High-resolution Signal Acquisition Module Recording 18-Lead ECG for Person Authentication

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Abstract – **This paper presents a high-resolution 16-channel ECG acquisition module with 24-bit amplitude resolution and sampling rate of 2kHz. The module is applied for collection of ECG database for the aims of development and testing of methods for person authentication via ECG. Such database could support the definition of optimal number of ECG leads and the optimal feature set and would facilitate the decision about the ECG applicability as a person biometric characteristic in different environments.**

Keywords – **ECG device, 24-bit ADC, 18-lead ECG, biometrics, person verification, identification**

I. Introduction

Nowadays, the reliability of the automatic person verification/identification is very important, considering the necessity of high security level in cases of financial transactions; access control for buildings, rooms and information; traveling, etc. Due to the technological development of compact sensors for acquisition of biological signals and the progress in biomedical signal processing for diagnostic purposes in the last decade, the idea for application of signals generated in the human's body for person authentication gains support. The analysis of the electrocardiogram (ECG) as a biometric tool was started about a decade ago, incorporating two general approaches: (i) methods, using measurements after detection of fiducial points; (ii) methods, analyzing the overall morphology of the ECG waveform. All methods rely on detailed zoom of specific temporal and amplitude ECG characteristics, and therefore, the more precisely the ECG is acquired (high sampling rate and amplitude resolution), the more reliable person verification/ identification can be supported.

Single lead ECG for person identification is acquired from palms [1] and fingers [2]. Although the described ECG devices implicitly assure comfort for the tested person, according to some authors, the reduction of the number of analyzed ECG leads limits the accuracy [3]. Others, however, report reliable identification accuracy of 94.3-95% with limited number of ECG leads [1,2]. Considering this uncertainty and the extended application of person authentication not only in social environment but also in medical setting, assisting and securing the collection of personal medical information, there is a need for high-resolution multi-channel ECG acquisition module, which could be used for collection of ECG data with redundancy. Such ECG database could be further analyzed in order to extract valuable information about the most reliable leads and features for person authentication.

This paper presents a 24-bit 16-channel ECG acquisition module, which is applied for collection of 18-lead ECG database for the aims of a detailed framework of the person verification/identification task. Such database could support the definition of the optimal number of ECG leads and feature set, and would facilitate the decision about the ECG applicability as a personal biometric characteristic in different environments.

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II. Hardware Concept

The presented ECG module provides synchronous acquisition of 16 ECG channels and one respiration channel via impedance measurement in lead I, with the capability for real-time data transfer to PC. The ECG is sampled at 2kHz, 24-bit amplitude resolution over an input range of ±400 mV (about 0.05μV/LSB).

The block diagram (Fig. 1) is including:

1) Two 8-channel Texas Instruments ADS1298R demonstration boards (ADC1, ADC2), each one embedding complete ECG Front-End module based on 24-bit, delta-sigma (ΔΣ) analog-to-digital converter (ADC) with a built-in programmable gain amplifier (PGA), internal reference, and an onboard oscillator.
2) Custom interface board providing PC connection of the ECG module. The board is based on the microcontroller Cortex STM32F103C8 and the USB to serial UART interface circuit FT232RL. The FT232RL data sheet claims operating rate at up to 3Mbps that guarantees the correct transfer of 16-channel, 24-bit data, sampled at 2kHz.

The power supply of the designed ECG acquisition module is 5V, provided via the available USB interface. The chips STM32F103C8 and FT232RL are powered directly from PC, while ADC1 and ADC2 are electrically isolated from the apart hardware according to IEC60601 standard, so that the ECG acquisition module complies with the requirements for patient safety. The DC-DC converter AM1D, rated to 6kV DC isolation, is used to produce an isolated power supply. The digital signals are

isolated by four-channel ADUM2401 magnetic isolators, rated for 5400V RMS.

A PC application under Windows is developed for data communication with the ECG acquisition module via USB. Three modes of operation are supported:

1) 12-lead standard ECG acquired via 10-electrode cable connected to 'patient cable 1';
2) 12-lead standard + 4-lead ECG acquired via 14-electrode cable connected to 'patient cable 1';
3) 12-lead standard + 7-lead ECG acquired via two 10-electrode cables connected to 'patient cable 1' and '2' (two inputs of 'patient cable 2' are not used).

