APPLICATION OF BLUETOOTH INTERFACE IN SYSTEM FOR KINESIOLOGICAL STUDIES

Daniel L. Tsvetanov[1], Vessela Tz. Krasteva[2], Ivo Ts. Iliev[1]

1) Department of Electronics - Technical University of Sofia ,8 Kl. Ohridski str., 1000, Sofia, e-mail: dzvetanov@daisytechbg.com, izi@tu-sofia.bg

2) Centre of Biomedical Engineering "prof. Ivan Daskalov" - Bulgarian Academy of Sciences Acad. G. Bonchev str., Bl 105, 1113, Sofia, e-mail: vessika@clbme.bas.bg

The aim of the present work is to develop a portable system for EMG studies in kinesiology, which is directed to analysis of the coordination of the muscles during movement/stationary in normal and pathologic conditions. A specific requirement to such systems is to provide freedom in the patient's movement, without the inconvenience due to the long cables movement and the difficulties in electrodes fixing. This was achieved by implementation of a wireless data communication based on the Bluetooth technology. The developed system for kinesiological studies consists of two parts: (i) portable EMG signal acquisition module and (ii) remote PC host with software for EMG data processing, visualization, recording and printing. The developed system was implemented in kinesiological studies for acquisition and registration of one-channel EMG signals. EMG recordings from surface electrodes and during sustained isometric muscle contraction and different loading levels were subjected to time-domain analysis and power spectrum estimation in order to demonstrate the adequacy of the recorded EMG signals.

Keywords: Acquisition system, Bluetooth interface, Myograph signals, FFT

1. INTRODUCTION

The electromyography (EMG) is a diagnostic method for acquisition and registration of the bioelectric activity potentials generated by the muscles. The main objective of the clinical electromyography is to investigate general muscle alterations, to determine the initiation of muscle activation, and to assess the coordination or imbalance of the different muscles, which are involved in the study of the movement [1]. The normal levels and the activity types are studied, aiming to detect any pathological changes provoked by different diseases. The special requirements to the hardware acquisition system of the analysis equipment have to be conformable to both the wide amplitude range (10μV-100mV) and the wide frequency range (2 Hz - 20 kHz) of the registered signals. This broad amplitude and frequency range of the EMG signals is due to the acquisition of the activity potentials from a variety of motor units, including single muscle fibers, as well as, large muscle groups. To cover the whole variety of EMG signal characteristics, the nowadays diagnostic EMG equipment is profiled in dependence of its particular application, including more narrow amplitude and frequency range, choice of adequate electrodes shape and placement, specific requirements to the registering system in dependence of the type of the study, etc [2].

The aim of the present work is to develop a portable system for EMG studies in kinesiology, which is directed to analysis of the coordination of the muscles during movement/stationary in normal and pathologic conditions. A specific requirement to such systems is to provide freedom in the patient's movement, without the inconvenience due to the long cables movement and the difficulties in electrodes fixing. This was achieved by integration of wireless communication between the EMG signal acquisition module and the PC host for data visualization and recording.

Fig. 1. Wireless EMG data acquisition system

2. Hardware and Software Solutions

The developed system for kinesiological studies consists of two parts (fig.1): (i) portable EMG signal acquisition module and (ii) remote PC host with software for EMG data processing, visualization, recording and printing. Both parts are communicating through wireless bluetooth interface.

