ADC MODULE FOR MECHANICAL MYO-TONOMETRY SIGNALS PROCESSING

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The paper deals with the design of a special purpose ADC module for processing and discretization of mechanical myo-tonometry signals. It is implemented in purpose to facilitate the medical staff in determination of signals parameters, necessary for calculation of characteristic muscles parameters used for biomechanical diagnostics of functional state of skeletal muscles. The functional block diagram of module with explanations of requirements for the design of main blocks is described. The algorithm of work and software parts with their functions is discussed. Results from mechanical myo-tonometry signals recorded by the described ADC module from one of the hand muscle of a patient are presented and discussed. Some ideas for future improvement of the accuracy, concerning design of acceleration sensor and analogue front-end of myo-tonometry instrument, are remarked in the conclusions.

Keywords: mechanical myo-tonometry, characteristic muscle parameters, biological signal processing

1. INTRODUCTION

Mechanical myo-tonometry (MMYOTON) is a method which performs biomechanical diagnostics of functional state of skeletal muscles [1, 2]. The principle of the MMYOTON lies in using of an acceleration probe to record the reaction of the peripheral skeletal muscle or its part to the mechanical impact and the following analysis of the resulting signal. The investigated tissue responds to the mechanical impact with damped oscillations. From this signal several characteristic myo-tonometry parameters (muscles frequency, elasticity and stiffness) could be determined. Some authors [3, 4, 5] prove that myo-tonometery is a reliable method for measuring skeletal muscle viscoelastic parameters; therefore, such electro-mechanical characterization of the skeletal muscle may provide new insights into muscle function and can help to diagnose the stage of pathological processes of muscles. The review of the references shows that MMYOTON is a promising method for development of new research of skeletal muscles and their functional state. This provoked the interest of medical doctors in Department of Physiology in Medical University of Plovdiv for development and realization of instrument for measurement of muscle response and further processing and registration.

2. PROBLEM STATEMENT

First, autonomous electronic module (MYOTONUS) with inductive sensor was designed from the technical staff of Medical University of Plovdiv. The inductive sensor converts the velocity (***v***) of the muscle movement, resulted from a short mechanical impact, to analogue electrical signal, which is amplified and processed by means of electronic circuits to produce two more signals: the original of muscle displacement (***x***) and the acceleration signal (***a***). Then, these three signals are registered on conventional three-channel ECG for visualization and further manual processing, in purpose to determine several parameters necessary for calculation of characteristics myo-tonometry parameters (muscles frequency, elasticity and stiffness). An idealized graphical visualization of the waveforms of muscle displacement (***x***), velocity (***v***) and acceleration (***a***) presenting muscle reaction to a single short mechanical impact is illustrated on Fig. 1 [1].

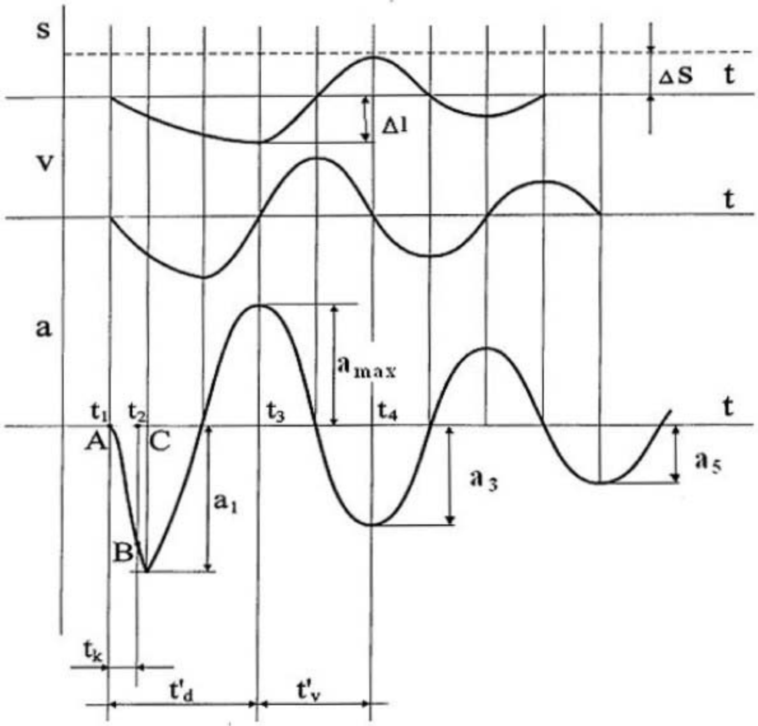

Fig. 1. Waveforms of displacement (***s***), velocity (***v***) and acceleration (***a***) signals presenting muscle reaction to a short mechanical impact.

