Design and Implementation of a Medical Telemonitoring System based on IoT

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Abstract-With the advancement of technology, healthcare and monitoring systems face significant issues. Internet of Things (IoT) in healthcare enables real-time health monitoring at a low cost. This paper aims to provide a medical telemonitoring system based on IoT for healthcare applications for doctors and paramedical staff. The system is made up of many sensors that can capture electrocardiograms (ECGs) in real-time and measure the temperature of the human body. The designed circuit is implemented and the obtained results are analyzed and discussed.

Keywords-e-health; Internet of Things; ECG

I. INTRODUCTION

With the rapid development of data and IT technology, healthcare monitoring systems are becoming of great concern [1, 2]. The modern human lifestyle among others, leads to many heart disorders such as arrhythmia, coronary occlusion, cardiac arrest, and heart inflammation. The early diagnosis of a heart disease may lead to minimization of deaths [3, 4]. Modern technologies such as the IoT, Artificial Intelligence (AI), and robotics systems play a vital role in revolutionizing the health care system [5]. Smart health monitoring can be an effective solution to the above challenges as it may takes less time and is more accurate [6, 7]. Several solutions based on ECG measurement systems allow to record and process the cardiac signal by placing skin electrodes on chest and limbs [8].

Many researchers worked on developing and designing a hardware-based ECG acquisition system [3]. Authors in [9] provide a fascinating review of the existing technologies that characterize commercial wireless ECG systems. The purpose of this study is to review the solutions described in the literature, besides commercially available devices and electronic components useful to setup laboratory prototypes. Authors in [10] proposed an IoT-based patient health monitoring system linked to the Cloud Talk platform. The proposed system streamlines the traditional workflow by providing all medical checkups, facilities, and tests in one location. Authors in [11] present an approach based on the Intel Galileo development board to gather and upload various data into a database for use by patients and doctors, making the traditional checkup process more convenient. Authors in [12] propose an automatic contactless thermometer to replace the traditional temperature measuring techniques and safeguard from human-to-human transmission diseases. The advantage of the proposed model is that it uses GPS coordinates and population density values towards identifying the most crowded areas. Authors in [13] proposed a system prototype for monitoring the heartbeat rate and body temperature of chronic patients using sensors. The monitored data are sent to a cloud database in real-time.

In this paper, we present an interactive virtual interface-based medical tele-monitoring system for doctors and paramedical staff, which is implemented using virtual interface-based software, LabVIEW, and IoT. The system aims to contact a Hospital Emergency Room for asking for first aids in case of positive diagnosis. Patient path estimation, ECG signal capture, human-body temperature, and hospital alarm management are the four main components of the system.

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II. THE ECG ACQUISITION SYSTEM

In this section, we explain the methodology followed to design and simulate the ECG acquisition system. The ECG is the most used non-invasive method for making a preliminary clinical diagnosis of cardiac diseases. It is a method of recording the electrical activity of the heart, which is generated by the heart's cells, during the cardiac cycle (both normal and abnormal) [14, 15]. The electrical activity of the heart is measured because every time the heart beats, an electrical signal flows through it. Electrodes are placed on the chest to record the signal. The architecture of the proposed system is shown in Figure 1. This System consists of sensors, which interface with an Arduino Uno R3 Module. The module transmits the sensor data to LabVIEW. The proposed approach is structured in two main phases:

- LabVIEW software was used to write the code of the application. The aim of the simulation is to evaluate the operation of the card, and know, beforehand, the quality of the results and develop design guidelines. Simulations were conducted on Win 10, NI Multisim Release 12.0.1, Arduino IDE Compiler 1.8.19 and NI LabVIEW14.
- Realization of the prototype and the physical implementation of the proposed system. In this step, we used the following tools to evaluate our algorithm: Electrodes to capture the signal from the human heart, passive components (resistor and capacitor), an Arduino board, a low frequency generator, an oscilloscope and a computer with I5 Processor and 8GB RAM.

