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Developing a model of low-budget heart tone amplifier to control the heart function as a part of a personalized medicine strategy

Abstract

Due to the development of instrumental medicine methods, it has become possible to design the devices for the personalized medical observation of the heat diseases. Since the electrocardiography is indispensible, accessible, non-invasive and highly informative method of the initial inspection and the subsequent observation of the heart patients, there is a need for an accessible electrocardiograph for using at home on a regular basis. The problem addressed in this study is the increase in life expectancy due to regular monitoring of cardiac activity. The objective of this study is the development of the technologically new, inexpensive, compact prototype of the electrocardiographic device that can detect and transmit the corresponding signals for the further processing, data recording and passing it to the attending cardiologist.

Keywords: heat, bioelectric potentials, heart tone amplifier, electrocardiography, heart diseases, Arduino, circuit board, electrodes

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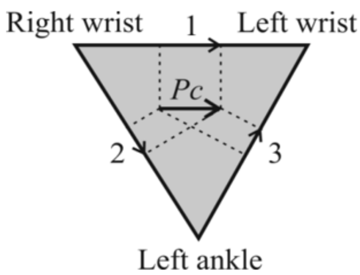
Introduction

The problems of monitoring the functional state of the body and its individual systems are relevant due to the possibility of preventing diseases that develop over time and lead to severe consequences. Regular monitoring of cardiac activity will allow for early detection and prevention of cardiovascular diseases. This will lead to improved quality of life and increased longevity. Therefore, there is a need for affordable personal devices that can be used by patients to monitor their heart function on a regular basis at home. Based on the above, the goal of this work is to develop a prototype of a new, technologically advanced, affordable, and compact electrocardiographic device that records, stores, and transmits heart signals to a cardiologist for further analysis.

The normal and pathological functional conditions of the human organs and tissues are reflected by bioelectric potentials. They are recorded and studied for the heart disease diagnosis. The following methods of the bioelectric potential registration are the most widespread: electrocardiography (ECG), electroencephalography of the human brain (EEG), electromyography of the peripheral nerve trunks and muscles (EMG).[1] It should be noted that the latter two methods currently are actively enhanced for their further application to control such portable robotic devices as exoskeletons and bionic prostheses.[2,3] The electrocardiogram is not a one-time method of the heart disease diagnosis. The long-term observation of the diagnosed patients as well as of their first-degree relatives is important for identifying the asymptomatic carriage. Therefore, the development of the portable, accessible electrocardiograph for autonomous recording of electrocardiograms at home on a regular basis is an actual task. The analysis of the literature sources implies that the heart bioelectric potential difference is measured between the points of the equilateral triangle, which are approximately located at the right wrist, left wrist and the left ankle (Figure 1).

The Figure 1 shows that the ECG for these leads represents the projections of the vector *Pc* on the sides of the triangle. Nowadays, these leads are considered standard or classic. They yield the bioelectric potential differences in time that are called electrocardiogram (ECG). For the correct ECG gauging and interpretation, it is important that it is properly recorded in the standard conditions: no noise and no shift of the record level from the horizontal are ensured and the standardization requirements are observed. Using the electrocardiogram, one can locate the excitation origin in the human heart; learn the coverage sequence of the human heart parts with that excitation; and estimate the excitation conduction velocity. Therefore, it allows assessing the heart excitability and conductivity, but not its contractility.



1 lead: right wrist – left wrist.
2 lead: right wrist – left ankle.
3 lead: left wrist – left ankle.

Figure 1 Standard leads.

Material and methods

The main methods of scientific research were scientific search, comparative analysis, and design and synthesis of devices. The problem was that there were a large number of devices on the market that were similar in their consumer characteristics and could be used to create a portable cardiograph. Therefore, it was necessary to use methods of comparative analysis and scientific search. Based on the analysis of the accessible electronic components, the Arduino Uno[4–8] circuit board has been selected as the primary one for the study. It features the ATmega 328 microcontroller on board (Figure 2). To achieve the research goal, we will use the method of scientific design and synthesis of a prototype of an affordable portable cardiograph.

