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DEVELOPMENT OF A MINIATURE DIGITAL UNIT OF A ELECTRODIAPHRAGMOGRAPH

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This paper is devoted to development of a small-sized microprocessor unit having no analogy and enabling to demonstrate on the monitor the curve resulted from diaphragm movement. By this unit it is possible to measure oscillation period, waves duration, and amplitude. It is possible to obtain the above mentioned biological data from hypodermic sensors, developed by the authors, placed at appropriate points. The paper states forth in details all electrochemical changes occurring in the body which interfere with receiving signals coming from biological sensors and conclusions have been made up on careful choice of sensors.

Key words: *sensor, electrode, biosignal, diaphragm, charge*

Introduction

Lungs located within the rib cage are a pair of spongy organs, which by breathing extract oxygen from the atmosphere and expel carbon dioxide from the bloodstream into the atmosphere. The lungs are covered by a thin tissue layer called the pleura. Human respiration rate and volume depend on oxygen demand of the body. An adult breathes around an average of 500 ml of air usually measured at rest, while sitting, in one normal or relax breathing, that is only 15 percent of the volume change occurs by endless up and down movements of the diaphragm. Presence of ion signals produced by the diaphragm movements is detected by a record produced by electrocardiograph which is evaluated as deviations of the isopotential line and is perceived as noise. In processing all electrocardiograms it is a usual practice to try to struggle against the noise by means of different technical solutions. On the other hand this noise contains important biological data which define functioning of different viscera. The produced ion potentials contain invaluable data. Through the latter one can arrive at a conclusion and assess on deviation of a given organ of a human body functioning from the norm. Among such organs are the diaphragm, stomach, intestines, etc., which perform rhythmical functioning, like the hearth of which changes of potentials have been deeply studied, in contrast to the above mentioned organs, therefore the study of principals of work of these organs is a topical issue. The problem is what biological generators are there and where they are located and if there are few, then what is the logical link on which they work. For example, there are the following three sinus, atrioventricular, and His bundles which are also called hearth generators. It should be noted that the second (atrioventricular) generator also performs time delay of impulses coming from sinus one, which is necessary for pumping entire blood from atrioventricular to ventricle of the heart. It should be noted that ventricles before atria contain blood up to 75 percent of their volume, for the mitral valve is open and it is closed only the moment ventricle of the obtained positive results of the MM-1 small-seized microprocessor electrocardiograph trials provide a basis for Marat Muradyan, Movses Muradyan, and Stepan Grigoryan - research workers of the chair of Microelectronics and Biomedical Devices of the National Polytechnic University of Armenia - to develop a new device designed to study the mechanism of enabling to record frequency and amplitude of the diaphragm. To develop such a device it is necessary to convert analog signal into digital one and to consecutively record these data with high accuracy. On the basis of the obtained digital data one can plot curves of oscillations on a graphic display by selecting a respective time quantity. In that case the device will show not an electrocardiogram which repeated approximately after each second, but the number of which the time of one nearly 5 times slower from electrocardiograph. Moreover, for noiseless recording of signals it will be necessary not only to suppress 50Hz industrial noise but also exclude signals of the electrocardiograph to obtain periodically repeated curve without markedly noise which will enable measuring not only repetition period – rhythm but also the oscillation amplitude. To record these data it will be necessary to remember the record of each patient, at the same time to display and remember the recording date with one second accuracy. The device should be able to display, record curves of patients diaphragm's numerous contractions to be able to perform dynamic control. All this require to provide the device with a large volume of memory to keep records of thousands patients. The device should have a graphic display being controlled by contacting symbols on the display. The same principle is applicable during measuring. The device should be portable, weigh not more than 200g, and be mounted in a plastic shockproof case.

The device should be powered by rechargeable batteries, at the time of their discharge the user will receive information, and the recharging of batteries will be carried out without removing the batteries from the device. To control the operation of the device, it is necessary to develop an appropriate software package.