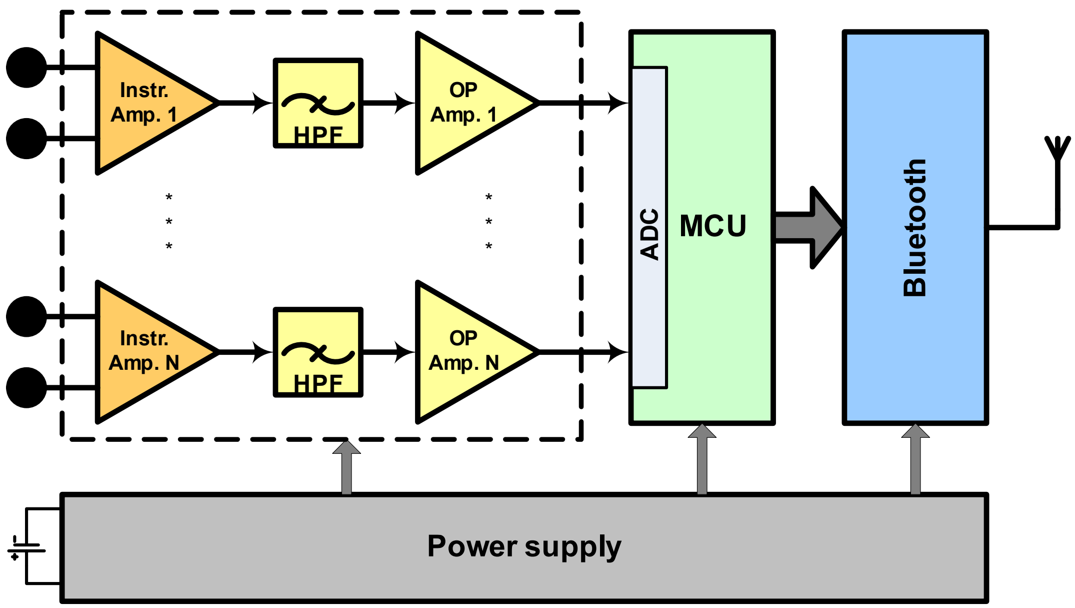


Fig.2. Block circuit of the portable EMG signal acquisition module

The block circuit of the portable EMG signals acquisition module is presented in fig. 2. The module was designed to acquire kinesiological EMG signals, which are in the frequency range (2-500 Hz), with input amplitude of about several milivolts. The portable acquisition module consists of the following parts:

- **Analog input amplifiers** – designed to amplify the low amplitude muscle signals (the total gain of the stage is about 350). The number of the input amplifiers is limited to the number of the analog inputs of ADC. Every amplifier section consists of the following three stages:

- *Input instrumental amplifier* with small gain for suppression of the common mode input voltages (e.g. power network sources impact);
- *High pass filter* for removing of the input DC. The first order filter was designed with frequency response defined at 2Hz;
- *Operation amplifier* (with low pass filter in the feedback) for amplifying the analog signal to the ADC input range (0-2.5V), and limiting its bandwidth to 500Hz.

- **Micro-Controller Unit (MCU)**. A micro-power controller with integrated ADC for sampling, converting, processing, and transmitting the captured analog data. (The Texas Instrument's MSP430F139 was chosen due to its 12bit 10-channel ADC and its ultra low-power operation – 250uA/MHz).
- **Bluetooth module** with all the required RF circuits and a processor for controlling the Bluetooth stack functionality (CSR's BTM2302).
- **Power supply module** that outputs all the required for the system voltages, derived from a single Li-ION battery. The module also controls the battery charging from an external voltage source.

The remote PC part of the developed system consists of a custom PC application software for myograph signals visualization, storing and control, which is running on a Bluetooth enabled system. The general view of the software is presented in fig. 3.

