledge bases (KB) are created at this juncture. This KB assists designers to made effective decisions in the design of biosensors in the design early levels. **Finding**: The mains of the organization of the automated method of the conceptual pattern of biosensors and model of two knowledge bases (KB) are described here. Bases consist of the 1-st - a knowledge base of the immobilized biologic elements (bio receptor) and the 2-nd KB - about the models of chains and physical-technical effects of different physical nature, which underlies principle of transducers action. It is planned to utilize energy-information patterns of chains (EIMC) for the organization of the 2nd KB. It allows describing the different processes by the same type of equations, invariant to the physical nature. **Conclusion**: The paper presents a model of several circuits: electrical, magnetic, mechanical, thermal, diffusion, moisture. Also, the article includes a list of physical and technical effects (PTE), which underlies the operating principle of transducers.

Keywords: Biosensor, Conceptual Design, Effects of Physical, Energy-Informational Model of Circuits (EIMC), Knowledge Database

1. Introduction

The biosensor is a tool that couples a bio recognition factor via a transducer and changes the recognition phenomena to a suitable mathematical signal[1].

Over the previous few years, many biosensors extended for the ions detection, tiny molecules, deoxyribonucleic acids (DNAs), proteins, cells and many others. They utilized in an extended area of applications from diagnostics of medical[2], assurance of food quality[3], environmental control[4], monitoring of industrial process[5,6] to biological warfare agent detection[7]. Main impacts devoted to their commercialization. In 2013, the world business of biosensors amounted to 11.39 billion $. Up to 2022, based on the Markets & Markets Forecast, this theme would enhance to 22, 68 billion $ via mean annual increase ratio of 11%[8,9].

The main advantage of CAD is that it focuses on R&D and thus saves resources on the experimental phase which is the necessary follow-up. Also, it creates a Knowledge Base (KB) that assists the researcher in forming hypotheses for decision making during the early stages of design that guide the subsequent development path. Biosensors are considered as a hot topic by worldwide since they exhibit high selectivity and sensitivity, relative simplicity, and low cost. But, they must have properly designed and developed by the aid of operational CAD techniques.

Schematic of a typical biosensor is an analytical system, which contains biological material (enzymes, cells, antibodies, antigens, receptors, DNA fragments), which is in direct contact or embedded in the physical-chemical sensor[10]. The generalized scheme of biosensor is shown in Figure 1.

Biosensors consist of two parts:

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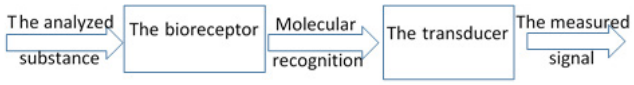


Figure 1. The generalized scheme of the biosensor.

- The biological sensing element (bio receptor). It is an ensemble of biological molecules with physical and chemical processes that convert environment properties into a measurable signal (electrical, optical, mechanical, thermal, etc.). For example, microorganisms, organelles, cell receptors, enzymes, antibodies, nucleic acids, etc.
- The transducer (converter) - converts the signal appearing as a result of interaction with an analyzing bio-particular element into another signal which is easier to measure. They use a variety of physical and chemical principles of action: optical, piezoelectric, electrochemical, and others.

The biosensor is designed for generating a digital electrical signal proportional to the concentration of a particular chemical compound or series of compounds. Design of Biosensors mainly consist of the solution of two problems, related to different fields of science:

- One of them is creating an efficient biological test object, which have high sensitivity, selectivity, durability. The object should produce a measurable signal with maximum efficiency. This problem is covered in the framework of the biological sciences.
- Another one is the design of a device for detection and further evaluation of the signal appearing on the system. This problem is an area of technical sciences.

The uniqueness of a biosensor is that the two components are integrated into one single sensor. Typically, the biosensor is designed for generating a digital electrical signal proportional to the concentration of the chemical compound or set of compounds.

The biosensors creation relates to the interdisciplinary study. So, it is vital to advance a unified system method in the theory of sensor elements that is constant to the used phenomena physical nature and procedure. It is advisable to select the non-equilibrium thermodynamics foundations[11,12] as a basic for the advancement of this method, since it allows to get a comprehensive system of transfer equations for the phenomena of different physical nature and other laws, without opening their molecular. In[13,14], the main propositions of Circuits Energy-Informational Models (EIMC) for the expressing of processes of various physical nature are modeled via the phenomenological equations of non-equilibrium thermodynamics and the main of elaboration of automated systems of the conceptual model of elements of the information and measurement according to EIMC.