Statement of the problem

The positive results of a carried out series tests of the small-sized electrocardiograph MM-1 developed by the authors provide the basis for the development of a new device that will allow physicians to measure and study the rhythmic changes in ion potentials caused by up and down movements of the diaphragm and which appear in the form of electrical signals coming from sensors installed at appropriate points of the skin. The curvilinear information thus obtained will surely serve for evaluation of the diaphragm operation, and enable measuring the duration and amplitude of rhythmically repeating spikes of the curve and assess the change of the curve shape.

Having the results of the above mentioned measurements and examining changes in accordance with age and sex of healthy people, it will be possible to study and find out their changes related to assessment and treatment of different pulmonary diseases. The study of the results obtained by the clinical trials of the given device will allow us to conduct new, more profound studies of this scientific direction, thus stimulate further development of the electrocardiograph.

Resuls

To record or study biological information subdermal or intradermal sensors are used, which, in fact, are converters designed to convert inner ion signals to electrical ones. After amplification of the obtained signals and suppression of signals of corresponding frequency range remains those signals which are in the frequency range selected for study. To solve the stated problem it is necessary to study and measure technical data of sensors in use and reveal physical and chemical phenomena occurring in biological object.

Study of sensor

Study of human anatomical and physiological characteristic properties shows that the human organism is a multilevel system consisting of community of interrelated different organs – cells, molecules, ions, chemical elements etc. Separate connections are unlike differ from each other both qualitatively and chemically. The mentioned differences lay the basis creation of various medical diagnostic methods, where as a diagnostic indices are ultrasonic, optical, x-ray, electromagnetic, magnetic and other physical indices and characteristics for work and survival of a biological object under study. In the framework of the classic electrophysiology on the level of the organs composition are studied such electrical characteristics as sequence of electrical potentials. Bioelectrical measurements are performed by devices developed for medicine and amongst them sensor-electrodes are irreplaceable. Artificial and natural solutions of electrodes as a consequence of influence of inner electrolytes of different composition and different density a electrochemical potential $\Phi_{\text{Э}}$ is developed

$$\Phi_{\text{Э}} = \Phi_{\text{БО}} + \Phi_{\text{ЭХ}} \quad (1)$$

where $\Phi_{\text{БО}}$ is biological characteristic, $\Phi_{\text{ЭХ}}$ is electrochemical potential on the line

The value of $\Phi_{\text{ЭХ}}$ can changed with time by complex and unforeseen laws. Overlapping of electrical signals may have a negative influence on measurement results, therefore it is necessary in developing biotechnical diagnostic systems to do thorough study of bioelectrical processes at all sensor lines and give a technical justification for a sensors system development in accordance with receiving signals characteristics. Fig. 1 shows one sensor line setting.

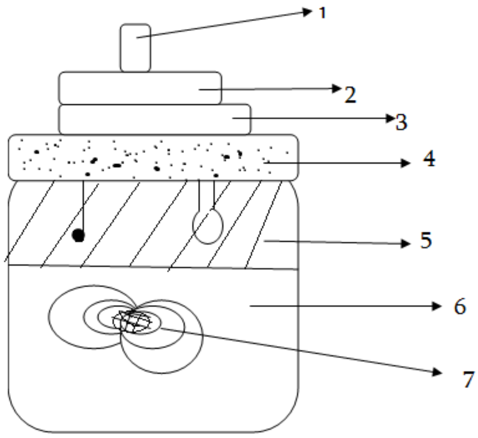

Figure 1. One sensor line setting
1-wire, 2-sensor, 3- artificial electrolyte, 4- natural electrolyte, 5- subdermal fat and sweat formation, 6- intradental electrically conductive substances, 7- electrogenerating part.

