# Patient autodiagnostic system with activity detection

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## Abstract

Heart disease and cardiovascular disease are becoming more and more common. The test method is best used when the patient's condition deteriorates. Specialist cardiac monitors and available heart monitors present results that are understandable to the specialist. The work presents a proposal for a self-diagnostic system based on the DSP signal processor. Also presented is a way of presenting the ECG measurement results in a way that is understandable to the average patient and allows for self-assessment.

## Introduction

The fast pace of life, stress and civilization factors are increasingly the cause of the heart and cardiovascular diseases. Untreated , can lead to serious complications and consequently death. To avoid this, the patient needs to be properly and promptly diagnosed. It is often the case that the symptoms of the disease occur in the unusual conditions, which result in the need for the patient to be tested during a worsening of patient condition. Of course, the interpretation of the test results should be conducted by a trained doctor, so that they can make the correct diagnosis. However, there are studies that have been conducted for many years by patients (body temperature, heart rate, blood pressure, etc.). Their results are indicative of the patient's state of health and, based on these results, the doctor may order additional tests. It all contributed to the proposal of the system of self-diagnosis of the patient, intended for use in people exposed to the cardiovascular diseases. Unlike the devices available on the market, the results of the study are to be presented in the numerical form with typical values and warning levels category that can be easily interpreted by the patient.

## Electrocardiography

An ECG signal provides the heart rate information [3,7]. It can be obtained from the patient's body through various ways of connecting the electrodes. The most popular three-electrode method with additional grounding electrodes proposed by Einthoven or the Goldenberg reinforcement consisting of placing two electrodes on the hands (RA and LA) and one on the leg (LF) as shown in Figure 1.

There are more advanced ways to connect the electrodes, eg. increasing their number to 6 or 12, which allows for a stronger signal and more information based on the analysis of the recorded waveform. The input signal to the device is directly the voltage signal. After strengthening and filtration we get a recorded heart activity. An example of the ECG signal is shown in Figure 2.

There are several distinctive points marked with PQRSTU. They represent maximum or minimum peak level in the measured signal. First, determine a reference level called the isoelectric line. Easier to designate it on the PQ section. Once you have determined the specific characteristics, you can determine the time between them. In this wave there are so-called. sections and spacing.

From a diagnostic standpoint, it is important to focus on:

- P-wave whose normal duration should be less than 120 ms, usually below 80 ms, and the amplitude in the recording should not exceed 0,25 mV depending on the electrode. Usually it is positive but it depends on the electrode
- Three further extremes usualy are analyzed as a total QRS complex whose duration should be within 70-110 ms; time of Q is less than 30 ms and the amplitude less than 0,1 mV; the amplitude of R is less than 1,5 mV,the amplitude of S is less than 0,5 mV
- T wave, with a duration of about 160 ms, the amplitude less than 0,6 mV
- U section, which can also occur, the amplitude is less than 0,2 mV
- PQ as the time from the end of the P wave to the beginning of the Q wave, typical duration 120 – 200 ms
- ST segment as the time from the end of the S wave to the beginning of the T wave
- PQ interval – time from the beginning of the P wave to the beginning of the Q wave
- QT inteval – time is depended of patient sex, 360-450 ms at men and 370-460 at woman

