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Lightweight embedded system for acquiring simultaneous electromyogenic activity and movement data (Function-EMG)

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ABSTRACT

In this paper we present a new system for measuring human musculoskeletal biomechanics by acquiring electromyographic (EMG) data simultaneously with motion data. This light microcontroller-driven measuring system can acquire data from six channels and transfer, monitor and record it in real-time into a microcomputer via USB connection. Recorded data can be stored in well known European Data Format.

1. INTRODUCTION

Electrical muscle activity, denoted as electromyography (EMG), is a consequence of the functional properties of the muscle cell. An EMG signal acquired using surface electrodes indicates the level of activity of a muscle, and may be for example used to diagnose neuromuscular diseases, emotions (when recorded from facial area), and dysfunction associated with musculoskeletal pain [1, 2, 4]. Surface EMG recordings are complex signals of interference of electrophysiological patterns with frequency band up to 150 Hz. The amplitude of surface recordings is typically some hundred microvolts.

Time-synchronized acquiring of movement data (change of angle, posture or motion) simultaneously with EMG makes totally new aspects of function diagnostics possible [3]. Recording movement data typically needs light, portable, and unobtrusive measurement system. At its best the measurement system minimally constrains the subject's motional performance.

In many experimental arrangements it is useful to be able record data bilaterally from subject, for example both limbs, or both sides of body, simultaneously. That is why at least two independent channels for movement sensors and two independent channels for EMG acquiring are needed. More advanced recordings need more channels for EMG data.

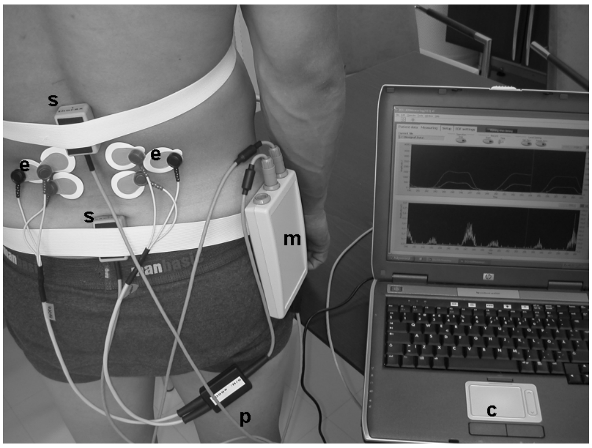

Fig. 1. The illustrative function-EMG measuring setup from low back area: m) main unit, e) surface EMG-electrodes, s) movement sensors, p) EMG preamplifier, c) microcomputer.

2. MEASUREMENT SYSTEM DESCRIPTION

2.1 Sensors

The EMG-preamplifier unit is composed of two amplifier stages. Three ECG surface electrodes (Medicotest M00S) are connected to amplifier with three wires to differential coupling. The signal is high-pass filtered (-3 dB corner frequency 5 Hz), amplified one thousand (1000x) times and output voltage is transferred to main unit. The EMG-preamplifier needs regulated -5 volts and +5 volts power supply, grounding and output for measured data. All sensors with their preamplifiers are powered through main unit.

Movement sensors are commercially available (jssf-Motion Sensor) based on inclinometric type element, in which the output voltage is proportional to sensors position. The sensors angle from upright position can be calculated from output voltage. Operational region is about 180 degrees. The movement sensors are capsulated in plastic box and they need regulated +5 volts power supply, grounding and output for measured data.

2.2 Main unit

The structure of embedded main unit contains separate isolated analog electronics part and digital electronics part. The analog part and digital part are shielded with optic coupling in SPI data bus and with DC/DC-converters in power supply exceeding standards for patient's safety of body floating medical electronic device. In the analog part sensors are connected to 12 bit analog-to-digital-converter (ADC, Microchip MCP3208 eight channel converter) via the anti-aliasing filters (Sallen-Keyn type low pass filters, -3dB corner frequency 250 Hz) [5]. The sampling frequency is 1000 samples per second per channel in all six channels used. The bidirectional SPI (Serial Peripheral Interface) bus connects the ADC and the microcontroller via fast optic coupling. The heart of the digital part is microcontroller (MCU, Microchip PIC 16F877) with Flash-memory containing all needed software of the main unit [6]. The digital part contains also USB driver circuit and connector and reset and power management components.