Line potentials

Electrode charging in electrode-electrolyte section

In placing of electrode on the skin in electrode-electrolyte section metal cations enter into electrolyte solution due to which a second electrical layer is developed on electrodes. Electrodes' ions interaction with fluid current-conducting layer causes charging in electrode-electrolyte section. As a result of charging the value of $\Phi_{\text{Э}}$ is determined by Nerest's equation depending on chemical activity a_{MZ} of the solution

$$\Phi_{\partial} = \Phi^0 + \frac{RT}{ZF} lg a_M \quad (2)$$

where Φ^0 is electrode potential on normal hydrogen electrode, R is gas factor, T is absolute temperature, Z_F is Faraday number.

Between two electrodes placed on the skin a potential difference Φ_{CM} occurs which depends on inconsistency between the electrode metals and can be determined by the following equation

$$\Phi_{CM} = \Delta\Phi^0 + \frac{RT}{ZF} lg \frac{a_{M_1}^{Z+}}{a_{M_2}^{Z+}} \qquad (3)$$

where $\Delta\Phi^0$ is a standard potential difference between electrodes, a_{M1}^{Z+} and a_{M2}^{Z+} are activities of the first and second electrodes in the electrolyte.

In the absence of external electrical influence we have an electrodynamic equilibrium. Influence of the external electrical field can bring to a dynamic disequilibrium of charges of the second layers of electrodes when the duration will be conditioned by the sum of cycles times and the difference of charges can reach to several hundred

Diffusion potential

The contact of two electrons possessing different electrochemical properties brings to a situation where the more mobile ions from high concentration fluids travel to fluids of lower concentration, that is a diffusion process begins charging them by positive or negative charge. The diffusion potential is determined by the following equation

$$\Phi_P = \frac{RT}{F} \frac{\lambda_a^\infty - \lambda_K^\infty}{\lambda_a^\infty + \lambda_K^\infty} ln \frac{a_1}{a_2} \qquad (4)$$

where λ_a^∞ and λ_K^∞ is the boundary mobility of anion and cation ions in infinite weakening of concentration, respectively, a_1 and a_2 are ion activity of the line electrolytes between two electrons. Figure 2 shows potentials measuring principal schemes.

The diffusion potential can reach to several hundred millivolts. By selecting symmetric electrodes and ointments of the same electrochemical properties which are equal internal intradental electrolytes the formation of these charges can be neutralized.

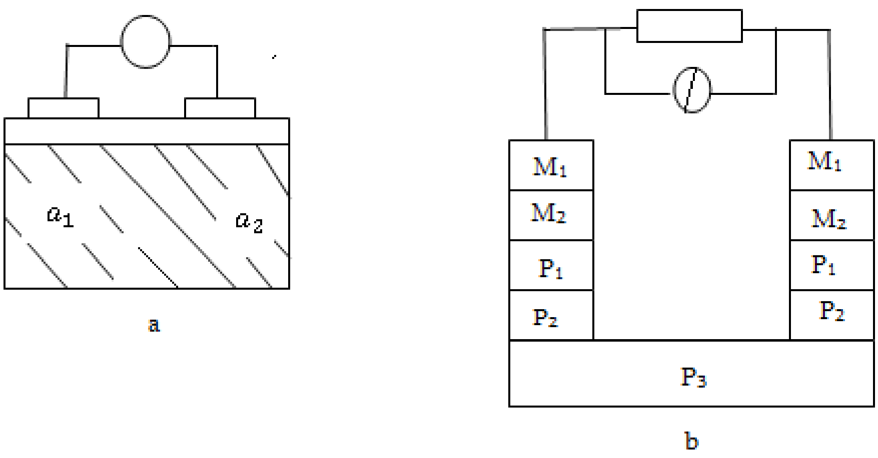

Figure 2. Principal schemes of potential measuring

a. potentials measuring circuit - a_1 and a_2 are indices of current-conducting solutions, b. structural diagram of the setting - M are electrodes and connecting wires, P are natural and artificial electrolytes.

