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A RESEARCH VISION

Design and Implementation of an Embedded system

Diseño e implementación de un Sistema embebido

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ABSTRACT

This article presents the design and implementation of an embedded system called TES ROv2.0 non-invasive, capable of capturing and transmitting relevant biomedical signals such as: electrocardiography signals, heart rate, oxygen saturation in the blood and arterial pressure with the Support from the Clinical Information System called "SARURO", in which a detailed process of these biomedical signals is visualized and carried out by a doctor or specialist, without direct contact with the patient. Therefore, researchers have been able to affirm that integrated systems are tools that offer great versatility in the medical information market, allowing acquisition, adaptation, transformation in remote places, without linking operation to a single communication alternative, making the Telemonitoring system more versatile in its functionality to transmit over WPAN, WLAN, LAN and CELULARE networks.

RESUMEN

Este articulo presenta el diseño e implementación de un sistema embebido llamado TES ROv2.0 no invasivo, capaz de capturar y transmitir señales biomédicas relevantes como: las señales de electrocardiografía, frecuencia cardíaca, la saturación de oxígeno en la sangre y la presión arterial con el apoyo del Sistema de Información clínico llamado "SARURO", en el cual se visualiza y efectúa un proceso detallado de estas señales biomédicas por parte de un médico o especialista, sin el contacto directo con el paciente. Por tanto, los investigadores han podido afirmar que los sistemas integrados son herramientas que ofrecen una gran versatilidad en el mercado de la información médica, lo que permite la adquisición, adaptación, transformación en lugares remotos, sin ligar el funcionamiento a una única alternativa de comunicación, haciendo al sistema de telemonitorización más versátil en su funcionalidad para transmitir por redes WPAN, WLAN, LAN y CELULARES.

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1. Introduction

Telecommunications have changed the perception of the world and how it interacts with its environment. An important aspect is health care, which has had substantial changes in recent years, with the use of technological advances. Which has generated various areas of research, development and innovation (R + D + i) such as Telemonitoring (TM) biomedical signal (SB), which are used as tools to examine the functioning of the human body, fulfilling an important role in medicine [1].

Ansermino author [2] highlights that much more than a phone, mobile device today has become an integral part of the way you interact in the world. DMs have the computing power, screen and battery power to become powerful medical devices that measure vital signs and provide intelligent interpretation or immediate transmission of information. Widespread adoption of DM, even in low-resource settings, promises to make monitoring of vital signs are available anywhere at low cost.

According to the above context the question of how to design and implement a tool that can capture and transmit network information useful biomedical telecommunications in detecting various diseases such as arises: cardiovascular, respiratory and hypertension, to perform appropriate diagnostic and timely in local or remote patients? Its purpose is to generate an appropriate and timely diagnosis using a tool able to capture and transmit biomedical telecommunications networks (PSTN), useful in the detection of various pathologies such as: cardiovascular, respiratory and hypertension,

As a result, it generated a development strategy for the design and implementation of an embedded system called TES ROv2.0, which functions as a communication tool between the patient and the treating physician. This tool allows to acquire, adapt and transmit information signals electrocardiography (ECG), heart rate (HR), oxygen saturation in the blood (SO 2) and blood pressure (BP) [3], via three devices (circuit boards) electronic trading as: EG01010 (OEM ECG Module - Medlab GmbH); PEARL 100 (OEM SpO2 Module - Medlab GmbH) and NIBP 2000 (OEM Module - Medlab GmbH).

Where visualization and analysis of SB was achieved through Information System Clinical called SARURO, owned by the National University of Colombia [4] and used in the Telemedicine Center in providing health services under this mode R + D, untethered operation to a single alternative communication, making the Telemonitoring system (TM) more versatile in their functionality to transmit WPAN networks, WLAN, LAN and cellular.

2. Problematic

According to the World Health Organization [5] coronary diseases cause more than 12 percent of annual deaths worldwide, accounting for 7.2 million deaths each year, so it is a priority to study and design tools allowing preventive diagnosis of these diseases, and also benefit the rehabilitation of patients suffering cardiovascular problems [6].

In Colombia, geographical conditions difficult, problems of public order in some places and the shortage of doctors and specialists willing to work in remote villages in urban centers, makes the TM as part of Telemedicine is a solution in providing health services, with some advantages such as reducing service times, access to specialist consultations, prevent disease with periodic controls, improve coverage and quality of service, taking care continuum and reduce costs among others.

