Proceedings of the

XVIII CONFERENCE on DESIGN of CIRCUITS and INTEGRATED SYSTEMS

dcis 2003

ORGANIZED BY THE COMPUTER
ARCHITECTURE AND NETWORKS GROUP
UNIVERSITY OF CASTILLA-LA MANCHA - SPAIN

CIUDAD REAL (SPAIN)
NOVEMBER 19-21, 2003

www.dcis.org

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Wireless Connection for ECG Systems Based on Bluetooth Technology

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Abstract— This paper describes both the design and performance of a wireless link based on wireless Bluetooth technology, for connecting the biomedical sensors with the corresponding medical monitoring equipment. The principal objective of this work is to replace the conventional cable connection for a wireless one, but without any modification in the monitoring system. So, the developed system has to work in a transparent way: transmitter will take the sensor signal and will transmit them and receiver will take the transmitted information and will reproduce the sensors signals in the input of the monitoring equipment.

Use of Bluetooth assures robust communications and low cost devices. Besides, using this technology is possible to improve the system for connecting sensors and medical equipments by means of data networks (LAN, WAN, INTERNET), not only with a direct connection.

The prototype presented in this works implements a wireless connetion for an Electrocardiogram (ECG) system, but the same scheme can be used with similar applications. It consists of a transmitter portable module, which is connected to patient, and a receiver module, which generates signals ECG monitor requires.

Index Terms—wireless connection between sensors and medical equipment, avoid modification in monitoring equipment., Bluetooth links.

I. INTRODUCTION

In this work we present a system for improving the performance of medical monitoring equipment. In this way, we make use of the Bluetooth (BT)[1] wireless technology for substituting the physical connection (cables) between patient and medical instruments by a wireless link. Besides, we want to get this objective without any modification of the medical equipment, because this would require expensive and complex homologation processes.

We pretend the designed system will perform the connection between biomedical sensors in patient and monitoring device in a transparent way. This allows old equipments to be actualized with this new characteristic without any change in the equipments

We have decided to use BT because of its robust links and the possibilities it introduces. Bluetooth is emerging as one of the most important technologies for personal area networks (PAN). Besides, this standard allows connectivity with others telematic networks, as it is compatible with several communication protocols[2] (IrDA, OBEX, etc). Therefore, Bluetooth devices can access even INTERNET.

Bluetooth technology works in the Industrial, Scientific and Medical (ISM) band, so it can be used in the proposed application of biomedical sensors. It uses spread spectrum techniques in the communication link, which introduces some improvements in interference rejection, and data security.

Other biomedical systems, which use wireless connections, have specific ad hoc schemes, which are different for each system and each application. In this work we present a general system for providing wireless links to every conventional systems without this issue. In order to this, the developed system has to record the information from the sensors and it has to reproduce, in the input of the monitoring equipment, a replica of the signal generated by the sensor in the patient side.

The particular application presented in this paper, performs the connection for an electrocardiogram equipment. It uses four sensor to obtain three signal. The signals are digitized in the patient side, transmitted and reproduced in the monitor size. The presented prototype follows a general scheme and we only need a few modifications to adapt it to other similar application.

II. GENERAL SYSTEM

Figure 1 shows the general scheme of the proposed system. It consists of to main modules: transmitter and receiver. The transmitter block is near the patient and must be portable and low consume and weight, in order to get as freedom as possible for the patient. Receiver does not need to be portable, as it will be connected to the medical equipment.
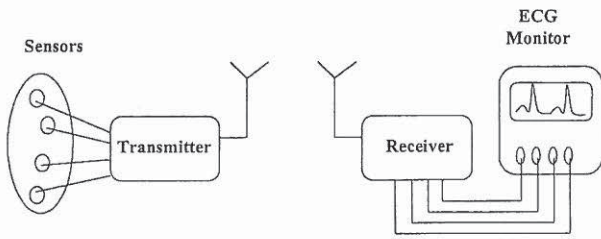
Fig. 1. *System scheme.*

Transmitter system performs two main processes: sensor signals conditioning, and digitizing. Once in digital format, signals are multiplexed and transmitted by the Bluetooth module. While receiver has to perform the reverse process: demultiplexing the received data from the BT module, converting them to analog signal and conditioning the amplitude and level of the signal to introduce in the ECG monitor. The system will work property when the ECG monitor obtains the same results than the case of direct cable connection[3].

