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# METHODS OF ECG-SIGNAL TRANSMISSION SYSTEM DEVELOPMENT

Viktor Ivel, Yuliya Gerasimova, Sayat Moldakhmetov and Pavel Petrov
North Kazakhstan State University named after M. Kozybayev, Petropavlovsk, Kazakhstan
E-Mail: sayatmoldakhmetov@gmail.com

**ABSTRACT**

The article concerns the concept of medical cardiodiagnostical automated systems based on wireless technologies, Matlab application package and ECS PhysioBank ATM database. This article considers the principles of Holter monitoring systems to be used at home. It describes the methods of application of electrocardiographic signals archive for debugging and setting up of the system developed. The undertaken study showed that the proposed methods shall create effective systems of daily cardiac activity monitoring characterized by high speed and low energy consumption.

**Keywords:** electro cardiosignals, ECG recorder, holter monitoring, wi-fi transceiver, arduino.

## INTRODUCTION

Holter monitoring is a continuous record of a patient's electrocardiogram (ECG) during the day. Such ECG monitoring is used when cardiac rhythm or conduction disorders that cannot be detected when recording a usual ECG are diagnosed.

As a rule, Holter monitoring methods involve recording of an ECG during the day on a stand-alone data medium such as flash memory card [1, 2]. However, the data recorded by the Holter monitor can be read and analyzed only after the recording time is over. Therefore, in order to continuously monitor the ECG of patients and further interpretation of the ECG on a real time basis, it is advisable to use direct wireless transmission of ECG from patients to a general server of a cardiology center or to a separate mini-computer at home. Such a system will allow informing the patient or a doctor on cardiac abnormalities.
Currently, there are wireless ECG signal transmission systems that operate using Zigbee [3, 4] or Bluetooth [5, 6] standards. The disadvantages of such systems include low data flow rate and a limited number of subscribers. A Wi-Fi network has no such drawbacks but its application was previously limited to high power consumption [7]. However, quite interesting wireless transceivers that show fairly low power consumption along with required features have recently appeared on the market of wireless devices. A bright example of this device class is the original Chinese transceiver - NodeMcu v3 Wi-Fi module with ESP8266 (ESP-12e) chip [8]. Application of these modules for the purposes of the wireless Holter monitoring systems shall solve the problem of increasing the transmission rate of electrocardiosignals (ECS), expanding the operating range and continuous operation of the system during the day and more.

## FLOW CHART

Figure-1 shows the flow chart of the Holter ECG Monitoring System designed for home use.
The main components of the system.

a) Special deflection cable for Holter monitoring including disposable electrodes.

b) Analog Devices cardiograph based on ADAS1000 integrated circuit. It is a five-channel block of analog amplifiers with filters and deflection shaping network [9], i.e. a specific flow chart for Holter monitoring. It is advisable to use a combined RISC-DSP Blackfin processor [10] together with it.