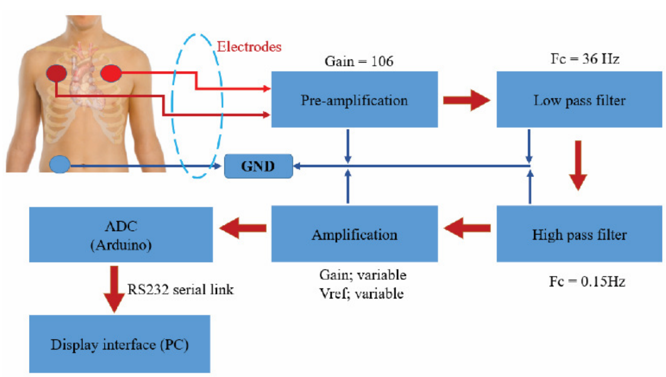

Fig. 1. ECG data acquisition system.

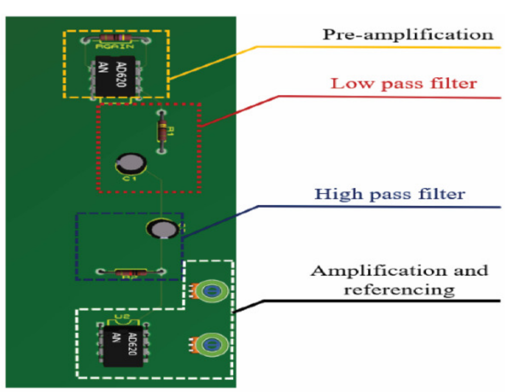

Fig. 2. ECG amplifier, high-and low-pass filters.

There are three stages in the process of simulation, i.e. pre-amplification, filtering, and amplification. The Analog to Digital Converter (ADC) is a significant data converter system. It is one of the main building blocks of the ECG detection system and health care integrated circuits [16]. Figure 2 depicts the ECG amplifier, consisting of high-and low-pass filters. We used the Multisim software to generate the circuit simulation results. Multisim is an industry standard SPICE simulation and circuit design software for analog, digital, and power electronics in education and research [17]. Figure 3 describes the framework used to develop and implement the proposed approach. Figure 4 represents the simulation model of the proposed system circuit in NI Multisim before assembling on a Printed Circuit Board (PCB).

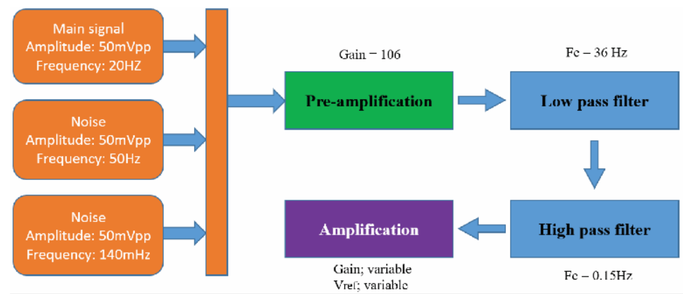

Fig. 3. Stages of the acquisition card.

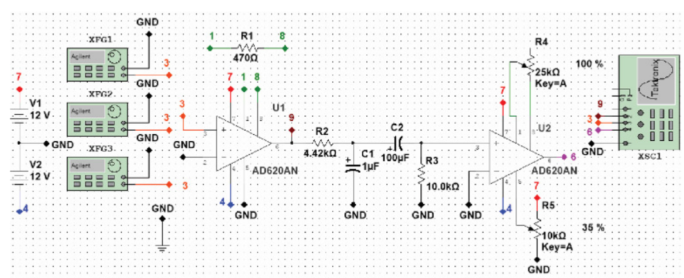

Fig. 4. Circuit diagram of the system.

A. Pre–Amplification

The pre-amplification stage raises the amplitude of the sensed ECG signal from about 0.02mV to about 5mV. The first stage consists of pre-processing the signal using a low pass filter to reduce noise. The pre-amplifier plays an important role in the circuit design. It not only extracts the useful EEG signal, but also reduces the interference signals to the lowest level. Pre-amplification is done using the well-known AD620 amplifier. The AD620 is highly suited for medical applications, such as ECG and non-invasive blood pressure monitors, due to its low noise, low cost, low input bias current, and low power [18]. Three different sinusoidal signals are generated:

- A signal with 50mVpp amplitude and a frequency of 20Hz (main signal).
- A signal with variable amplitude and a frequency of 100Hz which is supposed as noise and reacts on the main signal.
- A signal with variable amplitude and a frequency of 150mHz, considered as noise.

