International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 9, September- 2014

Single Channel Real-Time Wireless ECG Monitoring System

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***Abstract*— The purpose of this work is to design a working prototype of an ECG that acquires the electrocardiograph from astronauts or patients and sends it wirelessly via web publisher to a receiver unit such as computers and hospital monitors. This device will save time and effort of the nurses who are constantly following the patient's conditions and help them to operate more efficiently. At the same time, the goal of this paper is to minimize the cost of the device so hospitals can afford one for every patient, especially the ones that are in the Intensive Care Unit (ICU).**

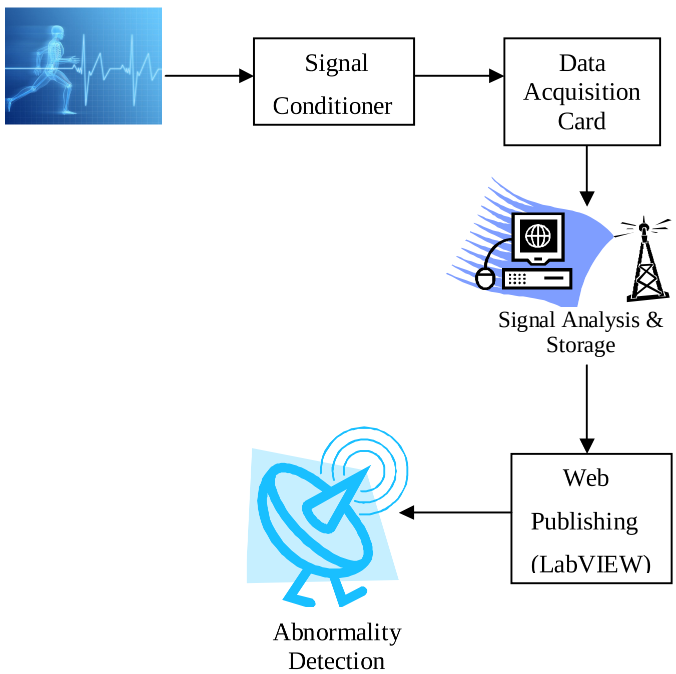
Keywords—ECG; Data Acquisition Card; Remote Monitoring; LabVIEW,

I. INTRODUCTION

The emergence of low power and robust wireless biotelemetry devices has increased patient mobility and efficiency of medical staff [1]. In health care centers and hospitals the usually measured biological parameters from the patients in ICU are ECG, Heart rate (HR), Blood Oxygen Level (sPO2) and temperature. The area, time interval and amplitude of ECG give the details about the heart. Any form of arrhythmia (disturbance in the heart rhythm) can be easily diagnosed using electrocardiograph. ECG gives the valuable information about the cardiac disorders. Mostly wired electrocardiograph is used for monitoring the ECG signals. It provides the necessary output waveform but it depends on the patient mobility. If continuous motion is identified from the patient that results in the artifact. It occurs along with the ECG signal and it is a kind of noise but seems to be the original waveform. The wired electrocardiograph is not patient friendly. The wired technique makes the system clumsier and it occupies large area. The patient feels discomfort while measuring the ECG waveform and also that the measurement has to be taken only when the patient is in the laboratory or in the hospital or in the operation theatre. After analyzing the waveform the doctor or the physiologist can initiate the treatment for the respective person. To make it comfortable for the doctor and the patient the wireless electrocardiograph has been designed. The wireless electrocardiograph provides that the patient can be monitored even from the house, in ambulance or any other places by the technicians and it can be observed and analyzed by the doctor for further treatment. More lives can be saved through reduction in time consumption by measuring the ECG signals in remote. It allows the technicians to monitor several patients simultaneously. This system is also applicable in military purpose for continuous monitoring of ECG signal. These advantages make the wireless ECG monitoring technique even more necessary for wide range of applications in various fields [2]. Electrical isolation for the equipment should be maintained properly that involves the safety of the patient and measuring device. To overcome all these drawbacks two separate devices have been constructed to achieve the overall goal.