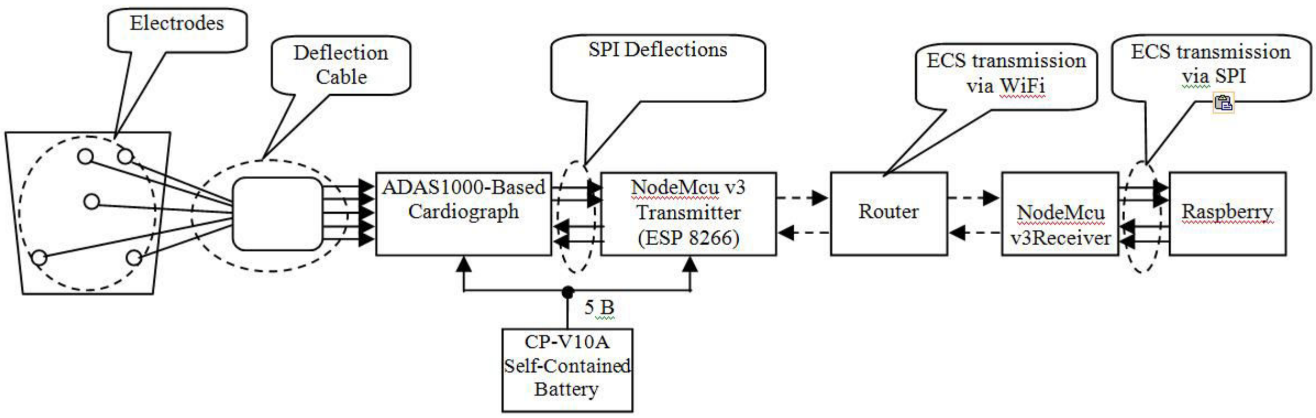


**Figure-1.** Flow chart of the Holter ECG monitoring system.

RISC-core can perform functions of system control, data pre-processing and graphical user interface shaping. A typical ECG processing algorithm (contour filtration, noise suppression and R wave detection) is implemented through a signal processor [11].

c) Wi-Fi transmitter that receives amplified and filtered electrocardiosignals through an SPI bus.

d) Router that provides wireless communication between transceivers.

e) Wi-Fi-receiver that receives ECS coming from the router and transmits them to the Raspberry mini-computer through an SPI bus.

f) Sony CP-V10A battery for power supply of the self-contained part elements of the system.

The program for signal transmission is written in Arduino IDE. The main task of the program is to minimize the time of one dimension transmission.

The purpose of the mini computer is to receive and interpret ECS, as well as to visualize the results of automated diagnostics and transfer them to the printer for printing the preliminary conclusion.

The ECS interpretation program for Raspberry shall be pre-created on a personal computer and then transferred to Raspberry.

## EXPERIMENTAL RESULTS

Signal models with performance data close to the real ECS with different pathologies or copies of pre-recorded real ECG signals are required to use for debugging and configuring the settings of wireless ECS transmission system, ECG analysis algorithms testing and different operation modes of the system. There is an archive database of PhysioBank ATM ECS [12, 13] which is a web resource containing well-described electrocardiographic signals and appropriate open source software for the biomedical scientific community. The technology of converting ECG copies into Matlab can be found in the application to the ECS data base [14]. Using this technology it is possible to record any ECG copy to the Matlab Workspace. Simulink and Simulink Desktop Real-Time packages and PCI-1710HG combined I/O board are used for obtaining the real ECS. Figure-2 shows the Simulink model of Workspace recorded ECS transmission to the output pins of PCI-1710HG (Analog Output) board.

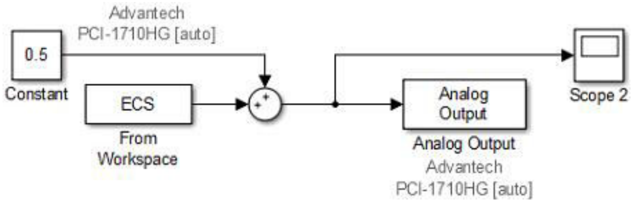


**Figure-2.** Simulink-model designed for receiving an actual ECS.

Since the ECS at the analog output of the PCI-1710HG board can only be positive, and the real ECS is a two polar signal, it is required to add a constant component (0.5 V) to this signal to shift it to the positive range. The external simulation mode – “external” – shall be run next. As a result, the Scope 2 unit receives a real electrocardiogram (Figure-3).

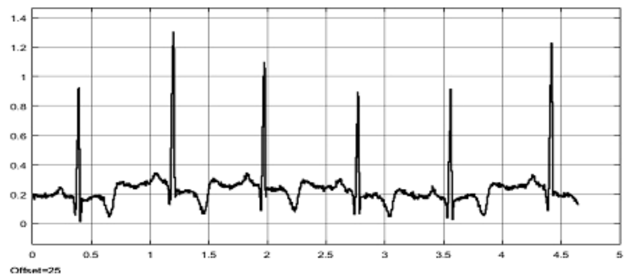


**Figure-3.** Oscillograph record of an ECS.

Figure-4 shows the structure of the Holter monitoring system for debugging and settings mode of the ECS wireless transmission system.

