Embedded Programmable Web-based ECG Monitoring & Detection System Using a Fast Algorithm

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***Abstract*—This paper presents the design of a complete portable package for a low cost embedded programmable ECG measurement and monitoring system implemented by a fast algorithm in detecting ECG characteristics points. This proposed system is expected to monitor the electrical activity of heart of the patient under critical care more conveniently and accurately for diagnosing which can be interfaced with computer to bring it under a network system widely for the doctor to monitor the patient's condition sitting in his own office without being physically present near to the patient's bed.**

Keywords- ECG; Characteristics Point; Microcontroller; Embedded Interface Circuit; Ethernet Network.

I. INTRODUCTION

Electrocardiography or ECG is a transthoracic interpretation of the electrical activity of the heart over time captured and externally recorded by skin electrodes. It is a noninvasive recording produced by an electrocardiographic device.

Electrical impulses in the heart originate in the sinoatrial node and travel through the intimate conducting system to the heart muscle. The impulses stimulate the myocardial muscle fibers to contract and thus induce systole. The electrical waves can be measured at electrodes placed at specific points on the skin. Electrodes on different sides of the heart measure the activity of different parts of the heart muscle. An ECG displays the voltage between pairs of these electrodes, and the muscle activity that they measure, from different directions, can also be understood as vectors. This display indicates the overall rhythm of the heart and weaknesses in different parts of the heart muscle. It is the best way to measure and diagnose abnormal rhythms of the heart, particularly abnormal rhythms caused by damage to the conductive tissue that carries electrical signals, or abnormal rhythms caused by electrolyte imbalances. In a myocardial infarction (MI), the ECG can identify if the heart muscle has been damaged in specific areas, though not all areas of the heart are covered.

The Holter ECG device is used most frequently for recording the ECG. Physicians apply the device to a patient when they need to monitor his or her ECG to find the abnormal cycles in the ECG throughout the day. The physicians have to interpret this large amount of ECG data to search for only a few abnormal beats in the ECG. Physicians may overlook some abnormal cycles due to fatigue and human error in interpreting such a large amount of data. Therefore, there is an urgent need for an automatic ECG interpreting system to help to reduce the burden of ECG interpretation.

II. EXPERIMENTAL SETUP

The block diagram of an Embedded Programmable ECG Monitoring System is shown in figure 1. The hardware of the system has been interfaced with the Microcontroller through Amplifier part. The three limb leads inputs: lead-I, lead-II, lead-III are coming from the three electrodes placed on the right arm (RA), left arm (LA) and left leg (LL) respectively. After that passing through the defibrillation protection system, these three inputs are fed into the amplifier part as the signals are too small to be useful. Then it is interfaced to the input of the internal ADC of the microcontroller. And there is a Ethernet chip at the output of the microcontroller to make it web-based as per requirement. There is a graphical LCD attached to the microcontroller to monitor the ECG data.

III. SIGNAL ANALYSIS & DETECTION

A. *ECG Waves and Intervals*

A typical ECG tracing of the cardiac cycle (shown in Fig. 2) consists of a P wave, a QRS complex, a T wave, and a U wave which is normally visible in 50 to 75% of ECGs. The baseline voltage of the electrocardiogram is known as the isoelectric line. Typically the isoelectric line is measured as the portion of the tracing following the T wave and preceding the next P wave. Physicians then interpret the shapes of those waves and complexes. They calculate parameters to determine whether the ECG shows signs of cardiac disease or not. The parameters are the magnitude & the duration of each wave, and the intervals, such as R-R, P-P, Q-T and S-T intervals.