First, a remote device is attached to the person being monitored. The remote device acquires the raw ECG signal from the Leads, which are placed in predefined areas of the body. A Data acquisition unit is connected to USB port of a P.C. The acquired ECG is then transmitted via the USB to the P.C for display. The necessary filter requirements (for ECG frequency band selection) and formatting of filtered ECG data (for transmission) was done through LabVIEW software. Second, for wireless transmission, a web publishing tool in LabVIEW software has been used which is universally reliable. **system design**

A. Block Diagram



B. Description

The first stage of the system consists of surface electrode. These electrodes produce a voltage related to the electric field produced by the beating of the heart. The second stage of the system consists of the amplifier hardware, which takes the electrocardiogram signal from the electrodes as its input. The signal is amplified and filtered to provide a meaningful output. The output signal from this stage is then sent to the NI-DAQ which corresponds to the third stage, in turn sends this analog data to LabVIEW for signal processing and data storage. The fourth stage is the wireless transmission of ECG signal through web publishing tool. At the receiving side, the fifth and final stage of this system is then the LabVIEW software can able to process this signal. VIs (Virtual Instruments) is graphical programs that are implemented to graph the data, and to process it (to make calculations for heart rate and to detect any abnormalities). The front panel of a LabVIEW program is a GUI that takes user profile inputs and uses this data for calculations [3].

II. HARDWARE DESCRIPTION

The hardware design in this project involves the usage of electrode, Signal conditioning circuit, Data Acquisition hardware interfaced with PC.

A. Usage of Electrode

An interface is necessary between the body and the electronic measuring device when recording potentials and currents in the body. Biopotential electrodes produce small voltages directly related to the changing electric field produced by a beating heart. The surface electrode is a practical electrode that approaches the characteristics of a perfectly non polarizable electrode. Perfectly non polarizable refers to the freedom of ions to pass through the electrode-electrolyte interface to be transduced into an electrical current. The electrode converts the ionic current produced by the body into measurable voltage, and the specially designed bio-amplifier magnifies this voltage.
The electrode-electrolyte interface is the junction where the ionic transfer occurs. A temporary current is induced in the electrode from the changing electric field of the beating heart. This current causes electrons and anions to move across the electrode-electrolyte interface in the direction opposite to the flow of the current, and for cautions to migrate across this interface in the direction of the current. This temporary separation of charge produces a temporary potential. This potential is created from a current induced from the heart and is thus directly related to the changing electric field produced by a beating heart. The ECG circuit hugely amplifies the potential, and the output gives the electric characteristics of a beating heart.
Fig 1 show this special Surface Electrode is of adhesive type, contains a small quantity of gel within the electrode itself. The configuration of the electrode as a button type also supports for replacing the electrodes very easily at the necessary case. Since the surface electrode is use and through, it is not possible to occur any skin diseases, skin irritations or any allergic reactions [4].

Fig. 1. Surface Electrode

B. ECG Amplifier Circuit

Furthermore, the ECG amplifier circuit should be able to correctly amplify signals from a patient, even though the patient might not be grounded due to displacement currents flowing to and from their body. The ECG circuit has a number of component parameters that must be met in order for it to operate effectively. First, an important factor for amplifiers is that the first stage (the preamplifier) must have high input impedance and low input bias current. High input impedance is necessary in an amplifier circuit to minimize loading effects. Loading occurs when the gain of the second stage of an amplifier affects the gain of the preamplifier. Low input impedance can cause loading, thereby affecting the characteristics of biopotential electrodes. This loading can result in a distortion of the output signal.
Another factor that can cause the distortion of the output signal is the input bias current of the op-amps. Input bias current is the amount of current that flows into the op-amp. Ideally, the input bias current is zero, but in practice there is always a small input bias current. Low resistance between the op-amp inputs compared to the feedback resistance can cause bias currents, so large resistors are placed between op-amp inputs to minimize this current.
Another important characteristic of the ECG amplifier circuit is that it must have a high gain since biopotential are usually on the order of mill volts. These signals must be amplified to a degree such that they are capable of being effectively displayed on recording devices. This means that the signals will have to have a magnitude on the order of volts, so gains of approximately 1000 are need for the ECG circuit. For that INA114 amplifier as shown in Fig 2 is used to provide high gain.