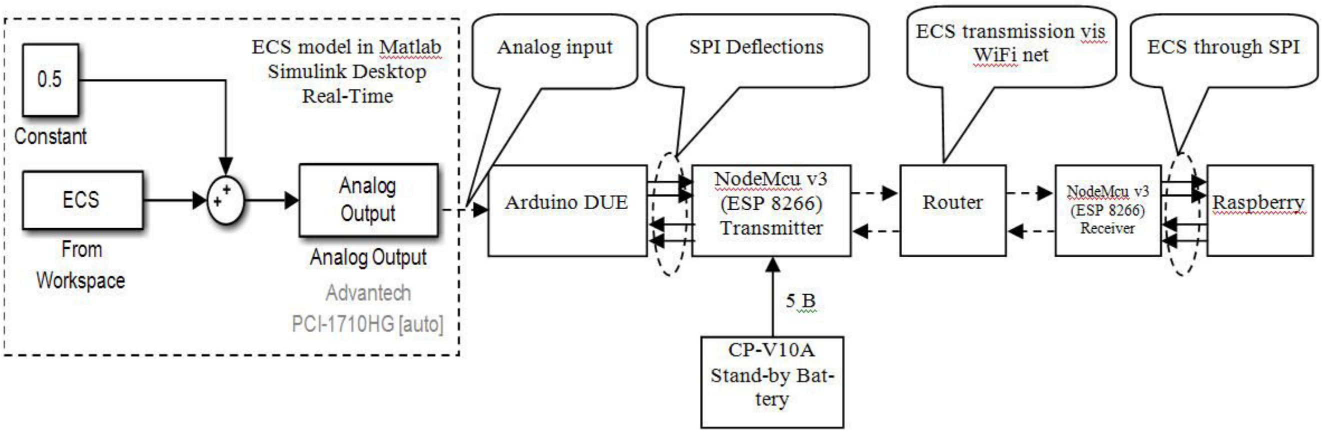


**Figure-4.** Debugging scheme for the Holter monitoring system.

In addition to the ECS model in Matlab the scheme includes Arduino Due platform based on Atmel SAM3X8E ARM Cortex-M3 processor. This board is distinguished from other Arduino platforms by a 12-bit ADC and SPI interface for communication with subsequent system units. The Arduino board receives an analog signal from the ECS model and transmits it via the SPI interface to the NodeMcu v3 (ESP 8266) transmitter.

The transmitter is programmed to transmit the ECS via the local WiFi network in the form of discrete 2-byte measurements via the router to the receiver (also based on NodeMcu v3). Then, also via the SPI interface, the signal is sent to the Raspberry microcomputer for final processing in order to restore the electrocardiogram and its further interpretation [15]. Figure-5 shows the entire assembled system.

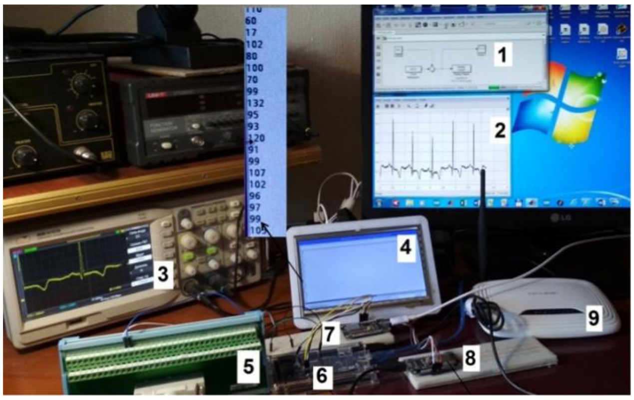


**Figure-5.** Debugging scheme for the Holter monitoring system.

The following system components in the figure are numbered as follows:

a) Simulink model to receive real ECS on the monitor screen;

b) Oscillograph record of an ECS obtained at Scope 2;

c) double-beam oscillograph to visualize the real ECS;

d) minicomputer Raspberry with on-screen ECG in digital form;

e) Adam-3968 connector terminal connected via cable to the PCI-1710HG board installed инещ the PCI bus slot of the personal computer;

f) Arduino Due platform;

g) NodeMcu v3 (ESP 8266) transmitter;

h) NodeMcu v3 (ESP 8266) receiver;

i) P-Link router.

It is important to note one feature of the of wireless ECS transmission algorithm aimed at reducing the power consumption of the system. The algorithm of signal transmission is designed in such a way so to exclude the transmission of information at times when the electrocardiogram lacks informative features, i.e. areas of ECG that correspond to the baseline of the signal.

Figure-6 shows an algorithm that describes the principle of transmission of ECG measurements for a single deflection.

