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To the Questions of the Creation of a Modern Non-Invasive Biopotential Meter

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ABSTRACT: In the article have possibilities of creating a non-invasive computer bio-meter of hardware and software, proposes the development of adequate mathematical models and algorithms for an automated system for processing health diagnostically data. Shows, the effective functioning of a non-invasive hardware becomes needs are primarily being utilized to control relatively simple computer interfaces, with the goal of evolving these applications to more complex and adaptable devices, including small sensors.

KEYWORDS: Computer bio-meter, non-invasive method, interference suppression, adequate model, hardware,adaptable devices.

I.INTRODUCTION

As we know, it is no secret that positive changes in all spheres of society are associated with the level of direct application and implementation of information and communication technologies (ICT) in practical activities. Scientific research aimed at solving problems and tasks arising in the integration process in ICT with the area of research under consideration are associated with the use of system analysis tools, data processing and management. In many cases, the integration process is manifested in the implementation of methods and means of automated system management. This is especially in demand in the field of medicine, where operational processing of the results of experiments and the adoption of a scientific - informed decision is required. And this is achieved using the below tools. In this connection, the task of developing a software shell for the effective functioning of a non-invasive glucometer apparatus becomes relevant. Here it is necessary to emphasize that the apparatus of non-invasive bio-meters will also be improved [3, 15].

II.RELATED WORK

An analysis and review of the methods of acquisition and digital processing of biomedical signals based on computer technology shows that the discoveries by Richard Caton [13] determine the electrical signals on the surface of the brain of animals. Later, in 1924, Hans Berger using a galvanometer on paper recorded a curve describing the biopotentials taken from the surface of the head using needle electrodes. To suppress interference associated with electromyographic signals, an atremor low-pass filter (LPF) is desirable, limiting the input signal range to 60-70 Hz, and to combat network interference a notch filter at 50 Hz (60 Hz) [4]. On the other hand, in some studies [9, 14], for example, stress tests, a shorter time constant is consciously chosen for better retention of the contour [5]. Thus, we can conclude that according to the survey of biomedical signals, in particular the ECG signal, the useful signal must be taken into accordance with standard leads, such a reference potential formation scheme is called the right leg driver circuit or Right Leg Drive Circuit (RLD). Bio potential meters using non-invasive equipment's have been a major focus of research and development. The use of conductive methods to produce results capable of monitoring heart rate and generating electrocardiogram waveforms has been reported by numerous researchers. In order to obtain adequate bio potential signals, intimate small skin-sensorcontact is required. For this purpose, the current state of the development of non-invasive bio-measuring devices has been analyzed and the problems of creating computer bio-measuring devices have been revealed [7, 8, 9, 14, 15].

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Setting goals and basis objectives are the questions of creating a computer bio-meter. To achieve this goal, the following theoretical and practical problems were solved:

- The study a complex of methods analog and digital filtering of cardio signals;
- analysis of the spectral-temporal characteristics of electrocardiogram signals by wavelet function methods;
- development of methods for increasing the efficiency of adaptive noise filtering algorithms in cardiac signals;
- creation of hardware and software for implementing the filtering method in cardiac signals;
- study the influence of the parameters of the proposed digital filter circuit on its characteristics in order to increase the filtering efficiency in cardiac signals;
- study the possibility of using the developed means of recording and processing cardiac signals to control the operating modes of medical complexes;

So, the basis of functional diagnostics devices based on computer technology should be a computer bioelectric meter built on a modern elemental base - multichannel low-noise operational amplifiers, multi-bit and multichannel integrated analog-to-digital converters (ADC), programmable logic matrices and / or microcontrollers [1,2,3]. The basis of this digital bio-meter is an ADC - the main characteristics of the entire system largely depend on its parameters. One of the advanced methods is the use of a multi-bit ADC (22-24 bit) as an ADC, which allows you to measure a biosignal directly from electrodes located on a bioobject.