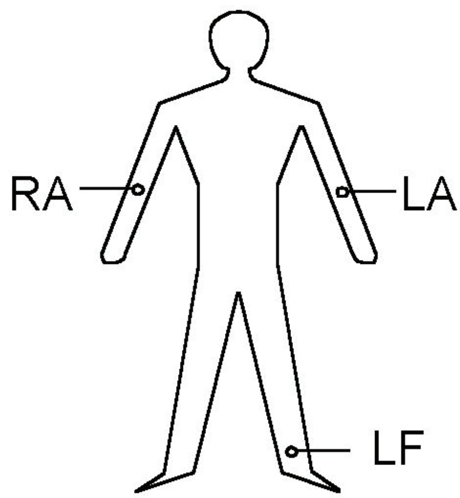


**Fig. 1.**
Points of connecting electrodes for ECG signal

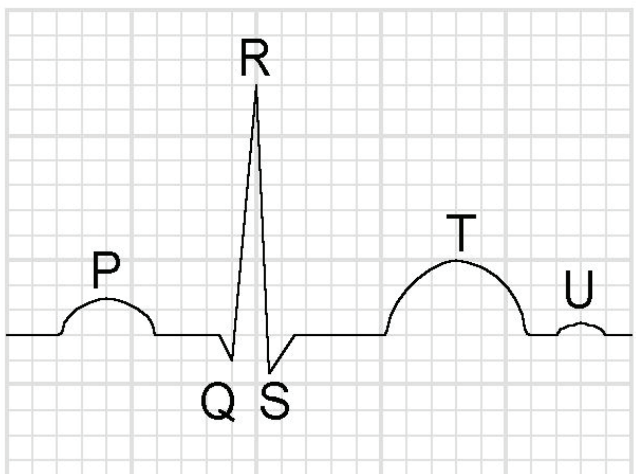


**Fig. 2.**
Typical ECG signal

The values are depended of age, weight, sex etc. For the patient, obtaining the ECG signal itself may be unreadable. It is more advantageous to present it in the form of numbers as in the case of other values measured by the patient himself with information about the correct values. In addition, signaling that the value is exceeded may be a sign of a disease anomaly. Therefore, the proposed layout should focus not so much on the presentation of the course itself, but its numerical conversion and only then should be presented.

The problem with determining an ECG signal is that the patient should be at rest in the correct position during the test. Failure to do so leads to the creation of artifacts on the course. In addition, contact with electrodes may be worse. Therefore, during the self-study, information about the patient's position and activity is needed

## Impedance cardiography

Another approach is the so-called impedance cardiography [2,4,6]. It uses impedance change due to the volume change caused by the blood flow. This method is relatively new and is not yet widely used in diagnostics. The arrangement of the measuring electrodes is shown in Figure 3.

Measurement of impedance is done by the four point method. Between points I1 and I2, alternating current of 20-100 kHz is applied from the current source. Between points V1 and V2, this voltage is measured, which is then amplified and converted to the impedance change. Impedance changes presented graphically represent the work of cardiovascular system.

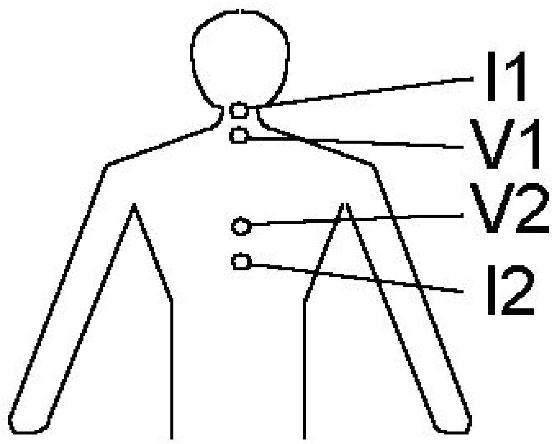


**Fig. 3.**
Points of connecting electrodes for impedance cardiography signal

## Patient activity detection

Both methods of study are important to maintain the patient's position during the test and to maintain it. If we do not follow this, the results may be unreasonable. During the self-examination, the patient should be informed when the appropriate test is being performed. Patient should also be checked for theirs position and movement during the test. If abnormalities are detected then this should be taken into account during the presentation of the test results. Ambiguous results should be clearly labeled or rejected for presentation.

Several sensors can be used. Accelerometers and gyros are popular, but more activity detection methods can be used. [5] For the needs of the autodiagnostic system, it is best to use a triaxial accelerometer. It is easy to attach it to one measuring electrode. The output signal includes the position information and motion information. At the accelerometer output we receive a voltage signal or an even easier to use sensor with digital signal output. Additionally using accelerometrs is highly accurate in detecting activity.

## Presentation of test results

In the case of the classic ECG method, the recorded course is presented as a graph and then interpreted by a doctor. In commercially available monitors, the ECG is presented by the graph and values. This approach is difficult for the patient. It is much simpler to present the results only in numerical form, determined from the course by the appropriate algorithm and the typical values. Of course, this limits the possibilities of diagnostics. With a recorded course on the memory card, it can be played and analyzed more precisely by the doctor. By processing the collected data, it should be taken into account, whether the patient activity signal has not exceeded the set value. Because the data collected over the whole study period can change their values, they need to show their average, minimum and maximum values. In addition to presenting the mean value of the most commonly occurring value, it is preferable. In case of exceeding the values dangerous to health, the patient should be clearly informed about this. In addition to displaying the same value, you can display the range of values that occur in the test history and the range of typical values.

Based on the defined values the state of danger is determined.

First state of danger. Values are in brackets. There is no visible danger.

