 http://dx.doi.org/10.18623/rvd.v23.5478

INTEGRATED MULTIPARAMETRIC MONITORING SYSTEM FOR THE ACQUISITION AND ANALYSIS OF BIOMEDICAL SIGNALS

SISTEMA DE MONITORAMENTO MULTIPARAMÉTRICO INTEGRADO PARA A AQUISIÇÃO E ANÁLISE DE SINALES BIOMÉDICOS

Article received on: 11/19/2025
Article accepted on: 2/19/2026

Holger Posada*
*Grupo de Espectroscopía Óptica y Láser, Universidad Popular del Cesar, Valledupar, Colombia
Orcid: https://orcid.org/0009-0005-0015-1735
hposada@unicesar.edu.co

Miguel Mejia**
**Ingeniería Electrónica, Universidad Popular del Cesar, Valledupar, Colombia
Orcid: https://orcid.org/0009-0002-6541-1057
miguelmejia@unicesar.edu.co

Jose Castro**
**Ingeniería Electrónica, Universidad Popular del Cesar, Valledupar, Colombia
Orcid: https://orcid.org/0009-0000-5493-9783
josecastro@unicesar.edu.co

Edwin Rivera*
*Grupo de Espectroscopía Óptica y Láser, Universidad Popular del Cesar, Valledupar, Colombia
Orcid: https://orcid.org/0000-0002-5572-3359
edwinrivera@unicesar.edu.co

Jorge Quintero*
*Grupo de Espectroscopía Óptica y Láser, Universidad Popular del Cesar, Valledupar, Colombia
Orcid: https://orcid.org/0009-0005-7755-2027
jorgequinteroe@unicesar.edu.co

The authors declare that there is no conflict of interest

Abstract
This work presents the design and construction of a multiparametric biomedical signal monitoring system intended for the acquisition, visualization, and analysis of physiological variables. The proposed system integrates three main components: a sensing module, a data acquisition system, and a graphical user interface. The sensing module was designed to acquire electrocardiographic (ECG), phonocardiographic (PCG), respiratory, and body temperature signals using noninvasive sensors and appropriate signal conditioning stages. The acquired signals are digitized through an Arduino Uno–based acquisition system and transmitted to a computer for processing and visualization. A graphical user interface developed in LabVIEW enables real-time monitoring, waveform display, and parameter supervision in a user-friendly environment. The prototype also incorporates electrical isolation

Resumo
Este trabalho apresenta o projeto e a construção de um sistema multiparamétrico de monitoramento de sinais biomédicos destinado à aquisição, visualização e análise de variáveis fisiológicas. O sistema proposto integra três componentes principais: um módulo de detecção, um sistema de aquisição de dados e uma interface gráfica de usuário. O módulo de detecção foi projetado para adquirir sinais eletrocardiográficos (ECG), fonocardiográficos (PCG), respiratórios e de temperatura corporal utilizando sensores não invasivos e estágios adequados de condicionamento de sinal. Os sinais adquiridos são digitalizados por meio de um sistema de aquisição baseado no Arduino Uno e transmitidos a um computador para processamento e visualização. Uma interface gráfica de usuário desenvolvida no LabVIEW permite o monitoramento em tempo real, a exibição de formas de onda e a supervisão de

and patient safety considerations according to biomedical equipment standards. Experimental results demonstrate that the system is capable of reliably acquiring and displaying the physiological signals under study. The developed prototype represents a low-cost and portable alternative for biomedical monitoring applications, particularly in clinical and home-care environments.

Keywords: Comprehension. Teaching Fractions. Play-based Learning. Participation. Motivation.

parâmetros em um ambiente intuitivo. O protótipo também incorpora isolamento elétrico e considerações de segurança do paciente de acordo com as normas para equipamentos biomédicos. Os resultados experimentais demonstram que o sistema é capaz de adquirir e exibir de forma confiável os sinais fisiológicos em estudo. O protótipo desenvolvido representa uma alternativa de baixo custo e portátil para aplicações de monitoramento biomédico, particularmente em ambientes clínicos e de cuidados domiciliares.