This implementation of the bio-meter has the following advantages:

A) No need for multi-channel low-noise amplifiers

B) Downsizing of the system

C) The possibility of applying the technology of saving the signal "as is"

The “as is” signal preservation technology allows you to save a biosignal as removed from the electrodes located on the bio-object without post-processing. This technology allows you to change the parameters of the system after measuring, for example, the sensitivity or frequency range of the measured signal.

III. SIGNIFICANCE OF THE SYSTEM

The microcontroller used to register biosignals must have the ability to process digital signals (DSP), high speed, large memory and rich peripherals. This criterion is well met by 32-bit STM32 processors with the Cortex M4 (3) core of ST Microelectronics (Fig. 1). In this implementation, in addition to a rich communication interface (USB, SPI, etc.), there is a real-time clock timer, an interface for the LCD module, an interface for the touch screen (touch panel), and an automatic direct memory access device (DMA) and the priority system of singing (Interrupt). The number of channels of the bio-meter can vary from 4-8 (ECG, EMG and Holter ECG) to 32 (EEG), depending on the type of bio-meter. Based on the above considerations means, the authors are propose the following structure of a modern multi-channel bio-meter (in Fig. 1.) consisting of several (3 pieces) of a fully-equipped (Front-End) ADC and ARM Cortex microprocessor.

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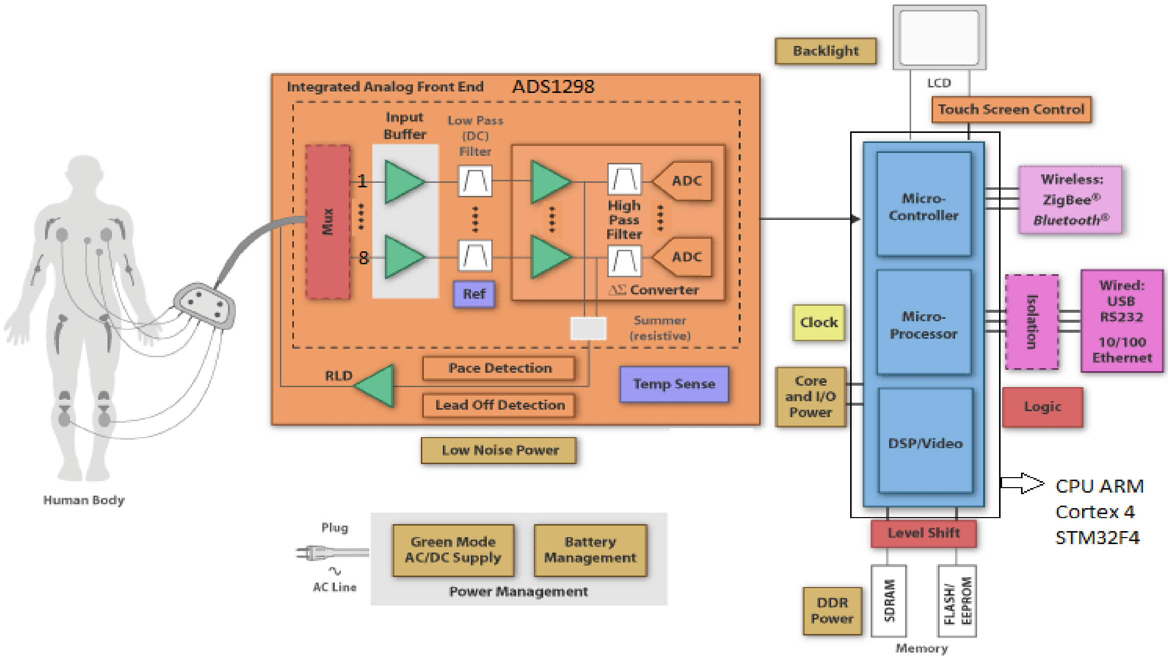

Fig. 1.The structure of a modern bio-meter based on a multi-channel 24-bit ADC Analog Front End(AFE) IC from Texas Instruments(TI) and a single-chip STM32 CortexM4 microcontrollers.