Second state of danger. One or several values are approaching the limit values, also for the maximum or minimum values recorded during the test. It is recommended to do more research and, if the situation recurs, a consultation with the doctor is advised.

Third state of danger. One or more values exceed the values within the permissible ranges. It is recommended to contact a specialist

Fourth state of danger. One or more of the values exceed the dangerous values, values vary very irregularly (large difference between minimum and maximum), no value can be determined. Urgent medical attention is needed. Possible serious threat to life.

Acceptable values are values that come from age, gender and are accepted as typical. Danger values should be set individually for the patient knowing his or her history of the disease. In the absence of a history of disease, it is important to assume that the third level of risk is a serious health or life threat.

Regardless of the severity of your risk, if the health hazard is suspected to appear, you should contact your healthcare provider immediately.

## Premisions of the system

The basic premise is the ease of use of the measurement system by the patient himself. Please note, that most of cardiomonitors will be used by a doctor. Often, those with a cardiovascular disease problem are older people, for whom technical equipment can be a problem.

Therefore, the basic premise is the simplicity of use. As with the electronic blood pressure monitor, the using of this is limited only to the push of the start button.

For proper measurement of the ECG signal, the measuring electrodes must be positioned correctly. In the case of self-measurement, it would be difficult to use disposable, one-time use electrodes, it is preferable to use bands with appropriately fixed electrodes, that the patient could apply and remove himself. The activity sensor needs to be placed on the left hand bands

Since the measurement of the ECG signal, measuring electrodes also requires, that the correct position is maintained during the test. The appropriate modes of operation, such as an audible signal should be indicated.

From the electric side of the measuring system, the basic assumption is patient safety. This applies both to the safety of the patient himself while operating the device and to protecting the device against the effects of the improper use. To reduce the risk of electric shock, it is a good idea to have the system powered by a battery.

While only typical input signals are used during a typical ECG signal measurement, this should not result in a voltage signal coming from the device on the electrodes, but should also provide for possible damage to the device. In order to minimize the damage to the device itself, it should be equipped with a connector that allows one to properly connect to the main unit. The device should meet the requirements for medical devices to be used directly by the patient.

Due to the existence of other methods of measurement of ECG signals than commonly used, it is also worthwhile to equip the main unit with the elements that will allow for their future realization. In this way, by simply modifying the software and attaching the appropriate sensors, you can extend the functionality of the measurement system to other test methods. This is of particular importance when using a measurement system to collect measurement data used for the research and for comparative assessment or possibly disease progression.

## Project of the system

The measurement signal is applied to the input of the measuring amplifier operating in the differential circuit. Depending on the measurement methods, the amplifier may have a programmed gain value. The amplifier can work with reference to the mass potential or to the external reference potential. A properly amplified signal goes to the analog to digital converter and next to the microcontroller circuit, which has a DSP core in its structure. Further processing of the signal (filtration and analysis) takes place already on the digitized samples. This makes it easy to modify the processing method only by changing the program. This solution is becoming increasingly popular in the construction of devices [1]. In addition, the world's leading chip manufacturers offer ready-made, energy-optimized processor solutions for medical applications. One example is the Texas Instruments family of MSP430 processors [8].

For impedance reocardiography, a current source is required, which should also be present in the device. A commonly used memory card may be used for the further analysis. In order to make the saved results of the studies easier to interpret, the system should be set to the real time clock (RTC). A keyboard, display and sound signaling should be provided to communicate with the user . As an acceleration sensor, it is convenient to use a model with a digital data bus, eg the commonly used I2C bus. In this case, a power supply and bus connections are required for connection to the sensor. The block diagram of the main unit of the system is shown on figure 4.

The use of the digital bus has another advantage. It can also be placed on the EEPROM type memory, which will store information about the measurement method and, for example, sensor configuration data. The connection of the accelerometer and EEPROM memory is shown in Figure 5.

