Wireless monitoring of Heart Rate using Microcontroller

J.S. Prasath
Asst. Professor, Dept. of EIE, Hindustan University.

Abstract - This paper describes the development of wireless monitoring of a heart rate based on a microcontroller. We can record the ECG signals and Heart beats of all patients in a single computer. These biomedical signals are acquired and then processed with a microcontroller. After processing, all data are sent to a communication interface that can send this information to a personal computer. For the patient suffering from the cardiac disease it is very necessary to perform accurate and quick diagnosis. For this purpose a continuous monitoring of the ECG signal, patient’s current heart rate and BP are essential. We can monitor the patient’s ECG signal by using Bluetooth transmission and reception in the central place in any hospital. The MATLAB software is used to simulate the ECG waveform.

Keywords - Microcontroller, Bluetooth, Instrumentation amplifier, Filter, MATLAB

I. INTRODUCTION

Early diagnosis for heart disease is typically based on recording of ElectroCardioGram (ECG) signal which is then studied and analyzed using a microcontroller. This paper presents the design and implementation of a compact microcontroller-based system used for wireless monitoring of heart rate on real time. An electrocardiogram (ECG) is a test that records the electrical activity of the heart. ECG is used to measure the rate and regularity of heartbeats as well as the size and position of the chambers, the presence of any damage to the heart and the effects of drugs or devices used to regulate the heart. Diagnosis of heart disease using ECG signals may be achieved by either correlating the pattern of the ECG signal with a typical healthy signal, characterizing the typical ECG signal using basic logical decisions, or more complicated algorithms to process in depth the heart disease. The first approach requires complicated mathematical analysis to obtain the required diagnosis, while the second one involves only simple analysis in most cases.

Electrical signals from the heart characteristically precede the normal mechanical function and monitoring these signals has great clinical significance. The ECG provides valuable information about a wide range of cardiac disorders such as the presence of an inactive part (infarction) or enlargement of the heart muscle.

II. NEED OF WIRELESS TRANSMISSION

An ECG/Blood Pressure signal is useful for a doctor to evaluate a patient’s heart condition relating to whether a heart attack has occurred - What parts of the heart is damaged - Irregular heartbeats - Whether the heart is not receiving enough blood or oxygen. It has been demonstrated, an ECG/Blood Pressure signal is extremely valuable, making it a conventional mechanism used in hospitals by both doctors and nurses. Similarly it provides the doctor or nurse with a trouble-free approach to the patient’s ECG/Blood Pressure signal. In fact, for patients in rural and regional areas an ECG report could be sent to a doctor for examination. Thus, this is a system in which the doctors at his/her house can treat the patient in the emergency condition in the hospital.
III. WIRELESS COMMUNICATION

The wireless technologies such as Bluetooth, GPRS, GSM or Wi-Fi allow wireless transmission to health or control centers. This system describes a low-cost, portable system with wireless transmission capabilities for the acquisition, processing, storing and visualization in real time of the electrical activity of the heart to a Personal Computer. The data acquisition unit, built here transmits ECG and BP signals using Bluetooth technology. Bluetooth technology was used in the system for reliable communication.

IV. THE ECG SIGNAL

The ECG signal measures the electrical activity of specialized heart cells that generate repetitive self-induced action potentials. Each action potential generated leads to a contraction of the heart muscle and thus the heartbeat.

Fig.1 The Heart Conduction System

The heart is divided into four distinct chambers. The upper chambers of the heart are called the Atria. They are electrically stimulated first. After some delay for allowing the atria to empty their contents, the lower chambers, called the Ventricles, are then stimulated. Initially, the right and left atria (also called auricles) are electrically stimulated to contract via the sinoatrial (SA) node located in the upper right atrium. The SA node is motivated through action potentials to maintain a heart rate of approximately 70 beats/minute. This action potential travels across the nerves of the atria causing depolarization and contraction, resulting in the P wave. The electrical signal continues from the SA node to the Atrioventricular (AV) node where a brief delay (~0.15 seconds) allows for atrial emptying (into the ventricles). The AV node transmits the signal to the Purkinje fibers (also called the Bundle of His) to cause ventricular depolarization and contraction, depicted as the QRS complex. Specifically, the peak of the R segment denotes the beginning of ventricular contraction. Post contraction begins a phase of repolarization, the T wave, in which blood is pumped from the ventricle chambers to the lungs or body. The T wave diffuses differently than the QRS complex, beginning in the outer segments of the ventricles and propagating inward thus creating a lower amplitude signal. Occurring shortly after the T wave, the U wave is the repolarization of the Purkinje fibers (rarely detectable due to low SNR). These contractions are a result of synchronized action potentials controlling all myofibrils (muscle fibers) to produce the electrical signals collectively called the cardiac cycle. The ECG signal can be visually represented by three major waves which are synchronized with the heart activity. The focus of the project relates to the basic measure that is related to the heart rhythm, the heart rate.

