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Software Approach in Noise Reduction on an ECG Acquisition Platform

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***Abstract* – Given the higher and higher incidence of heart related diseases, including the social costs, the early diagnosis becomes increasingly important. The ECG technique is a very useful diagnosis tool. It is relatively inexpensive, irradiation-free and readily available. One of the main issues to tackle when developing an ECG signal acquisition device is to ensure noise and artefact removal. This paper introduces a filtering solution based on a combination of a high pass filter and a low pass filter.**

Keywords – ECG, low pass filter, high pass filter, C#

I. INTRODUCTION

Nowadays the use of technology for diagnosis and treatment is wide-spread. It essentially covers almost every application field of medicine from classical x-ray examinations to modern radiation therapy devices such as linear accelerators. Heart diseases are the underlying cause of death for about 800,000 per year people in the USA, that is roughly 1 death every 40 sec [1]. Given this, the importance of early diagnosis is straightforward and routine exams play an important role in this. Preventive medical examinations which use electrocardiograms are more and more available also due to the relatively low-cost and wealth of diagnostic information output of the examination in comparison with other advanced diagnostic tools such are cardiac CT or cardiac MRI. The latter are mostly being used for advanced diagnostic and not for routine diagnostic or screening. Another major advantage of ECGs is that most modern devices are portable, therefore can be used outside the cardiologist's office (e.g. ambulance, home, etc). This is particularly important since most of cardiac patients are senior people and in many cases they suffer from associated diseases which prevent them travelling easily.

The Electrocardiogram (ECG) consists of a series of bio-signals graphically printed in order to display the electric activity of the heart [2]. A typical ECG reflecting 1 cycle of cardiac activity looks like in Fig. 1.

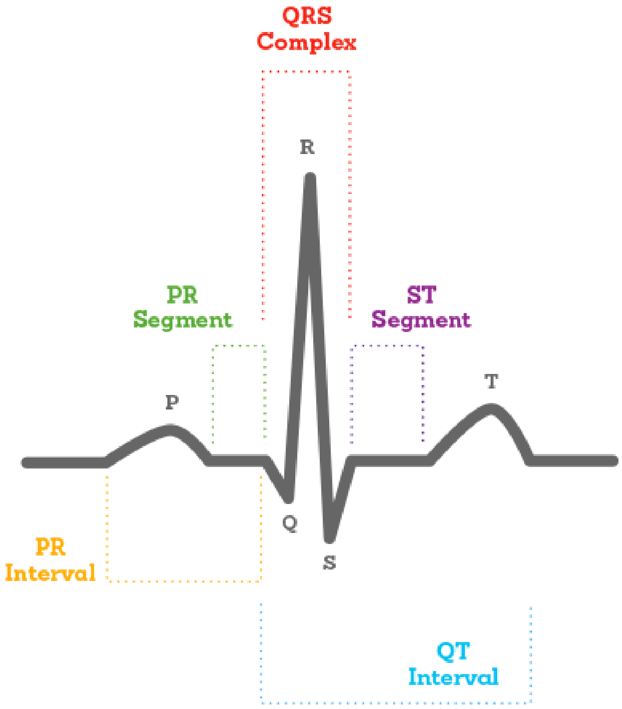

Fig. 1. A typical ECG shape, from: https://www.alivecor.com/education/ecg

The P wave graphically shows the amplitude (in mV) and length (in sec) of atrial depolarization; the PR segment illustrates the time required by the electrical impulse (in sec) to pass from the sinus node to the atrio-ventricular node; the QRS complex illustrates the fast (time-wise) and strong (voltage-wise) depolarization of the heart ventricles; the ST segment is associated with the time (in sec) of depolarized ventricles while the T wave shows the repolarization of the heart ventricles. Any modification in the heart activity (due to medical conditions) will be reflected in the ECG waves on either axis (time, amplitude or both).

Altered ECG wave shapes offer immediate diagnostically relevant information for the cardiologist. There are specific ECG patterns in the waves, each of them presenting a specific cardiac activity. Waves amplitude, wave lengths lack of specific waves or extra waves can indicate even potentially life-threatening medical conditions. The relative low cost of ECG devices make it among the first choices device in cardiology. The relevant ECG signal consists of low frequencies (0.05 Hz – 100 Hz) with a voltage level between 0.5 mV and 5 mV [3]. Due to this fact, the ECG signal is subject to various sources of noise: contact noise, myo-electric activity (muscle contraction – except the heart) noise, power-line noise and leads noise. Contact noise can be significantly decreased by increasing and improving the skin contact, leads noise can be decreased by using higher quality signal acquisition systems [4], [5]. However, power-line noise, myo-electric activity noise cannot be removed. Therefore, digital filters are an attractive option for improving the ECG signal, without removing the clinically relevant parts of the signal [6]. The present paper introduces an ECG signal acquisition platform and implements a combination of a high pass filter in order to reduce the baseline drift in the signal and low pass filter in order to reduce the noise induced by spontaneous muscle contract (other than heart) and the power grid.