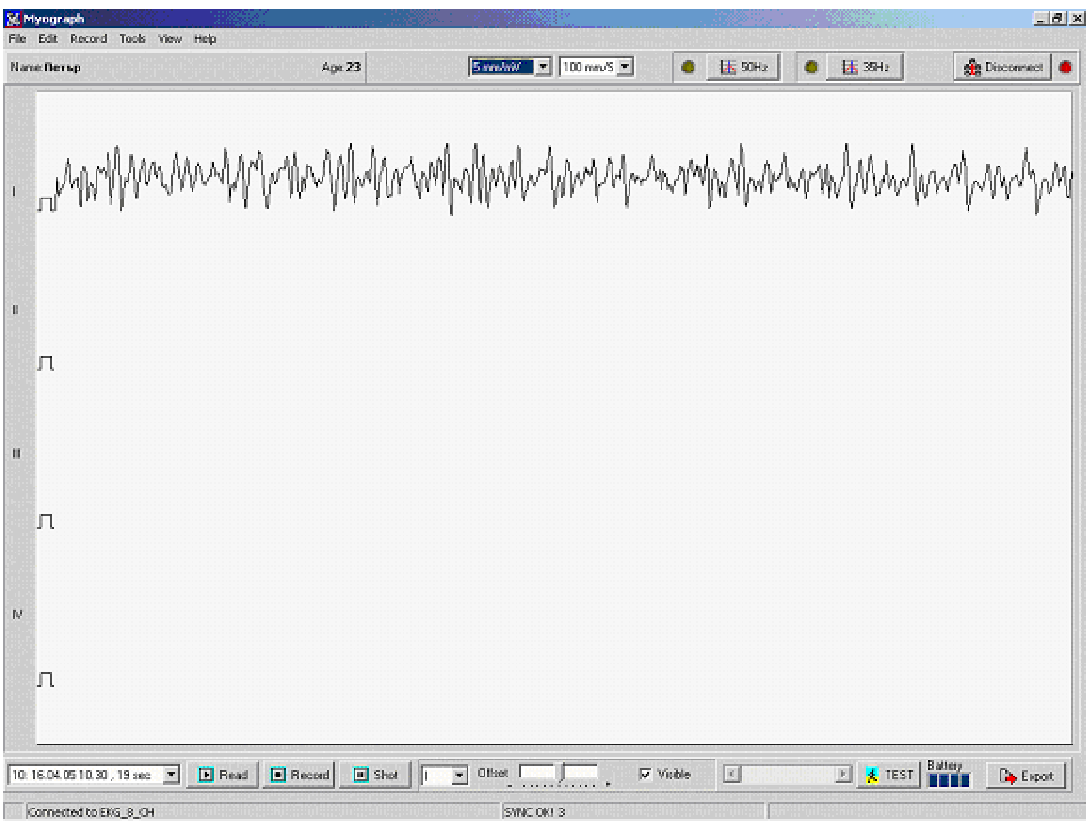


Fig.3. General view of the PC application of the Myograph system

After connected to the remote registering device, the real-time EMG signal from the electrodes is displayed. The signal characteristics (speed, amplitude, DC offset) could be changed in runtime. The software supports a patient's database, which contains an additional information about the patient. Moreover, each EMG record is identified with a number, captured time, record length, and is attached to the respective patient database. Capturing the data begins by pressing the "record" button, and finishes when the "stop" button is clicked. An EMG signal recording could be selected from the database and processed offline. The processing includes filtering, zooming and shifting (left and right, up and down). The signal on the screen can be printed anytime by pressing the "print" button. Exporting the data to an ASCII file (e.g. for further post-processing in Matlab) is also supported.

The wireless range that the Bluetooth technology provides is up to 100m (in moderate obstacle environment), which does not limit the motion activity of the analyzed patient. Moreover, an average power consumption of 15mA from a regular Li-ION battery makes it the ideal portable equipment for long-term analysis, which can be attached with short cables directly to the patient's body.

3. Results

The developed system was implemented in practice during kinesiological studies for acquisition and registration of one-channel EMG signals with sampling frequency up to 2kHz. The sampling frequency is not limited by the bluetooth channel badwidth (720kbit/s), but its only limitation results from the real-time EMG data visualization on the PC screen. Several examples of EMG signals, which were acquired through small surface electrodes, placed over the biceps brachi (the position of fig.1), are presented in fig.4. The applied sampling frequency is 1 kHz. The EMG signals demonstrate the EMG time-domain activity during arm flexion with sustained isometric muscle contraction and different loading levels. The time-domain kinesiology study observes the form of the EMG trace for a period of 10-20 s in order to detect any disturbances in the bell-shaped muscle activity.

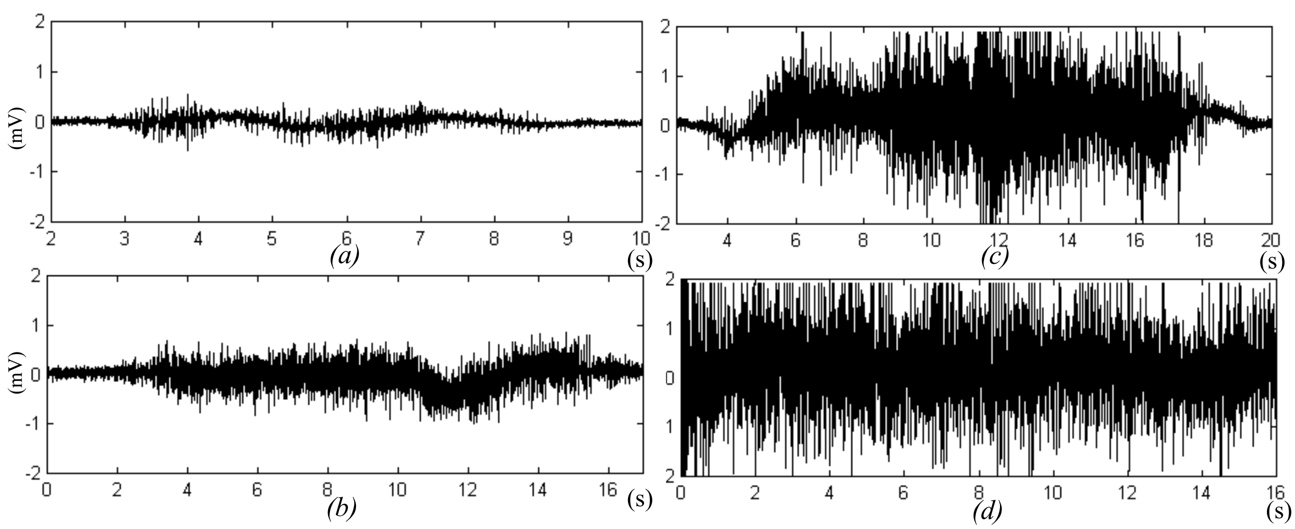


Fig.4. Time-domain graph of EMG signals, acquired during: (a) flexion of the arm (without loading); (b) flexion of the arm (picking up a load of 4 kg.); (c) flexion of the arm (picking up a load of 8 kg.); (d) sustained isometric muscle contraction.