Palavras-chave: *Compreensão. Ensino de Frações. Aprendizagem Lúdica. Participação. Motivação.*

1 INTRODUCTION

One of the major advances enabled by microelectronics and modern computing has been the development of electromedicine, which has significantly contributed to improving the understanding and delivery of healthcare services. These technological advances have led to the emergence of a wide variety of medical devices and systems capable of performing diverse diagnostic, monitoring, and therapeutic functions. The integration of microelectronic components with computational tools has allowed biomedical instrumentation to achieve greater precision, portability, and real-time data processing capabilities, thereby enhancing clinical decision-making and patient care (Webster & Clark, 2010; Enderle & Bronzino, 2012).

In this work, the design and construction process of a multiparametric biomedical signal monitoring system is presented. The proposed system is intended to support the diagnosis and monitoring of essential vital signs and to facilitate additional medical inferences through the acquisition and analysis of physiological signals. Furthermore, the system is oriented toward home-based healthcare (home care) applications due to its versatility and the integration of a computer-based graphical user interface that allows efficient visualization and interpretation of biomedical data. Such monitoring platforms are increasingly relevant in modern healthcare environments, particularly in the context of remote monitoring and telemedicine solutions aimed at improving patient follow-up outside traditional clinical settings (Pantelopoulos & Bourbakis, 2010; Webster & Clark, 2010).

Vital signs are physiological signals or responses exhibited by a living human being that reflect the basic functions of the organism; these parameters indicate the hemodynamic status of the patient. The main physiological parameters commonly considered include heart rate, respiratory rate, blood pressure, peripheral temperature, among others. These indicators provide essential clinical information about the functioning of the cardiovascular, respiratory, and thermoregulatory systems, and they are widely used for the initial assessment and continuous monitoring of patient health conditions (Webster & Clark, 2010; Guyton & Hall, 2021).

Physiological parameter monitors, also known as patient monitors, are electronic devices designed to measure, acquire, and display information related to a patient's vital signs under continuous observation. The importance of these systems, widely used in intensive care units, emergency departments, and hospital wards, lies in their ability to provide real-time visualization and reliable monitoring of physiological variables. Such capabilities facilitate timely clinical decisions and improve the efficiency of medical and paramedical staff in critical care environments (Enderle & Bronzino, 2012; Pantelopoulos & Bourbakis, 2010).

Vital signs monitoring systems can be classified according to the parameters they are capable of detecting, processing, and displaying, as well as according to the configurations used for signal processing and analysis. These systems may be designed for different patient populations, including adult, pediatric, or neonatal patients. Based on these criteria, as well as factors such as the possibility of expanding the number of monitored variables, a wide range of monitoring systems is available in the market with different levels of complexity and cost. These systems are typically categorized according to their clinical application, including basic monitoring, intermediate monitoring, transport monitoring, surgical monitoring, or anesthesia monitoring, as well as the robustness and reliability of their hardware and software architectures (Webster & Clark, 2010; Enderle & Bronzino, 2012).

The proposed solution aims to develop a biomedical variable monitoring system in which visualization and additional functionalities are performed on a platform separate from the acquisition hardware. Communication between the hardware module and the visualization platform—such as a personal computer—enables the implementation of advanced data processing, graphical representation, and system control. This approach seeks to reduce costs while improving portability, versatility, and functional capabilities compared to conventional monitoring systems, thereby providing an accessible alternative for biomedical monitoring applications, particularly in flexible or home-care environments (Pantelopoulos & Bourbakis, 2010; Baig, GholamHosseini, & Connolly, 2013).

The number of patients suffering from physiological disorders who require continuous monitoring is considerably high in many regions. However, the cost of the medical equipment required for such purposes is often prohibitively expensive, and the existing classification and complexity of these monitoring systems limit their availability for public healthcare institutions or for acquisition by private individuals. Consequently, many healthcare systems face significant challenges in providing adequate technological resources to meet the growing demand for patient monitoring, particularly in regions with limited economic resources (Pantelopoulos & Bourbakis, 2010; Baig *et al*., 2013).

