31st Annual International Conference of the IEEE EMBS
Minneapolis, Minnesota, USA, September 2-6, 2009

A smart modules network for real time data acquisition: Application to biomedical research

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Abstract—**Healthcare monitoring applications require the measurement and the analysis of multiple physiological data. In the field of biomedical research, these data are issued from different devices involving data centralization and synchronization difficulties. In this paper, we describe a smart hardware modules network for biomedical data real time acquisition. This toolkit, composed of multiple electronic modules, allows users to acquire and transmit all kind of biomedical signals and parameters. These highly efficient hardware modules have been developed and tested especially for biomedical studies and used in a large number of clinical investigations.**

Keywords— **Real time, modules network, smart sensors, biomedical signals**

I. INTRODUCTION

Clinical or experimental biomedical research usually requires the measurement and the analysis of physiological parameters such as ECG signal, arterial blood pressure (ABP), respiratory parameters and so on. Usually, these parameters are given by medical devices equipped with specific sensors. However, these devices, personalized for the clinical diagnostic, perform special signal processing to obtain filtered and averaged parameters such as, for example, the mean heart rate value issued from the ECG signal. Therefore, such devices are not suitable to get primary signals which are essential in biomedical research. Furthermore, the large number of collected information involves data centralization and synchronization difficulties.

To answer these questions, we have developed a hardware biomedical data acquisition board [1] which, connecting to specific software [2] for driving and computation, represents an efficient solution to develop a complete real time biomedical signal processing application.

II. METHODOLOGY

General concept:

The data acquisition board, especially adapted for the medical field, has been developed as a multiple hardware modules network able to acquire all kind of biomedical data, analog or digital, representing a waveform such as ECG or ABP or a parameter such as cardiac rhythm or respiratory rate.

The network is composed of several acquisition modules linked to a master module which communicates with a commonly available personal computer through an asynchronous USB connection.

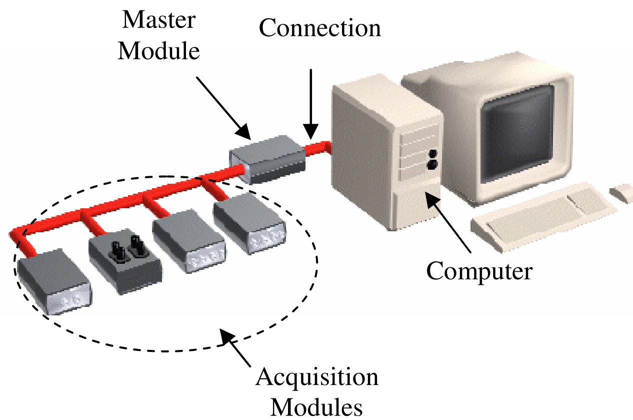

Fig. 1: Acquisition board general scheme.

Each acquisition module includes, in addition to the transducer:

- the signal conditioning,
- the signal validation (control, filtering) ,
- the signal digitalization,
- the communication hardware.

The acquisition modules are linked to the master module through a network which is based on a RS485 multi point, half duplex connection [3]. A specific master/slave communication protocol allows acquiring, digitalizing and transmitting the biomedical signals in real time. In that way, the master module includes a hardware sampling clock that synchronizes the analog to digital conversion by sending a specific command to all the acquisition modules simultaneously. The digitalized data are then directly transmitted in queue to the PC through the asynchronous USB port. This procedure allows assuming a synchronous and real time data acquisition using any kind of operating system. The master module also transmits the power supply to the acquisition modules throw the network connection.

In a functional point of view, the whole system is composed of both a hardware part and a software part implemented on the PC. The hardware part is composed of the master module and several acquisition modules integrating multiple acquisition channels. The software part integrates a "Driver", which is in charge of the hardware configuration and data acquisition, and an "Application" part which is in charge of data processing, centralization and visualization.

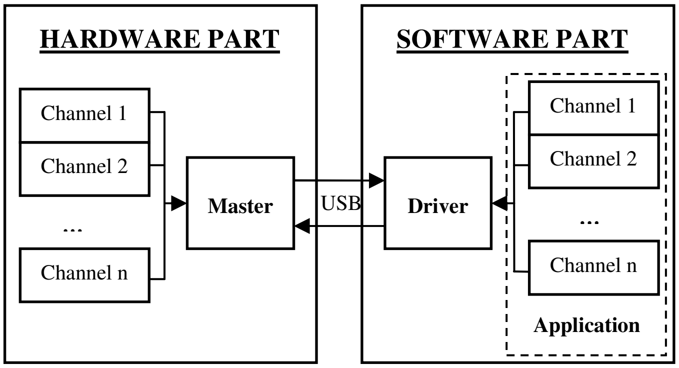

Fig. 2: functional scheme of the system

A specific communication protocol has been developed for the communication between the different elements of the network. This protocol is optimized for the real time transmission of the sampled signals. Its software implementation is divided on both the driver and the electronic modules microprocessors.

