High-Performance, Low-Cost EKG Acquisition System for an IBM-PC

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Abstract – **It is analyzed a low cost - high performance EKG acquisition system thought to be use in private medical cabinets. The EKG amplifier is connected to an IBM-PC. The software implemented in LabVIEW allows an easy to use interface and a good programming environment to perform data acquisition, processing and visualization of biological signal. Two ways of interconnecting the data acquisition system with the PC is possible.**

Keywords – **Data acquisition system, EKG Virtual Instrumentation**

I. Introduction

The EKG is widely spread through hospitals and clinics for diagnosis or/and monitoring of the cardiac activity of the patients. The design of this acquisition system is as cheap as possible without renouncing to its high performances. The most important characteristics are: a high common mode rejection EKG amplifier (> 100); a high-voltage input protection circuit; a bandwidth of 0,05 ... 250 Hz; recording and storage of electrocardiograms in a PC; powered by batteries; small dimension and very light weight; connected by a standard serial interface with a PC; an easy to use software implemented in LabVIEW. All of this makes the board to be cheaper because it does not contain expensive accessories that an EKG usually has as the pagewriter, the waveform display, etc. These are expensive units, some of which have consumable (recording chart paper, ink, etc.). The functions of these units are done by software running on PC.

This acquisition system amplifies the EKG signal and digitalizes it using a microcontroller. The microcontroller also has the job of controlling the system and the communication with PC. The PC acquires the 12 EKG leads, control the acquisition system and display the data acquired.

The software used to make signal acquisition, processing and user interface is developed in LabVIEW programming environment. LabVIEW ave built-in functionality for data acquisition, system control, measurement analysis, and data presentation. With LabVIEW it's easy to create a friendly, intuitive and natural human interface. LabVIEW was selected as the programming languages of this software because it is a graphical programming language based on C witch makes it very easy to debug. In addition, LabVIEW contains libraries for serial port data acquisition [1].

The isolation of the signal is made optically in the digital part of system. All the components of the system are low power devices witch make it possible to be powered by batteries. In this way, it can be assure the conditions of protection imposed by medical instrumentations.

II. Acquisition System Design

The block diagram of the EKG acquisition system is shown in Fig. 1.

Ten **Electrodes** (Ag/AgCl) measure the bio-potentials generated by the heart. **Electrodes Interface** assures the interconnection of the biomedical signal source and the EKG amplifier (Fig. 2). It protect the input of the EKG amplifier from the cardiac defibrillator, the cardiac stimulator or/and the high voltage that can arise from the touching by mistake of the patient of a body or object found under the network voltage. The high voltage that can appear is limited using a simple limitation circuit with BAV45 picoampere diode, needed to preserve the high common mode input impedance realized by the buffers. The Electrodes Interface also protects the patient against electrical shocks. The filters included in the interface attenuate the perturbation signal produce by the RF components (delivered by emitters or/and by electrosurgical equipment).

The **Lead Creation** block using the AD627 instrumentation amplifiers obtains the 12 leads. This is a micro-power, good CMRR amplifier specially designed for low-power medical instrumentation [2]. The EKG leads signals are first amplified with a gain of 10 because it is needed to eliminate the DC component before a higher amplification to assure a linear response. A High-Pass Passive Filter (**HP Filter**) with a cut off frequency of 0.05 Hz eliminates the DC component. A 16:1 CD4067 Multiplexer (**MUX**) select one of the 12 leads witch are amplified by an **Amplifier** (LF353) with an adjustable gain around 100.

A **Low–Pass 4th Order Active Bessel Filter** [3] (Fig. 3) follows to be uses as an anti-aliasing filter with a cut-off frequency of 250 Hz. The Bessel filter is use because in EKG application the phase is very important because a phase error change the shape of waveforms.

The **Microcontroller** acquires the analog signal from the EKG amplifier using only one channel. The analog to digital conversion of the EKG analog waveform is accomplished