In this article, the data technology of functional-structural pattern of biosensors is defined. It is according to the two knowledge bases (KB):

Table 1. The basic and additional criteria of EIM

Criteria	The equation
first criterion (energetic):	$U \cdot I = N$, (N - power); [Wt]
static criterions	$I \cdot L = PorP \cdot D = I$; $U \cdot C = QorQ \cdot W = U;\ I \cdot R = UorU \cdot G = I; I' \cdot R = U' orU' \cdot G = I'.$
dinamic criterions	$U = \frac{dP}{dt} orP = \int Udt;\ I = \frac{dQ}{dt}\ or\ Q = \int Idt;$
parametric criterions	$U' = I'R + IR'\ orI' = U'G + UG';$ $P' = U = Q'R + QR' = IR + QR' or\ Q' = I = P'G + pG' = UG + PG';$ $U = P' = I'L + iL' or\ I' = P'D + PD' = UD + PD';$ $U' = Q'W + QW' = IW + QW' or\ Q' = P'D + PD' = UD + PD'$
criterions with distributed parameters	$\frac{\partial Q'_x}{\partial t} = I'_x = c\frac{\partial U}{\partial t} or \frac{\partial I}{\partial x} = c\frac{\partial U}{\partial t};\ \frac{\partial P'_x}{\partial t} = U'_x = l\frac{\partial I}{\partial t}\ \ or\ \ \frac{\partial U}{\partial x} = l\frac{\partial I}{\partial t}$

- Bioreceptor database that reflects the properties of the monitoring medium as a signal of a physical nature (electrical, magnetic, thermal, optical and other signals).
- The database of models of chains and physical-technical effects of different physical nature, which underlies principle of transducers action. This database can be developed by Energy-Informational Models of Circuits (EIMC).

As a result, a single systematic approach is provided to organize the knowledge about the physical and chemical effects and bioreceptor. The facility for a functional and structural description of the physical principle of operation of the device is also given. Also, the EIMC model let advancing a method of automated support of the biosensors conceptual model.

2. Different Physical Nature EIMC

EIMC allowed changing to formed expression of sensor elements procedures via employing factor structural theme[13,14]. However, there is a set of processes which are frequently used in the construction of transducers for biosensors. They are oscillations processes, parametric amplification, etc., the main feature is that values and parameters of the various physical nature change over time. Therefore, additional values and parameters are included. They characterize the speed of change of the basic values and EIMC parameters (Table 1).

In all of these criteria, it is assumed that the values and parameters can be either constant or variable in time. In the latter case, the above criteria are satisfied for the instantaneous values and circuit parameters. We introduce the notation for the B magnitude (this can be Q, P, I, U and their derivatives) and the notation for the parameter Π (it can be C, W, R, G, L, D, and their by-products). The values of the parameters B and Πof the EIMC may changeover the time under various laws. The most commonly used two types of equations are:

- Linear equation $B = B_0 + kt$ и $\Pi = \Pi_0 + |k|t$, and the rate of change of the magnitude $B' = k = const$, the rate of change of the magnitude $\Pi' = |k| = const$ and is always positive;
- Sine change $\dot{B} = B_0 + ksin(\omega t)$ and $\Pi = \Pi_0 + |k|sin(\omega t)$, and the rate of change of the magnitude $\dot{B}' = k\omega cos(\omega t)$, and rate of change of the parameter $\Pi' = |k\omega|cos(\omega t), k \leq 0{,}5\Pi_0$.

The Table 1 shows that if one of the values varies over time by a certain law, then the other value associated with the first one through the constant parameter is changed by the same law.

The authors found the approach of generalized parameters and generalized-parameters to define the procedure in the various physical nature circuits (thermal, mechanical, electromagnetic, moisture transfer, diffusion) Table 2.

The whole difference of interactions among values and parameters can be represented as a complex model.