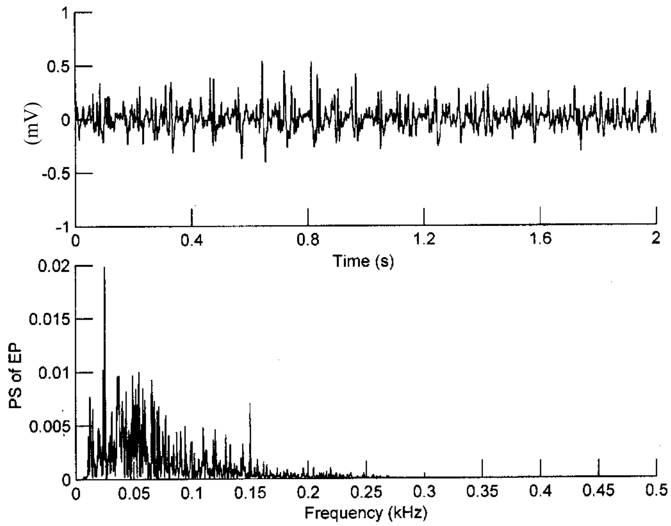
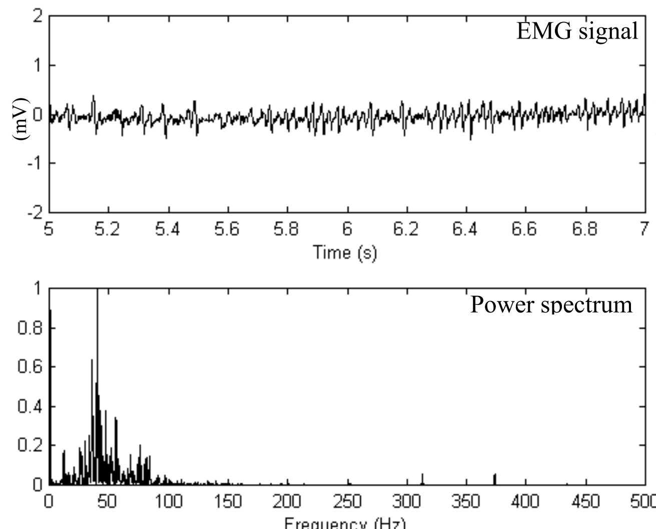
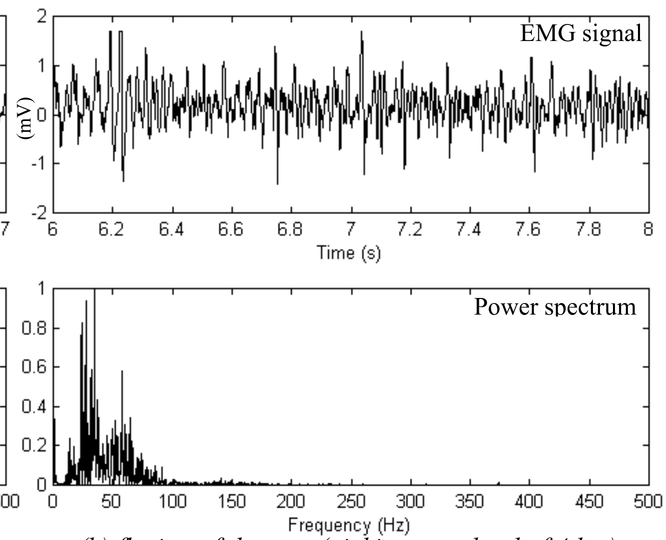


