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INTELLIGENT PULMONARY NOISE RECORDERS

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Abstract – *The schemes for using the simplest single-channel device for wireless recording of lung noise on a smartphone and a microcontroller based four-channel device for simultaneous recording of lung noise in different parts of the patient's chest and outside his chest are developed in this paper. Prototypes of such devices, combined with microphones using auxiliary equipment was made. Trial recordings of lung noises and wireless transmission to the smartphone were made. It is shown that the use of byte format of recording with a frequency of 8 kHz is sufficient to provide the required dynamic range for further analysis of the noise. The device is mounted in a lightweight plastic housing that can be attached to the patient's clothing and allows long-term (up to 24 hours) continuous monitoring of respiration. The autonomy of its operation is ensured by the presence of a lithium-ion battery, with the ability to charge from any source of 5V DC, such as from a USB port from a PC or from a charger of a smartphone. The transmission of data of monitoring is wireless using Bluetooth.*
Obtained: structural and schematic diagrams of single and multi-channel sensors for electro-auscultation of the lungs with a wireless data transmission channel, which opens up new opportunities for the creation of automated single-channel and multi-channel systems for diagnosing the condition of the lungs. It is concluded that the created single and multi-channel sensors in their technical capabilities fully meet the needs of automated systems for diagnosing the condition of the lungs by acoustic noise.

Keywords: *acoustic noise, detection of lung pathologies, differential diagnostics of noise, four-channel device, noise spectra, respiratory phases, single-channel device.*

I. INTRODUCTION

The overcrowding of the health care system and the lack of qualified doctors- have raised the question about the necessity to create (based on the technical means available to the population: smartphones and PCs) a "virtual family doctor" who could take on the initial diagnosis of diseases lungs by acoustic noises of the respiratory process and thus significantly unload the system of primary medicine,

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especially during pandemics, and improve the quality of medical care to the population [1-7]. The key task to solve this problem is the development of autonomous acoustic sensors for single-channel and multi-channel auscultation systems. This part discusses the features of its solution.

II. A SINGLE-CHANNEL DEVICE

To implement the simplest single-channel device for recording lung noise [1] was used a smartphone «Samsung A107F» and a headset «Xiaomi Mi Bluetooth Headset» (Fig. 1), which operates with a smartphone using the Bluetooth 4.1 interface.

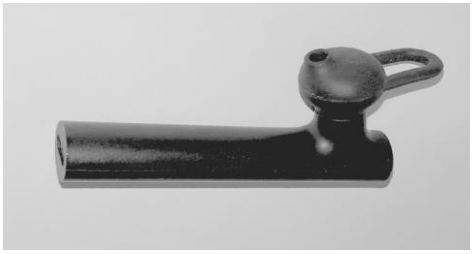

Fig. 1. «Xiaomi Mi Bluetooth Headset».

The headset has small dimensions (56 mm x 10 mm) and weight (65 g). The distance at which the headset can be removed from the recording smartphone without loss of communication is about 10 m and depends on how much space between the headset and the smartphone is free for radio waves with a frequency of 2,5 GHz. The continuous operation time of the headset before recharging of the built-in battery is about 5 hours.

Given the main purpose of the headset «Xiaomi Mi Bluetooth Headset», it is clear that it can only make a single-channel recording. To implement such a recording, you must first install it on a smartphone, for example through «Play Market», the program «Voice Recorder», which allows you to select the sound source for recording, and change the choice of the built-in microphone, which is set «default» to choose «Bluetooth device». Then, setting the headset face down on the selected auscultation point, turn on the recording mode on the recorder. After taking the required number of inhales and exhales - stop recording.

The microphone of the headset "Xiaomi Mi Bluetooth Headset" is located in the end part of the case next to the charging connector of the built-in battery. Several options for using such a headset were considered.

If you need a long stay Bluetooth headset at one of the points of auscultation, it is proposed to use a suction cup, which is specially redesigned to install the headset in it so that the headset touches the patient's body at the point of auscultation with its end (Fig. 2.).