Key for Table 2:

$U_e, U_\mu, U_{ml}, U_{ma}, U_t, U_h, U_d, U_{mo}$ - impact values; $I_e, I_\mu, I_{ml}, I_{ma}, I_t, I_h, I_d, I_{mo}$ - reaction values; $Q_e, Q_\mu, Q_{ml}, Q_{ma}, Q_t, Q_h, Q_d, Q_{mo}$ - charge values; $P_e, P_\mu, P_{ml}, P_{ma}, P_t, P_h, P_d, P_{mo}$ - momentum values; $R_e, R, R_{ml}, R_{ma}, R_t, R_h, R_d, R_{mo}$ - parameter resistance; $C_e, C_\mu, C_{ml}, C_{ma}, C_t, C_h, C_d, C_{mo}$ - parameter Capacity; $L_e, L_\mu, L_{ml}, L_{ma}, L_t, L_h, L_d, L_{mo}$ - parameter Inductance; φ - the electric potential (φ_1-φ_2 - potential difference, ie voltage); $w_в$ – number of turns; H - magnetic field strength; F - strength; T - temperature; Φ - magnetic flux; v - linear velocity; S - entropy; x - linear displacement; l – length of the circuit; s – circuit cross-sectional area; V_0 –sub circuit volume; η - coefficient of internal friction (dynamic viscosity); E – coefficient of elasticity; m - mass, $\rho_{ý}$ - electrical resistivity; ε - dielectric permittivity; μ - magnetic permeability; λ - thermal conductivity; c – specific heat; ρ - density of the circuit material; R – rotation radius; ω - angular velocity; α – angle of rotation; M – force moment; I –inertia moment; p – hydraulic pressure (p_1-p_2) - differential pressure; a - velocity of sound; G - modulus of shear; I_p - polar moment of inertia, D_k – diffusion coefficient [m²/s]; .C_k – the concentration of the k-th component [mol/m³]; R=8,3144621 – gas constant [J/mol K]; $\Delta\mu_k$ – the difference between the chemical potentials [J/mol]; J – diffusion flux of k-th

Table 2. Generalized values and parameters for chains of different physical nat

Circuit nature	Generic value				Generic parameters		
	Impact	Reaction	Charge	Pulse	Resistance	Capacity	Inductance
Electric	$U_e = \varphi_1 - \varphi_2$	$I_e = \frac{dQ_e}{dt}$	Q_e	$P_e = \Phi = \int U_e\, dt$	$R_e = \frac{\rho_e l}{S}$	$C_e = \frac{\varepsilon S}{l}$	$L_e = \mu \frac{S}{l} w_e^2$
	[V]	[A]	[C]	[Wb]	[Ω]	[F]	[Гн]
Magnetic	$U_\mu = I_e w_e = HI$	$I_\mu = \frac{d\Phi}{dt}$	$Q_\mu = \Phi$	$P_\mu = Q_e w_e = \int U_\mu dt$	$R_\mu = \frac{S}{\rho_e l}$	$C_\mu = \mu \frac{S}{l}$	$L_\mu = \frac{\varepsilon S}{l}$
	[A]	[V]	[Wb]	[C]	[1/Ω]	[H]	[F]
Mechanic (linear)	$U_{ml} = F$	$I_{ml} = v$	$Q_{ml} = X$	$P_{ml} = mv = \int F dt$	$R_{ml} = \eta \frac{S}{\Delta x}$	$C_{ml} = \frac{l}{SE}$	$L_{ml} = m$
	[N]	[m/s]	[m]	[kg m/s]	[N s/m]	[m/N]	[kg]
Mechanic (angular)	$U_{ma} = FR$	$I_{ma} = \omega$	$Q_{ma} = \alpha$	$P_{ma} = J\omega = \int M dt$	$R_{ma} = \eta \frac{S}{l} R^2$	$C_{ma} = \frac{l}{GI_p}$	$L_{ma} = J = \sum_{i=1}^{n} m_i R_i^2$
	[N m]	[rad/s]	[rad]	[N m s]	[Pa s m^3]	[rad/(N m)]	[kg m^2]
Thermal	$U_t = T_1 - T_2$	$I_t = \frac{dS}{dt}$	$Q_t = S$	$P_t = \int (T_1 - T_2) dt$	$R_t = \frac{lT}{Sl}$	$C_t = \frac{c\rho V}{T}$	
	[K]	[W/K]	[J/K]	[K s]	[K^2/W]	[J/K^2]	
Hydraulic	$U_h = P_1 - P_2$	$I_h = \frac{dV}{dt}$	$Q_h = V$	$P_h = \frac{mV}{S} = \int (\Delta P) dt$	$R_h = \frac{8\pi l}{S^2} \eta$	$C_h = \frac{m}{\rho^2 a^2}$	$L_h = \frac{\rho l}{S}$
	[N/m^2]	[m^3/s]	[m^3]	[N s/m^2]	[N s/m^5]	[m^5/N]	[kg/m^4]
Diffusion	$U_d = \Delta \mu_k$	$I_d = Js$	$Q_d = \int_0^t I_d dt$		$R_d = -\frac{RT\Delta x}{D_k C_k s}$	$C_d = \frac{sC_k}{RT}$	
	[J/mol]	[mol/s]	[mol]		[mol^2/J s]	[mol2/J s]	
Moisture transfer	$U_{mo} = \frac{U}{c_{mo}}$	$I_d = J_{mo} s$	$Q_{mo} = M_{mo}$		$R_{mo} == \frac{l}{A_{mo}\rho_{mo} c_1} U_{mo} = \frac{U}{c_{mo}}$		$I_d = J_{mo} s$
	[J/kg]	[kg/s]	[kg]		[(sJ)/kg^2]	[J/kg]	[kg/s]