3. Applied studies

In the project Current methods for the characterization of the Electrocardiogram. Authors [7] stand out the electrocardiogram (ECG) is the P-QRS-T wave representing cardiac activity of the heart. Subtle changes in electrical potential patterns of polarization and depolarization are indicative of the disease affecting the patient. These clinical features of the time domain waveform of the ECG can be used in the diagnosis of heart health. Due to the presence of noise and minute values of morphological parameters, it is very difficult to identify classes ECG accurately by eye. This document describes several systems cardiac diagnostic computer aided (CACD), analytical methods, future challenges addressed and screening of cardiovascular disease are reviewed.

The methods developed for mastering time, the transform domain and frequency domain analysis of the frequency of the time, as the wavelet transformation, cannot by themselves accurately represent the inherent distinctive features. Therefore, nonlinear methods can capture small variations in the ECG signal and provide improved accuracy in the presence of noise is discussed in greater detail in this review. CACD a system that exploits these nonlinear characteristics can help doctors diagnose cardiovascular disease more accurately. Which presents significant contributions to the three elements that were selected in this research as cardiovascular diseases, respiratory and hypertension, for conducting diagnostic appropriate and timely patient in local or remote?

Another important project is a universal wireless device for recording of biomedical signals, by [8] where authors report on the wireless acquisition system is provided that SB it has been recently developed and applied in a hospital. The authors describe a universal wireless device (bioelectric amplifier) with a case study of wireless communication. They described the advantages and disadvantages of standards considered. The most important feature of the bioelectric amplifier is the ability of the SW configuration to the specific requirements which occur during the registration of different signals. The study shows examples of ECG (Electrocardiogram), EEG (Electrogastrography), EOG (electro-oculography) and EEG (Electroencephalography) with the same wireless device. The portable unit is in clinical trials testing and preliminary evaluation indicates acceptance by medical personnel. Additional advantages are the relatively low cost of manufacture and the possibility of implementing other wireless transmission standards, which is relevant to this investigation.

3.1. Legal framework

To avoid or minimize risks that may present a medical device for SB TM is vital to consider the requirements in the technical standards throughout the design process of the SE. This will, in turn, a reduction in both time and manufacturing costs at the time of marketing the team. Careful design ensures early detection of errors or faults that would otherwise have arisen to the end of the process. Below are the most relevant standards that are related to this research are presented. (The information in this section is based on the technical report Legal Framework for Medical.

3.2. Delimitations Licenses

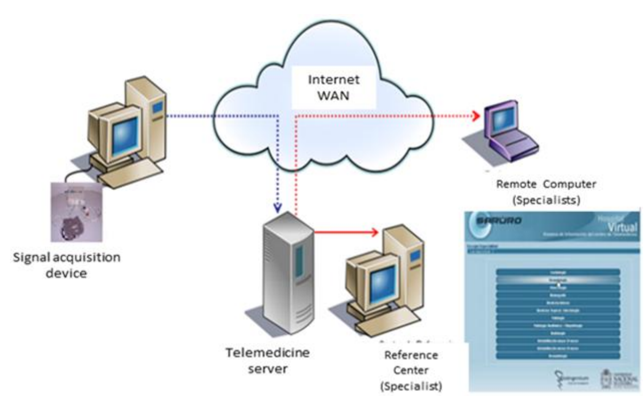
In the Department of Electrical and Electronic Engineering (DIEE) of the National University of Colombia [9] has been working on the design and implementation of electronic platforms using modern technology under the Linux or Debian system [9] classified in Copyleft Hardware (HC) corresponding to HW systems with printed circuit boards in housings.

Which meets the characteristics of free SW projects, among which are: the possibility of the files required to attend, reproduce, modify and use (even for commercial purposes) existing projects; using SW open design; licenses under the licensing scheme Creative Commons (CC) BY - SA, which enables the distribution, modification and solution even for commercial purposes, with the conditions: give credit to the author of the original work and derived works to have the same scheme license [10].

4. Methodology

TES ROv2.0 the proposed system was worked through a methodology for Technology Transfer (TT) and knowledge in the DIEE designed with the aim of spreading the use of this technology in creating solutions to local problems TM field of SB. The development of this research is based on the structure of the system TM of the Telemedicine Center (CT), which is shown in Figure 1, whose function captures, process, and adapts display signals. There the operation of the system begins with the acquisition of biomedical signals using an electronic device and a Personal Computer (PC), which processed and signals suitable for transmission to the information system SARURO observed. The information system is installed on the computer, which has the graphics application to view the information locally and allow shipment to the server Telemedicine, from which the information is transmitted to the reference center or to the place where is connected the physician and / or specialist. In the signal acquisition device, it is needed to design and implement a tool capable of transmission over wireless networks to the SARURO system of information from the SB acquisition cards, according to the purpose of the study.

