General-Purpose Module for Acquisition of Low-frequency Bio-Signals and its Application to Skin Conductance Monitoring

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***Resumo* – Este artigo descreve o desenvolvimento de um módulo de aquisição de sinais biológicos de baixa frequência, assim como a sua importância e aplicações, em particular na monitorização de conductância da pele.**

***Abstract* – This paper describes the development of a general purposes module for acquisition of low frequency bio-signals, its importance and applications, in particular in the skin conductance monitoring.**

I. INTRODUCTION

The growing importance of monitoring low-frequency biosignals in polygraphic recordings led us to the development of a general-purpose module for acquisition of this type of biosignals. We developed a scalable board, based on a single chip processor of very low cost that can be used in several scenarios of low-frequency biosignals acquisition. The particular case of the application of this board to Skin Conductance Monitoring will be presented

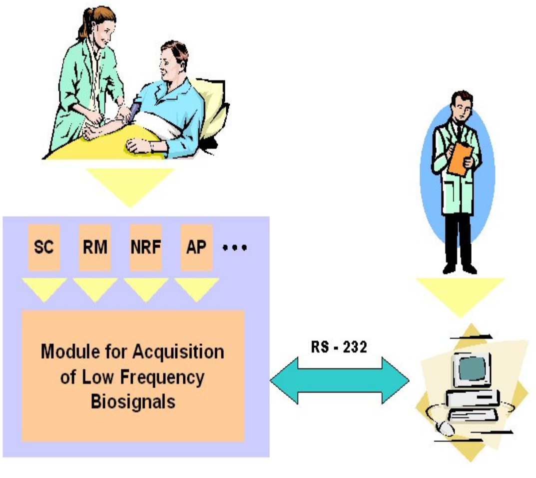

Fig.1 –Using the Acquisition Module

II. BACKGROUND

Low Frequency biosignals such as Skin Conductance (SC), Respiration Movements (RM), Nasal Respiration Flow (NRF), Arterial Pressure (AP), etc. are many times important to be monitored in polygraphic recordings in different clinical environments. One problem usually encountered is that the commercial devices available in the market are analogue or the equipment manufacturer does not release its digital output or the solution is not scalable and often expensive.

We developed a general-purpose low cost acquisition board for low frequency biosignals (Fig.1) based on a single-chip microcontroller to answer to this problem.

III. HARDWARE ARCHITECTURE

A. Multiple Analogue Channel Module

The board was based on the MICROCHIP Microcontroller PIC16C73A [1], an 8-bit microprocessor with Analogue to Digital converter, featuring a high-performance RISC CPU, wide operation voltage range and low power consumption. [2]

The use of the PIC16C73A enabled us to have up to five analogue inputs that can easily be increased to 10 or more with the use of multiplexers, due to the 20 MHz clock of the Microcontroller.

Because of the very low frequency variation of the targeted biosignals we used an 8 MHz high-speed AT strip cut crystal oscillator. A much slower crystal could be used for this particular task because the reconstruction of these low frequency biosignals don't need more than ten samples per second, but it was chosen in order to give the possibility of the use of the 5 analogue inputs of the Microcontroller (with or without previous multiplexing).

It has a Universal Synchronous Asynchronous Receiver Transmitter (USART) that allows communications up to 115 Kbps independently of using a 20 MHz clock or an 8Mhz clock. It requires one Level Converter Buffer to convert the digital serial signal between the Microcontrollers's USART and the serial port, from TTL levels to RS-232 levels.

The voltage reference to the internal Analogue To Digital Converters (ADC) should be defined by an add-on board except in the case where that voltage is 5V, which means that the voltage reference can be extracted from the power supply.

