

# Low-cost electrocardiogram monitoring system for elderly people using LabVIEW

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## ABSTRACT

Cardiovascular diseases increase due to factors such as obesity, an inadequate diet, and are a problem due to shortages of medical personnel and hospitals. In this case, the implementation of technological solutions is presented as a necessity to prevent heart diseases. Various approaches are used to design low-cost electrocardiogram (ECG) devices, from the use of Bluetooth technology to facilitate data transmission, to the development of wearable ECG devices that use artificial intelligence. The objective is to develop a monitoring system in LabVIEW to visualize the heart rhythms of older adults in the city of Lima (Peru), focusing on ease of use and adaptation to their needs, with the purpose of collaboration between health professionals. A development approach is used that encompasses design, implementation, and iterative testing, as well as practical evaluations and pilot testing. As a result, the correct functioning of the ECG device was validated. Electronic components and electrodes were integrated into the board to capture cardiac signals, energized with batteries and sending the information to an interface in LabVIEW. In conclusion, a portable ECG device has been developed that uses operational amplifiers (Op-amps) and analog filters to reduce noise in cardiac measurements and an intuitive interface in LabVIEW.

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## 1. INTRODUCTION

The growing population of older adults in Metropolitan Lima requires specialized and accessible medical care to guarantee their well-being and quality of life. Cardiovascular diseases, such as stroke and heart disease, are the leading cause of death globally, especially in low-resource countries, accounting for more than 75% of global deaths [1], [2]. In this context, continuous monitoring of heart rhythms is presented as a vital tool for the detection of possible arrhythmias [3].

Cardiovascular diseases, driven by obesity, atherosclerosis, and poor diet, represent one of the leading causes of mortality worldwide due to their effects on metabolism and cardiovascular health [4]. In the case of hospitals in Peru, they face significant problems due to deficiencies in internal management, insufficient acquisition of medical supplies, lack of modern medical equipment which, combined with poor infrastructure, results in chaotic care and untimely for seriously ill patients [5]–[7]. Furthermore, the shortage of human resources in the MINSA (Peruvian Ministry of Health) is worsened in the poorest regions, where the lack of personnel prevents timely care [8]. This is why the use of low-cost technologies can contribute to

preventing cardiovascular diseases in the elderly population of Lima, given the high prevalence of risk factors.

In the review of the literature, studies have been found that focus on designing a low-cost and easy-to-use electrocardiogram (ECG), focusing on capturing cardiac electrical signals, filtering noise, and transmitting them [9], adding in some cases Bluetooth technology to facilitate the early diagnosis of cardiac diseases [10]–[12] while other authors [13]–[15] present an approach on the design of a simulator of electrocardiographic signals, highlighting the reduction of cost by converting analog to digital signals. On the other hand, there have been significant advances in the monitoring and detection of cardiac arrhythmias [16], [17] through the development of a portable ECG device [18], data transmission through artificial intelligence while other research [19] presented a prototype based on machine learning for the detection and classification of arrhythmias in low-cost ECG devices with MATLAB and PSoC4 [20], [21]. Finally, big data systems allow medical decision making based on historical data to optimize medical signal monitoring processes [22], [23], focusing, in some cases, on energy savings [24].

Therefore, the objective of this research is to design a monitoring system based on LabVIEW for the visualization of the heart rhythms of older adults in Metropolitan Lima, which is easy to use and adapted to the needs of older adults. The system will provide a cardiac signal monitoring solution, through secure and accessible information storage, facilitating analysis between health professionals. This can be complemented with automatic notification mechanisms to alert about possible anomalies, improving timely medical care.

## 2. RESEARCH METHOD

The research focuses on developing an electronic device to collect the heart rhythms of people over 60 years of age and evaluate its effectiveness. A combined technology development approach is used, involving design, implementation, and iterative testing of the device, along with practical evaluations and pilot tests to validate its usefulness. In addition, easy-to-use features are integrated into the design of the device, considering the needs of older people for the successful adoption of the system in their daily lives.