Of course with the possibility of autonomous (battery power), LCD touch screen, micro CD memory and also having a wireless connection.The ADS1299 ADC (8) is connected to the microprocessor via the SPI serial port, in cascade mode, in the Daisy-Chain mode [1,2]. At the same time, 216 bits = 24 status bits + 24 bits * 8 channels = 3 bytes + 3 bytes * 8 channels = 27 bytes for each ADC are read in the DMA device by direct memory access. The code of this algorithm in C ++ is given below. This EXTI9_5_IRQ Handler subroutine interrupt service is called by the readiness signal (**Data Ready (DRDY)**) of the ADC and allows using the DMA2 root channel to write 27 + 1 bytes of data through SPI1 to the memory received from the ADC. After receiving all 27 bytes, the DMA device generates a preference signal to proceed to the maintenance of the DMA2_Stream0_IRQ Handler routine. This subroutine creates a stream of 25 samples of 32 bit biosignal values over the entire 24 channels (Fig.2).

To adequately display the ECG signal and an ECG device operation signal pre-filtering is needed. The first step is to remove baseline drift (zero) so that the signal is always displayed within the screen. This is necessary because of the features of the ADS1298 ADC, which digitizes the signal with a DC. Mathematical view and algorithm this can be achieved [1] by a simple IIR digital filter HPF(1):

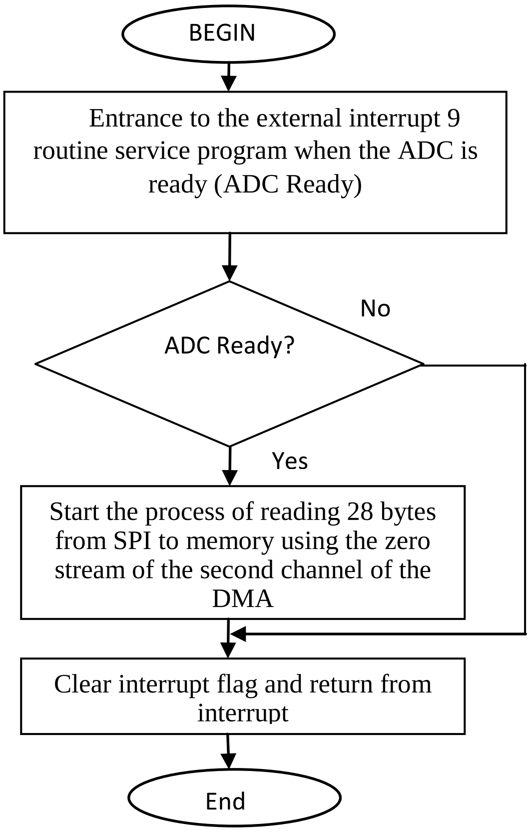

Fig. 2.Block diagram of the algorithm for the accumulation and service of the interrupt on the readiness of the ADC

$$H(z) = \frac{z-1}{z-0.995} \quad (1)$$

The difference equation for such a filter is expressed by the formula (2):

$$Y(n) = [X(n) - X(n-1)] + 0.995 \times Y[n-1] \quad (2)$$

The amplitude and phase characteristics of the filter specified by equation (1 or 2) to remove the drift of the signal of the display in Fig. 3.After digitization, the ECG signal has HF noise and interference. They can be loosened by a simple 3-order lowpass FIR Hanning, defined by the expression(3):

$$Y(n) = \frac{1}{4}[X(n) + 2 \times X(n-1) + X(n-2)] \quad (3)$$

Hanning filter transfer function defined by the expression (4):

$$H(z) = \frac{1}{4} \times [1 + 2 \times Z^{-1} + Z^{-2}] \quad (4)$$

The result of high-pass filtering based on formula (1) is shown in Figure 4.
For transferring the ECG data packet from the controller to the computer, the optimal asynchronous serial transmission method is USART (universal serial asynchrony receiver transmitter). In computers running under MS Windows, such ports are called COM (communication port - COM1, COM2 ...) and real such ports work in the industry standard