Mode (1) uses only ADC1 inputs, while modes (2) and (3) use both ADC1 and ADC2 inputs. The synchronous operation is managed by ADC1, which generates the master clock (EXT_CLK) for ADC2 and provides common Wilson Central Terminal (WCT) and common potential for the driven right leg (ELEC_RL = ELEC_RA + ELEC_LA + ELEC_LL) for both ADC boards.

All data are transferred to the PC in real time. This allows user-friendly visualization and recording of multi-lead patient ECG in the experimental environment.

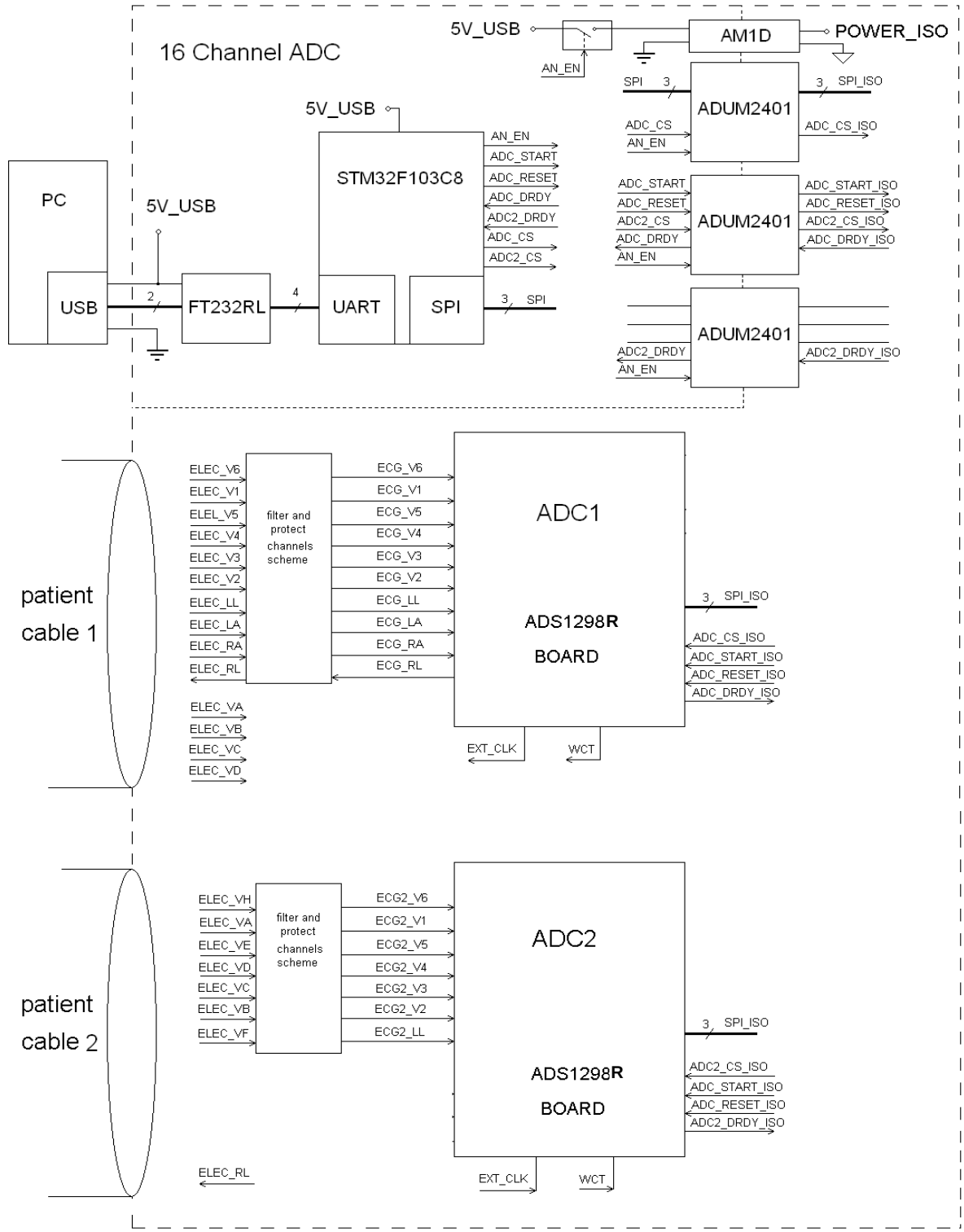

Fig. 1. Block diagram of the 16-channel 24-bit ECG acquisition module.