Table 3. Brief description the physical phenomena, used in the conceptual design of electrochemical biosensors, in terms EIMC

Potentiometric PTE	The electric influence (voltage) in terms EIMC[14]: $U_e = E = E_0 + \frac{\Delta\mu}{nF}$ or $U_e = E_0 + K_{UdUe} \cdot U_d$ Where E – potential of ion-selective electrode [V]; E_0 - standard oxidation-reduction potential of definition ion [V]; n - the number of electrons participating in the electrochemical reaction; *F* - Faraday constant equal to 96,48533 [C/mol], $U_d = \Delta\mu$ - the chemical potential [J/moll]. $K_{UdUe} = \frac{1}{nF}\left[\frac{\text{mol}}{\text{C}}\right] K_{UdUe} = \frac{1}{nF}\left[\frac{\text{mol}}{\text{C}}\right]$ – Coefficient of inter circuits PTE linking the action value of diffusion circuits and electrical circuits one.
Amperometric PTE	Faraday's law determines the relation between the current I.e. and the number of agents involved in the electrode process [14,15] $I_e = \frac{nFSD\kappa C}{\delta} = K_{UdUe} \cdot U_d$ $I_e = \frac{nFSDC}{\delta} = K_{UdIe} \cdot U_d$ here C - the concentration of the reagent [mol/m³], δ is a constant determined by the thickness of the electric double layer [m], S - area of the electrode [m²], D - diffusion coefficient [m²/s], κ – coefficient taking into account linkage between concentration and chemical potential ($U_d = \Delta\mu_k \approx \kappa \cdot C$).
Conductometric PTE	The conductivity of the solution depends on the number of ions per unit of the solution volume, i.e. on the concentration C and on the mobility of these ions *v* [m²/W s]. $G_e = \alpha F v \frac{S}{l} C$ or $G_e = \alpha F v \frac{S}{l} \kappa U_d$ Where *l* — electrode spacing, [m]; S — electrode area [m²]; κ - factor of proportionality($U_d = \Delta\mu_k \approx \kappa \cdot C$), *F* - Faraday constant equal to 96,48533 [C/mol], α - coefficient of dissociation (at low concentrations it can be assumed that α = 1)[16].
Capacitive PTE	The total capacity of the electrical double layer in dilute solutions [17]: $C_e = C_{Di} \approx C_{diff} = \varepsilon\varepsilon_0 k = \sqrt{\frac{Az^2e^2\varepsilon\varepsilon_0 C_i N_A}{kT}} = K_{UdCe} \cdot U_d^{0,5}$ where the coefficient of intercircuit effect K_{UdCe}, showing relation between capacitance (C_e) and concentrations of the test substance (U_d); *A* - constant, *z* – ionic valence, *e* – electron charge, C_i– ion concentration (mol), N_A - Avogadro's number, $\varepsilon\varepsilon_0$ - absolute dielectric constant of the sample, *k* - Boltzmann constant, *T* - the absolute temperature, *S* - area of the electrodes of the cell and *d* - the distance between the electrodes. The dependence of the double layer capacitance on the concentration is nonlinear.
Thermometric PTE	Thermometric sensors register the amount of heat releasing during biochemical reactions[18] : $\Delta U_e = mZ\Delta U_t = -mZ\frac{\Delta H}{C_p} Q_d = K_{QdUe} Q_d$, Where *m* - the number of thermocouples thermopiles, *Z* - the See beck coefficient, $\Delta U = \Delta U_e$ – electrical voltage occurring in the thermocouple, $\Delta U_t = \Delta T$– the temperature difference at the ends of the thermocouple[19].

