Development of a Device for Non-invasive Recording of Biomedical Signals in Rats (*Rattus Norvegicus Domestica*)

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***Abstract*— Cardiovascular diseases continue to be the most urgent problem worldwide, so conducting preclinical animal trials is an integral part of drug development. The most common types of model animals are rats, since they have a similar structure of the cardiovascular system to humans. This raises the question of non-invasive, safe recording of biomedical signals in rats.**

Keywords— electrocardiogram, photoplethysmogram, rat, pharmacology

I. INTRODUCTION

One of the most common methods of evaluating the pharmacological effect of drugs is testing on laboratory animals. It involves taking an electrocardiogram (ECG) and a photoplethysmogram (PPG). Preclinical drug trials are necessary because they can determine the indications for the use of drugs, contraindications, side effects and properties of already patented drugs in order to better determine the scope of clinical trials and the possibility of their drug behavior. Since the characteristics of ECG and PPG are very similar in rats and humans, it becomes necessary to obtain reference values of various indicators, including ECG and PPG parameters. That is why rats are the most common species used in experimental studies of cardiac physiology and electrophysiology. However, there are practically no complexes consisting of two devices at once (ECG and PPG), although the analysis of these two types of biomedical signals at once is important for assessing the state of the rat's cardiovascular system.

II. A MODERN APPROACH IN LABORATORY PRACTICE

Currently, invasive ECG recording devices are mainly used in laboratories, which require surgical intervention and anesthesia, as a result of which the rat may die from blood poisoning, or anesthetics are used during recording signals that affect heart rate variability, and also have a fatal outcome. Another method of ECG registration is telemetry. Telemetric sensors are implanted under the animal's skin to reduce external interference, but this method is also not safe [1].

There are also non-invasive electrocardiogram recording methods, but most of them interfere with the signal from various manipulations with the rat during signal recording. For example, putting a cotton jacket [2] on an animal will cause a lot of stress interference due to an uncomfortable feeling on the rat's body and a state of stiffness, it is also impossible to securely attach the electrodes on the jacket to the rat's chest, which will cause movement artifacts. Another non-invasive way of recording an electrocardiogram is the location of a rat secured with Velcro (strips of fabric overlap the rat criss-cross) on electrodes located on a special block [3]. The disadvantage of this method is the unreliability of the attachment. The animal can escape from it if the Velcro is loosely secured, or slip out from the back side due to an uncomfortable position. Also, if you squeeze the rat hard, it will lead to stress, which will affect the results of the analysis. Another disadvantage is the mobility of the animal during the study, which will cause movement artifacts that can also distort the results.

Photoplethysmography recording devices are also divided into invasive and non-invasive. The disadvantage of invasive is the use of complex experimental procedures that expose animals to infection and inflammation, and they cannot be performed on rats that are too small in size. Non-invasive methods may also include the use of anesthetics that adversely affect the physical condition of the rat, as well as the use of special devices on the animal's body that cause discomfort during recording, which causes interference in the signal [4].

In response to this, a non-invasive dynamic physiological monitoring system was developed in this study, which allows simultaneous recording of an electrocardiogram and a photoplethysmogram in rats, without the use of anesthetics.

III. PROPOSED CONCEPT

In this study, the following concept of a device for recording the electrical activity of the heart in rats is proposed (Fig. 1).

