Complex Device for Heart Activity Monitoring

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Abstract – this paper presents description of the complex device for heart activity monitoring based on ARM microcontroller; there are described structural scheme of the device, analogic module, user interface, and technical parameters of the device.

Index Terms – Cardiovascular system, photopletismography, device, signal

I. INTRODUCTION

The proposed system is assigned to the investigation of cardiovascular medical technology, the operating principle of which is based on the method of photoplethysmography wave and the electrocardiography. Photoplethysmography principle is reflection of radiation from blood cells moving through the small vessels, under the skin. [3,4]

Photoplethysmography recording and processing allows obtaining information about the state of cardiovascular system, the segmented blood pressure, detection of blood vessel damage through screening large caliber method.

The device allows also investigating the variability of cardiac rhythm based on processing of the photoplethysmography and electrocardiography signals.

II. STRUCTURAL SCHEME OF THE DEVICE

The device is composed of several modules: ARM microcontroller, the analog module LCD Display with touch screen panel, SD Card memory, Real Time Clock (RTC) module, serial to USB converter, a battery and a power management module (figure 1).

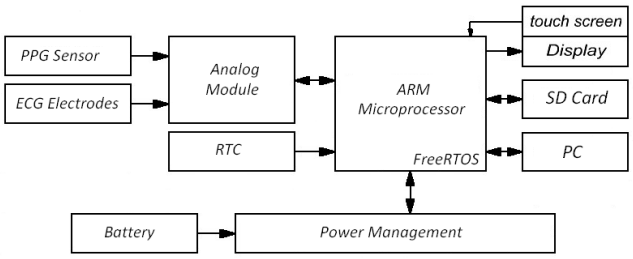

Fig.1. Structural diagram of the device

The functionality of the device is based on a Cortex-M3 Advanced Reduced instruction set computer Microcontroller (ARM) Microprocessor LPC1768, with 32-bit architecture that works at the clock frequency of 100 MHz's, designed for embedded applications requiring a high level of integration and low power dissipation.

Its functions are the following: interaction with the analog module into a digital signal conversion, changing the operational amplifier gain of the final cascade to achieve an optimal level of input signal at ADC, digital signal processing; interaction with Color display and touch screen; menu-user interface; interaction with the power control unit – ensuring the transition to sleep regime, provident power to all blocks of the device in active mode operating voltage level monitoring of battery charging. By connecting the computer through the USB interface device can operate as a computer peripheral mode – photoplethysmography signal can be collecting and send directly to your computer , or read from memory and transmitted to the personal computer only necessary data.

The internal Data Base is designed to perform dynamic allocation of memory space for the patients and signals. It can capture more than 65 thousands patients and 240 signals for each patient.

Analog site of the device consists of a channel that process signal from the photoplethysmograph sensor and a channel of ECG processing. Figure 2 shows the block diagram of the analog part of the device.

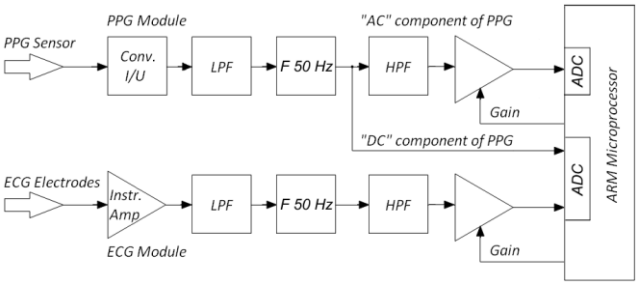

Fig.2. Block analog scheme of the device

The photodiode of the sensor is connected in a circuit of Current to Voltage Converter. The signal from the output of it will be dependent of the level of the light which will pass through the biological material.

The analogic signal from the exit of the converter is filtered against high frequency noises by a 3 order active Low Pass Filter. The active Notch filter clears the signal of interference from Alternative Current supply with 50 Hz frequency.

The device measures both fast component and slow component of photoplethysmography, so further the signal is separated into two signals: signal of slow component and signal of fast component of photoplethysmography.

To obtain fast component from the signal, the dc component is removed by using a 3 order High Pass Filter (figure 2). After it, the output signal is amplified using amplifier with gain which can be change by the microcontroller, to obtain optimal level of the signal at input of the Analog to Digital Converter.