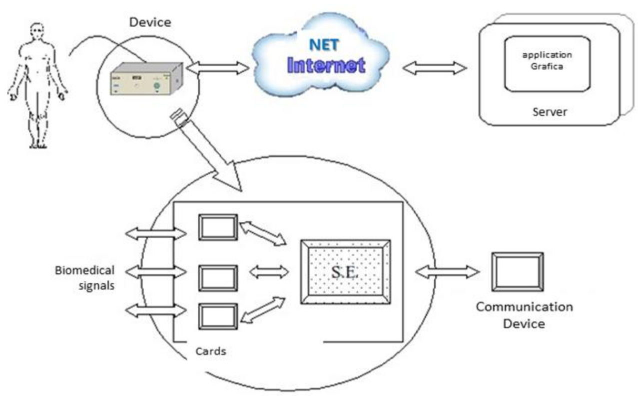
Figure 1. General diagram of the system TM of SB [11].



4.1. Enlistment process

In Figure 2, the general outline of the implemented solution in which the SE is presented as part of the device embodying the TM of the SB is specified. This SE, allows to acquire, adapt and transmit information ECG signals, FC, SPO2 and PA, to the "SARURO" system, where the signal is displayed and you have the option of local or remote monitoring via a web application (UNAL, 2009) without linking the operation to a single alternative communication. The SE can be used to transmit network WPAN, WLAN, LAN and cellular, making the system more versatile TM operation

Figure 2. Scheme generates the solution to be implemented.



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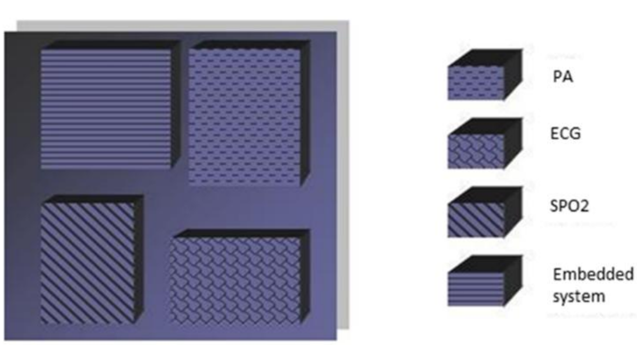
4.2. Signal acquisition device

The device TM SB in Figure 3, the inner plane in which the locations of the SE and the three TES ROv2.0 acquisition cards signals identify occurs.

Figure 3. Inner Plane of the signal acquisition device.



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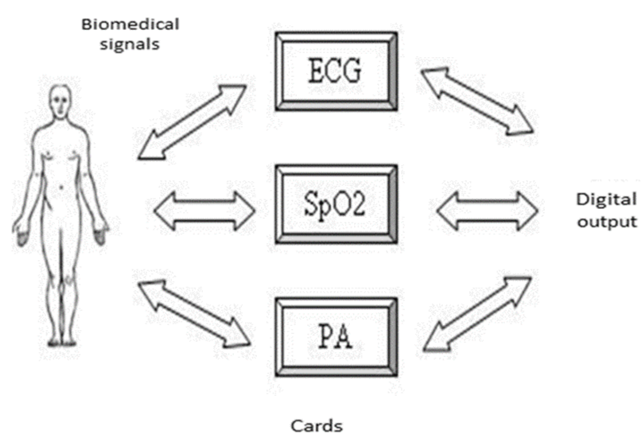
4.3. Acquisition of Biomedical Signals

SB selected for the development of this research correspond to the ECG, HR, BP and SPO2.As shown in Figure 4, this group of SB are used in CT to monitor the status of patients Care Units Intermediate (ICUs), either in the diagnosis, monitoring and / or control of a disease. For the acquisition of the SB, a set of electronic components used OEM (is the acronym for Original Equipment Manufacturer) which can be seen in Figure 5, acquired by the CT. These cards are manufactured by the German company Medlab, being a renowned company in the manufacture of medical devices, especially in Europe, including electronic components OEM meeting international standards 90001: 2000, which comply with the provisions of the technical standard EN60601-1, in which the general safety requirements to be met by medical devices are specified.

Figure 4. Acquisition of SB.