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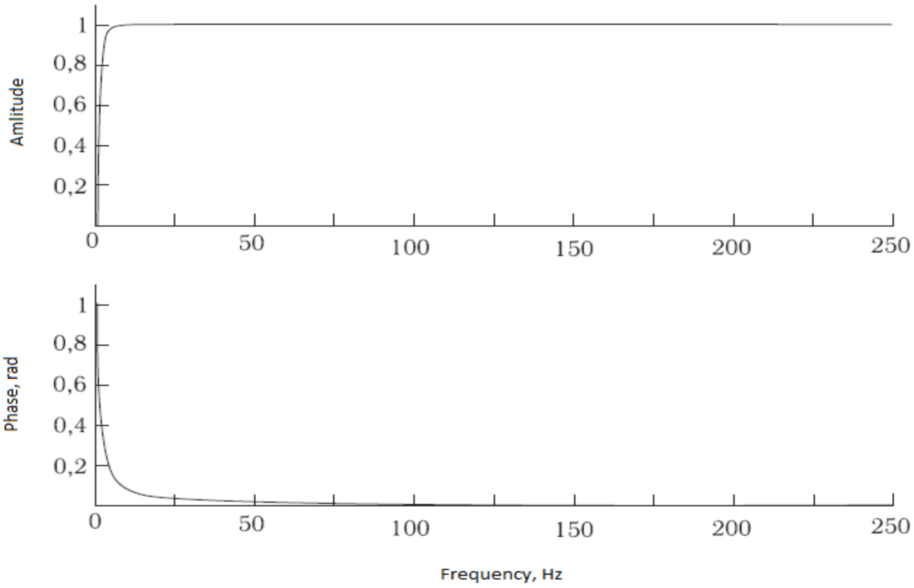

Fig. 3. Amplitude and phase characteristics of the filter specified by equation (1) to remove the signal drift.

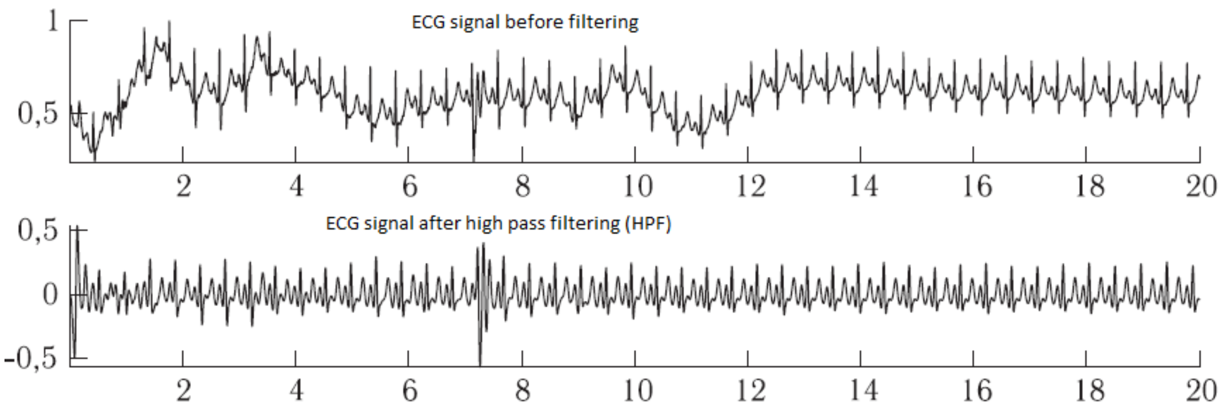

Fig. 4. ECG signal before and after filtering HPF.