In order to ensure the proper functioning of the autodiagnostic system, a suitable control program is required. It should provide the opportunity to measure, process and present the results. In addition to

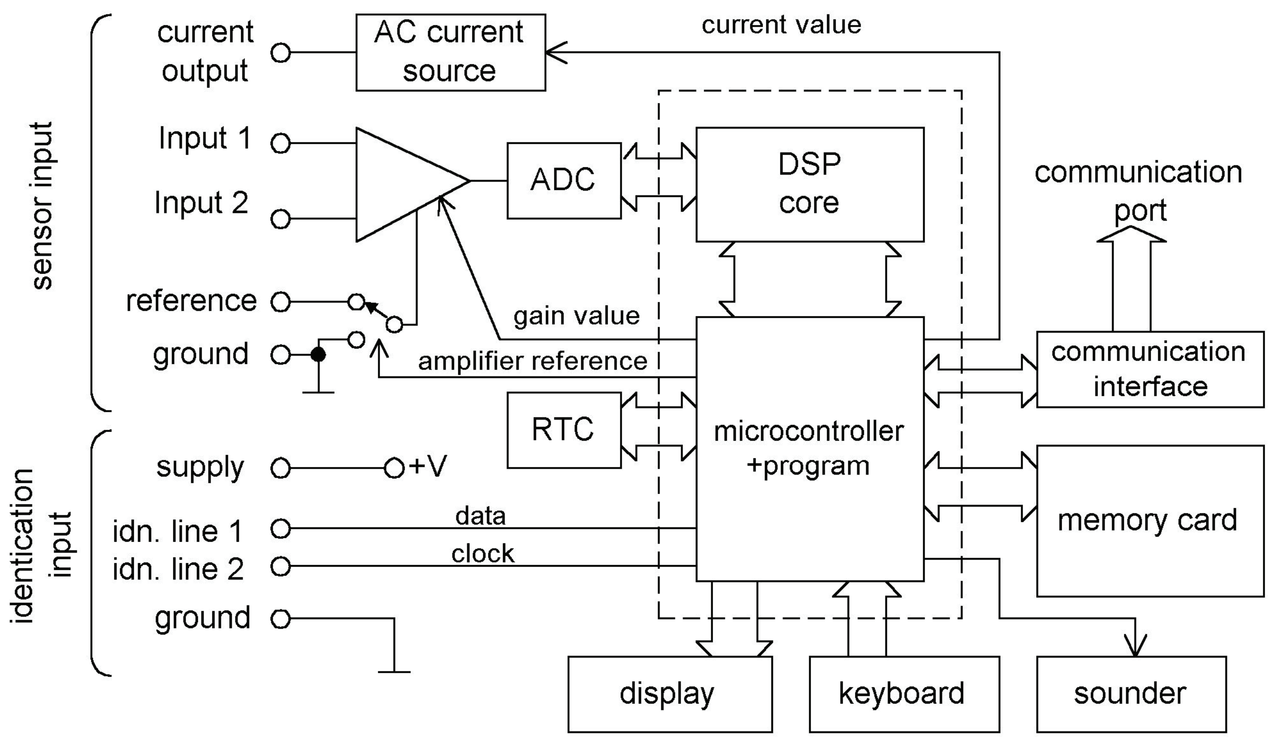


**Fig. 4.**
Block diagram of main unit of the system

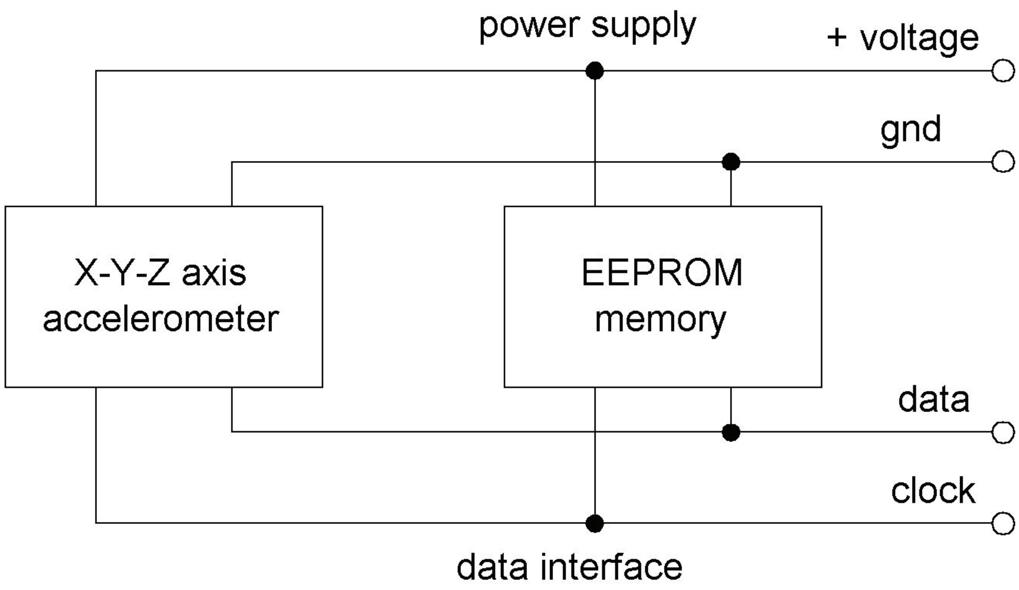


**Fig. 5.**
Connection of acclerometer and EEPROM memory

the doctor's diagnosis, the measured values should be stored on the memory card. The procedure of measurement should be simple for the patient and properly signaled. In case of an error, the measurement should be interrupted and a message about its cause will be presented. In addition to the main algorithm used in the measurement, the user needs to set up the device. It must be able to set basic settings such as the clock, date, patient birth date, and configuration data, including calibration of the device. This part of the program can be locked to protect changes by patient.

By using a flash memory microcontroller, we have the opportunity to make future changes to software including new measurement methods and improved data processing algorithms. When adding new measurement methods with other sensors, the information of this is stored in EEPROM memory. Once read, the system can verify, that the current version of the software allows you to perform the test. If this is the case, the appropriate configuration and the appropriate data processing algorithm will be selected. If not, patient should see a message saying that they need to upgrade to a newer one. In normal cases, when using a given set of sensors (eg ECGs) for a user, the software version should not be relevant until a new set of sensors is connected to the main unit and that are not included in the program version.