Electrocardiograph signal (ECG) is gathered using three electrodes placed on the patient's body - two active

electrodes and one neutral electrode. The signal is amplified with an instrumentation amplifier, after which the high frequency noises are removed using a low-pass filter, the dc component is filtered using a high-pass filter, and 50 Hz noises are filtered using an active Notch filter.

Getting data from analog to digital converter, microprocessor continuously monitors the signal level. If the signal amplitude is too low for a period of time, will made to increase the coefficient of amplification, if too high - to zoom out.

The display of the device is an LCD Color, with resolution of 320×240 pixels and 65 536 colors, which allows to display the time evolution of one or two signals simultaneously, but also create a user interface, extensive menu, intuitive and easy to interact. The menu consists of pages, buttons, keyboard - similar to a personal computer, making it easier to access the menu for personal computer users.

III. USER INTERFACE

The user menu of the device is designed to be intuitive and easy to use. It is based on high resolution color display of the device and operator's interaction with device through touch screen panel.

User menu consists of four pages: "Patient", "Signal", "Graph" and "Setup."

The page "Patient" is intended to work with the database: add a new patient into the database or choose a patient previously investigated. At the bottom of the window, is the keyboard, similar to the personal computer, designed to introduce a new patient database. The database's interface allows us to navigate through the list of patients to look for a particular patient in the database, to remove a patient and to select a particular patient (figure 3).

Fig.3. Patients Database window

On the page "Display" operator can choose desired signals to be represented: fast and slow component of the photoplethysmography and electrocardiogram. On the same page there is signals database where operator can look through stored signals, delete or choose one for displaying. The signal's name consists of the date and time when it was collected.

The page "Graph" is intended to represent the time evolution and processing results of collected data. If a signal from the internal memory was selected for displaying on this page, it is possible to place photoplethysmography basic points directly on the screen, using touch screen panel, and to calculate photoplethysmograph few basic parameters, which can give some clues about the state of the cardiovascular system.

On the figure 4 the photoplethysmography signal from the memory and placed basic points are presented.

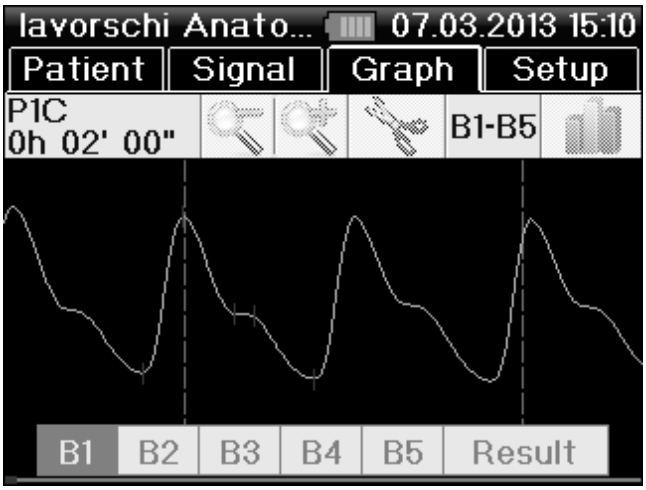

Fig.4. Processing of photoplethysmography signal

The operator has possibility to navigate through signal, zoom in or zoom out the signal, to cut a part of the stored signal which represents noises or movement artifacts.

After digital processing of the stored signals the device determines moments of the heart contraction. Analyzing the cardiac intervals the device can do statistical processing of the heart rate variability.

The first result is the Rhythmogram which represents natural variations of the hearts rhythms (figure 5). I gives important indications of the reaction capability and "healing power" of an organism.

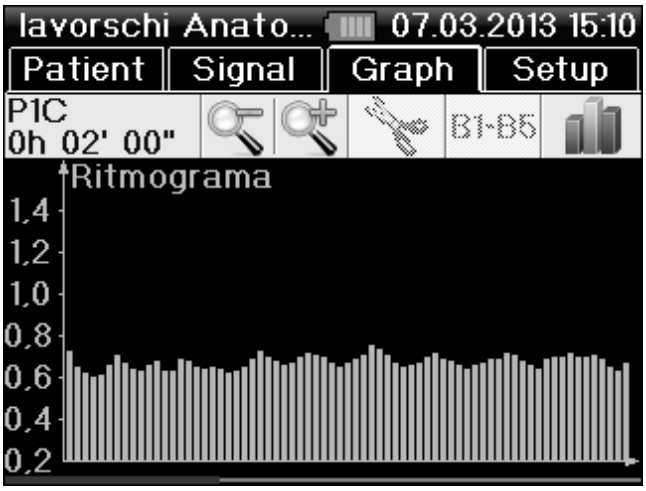

Fig.5. The Rhythmogram

The histogram allows determining an evident deviation of the cardio intervals from the normal area. Figure 6 shows an example of the histogram. The green rectangles

represent the normal area, red rectangles – tachycardia and yellow rectangles - bradycardia.