III. TRANSMITTER MODULE

Emitter system performs the processes needed for obtaining the biomedical signal from each ECG sensor in the patient body and its transmission to the reception stage by means of the BT connection. In this work, we are working with the monitoring ECG type [4], which uses four sensor in the patient body placed as in figure 2.
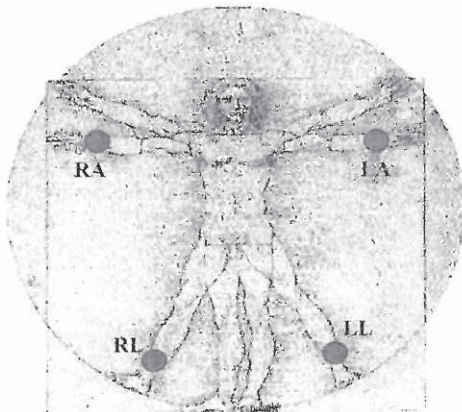

Fig. 2 ECG sensors placing.

These systems use electrodes as sensor, which turn the ionic current into electric current. After that, ECG monitor take the sensors signals and calculate the difference of potential between three of them (RA, LA,LL), using RL as ground reference[5]. We can se this potentials in figure 3.
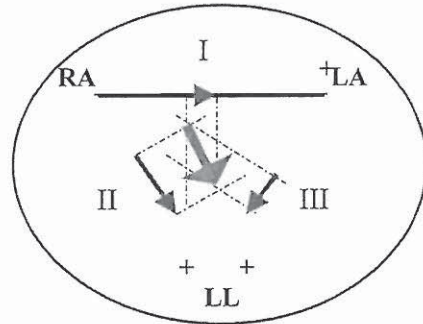

Fig 3. ECG potentials.

As the presented system must work in a transparent way, it has to provide the ECG monitor with the RA, LA, LL and RL signals, or exact versions of them. In order to obtain this, transmitter module performs processes of recording the sensor signal and sending them to the receiver. The ECG signals bandwidth is from 0.5 Hz to 50 Hz, but in this work we have use a 700 Hz bandwidth for higher resolution and precision in signal reproduction[3].

The general scheme of the transmission module can be seen in figure 4. It Consist on:

- A sensor signals conditioning, which adjust the electric signals values.

- An analog to digital conversion block, as BT links performs digital communications. So electric signals from sensor have to be converted into data and multiplexed in order to be send by the BT connection.

- A control stage for synchronizing all the operations before and managing the communication protocol.

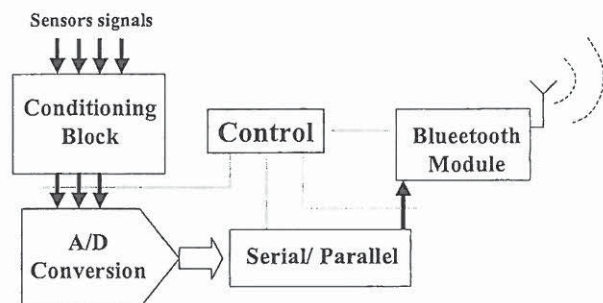- A Bluetooth module, which implements the hardware needed for the radio communication.

Fig. 4. Transmitter block diagram.

As Bluetooth module, we are using the ROK101008 from ERICSSON, which includes the physic level of the BT protocol: radio an base band. The higher levels of the

protocol, which are grouped in a block called HOST, are software implemented into a micro-controller PIC 16F874 from MICROCHIP. In this way we obtain a complete BT device by merging these two parts (ROK and HOST).

