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APPLICATION OF VIRTUAL INSTRUMENTATION IN ACQUISITION OF ELECTROPHYSIOLOGICAL SIGNALS

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ABSTRACT

In this paper, virtual instrument for high quality recording of heart potentials (ECG) was designed and realized. It is composed of standard electrodes, bioamplifier, National Instruments data acquisition card (DAQ) and PC.
Bioamplifier has high gain (80db) and CMRR (>100db) as well as active baseline suppression. DAQ card enables digitalization of signals. Software module on PC, developed in LabVIEW, represents the user interface and includes features for visualization, processing, and archiving of recorded signal as well as patients data.

KEYWORDS:

virtual instrument, LabWiev, interfaces, visualization, processing, archiving, recording

1. INTRODUCTION

In normal clinical practice, several medical instruments are required for the measurement and monitoring of various physical and physiological data. These instruments function as single, stand-alone devices capable of performing individual tasks and lack the flexibility required to perform multiple tests and kinds of monitoring. In addition, small medical clinics may not have all the required instruments, meaning that patients have to be referred to medical centers for simple physiological tests. It is thus of great value to develop a general-purpose instrument with the cost of a single-functional instrument which can measure different biomedical data [1].

Recently advances in electronics, have made it possible to construct multi-channel systems from just a few high-level off-the-shelf (standardized) components [2]. Because the user controls the technology through software, the flexibility of virtual instrumentation is unmatched by traditional instrumentation. The modular, hierarchical programming environment of virtual instrumentation is inherently

reusable and reconfigurable. These advantages of virtual instrumentation are the basis for increased performance and reduced costs. Moreover, as PC technology continues to evolve so too will the capabilities of virtual instruments based on PC technology [3]. A user can program the same piece of hardware to be an oscilloscope, data logger, or electrocardiograph [4]. Electrocardiography is very common measure in medical practice. Through the use of PCs, ECG data can now be recorded to disk and analyzed with greater flexibility for a more cost-effective solution [4].

2. RECORDING OF ECG SIGNALS

The problems that have to be taken care of recording ECG are [5]: find an optimal hardware configuration

- a front-end : the front-end (an interface between the patent and computer) is responsible for amplifying the analog signals, performing any necessary filtering, and converting the signals into digital form for storage. It requires several aspects to be taken into consideration: good amplification, interference and artifact rejection, isolation and patient.
- frequency sampling rate of analog to digital conversion, there has to be compromise between sampling rate, resolution of AD converter and an amount of data and cost of device on the other hand.

The election of the optimal computer hardware configuration is not a big problem now like it was before. Today a standard PC or laptop with additional data acquisition card and general-purpose software are available. These systems satisfy the needs for acquisition of ECG signals, analyses, storage and display of recorded data.

The interface between patent and instrument must amplify signal, provide an adequate filtration and convert measured signal into digital form. The required differential impedance is Z_d>10MQ and the common impedance is Z_{com} > 100 MQ. The recording signals are very small compared to the noisy environment, so it needs a gain in the range from 60dB to 100dB, a frequency range from at least 0.1 Hz to 100 Hz [6]. A preamplifier needs a high common mode rejection ratio (CMRR > 1 10dB). Isolation must be considered for all human subject connections, including recording electrodes and other transducers. Isolation provides an electrical safety barrier against accidental electrocution [2].

The higher resolution the better are recorded data, but then there is redundancy. With a small sampling rate the aliasing may occur. By Shannon's theorem the smallest frequency of sampling must be twice of the greatest frequency of measured signal. Physiologically important spectrum of ECG is up to 50 Hz. Nowadays the recommended sampling rate frequency is 250 Hz (long term monitoring) to 500Hz and 1KHz (heart rate variability analysis) [7].

3. BIOPOTENTIAL AMPLIFIER

The biophysiological signals are very small compared to the noisy environment elsewhere, the base line is very frequently unstable, and there are different artifacts. The amplifier should use low power components and occupy small PCB area, if it is to be used within portable systems.

For good CMRR of three op-amp I.A. high-gain input stage is needed. In order to avoid saturation due to high amplification of contact potentials arising at electrode-electrolyte interfaces an ac coupling is required [8]. This can be achieved with the passive elements by, for example: (1) placing a series capacitor with the gain setting resistor of the full differential input amplifier, (2) placing coupling capacitor directly at the amplifier's inputs [9], or (3) using bootstrapped buffer which provides both ac coupling and high input impedance [8]. All these ac-coupling configurations can cause a degradation of CMRR and noise characteristics of the circuit [10], [11]. Also, passive dc suppression techniques often require impractical high-valued passive components.

Most of the above problems can be overcome by using active dc suppression techniques. [11]. Some two op-amps configurations and monolithic instrumentation amplifiers based on the current feedback principle [10], provide active dc suppression using the integrated version of the output. In the realization of electrophy siological amplifiers with such active dc suppression, there is a general problem how to subtract input differential voltage with dc-offset and integrated version of the output. It has to be done without degrading the amplifier's balanced structure and CMRR.