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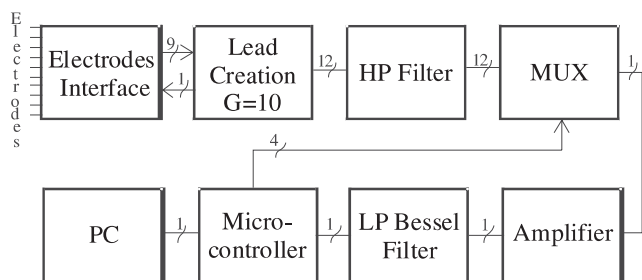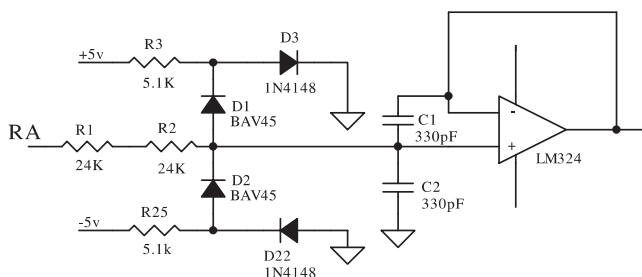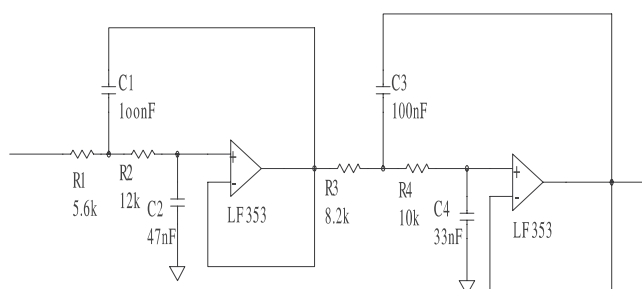
Fig. 1. Block Diagram

Fig. 2. Electrode Interface

Fig. 3. Low–Pass 4th Order Active Bessel Filter

using a 10-bits ADC found in the **Microcontroller**. The software implemented in assembler assures a sampling rate of 6 KHz. This sampling rate must be achieve because each lead has a minimum sampling rate of 500 Hz, and the number of leads acquire is 12 (500 Hz*12=6 KHz). The **Microcontroller** also control the acquisition time of each of the twelve leads. This is done by establishing the commutation time of each channel of the multiplexer. The **Microcontroller** choused is the Analog Device PIC16F877. The **Microcontroller** transmits the digitalize signal to the **PC** using the USART (The Universal Synchronous Asynchronous Receiver Transmitter) also known as a Serial Communications Interface [4]. The transmission is at a rate of 115.200 BPS.

The communication between the microcontroller and the PC is possible in one of the following ways:

- using the standard serial port and an optocoupler to isolate the digital signal;

- using an infrared emitter in case in witch the PC has an IrDa standard port. In this way, there is no need to use additional ways of isolating the signals, but the acquisition system must be in a short range of the PC (10 to 60 cm from the PC).

The PC communicates the data using its serial port or its infrared port and acquires data raw - the EKG leads. The interface with the user implemented in LabVIEW, accomplish the following demands:

- selection of one of the following data presentation: 3 leads visualization; 6 leads visualization; 12 leads visualization;

- access to the patient file and the possibility to update it;

- storage or/and printing data;

- possibility of visualization the 12 standard lead in two ways: *automatically* (with a fix length of the recording waveform) and *manually* (with different length of recording the leads waveform);

- to monitor the rate of the pulse;

- the possibility of setting the speed of the recording;

- easy to use interface that allows medical personnel without a degree in electrocardiography to work with the system;

- possibility to measure the duration as well as the amplitude and the dimension of the elements of the electrocardiogram (the P and T wave, the PQ and ST segment, the QRS complex, etc);

- the possibility in future research of being able to implement a software witch allows the diagnosis of a number of illnesses of the heart.
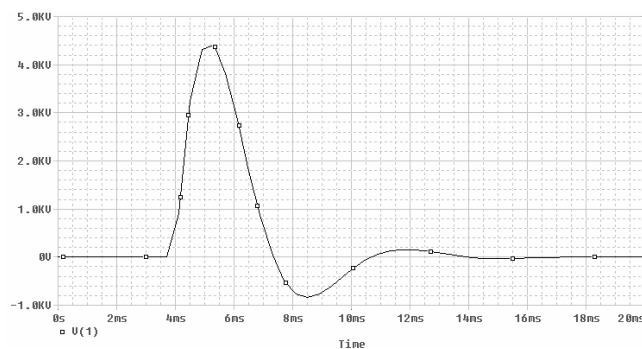

Fig. 4. Defibrillation Impulse.

III. Circuits Simulation

A defibrillation impulse can generate between two electrodes a voltage up to 4.2 KV and duration of 3 ms (Fig. 4). The **Electrodes Interface** gives a protection at the inputs of the EKG amplifier as shown in Fig. 5.

The High-Pass Passive Filter cut the DC component of the leads as shown in the Bode diagram of Fig. 6.