RS232, but modern USB exchange devices also create virtual COM ports. Therefore, the use of such a port for transmission, which has wireless and USB versions of the converters (controller-computer bridge), makes the ECG controller universally modular.

The amplitude and phase characteristics of the filter specified by equation (3 or 4) and results to Hanning LPF of the display in Fig. 5

Figure 6 shows the result of the filter LPF Hanning.Determination of the exchange interface and calculation of the data transfer traffic of the ECG bio-meter.By default, one byte in this method is transmitted in 10 consecutive bits - 1 start bit +8 data bit + 1 stop + 0 bit parity / odd check. Then, for example, to transmit 16 bit ECG samples, 16 bits = 2 bytes => 2 * 10 = 20 bits are required.

We are calculate the minimum required ECG data rate via USART:500 times per second x 20 x 8 channels = 80,000 bot.The nearest traffic, advising the transmission of this information from a number of standard USART (COM-RS232) port exchange rates, is 115200 bot.Data sent to the PC via UART contains eight ECG leads [7]. These signals are sent at a rate of 500 packets per second.The program installed in the computer calculates the remaining four ECG leads using data from the 1 lead and 2 lead [7].

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For transmission to a computer, two types of ECG data packet are generated:the first packet type is repeated every second once and is called a full packet, where there is a header consisting of 2 bytes of synchronization, 1 byte with heart rate (HR), 1 byte of lead status (is there an electrode connection or not skin) and 16 bytes of data from eight ECG leads (Table 9), the second type of packet, called a shortened packet, has 1 byte packet number and 16 bytes of data from eight ECG leads (Table 10), and the packet number increases with each new packet.

