Towards a Wearable Device for Capacitive Monitoring of Electrical Bioimpedance of Human Body

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***Abstract*—In this paper, the idea of an electronic device for capacitive monitoring of the rate of breathing and pulse of a human by the means of electrical bioimpedance, is presented. An initial characterization of the prototype of the electronic device is made through the comparison with the computer model. The initial results of the experimental measurements with the relevant discussion and conclusions are submitted.**

***Keywords*—capacitive electrode, electrical bioimpedance, electronic measurements, heart rate, respiratory rate**

I. Introduction

The need for wearable devices, capable of monitoring the vital signs of a human is showing the growing trend in today's world of health awareness. The keywords hereby are: the ease of use, proposing the utilization of capacitive measurements; the oblivious monitoring that implies the small sizes etc.

There are solutions and prototypes available for monitoring the vital signs of human. The monitoring of the changing capacitance of the human trunk during the in- and exhalation [1]; the determination of the shift of wavelength in utilization of optics to monitor breathing [2]; the usage of inductive coil sensors for the monitoring of heart rate (HR) [3] etc. EBI is among the popular technologies: a wearable wirelessly connected prototype of a device to monitor the condition on the tissues [4]; the measurement of the HR from forearm [5] etc.

In this paper, the idea and a prototype of an electronic wearable measurement device for monitoring breathing and HR by the means of EBI by using capacitive connection to the object, is presented. The initial characterization is done on the ground of the preliminary measurements and compared to the computer simulation. The basic principle and the experimental setup are described together with the ongoing developments and plans for the future improvements. The goal is to study the possibility of monitoring the breathing and HR by experimented custom made wearable measurement device.

II. Basic Principle and the Charaterization Of the Device

A. Basic Principle and the Realization of the Device

The idea of the device includes the excitation of the object by a square wave signal and measuring of the real part (ReZ) of the total impedance (modulus |Z|) by using two-electrode configuration. First, the signal is amplified with an inverting amplifier with the gain of 10, multiplexed by analog switch and finally, before low- and high pass filtering, integrated (Fig. 1). The output of the device is dc voltage, which value is expected to increase or decrease because of the in- and exhalation and the changing amount of blood in vessels. The calculation of the value of ReZ will be done by proceeding stages of the device.

The device was realized with discrete electronic components and prototyping printed circuit board (PCB). The square wave generator was based on logic NAND gates of type 74HCT00D and the output was set to 6 MHz – the maximum frequency where the generated square wave was tolerably symmetrical. The op-amps were of type LT6221CS8 by Linear Technology, offering the bandwidth of 60 MHz. The same parameter of the analog switch was 100 MHz, offered by TS5A3159 of Texas Instruments.

B. Characterization of the Device

For setting the configuration of the circuit and evaluating the readymade prototype, a computer model in modelling environment Multisim 13.0 was composed. The virtual op-amps with adjustable parameters were used and the tolerances of passive components were chosen to be the same as in readymade prototype.

In the computer model, human trunk was represented by a single resistor and CMOS transistor of type VN10LF by Diodes Inc. The ratio of voltage divider was set to 10:1, setting the invariable value of the total impedance.

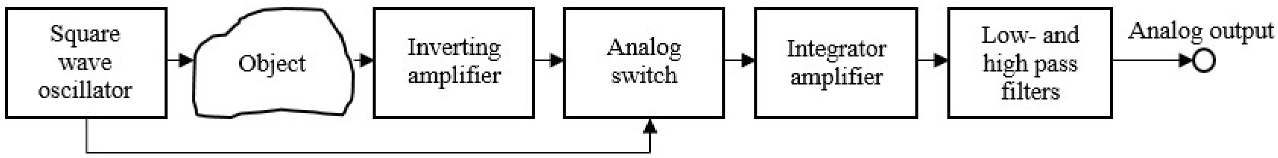

Fig. 1. Block diagram of the electronic measurement device.