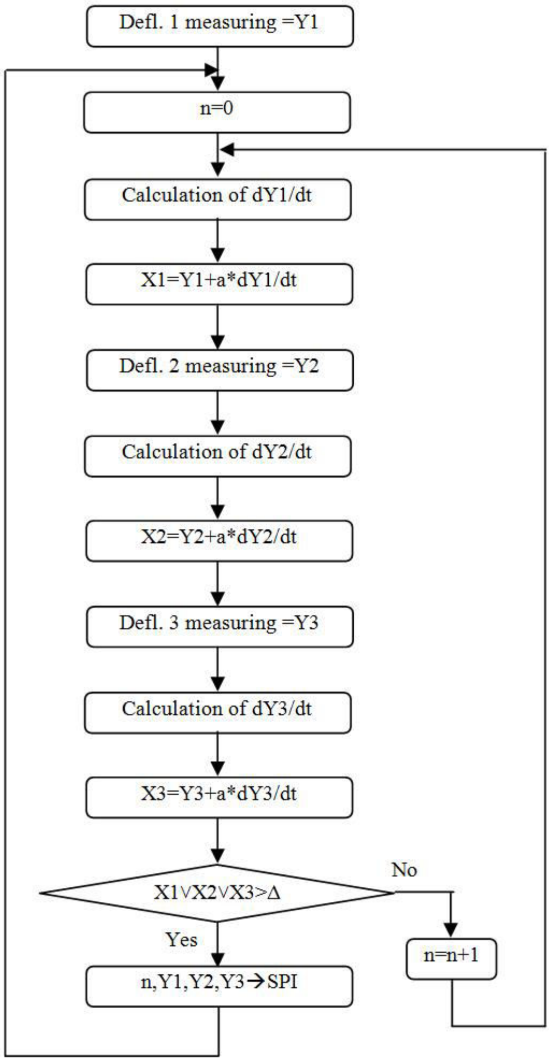


**Figure-6.** ECG transmission algorithm at ECS baseline parts.

The initial algorithm operation (Figure-6) corresponds to the measurement of the first Y1 deflection of ECG. The second action is to set the counter to 0, i.e. n=0. Then follows the operation of calculating the first ECG derivative – dY1/dt. Then we get the sum of the ECG value with its derivative in a certain proportion - X1=Y1+a*dY1/dt. Then this cycle of operations is repeated for the second and third deflections. After that there is a comparison operation: if any of the values of X1, X2, X3 is greater than the threshold limit value - Δ (which means that the informative ECG element begins), then all the ECG data is transmitted via the SPI interface to the receiver. If any of the values X1, X2, X3 is less than the threshold value, the information is not transmitted to the receiver and the measurement cycle is repeated. At this time, the receiver of the ECG record previous values of Y1, Y2, Y3. Thus, the transmission time and the operating time of the transceivers is reduced for the period of the ECG baseline and thus provides significant energy savings.

## RESULTS AND DISCUSSIONS

The result of the research work is the structure of the wireless system of Holter ECG monitoring designed for home use by patients who are prescribed daily monitoring of the cardiovascular system in order to diagnose arrhythmias and cardiac conduction. Besides we offered a debugging complex for configuring the system of wireless ECS transmission using an open ECG database and software and hardware to obtain real copies of ECG with various pathologies.

The proposed algorithm of wireless transmission of ECG measurements reduces the active operation time of transceivers by 30% according to preliminary estimates and actually reduces the energy consumption by the same percentage.

The presented work refers to the hardware of the Holter ECG monitoring system and is the basis for the development of the software part of the system. It is planned that the software part of the system that implements the algorithm of ECG interpretation will rely on the machine interpretation of the ECG according to the method of V. N. Orlov [16], and the program itself will be developed in C++ language to maintain continuity with the program designed for the wireless ECS transmission written in Arduino IDE.

## CONCLUSIONS

Analysis of the results of the experiments and the obtained diagrams of the real ECG shows that the combined use of PhysioBank ATM archive database of ECS, Arduino platform, PCI-1710HG combined I/O board and Matlab allows creating an efficient and economical system of Holter ECG monitoring based on wireless technology using modern transceivers of NodeMcu v3 class and single-board electrocardiograph on the basis of ADAS1000 chip.

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