Fig.2. «Xiaomi Mi Bluetooth Head-set», mounted on the suction cup.

Pulmonary noise tests were performed at several auscultation points using the «Xiaomi Mi Bluetooth Headset». The sampling rate during recording was limited by the capabilities of the wireless headset at 8,000 samples per second. However, the records obtained with such a sampling rate are quite informative and, at the same time, there is no congestion of the data channel. An example of one of these records after mathematical processing is presented in Fig.3.

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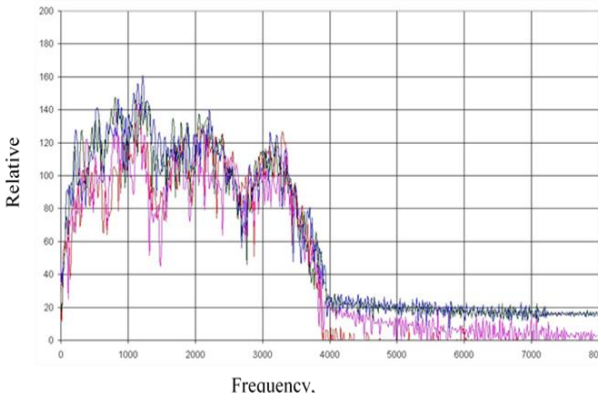

Fig 3. Spectral components of the recording of two breaths and two exhalations, obtained using a wireless headset «Xiaomi Mi Bluetooth Headset».

Fig. 3 shows that the informative recording is present only at frequencies up to 4 kHz. This is because the direct purpose of the wireless headset (reception and transmission of voice messages) does not involve the transmission of audio signals of the broadband spectrum, and the data channel is intentionally limited in frequency by hardware.

To increase the sensitivity of the Bluetooth headset microphone, you can use the tip of the phonendoscope, which is used in medical practice, including for listening to lung noise. For this purpose, a special adapter was made that connects the Bluetooth headset with the tip of the phonendoscope. The resulting design is shown in Fig. 4.

Fig 4. «Xiaomi Mi Bluetooth Headset» mounted on the phonendoscope tip.

Test recordings were also made using the «Xiaomi Mi Bluetooth Headset» mounted on the tip of the phonendoscope. The result of the mathematical processing of one of the records is presented in Fig. 5.

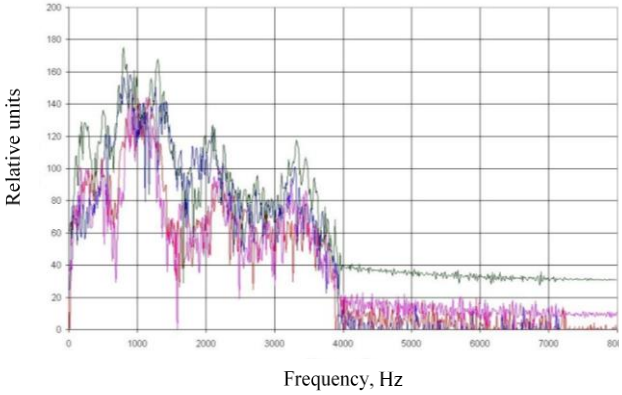

Fig. 5. Spectral components of the recording of two inhalations and two exhalations, obtained using a wireless headset «Xiaomi Mi Bluetooth Headset» mounted on the tip of the phonendoscope.

Based on the conditions of use of the wireless headset «Xiaomi Mi Bluetooth Headset», it is clear that at the same time with the help of one headset you can record noise on one smartphone only at one point of auscultation.

III. MULTI-CHANNEL STAND-ALONE MICROCONTROLLER DEVICE

A four-channel autonomous microcontroller device with wireless transmission of the recorded data to the processing device has been developed for the implementation of synchronous recording of lung noises heard at different auscultation points. The block diagram of such a device is presented in Fig. 6.