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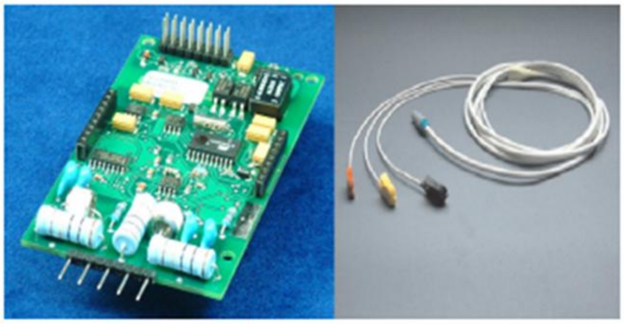
Then the implemented cards are presented in the proposed system TM, with its main technical characteristics

4.4. Acquisition of the ECG signal

To achieve this signal used card commercial reference EG01010 (OEM ECG Module - Medlab GmbH), shown in Figure 5, which is manufactured according to IEC 60601-1 and can be used in the development of equipment for monitoring signals.

Figure 5. Electronic components to capture ECG [12].



The signals are captured with surface electrodes low impedance and allow detection of the three bipolar leads signal. The communication protocol established by this card, use the asynchronous RS232 standard. In Table 1, the configuration of this card is observed with the following technical characteristics: Size: 52.5mm x 77mm, maximum height 10mm; Weight: 28g; : 5V ± 10%; Power consumption: about 150 mW; Current consumption: 26 to 30 mA; galvanic isolation card; Detection range of the heart rate: 30-250 lpm; Heart rate accuracy: ± 1%, ± 1 digit; 60 Hz notch filter; galvanically insulated conductive wires to protect against external noise and designed to withstand voltages defibrillation

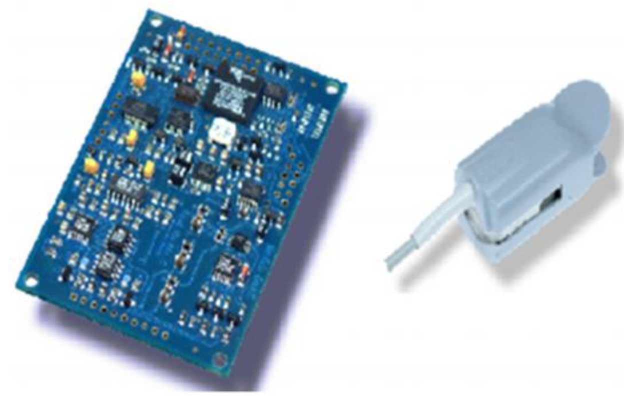
Table 1. Setting card for capturing the ECG signal [13].

Elements	Setting
Communication speed	9600 baud
Number of data bits	8
asynchronously	bidirectional
Stopbit	one
Parity	Any

4.4.1. Measurement of oxygen saturation in the blood

IEC 60601-1: 1996 11 presented in Figure 6. The module complies with the following standards - for the acquisition of this signal oximetry sensor and commercial reference card PEARL 100 (Medlab GmbH SpO2 OEM Module) is used IEC 60601-1-4: 2001 and EN ISO9919: 2005.

Figure 6. Electronic components for measuring SpO2 [14].



The card allows you to capture and measure the level of SO2, the AC component of the absorbed light in the infrared region and HR. The communication protocol established by this card, using asynchronous RS232 standard, in Table 2, the configuration of this card shown with the following technical characteristics: 77mm x 53mm size, maximum height of 6mm; Weight: 23g. Power: 2.5 - 5.5 V; Current consumption: 33-60 mA; Power consumption: 100 - 150 mW, depending on the supply voltage. Range for measuring FC: 30 - 250 lpm; FC accuracy: ± 1%, ± 1 digit. Measuring range of the level of SO2: 0% to 100%.

Table 2. Configuration card to capture and measure the level of SO2.

Elements	Setting
Communication speed	9600 baud
Number of data bits	8
asynchronously	unidirectional
Stopbit	one
Parity	Any

4.4.2. Blood Pressure Measurement

For the acquisition of this signal the bracelet and commercial reference card NIBP 2000 (OEM Module - Medlab GmbH) is used, shown in Figure 7. The module is manufactured to meet the standards: EN IEC 60601-1, EN IEC 60601- 2-30: 2000, EN ISO 1060-1: 1995, EN ISO 1060 3: 1997 and EN ISO 1060-4: 2004.

Figure 7. Electronic components for measuring PA [15].