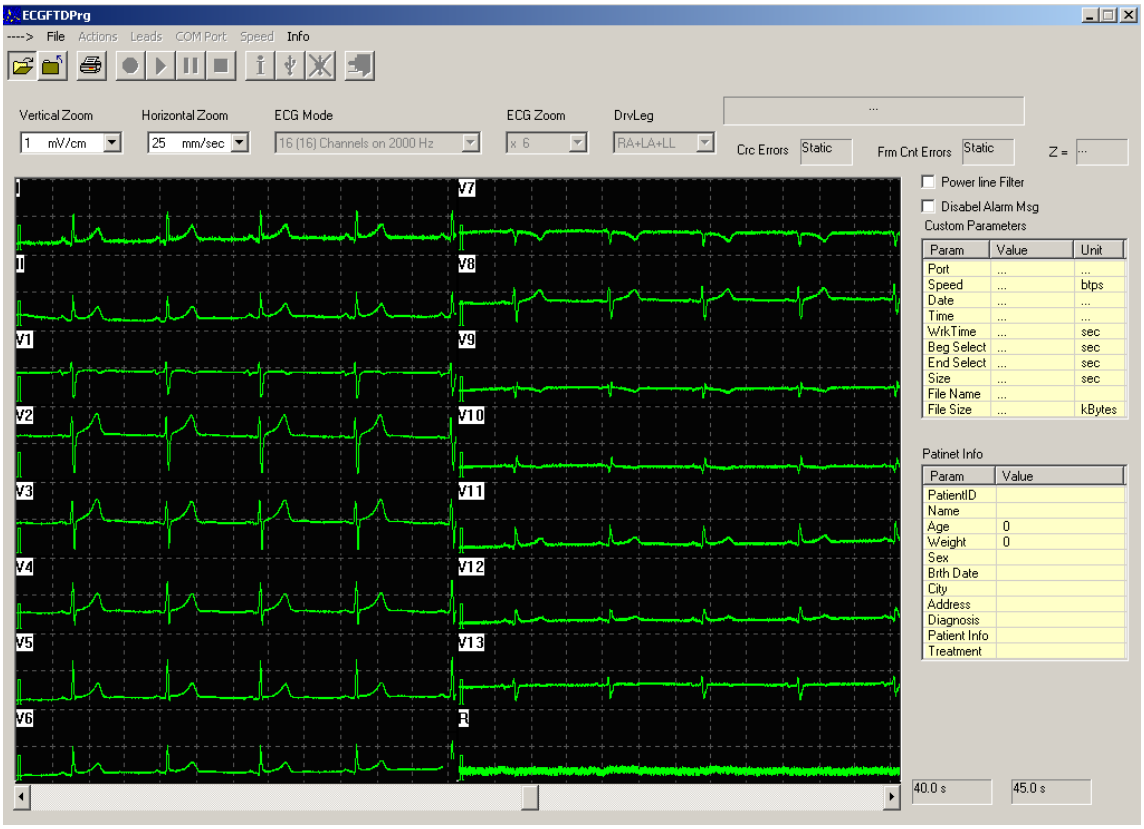

Fig. 2. Main window of the PC application for management of the real-time signal acquisition, recording and visualization of multi-lead ECG (I, II, V1-V6 (standard), V7-V13 (additional)) and one respiration channel (R).