II. MATERIALS AND METHODS

The ECG system consists of a development board based on the ATmega328P microcontroller (Atmel, USA), Fig. 2, and a bio-signal acquisition board (Olimex, Bulgaria), Fig. 3. The development board has the ability to connect up to 6 stacked acquisition boards for full 12-lead ECG. Without reducing the generality, a single set of electrodes (3-leads) where used (Philips, The Netherlands). Bio-signal data was sent to an IBM-PC via the USB port. Data processing and software implementation was done in C# (Visual Studio 2008). The entire application was deployed on a Windows-based computer and the ECG signal was displayed using the MS-Chart control from standard visual controls included in the Windows Forms of the Visual Studio Development Environment.

Fig. 2. Development board based on ATmega328P micro controller

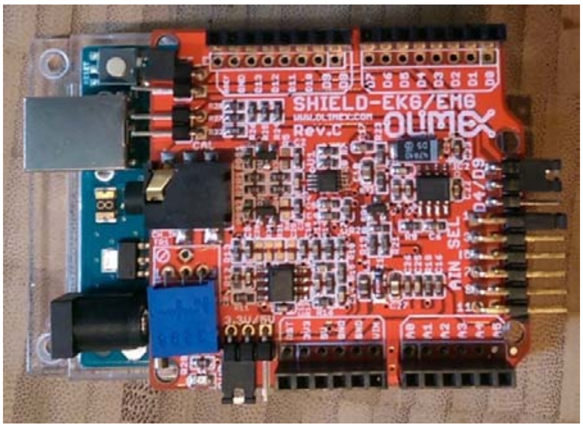

Fig. 3. Bio-signal acquisition board interfaced with the development board

From the connectivity point of view, DATAOUT was available via the Analog Output (A0) of the ATmega 328P microcontroller. Table 1 defines the connectivity parameters of the bio-signal acquisition board.

Table 1. Communication parameters between the bio-signal acquisition board and ATmega 328P microcontroller.

Bits per character	8 bits
Baud rate	57600 bps
Parity bits	No parity
Start bits	1 bit

For the high-pass filter the cut-off frequency was established at 150 Hz. For the low-pass filter, the following cut-off frequency was used: 0.67 Hz.

Fig. 4 shows the processing pipeline. The high-pass and low-pass filter are done on the computer-side, rather than the board side in order to obtain a real-time ECG form on the computer (board-side computation were to found to be time-wise expensive).

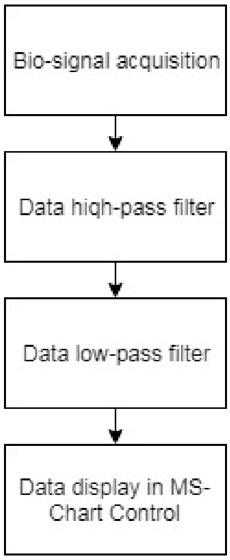

Fig. 4. Processing pipeline

III. RESULTS

Fig. 5 shows the ECG as it would be obtained with no application of post-processing filters. It is noticeable the ECG waveforms are deflected upwards, thus creating a drift which may mislead the clinical interpretation.

Fig. 6 shows the ECG wave form after the application of the high pass filter in the preprocessing phase. The wave forms are flat but low-frequencies clearly disrupt the P, T waves as well as PQ and RT segments.

Fig. 7 shows the ECG waves as obtained after application of both high pass and low pass filter. All the waves and segments are visible. The frequencies that were not removed are mostly likely due to the motion artifacts. Further processing would have removed them but also alter the P-wave and the T-wave, thus eliminating potentially important diagnostic information.

IV. DISCUSSION

This article introduces a mobile and versatile platform for ECG signal processing. Since access to raw data is readily available via the analog pinout, there is a myriad of applications that can be implemented in order to further study the ECG signals. The platform can be used in any environment since it can be powered on batteries. Its flexibility and mobility can be further increased by use of a graphic LCD to plot the ECG waves rather than the laptop. This would however increase the computational time since all the data processing, including programming the LCD would be done on the board side.