Técnica Electromédica Espeleta Salazar Ltda. is a biomedical maintenance company dedicated to the servicing and repair of electronic and optical equipment, with specialization in biomedical devices. The company provides services to both public and private healthcare institutions, including the E.S.E. Hospital Rosario Pumarejo de López in Valledupar, among others. In order to offer innovative and high-quality services, the company currently requires a portable multiparametric biomedical signal monitoring system that could be offered as part of the technological equipment supplied to the institutions where it provides technical support and maintenance services.

For this reason, the project proposes the design of a low-cost portable electronic prototype capable of performing continuous monitoring of physiological signals in clinical and hospital environments. Additionally, the system is intended to be used in home-care settings as an alternative to reduce the number of non-critical patients occupying hospital resources. Patients whose clinical condition allows remote supervision could be monitored from their homes under appropriate medical guidance, contributing to more efficient healthcare management and improved patient follow-up (Pantelopoulos & Bourbakis, 2010; Baig *et al*., 2013).

Furthermore, the focus of the project is particularly directed toward patients with cardiovascular disease (CVD), given the high mortality rates associated with this condition. Cardiovascular diseases remain one of the leading causes of death worldwide and represent a significant public health concern in many regions. Continuous monitoring of key physiological parameters is therefore essential for early detection and management of cardiovascular complications (World Health Organization, 2021). In addition to conventional physiological variables commonly measured in monitoring systems, the proposed system incorporates phonocardiography as an additional parameter, which is not typically included in conventional commercial monitoring equipment but can provide valuable information about cardiac function and heart sound abnormalities (Springer *et al*., 2016).

The objective of this project is to design and build a multiparametric biomedical signal monitoring system capable of acquiring, processing, and displaying physiological variables relevant to patient health assessment. To achieve this goal, a sensing module will be developed to measure physiological variables such as body temperature and to acquire signals for electrocardiography (ECG) and phonocardiography, allowing the visualization of their respective waveforms. In addition, an interactive graphical user interface will be programmed and implemented to enable the monitoring, processing, and graphical representation of the acquired data. The system will also include a data acquisition module designed to establish communication between the sensing hardware and the monitoring and visualization platform. Finally, appropriate patient isolation and biosafety mechanisms will be incorporated in accordance with biomedical equipment standards to ensure safe operation during physiological signal acquisition.

2 METHODOLOGICAL ASPECTS

The methodological development of the proposed multiparametric monitoring system was structured into four stages: sensor module design, user interface development, data acquisition implementation, and electrical safety integration. First, a noninvasive sensing module was designed to acquire electrocardiographic (ECG), phonocardiographic (PCG), respiratory, and body temperature signals. For ECG acquisition, disposable Ag/AgCl surface electrodes were selected due to their stability and suitability for biopotential recording, while the analog front-end was based on an INA128 instrumentation amplifier because of its low-power operation and high common-mode rejection ratio, which are desirable features for low-amplitude biomedical signals. Signal conditioning included active filtering and level shifting to improve visualization and reduce interference. In particular, the ECG channel employed a band-limited filtering strategy consistent with the usual frequency content of clinical ECG signals, together with a 60 Hz notch stage to attenuate power-line contamination.

For respiratory monitoring, a nasal thermosensor-based probe was used to detect airflow-related thermal changes during inhalation and exhalation. The resulting signal was conditioned through amplification and comparison stages to obtain a usable waveform for respiratory-rate estimation. For phonocardiography, heart sounds were captured using a conventional stethoscope chest piece coupled to an electret microphone, allowing acoustic cardiac vibrations to be converted into electrical signals. The PCG analog chain incorporated amplification, band-pass filtering, 60 Hz rejection, and DC level shifting, with cutoff frequencies selected according to the typical spectral range of the principal heart sounds. Body temperature measurement was performed with a skin-contact thermistor sensor, and the temperature value was estimated in software from the measured resistance using a thermistor calibration model based on the Steinhart–Hart relationship.