The three signals were introduced to the AD620 through pin 3. Then, a balanced 9v supply was applied to the AD620. A resistance R1 of 470Ω was added to have a gain equal to 106 according to:

$$G_{ain} = \frac{49.4k\Omega}{R_g} + 1 \quad (1)$$

Figure 5 shows the circuit design. Figure 6 illustrates the pre-amplification block results, the results show an informative signal with a main frequency of 20Hz, to which noise signals of 100Hz and 150mHz is superimposed.

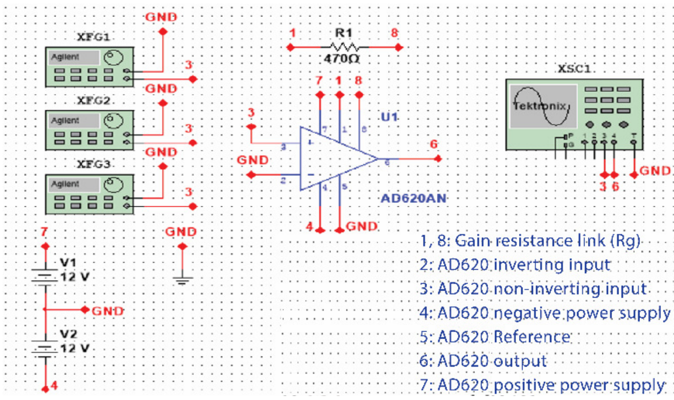

Fig. 5. Pre-amplification circuit.

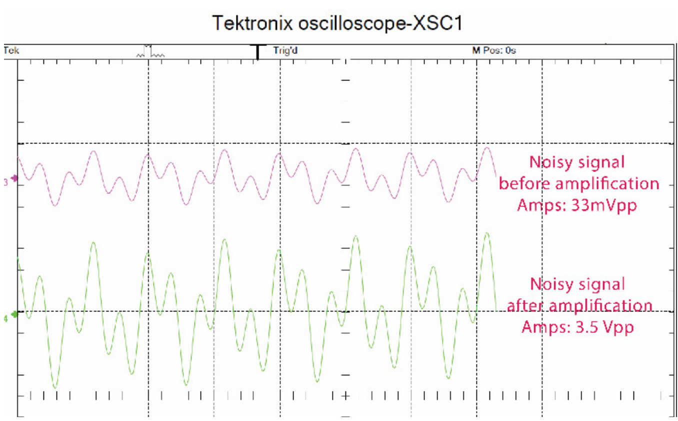

Fig. 6. Pre-amplification block results.

ECG signals are frequently affected by various sources of noise, and baseline drifting is typical. Signal conditioning is unquestionably required to permit automated ECG analysis. A filtering approach is employed to provide baseline correction and noise suppression with minimal signal distortion.

B. Filtering

Generally, the ECG signal can be corrupted by different types of noise and artifacts that can occur within the frequency band of interest and have comparable properties to the ECG signal itself. We must process the raw ECG data in order to obtain valuable information from the noisy ECG signals. Filters are used to remove many forms of noise, including baseline wander, 60Hz power line interference, muscle noise, and motion artifacts. In this section, we use two filters to eliminate the frequencies considered as noise. Two passive filters are placed in series, as shown in Figure 7. The cutoff frequency *Fc* of the filter is calculated according to:

$$Fc = \frac{1}{2\pi RC} \quad (2)$$

The two filters used for this block are:

- First, a low-pass filter around the cutoff frequency of Fc=36Hz to eliminate the 50Hz noise.
- Second, a high-pass filter around the cutoff frequency Fc=0.15Hz.

We cannot eliminate frequencies higher than 1Hz since sometimes we find cases where the ECG frequency takes a value of 2 or 3Hz. So, it is not recommended to eliminate these frequencies since we risk losing information. Figure 8 describes the result obtained at the output of the filter. It can be seen that the noise has been largely attenuated by this filter, especially the ripples, which have frequencies of 100Hz and 150mHz.