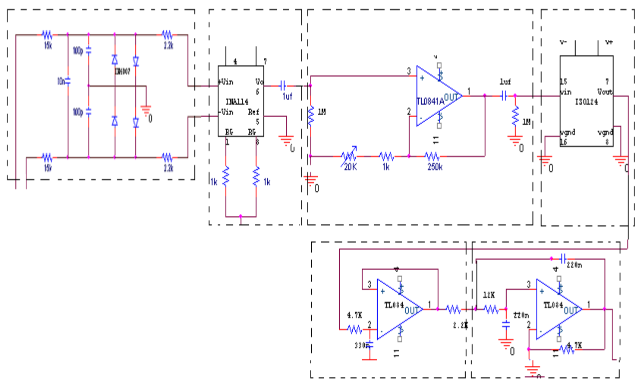


Fig. 2. Amplifier Circuit

C. Data Acquistion Hardware

Data acquisition (abbreviated DAQ) hardware is used for the process of sampling of real world physical conditions and conversion of the resulting samples into digital numeric values that can be manipulated by a computer. Data acquisition and data acquisition systems (abbreviated with the acronym DAS) typically involves the conversion of analog ECG waveforms into digital values for processing. In this project, NI USB-6009 shown in Fig 3 is used for data acquisition. The components of data acquisition systems include:

- Sensors that convert biological parameters to electrical signals.
- Signal conditioning circuitry to convert sensor signals into a form that can be converted to digital values.
- Analog-to-digital converters, which convert conditioned sensor signals to digital values.

Fig 4 shows the experimental setup of real-time ECG monitoring system.

Fig. 3. NI USB-6009

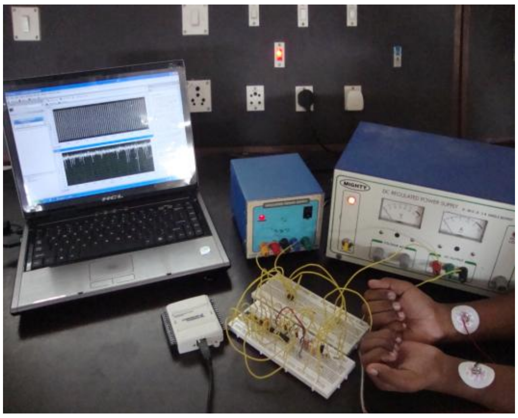
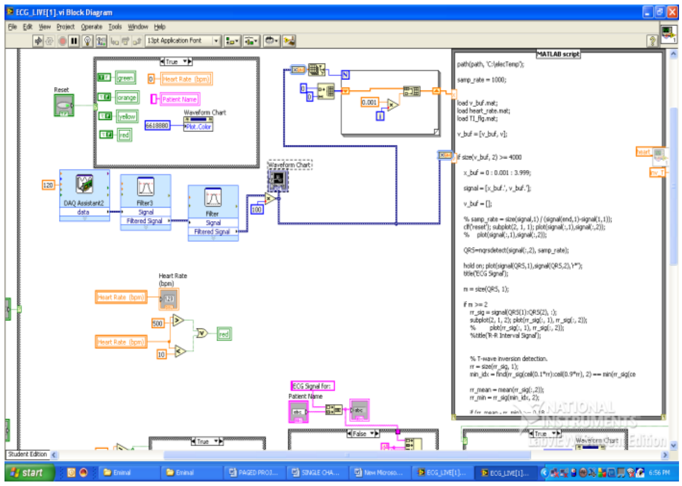


Fig. 4. INSTRUMENT SETUP

III. SOFTWARE DESCRIPTION

The functional algorithm used for the real time ECG monitoring using LabVIEW is shown in the following block diagram:-



This building block DAQ Assistant captured the ECG signal through the USB to the PC and then filtered through two individually designed Band stop and Low pass filter. Finally the real time signal is displayed on PC through waveform chart.

LabVIEW is used to not only process and acquire the signal, but to also develop a user friendly interface that automatically alerts the user to any abnormalities or arrhythmias detected. This particular ECG is developed to detect left ventricular hypertrophy and old myocardial infarction. It will also automatically display the heart rate and whether or not the patient's heart rate is within a healthy range.

This view of the GUI shows a normal, healthy ECG signal. The indicator lights (6) in Fig 5 will change colour depending on the diagnosis. Additionally, the Green trace turns red if any abnormalities or arrhythmia is detected [5].