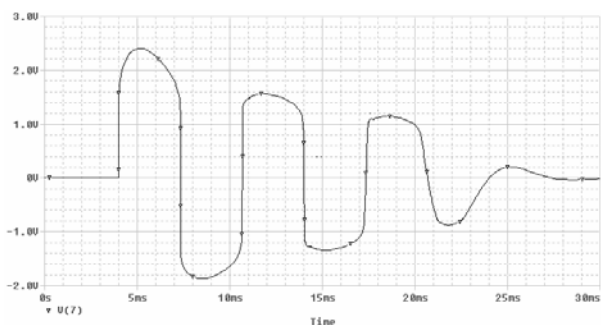The Bode simulation of the anti-aliasing filter is shown in Fig. 7.
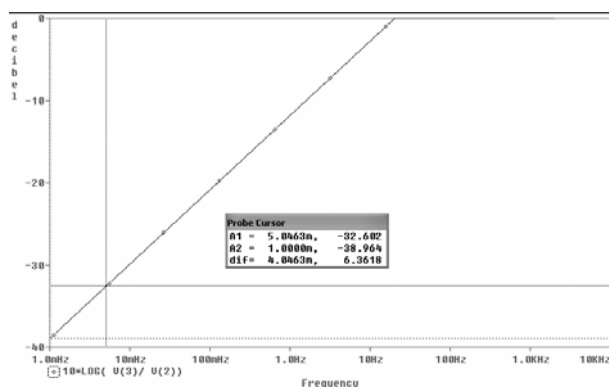
Fig. 5. Electrode Interface result
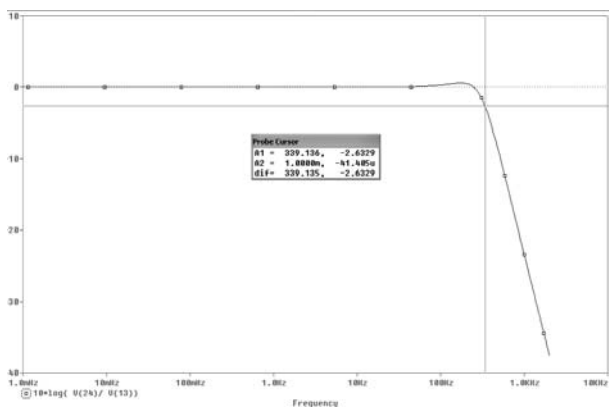

Fig. 6. Bode Plot of High-Pass Filter

Fig. 7. Bode Simulation of the anti-aliasing filter

IV. Results

The friendly user interface design is shown in Fig. 8:

From the user interface, the doctor can choose one of the three ways of visualization of the leads.

The first visualization mode shows either the bipolar leads (I, II, III), the augmented unipolar leads (aVR, aVL, aVF) or the unipolar precordial leads (V1, V2, V3 or V4, V5, V6). Fig. 9 shows the bipolar leads.

The second visualization mode shows either the bipolar leads and the augmented unipolar leads (I, II, III, aVR, aVL, aVF), or the unipolar precordial leads (V1, V2, V3, V4, V5, V6).

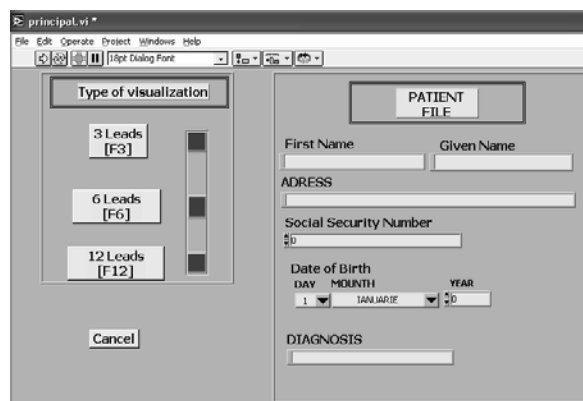The third visualization mode shows all the 12 standard leads.

Fig. 8. User Interface

Fig. 9. Bipolar leads (I,II,III)

V. Conclusions

The EKG acquisition system is cheap compare to other similar EKG. This makes it possible for not only hospitals and big clinic, but also to smaller medical facilities to be equipped with an EKG system.

The acquisition system powered with batteries prevents the patient and the device of receiving macro shocks that can put in danger the life of the patient and of the device.

Being such a small and weightless device used with a laptop or home PC, it is easy to make medical checkup at the patient home.

The software implemented in LabVIEW give the possibility of making further software implementation of desire diagnosis, waveform studies, storage of useful information in data bases, etc.

Adding memory capacity to the hardware and changing the firmware software, it is easy to transform this device in a Holter recording system.

References

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