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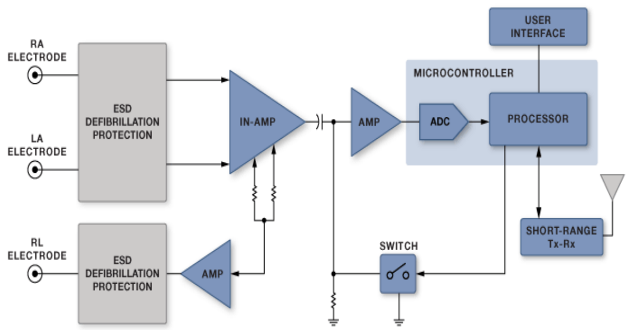

Figure 1. Block Diagram of the Whole System

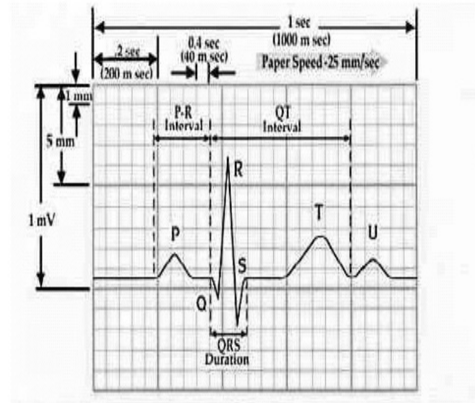

Figure 2. A Typical ECG Waveform

B. Method to Detect ECG Characteristics Points

The method used in this paper to detect ECG characteristic points (P, Q, R, S, T) is actually based on slope detection. But from many aspects it is different from conventional slope detection techniques. QRS complex is the most prominent wave in an ECG signal. For an automated ECG pattern recognition system, detection of QRS complex is the very first job to be done. Throughout the whole data if we can locate the positions of the QRS complexes, then detection of other points such as P & T waves can be done. This complex is composed of approximately four straight lines. Q point is found in between P wave and R peak. This point can be approximated by the intersection of two straight lines with different slopes. But in practical data, this point is not composed of two straight lines. So to detect it properly we made the lines straight. Similar straight line approximation can be assumed to detect R and S points. P wave can be treated as a half cycle sine wave. To approximate it with straight lines we need 6 to 8 straight lines with different slopes. In Fig. 3, a straight line realization of P-wave is given. T-wave is found after QRS complex and it can also be considered as a half cycle of a sine wave. Straight line approximation is also possible here.

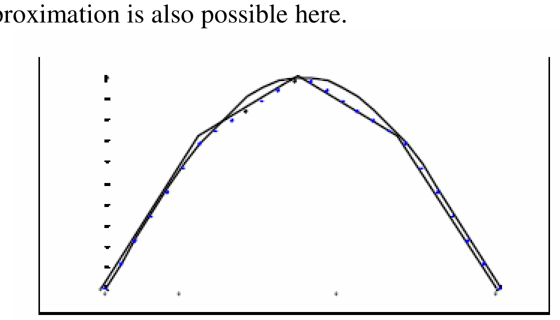

Figure 3. Straight-line realization of P wave

C. Flow Chart of ECG Detection

The flow chart for the detection of ECG is shown in Fig. 4.

In order to accurately detect the heart rate in the ECG signal, filter banks analysis in Matlab is used on the filtered ECG signal. This algorithm can also be used to detect abnormalities in the ECG signal. This includes displaying the heart rate and alerting the user if an abnormality is detected. The flowchart below breaks down the tasks needed to accomplish signal analysis in greater detail to detect any kind of abnormality in ECG signal.