4.5. *Telemonitoring System (STM)*

The implemented solution is based on the design of an SE, which functions as a communication tool between SB capturing and transmitting information over wireless networks information system "SARURO". In Figure 8, the step which will be for the enlistment of the process is in Figure 8.

The BeagleBoard, DevKit325015, or ATMEL ATEVK110016 or design an SE itself: two options at this point which corresponded to use a commercial SE as had. To make the decision to build a SE own criteria presented in Table 3 were taken into account, with which I set to design and implement the SE TES ROv2.0 was one of the best options at the time.

Figure 8. Enlistment of the SE - TES ROv2.0.

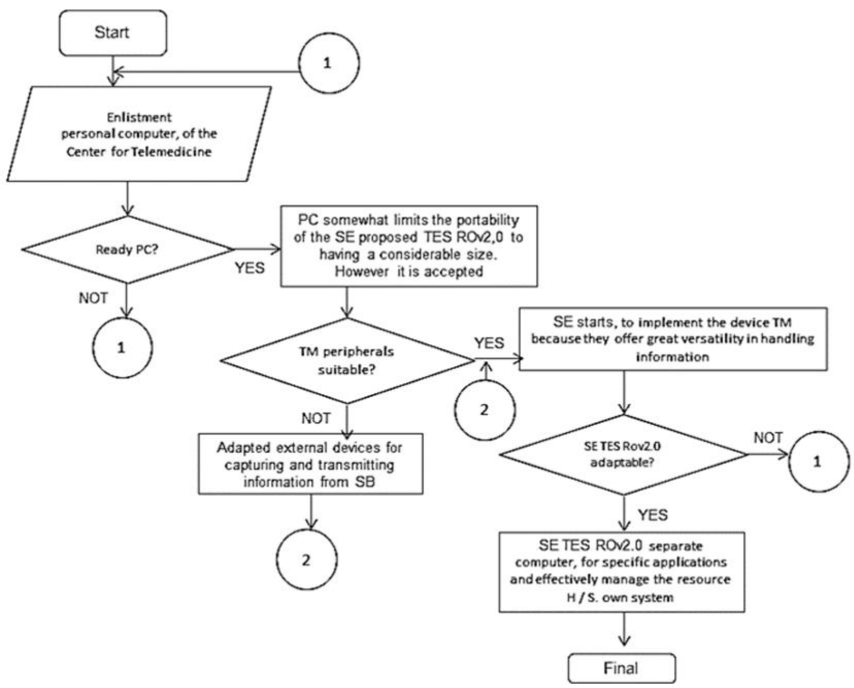


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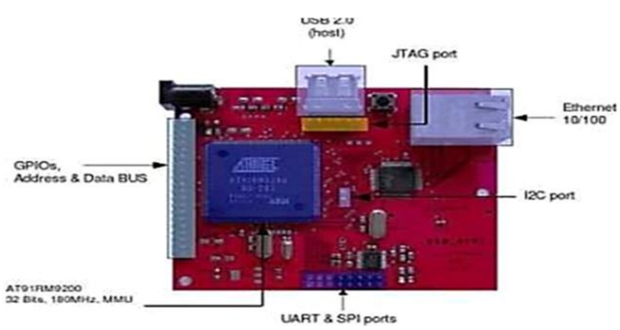
Table 3. Criteria analyzed for the design and implementation of the SE - TES ROv2.0.

Aspects to evaluate	Commercial	Own
Knowledge of the architecture of the system	DO NOT	YES
Operation of each component	Global	YES
Fabrication process	DO NOT	YES
Programming Information	Partial	YES
Design methodology	SW	HW / SW
changeable -Flexibility	DO NOT	YES
Possibility of generating new products	DO NOT	YES

4.5.1. The design of the TES system ROv2.0

Based on the development platform ECB AT91 (Camargo, 2011a), designed at the National University of Colombia, it is a platform developed for academic applications industrial. In Figure 10, the scheme of this platform and how to access it via the serial, USB and Ethernet port is observed. It is implemented with ARM9 180MHz (ATMEL AT91RM9200) processor and its dimensions are 85 mm x 77 mm, supported by three different distributions embedded OS: Debian GNU / Linux, and Buildroot Openembedded (EmQbit, 2010). This becomes part of the electronic platforms of the DIEE (Camargo, 2008).