The implementation procedure begins with the design and development of the electronic device, focusing on the selection of sensors, electronic circuits, and software. The descriptive diagram of operation (Figure 1) shows the beginning of signal acquisition and subsequent treatment to eliminate noise, using a notch filter, a band-pass filter and a final amplification stage. Subsequently, the conditioned signal will be converted from analog to digital using an Arduino Uno module. The information is displayed through a graphical interface created in LabVIEW, obtaining a detailed representation of the heart signal.

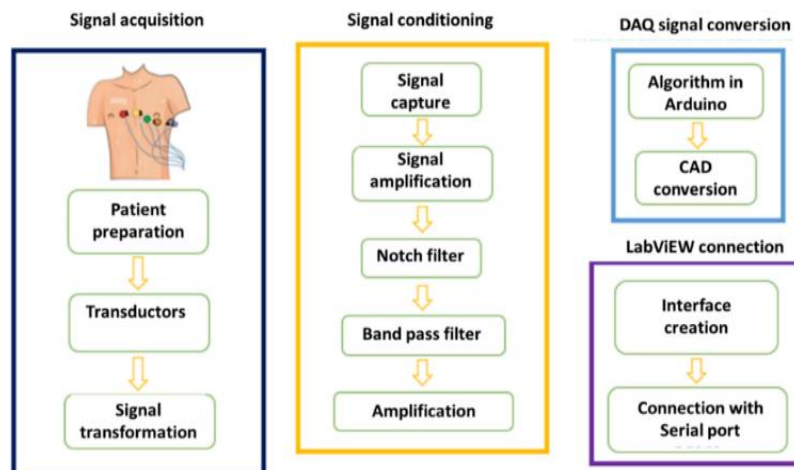


Figure 1. Descriptive diagram of operation

### 2.1. Components

For the design of the acquisition stage, essential electronic components required to assemble the hardware stage are used, among which we have: i) instrumentation amplifier: which is built with high impedance operational amplifiers (Op-amps) at the input using the AD620 device [25]; ii) Op-amps: the LM741 is used as an inverting comparator, adder and filter to process the signals obtained by the transducers [26]; iii) ECG cable with jack output: snap connectors are used to facilitate connection to the

circuit, allowing the second derivative to be analyzed (left leg with right arm); iv) electrodes: it is used to acquire the electrical activity generated using an silver/silver chloride (Ag/AgCl) electrode; and v) Arduino Uno it integrates an ATmega328P microcontroller and an analog to digital conversion (DAQ) module, conducting programming through its integrated development environment (IDE).

## 2.2. Electrocardiogram circuit stage design

The ECG circuit has a set of stages that range from signal transduction through the electrodes, through the stages of amplification, filtering and DAQ using Arduino UNO, until reaching the LabVIEW interface used to analyze the patient's signals (Figure 2). The stages are: i) transduction: it captures electrical signals from the heart through electrodes placed on the skin; ii) circuit amplification: an AD620 Op-amps is used to compare and adjust the captured ECG signal, to eliminate noise and maintain a good frequency response; iii) signal filtering: low pass and high pass filters are used. Additionally, a 60 Hz notch filter is implemented using resistors and capacitors to eliminate electrical interference. In addition, there is a reverse amplification process that establishes a gain of 50 with the purpose of inverting the signal; and iv) data acquisition with Arduino and LabVIEW: the analog signal is converted through transduction and filtering to a digital signal using the ATmega328P microcontroller. Subsequently, this data is displayed on a PC for analysis and treatment of the patient.