The master module:

The master module takes a leading part in the communication between the connected modules. Built around a micro-processor which drives the complete interface, this module is in charge of three essential functions:

- configure the modules and the input/output channels,
- give the sampling rhythm in real time,
- command the modules in real time.

Figure 3 shows the synoptic scheme of the master module.

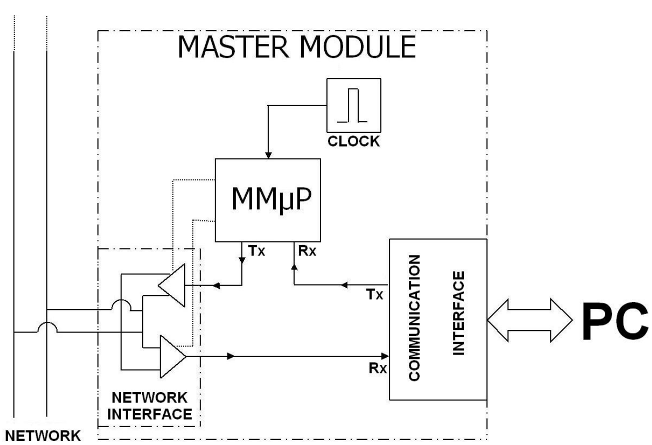

Fig. 3: Master module synoptic scheme

Each command or information issued from the PC is red by the Master Module microprocessor (MMµP) through the Rx Input. Then, the sent messages are decoded and processed by the MMµP. Commands and information addressed to the modules are emitted by the MMµP through the Tx Output.

A Real Time clock allows the synchronization of the signals sampling. At each clock top, the MMµP sends a command on the network. This command is simultaneously interpreted by all the connected modules which are continuously on the watch of the network. Then, each module samples the inputs signals and transmits the sampled data in an order imposed by the MMµP. To optimize the information flow, the sampled data are directly transmitted to the PC without any intervention of the MMµP (Rx Output of the PC communication interface). This particularity is possible thanks to the half-duplex command of the network interface which physically realize the connection with the PC communication interface.

Acquisition modules:

From a hardware point of view, all the network's modules are built on the same principle. Each module is composed of two distinct parts:

- Conditioning.
- Digital process.

The digital part, which is based on the use of a microprocessor, is the same for all the modules. Only the microprocessor software is specific to the module. This part integrates an analog to digital converter and a serial communication port to allow the communication with the network. Exchanges with the conditioning part are assumed by an Input/Output parallel bus.

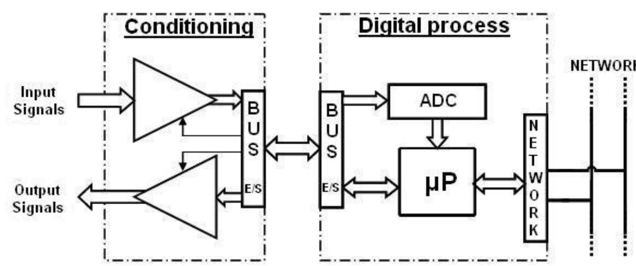

Fig. 4: Acquisition module synoptic scheme

While the main use of the network is the analog data acquisition, the hardware structure is also adapted to multiple other needed. In fact, as only the conditioning part depends of the use, its specificity determinates the whole module characteristics. The input/output bus communicating with the digital part allows three kind of Input/Output: analog, logical and serial digital data. In that way, it is possible to develop all kind of conditioning for various using such as:

- Analog/logic/digital signals acquisition.
- Analog/logic/digital signals restitution.

Furthermore, each module can integrate, if needed, an input transducer (such as a blood pressure transducer) or an output actuator (such as an electro-valve).

In that way, connecting to the master module, all these specific modules give a plug and play solution for rapid data acquisition applications development.

To respond to any kind of data acquisition problem, the modules network proposes three categories of acquisition modules:

- Specific modules, such as ECG, EEG, blood pressure, respiratory flow or temperature signal acquisition. These modules include the specific bio-amplifier and allow direct measurement of the biomedical signal,
- An analog module, which includes four amplifying chains with software adjustable gain and offset for analogical inputs. This module allows the system to be connected to all kind of devices analog output.
- A numerical module, which allows the system to be connected to the RS232 numerical output of any biomedical device.