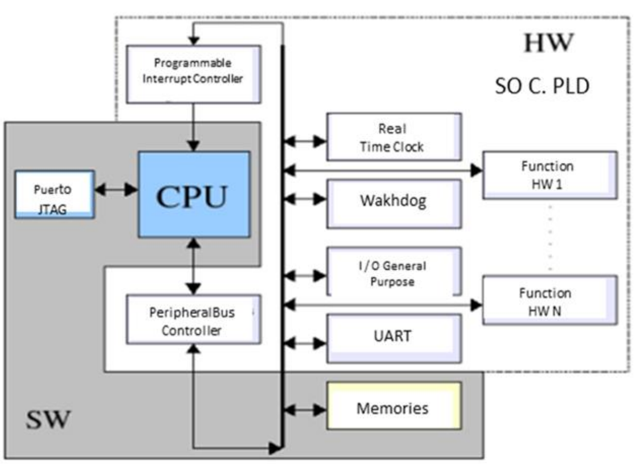
Figure 10. ECB AT91 platform [16].



4.5.2. Description The system TES ROv2.019

It is based on the architecture shown in Figure 11, in which specific components of HW / SW, designed in parallel in order to fulfill the specific activity integrate named above.

Figure 11. Architecture typical of the SE [17].

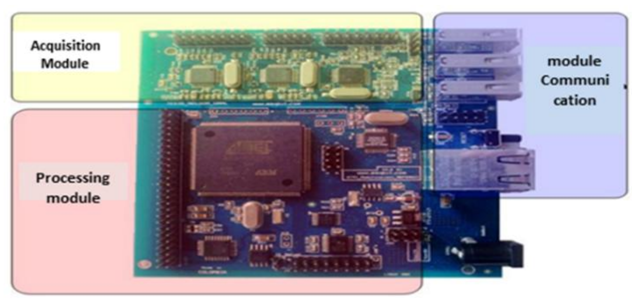


The characteristics of the TES ROv2.0 designed system are: ARM920T processor 180 MHz; Dimensions: 11cm x 10cm, maximum height of 2cm. : 5V ± 10%; serial Flash memory 2MB, 32MB SDRAM memory; PCB (Printed Circuit Board) of two layers; A slot for SD / MMC memory; 10/100 Ethernet interface; 6 serial ports (RS232), an I2C port; and 4 USB ports.

4.5.3. System modules TES ROv2.0

The TES ROv2.0 implemented system is shown in Figure 12, in which three modules are identified that comprise: Processing: are the components constituting the fundamental architecture of the TES ROv2.0 system is based on the development platform ECB AT91; Acquisition: is the sector that is responsible for capturing the information from the SB acquisition cards; Communication: corresponds to the electronic components designed for communication of the system, either wired or wireless networks, a clinical information system.

Figure 12. Modules SE proposed TES ROv2.0.



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Both the communication module as the acquisition constitute the main contribution of HW ROv2.0 made in the TES system, which were custom designed for the capture and transmission of SB to the clinical information system SARURO.

4.6. Capturing SB SARURO

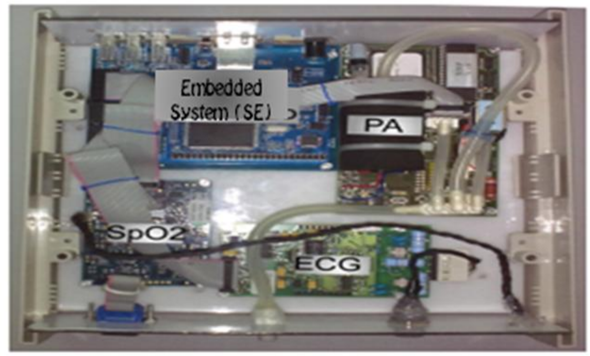
Catches with the information system SARURO are presented in Figure 13.

Figure 13. Viewing SB in the information system SARURO.

Source: own.

Capturing the above signals is performed through the integration of the device TM, where a commercial medical source, which supplies an output voltage of 5V with a maximum current of 2A, and a box is used, in which integrate electronic elements. The final integration of the device shown in Figure 14, with the three acquisition cards SB.

Figure 14. Internal structure of the device for TM.



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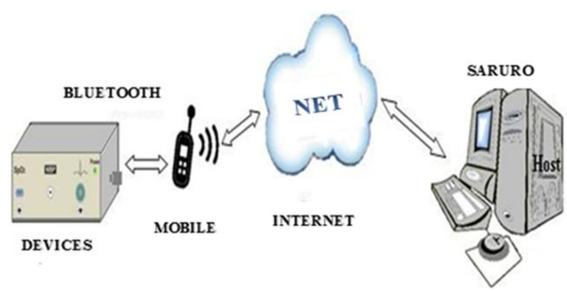
An external power MW117 model manufactured by Ault INC in 2010, which meets the technical requirements laid down in IEC 60601- 1. Further standard worked with a box model C-275 manufactured by the company PacTec used. Its external dimensions are: 23.37cm x 21.59cm x 7.87cm. The structure material is ABS (UL 94 HB), resistant to alcohols, alkali, detergents, fats, waxes, oils and aliphatic hydrocarbons, optimal for medical applications.