Heart Rate Calculation

The number of beats per minute is calculated using a three beat average. In the main function of the supporting software, the time scale is tracked using two variables, counter and pulse period. Pulse period is incremented by one during every sample period, and because we sample at a rate of 512Hz, it is relatively easy to track the timescale based on the number of counts in the pulse period. Whenever there...
is a beat detected, the counter is reset. The pulse period is accumulated for 3 consecutive beats, and on the third beat the heart rate is calculated using the formula below.

\[
\text{Heart Rate} = \frac{1}{\frac{1}{3 \times 512 \times 60}} = \frac{92160}{\text{pulseperiod}}
\]

**ECG Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart Rate</td>
<td>60 – 100</td>
<td>Beats Per Minute</td>
</tr>
<tr>
<td>PR Interval</td>
<td>0.12 – 0.20</td>
<td>Seconds</td>
</tr>
<tr>
<td>QT Interval</td>
<td>0.39 ± 0.04</td>
<td>Seconds</td>
</tr>
<tr>
<td>P Wave Duration</td>
<td>0.12</td>
<td>Seconds</td>
</tr>
<tr>
<td>QRS Width</td>
<td>0.05 – 0.1</td>
<td>Seconds</td>
</tr>
<tr>
<td>T Wave Duration</td>
<td>0.08</td>
<td>Seconds</td>
</tr>
</tbody>
</table>

**Fig. 2 Relationship between the heartbeat and pressure changes in the heart chambers**

V. BLOCK DIAGRAM

Fig.3 shows the block diagram of ECG module. The ECG signal is an electrical signal generated by the heart’s beating, which can be used as a diagnostic tool for examining some of the functions of the heart. It has a principal measurement range of 1 to 3 mV and signal frequency range of 0.05 to 140 Hz. ECG signals were acquired through a low power consumption ECG amplifier. The ECG amplifier can construct with a gain of 1000, a CMRR of 80dB and a frequency bandwidth of 0.05-100 Hz.

These signals are both amplified and filtered to the required specifications. The duration between peaks of the QRS waves can be used to calculate the beat-to-beat heart rate. The output waveform from the ECG amplifier is then fed to the rest of the system. Proper ECG signal acquisition is carried out using filters for noise suppression and amplifiers to enlarge the signal amplitude as much as possible, while keeping it within the input voltage range of the analog to digital converter (ADC). The task of the ADC is then to digitize the analog voltage with a resolution high enough to represent the original signal. These values can then be collected by a microcontroller (MCU) which maintains the connection with the wireless transmitter.

**Fig. 3 Block Diagram of microcontroller based wireless heart rate monitoring system**
VI. SIGNAL CONDITIONING CIRCUIT

Electrodes

In order to measure potentials in the body, an interface is needed between the body and the measuring device. This function is performed by biopotential. They serve as transducers to change ionic current flowing in the body to electrical current carried by electrode wires to the measuring device. One of the most important characteristics of electrodes is that they should not polarize. This means that the electrode potential must not vary considerably even when current is passed through them. Electrodes made of Silver-Silver Chloride have been found to yield acceptable standards of performance. These electrodes are also nontoxic and are preferred over other electrodes like Zinc-Zinc Sulphate, which are highly toxic to exposed tissue. The Silver-Silver Chloride electrodes meet the demands of medical practice with their highly reproducible parameters and superior properties with regard to long term stability. Hence, these electrodes were chosen for signal acquisition.