The same micro-controller is use in other process, as control or signal digitizing. This device is selected for RAM and ROM size, and because it has a built-in analog to digital converter with eight multiplexed inputs. As we said above, ECG takes three sensor signals referred to the fourth (RL) as ground, so system has to digitize and transmit three signal. Once digitized, micro-controller performs the data multiplexion, the parallel to series conversion and finally, the connection with the BT ROK by means of the HOST software.

Conditioning block is the first stage in the transmission process and it is responsible for amplifying and filtering the signals from sensors. As we have said before, there are three signal to be transmitted, so this circuitry consists of three amplifiers and three filters with the same scheme. We have used AD623AN amplifiers from ANALOG DEVICES, and passive RC filters. Figure 5 shows the Conditioning circuit scheme.
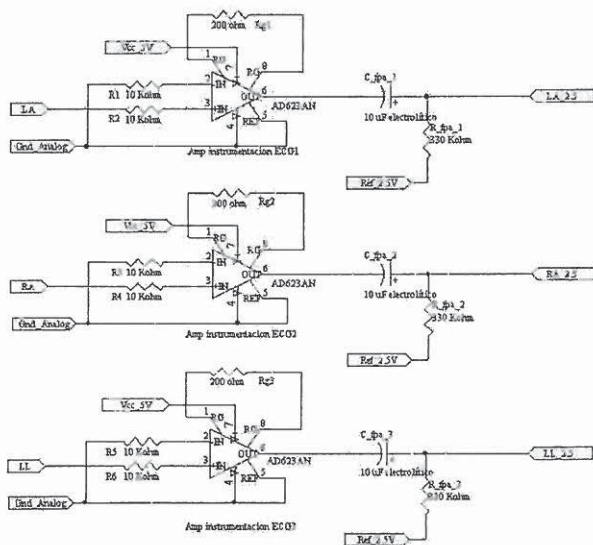

Fig 5. Conditioning block scheme.

The three output signals of this circuit are connected to the micro-controller A/D conversion inputs for digitizing and transmission processes. Figure 6 shows the implemented transmitter system.

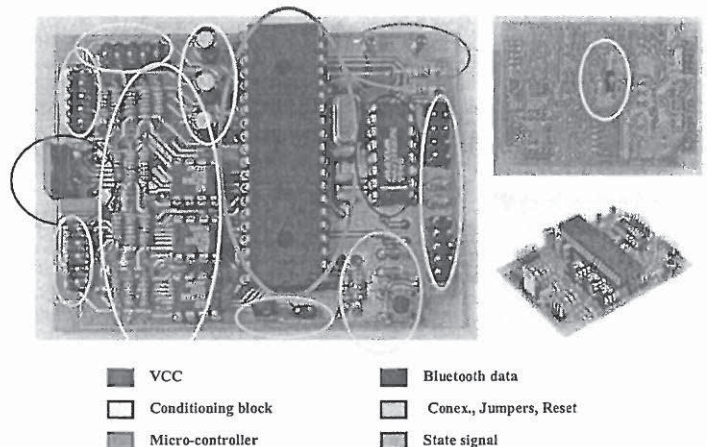|	
■ VCC	■ Bluetooth data
□ Conditioning block	■ Conex., Jumpers, Reset
■ Micro-controller	■ State signal

Fig. 6. Emitter system.

IV. RECEIVER MODULE

This system performs the needed processes for recovering the analog signals from sensors. It implements the data reception from emitter, the signals demultiplexion and the digital to analog conversion. Then we will have three outputs signal, which are connected to the ECG monitor, while the reference signal RL in the ECG is taken from the receiver ground[3]. The main blocks can be seen in figure 7 and they are the following:

- Blueetooth reception stage, which communicates with the emitter terminal and recovers the information.

- Demultiplexion block to obtain the different signal from sensor RA, LA and LL.

- Digital to analog conversion circuit, which regenerates the analog signals.