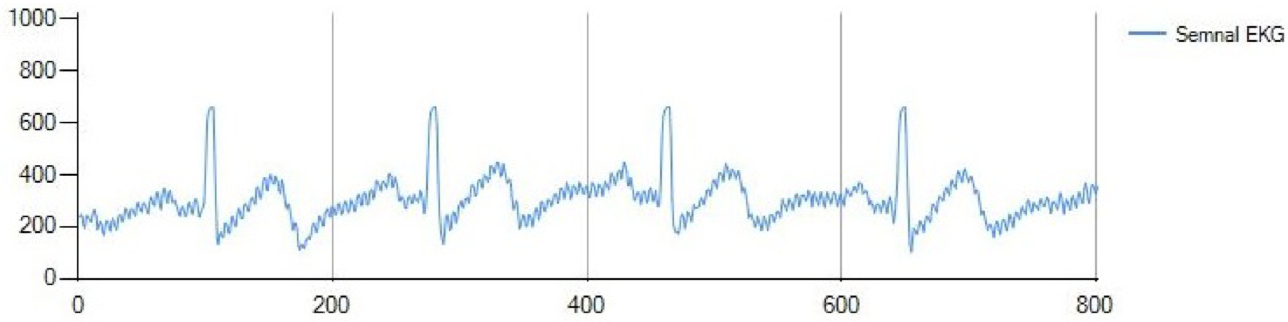

Fig. 5. ECG with no filter application

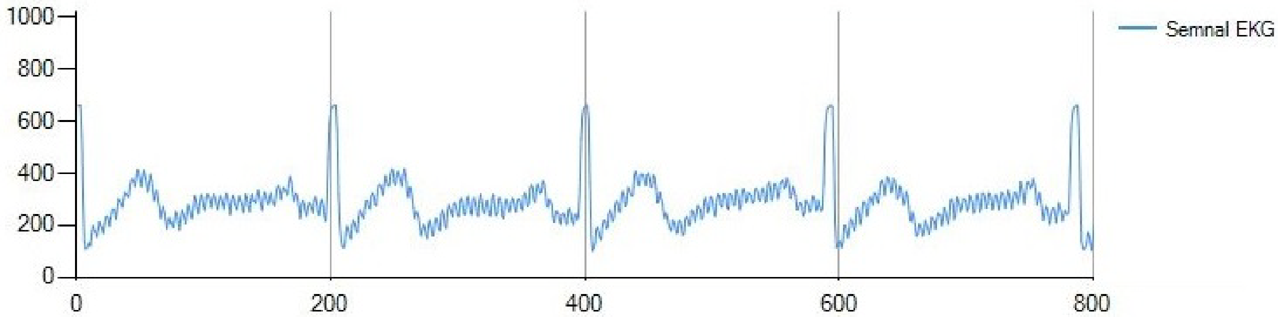

Fig. 6. ECG with high pass application

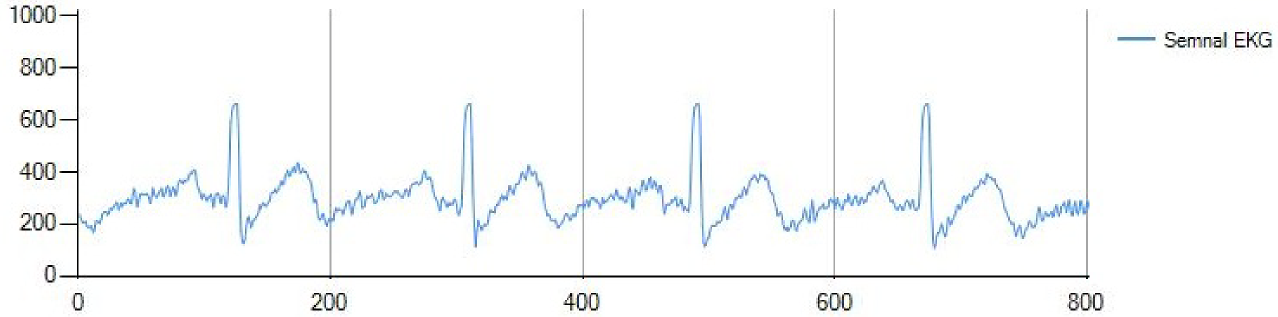

Fig. 7. ECG with high pass and low pass application

V. CONCLUSION

We have introduced a development platform for ECG signal acquisition. It is highly flexible and suitable for various types of filter development. Moreover, it can be used for teaching purposes in the medical schools.

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