The acceleration value of the first period of oscillations, calculated from the oscillation graph, characterizes the deformation of the tissue. The data of the next oscillation period provided the basis for calculating the ***oscillation frequency of the tissue (f)*** [1, 2]:

(1) $$f = \frac{1}{T}[Hz]$$

where: ***T*** is the oscillation period in seconds.

The logarithmic decrement ***(Θ)*** of damping was calculated according to following relation:

(2) $$\Theta = \ln\frac{a3}{a5}$$

where: $\boldsymbol{a_3}$ and $\boldsymbol{a_5}$ are the oscillation amplitudes (the third and fifth minimum) of acceleration (***a***) signal.

The logarithmic decrement of the damped oscillations characterizes ***tissue elasticity***. The decrement is inversely proportional to elasticity. ***Stiffness (C)*** reflects the resistance of tissue to the force that changes its shape and it was calculated by formula:

$$C = \frac{m.a_{\max}}{\Delta l}[N/m] \qquad (3)$$

where: $\boldsymbol{m}$ is the mass of the sensor in the testing end of myo-tonometer, $\boldsymbol{a_{max}}$ - the maximal amplitude of oscillation in (***a***) signal, $\boldsymbol{\Delta l}$ - the amplitude of the first minimum of the displacement (***s***) signal.

The tissue tone is a biomechanical property of the tissue which can be characterized by two main parameters: stiffness and elasticity.

The manual determination of signal parameters from the ECG paper records, as it was done before, is very time consuming, boring and not enough accurate. This was the reason to design a special purpose ADC module for processing and discretization of mechanical myo-tonometry signals. The main requirements for design and realization of the module are described in this paper.

3. DESIGN OF ADC MODULE

The main aim in design of the presented ADC module was to perform amplification, filtering and discretization of the three analogue signals, registered by the described above module MYOTONUS, for a defined period of time, to transfer data to a PC and save them in a file for further visualization and digital processing. The technical requirements for the design of ADC module are determined from the specifics of the signals and the output parameters of the existent MYOTONUS module.

The shapes of the registered signals, as it could be seen from fig.1, are damped oscillations produced as a result of a short mechanical impact on investigated muscle. The frequency of oscillations is in the range of several Hz to 30Hz, depending on the functional state of the tissue. The amplitudes of the signals in the outputs of MYOTONUS module are in the range from -10mV to + 10mV. After first amplification of the signal, a stop-band filter for rejection of 50Hz interference in every one of the three channels is necessary to be realized.

For registration of myo-tonometry signals short mechanical impacts on the investigated muscles are produced by a small electronic hummer every second. Considering the recommendations of medical doctors to have 10-11 muscle responses, the period of time for registration of myo-tonometry signals is fixed to approximately 11 sec.

The functional block diagram of the described ADC module for mechanical myo-tonometry signals processing is illustrated on Fig. 2.

The analogue part of the module is presented by the three analogue channels, where amplification and filtration of the three signals (***s, v, a***) coming from MYOTONUS module are performed. Every analogue channel consists of three stages: Input amplifier, 50Hz stop-band filter and additional amplification stage with dc-level shifting. The whole gain of amplification in every channel is 200, distributed between input amplifier and the third stage. To position the signals in the middle of input range of AD-converter a dc-level is added to the amplified signal in the third stage of the three analogue channels. This dc-level does not represent the real physical situation for recorded signals (muscle displacement, velocity and acceleration) and has no relation to the interested characteristic muscle parameters.