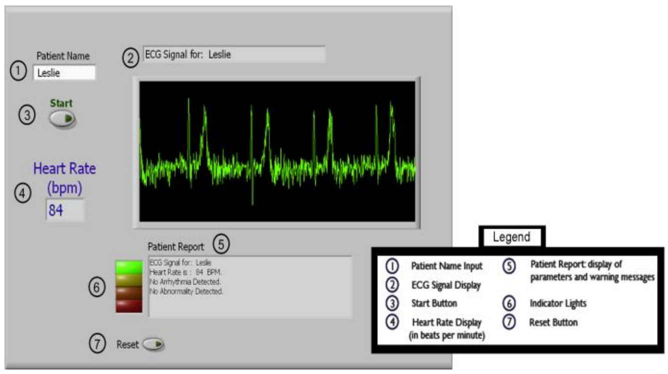


Fig. 5. Graphical User Interface

The user interface consists of several useful features. First, there is a text input for the patient's name to avoid confusion in the clinic. Second, the ECG chart is automatically updated with the name and live signal data. Third, the user can control the data acquisition periods. The heart rate and any abnormalities are displayed in the patient report. The warning lights to the left of the patient report correspond to the current condition of the patient's ECG. If everything is normal, the green light is on and the signal is green. If an arrhythmia is detected, the yellow light turns on and a warning message will appear in the patient report that indicates the type. Similarly, the orange light turns on if an abnormality is detected and a warning message appears in the report. For either of these, the ECG trace turns red in the chart window. A red light indicates that no recognizable signal is being detected. This can mean that the patient has flat-lined, that the circuit board is not powered or that the leads are not connected properly. As a result, the warning message will ask the user to check the lead and power connections. Finally, the form can be reset between patients [6].[7].[8].

IV. RESULT AND DISCUSSION

The resulted ECG waveform as shown in the Fig.6 can be viewed in the PC by using the front panel of the LabVIEW software. Using the web publishing tool in the LabVIEW, we can directly send this waveform to the remote side which is cost effective. Also it saves time by giving the abnormalities on comparison with the normal characteristics of an ECG signal. Also all the parameters can be stored which can be use it for later analysis.

At the remote side, the doctors can view the real-time situation of the patient with respect to all abnormalities in a cost – effective and in a timely manner.

This project primarily pertained to the development of a wireless monitoring system for ECG. However, the concepts, techniques and design approach used for the development of our wireless ECG system will be further modified to encompass several different biopotential such as EMG, EEG and oxygen saturation in hemoglobin. Hence, the Wireless ECG Monitoring System is a stepping stone for the development of a Multi-parameter Wireless Biomonitor.

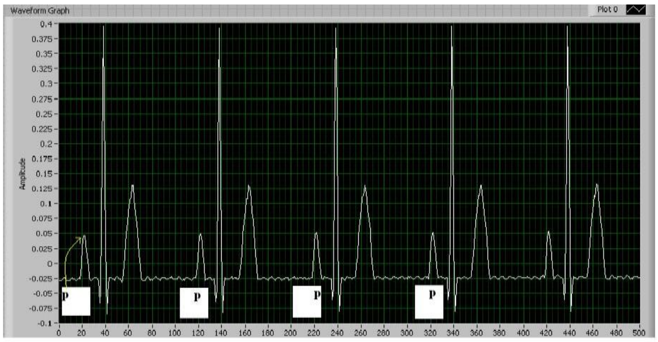


Fig. 6. Resultant Waveform

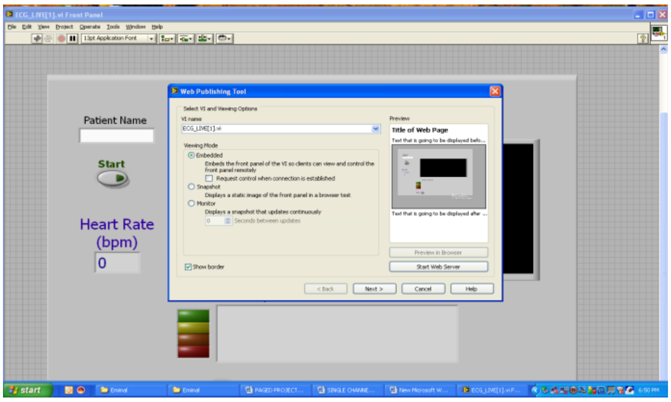


Fig. 7. Resultant Web Published Transmitted Wave

For further analysis and discussion, the ECG wave can be stored in any format and can be retrieved at any time by any one from anywhere in the world.

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