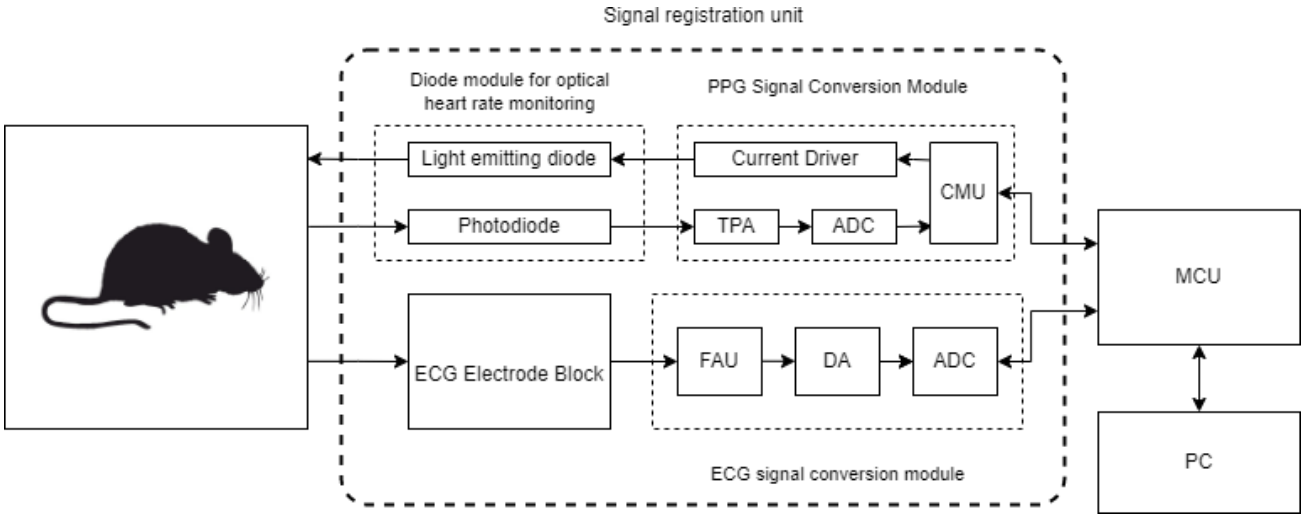

Fig.1. Block diagram of a device for recording ECG and PPG in rats

The signal registration unit consists of two parts: the PPG signal conversion module and the ECG signal conversion module.

The diode module for optical heart rate monitoring is designed as a clamp that needs to be attached to the tail of a rat, preheating the animal to a temperature of 28-32˚C for 10-15 minutes to enhance blood flow in the tail. LEDs work in the red and infrared regions of the spectrum, since ultraviolet radiation (10 - 380 nm), as well as visible light in the blue and violet ranges (380 - 485 nm) is strongly absorbed by surface tissues. Light radiation is passed through the studied section of the biological tissue, then the light gets to the radiation receiver (photodiode). Next, the signal from the photodiode enters the PPG signal conversion module, where, using the control module unit (CMU) via the communication protocol (I^2C) with a microcontroller (MCU), it is digitized using an analog-to-digital converter (ADC) in order to further calculate the necessary indicators of the rat's condition. After the FPG, the signal should be displayed on the screen of a personal computer (PC).

Data from the ECG electrode block is sent to the ECG signal conversion module (ADS1292). ADS1292 is a multichannel 24–bit analog-to-digital converter (ADC) with sigma-delta simultaneous sampling, built-in programmable amplifier, internal reference and built-in generator. Sigma-delta high-resolution ADC is used to reduce signal amplification in order to reduce the likelihood of over-amplification, which can lead to the loss of the useful component of the rat ECG signal. The ECG module consists of a filtering and amplification unit (FAU), which is necessary to get rid of unnecessary signal interference and to increase the amplitude of the useful signal. Further, the filtered and amplified ECG signal passes through a differential amplifier (DA) designed to amplify the difference between the two voltage inputs, but suppressing any voltage common to the two inputs, and is further digitized using an analog-to-digital converter (ADC), and is transmitted to a PC using an ESP32 microcontroller (MCU).

IV. Conclusion

In this study, the analysis of existing methods for recording biomedical data in rats was carried out, their shortcomings were revealed. The concept of a device for noninvasive registration of electrical activity of the heart, consisting of ECG and PPG modules, was also proposed. In the next work, the layout of this device will be presented, as well as the signals received with it.

References

[1] Kim, M. J. Validation of non-invasive method for electrocardiogram recording in mouse using lead II / M. J. Kim, J. E. Lim, B. Oh // Biomedical Science Letters. – 2015. – Vol. 21(3). – P. 135–143.

[2] Pereira-Junior, P. P. Noninvasive method for electrocardiogram recording in conscious rats: feasibility for heart rate variability analysis / Pereira-Junior, P. P. et al. // Anais da Academia Brasileira de Ciências. – 2010. – Vol. 82(2). – P. 431-437.

[3] Kumar, P. Noninvasive recording of electrocardiogram in conscious rat: A new device / Kumar P. et al. // Indian journal of pharmacology. – 2017. – Vol. 49(1). – P. 116.

[4] Chang, W. Y. Noninvasive photoplethysmography monitoring in free-moving rats / W. Y. Chang, C. C. Chen, S. C. Su // 2017 IEEE International Conference on Mechatronics and Automation (ICMA). – 2017. – P. 1682-1686.