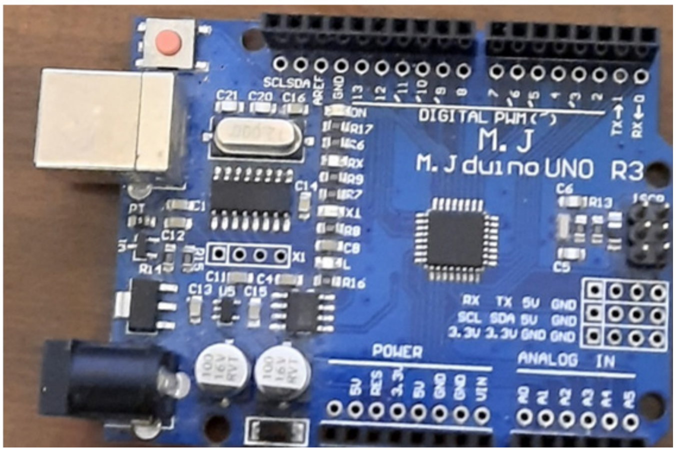


Figure 2 The general view of the Arduino UNO.

The selected circuit board implements the access to the microcontroller peripheral devices – to the analogue-to-digital converters (ADCs), to the digital input-output ports, to the communication buses (including PC and SPI), to the serial interfaces. The microcontroller executes the compiled code of the program, thus linking together all incoming information, and passes it to the computer. The circuit board ADS1292 is the highly integrated analogue-to-digital converter that is designed for detecting biomedical signals (Figure 3). It supports the multi-channel configurations, which allows connecting up to two independent ECG channels. The AD8232 circuit board is the analogue part that can be used for detecting the ECG signals. It ensures the input data amplification and basic filtering (Figure 4).

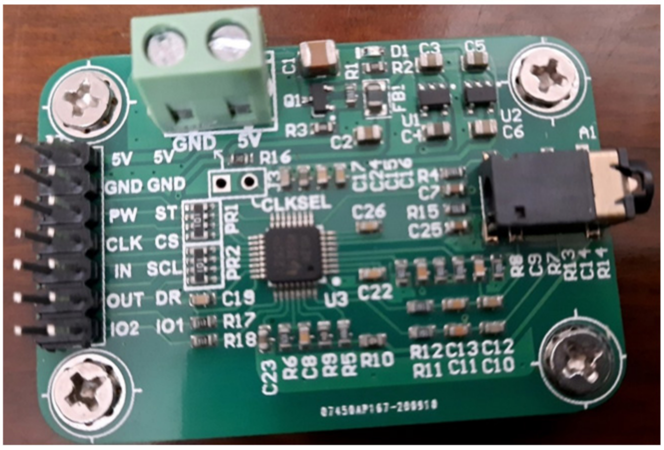


Figure 3 The ADS1292 circuit board.

The circuit board amplifies the weak electrical signals coming from the electrodes up to the level that can be processed by the Arduino Uno. The built-in filters of the circuit board suppress the noises, including the shift of the baseline and the high-frequency interference. The output analogue signal is transmitted to one of the analogue input of the Arduino Uno, where it is transformed by the built-in ADC of the microcontroller into a digital form.

Thus, the hardware selection has been made for designing the accessible, portable electrocardiograph that can be applied for regular control of the personal heart activity as a part of the personalized medicine strategy.

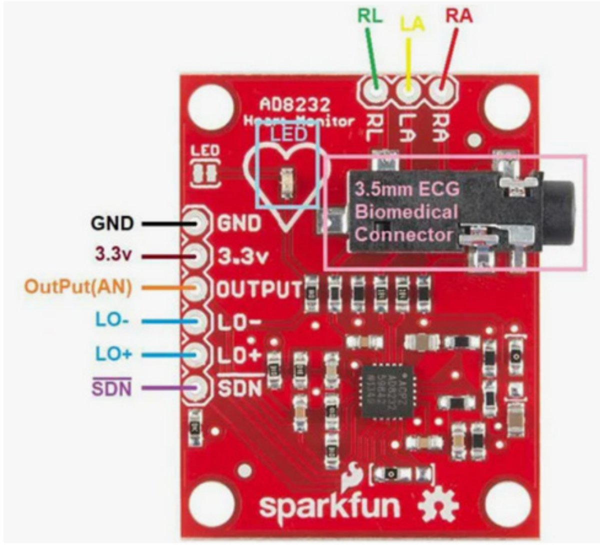


Figure 4 The AD8232 circuit board.