The 8-bit ADC of the Microcontroller provides a 256 level digital output that is enough to the targeted biosignals, which have a very low voltage range

In Fig.2 one can see the schematics of the developed module. It shows us that not only the analogue inputs

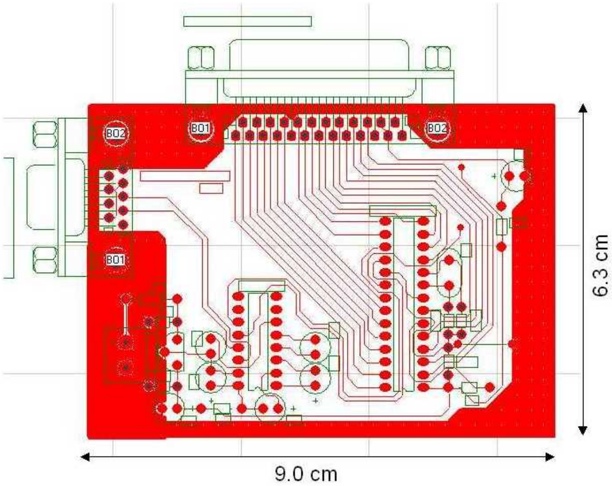

Fig.3 – PCB of the multiple analogue channel module

[AN0…AN4] are available in the I/O bus, but also two bi-directional digital ports ([RB0…RB7], [RC0…RC7]), that can be used. Although some of these pins have other particular functions, i.e., RB4 and RB5 are interrupt on change pins, RC0 and RC1 are Timer 1 output and input respectively and RC6 and RC7 are the Tx and Rx pins of RS-232 serial communication. This allows one to have, if desired, some digital control over other devices in the system or to synchronize more than one acquisition board.

In Fig. 3 we present the PCB design of the board.

This Board was created in a way that it would be easy to develop reduced versions of it, that would fit in the needs of different scenarios, i.e., different number of channels required, reference voltage and possibly change of the frequency of the crystal oscillator, among others.

B. Single Analogue Channel Module

Based on a the multiple channel module described in the previous section, a new board was designed with the same characteristics of the board in Fig.3, except for the fact of having only one analogue channel available.

Considerable reduce in PCB area was achieved as can be depicted in Fig.4.

Reducing the number of analogue channels and not using the digital ports (except for communications) allowed the reduction of the dimension of the board from 9,0 cm x 6,3 cm to 7,2 cm x 4,0 cm, that represents an almost 50% reduction of the area spent.