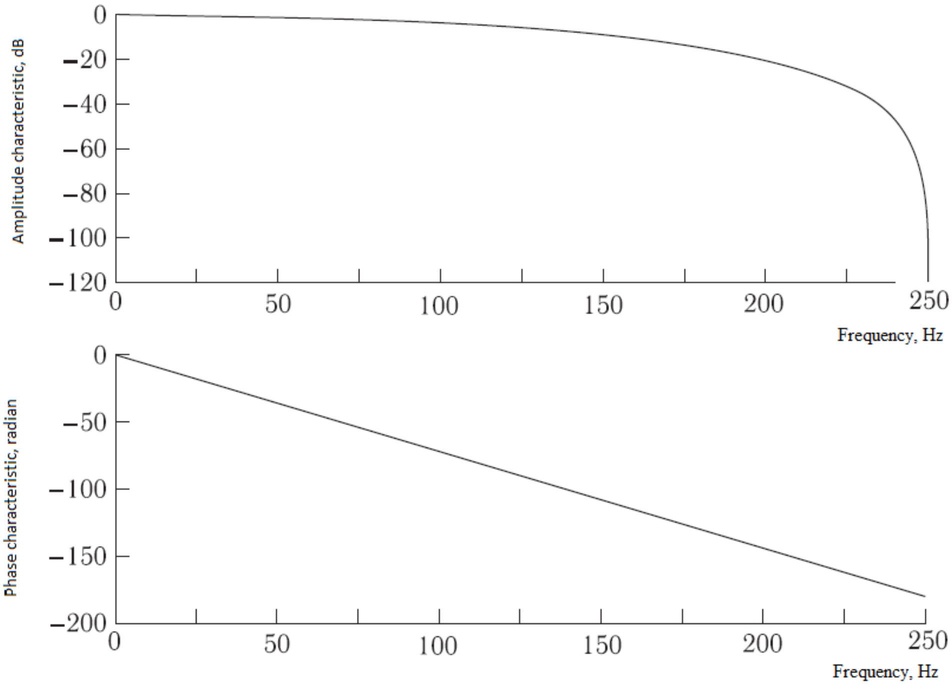

Fig. 5.Amplitude and phase characteristics of the Hanning LPFfilter

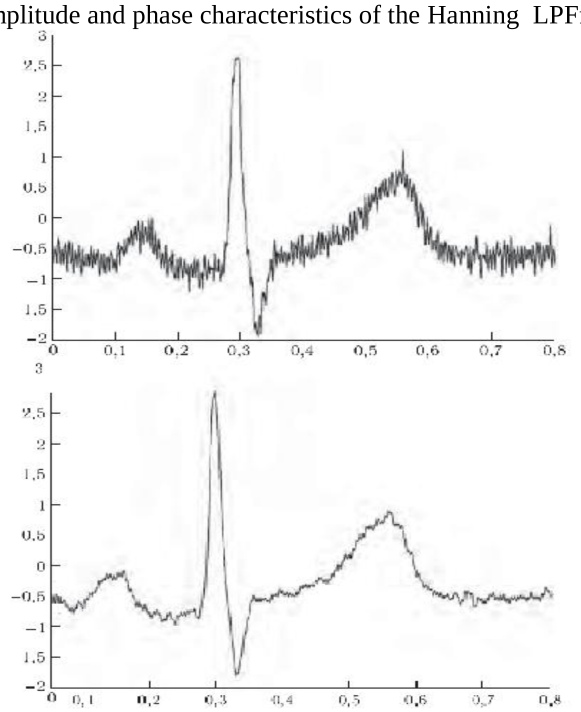

Fig. 6. Result filtration by LPF Hanning.

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Table 9. Format of a complete ECG data packet (where, SB is the most significant byte, LB is the least significant byte).

1) x55	2) xAA	3) R	4) LeadOn/ off	5) I		6) II		7) C 1		8) C 2		9) C 3		10) C 4		11) C 5		12) C 6	
13) Sync (2 bytes)		14) 1 bytes	15) 1 bytes	16) B	17) B	18) B	19) B	20) B	21) B	22) B	23) B	24) B	25) B	26) B	27) B	28) B	29) B	30) B	31) B
32) Packageheader				33) ECG data 8 leads															

Thus, 1 full and 499 reduced packet is transmitted within one second, and at the same time traffic can be calculated as follows:1x (4 bytes header +16 bytes of data) x10 + 499x (1 bytes header +16 bytes of data) x10 = 100 +84 830 = 84930 bot (or bits / sec).Therefore, the UART configuration is set to 115200 bps, 8 data bits, 1 stop bit and no parity is enough to transmit ECG data.

Table 10. The format of the reduced ECG data packet (where, SB is the most significant byte, LB is the least significant byte).

34) Number of Package	35) I		36) II		37) C1		38) C2		39) C3		40) C4		41) C5		42) C6	
43) 1 bytes	44 B	45 B	46 B	47 B	48 B	49 B	50 B	51 B	52 B	53 B	54 B	55 B	56 B	57 B	58 B	59 B
60) Packageheader	61) ECG data 8 leads															

IV.CONCLUSIONS AND RECOMMENDATIONS

In embedded systems, such as portable ECG systems, it is desirable to use algorithms based on differentiation and time analysis based on a priori data of ECG signals.The Pan and Tompkins algorithm passed the test of time; it is popular and high-speed with good quality analysis of QRS complexes.In stationary computer ECG systems, algorithms for analyzing ECG based on neural networks and wavelet transforms are promising.

V. RESULTS

The results of research on the development of adequate mathematical models and software and software for improving the functions of processing removable experimental data and diagnostics, automated ECG meter, will be announced in subsequent publications.

Heartbeat the article describes the main aspects of the development of functional diagnostics devices based on computer technology. The device for functional diagnostics of a bio-measuring, built on a modern element base (multi-channel low-noise operational amplifiers, multi-bit and multi-channel integrated analog-to-digital converters (ADC), programmable logic arrays and / or microcontrollers), is considered in detail. A structure of a modern bio-measuring based on a multi-channel 24-bit ADC.

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