- Conditioning block, which adapts signal levels to values required by ECG monitor.
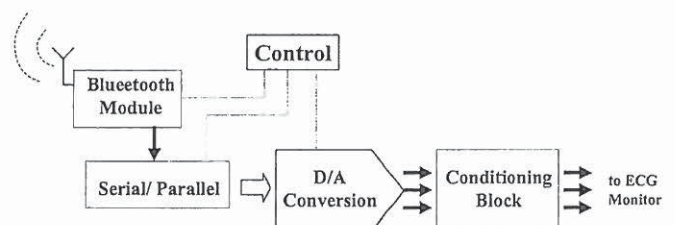
- Control system.

Fig 7. Receiver block diagram

The Blueetooth module and the HOST software are identical to those used in transmission: ROK 101007 and a program installed into the PIC16F874 micro-controller

memory. In this case, system are programmed in reception mode for recovering the transmitted data from the patient module.

The demultiplexion process and control routines are implemented in the micro-controller. In first place, multiplexed data from the three signal are presented in one of the micro-controller output ports. Then we use there control signal (also generated by the micro-controller) to split the three signal into three different latch. Therefore, after this process, we have three different digital streams with the digitized signal. Finally, we have used three DAC0800 from NATIONAL SEMICONDUCTOR, as digital to analog converters.

Conditioning circuit consist of operational amplifiers (AD824AN from ANALOG DEVICES) for signals levels adjustment. Figure 8 shows the implemented receiver.
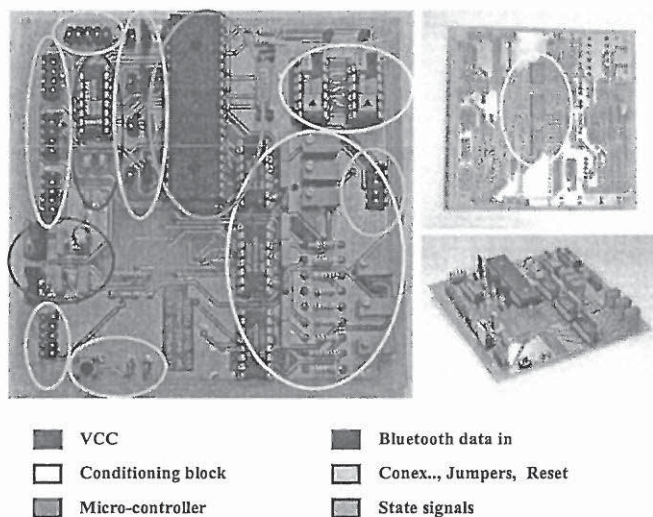

■	VCC	■	Bluetooth data in
□	Conditioning block	■	Conex.., Jumpers, Reset
■	Micro-controller	■	State signals

Fig. 8. Receiver system.

V. RESULTS

The whole system follows the scheme shown in figure 8. We can see on the left-hand, the transmitter system and the bluetooth module, while on the right-hand receiver and the same bluetooth module are presented. We also can observe the system connection: the sensors from the patient are connected to the transmitter and the receiver outputs are connected to the ECG monitor inputs.
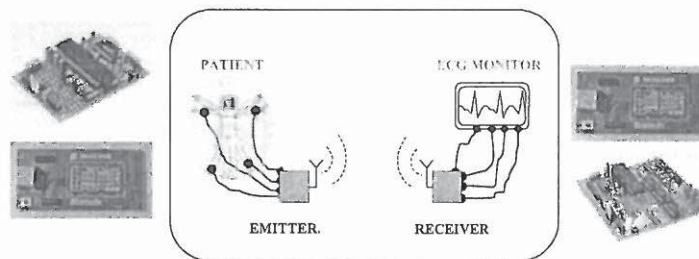

Fig 8. System scheme.