II. PC Application

The PC application developed in Visual C++ 6.0 controls the ECG acquisition and visualization in real time, as well as the recording of signal data on the hard disk. The main window of the application (Fig. 2) contains user control tools for selection of:

- *ECG Mode* – possible acquisition of 12, 16 or 19 ECG leads;
- *Vertical Zoom* – three standard values for the possible vertical zoom: 0.5 mV/cm, 1 mV/cm, 2 mV/cm
- *Horizontal Zoom* – three standard values for the possible horizontal zoom: 12.5 mm/s, 25 mm/s, 50 mm/s;
- *ECG Zoom* – programmable hardware internal amplification. The default value is 6. Other possible values are 1, 2, 3, 4, 8, 12.

The following controls are available on the GUI toolbar:

Open a file saved on the hard disk
Close the opened file
Start saving received data to temporary memory buffer
Start data acquisition
Pause/Start the ECG curves drawing
Stop acquisition data and save the data from the temporary memory buffer to the hard disk
Show the patient's info dialog
Connect application to the device
Disconnect application from the device
Close the application

III. ECG Data for Person Authentication

The designed 16-channel, 24-bit ECG module (Fig. 3) is used for collection of ECG database dedicated to fundamental research in the area of ECG biometrics. The potential for person authentication via ECG should be studied in a multi-lead, high-resolution scale, with acquisition of the following 18 ECG leads (Fig. 4):

- Six standard peripheral leads acquired via 3 electrodes on the limbs: left arm (LA), right arm (RA), left leg (LL) (Fig. 4a);
- Six standard precordial leads (V1, V2, V3, V4, V5, V6) and one right precordial lead (V3R) acquired via 7 chest electrodes (Fig. 4b);
- Two posterior leads (V7, V8) acquired via 2 electrodes on the back (Fig. 4c);
- Frank bipolar leads (X,Y,Z) acquired via V6 and LL plus 4 additional electrodes I, E, H, M (Fig. 4b,c): X = V6 – I, Y = LL – H, Z = M – E.

Fig.3. ECG acquisition module connected to PC

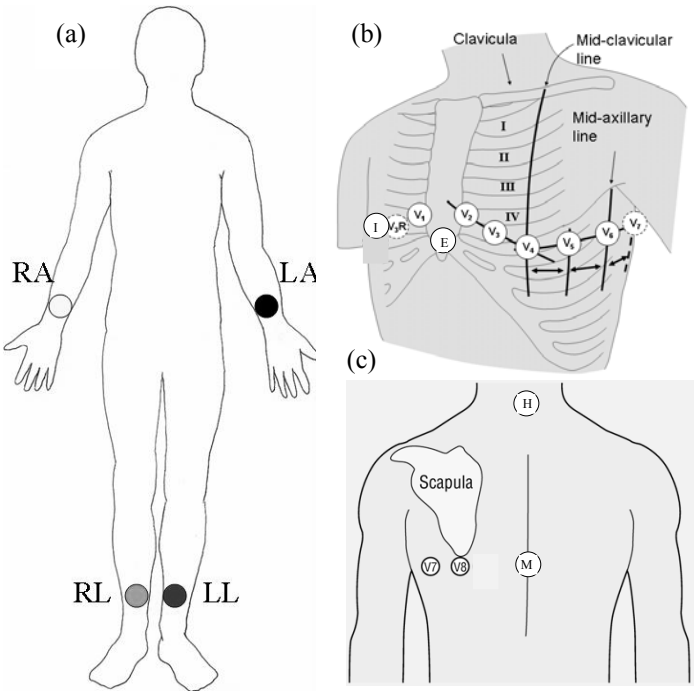

Fig. 4. ECG electrodes placement for acquisition of 18-lead ECG: 12 standard leads via RA, LA, LL, V1, V2, V3, V4, V5, V6; 1 right chest lead via V_3R; 2 posterior leads via V7, V8; 3 Frank bipolar leads (X,Y,Z) via I, E, M, H electrodes.

Figures 5 and 6 illustrate an example of 5s 18-lead ECG and 1 respiration channel acquired and recorded with the designed high-resolution ECG acquisition system. During recording, no filtering is applied to leads, keeping small details of the original ECG morphology unchanged by the filter bandwidth that might be of interest in an offline study for person authentication.