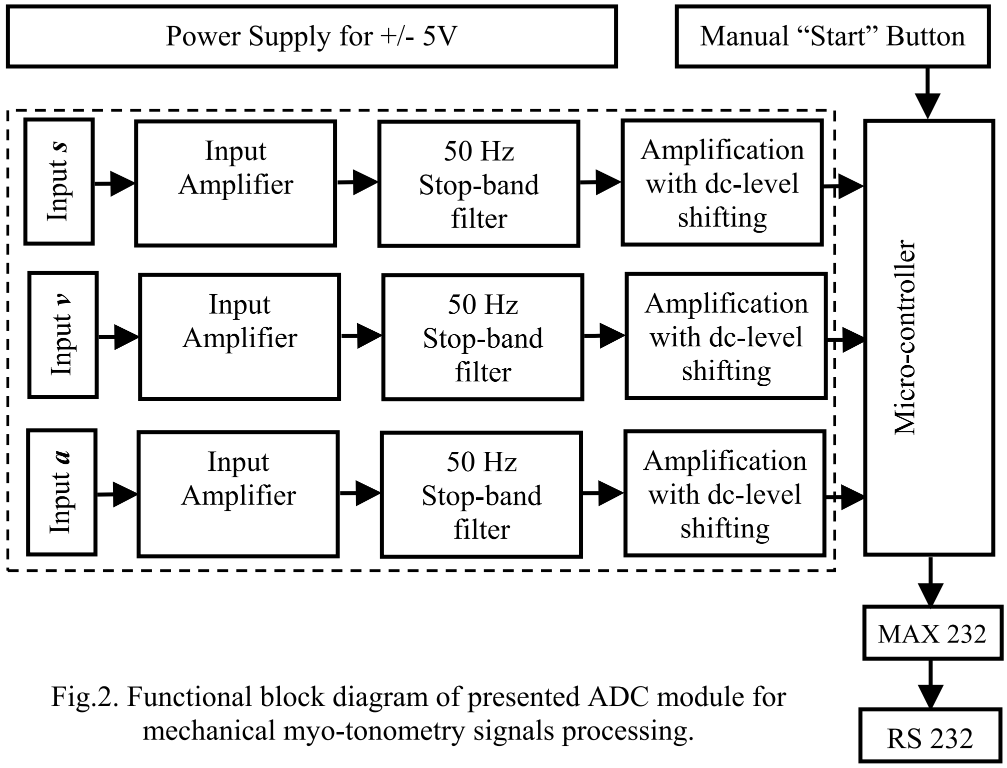

Fig.2. Functional block diagram of presented ADC module for mechanical myo-tonometry signals processing.

The choice of suitable microcontroller is based on several technical requirements: low power consumption, internal AD-converter (at least 3-channels), high efficiency, embedded hardware for serial communication, available tools (KIT) for design and programming. In our design we have chosen microcontroller ATMega8 [6] produced by Atmel Corp. Taking into consideration that all older PCs have at least one serial port, for connection between the ADC-module and PC the RS-232 interface is employed. Conversion of logical levels from TTL to RS-232 is realized by integrated circuit MAX 232.

The algorithm of work for microcontroller could be divided into two parts. The main part is responsible for:

- initial initialization of microcontroller after switching power "ON";
- watching for the signal from manual "Start" button;
- discretization of the signals, coming from the three analogue channels to the AD-converter inputs, with frequency of 675Hz;
- data conversion into ASCII code;
- asynchronous serial data transfer, by means of embedded USART controller - (the speed of data transfer is 115 200kbs and the format of data is (8-1-N)).

The AD-conversion is with 10-bit accuracy, thus every measured value is represented and transferred to the PC by five bytes – four data bytes and one for symbol "CR".

The other part of algorithm is dealing with timers. It is responsible for:

- setting the frequency of discretization to 675Hz;
- software setting of a flag for start of new measurement;
- counting the time for the whole period of registration of myo-tonometry signals to be approx. 11sec.

To accept the data in the PC, first we used standard terminal program (HyperTerminal for Windows). The data are saved in a text file and then they could be read and visualized by some other programs. Later, because it was necessary to perform some digital processing and analyzing of recorded myo-thonometry signals, a special purpose MATLAB Toolbox was designed, described in a next paper.

