Demo: Mobile ECG Monitoring System Prototype on the Base of Texas Instruments Hardware and Android Platform

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***Abstract*—This paper describes a solution for mobile heart monitoring. In part of hardware, the authors focused on engineering problems of increasing the number of ECG leads and increasing the sampling rate. It potentially allows to increase the effectiveness and accuracy of localization and to decrease the influence of pacemaker pulses on the ECG signal recording respectively. Implementation of hardware and software parts is described. Proposed solutions are suitable for portable heart monitoring systems.**

I. INTRODUCTION

Currently, most portable ECG devices, in contrast to their stationary counterparts, have the following problems:

- Low information content and low possibility of localization of myocardial infarction in three standard leads;
- Most devices for recording of ECG signal are liable to pacemaker pulses [6].

These tasks can be resolved by using up to 12 lead ECG systems, but it's hard to make them portable and easy-to-use for unprepared person.

II. IMPLEMENTATION

A. Hardware

The use of 3 leads is not enough to determine some types of myocardial infarction, so authors selected a scheme using 4 leads which provides more sensitivity to a specific types of myocardial infarction.

However, ADS1298R are sufficient for implementing a system of 4 or more (up to 8) leads, but the bottleneck in this system is System-On-Chip (SoC) CC2540 (reference to us) working in the Bluetooth 4.0 standard. Because of the spread of Bluetooth 5.0 technology, the authors consider it advisable to replace the outdated SoC 2540 with the more modern CC2640R2F solution, developed by Texas Instruments as well. The structure of the device is shown in Fig.1.

The CC2640R2F [5] device contains a 32-bit ARM Cortex-M3 core that runs at 48 MHz as the Main Core and ultra-low power Sensor Controller. This sensor controller is applied for interfacing external sensors and for collecting analogue and digital data autonomously while the rest of the system is in sleep mode. The interaction with the wireless protocol BLE is engaged in the RF core.

The RF Core contains an ARM Cortex-M0 processor that interfaces the analog RF and base-band circuitries, handles data to and from the system side, and assembles the information bits in a given packet structure. The RF Core offers a high level, command-based API to the Main Core. The RF Core is capable of autonomously handling the time-critical aspects of the radio protocols (Bluetooth low energy) thus offloading the Main. The RF core has a dedicated 4-KB SRAM block and runs initially from separate ROM memory. Unfortunately, the ARM Cortex-M0 processor cannot be programmed.

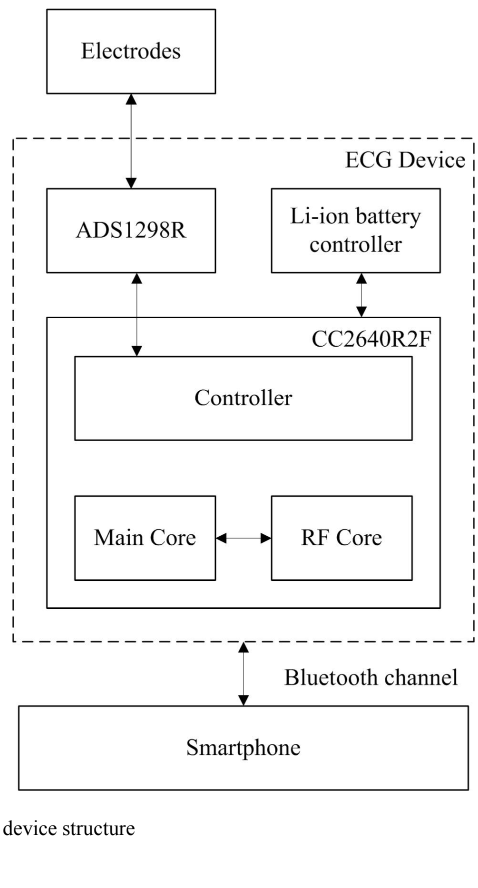

Fig. 1. ECG device structure

Application of CC2640R2F allowed reorganizing the structure of the device, transferring work with wireless data transmission and ADC routine not just into separate threads, but into separate hardware modules specializing in these tasks.

Due to the transition to the new architecture, it was possible to reduce the current consumption from 17 to 11 mA.

Due to increased data transmission speed, it is possible to solve the problem with a pacemaker pulses in ECG signal by simply increasing the A/D Sampling rate to 2000 Sps (0,5 ms interval) [7]. ECG device prototype is shown in Fig.2.