In each version of the program two main blocks of the program should be implemented – initialization procedure and measurement procedure. Initialization should be made after the device is turned on. It is to check the correct operation.

It includes the following steps:

- check if the memory card is present and its correct format
- sensor type detection based on EEPROM memory (ie measurement method).

If initialization is successful, the device should signal readiness for the test. If, for some reason, an error has occurred, it should also be clearly indicated and a hint on how to remove it should appear. It is important to start the device quickly - the test is to take place when the symptoms of the disease are suspected and not after they have resolved. The block diagram of initialization procedure is shown on figure 6.

Proper measurement should include the following steps:

- connection sensor test reading of EEPROM (to avoid disconnection or change of already using on the device)
- readiness readout and waiting for patient readiness signaling by pressing the button
- after pressing the button, the device should wait for a set time before measurement to allow the patient to be positioned in the test

position (this time can be declared in the configuration menu)

- sound signaling of the beginning of the measurement (from this moment the patient should remain in the proper position for the test)
- performing measurements (sampling data to microcontroller memory)
- sound signaling of the measurement end
- filtering recorded values, saving of samples and results to a memory card
- presentation of measurement results on the display with values that may have been exceeded and state of danger

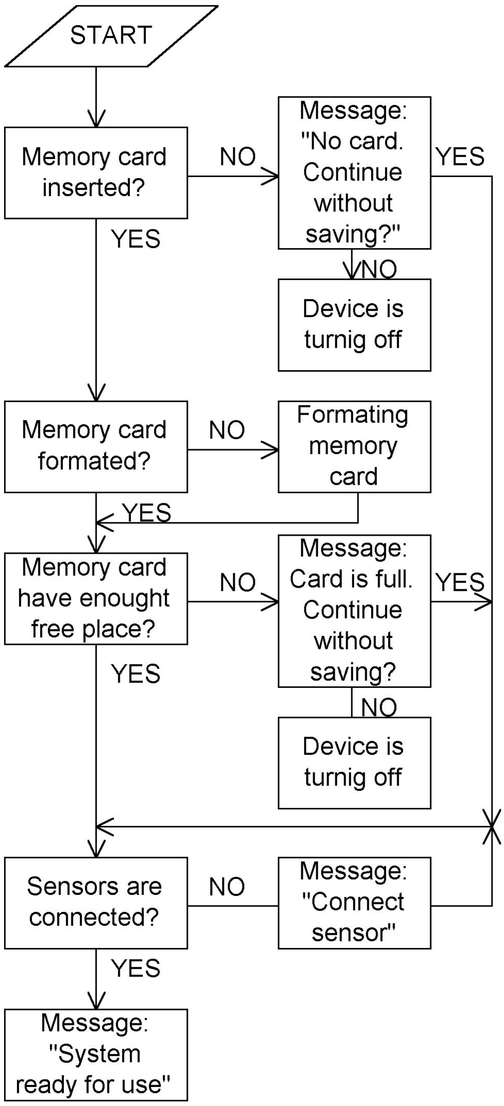


**Fig. 6.**
Block diagram of initialzation procedure

The block diagram of measurement procedure is shown on figure 7.