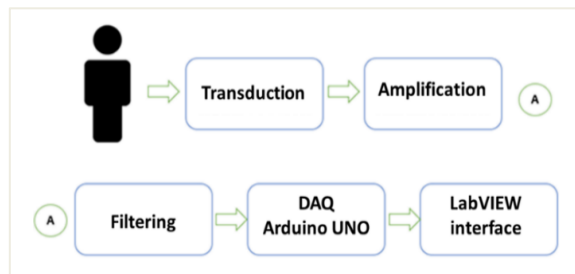


Figure 2. Block diagram

## 2.3. Printed circuit board design

The process of creating a printed circuit board (PCB) is crucial for electronic development. The Proteus design software is used to generate the signal routing diagram to avoid interference and optimize performance (Figure 3). This design is then translated into a manufacturing diagram, which includes details on the physical arrangement of components on the board, location of holes, and other aspects for production (Figure 4).

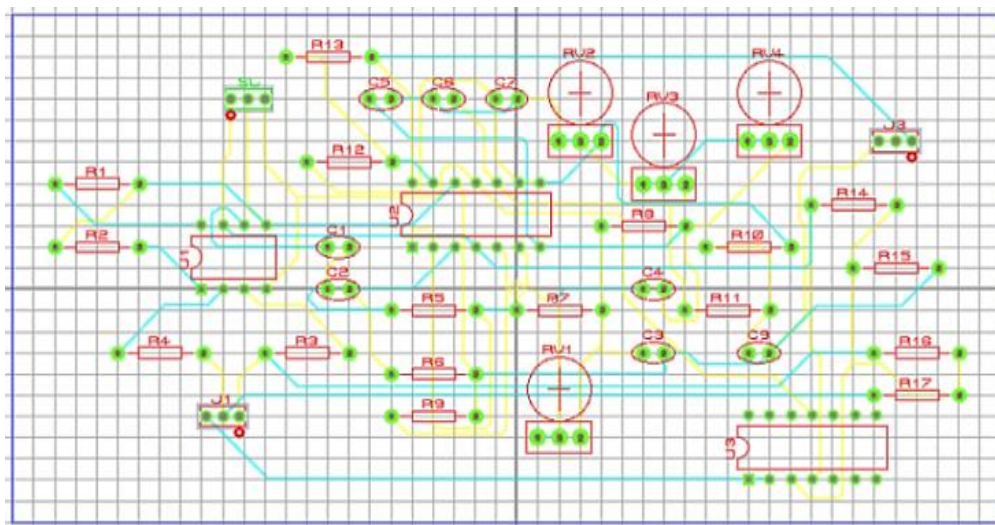


Figure 3. PCB routing diagram for ECG signal acquisition

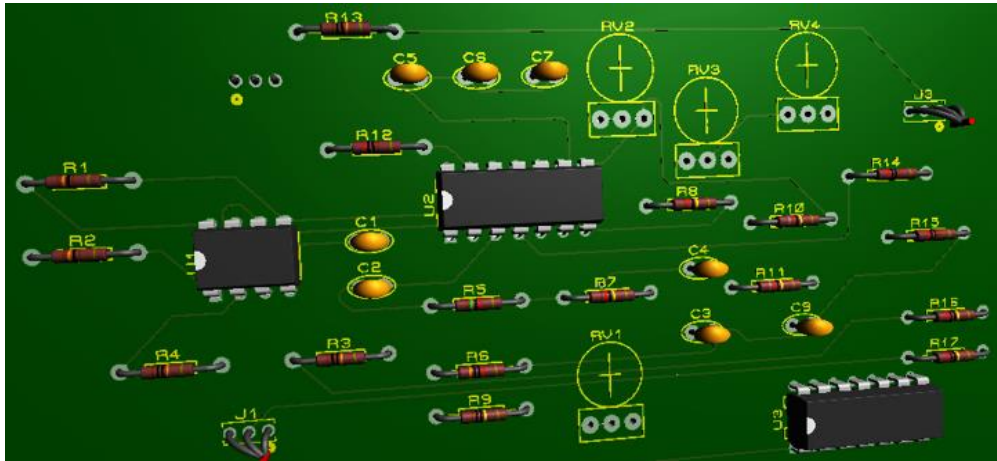


Figure 4. 3D model of the ECG signal acquisition system PCB

**2.4. Acquisition algorithm**

The algorithm is responsible for reading signals using two digital control pins (pin 10 and pin 11) and one analog pin (A0). During the initialization process, serial communication is configured at a speed of 9600 baud and pins 10 and 11 are established as digital inputs. Within the main loop it is checked if either of the two digital pins (pin 10 or pin 11) are high. The analog value from pin A0 is then read and printed to the serial port for verification. After each read, there is a 5 milli second delay inside the loop (Figure 5).