4. RESULTS

An example of myo-tonometry signals, recorded by the described ADC module, from one of the hand muscle of a patient is visualized on Fig. 3. The scale in the X-axis is in msec and in Y-axis - in the received from ADC module digital values. Now the signals parameters necessary for calculation of described characteristic myo-toniometry parameters could be determined easily and more accurate.

As it could be seen from the graphics there is a 50Hz interference left on the signals. Additional digital filtration is recommended in such case.

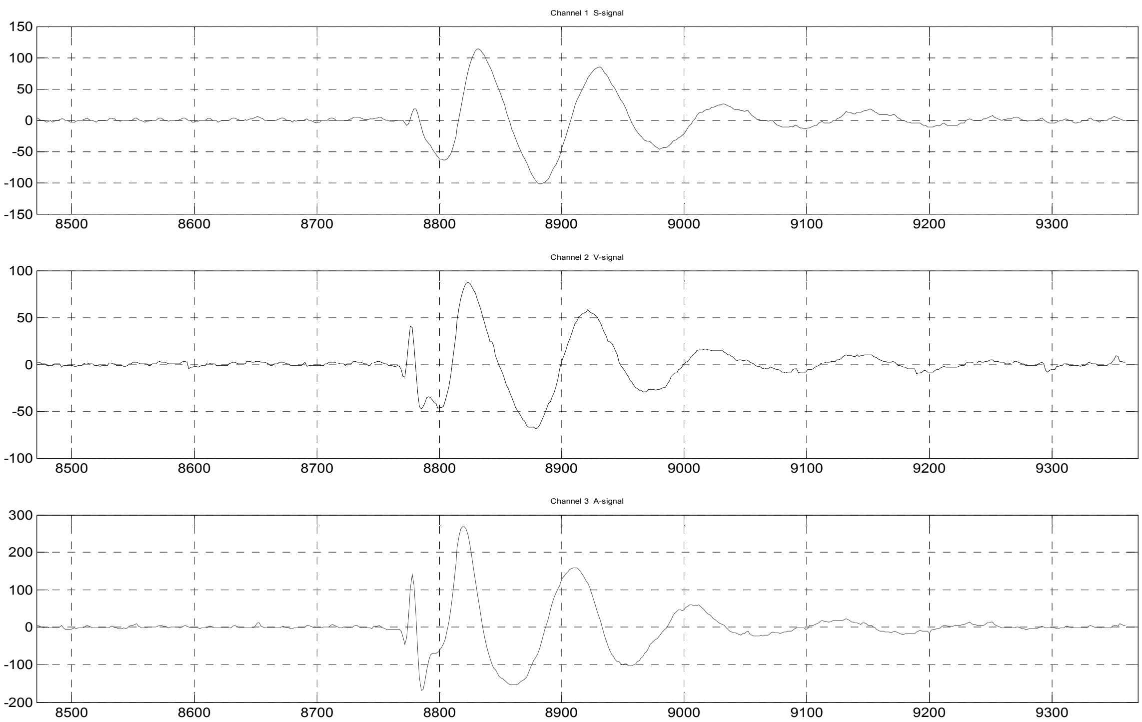

Fig.3. An example of recorded real myo-tonometry signals, registered by presented ADC module.

The accuracy of the whole measurement of myo-tonometry signals highly depends on the design of MYOTONUS input module, where the displacement (***s***) and acceleration (***a***) signals are received by means of analogue integration and differentiation.

To improve the accuracy, we intent to design a new analogue frond-end using suitable acceleration sensor, and after amplification and discretization of (***a***) signal, to receive the displacement (***s***) and velocity (***v***) signals by digital processing. In such a way some drawbacks of analogue signal processing will be overcome.

5. CONCLUSIONS

This work proves that the designed special purpose ADC-module allows to perform processing and visualization of mechanical myo-tonometry signals, which facilitate medical doctors in biomechanical diagnostics of functional state of skeletal muscles.

In the process of data collection we also noticed that the place and type of the mechanical impacts over investigated muscle have influence on the shape of recorded signals. Therefore, the future step for improving the myo-tonometry instrument will be the design of special mechanical construction to fix the relative positions of the electronic hummer and the acceleration sensor in order to assure equality in conditions for registration of myo-tonometry signals.

6. REFERENCES

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