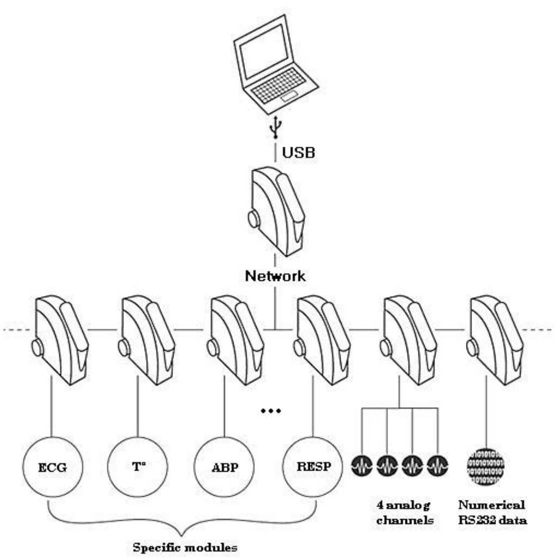

Fig. 5: existing acquisition modules.

This network allows plugging multiple acquisition modules, without limitation of type or number.

Figure 6 shows the synoptic scheme of several modules linked on the network.

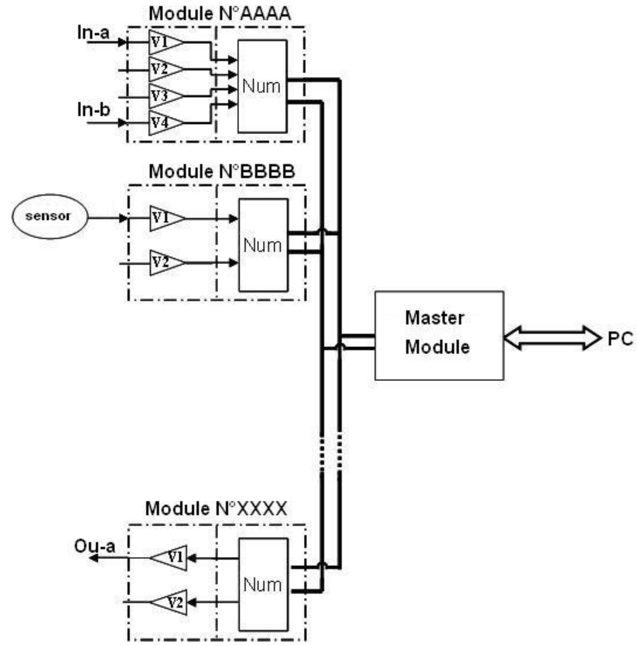

Fig. 6: network assembly example.

III. Application

We developed a software application (Physiotrace) for the hardware configuration and the data acquisition, processing, centralization and visualization. In addition to the module network, this software, based on the use of a DSP components library, constitutes an efficient and simple way to develop biomedical DSP systems and reduce consequently the application development time [2].

The DSP software library is composed of a large number of low level components (numerical filters, arithmetic or logical operators, spectral analysis components,…), but also by a large number of high level components, created by assembling, which are specific to the biological signals analysis (ECG, blood pressure, Heart Rate Variability,…).

These components are packaged according to their functionalities. In that way, we obtained 9 DSP components packages:

- **The data acquisition and pre-processing package** includes drivers which are in charge of hardware configuration, data acquisition, decoding and up stream components data transmission. In addition to the modules network driver, this package contains other drivers which allow connecting the software directly to a monitoring device without using the network.
- **The filtering package** contains high pass, low pass, band pass filters and tresholding components.

- **The basic functions package** contains arithmetic, trigonometric and logical operators.
- **The detection package** contains classic comparators and specific detectors adapted to biological signals (ECG QRS detection, systolic and diastolic arterial blood pressure detection, respiration flow 0 over crossing ...).
- **The cyclical measurements package** contains components which allow computing several parameters between two detection triggers. This package includes minimum, maximum, magnitude, mean, standard deviation, sum, integral, time and frequency computation.
- **The moving window measurements package** allows to compute minimum, maximum, magnitude, Root Mean Square, mean, standard deviation, sum, integral, time and frequency values continuously in an adjustable moving window.
- **The frequency analysis package** contains re-sampling, windowing, Fast Fourier Transform and Wavelet Transform components.
- **The biomedical package** contains components which have been developed especially to analyze a specific biomedical signal (ECG, Arterial Blood Pressure, Respiration...).
- **The visualization package** allows displaying data analysis results. This package includes scope, chart, XY plot, digital display and table components.

To allow users who are not specialists in software development to create biomedical DSP applications, PhysioTrace integrates a visual programming language which is based on the data flow visual programming principle. This language consists to draw the functional diagram of the DSP algorithm and allows developers to create graphically a complete DSP application.