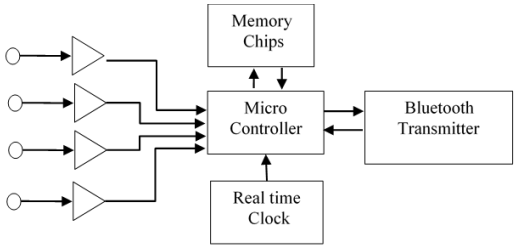

Fig. 6. Block diagram of a microcontroller device for recording, accumulation and transmission of pulmonary noise data.

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Electret microphones are mounted on microphone amplifier boards. Amplified sound signals of lung noise, taken from different points of the chest, are simultaneously digitized by analog-to-digital converters of the microcontroller and recorded in memory chips.

The use of memory chips in the device circuit is due to the fact that, in the case of direct transmission of digitization results to the control device, the transmission rate will be limited to 2000 samples per second, while the transfer of results to memory chips allows you to increase this speed to 50,000 samples per second.

At the end of the recording session, the received information provided with the time identifier obtained from the independent real-time clock chip is transmitted via a wireless communication channel to the control device. Such a device can be a laptop or smartphone.

The device uses omnidirectional condenser electret microphones BCM-9765P (Fig.7), which have the following main characteristics:

- frequency range – 20 - 16000 Hz;
- electrical resistance – 2.2 kOhm;
- current consumption – not more than 0.5 mA;
- operating voltage – from +1.5 V to +10 V;
- signal-to-noise ratio – not less than 60 dB;
- sensitivity at a frequency of 1 kHz – -44 dB (0 dB = 1 V / Pa)

Fig. 7. Electret microphone BCM-9765P.

Digitization of electrical signals is carried out by an analog-to-digital converter (ADC) of the microcontroller. To amplify the weak microphone signals to the levels required for normal ADC operation, the device uses a microphone amplifier using the MAX4466 chip, which is specially optimized by the manufacturer for use as a microphone preamplifier. It is implemented in the small SC70 case, which allows, using passive SMD elements to implement the amplifier on the printed circuit board (PCB) and place it directly on the body of the electret microphone.

The microphone with the amplifier, in one variant, is built in the case of a nozzle of a phonendoscope (Fig. 8), in other variant – is connected to a nozzle of a phonendoscope through the transition plug (Fig. 9).

Fig. 8. Microphone built into the body of the phonendoscope.

Fig. 9. Microphone connected to the nozzle of the phonendoscope.

Given the need to manufacture a device with a small size, the scheme (Fig. 6) was developed using a minimum number of housings and using surface mount technology (SMT). The exception of this case is the presence of the programming circuit of the microcontroller and the interface circuits for communication with a PC. Both of these circuits are used at the stage of adjustment and can be eliminated without compromising the efficiency of the structure, which will further reduce the size and weight of the device.

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Fig. 10. Assembled device board.

In fig. In Fig. 10 shows the main components of the manufactured device:

1. Four input channel connectors;
2. Board «DS1302-MOD» real-time clock;
3. LI-CHARGER-MicroUSB board with connected recharging cord;
4. Four «AT25DF321A» memory chips for each of the channels;
5. Lithium-ion battery «LP705085-PCM-LD»;
6. Connector for wired communication with PC;
7. «HC-05-BLUTOOTH» board for wireless communication with a PC;
8. Microcontroller «ATXMEGA128A4»;
9. Connector for programming the microcontroller;
10. Microphone amplifier board with microphone;
11. The tip of the phonendoscope.

IV. DATA TRANSMISSION SYSTEM.

When choosing the type of wireless channel, for transmitting digital lung auscultation results to the control device, we were guided by the fact that the intended scope of the device does not require a long transmission range, which, in turn, allows not to spend extra energy to transmit information and accordingly, increase the operating time of the device between battery charging sessions.