In the second stage, a graphical user interface was developed in LabVIEW 2015 to visualize and process the physiological variables acquired by the sensing hardware. The interface was organized into independent monitoring panels for ECG, PCG, and respiration/temperature, enabling waveform display and parameter supervision in a user-friendly environment. Communication between the software platform and the embedded hardware was established through the LabVIEW Interface for Arduino toolkit, which allows the Arduino board to be controlled from LabVIEW for acquisition-oriented applications. Although this toolkit was later superseded by LINX, it remains appropriate for the implementation described in this prototype.

In the third stage, the data acquisition system was implemented using an Arduino Uno development board based on the ATmega328P microcontroller. Its internal analog-to-digital conversion resources were used to digitize the conditioned analog signals produced by the sensor modules, after which the sampled data were transmitted to the computer for visualization and additional processing in the graphical interface. This architecture allowed the sensing stage to remain simple and low-cost while shifting computational tasks and graphical rendering to the external software platform.

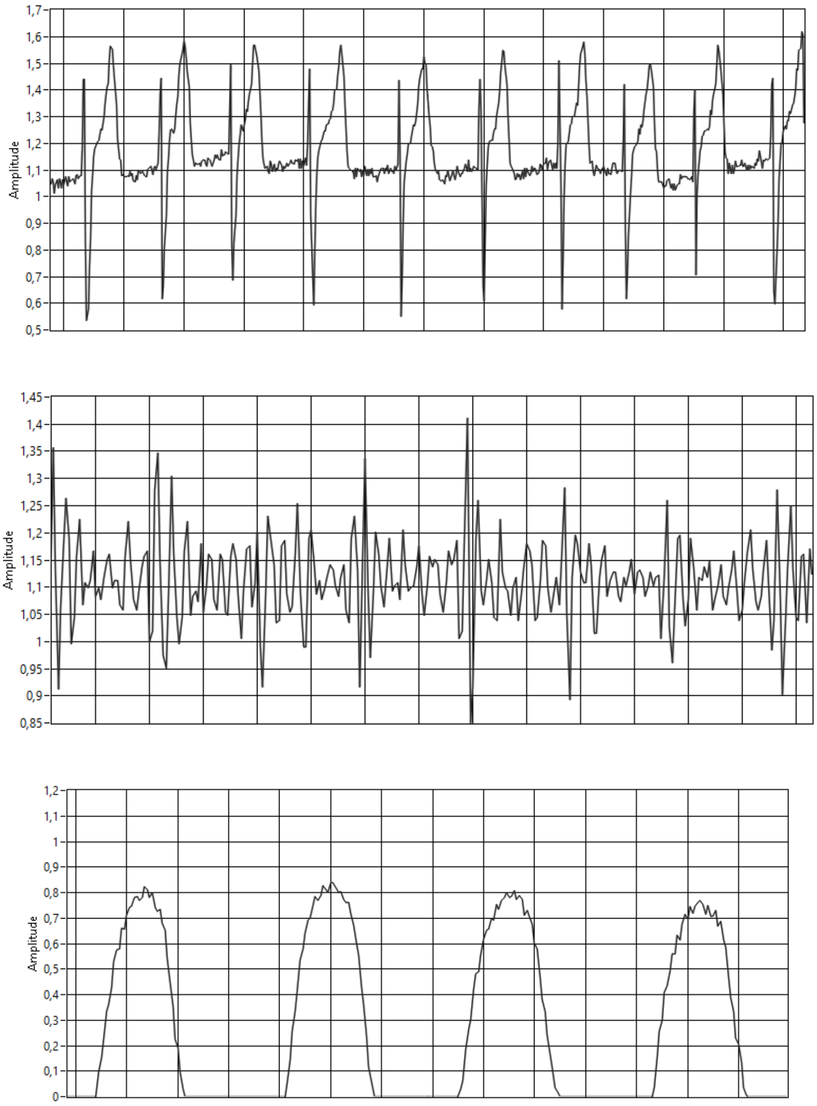
Finally, patient protection was considered through the incorporation of grounding, coupling, and isolation strategies aligned with the general safety principles of medical electrical equipment. Because the prototype was conceived as a noninvasive monitoring system, the design emphasized basic electrical safety and signal isolation between stages, including capacitive coupling and impedance adaptation. These decisions were guided by the general framework of IEC 60601-1 for basic safety and essential performance, together with IEC 60601-1-2 considerations regarding electromagnetic disturbances in medical electrical systems.