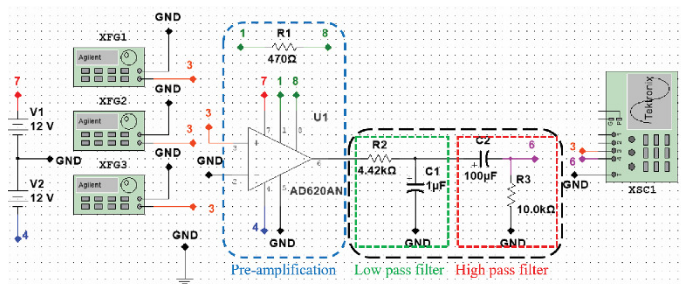

Fig. 7. Pre-amplification and filters.

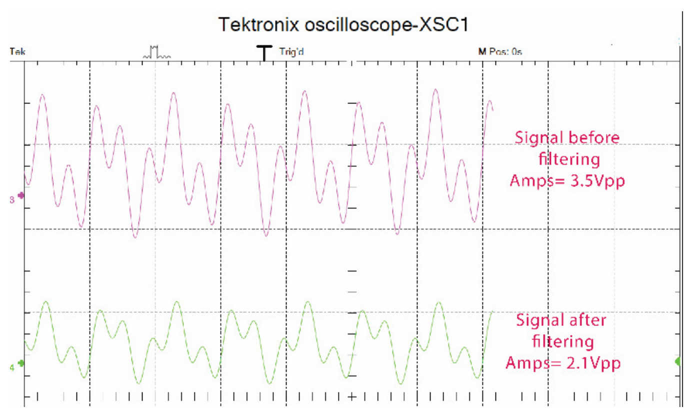

Fig. 8. Filtering result.

C. Amplification

This section is devoted to the design of an instrumentation amplifier of low frequency biomedical signals. An ECG signal is weak, with a magnitude of about 1mV, so a high gain amplifier is required to acquire this small signal. The amplification gain remains adjustable and also the reference value. Practically, to vary the gain and the reference voltage we use two 10kΩ potentiometers, one placed in pins 1 and 8 to adjust the gain and the other placed on reference pin 5. The block diagram and related voltage gains of the circuit for different values of resistances are depicted in Figure 9. We obtain an amplified signal at 6.13Vpp and totally detached from the noise as shown in Figure 10.

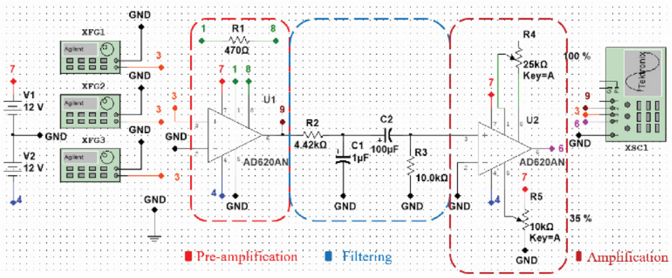

Fig. 9. Diagram of ECG signal detecting, amplification, and filtering.

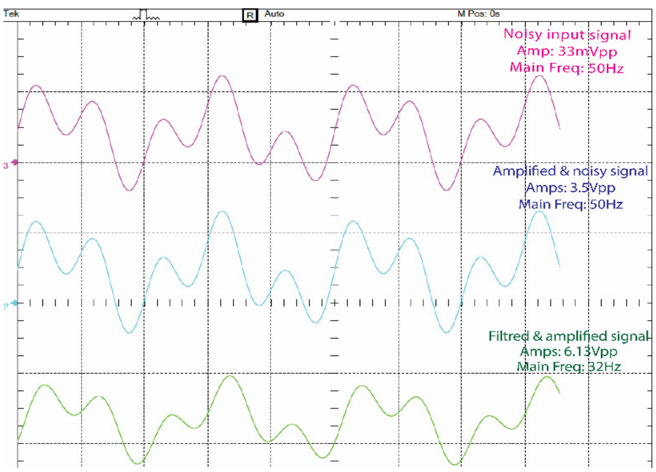

Fig. 10. Amplified and filtered output signal.