It was decided to use a «Bluetooth» specification to transmit data over a wireless line. For communication, the method of spreading the spectrum with abrupt frequency tuning is used, which provides resistance to broadband interference, is easy to implement, and the equipment that uses it has a low cost.

In a Bluetooth connection, the carrier frequency of the signal changes abruptly 1600 times per second, and the sequence of switching between frequencies for each connection is pseudo-random and is known only to the transmitter and receiver, which are synchronously reconfigured from one carrier frequency to another. Thus, if several pairs of transceivers work side by side, they do not interfere with each other, and digital data, in case of loss of the information packet, will be retransmitted.

The developed communication channel between PC and microcontroller uses the communication module «HC-05-BLUTOOTH». This Bluetooth module is designed to transmit information at a speed of 721 kbps for short range communication between devices.

The module allows you to connect the microcontroller to PC, laptops, and any other devices that have Bluetooth running in master mode. To use the Bluetooth module, you need to write a special software to the microcontroller, you need to create a COM port on the PC via Bluetooth (if such a port is not present in the computer). The Bluetooth module is controlled from the master Bluetooth device. Data is transmitted according to the UART standard, which is in most embedded systems (such a port is present in almost all microcontrollers, or is easily organized programmatically). It is also possible to control with AT-commands.

The ATXMEGA128A4 microcontroller is used to digitize the signals transmitted by the microphone amplifier as well as to transfer the digitized values to a PC or smartphone. This microcontroller is one of the models of AVR series microcontrollers from Atmel Corporation. It is capable of operating at a clock speed of up to 32 MHz and includes a machine for working with peripherals using a variety of interfaces (SPI, I2C, UART standard).

The window of the software on the PC screen looks like this (Fig. 11).

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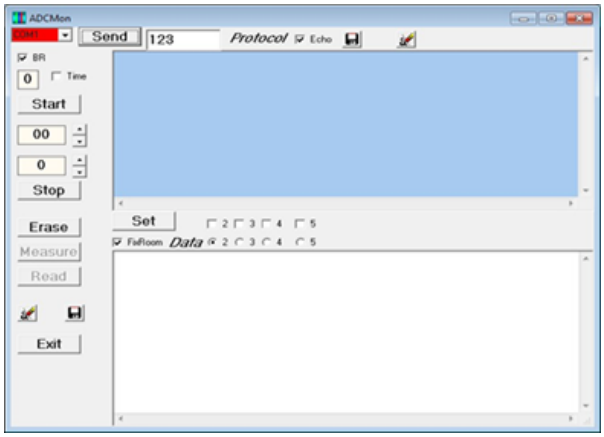

Fig. 11. Software window.

V. CONCLUSIONS

Schemes of using the simplest single-channel device for wireless recording of lung noise on a smartphone and a micro-controller four-channel device for simultaneous recording of lung noise at different points of the patient's chest and outside his chest have been developed. Prototypes of such devices with microphones using ancillary equipment, were made. Pilot recordings of lung noises and followed by their processing by mathematical methods are performed. The four-channel device is mounted in a lightweight plastic housing that can be attached to the patient's clothing. Its autonomy is ensured by the presence of a lithium-ion battery, with the ability to charge from any 5V DC source, for example, from the USB port of the PC or from the smartphone charger.