Fig.5. EMG signal and its power spectrum from a standard EMG system

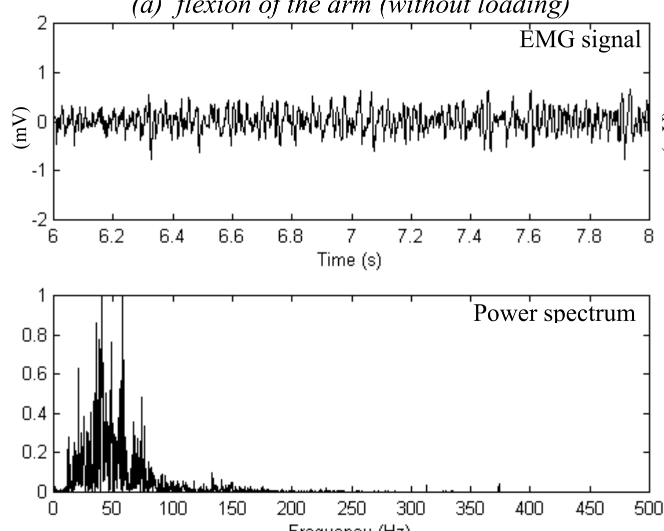
In addition to the time-domain analysis, a study of the EMG signal in the frequency domain is also applied in practical experiments. We performed Fourier transform to estimate the EMG power spectrum for 2s episodes of muscle activity during the arm flexion. The comparison between the EMG signal and its power spectrum (acquired with standard EMG system (fig.5)) and the signals, which are acquired with the developed EMG system (fig. 6) demonstrated the adequacy of the new EMG recordings for diagnostic studies.



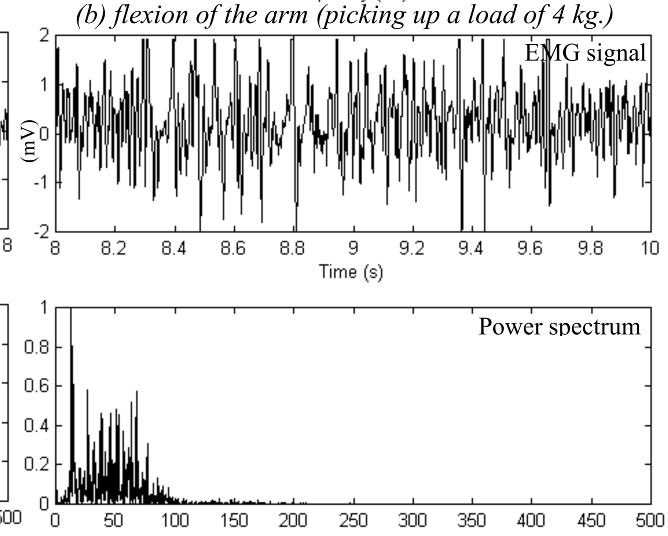
(a) flexion of the arm (without loading)



(b) flexion of the arm (picking up a load of 4 kg.)



(c) flexion of the arm (picking up a load of 8 kg.)



(d) sustained isometric muscle contraction

Fig.6. EMG signal frame of 2s and its power spectrum for the examples of Fig.4.

4. Discussion and Conclusion

In the first instance, EMG signal kinesiological analyses are qualitative with the inspection of the shape of the raw signal (Fig.4), searching for a muscle activity fatigue for a preset period of time (for example 10-20s). This technique is based on the suggestion that weakness in certain muscles relates to specific disease states or imbalances in the body [1]. In the last decades, the application of mathematical models and statistical analyses has offered a better understanding of the EMG signal properties, allowing the evaluation of the physiologic events of muscles. The EMG signal is analyzed in the time domain with a number of indexes such as, the mean area under some parts of the EMG waveform, or the root mean square index [2] $RMS = \sqrt{(\sum_{i=1}^{N} X_i)/N}$, where X_i is the i-th sample of the digitized EMG signal with a total number of N samples involved into analysis. A lot of studies apply spectral analysis techniques [4-6], accepting that the power frequency components are indicative for the activation of a definite muscle groups. In normal conditions, the EMG signal spectrum has a particular bell-shaped form (with central or median frequency, which are used as a descriptors) and any other changes are symptomatic for pathological conditions. The reported change of the time-domain signal waveform and the spectrum shape during a constant isometric contraction as the force level is increased [5], was also demonstrated in our study (fig.4 and fig.6). The signal power spectrum is representative for the adequate performance of the input amplifiers embedded in the developed system, which magnify the differential input EMG signal, and suppress the common interference from the power network sources. There is not observable a large peak with the frequency of the power supply voltage.

The development of the new EMG signals registration system, which: (i) operates with small and light portable module, connected to the patient electrodes, (ii) transmits data through wireless bluetooth interface and (iii) processes/visualizes the EMG signals by a user-friendly software on remote PC, gives great possibilities to expand the application of the kinesiological studies in long-term monitoring of muscle activity and the early diagnostic of pathologic muscle conditions.

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6. References

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