Field-effect transistor PTE	Recently, increasing interest has been given to biosensors based on the field-effect transistor (FET). They have some benefits, which include a greater signal-to-noise ratio, fast measurement capabilities, and compact or portable instrumentation[20,21]. The drain current $I_e = \frac{\mu_n C_g W}{L} \cdot (U_g - U_0) \cdot U_{sd}$, where μ_n – the electron mobility in the channel [m²/(V s)], C_g - the capacitance per unit area of the gate insulator [F/m²], W - the width of the gate [m], L – the effective channel length [m], $(U_g - U_0)$ – the portion of the gate voltage which created the channel [V], U_{sd} - the voltage between the source and the drain [V]. Since the capacitance of the gate insulator is expressed as a capacitance per unit area, we must multiply by the area of the gate, WL: $C_g WL \cdot (U_g - U_0) = Q_g = Q_e$. So the drain current is given by $I_e = \frac{\mu_n}{L^2} \cdot Q_e \cdot U_{sd}$, and $G_e = \frac{I_e}{U_{sd}} = \frac{\mu_n}{L^2} \cdot Q_e$. The coefficient of intercircuit PTE $K_{QeGe} = \frac{\mu_n}{L^2}$ [1/(Om·C)]
Piezoelectric PTE (direct)	Among all the physical transducers, piezoelectric systems have emerged as the most attractive due to their simplicity, low instrumentation costs, possibility for real-time and label-free detection and generally high sensitivity. Physical formula of PTE description: $Q_e = d \cdot F$, **where** $F = U_{ml}$ $Q_e = d \cdot F$, **where** $F = U_{ml}$ –the force [N], and the charge $Q_e = d \cdot U_{ml}$ $Q_e = d \cdot U_{ml}$ [C], d–the piezoelectric coefficient [C/N]=[m/V]. The coefficient of intercircuit PTE: $K_{UmlQe} = d$ - the piezoelectric coefficient [C/N]=[m/V].
Piezoelectric PTE (reverse)	The reverse piezoelectric effect: the internal generation of a mechanical strain ($\varepsilon = \Delta l / l$) resulting from an applied electrical field strength Ee [V/m]. Physical formula of PTE description: $\varepsilon = \frac{\Delta l}{l} = \mathbf{d} \cdot E_e$ where $Q_{ml} = \Delta l$ - the displacement of the faces quartz plate [m]; d - the piezoelectric coefficient [C/N]=[m/V]. The electric field strength $E_e = \frac{U_e}{l}$ [V/m], then $Q_{ml} = d \cdot U_e$ and the coefficient of intercircuit PTE: $K_{UeQml} = d$ [m/V].
Pyro electric PTE	Pyro electric biosensors generate an electric charge (Q_e) as a result of a temperature change ($\Delta T = U_t$)[22,23]. Physical formula of PTE description: $\Delta P = \gamma \cdot \Delta T$, where γ – pyro electric coefficient [C/m² K] and changes of polarization of a dielectric material $\Delta P = \Delta\sigma = \frac{\Delta Q_e}{S}$ [C/m²] (S – area of the bioelectric face [m²], ΔQ_e - electric charge [C], $\Delta\sigma$ - charge surface density, compensating polarization of pyroelectric [C/m2]). As a result of the transformation we obtain $\Delta Q_e = \gamma \cdot S \cdot \Delta U_t$ The coefficient of intercircuit PTE: $K_{UtQe} = \gamma \cdot S$ [C/K]
Electro osmosis PTE	Electro osmosis is the motion of liquid induced by an applied potential across a porous material, capillary tube or membrane, micro channel. For nonconductive micro particles with a flat surface in systems with a thin electric double layer can be considered that the electrophoresis rate equal to the rate of electro osmotic slip, ie $I_{ml} = u = \frac{\varepsilon\varepsilon_0\zeta}{k\pi\eta l} U_e$, and the coefficient of intercircuit PTE: $K_{UeIml} = \frac{\varepsilon\varepsilon_0\zeta}{k\pi\eta l} \left[\frac{m}{V \cdot s}\right]$