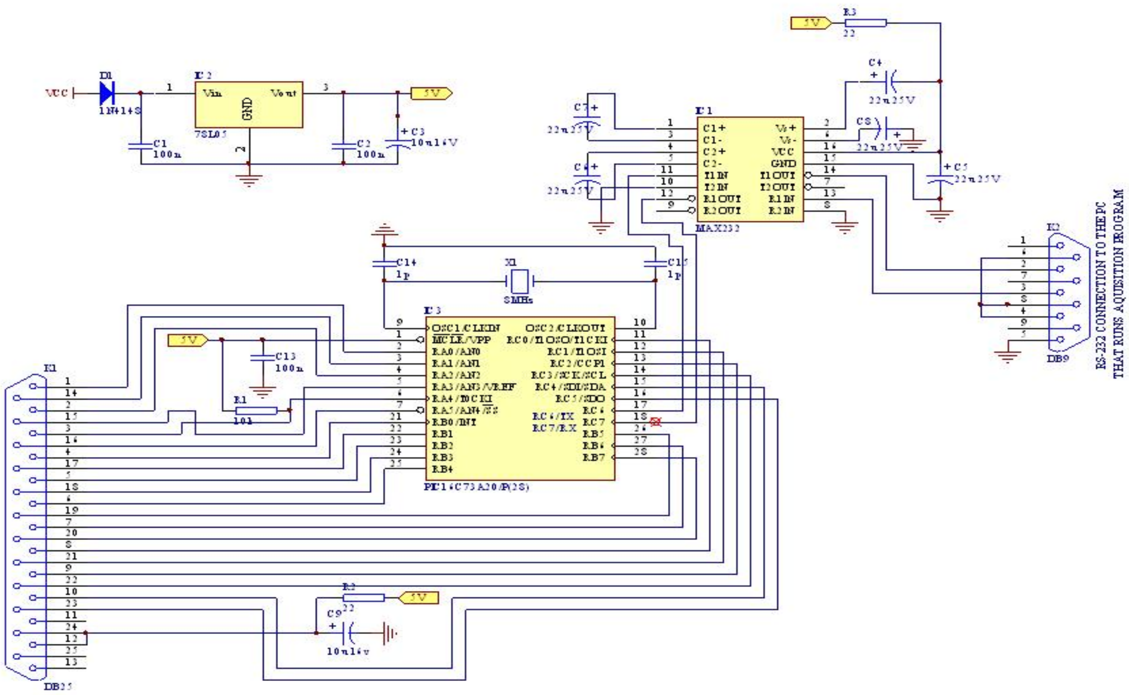

Fig.2 –Schematics of the multi analogue channel module

IV. SOFTWARE

The software for the Microcontroller can be developed in C or Assembly Languages. Using Microchip's developing tools, more precisely MPLab software, one can debug the program using Microchip's PIC simulator. [3]

The PIC has 8K x 14 words of Program Memory and 368 x 8 bytes of Data Memory, which allows the construction of medium complexity software.

The Assembly for this microprocessor has only 35 single

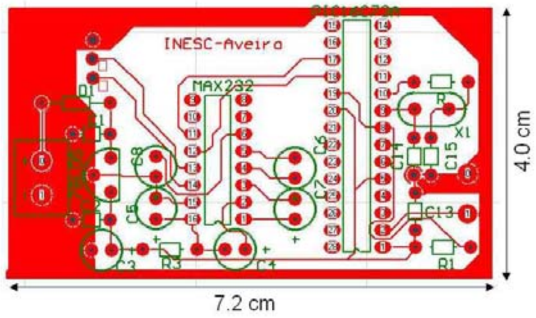

Fig.4 - PCB of the single analogue channel module

word instructions, all of them single cycle except for program branches, which are two cycle.

V. APPLICATIONS

As mentioned before the module developed can be used in several scenarios of acquisition of low frequency biosignals.

In this paper we present one application of our module, which is already in use.

A. Skin Conductance Level Application

The first application for the module was to acquire the output analogue signal of a Skin Conductance Level Meter in order to send the data to a desktop PC, using RS-232 communications. This work was developed in the scope of project BioDreAMS. [4][5]

We used the board of Fig.4., which has one channel for the acquisition of analogue signal.

Skin Conductance Level Signal

One shall look more deeply into the Skin Conductance Level (SCL) signal, in order to understand the use of the board.

In this case of SCL signals when the subject is on rest, the intensity of the signal has almost no variation (Fig.5). On the other hand when the subject is experiencing emotional materials the signal can have high intensity variations of low frequency (Fig.6).

Skin Conductance is the reciprocal of Skin Resistance (SR), measured in micromhos (μmhos) (also know as Siemens). It is best measured by imposing a constant voltage (0.5 Volt) across the active segment of the body (typically the fingers), and measuring the change in voltage across a very small resistor in series with that

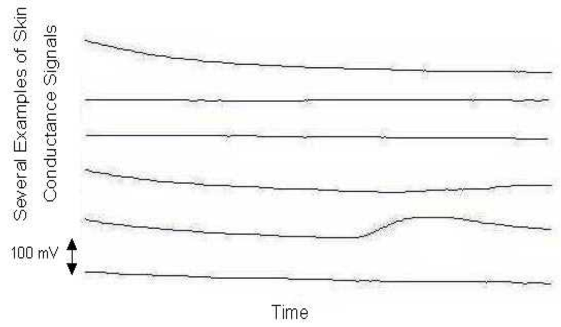

Fig.5 – Examples of skin conductance signals when the subject is on rest

segment.

The Skin Conductance Response (SCR or Δ SCL) is derived from the SCL signal by passing it through an appropriate filter and amplifying the result signal.

The amplitude of SCL measurements depends on the

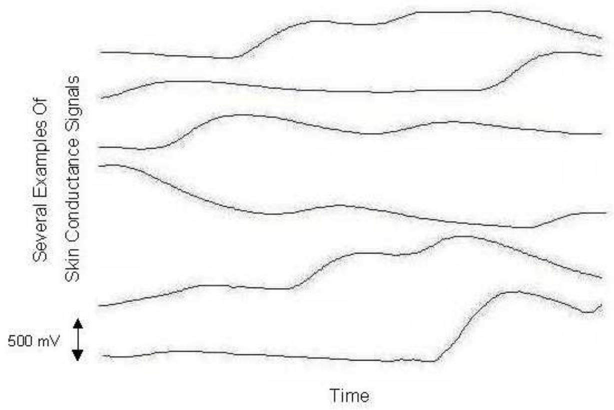

Fig.6 – Examples of skin conductance signals when the subject is experiencing emotional events

density of sweat glands in the area chosen, on the degree of psycho-activity of the sweat glands in that region and the size of skin area in contact with the electrode.