Potential deviation due to absorption phenomena

Free ions and cations in biological electrolytes can enter into chemical and physical interaction with the electrode and change its potential due to adsorption processes. The change of the potential to negative side can bring organic and inorganic anions, chlorine, bromine, iodine and fatty compounds. Potential change to the positive side can bring cation, amine CH^+ compounds. Redox reaction is called a process when two reagents interacting with each other from one electrode is conveyed to the other. Discuss this phenomenon referring to a physical model presented on Figure 3. Here in two glassware are filled with the same chemical content but different ferrous iron and ferric iron solutions. This model of the redox reduction pair illustrates a mechanism of a number of processes which run in a living organism, for example, feritin and trasferin. Electrodes in this model are made of platinum. They do not in these solutions therefore ion processes differ from electronic processes.

Ions are forced out from Fe^{3+}solution and tend to F_2 solution to produce current in the external circuit, which leads to development of Φ_{0-B} potential on Rbx resistence. The potential is determined by the following formula

$$\Phi_{0-B} = \Phi^0_{0-B} + \frac{RT}{ZF} lg \frac{a_0}{a_b} \quad (6)$$

where Φ_{0-B} is the redox reduction potential, a_0, a_b are acidiferous and reduction activities, respectively. It should be noted that depending on substances potential can reach to several hundred millivolts

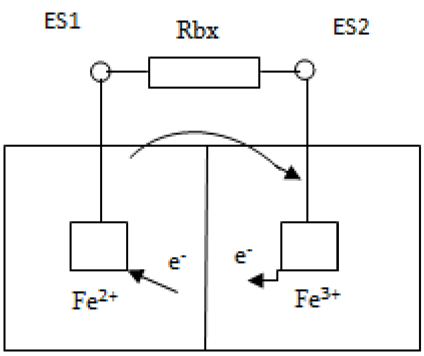

Figure 3. Electrons movement in case of redox reaction

Equivalent scheme of a bioobject-electrolyte-electrode-measuring device system can be represented as shown in Figure 4.

$E_{БО}$ and $E_{ЭХ}$ are bioelectrical and biochemical potentials, respectively, $R_Э, C_Э, R_{БХ}, C_{БХ}$ are indices of the electrode and measuring instrument

In detailed study of the lead one should also take into account impedance characteristics of the skin, tissues, and organs, especially at the electrode-skin point. biological solutions and electrode contact substance reaction in low and very low frequencies is expressed as active resistance the value of which is inversely proportional to areas of electrodes. In a particular case when microelectrodes are used their capacity $C_Э$ can reach to several microfarads and the resistance to a dozen megaohms. Calculated characteristics Φ_{CM}, $R_Э$, $C_Э$, of the electrodes' system and their possible time deviations should be taken into consideration, as in case of coincidence of bioobject and measuring system frequencies differentiation of the real generating biological signal and electrochemical signal becomes very difficult. real Rhythmic changing biological signal and dynamic change of the electrode potential enable to classify electrodes into two groups – rechargeable electrodes and not rechargeable electrodes.

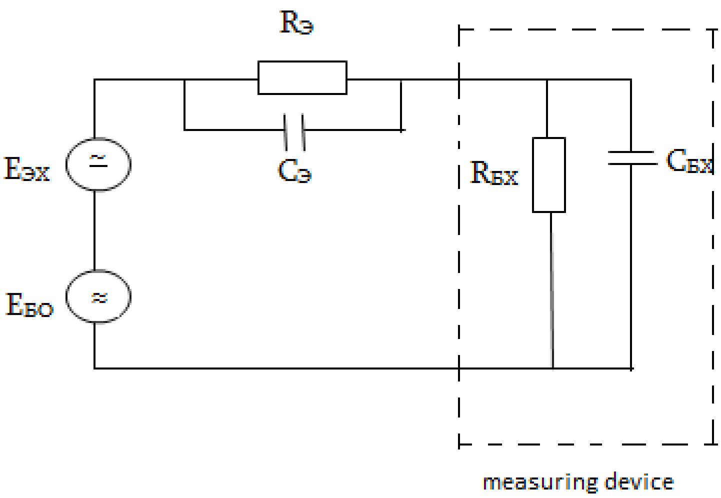

Figure 4. Measuring circuit

Taking into account the above exposition serious problems are encountered in recording the diaphragm movement as the range of the diaphragm frequency nearly 5 times lower from the electrocardiogram range, then all characteristics of electrodes should be taken into account and decrease, if possible, values of changes of obtained signals. It is obvious that Ag-Cl jacketed metal electrodes should be used. The principle block scheme of the device under development can have the view as presented in Figure 5.