One good solution of this problem, presented in [11], is to place a true floating voltage controlled voltage source in the I.A.'s input loop opposite to the dc-input offset source. This floating source was realized as an anti-parallel configuration of two general-purpose optocouplers. In our solution subtraction was done by placing Analog Device's AD8138 differential-to-differential amplifier in the I.A.'s input loop opposite to the dc-input offset source. We designed an ac-amplifier with gain of 80dB, high-pass cutoff frequency of 0.1 Hz and dc-input range of ±90mV

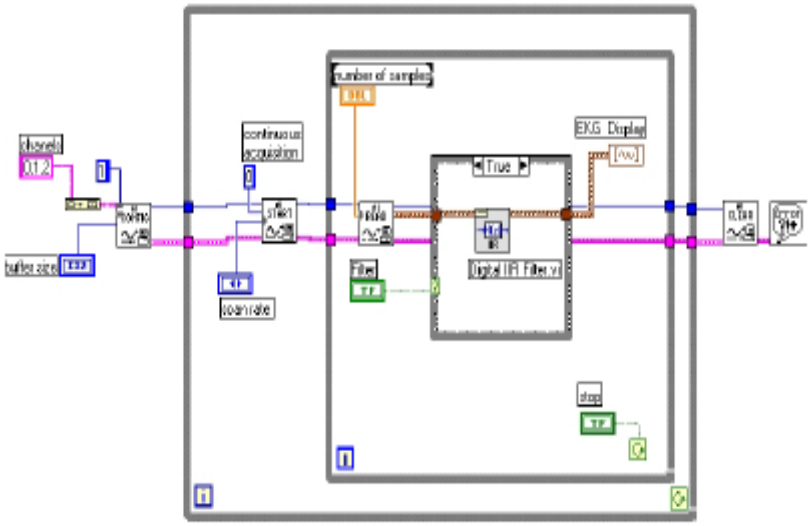
4. SOFTWARE INTERFACE

A software application was deigned in Lab VIEW G programming language. On the figure is application main window. Acquisition parameters can be set by using controls in this window. Sampling rate frequency has to be set before staring the acquisition; default value is 500Hz. Acquired signal is displayed on-line on the graph. Signal can be viewed filtered or in row form. The filter used in this paper was Buterworth low-pass filter with cut-off frequency 50 Hz. The power-line interference can be suppressed, and measurement is satisfying because a spectrum of heart frequencies is up to 50 Hz.

Recorded signals are saved in predefined files, which names consist of name of the patent and a date of recording e.g. PetarPetrovic_12_7_2002. The name can be changed. The recorded data are in spreadsheet format. After recording the signal can be viewed in last 30 seconds by moving scroll bar on the bottom of the graph. The data are stored in file like they are viewed on display. While recording signal is displayed in real-time, the controls for sampling, acquisition and filtering are out of function and shadowed. This is because on-line reconfiguration of acquisition subsystem in Lab VIEW would cause an error.

PICTURE 1. RECORDING OF ECG SIGNAL

On picture 2, is a simplified source code in Lab VIEW. It's called *block diagram.* Icons on diagram represent virtual instruments (VI) in Lab VIEW, which are main tools for G-programming. This code corresponded to the interface on picture 1. First, by using proper virtual instruments, acquisition card, analog channels and buffer for acquired data are configured. The virtual instrument *AI_Config* (Analog Input Configuration) does that. Virtual instrument *AI_Start* sets speed of acquisition and the way whether continuous or not. In this paper was set a continuous acquisition, which uses circular buffer defined by *AI_Config.* Acquired data are stored in buffer. The virtual instrument *AI_Read* empties the buffer with desired speed e.g. defined number of samples. This part of program is in the infinite while loop. When starts, the applications read over and over acquisition buffer and sands data to display. There is an option to pass the data throw the filter. The data are displayed on graph *ECG display.* By pressing the button STOP, application exits the while loop and by virtual instrument *AI_Close* configuration are deleted. On that way the acquisition card can use other applications.



PICTURE 2. SIMPLIFIED BLOCK DIAGRAM

5. HARDWARE CONFIGURATION

The core of virtual ECG monitoring device is standard PC computer - Pentium I, 166 MHz, 64 RAM. National Instruments acquisition card AT-MIO-16E with 16 analog inputs. Application is programmed in Lab VIEW language. Analog amplifier used in this paper is formerly described. On the picture 3, is shown a one channel recording because it is used one channel amplifier although monitor can display 3 channels simultaneously and they can be chosen by buttons. Sampling rate is 500Hz and the low-pass filter is turned on with cut-off frequency of 50Hz.

6. CONCLUSION

In this paper is presented a virtual medical instrument for monitoring of ECG signals. It is developed multichannel ECG monitor by using LabVIEW software and standardized hardware components. The electrophysiological amplifier with active dc-suppression was used. It provides ac coupling from the first stage without degrading CMRR, input impedance or noise characteristics. The instrument is easy to use and implements. It is possible to be upgraded with new software in order to perform more advanced ECG signal processing.

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