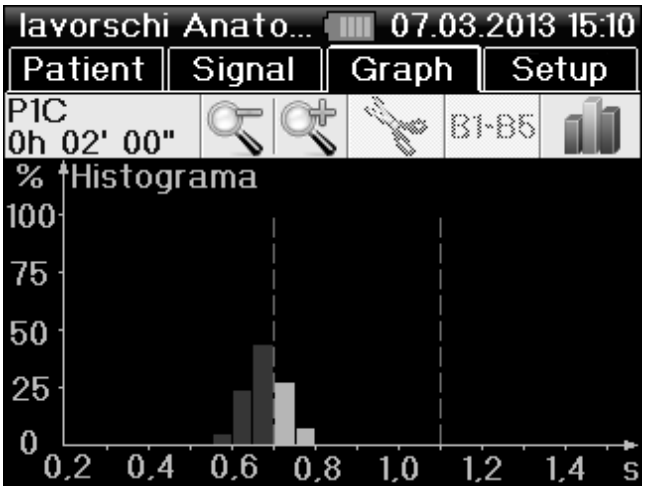

Fig.6. The Histogram

The page "Settings" contains the device settings: time and date setting, backlight, viewing of memory status and option for switching off the device.

Through this page operator has possibility to adjust the date and time of the real time clock module (figure 7). Date and time are used to give a name to the stored signals with information. After it, operator can find a needed signal knowing when it was stored in.

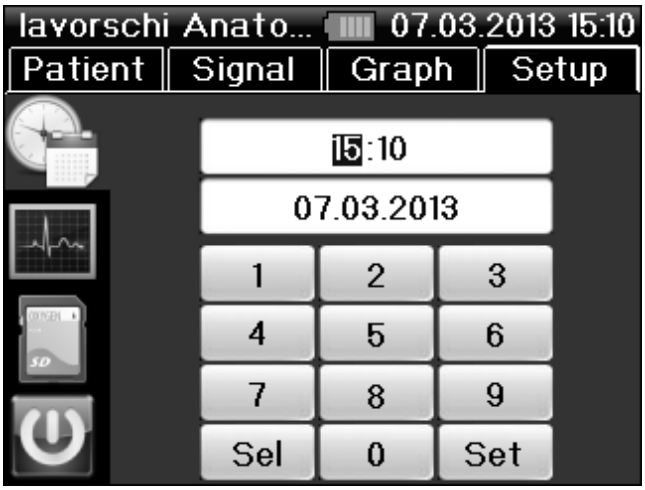

Fig.7. “Setup” Page

A fairly large part of the energy consumption of the device is due to the LEDs backlight. Reducing energy consumption of the device is provided by the automatic switch off the lights over a certain amount of time after you pressed a touch screen panel. The interval of time can be set by choosing optional values: 20, 40 or 60 seconds.

The operator of the device can see the level of memory usage and has the possibility of clearing of all the data from memory (formatting of the SD Card memory).

IV. CONCLUSION

The developed device for heart activity monitoring allows the time analysis of electrocardiograms and photoplethysmograms, quality parameters, visual comparing of the stored signals and collected at the moment, allows study heart rate variability.

The system has the following technical parameters:

- Number of channels – 1 channel of slow and fast components of photoplethysmography and 1 channel electrocardiography;
- Frequency Band – from 0.5 to 18 Hz (PPG) and hhhhhhhhhhhhhh from 0.5 to 80 Hz (ECG);
- Signal sampling frequency – 500 Hz;
- Active mode power consumption – 0.6 W;
- Minimum operating time without recharging in active mode – 16 hours;
- Dimensions – 110x65x30 mm;
- Weight 200 g.

The measurement and data processing of the designed device has technical characteristics (price, size, number of functions performed, parameters) high, competitive with existing ones and can be recommended for the production and subsequent implementation in health care.

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