Magneto resistancePTE	Magneto resistance is the property of a material to change the value of its electrical resistance when an external magnetic field is applied to it. In combination with electrochemistry used a magnetic monolayer of streptavidin-coated magnetic particles to construct an immune magnetic electrochemical sensor for the detection of atrazine[24,25] In engineering calculations expression is frequently used for the relative change of the resistance of a semiconductor in a magnetic field:, where $\Delta\rho$ is the change of resistance due to the magnetic field B, and ρ_0 corresponds to B=0, n=1…2 —exponent that depends on the magnitude of the magnetic induction B; C - the shape factor. Hence: $R_B = R_0.[1 + C(\mu B)^n] = R_0 + \Delta R_B$. Where $\Delta R_e = \Delta R_B = R_0 C(\mu B)^n = R_0 C\left(\mu B \frac{S}{S}\right)^n = R_{0e}\frac{C}{S^n}(\mu Q_{mg})^n$. For strong magnetic fields n=1, then $\Delta R_e = R_{0e}\frac{C}{S}\mu \cdot Q_{mg} = K_{QmgRe} \cdot Q_{mg}$, and the coefficient of intercircuit PTE: $K_{QmgRe} = R_{0e}\frac{C}{S}\mu$

component [mol/m^2 s]; c_{mo} – specific isothermal moisture content (the analog of the specific heat of the material) [kg/J]; A_{mo} – moisture diffusion coefficient [m2/s], ρ_{mo} – matter density [kg/m3].

Physical Impacts Utilized in the Electrochemical Biosensors Conceptual Model

The majority of usable biosensors today use several types of transducers for converting the action of the baroreceptor into a measurable signal. Transduction can be conducted by a great variation of approaches. Most transduction forms can be classified into several classes:

- Electrochemical detection methods (aerometric, potentiometric, the change of conductivity and capacity).
- Mass detection methods (piezoelectric transducers),
- Heat detection methods (thermometric),
- Optical detection methods (photometric),
- Other methods.

But, novel transducers kinds are continuously being advanced for application in biosensors. Each of mentioned categories involves several various subcategories, making a nearly infinite number of probable transduction approaches or mixing of approaches. The use of energy-information model makes it feasible to develop a convenient and intuitive conceptual design environment for the synthesis of the principle of operation of biosensors. Some of them were considered in[14] so here we give only a brief description several related physical phenomena in terms EIMC (Table 3).

Elaborated technology should provide a single systematic approach to the organization of knowledge about physical and chemical effects and bio-receptors. It also should provide a functional and structural description of the physical principle of the designed decision.

The process of biosensors designing can be divided into two phases. On the first stage, the proper bio-receptor (test-object) is selected from the data base. It should be able to recognize required compound and generate the output signal (the concentration of electric charge, the electric resistance, the mass of the extracted substances, etc.). The second stage is the synthesis of the transducer (converter), for which the output value of the test object is input. Therefore, the following knowledge bases are needed for the development of the system architecture:

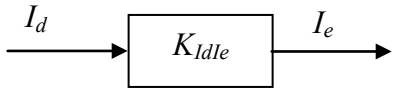
The knowledge base of the biological sensing element (baroreceptor). Bio receptor ensures the formation of the analytical signal for its subsequent changes in the transducer. It can be any biological structures: enzymes, antibodies, receptors, nucleic acids, and living cells. Each object has some parameters (sensitivity, the test substance, the kind of reaction in the test material reliability of the signal registration, parameters of the environment under which the reaction is carried, etc.). The combination of these parameters leads to the selection of the transducer (transducer) from the first base. Information about each bio receptor presented as a passport (Table 4).