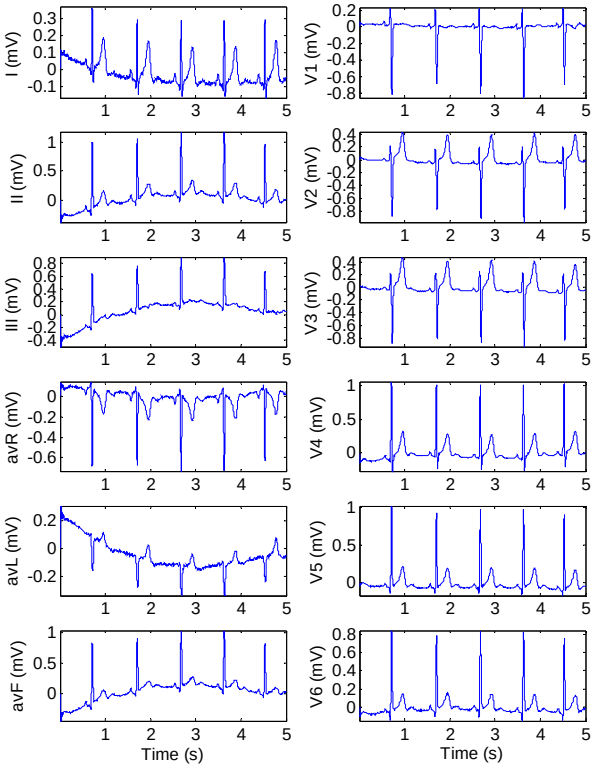

Fig. 5. Example of standard 12-lead ECG, acquired via the designed ECG module.

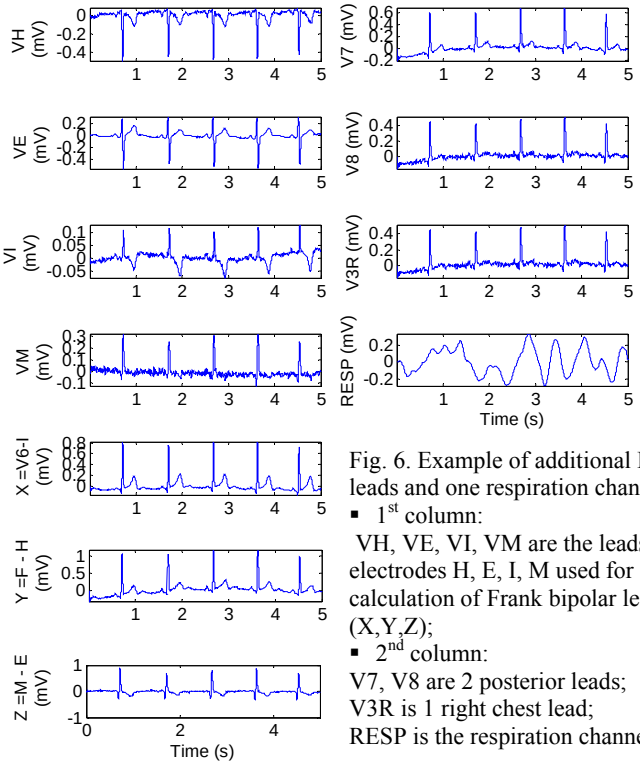

Fig. 6. Example of additional ECG leads and one respiration channel:
- 1st column:
VH, VE, VI, VM are the leads of electrodes H, E, I, M used for calculation of Frank bipolar leads (X,Y,Z);
- 2nd column:
V7, V8 are 2 posterior leads;
V3R is 1 right chest lead;
RESP is the respiration channel.

V. Discussion and Conclusions

This paper presents a 16-channel, 24-bit ECG acquisition module and a PC application for real-time data management, applied for recording of a large database for the aims of person authentication. The conditions required for collection of such database are:
- Recording of 18-lead ECG provides the opportunity to derive general conclusions about the potential of any ECG lead and the set of the most reliable leads as a biometric measure for person verification/identification;
- Recording of high-resolution ECG, sampled at 2kHz, 0.05μV/LSB provides the opportunity to study details of any temporal and amplitude relations that might help understanding of inter and intra subject differences.
- Recording of two ECG recordings per person: ECG(t1) and ECG(t2), where t2≥t1+6 months provides long-term tracking of ECG intra-individual morphology variation.

V. Acknowledgements

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