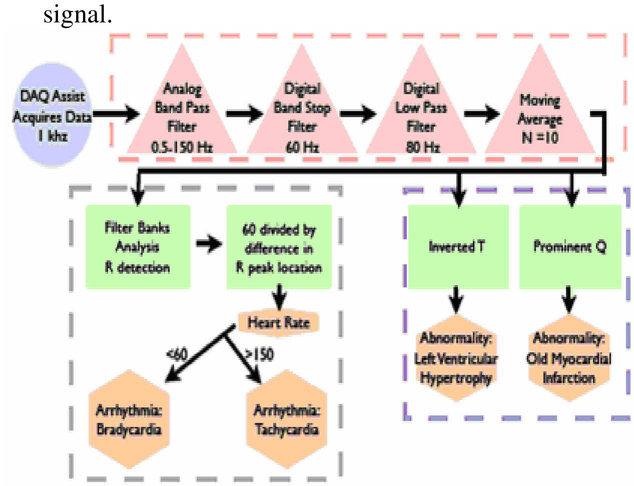

Figure 4. Flow Chart of ECG Detection

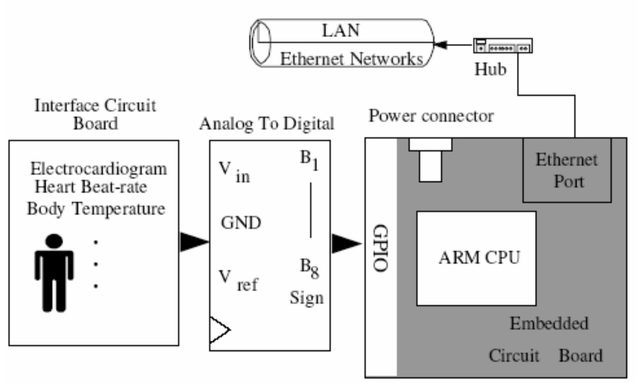

Figure 5. The medical measurement interface and embedded circuit board

IV. Hardware Description

Fig. 5 shows the hardware design of the ECG measurement interface circuit board and the embedded board used to transmit this digital ECG signal to a medical web server by networks. The hardware module consists of Interface Circuit Board and Embedded Circuit Board. Also the amplifier part is shown in Fig. 7 separately.

A. Interface Circuit Board

The operation procedure shown in Fig. 6 can be explained as follows:

1. In Fig. 6, the ECG sensor is used as the input stage, which requires very high impedance that is often attained by using a CMOS input circuit in order to both match the impedance of the ECG signal source and to pick up larger amplitude of the ECG signal.

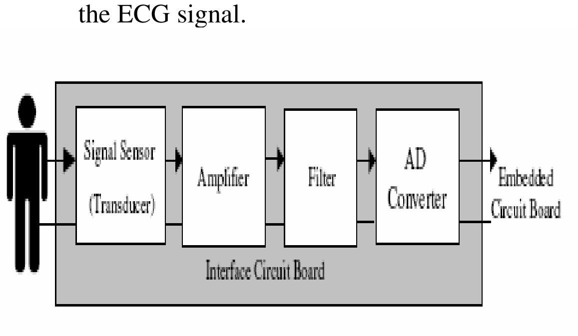

Figure 6. The function of the interface circuit board

2. Due to the difficulty of the reduction of the noise in the very small amplitude of an electrocardiogram signal, we need to use a differential amplifier to suppress the common-mode noise. In addition to preventing any electrical shock to the tested body, we use an isolated amplifier that can not only amplify the ECG signal but also provide DC power supply isolation by means of a magnetic coupling mechanism. To amplify the electrocardiogram signal further, we use a main amplifier. However, because the DC offset voltage could saturate the amplifier, we must adjust the DC offset voltage of the amplifiers very carefully.
3. Because the medical signal can induce the noise nearby the location of the ECG, we need to use a 60 Hz band rejection to suppress this noise and a low pass filter to reduce the high frequency noise. In addition, to minimize the error of any component, we shall use an adjustable component in order to locate the best band rejection frequency. Usually, the bandwidth of the medical signal is low frequency; we, therefore, use a high-order low pass filter to suppress the high frequency band.
4. The sampling rate of the analog to digital conversion will decide the resolution of the medical signal. The embedded circuit board is used to control the analog to digital converter, to receive the data of conversion, and to send out the digital data to the embedded circuit board.