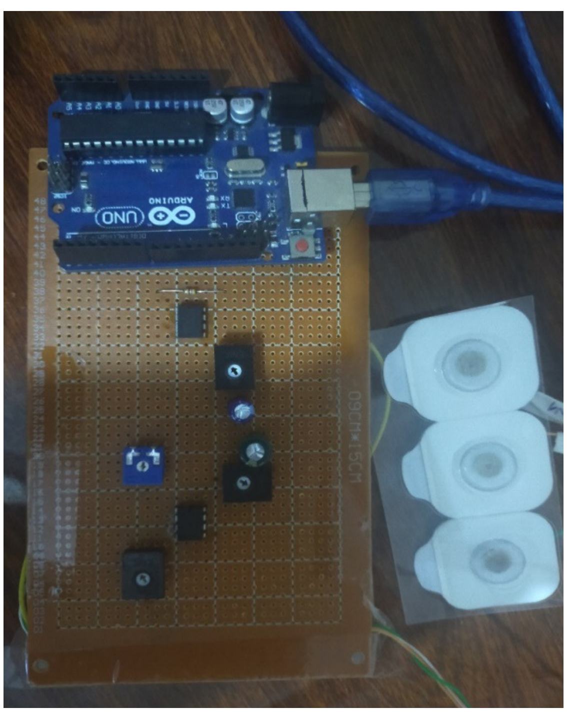

Fig. 11. Arduino hardware board.

D. Analog to Digital Conversion

An ADC is interfaced to an Arduino Uno via Serial Peripheral Interface. Figure 11 shows the breadboard allowing to convert signals sent from the ECG sensor to the Arduino through the ADC.

III. TEMPERATURE DETECTION SYSTEM

LM35 is a temperature measuring device having an analog output voltage proportional to the temperature. In general, normal body temperature is 36.1°C or above. Pin 1 of the LM35 is linked to the Voltage pin (VCC) of the Arduino Uno board in the circuit diagram to receive a 5V supply voltage. Both the pulse sensor and the Arduino board's Ground pin (GND) are interconnected. The Arduino's output pin (VOUT) is linked to the Analog Pin (A0) and gives a voltage output, which is then converted to temperature.

IV. LABVIEW INTERFACE

The ADC converts the analog output of the instrumentation amplifier to a digital signal. We propose a Graphical User Interface (GUI) in LabVIEW to display the ECG wave forms and to record the ECG data over a period of time. The ECG output from the circuit will be the input data in the LabVIEW interface where the data can be processed, stored, and displayed. Figure 12 shows the block diagram of the ECG system using system on chip.

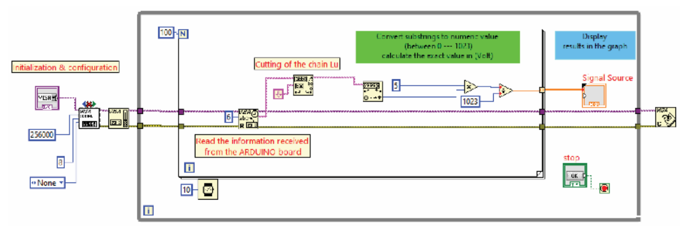

Fig. 12. Block diagram made with the LabVIEW.

Figure 13 shows the result obtained by our card from a test on a teenager. It clearly shows that the ECG signal obtained is correct and totally detached from the noise source. It is noted that the treatment and diagnosis of this signal remains the work of specialist cardiologists.

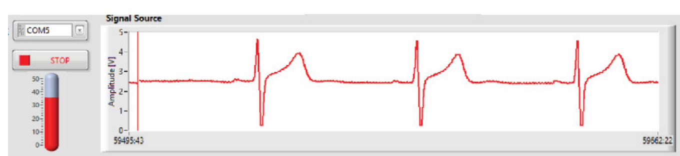

Fig. 13. ECG signal after filtering.

In the patient table system, the collected data are saved and updated in real time. ECG signals are sent from the patient's mobile device to the hospital's remote database server. The following information appears on each patient's table:

- Patient ID
- Temperature

- ECG data acquisition
- Patient location
- Predicted states

V. Conclusion

The current paper presents the design and implementation of a medical telemonitoring system based on IoT and its integration with LabVIEW for recording the ECG data and measuring body temperature. LabVIEW was used to acquire the ECG signal samples from the data acquisition card, to save the data, and to display information about the patient health.

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