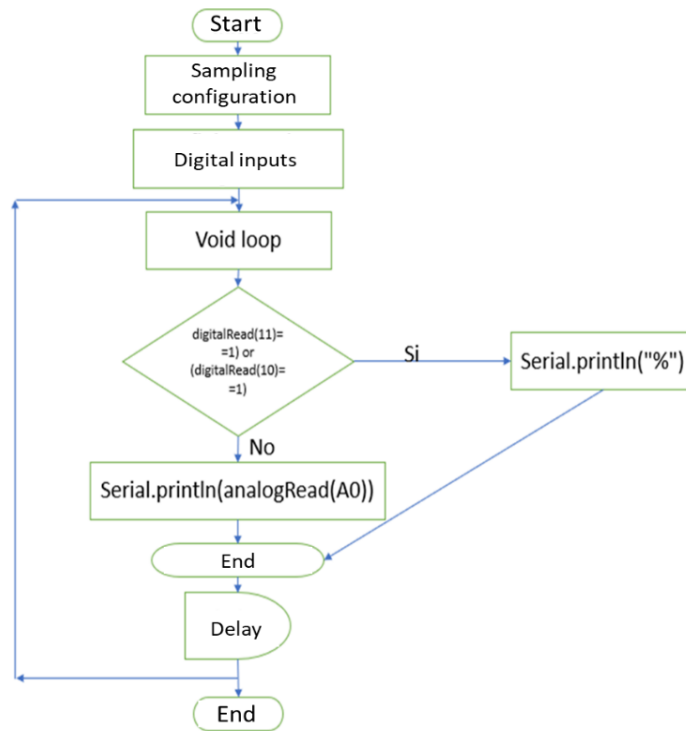


Figure 5. Acquisition algorithm flowchart

**2.5. Graphical interface in LabVIEW**

In LabVIEW, is create a graphical interface by selecting a waveform chart and customizing it with a scale from 0 to 100 on the x-axis and 0 to 4 on the y-axis. A light-emitting diode (LED) is added, a stop button and numerical indicators are incorporated to show the beats per minute (BPM), the pulse rate and a

serial port control (Figure 6). Furthermore, the flexibility of LabVIEW not only allows the creation of an intuitive interface, but also facilitates the implementation of signal processing algorithms in real time.



Figure 6. LabVIEW dashboard

In LabVIEW, the node creation process is essential to effectively understand and analyze cardiac signals. First, nodes are generated for the input of ECG and BPM data, which come from sensors connected to the Arduino module. Signal processing nodes are used to filter and condition ECG signals, removing unwanted noise and preparing them for analysis. These elements connect to display nodes, which represent the ECG signals and BPM data graphically and numerically respectively (Figure 7).