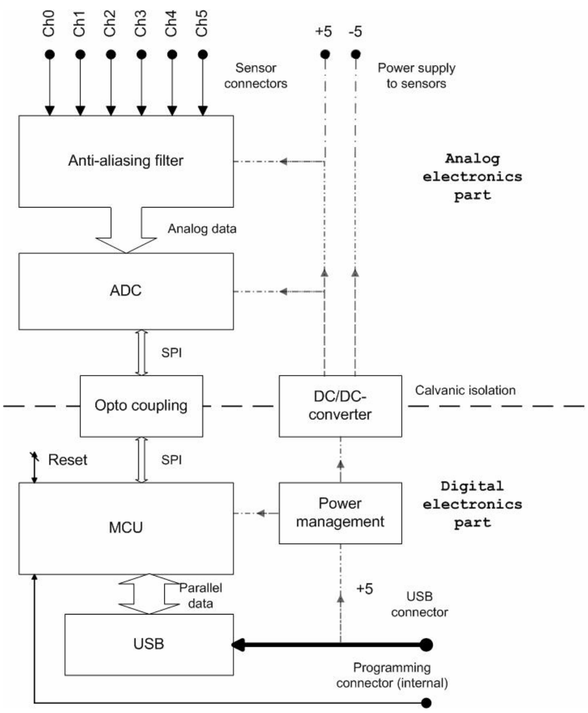

Fig. 2. The block diagram of the main unit.

2.3 USB data transfer to microcomputer

The USB (Universal Serial Bus) connection make both power feed from microcomputer and overwhelmingly faster data transfer possible [7]. Via USB connection all needed power can be supported to embedded main unit and no batteries are needed. We have used FT245BM USB FIFO circuit (Future Technology Devices Intl. Ltd, 2002) to equip PIC microcontroller with standard USB connection [8]. The bidirectional connection between USB circuit and MCU is 8 bits parallel. On-board circuit implements USB controller, protocol engine and transceiver in one chip. It also offers virtual COM port (VCP) drivers for microcomputer operating system (Windows 98/Me/2000/Xp) so that the measuring system device looks like a standard COM port to the application software. Although USB Direct Drivers and software interface is also available for microcomputer operating system, we have used VCP alternative to keep compatibility with older card versions with standard COM connection.

Data transfer from embedded main unit to PC microcomputer is real-time, which is essential in many intended target of usage. The changes in the electromyogenic and motion event can be seen on the screen with some ten milliseconds lag. Data transfer and monitoring program for microcomputer side is implemented with the LabVIEW 6.1 (National Instruments Inc, USA) development system. The program can save recordings up to 40 s duration in European Data Format (EDF) [9], which supports usage of many third-party biosignal applications and also user initiated application development. Patient and recording identification information can be saved to files together with recorded data. Separate program modules (LabVIEW virtual-instruments) have been implemented for writing and reading EDF files.

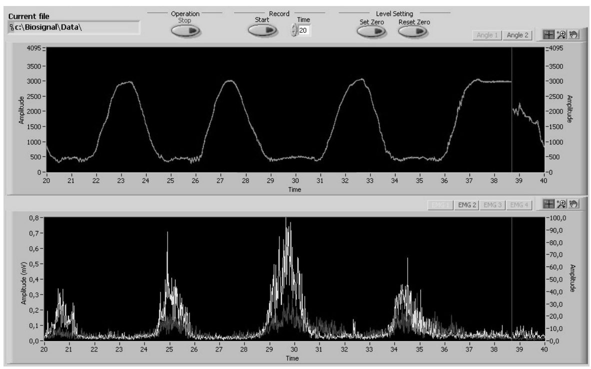

Fig. 3. Snapshot from a recording. In upper graph motion data in raw format and in the lover graph EMG activity.

The data transfer and monitoring program saves EMG data direct converter 12 bit integer format, in which value 1000 means 1000 mV respectively when EMG-preamplifier is used. The motion data is saved in integer values 100 times degrees, but can be also saved in raw data format.

3. TESTS OF THE SYSTEM

Movement sensors connected to main unit are calibrated using calibrating bench with protractor. With extensive tests the relation between output voltage and sensor angle is defined better than ±2 degrees accuracy.

EMG-preamplifiers, also in connection with main unit, are calibrated with voltage generator and precision attenuator using sine wave signals (sum of up to three sine). Within tests the error is less than 12% with 20 Hz input signal frequency and less than 7% with 100 Hz frequency.

The whole measuring system for function-EMG is also passed all patient safety tests, including leakage current and EMC tests needed for using measuring system in clinical context and will be commercially available. First preliminary testes with young healthy volunteers have been already done and preliminary results have been very promising.

4. CONCLUSIONS

The possibility to measure synchronously other data in parallel to electromyogenic activity with totally portable system inspires us to many fresh ideas. Instead of movement data the parallel synchronous data can be acquired for example from gym equipment or it can be timing pulse data from video recording system.

In nutshell, the novelties of developed system in addition to polygraphy data source are portability, innovative use of USB connection in biomedical purposes and fresh application of EDF file format. Although the current results are auspicious, extensive additional development is in process in order to produce a versatile multipurpose measuring system.

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