The Skin Conductance Response (SCR or Δ SCL) is derived from the SCL signal by passing it through an appropriate filter and amplifying the result signal.

The amplitude of SCL measurements depends on the density of sweat glands in the area chosen, on the degree of psycho-activity of the sweat glands in that region and the size of skin area in contact with the electrode. [6]

Software specifications for the Skin Conductance Meter Application

The output of the Skin Conductance Meter (Δ SCL) has a voltage range of 0 to 5V. This is the signal that our module will deal with.

The serial port was configured for a Baud-rate of 9600 bps, using 8 data bits, 1 stop bit and no handshaking.

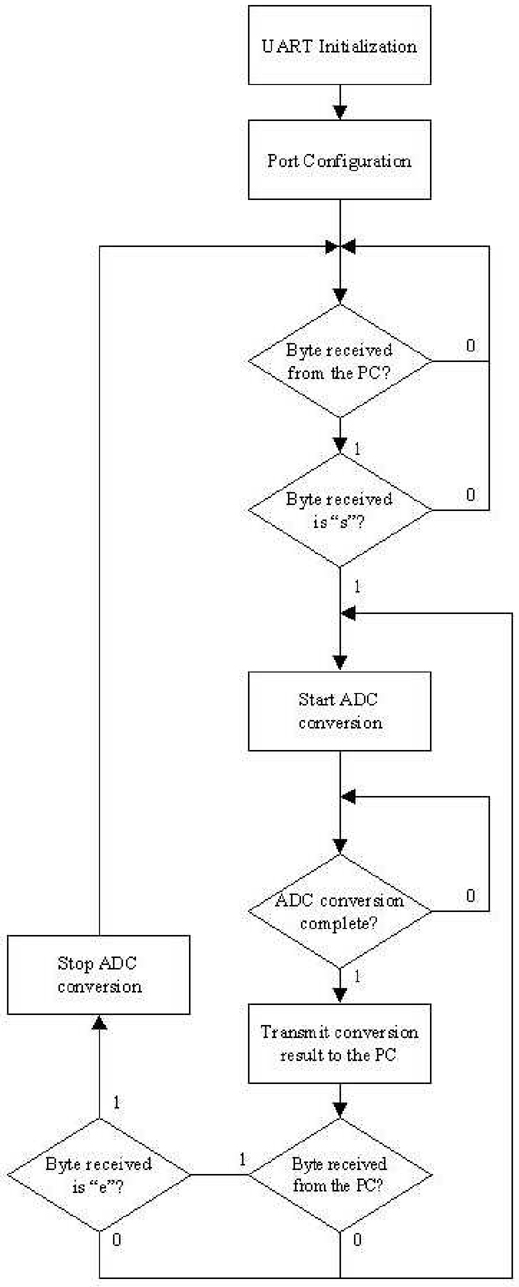

Fig.7 – General Algorithm of the software of the skin conductance level application

In Fig.7, can be depicted the general algorithm of the software of the SCL application. As one can see the program doesn't use interrupts, it is base on a polling structure.

VI. CONCLUSION

A general description of the development of a general-purpose module for acquisition of low-frequency bio-signals was presented.

Fig.8 – User interface of the application BioDreAMS. SCS is the lower one.

The module worked as we expected, and was easily implemented with success in the BioDreAMS project.

In Fig.8 can be depicted the user interface of the application BioDreAMS. The Skin Conductance Signal is the lower one.

We hope to use the module in the near future for the acquisition of other low-frequency bio-signals besides Skin Conductance Signal.

From this we conclude that the use of this module is an inexpensive and reliable solution for acquisition of low-frequency bio-signals.

VII. BIBLIOGRAPHY AND REFERENCES

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