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REFERENCES

1. Lutsenko V., Luo Iyan, Babakov M.: Signatures of acoustic noise of lung pathologies, All-Russian open scientific conference "Modern problems of remote sensing, radar, propagation and diffraction of waves", Electronic resource http://www.mivlgu.ru/conf/armand2019/konspekt-2019/index.html , Murom. P.671-678, (2019).
2. Lutsenko V., Luo Ian, Babakov M.: Simulation model of acoustic noises of the respiratory process and technology of signature allocation in lung pathologies , VII International scientific-practical conference "Signal processing and non-Gaussian processes", dedicated to the memory of Professor Kunchenko YP, Proceedings, C.40-42, (2019).
3. Babakov M., Ishchuk D., Lutsenko V., Lutsenko I., Lo Iyan : Signatures of acoustic noise in pneumonia , II International scientific-practical conference "Information systems and technologies in medicine" (ISM – 2019), Kharkiv, Ukraine: coll. Science. pr. - Kharkiv: Nat. aerospace Univ. ME Zhukovsky "Kharkiv. aviation. Inst. ", 220 pp., pp.68-69, (2019).
4. Babakov M., Lutsenko V., Lutsenko I., Lo Iyan :Technologies for allocating acoustic noise signatures in lung pathology, II International Scientific and Practical Conference "Information Systems and Technologies in Medicine" (ISM-2019), Kharkiv, Ukraine: Coll. Science. pr. - Kharkiv: Nat. aerospace Univ. ME Zhukovsky "Kharkiv. aviation. Inst. " 220 pp., pp. 30-31, (2019).
5. Babakov M., Ishchuk D., Lutsenko V.: The concept of building a multi-channel automated system for the analysis of acoustic noise for differential diagnosis of lung conditions , II International scientific-practical conference "Information systems and technologies in medicine" (ICM-2019), Kharkiv,

Ukraine: coll. Science. pr. - Kharkiv: Nat. aerospace Univ. ME Zhukovsky "Kharkiv. aviation. Inst. ", 220 pp., P.179-181, (2019).

6. Babakov M. , Kryvenko O., Lutsenko V., Lo Iyan: Automation of the process of monitoring lung pathologies by acoustic noise , III International scientific-practical conference "Information systems and technologies in medicine" (ISM-2020) [Text]: coll. Science. pr. - Kharkiv: Nat. aerospace Univ. ME Zhukovsky "Kharkiv. aviation. Inst. ", P.167-168, (2020).
7. Babakov M., Shubnyi O., Glamazdin V., Lutsenko I.: Autonomous acoustic sensors for single-channel and multi-channel electro-auscultation systems , (ICM – 2020) [Text]: coll. Science. pr. - Kharkiv: Nat. aerospace Univ. ME Zhukovsky "Kharkiv. aviation. Inst. " , P.171-172,(2020).

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ІНТЕЛЕКТУАЛЬНІ РЕГІСТРАТОРИ ЛЕГЕНЕВОГО ШУМУ

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Реферат – *У роботі розроблено схеми використання найпростішого одноканального пристрою для бездротової реєстрації легеневих шумів на смартфоні та чотириканального пристрою на базі мікроконтролера для одночасної реєстрації легеневих шумів у різних відділах грудної клітки пацієнта та поза грудною кліткою. Виготовлено дослідні зразки таких пристроїв, суміщених з мікрофонами за допомогою допоміжного обладнання. Були зроблені пробні записи легеневих шумів і бездротова передача на смартфон. Показано, що використання байтового формату запису з частотою 8 кГц є достатнім для забезпечення необхідного динамічного діапазону для подальшого аналізу шуму. Апарат змонтований в легкому пластиковому корпусі, який кріпиться до одягу пацієнта і дозволяє тривалий (до 24 годин) безперервний моніторинг дихання. Автономність його роботи забезпечується наявністю літій-іонного акумулятора, з можливістю заряджатися від будь-якого джерела постійного струму 5 В, наприклад від USB-порту від ПК або від зарядного пристрою смартфона. Передача даних моніторингу бездротова за допомогою Bluetooth.*

Отримано: структурні та принципові схеми одно- та багатоканальних датчиків електроаускультації легень з бездротовим каналом передачі даних, що відкриває нові можливості для створення автоматизованих одно- та багатоканальних систем діагностики стану легені. Зроблено висновок, що створені одно- та багатоканальні датчики за своїми технічними можливостями повністю відповідають потребам автоматизованих систем діагностики стану легень за акустичним шумом.

Ключові слова – *акустичний шум, виявлення легеневих патологій, диференціальна діагностика шуму, чотириканальний пристрій, спектри шуму, фази дихання, одноканальний пристрій.*