4.6.1. Operation in WPAN Networks (Bluetooth)

Figure 15. Diagram of the Telemonitoring system for the WPAN network.



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The operation consists of acquiring the biomedical signals with the embedded system and using a Bluetooth USB device to establish communication with the Bluetooth of a cell phone (creating a WPAN network). The cell phone has a data plan enabled, allowing communication with the host via the Internet

(This configuration is very similar to that made with the cell network). The scheme of the implemented communication system is presented in Figure 15.

4.7. Device panels

In Figure 16, the connectors are identified for each of the cards. "SpO2" identifies the connector for the oximetry sensor, "NIBP" corresponds to the hose connector to measure blood pressure and the latter corresponds to the connector for probes electrocardiography.

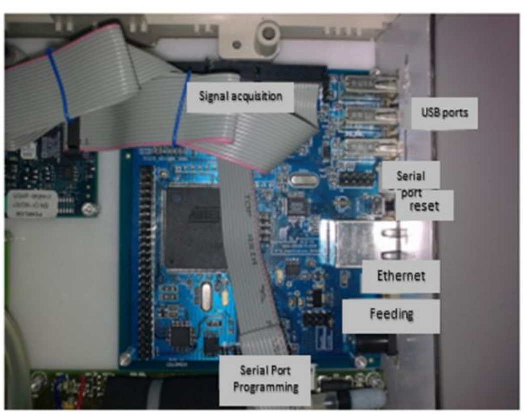
Figure 16. Role of the device Front [18].

The three USB ports, auxiliary serial port, Ethernet port, the reset and the connector for supplying the system: In Figure 17, the back panel of the device where the identified location is observed

Figure 17. Posterior paper Device [19].

In Figure 18, the connectors of the system TES ROv2.0 available are identified, as they are the signal acquisition; USB ports; serial port; reset; Ethernet; feeding; and serial port programming [20].

Figure 18. Connectors System TES ROv2.0.



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4.7.1. *List of Symbols*

- f: Frequency (s)
- Hz: hertz frequency unit
- M: media arithmetic
- Ms. Milliseconds (unit time)
- µV: Micro Volt (unit of electric potential difference)
- hi: start time
- tf: Final time
- f (t): Depending on the time
- min.: minutes
- mm: millimeter
- ARM: Advanced RISC Machines.
- CACD: Computer Aided Diagnosis Heart
- CC: Creative Commons
- CT: Telemedicine Center
- CP: Personal Computer
- DIEE: Department of Electrical and Electronic Engineering
- ECG: Electrocardiogram
- EGG: Electrogastrography)
- EOG: Electro-oculography),
- EEG: Electroencephalography
- E / S: Input / Output.
- DM: Mobile Devices
- DTM: Device Telemonitoring
- FC: Heart rate
- HW: Hardware.
- LAN: Local Area Network or Local Area Networks.
- OE: Openembedded.
- PA: Blood pressure.
- PAN: Personal Networks or Personal Area Network Area. '
- PPP: Point to Point Protocol or Point to Point Protocol.
- RAM: Random-access memory.

- RC: Red Cell
- RFCOMM: Radio Frequency Communication or radio.
- RISC: Reduced Instruction Set Computer.
- ROM: Read-only memory.
- RTB: Biomedical Telecommunication Networks
- RT: Telecommunications Networks
- SB: Biomedical Signals
- SE: Embedded System
- SoC: System-on-Chip.
- SW: Software.
- OS: Operating System.
- TA: Blood Pressure.
- TM: Telemonitoring
- TT: Technology Transfer
- UCI: Intermediate Care Unit
- UNAL: National University of Colombia.
- WLAN: Wireless Local Area Networks.
- WPAN: Wireless Personal Area Network.
- TSB: Biomedical Signal Transmission

List of Acronyms

- Ethernet LAN Network most widely used worldwide.
- Bluetooth: Industrial Specification for WPANs.
- SpO2 saturation calculation oxygen blood by the method of pulse oximetry
- WiFi: Technology based WLAN specifications IEEE 802.11
- OEM: is the acronym for Original Equipment Manufacturer

4.8. Features Directions in Research

It is important first of all to highlight the main characteristics that were achieved in the project regarding transmission, storage and data processing such as: Regarding the transmission of bluetooth to implement the WPAN network, a coverage area of 10 to Approximately 15 meters, allowing the transmission of voice and data in a picoNets-based communication system, consisting of a master node and up to seven slave nodes, although additionally there may be 254 devices waiting to join the picoNets.