Instrumentation Amplifiers

The instrumentation amplifier is basically a differential amplifier that amplifies the difference between the two input signals. Hence the common mode signal is effectively eliminated. Two buffer amplifiers at the input of each signal are provided to offer very high input impedance. The gain of the instrumentation amplifier is set around 1000.

Band pass Filter

To remove the unwanted frequencies in this case requires a highly selective band pass four order filter. The attenuation of low-frequency components is designed to remove the baseline (or DC) drift and obtain stable EGG recording.

Microcontroller Unit

A Microchip 8-bit microcontroller AT89C51 by is used for outputting the values sequentially. It provides a variety of fast addressing modes for accessing the internal RAM to facilitate byte operations on small data structures. Microcontroller is used for storing the values of ECG and Blood Pressure waveforms. The AT89C51 is a low-power, high-performance CMOS 8-bit microcomputer with 4K bytes of Flash programmable and erasable read only memory. By combining a versatile 8-bit CPU with Flash on a monolithic chip, the Atmel AT89C51 is a powerful microcomputer which provides a highly-flexible and cost-effective solution to many embedded control applications.

The Bluetooth Transmission Module

Bluetooth technology is the wireless protocol used in the transmitter. Bluetooth has many advantages. First, it is available in a user-friendly modular form. There are many available Bluetooth devices which hide the Bluetooth stack and allow the user to interact with the device using simple modem commands. This reduces development time considerably. In addition, Bluetooth is a common technology on mobile phones, and this will expand the range of use for the transmitter. The Bluetooth Intelligent Serial Module HM1100 is the device selected for the wireless module.

VII. SIMULATION OF HEART RATE USING MATLAB

The aim of the heart rate simulator is to produce the typical ECG waveforms of different leads and as many arrhythmias as possible. The heart rate simulator is a Matlab based simulator and is able to produce normal lead 1 ECG waveform. Figure 4 shows the visual representation of ECG waveform.
Fig. 4 Representation of ECG waveform

VIII. SIMULATION RESULT OF HEART RATE

In this experiment, an ECG waveform with standard specification like Heart beat: 72, Amplitude of P wave: 25mv, Amplitude of Q wave: 0.025mv, Amplitude of QRS wave: 1.6mv, Amplitude of S wave: 0.25mv, Amplitude of T wave: 0.35mv, Amplitude of U wave: 0.035mv, Duration of P wave: 0.09 second, Duration of Q wave: 0.066 Sec, Duration of QRS wave: 0.11 sec, Duration of S wave: 0.066 sec, Duration of T wave: 0.142 sec, Duration of U wave: 0.0476 sec, P-R interval: 0.16 sec and S-T interval: 0.18 sec taken and simulated in MATLAB.

With the help of different electrode we monitor the heart bit of the heart and store the heart bit sound in AT89C51 microcontroller then stored result transmitted to personal computer with the help of Bluetooth device. The Bluetooth device interfaced with MATLAB by Graphical user interface (GUI).

Fig. 5 Simulated Heart Rate waveform using ECG

IX. CONCLUSION

In this paper, the implementation of wireless monitoring of heart rate based on microcontroller for real time analysis of ECG signal and then simulation of these ECG signal in MATLAB has been investigated. The system has been tested successfully on simulated ECG signals. A wireless ECG transmission system, using Bluetooth device, is able to transmit, record and display the ECG signal in real time. This work introduces the wireless communication electrocardiogram detection system with the use of AT89C51 microcontroller and the communication module. Here we use Bluetooth device for the wireless telemedicine. By using bluetooth transmission and reception we can monitor the ECG signal of patient in the central place in any hospital.

ACKNOWLEDGMENT

I wish to thank Professor Ramachandraiah for provided the guidance for this work and faculty members of the EIE department, Hindustan University for their great support in this work. I also thank the management of Hindustan University for their continues support and encouragement.
REFERENCES


Prasath is an assistant professor in department of electronics and instrumentation engineering at the Hindustan University, Chennai. He got a Bachelor degree in electronics and instrumentation from Madurai Kamaraj University, 2002. He got a Master degree in process control and instrumentation from Annamalai University, 2007. He presented and published the research papers in the area of underwater sensors, process control, industrial automation and Micro-Electro Mechanical Systems. He is a member of ISTE. His research interests include process control, microcontroller, microprocessor, wireless sensors and industrial automation.