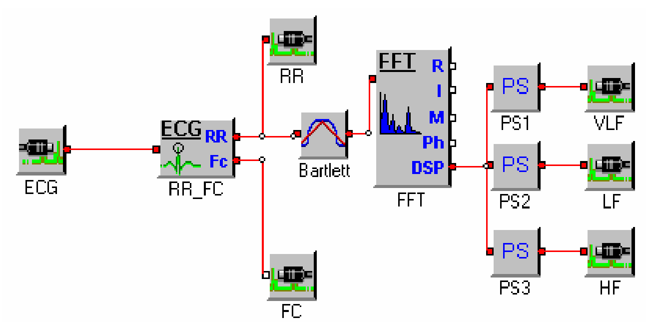

Fig.7: a PhysioTrace DSP chain. This example shows a Heart Rate Variability (HRV) analysis DSP chain. The RR and heart rate parameters are computed using the ECG component. A Bartlett windowing is applied to the RR series and a Fast Fourier Transform is performed. Finally, the power spectrum in the Very Low Frequency (VLF), the Low Frequency (LF) and the High Frequency (HF) domains are delivered by the PS components.

PhysioTrace also includes a user interface creation system which allows users to develop their own execution graphic interface efficiently and quickly by simple drag and drop scope and display objects on the programming form.

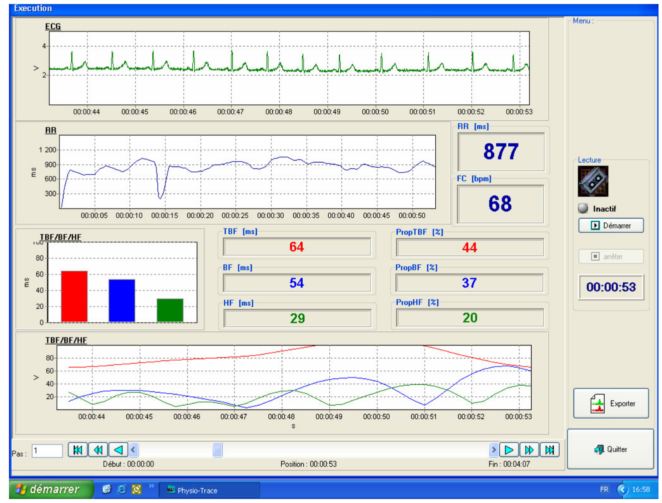

Fig. 8: a PhysioTrace execution interface. This example shows the HRV analysis results. The ECG signal is displayed on the higher scope. The RR series is displayed on the scope below. Instantaneous heart rate values (BPM and ms) are displayed right to this scope. Very low, low and high frequency contents are displayed using bar graph, instantaneous values displays and trend curves.

IV. Conclusion

The whole system has been tested in a large number of clinical studies [4, 5] and used for the development of innovative technologies for biomedical monitoring systems [6]. For each developed application, the main interest of this toolkit seemed to be the easiness in the modules assembling and in the DSP algorithm creation.

References

- [1] R. Logier, A. Dassonneville, "Système d'acquisition modulaire et temps reel de signaux, et notamment de signaux biomédicaux", demande de brevet N° 0315130, CHRU de Lille & Estaris Monitoring, 2003.
- [2] J. De jonckheere, R. Logier, A. Dassonville, G. Delmar, C. Vasseur – PhysioTrace : An efficient toolkit for biomedical signal processing - Proceedings of the 27th Annual International Conference of the IEEE Engineering in Medicine and Biology Society. 2005.
- [3] Logier R. – Contribution à l'étude conceptuelle des instruments intelligents : une méthodologie appliquée au monitorage médical – Thèse de Docteur Ingénieur, Université des science et Technologie de Lille, 1995.
- [4] Jeanne M., Logier R., Tavernier B. - Heart Rate Variability: which paramaters do assess depth of analgesia during general anaesthesia? – EHS-BAVAR, International Conferences of Cardiology, Angers – France – June 11 & 12th 2004.
- [5] Nseir S. , Duguet A., Copin M.C., De Jonckheere J., Zhang M., Similowski T., Marquette C.H. - Continuous control of endotracheal cuff pressure and tracheal wall damage: a randomized controlled animal study – Critical Care (200) – to be published.
- [6] De jonckheere J., Narbonneau F., Kinet D., Zinke J., Paquet B., Depré A., Jeanne M., Logier R. – Optical fibre sensors embedded into technical textile for a continuous monitoring of patients under magnetic resonance imaging – Proceeding of the 30th Annual International conference of the IEEE Engineering in the Medicine and Biology Society, Vancouver, August 2008.