This process operates at low power levels, most commercial devices transmit at 1 or 10mW, in the 2.4GHz band with frequency shift modulation. Bandwidth can be 721 Kbps in one direction and 57.6 Kbps in the other direction for an asymmetry configuration, or 432.6 Kbps in both directions for a symmetric configuration.

This Embedded System offers various information storage devices to start the System, run programs and manage resources such as volatile and non-volatile memories, peripherals, serial or SCI communication interfaces, synchronous serial, modem, network cards, ports and converter among others.

According to the previous context, in the SE, is recommended deploy and compare various communication protocols and TSB whether owned or using international standards that exist for transmission, so that is possible to compare the performance, efficiency and quality in the transmission of information from these systems in greater detail.

An analysis of compression, error detection and encryption of biomedical signals, taking into account the resources HW / SW available in the SE.

Analyze the robustness and electrical safety of the system implemented in order to perform technical tests set out in standard NTC 60601-1. Calculate the computational cost of the programs implemented in the SE performing communication with the information system SARURO, in order to establish the efficiency of the SW in the SE and thus determine the improvements possible that you can do to optimize design.

Explore new applications for the SE as the detection of environmental variables: temperature, humidity, sound pressure level among others, for transmission and control of the conditions of a greenhouse or to perform monitoring and control systems in an industry.

Modify Featustics of the HW / SW for measuring other parameters that allow the exploration of new subjects of study like WSN (Wireless Sensor Networks) in such solutions especially remote level (regional)

Work on the implementation of communication protocols for SE with these features, expanding environment solutions in the area of health, education, agriculture and environment among others.

5. Conclusions

This research presents the design and implementation of a TES SE ROv2.0 for the acquisition and transmission of SB through the RC, which functions as a communication tool between capture and display of the signals. The TES ROv2.0 system allows storage, adaptation and transmission, network WPAN, WLAN, LAN and cellular networks, the corresponding information: SP02 level, BP, HR and ECG. This information is sent to the information system SARURO where the visualization and analysis of information is performed by a doctor and / or specialist. TM system can be used for / or local and remote monitoring.

ROv2.0 TES system is an economical solution for implementing the SB TM devices, as its cost, an amount of 100 units is approximately $ 50 per card and integrates the elements necessary to connect directly OEM cards signal acquisition. On the other hand, implement the solution with a commercial SE is priced at $ 140 to $ 240 dollars, which corresponds to the value of the embedded system and external devices needed to adapt acquisition cards. A's have done a tailored solution, in addition to reducing costs by more than about 50%, the design of the device is also simplified, making it robust and easy to integrate into the team.

Standards and safety requirements, national and international, to be met by a device for SB TM, study contained in the technical report was identified: "Legal Framework for Medical Devices in Colombia". This activity was detected in the national regulation for medical monitoring equipment it is in an exploratory stage and has a shortage of qualified personnel to guide the production and marketing processes.

TM device proved to be a useful tool in the medical field for monitoring and control of patients. This tool can be used in prevention or treatment of disease, becoming a tangible example of the use of ICT in this area. Similarly, with the use of this device it is both reduces the time and cost of treating a patient who is in regions difficult to access because there is no need to transport neither the patient nor the physician and / or specialist site where you are the other. It also allows for a more appropriate diagnosis and appropriate for which you can receive in these places, because it allows a specialist to analyze quickly and from anywhere with internet access, the SB of the patient.

In the implemented solution, a TT and knowledge is done in the field of SE, which reduces the current deficiencies in Colombia in the design of HW for technological applications in medicine and ICT. It also constitutes an enriching academic experience, which minimizes technological dependence on the development of communication tools for these devices.

In the process of development of the device TM, an approach was made to the rules, thematic and commercial devices used worldwide in research and development of medical equipment in order to identify design methodologies and architectures HW / SW used in the SE and apply them in the field of Telemedicine. In addition, during the development of the project was established that the SE are tools that offer great versatility in handling medical information, allowing for the acquisition, adaptation, processing, transmission and efficient management for various wireless networks.

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