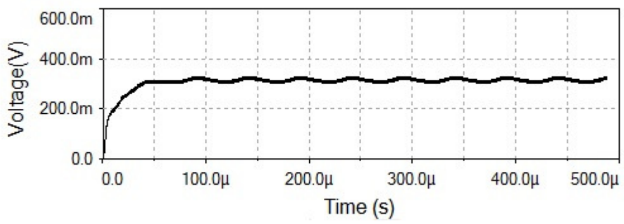

Fig. 2. The shape of the output signal of the computer model.

The amount of the change of ReZ was set by the variable resistance of the channel of the MOSFET, driven by the function generator with a sinus signal of frequency of 20 KHz with amplitude of 0.1V and offset of 2.25V. These values were set by observing the modulation on top of the carrier signal to be visually maximally symmetrical.

The output signal of the computer model showed the availability of the change of the resistance of the MOSFET channel (Fig. 2), constituting approximately 6% of the peak of the measured voltage.

III. Measurement Setup

To measure the impedance of the trunk, large plate surface electrodes of type 22 4773 Electrosurgical Grounding Plates by Niko Medical Products were attached onto the outer surface of a cotton shirt to increase the capacitive connection and ease the measurement experiments. The placement of electrodes cradles the idea of vertically covering the area, where the lungs, heart and large blood vessels are located (Fig. 3). The object was dressed into the shirt, asked to stand still and breathe deeply.

The measurements were done by using the Infiniium 9000 series oscilloscope DSO9204H of Agilent. The result is shown in voltages in time scale, representing the change of the impedance of the trunk (Fig. 4).

IV. Initial Results

From the achieved result, the availability of breathing can be seen (three recognizable breathing cycles in Fig. 4). Nevertheless, HR cannot be recognized by the eye – the reason is assumed to be the small change of ReZ, caused by the pulsating blood, when compared to the additive distortions – presuming the utilization of special algorithms.

The measurement result is containing high frequency noise of 100 MHz (seen as blurred line of the signal in Fig. 4). This is assumed to be caused by the external noise sources,

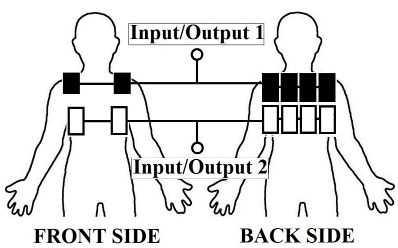

Fig. 3. The setup of the measurement.

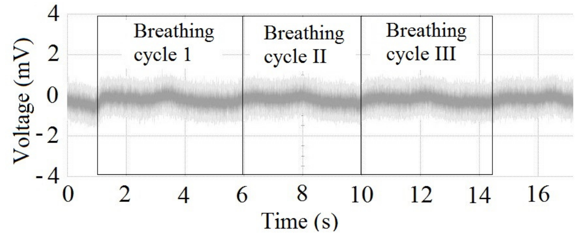

Fig. 4. The measured output signal of the device in the case of measuring the breathing and HR of a real living subject.

which are affecting the measurement setup by the long leads, the discrete electronic components in the design of the prototype etc. To reduce this effect, a first-order low-pass filter with cut-off frequency of 500 Hz at the input of oscilloscope.

The amplitude of the measured voltage, caused by in- and exhalation, stays in the range of 0.5 mV. At the same time, the amplitude of the noise reaches up to 1 mV. The frequency of breathing, according to the recognizable three cycles in Fig. 4, is about 0.25 Hz, constituting about 15 breaths per minute.

V. Conclusions and Future Work

The preliminary results of the capacitive measurements by using the first prototype of the custom made electronic measurement device show the availability of breathing. Nevertheless, the data of HR is not visually available because of the concurrent high frequency noise. This high frequency noise is expected to be further suppressed by using a sharp cut-off frequency low-pass filter at the input of the oscilloscope.

After the full characterization of the prototype of the measurement device and the calculations of the output signal, the next steps will be the switching to the battery based power supply and the placement of the device into hermetic enclosure. After that, the device will be installed into the garment and series of experimental measurements will be done.

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