3 RESULTS

At the end of the design and construction process, a sensing module capable of acquiring the desired physiological variables was successfully developed. Additionally, as an added value, an extra module for respiratory signal acquisition was designed and implemented. Figure 1 presents the resulting signals obtained from each of the sensing modules for a patient with a normal health condition.

Figure 1

Signals acquired by the sensing module: (a) ECG, (b) PCG, (c) Respiration.

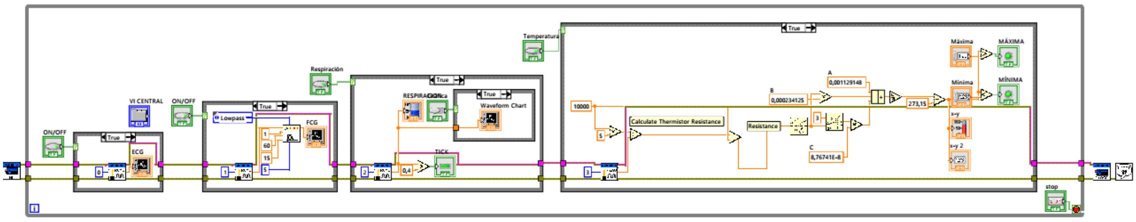


The complete electronic design of the system is presented in the annex chapter of this work.

After constructing the sensing modules, a data acquisition system was developed to enable the digitization and processing of the signals for subsequent visualization and analysis. As described in the design section, this system is based on an Arduino UNO module controlled through the LIFA_BASE firmware using LabVIEW. The acquisition and processing diagram is shown in Figure 2.

Figure 2

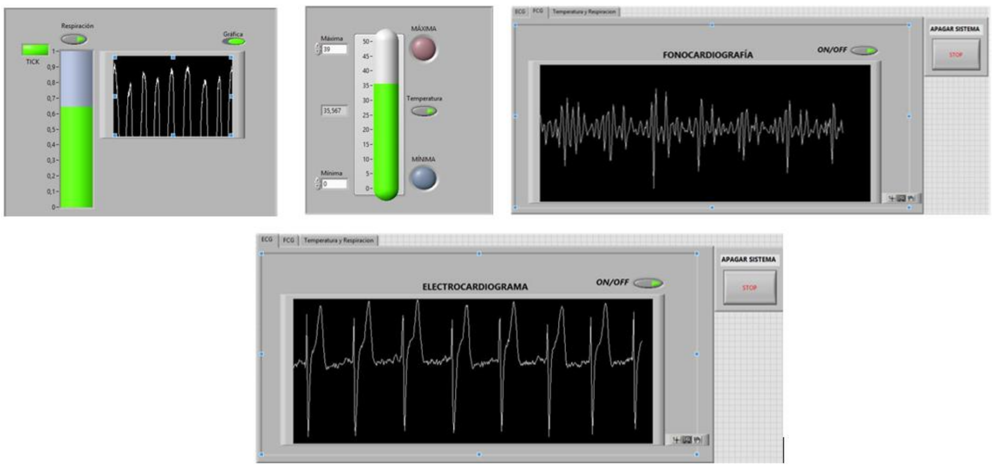
Block diagram of the acquisition system in LabVIEW.



A dynamic graphical user interface was designed to enable the visualization of the signals obtained from the sensing modules and to review the data in an intuitive and illustrative manner. Figure 3 shows the different components of the interface during operation.