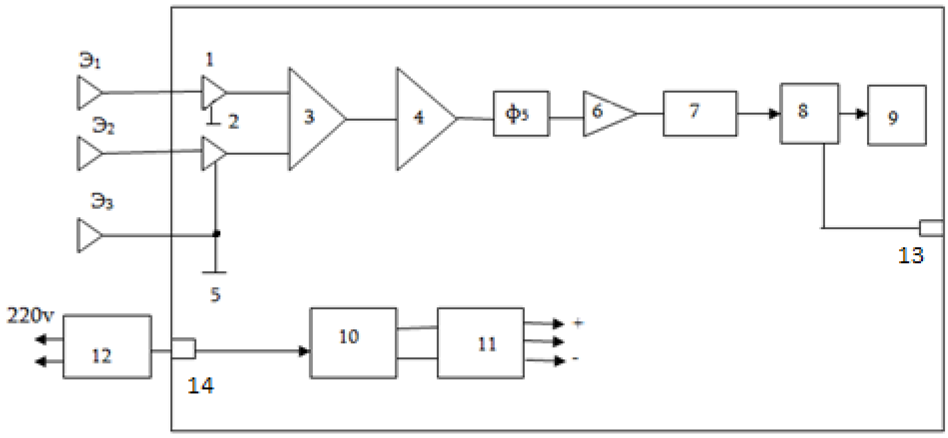

Figure 5. Principle block scheme

$Э_1, Э_2, Э_3$ **Electrode sensors**

1,2. Voltage adapters

3,4,6. Voltage amplifiers

7. Analog-to-digital converter

8. Microprocessor

9. Display

10. Rechargeable accumulator

11. Voltage regulator

12. External standard charging device

13. USB

14. Charge switch

Conclusions

Conclusions drawn from the present study are:

Organs of all animals which work in a continuous rhythmic regime surpassrepeated biological ion signals which are in different frequency ranges.

In recording signals of one continuously working organ signals of the other continuously working organ are presented as murmurs for their frequency ranges are different.

Sensors placed on the skin are charged due to electrochemical processes and that charges impede recording of biological signals.

The microprocessor digitized small-sized device developed by the authors enabled with the use of subdermal electrodes for the first time to plot the curve of a diaphragm electrograph in presence of electrocardiogram signals which are considered as noise. To annul these noises research is carried out.

References

1. A-Z Health Guide from WebMD: Medical Tests, Electrocardiogram, June 09, 2006
2. Приборы и средства функциональной диагностики: лаб.практикум для студ. спец. 1-39 02 03 «Медицинская электроника» всех форм. обуч. / Н.С. Собчук, Т.А. Имшехецкая. – Минск: БГУИР, 2008. – 34с.
3. http://www.altomedika.ru/index.php/about-company/history/114-1996-programmiruemyj-imitator-ekg - программируемый имитатор ЭКГ
4. Paul J. Michalek. An authentic ECG simulator. Thesis, Computer Engineering University of Central Florida, USA, 2006
5. SERVICIENCIA, S.L. SPAIN, 2002. Source on the Internet: ECG Simulator, Ferronato - FC3D, Available at: http://www.serviciencia.es/fc3-in.htm.
6. HE Instruments, Product Brochure. Source on the Internet: - http://www.heinstruments.com/files/TechPatient%20CARDIO%20Brochure.pdf
7. Lionheart 3. Multiparameter Patient Simulator. User Guide. Printed in the USA.Manual P/N 5181000 Rev.F, September, 2002
8. MULTI-PRO 2000, Electrical Safety Analyzer / 12 Lead ECG Simulator, Netech Corporation, 60 Bethpage Drive, Hicksville, NY, Source on the Internet: netech.org, http://www.netech.org/Products/details/MultiPro-2000_53