At each stage should be checked for correctness, such as whether the patient is not moving at the time of the test, which can significantly affect the results of the test. The given program structure is general, its detailed implementation depends on the test method, i.e. it is selected when the corresponding set of sensors is connected.

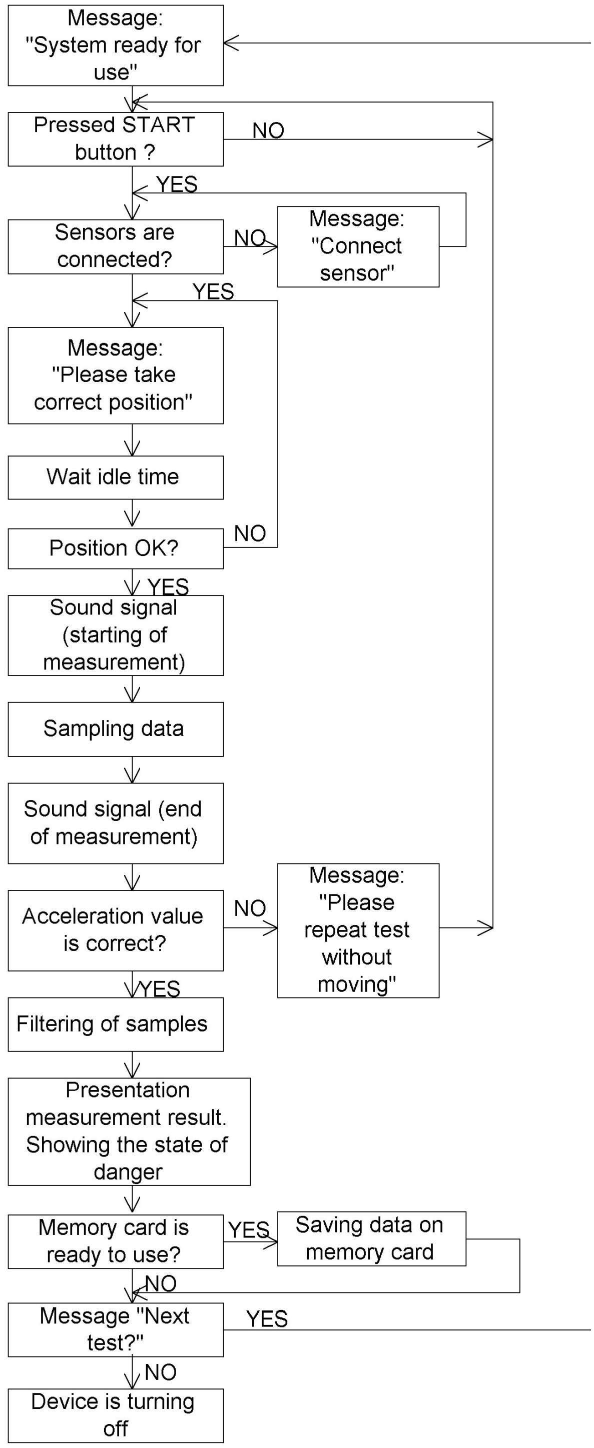


**Fig. 7.**
Block diagram of measurement procedure

## Conclusions

The paper presents the idea of constructing a patient's autodiagnostic system. The next step is to build a prototype layout and test it in the practical conditions. The measuring system is designed to be open to allow easy expansion. By modifying the program, you can easily change the measurement algorithm. From the point of view of the results, the appropriate selection of the signal filtering method may be important. In addition to the collected samples, the algorithm can be expanded to automatically determine other parameters and present them in numerical form - such as the angle of inclination of the axis or steepness of the slope, which will help to find the patient's illness.

Changing the sensors to other ones also makes it possible to change the types of test to other ones using sensors that output a voltage or digital signal on the I2C bus. It is relatively easy to develop such a system with additional sensors, such as ambient temperature and pressure sensors, which would make it possible to determine the effect of weather conditions on the test results. Flexibility of construction distinguishes this system from the devices available on the market. In addition, the proposal to present results in numerical form and not in the form of a graph should be shown and state of dangerous significantly facilitate the use of such a system for those who do not have much medical knowledge. The device can be a valuable diagnostic tool for a patient with cardiovascular disease.

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