Figure 3

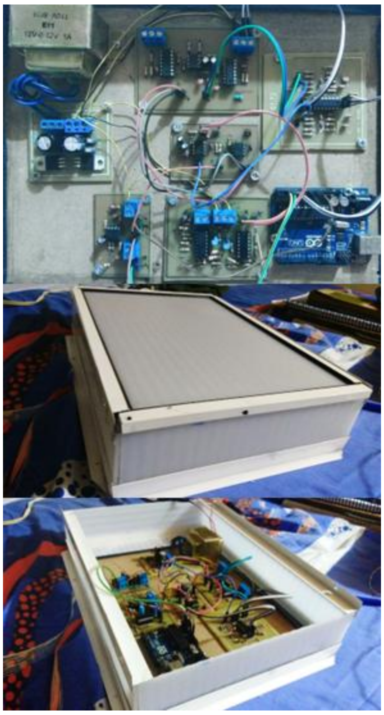
Signals and indicators in the user interface: (a) Respiration, (b) Temperature, (c) PCG, (d) ECG.



After completing the design of the system components, we were able to assemble a functional device suitable for use under the recommended conditions for equipment of this type, thereby fulfilling the general objective of this work. Figure 4 shows images of the developed device.

Figure 4

Images of the assembled prototype.



4 CONCLUSION

With the development of the prototype, the expected multiparametric biomedical signal monitoring system was successfully designed and built, with proper operation of its components and conditions suitable for its use.

The design and construction of a sensing module composed of several submodules were completed. This module is capable of acquiring body temperature and displaying ECG and phonocardiography waveforms and, as an added feature, acquiring and plotting the respiratory signal.

An interactive and user-friendly graphical user interface was developed to process and monitor the corresponding physiological variables.

A data acquisition system was designed to function as an interface between the sensing module and the graphical user interface, linking these two elements and enabling communication between them.

Patient isolation and safety mechanisms were implemented according to standards consistent with the type of biomedical equipment designed and constructed.

REFERENCES

Baig, M. M., GholamHosseini, H., & Connolly, M. J. (2013). A comprehensive survey of wearable and wireless ECG monitoring systems for older adults. Medical & Biological Engineering & Computing, 51(5), 485–495. https://doi.org/10.1007/s11517-012-1021-6

Enderle, J. D., & Bronzino, J. D. (2012). Introduction to biomedical engineering (3rd ed.). Academic Press.

Guyton, A. C., & Hall, J. E. (2021). Guyton and Hall textbook of medical physiology (14th ed.). Elsevier.

International Electrotechnical Commission. (2005). IEC 60601-1: Medical electrical equipment—Part 1: General requirements for basic safety and essential performance. IEC.

International Electrotechnical Commission. (2014). IEC 60601-1-2: Medical electrical equipment—Part 1-2: General requirements for basic safety and essential performance—Collateral standard: Electromagnetic disturbances. IEC.

Pantelopoulos, A., & Bourbakis, N. G. (2010). A survey on wearable sensor-based systems for health monitoring and prognosis. IEEE Transactions on Systems, Man, and Cybernetics: Systems, 40(1), 1–12. https://doi.org/10.1109/TSMCC.2009.2032660

Springer, D. B., Tarassenko, L., & Clifford, G. D. (2016). Logistic regression-HSMM-based heart sound segmentation. IEEE Transactions on Biomedical Engineering, 63(4), 822–832. https://doi.org/10.1109/TBME.2015.2475278

Texas Instruments. (2015). INA128 precision instrumentation amplifier datasheet. Texas Instruments.

Webster, J. G., & Clark, J. W. (2010). Medical instrumentation: Application and design (4th ed.). Wiley.

World Health Organization. (2021). Cardiovascular diseases (CVDs). https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds)

Authors' Contribution

All authors contributed equally to the development of this article.

Data availability

All datasets relevant to this study's findings are fully available within the article.

How to cite this article (APA)

Posada, H., Mejia, M., Castro, J., Rivera, E., & Quintero, J. (2026). INTEGRATED MULTIPARAMETRIC MONITORING SYSTEM FOR THE ACQUISITION AND ANALYSIS OF BIOMEDICAL SIGNALS. Veredas Do Direito, 23(5), e235478. https://doi.org/10.18623/rvd.v23.5478