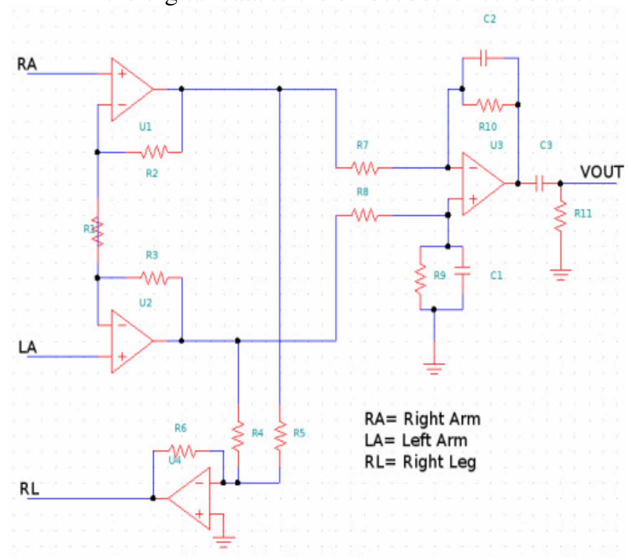

Figure 7. Amplifier Interfacing Circuit

B. Embedded Circuit Board

The ECG signals of patients are transmitted in digital form to a medical information server through an embedded circuit board and Internet. The embedded circuit board comes equipped with a full Internet interface and its operating system (OS) which is programmed by the above mentioned fast algorithm and loaded in the microcontroller that is used.

V. Software Implementation

Fig. 8 shows the software flowchart of our embedded circuit board for the ECG measurement system from remote distance incorporating the web-based network system.

The major functions of this program are to collect the ECG digital data into the remote medical server from the embedded circuit board through the Internet. In addition, our software modules can also store the digital ECG signal data and display the ECG on the LCD display of the embedded circuit board, and transmit information to the remote medical server through either the Internet or wireless networks.

The basic operational steps of Fig. 8 may be briefly described as follows: (1) Load Operation System and reset the system; (2) Start the Boa web server; (3) Analog to Digital Conversion; (4) If Converted, finish; (5) Store the digital data to buffer; (6) If Continue, convert; (7) If Data buffer full; (8) Send the digital data from the socket to Internet; (9) Send finish and wait.

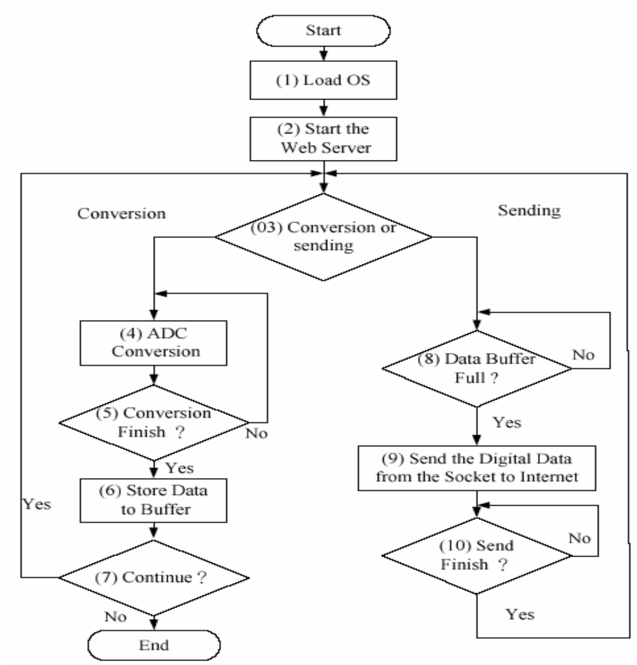

Figure 8. The software flowchart on the embedded circuit board for the ECG data collecting and sending.

VI. CONCLUSION

Sometimes for some special patients need to be monitored his or her heart condition regularly even if he or she is not in the hospital and again doctor may want to check different patient's condition simultaneously without going to their bed physically. Our proposed system is expected to serve this kind of purpose more conveniently as it is portable, faster, easier to handle and last but not the least it is very low cost as we can make it locally. This kind of ECG measurement system can be made available to the general people much more easily.

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