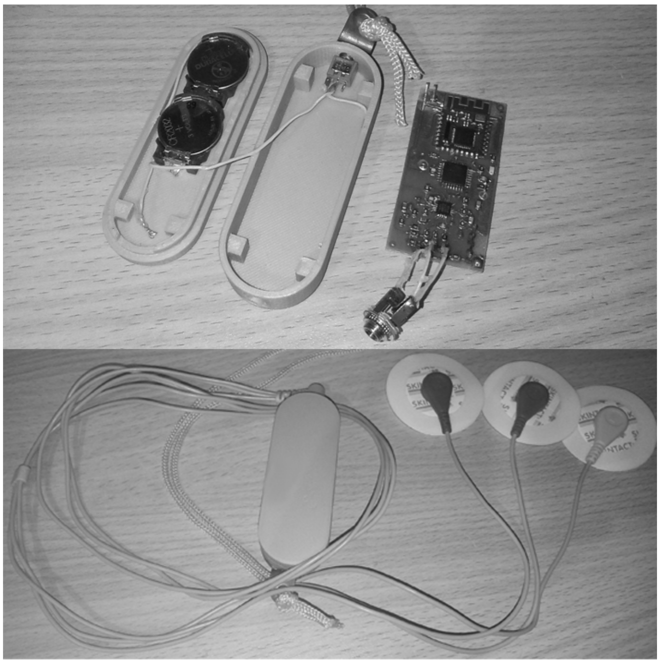

Fig. 2. ECG device prototype

In terms of energy efficiency, an important parameter is the transmitting power of the transceiver. The authors propose to control this power in order to reduce it depending on the distance to the receiver in which the smartphone acts. This functionality is provided by the built-in capabilities of the SoC CC2640R2F and the control application on the smartphone, which can measure the data loss and adjust the transmitting power. Approximate parameters of the transceiver are shown in TABLE I

TABLE I. APPROXIMATE PARAMETERS OF THE TRANSCEIVER

Distance	**Less than 1 meter**	**From 1 up to 5 meters**	**From 5 up to 10 meters**	**Greater than 10 meters**
TX Power	-21 dBm	-6 dBm	0 dBm	+5 dBm

B. Software

The authors have improved the mobile application that was described in paper [4].

The user interface has been refined. The main functionality is divided into several related windows, which allows to simplify the application's main screen, previously full of information (see Fig.3).

Authors have changed the format of data stored in the memory of the smartphone. Now at the beginning of each record, there are metadata, namely:

- Recording type: automatic or on-demand;
- Precise date and time of the recording;
- A/D sampling rate of the record;
- Minimum, average and maximum heart rates;
- Preliminary analysis data.

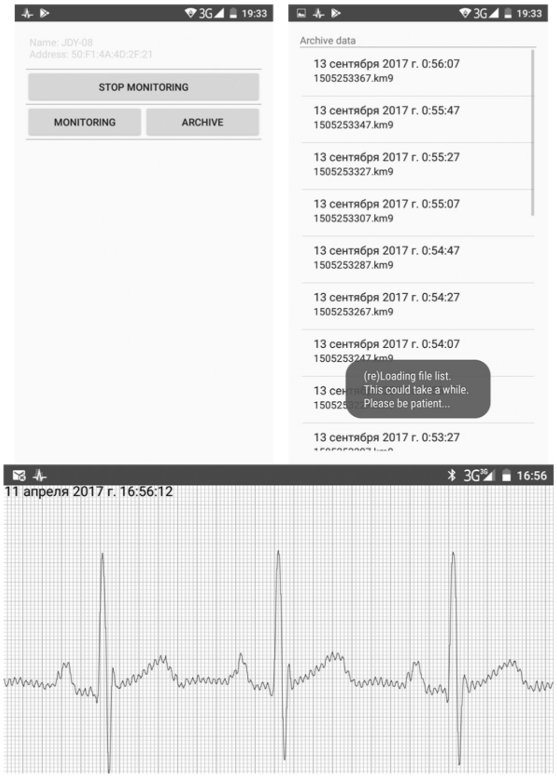

Fig. 3. Application visual forms

The structure of the transmitted packet has also been changed, since in the standard Bluetooth 5.0 the useful packet size is increased from 31 octets to 255 octet packets.

A/D sampling rate of the ECG device is now adjustable from the software. In addition to minimally necessary 500 Sps, ECG can be recorded with an A/D sampling rate of 1000 and 2000 Sps.

The duration time of each recording is increased to 30 seconds by recording a certain number of values at a specified sampling rate from the start time of the recording: the number of ECG readings will be 15000 for 500 Sps for 1 lead, for 1000 Sps - 30000, for 2000 Sps - 60000 samples, respectively.

The automatic power control function is added depending on the distance between the receiving and the transmitting devices.

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