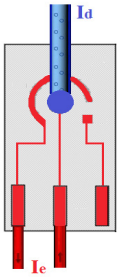
The knowledge base of known physical effects and phenomena (PTE) by the energy-information model of chains of different physical nature (EIMC). This base is used for the synthesis of the physical operating principle of transducers. Knowledge is presented in formalized model

Table 4. Example of the passport of bioreceptor

Analyze	**glucose**	
Baroreceptor (kind of biological components)	ferment	glucose oxidase
Type of change detected	Redox reaction (e- evolution) $Ox + ze^- \leftrightarrow Red$, wheeze$^-$ — number of electrons passing through the boundary of electrode / solution. Glucose + O_2 → H_2O_2 + laconic acid H_2O_2 → O_2 + $2H^+$ + $2e^-$	
Immobilization	Electro polymerization at constant potential of 0,75 V for 60 min	
Electrode	Platinum/Polyaniline-polyvinylsulphonate (Pt/Pani-Pvs) Electrode	
Operational characteristic		
Sensitivity0,372 [μA/mM]	Detection limit – 1,0 – 10,7 [M]	
Input range 0,05 – 2,50 [mM]	Relative error 2-5 %	
Response time - 200 [s]	Operational stability[1] 8,64 105[s]	
Measurement time[2] -300 [s]	Storage stability (+4°C) – 200 [day]	

Table 5. The example of the passport of physical and technical effect (PTE)

PTE title: **Amperometric PTE**	
Unit of parametrical structural schemes 	*Formula in EIMC terms:* $I_e = K_{IdIe} \cdot I_d$
Derivation of PTE formula Faraday's law: $I = nF\frac{dN}{dt} = nFSJ$ where dN/dt – oxidation or reduction rate [mol/s]; F – Faraday constant 96485,33 [C/mol]; n – electrons transferred per ion; S – area of the electrode [m^2]; *J* – flow of material per unit surface area [mol/(s·m^2)] Equation can be transformed in terms of EIMC: $I_e = K_{UdIe} \cdot I_d$ $I_d = SJ$ - diffusion value of reaction [mol/s]; $I_e = nFI_d$ electrical value of reaction (electric current) [A]; $K_{IdIe} = nF$ the coefficient of intercircuits PTE linking the action value of diffusion circuits and electrical circuits one.	
Formula of PTE coefficient $K_{IdIe} = n \cdot F$ [C/M]	
The designations of the quantities in formulas	
F – Faraday constant [C/M]; n – electrons transferred per ion; S – area of the electrode [m^2]; *J* – flow of material per unit surface area [M/m^2]	F=96485,33 [C/M]; n = 1 -2 S = 1-2·10^{-6}m^2
Values of operating characteristics	

Sensitivity: 400 - 1800 [A/(M·m2] Price: 6 - 10 Reliability: 10^{-3} – 10^{-4} [1/hour] Error: 5 % Non-linearity: 10 %	Input range: 0,05 – 2,50 [mM] Speed: 0,05 [s] Dissipation: 10% Ecological compatibility: 1×10-8 [kg/s] Weight: 0,0005 [kg]
Image of technical implementation  	*Short description* These biosensors are registered current produced as a result of oxidation or reduction of biochemical reaction component at the electrode.

of the passport of PTE, which contains a brief and complete description of physical and technical effect, input and output values, typical values of performance, and the formula for calculating the transmission coefficient, by known physical laws. The example of the passport of physical and technical effect is presented in Table 5.

Various immobilized biological elements (test objects) can be combined with a differences of transducers (transducers). It allows you to make an extent range of various kinds of biosensors and to select the best solutions for the base of its action.

Synthesis of the biosensor is carried out in two stages. On the first stage, the test object should be found in the base of test-objects. It should answer the following requirements: to recognize the required substance, to generate some output quantity (the concentration of electric charge, the electric resistance, the mass of the extracted substances, etc.). The next stage is the synthesis of the transducer for which the output value of the test object is input. A necessary and sufficient condition for the integration is the complete coincidence of the output value of the previous element and input value of the next element in the chain. This designed device will be workable if the range both values intersect.