In order to check the correct operation of the system we need a patient, who will provide the sensors signals, and a ECG monitor, which will display the signal generated at the receiver output. In this work we have used a biological signal simulator from LIONHERART as source of ECG signal, to obtain clear and well-known reference signal. On the other hand, we have implemented an additional circuit with passive filter and differential amplifiers, which makes possible to use an oscilloscope as an ECG monitor. In figure 9 we can see, in upper side, the connection between the biological signals simulator and the transmitter module, and in the lower side, the receiver with the additional circuit and the oscilloscope. We can also appreciate the ECG signal obtained in the oscilloscope screen.
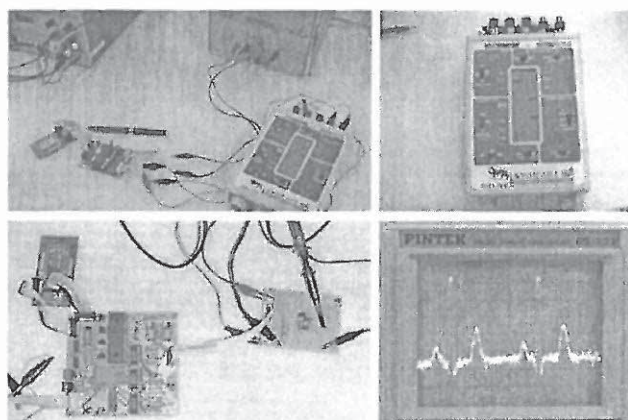

Fig. 9. Transmitter (up) and receiver (down) connections.

In figure 10 we present the obtained ECG signal in detail. We have check that all the ECG signal characteristics are well defined and the system works properly[3].
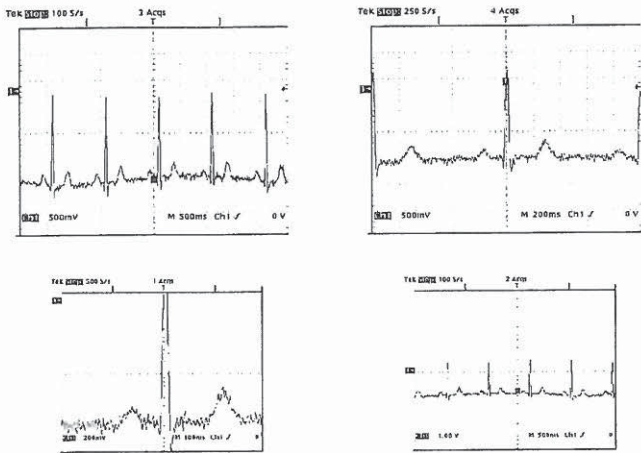
Fig. 10. Obtained ECG signal.

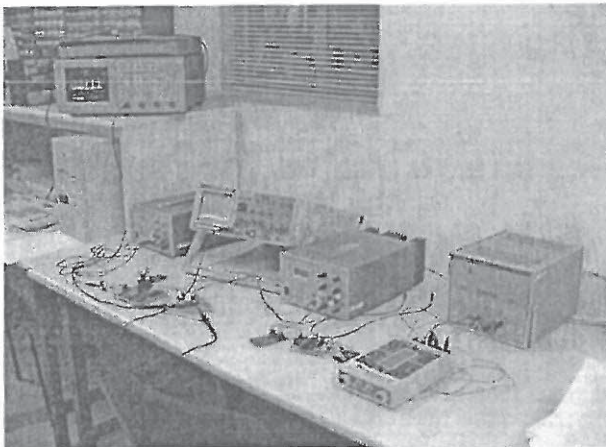Finally in figure 11 we present the experiment setting from which we have obtained the presented signals.

Fig. 11. Experiment setting.

VI. CONCLUSIONS

The main objective of this work is the implementation of a system for wireless connection between sensors and medical equipment, an ECG monitor in this particular case. We try to substitute the cables used in these equipments, in order to give more freedom and comfort to patients.

Designed system has another important requirement: the insertion of the prototype must be done without any modification in the medical equipment. Therefore, the system has to take the biological signal from sensors in the patient body, to transmit them and to generate an exact replica of these signals in the receiver output. With this characteristic, we can use the system for practically any other device. We only need a few modifications for adapting the system to each application. On the other hand, this issue avoids expensive and complex homologation processes.

We have selected Bluetooth wireless technology in order to provide the system with a robust and flexible link. Besides, it implements communication protocols compatibles with several data networks (IrDA, OBEX,...), and this can be used in future works as telemedicine applications, for example.

VII. ACKNOWLEDGMENTS

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