References

1. A-Z Health Guide from WebMD: Medical Tests, Electrocardiogram, June 09, 2006
2. Instruments and tools for functional diagnostics: Laboratory practice for students of 1-39 02 03 "Medical electronics" specialty / N.S. Sobchuk, T.A. Imshekhetskaya. – Minsk:, 2008. – 34p.
3. http://www.altomedika.ru/index.php/about-company/history/114-1996-programmiruemyj-imitator-ekg programmable ECG simulator
4. Paul J. Michalek. An authentic ECG simulator. Thesis, Computer Engineering University of Central Florida, USA, 2006
5. SERVICIENCIA, S.L. SPAIN, 2002. Source on the Internet: ECG Simulator, Ferronato - FC3D, Available at: http://www.serviciencia.es/fc3-in.htm.
6. HE Instruments, Product Brochure. Source on the Internet: - http://www.heinstruments.com/files/TechPatient%20CARDIO%20Brochure.pdf
7. Lionheart 3. Multiparameter Patient Simulator. User Guide. Printed in the USA.Manual P/N 5181000 Rev.F, September, 2002

8. MULTI-PRO 2000, Electrical Safety Analyzer / 12 Lead ECG Simulator, Netech Corporation, 60 Bethpage Drive, Hicksville, NY, Source on the Internet: netech.org, http://www.netech.org/Products/details/MultiPro-2000_53

ԷԼԵԿՏՐԱՍՏՈԾԱՆԱԳՐԻ ՓՈՔՐԱՉԱՓ ԹՎԱՅՆԱՑՎԱԾ ՍԱՐՔԻ ՄՇԱԿՈՒՄԸ

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Հոդվածը նվիրված է նմանակը չունեցող փոքրաչափ միկրոպրոցեսորային սարքի մշակմանը, որի շնորհիվ հնարավոր կլինի ցուցադրել ստոծանու շարժումներից առաջացած կորագիծը սարքի դիսպլեյի վրա: Սարքի միջոցով կարելի է չափել կորագծի տատանման պարբերությունը, ալիքների տևողությունը և ամպլիտուդան: Մեր կողմից մշակված մեթոդով համապատասխան կետերում տեղադրված ենթամաշկային տվիչներից կարելի է ստանալ բիոլոգիական վերը նշված ինֆորմացիան: Հոդվածում մանրակրիկիտ շարադրված է օրգանիզմում կատարվող էլեկտրաքիմիական գործընթացները, որոնք խանգարում են տվիչներից բիոլոգիական ազդանշանների ստացմանը և տրված են եզրահանգումներ տվիչների ընտրության վերաբերյալ: Տրված է նաև սարքին ներկայացվող պահանջները և մշակվող սարքի բլոկ սխեման:

Բանալի բառեր. Տվիչներ, էլեկտրոդներ, բիոազդանշաններ, ստոծանի, լիցք

РАЗРАБОТКА МАЛОГАБАРИТНОГО ЦИФРОВОГО ЭЛЕКТРОДИАФРАГМОГРАФА

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Работа посвящена разработке малогабаритного, микропроцессорного прибора, не имеющего аналога. Прибор показывает на собственном цветном графическом дисплее работу диафрагмы в реальном масштабе времени. В полуавтоматическом режиме можно измерить ритм дыхания, длительность и амплитуду кривых, полученной информации. Биологическая информация снимается с помощью трех нательных электродов, установленных в определенных точках грудной клетки. В статье подробно рассматриваются электрохимические процессы, происходящие в организме при установке электродов. Дается рекомендация по подбору электродов, а также приводятся блок-схема прибора и технические требования к нему.

Ключевые слова. Датчики, электроды, биосигнал, диафрагма, заряд