The performance of the synthesized technical solution is calculated able if you know the performance of each effect in the chain. The synthesis of all possible chains is made on the given input and output variables. It is based on the two principles: (1) next entry has the equal quantity that the output of the previous effect; (2) the value range of the next input is less than the value range of the previous output. The performance of the each synthesized circuit is calculated by the performance of its effects. The calculated characteristics are compared to user requirements. The final step is the ranking and selection of the best options.

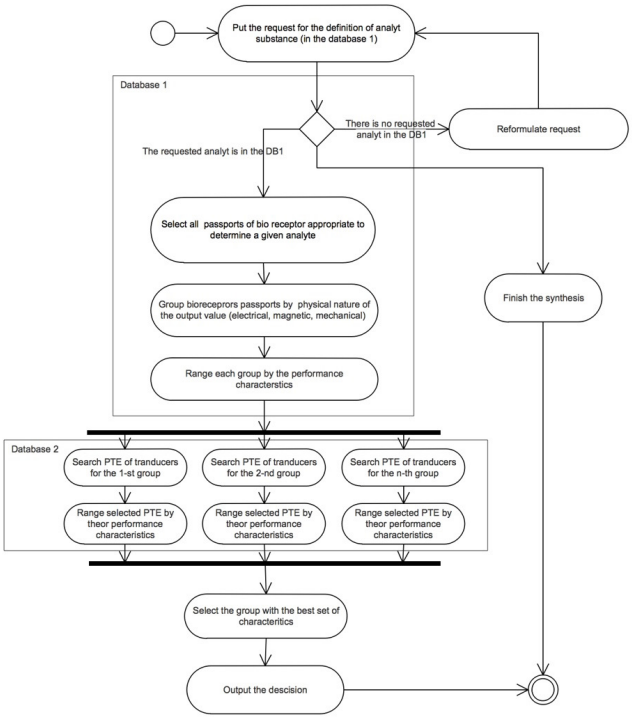


Figure 2. Biosensors synthesis UML activity diagram.

In the paper[14] authors had built the class model for the information system of concept design of biosensors.

The main classes are "PTE passport", "Test object passport", and "Synthesis Manager" describes the mechanisms of multi-criteria ranking and selection of the synthesized chains on the base of their performance. The UML model is described in the article. This UML Activity Diagram (Figure 2) shows the central principle of the biosensors synthesis, described above.

Creation of information technology of the functional structural design of biosensors allows the following:

- Significantly reduce the development time for new solutions;
- Increase the productivity and quality of the solutions and to expand the solution space through the use of multi-disciplinary knowledge bases;
- Improve the quality of students training by involving trainees directly in real projects and virtual creative teams.

3. Conclusion

At the heart of the information method of functional-structural model of biosensors, there are theoretical principles of energy-information models of circuits that are constant to the physical nature of the procedure happening in mechanical tools. The basis also includes tool factor structural graph, let to create an algorithm of seek and choose of novel mathematical solutions by the aggregate performance.

The process of designing of biosensors can be divided into two stages. The first is the selection of decision variants in the test objects data base. The decision should recognize the target compound determine the output value of the test object (concentration, electric charge, the electric resistance, the mass of the extracted substances, etc.). The second is the synthesis of the transducer (converter), for which the output value of the test object is the input of transducer (converter).

Therefore, for the development of the architecture of the system the following knowledge bases should be created:

- The knowledge base of known physical effects and phenomena by the energy-information models of circuits (EIMC) of different physical nature is used for the synthesis of the physical operating principle of inverters (transducers). Knowledge is formalized in the form based on a single model of the passport of physical-technical effect which contains a summary and a complete description of physical-technical effect, input and output variables as well as the average values of standard performance and the formula for calculating the transfer rate by known physical laws.
- The knowledge base of immobilized biological elements (test objects), ensuring the formation of the analytical signal for the subsequent changes in the transducer. It can be any biological structures: antibodies, enzymes, nucleic acids, receptors, and living cells. Each object has some parameters (the test substance, the kind of reaction to the test substance, sensitive, reliable registration parameters of the environment under which the reaction is carried). The selection of converter (transducer) from the first base is made of these parameters.

Various kinds of immobilized biological elements (test objects) can be combined with a variety of transducers (transducers). It allows you to create a various kinds of biosensors and to select the best solutions for the aggregate performance.

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