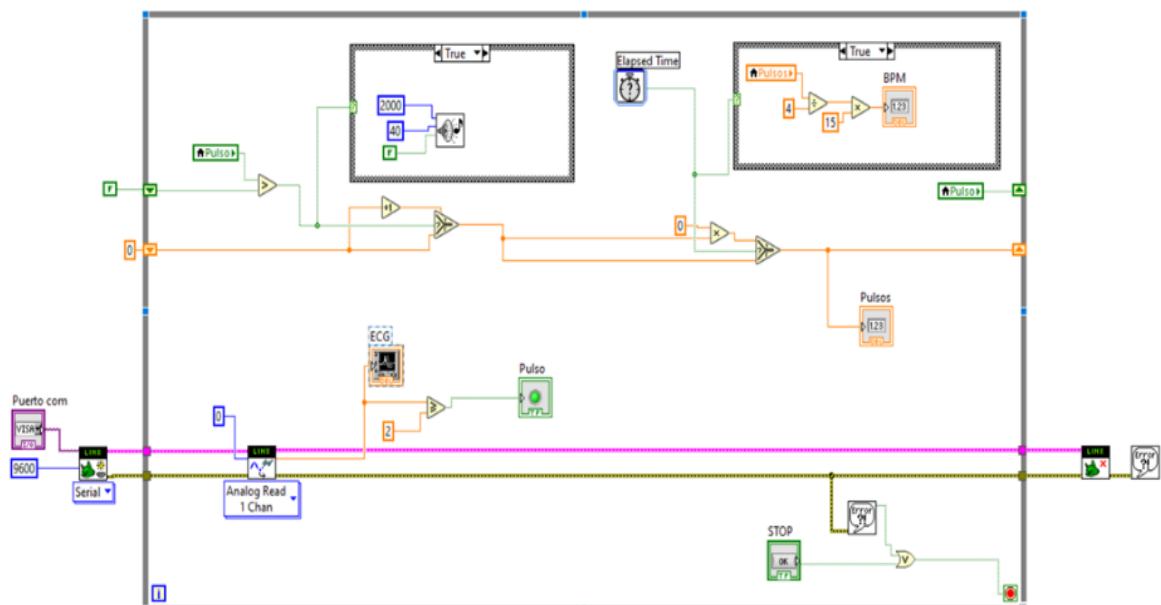


Figure 7. Block diagram in LabVIEW

### 3. RESULTS AND DISCUSSION

#### 3.1. Electronic board for electrocardiogram signals

This section shows the electronic components, previously described in the previous sections, initially integrated into a test board to evaluate their operation, obtaining good signal amplification and low noise. After finalizing the PCB design through the Proteus program, the next step was the manufacturing of the board. A suitable Bakelite is carefully selected, and precautions taken when dipping it in acid to ensure that the tracks match the design exactly, avoiding potential failures that could affect signal capture. Once the PCB is ready, we proceed to solder the components in place (Figure 8).

On the electronic board, double tracks were used in both the top and bottom views, necessary due to the considerable number of components. These tracks allow the interconnection of electronic materials and are essential to reduce the noise generated during connections. The components are then integrated into the PCB board, considering crucial aspects to ensure the precision and stability of the device. Specific electrodes are used that are strategically placed on the patient's arms and right leg, optimizing signal capture, with the device powered by two 9 V batteries (Figure 9).