Results

The portable electrocardiograph is assembled based on the selected components. The connection of the ADS1292 circuit board to the portable electrocardiograph is illustrated by the Figure 5, which shows the electrical contacts of the circuit board. The electrical power is supplied to the circuit board by connecting the 3.3 V pin of ADS1292 circuit board with the 3.3 V input of Arduino Uno, and connecting the GND pin of ADS1292 with the GND pin of Arduino Uno. The ADS1292 circuit board is connected to the Arduino Uno via the SPI interface. The registers of the ADS1292 circuit board are set up via SPI in the process of the board initialization. The set up can include the working mode (one-channel, three-channel) and sampling frequency selection, for example. The AD8232 circuit board does not require initialization, since it is an analogue board. The impulse, transmitted to its analogue pin, makes it operable. The prototype testing resulted in a cardiogram-like signal, as shown in Figure 6.

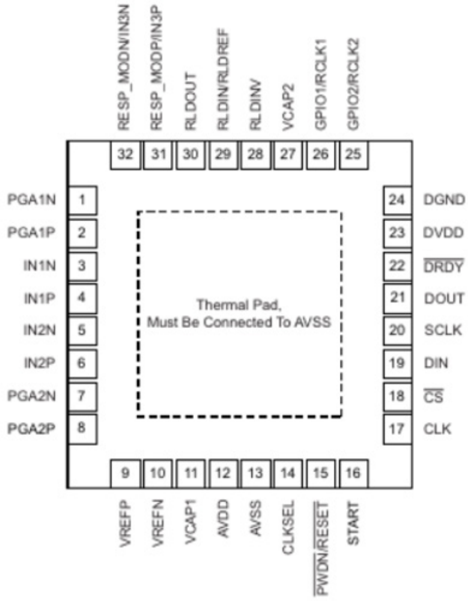


Figure 5 The electrical contacts of the ADS1292 circuit board.

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Figure 6 A cardiogram-like signal obtained from testing a prototype cardiograph.

Thus, the functionality of the created prototype of a low-cost cardio amplifier for monitoring the heart's performance within the framework of a personalized medicine strategy has been tested. It has been established that it is capable of recording and transmitting a signal similar to a cardiogram. In the future, based on comparisons with empirical data, it is necessary to fine-tune the software settings of the equipment used, improve the isolation from external noise, and carefully select the locations and methods of attaching the recording electrodes on the body of the person being examined. Thus, the prototype of the portable, accessible device for capturing and recording electrocardiogram is designed. Thus, the goal of creating an affordable portable electrocardiograph has been achieved through the use of comparative analysis, scientific research, design, and synthesis methods.

Discussion

As a result of the conducted research, using analysis and synthesis methods, a technologically new affordable compact prototype of an electrocardiographic device has been created for the first time, which records and transmits signals to a personal computer. This solves the problem of improving the quality and duration of people's lives through regular monitoring of their heart activity. The Arduino Uno is the central element of the system, which coordinates data interchange between the circuit boards and the output of the obtained data to the Serial Monitor or their transfer to the computer via USB for the further processing and visualization. The Arduino integrated development environment (IDE) and the Arduino software are connected to the Arduino hardware for loading and interacting with the corresponding programs [6-8]. The interaction of the Arduino Uno microcontroller with the ADS1292 and the AD8232 circuit boards allows creating an accessible, compact and effective device for detecting the ECG signals. This is a new result that allows us to move towards personalized medicine.

Conclusion

The component selection, using scientific research methods and comparative analysis, for the heart tones amplifier has been made in the current study. The device is made up of the standard Arduino Uno component and the AD8232 and ADS1292 modules. These components are accessible in today's Russian reality. The software support is developed using the Arduino IDE. The designed prototype is capable of detecting the electrocardiographic signals, registering bioelectric signals, digitizing them and transmitting them to the personal computer for the further analysis. Unlike analogues, this prototype has the lowest possible price and is easy to assemble. It also demonstrates the possibility of independent development of the accessible devices for the cardiac monitoring in the process of the heart disease observation. Virtually any patient in need can independently design and start using such a device very cheaply. In the future, it is planned to expand the application domain of the developed technology on exoskeleton devices and bionic prostheses.

Acknowledgments

None.

Conflicts of interest

The author declares there is no conflict of interest.

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