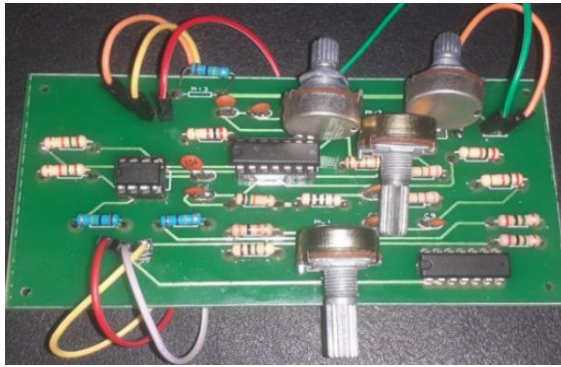


Figure 8. PCB for ECG acquisition

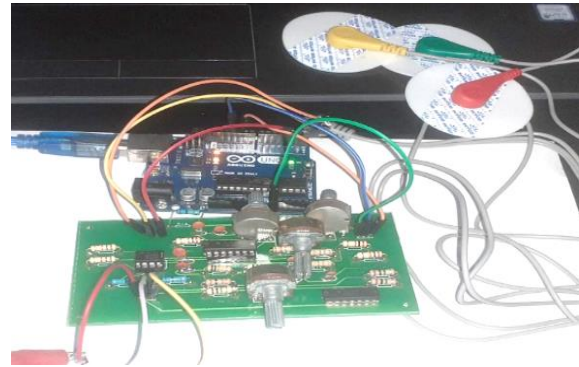


Figure 9. Interconnection of the PCB to the Arduino module and the computer

### 3.2. Visualization of electrocardiogram signals in LabVIEW and the Arduino IDE

The Arduino hardware module is used to display the signal captured with the serial plotter tool, which allows generating accurate graphs of the signals clearly showing the QRS complex and the P and T segments. It is important to mention that there is a slight noise in the signal, which can be attributed to several factors such as grounding and noise (Figure 10), which is almost zero due to the use of filters. This low-cost design offers an optimal tool for rapid diagnosis of diseases in older adults. The graphical interface, created in LabVIEW, has the function of displaying the digital signal coming from the Arduino through the serial port and includes a cardiac pulse counter that detects peaks in the signal greater than a maximum voltage, calculating the BPM (Figure 11). Every 15 seconds and using a buzzer that sounds with each pulse. At the top of the LabVIEW interface, there is a stop button to stop the process.

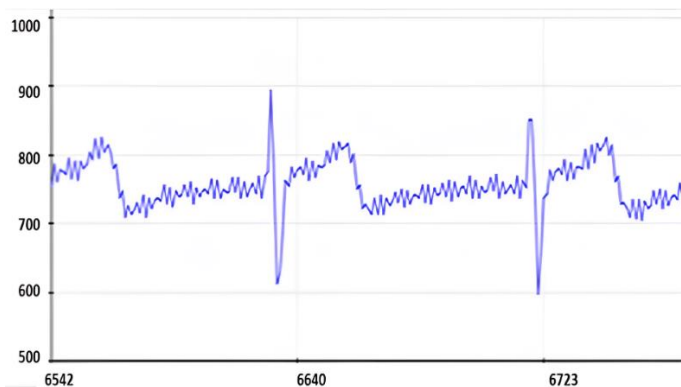


Figure 10. Visualization of the ECG signal in the Arduino IDE



Figure 11. LabVIEW interface for signal visualization

Using the captured signals, the results of Table 1 are obtained, which presents evaluation results for some patients. In the normal context, the human heart usually beats between 60 and 100 times per minute, however, in individuals who exercise regularly or take medications to reduce heart rate, the heart rate may be less than 60 BPM. By analyzing the cardiac characteristics of these patients, it is observed that the data obtained are within the expected ranges, thus validating the optimal performance.

Table 1. Acquired data

Patient	Sex	Age	Heart rate (BPM)	Medical conditions
A	M	62	60	NO
B	M	25	75	NO
C	F	61	67.5	NO
D	M	66	67.5	NO

#### 4. CONCLUSION

This research has culminated in the development of a portable ECG device using analog filters and an intuitive graphical interface in LabVIEW, significantly reducing noise. Optimization of ECG frequencies and effective communication between components have improved the accuracy and clarity of the signals obtained. The correct functioning of the system and use of low-cost components underlines the economic viability of the technology used. In relation to noise and interference reduction, the use of Op-amps has proven to be crucial to effectively reduce noise and interference in ECG measurements. Additionally, the application of analog filters has allowed the ECG frequencies to be limited to a specific range, effectively eliminating unwanted noise. In the case of the intuitive graphical interface, the use of LabVIEW has provided an intuitive visual platform for the analysis of cardiac signals. In addition to offering a clear representation of the data, it has also facilitated the subsequent analysis of the results, improving the monitoring capacity of medical personnel, related to the portability of the device. In addition, the interface in LabVIEW is used as a tool that provides the diagnostic capacity of medical personnel in clinical environments, homes, and ambulances.

The feasibility of a portable and accessible ECG device that uses electronic technologies for the detection and visualization of cardiac signals has been demonstrated. Despite significant achievements, future research could focus on integrating artificial intelligence for more accurate diagnoses, implementing wireless technologies for remote monitoring, and including early warnings. Additionally, may include customization of the system to adapt to various medical conditions, and the inclusion of telemedicine.




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