Open Hardware Platform For Reconstruction Of ECG Signal

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Abstract
At present the heart disease is one of serious disease that may threaten human life. The electrocardiogram is important role in the prevention, diagnosis the abnormality of patients & rescue of heart disease. An ECG is used to measure the electrical activity of the heart treated as a vector quantity. It measures the rate and regularity of heartbeats. The goal of this project is to develop a device classified as a "Open hardware platform for reconstruction of ECG signal ".A remote device is attached to the person being monitored. The remote device acquires the raw ECG data from the Leads which are placed in predefined areas of the body. In this paper three lead ECG monitor system is present, which can be used for measurement & recording of human electrocardiogram. ATMEL Atmega8 AVR series microcontroller is the heart of system which is in the Severnio board. The ECG signal from the body is amplified and filtered by the instrumentation amplifier. Sevrenio is an open hardware, Bluetooth wireless communication, single microcontroller, multiple I/O platforms, used in this project to interface our electrocardiogram Signal conditioning circuit to the PC. Necessary filter requirements (for ECG frequency band selection) and formatting of filtered ECG data (for transmission) both occur in the Severnio board in which AVR microcontroller is present. A second Data acquisition unit is connected to Serial port of a P.C. The data is then transmitted via the serial port to the P.C for display. A user friendly graphical interface (GUI) was constructed using Visual Basic 6.0 enterprise edition. The GUI allows for the monitoring of real time ECG data. A database was implemented using MS Access 2000. This allowed for storage of the ECG data.

Key Words: Open Hardware ECG, Electrodes, Severnio Board, Serial cable, PC.

INTRODUCTION
Cardiac disease is one of the most dangerous threats to human health. Moreover, due to the problem of aging of population is getting worse and worse, the number of cardiac deaths is sustained increasing [6]. ECG diagnosis has the advantages of convenience, precision and low-cost, and therefore ECG diagnosis has been widely used nowadays. An electrocardiogram (ECG) is an electrical recording of the heart that depicts the cardiac cycle. It is routinely used as a first course of choice in diagnosing many cardiovascular diseases [7].

A. ECG Measurement
The potential created by the heart wall contraction spreads electrical currents from the heart throughout the body. The spreading electrical currents create different potentials at different points on the body. Leads are placed on the body in several pre-determined locations to provide information about heart conditions. The cardiac signal, typically 5 mV peak to peak, is an AC signal with a bandwidth of 0.05 Hz to 50 Hz
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The Three Lead ECG
The electrical activity can be represented as a dipole (a vector between two point charges). The placement of the electrodes on the body determines the view of the vector as a function of time[1]. Figure 1 represents the most basic form of the electrode placement which is based on Einthoven's triangle. This theoretical triangle is drawn around the heart with each apex of the triangle representing where the fluids.

Around the heart connect electrically with the limbs. Lead I measure the differential potential between the right and left arms, Lead II between the right arm and left leg, and Lead III between the left arm and left leg.
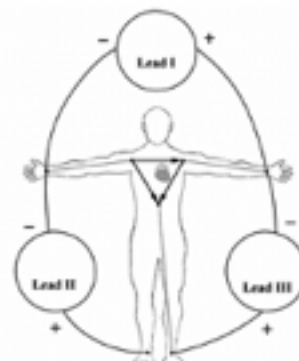

Figure 1: The Three Leads
Einthoven's law also states that the value of any point of the triangle can be computed as long as values for the other two points are known [1]. The Einthoven limb leads (standard leads) are defined in the **Figure**

SYSTEM FUNCTIONALITY
ECG Design

The heart electric signal has a very small amplitude (around1mV) and is immersed into other greater signals produced by the body. To be able to measure the heart signals, first they must be amplified and filtered form those we are not interested in. If the goal is to digitize the ECG signal the frequencies of the heart signal goes from 0.05Hz to 100Hz, first the frequencies out of that range must be minimized and then they should pass through a stage of amplification, later, the resulting signal has to be Manipulated so it can be in the range of 0-5V in order to be digitized.

A. Signal Acquisition

The circuit used for acquire the heart signal is an instrumentation amplifier (figure 3) which is divided into three sections. The section A works as a voltage follower of the two input signals, the circuit has a high input impedance and can be connected to other devices or human signals without changing the shape of the signal to be measured. The section B is a differential amplifier, it takes the difference between the two input signals and multiplies it times a factor. Basically this ECG system takes the difference between the two voltages measured in both arms having as a reference voltage that measured in one leg. In the figure, the inputs labeled as VRA and VLA represent the Voltage of the Right Arm and the Voltage of the Left Arm, respectively, while the VLL input represents the Voltage of the Left Leg acting as a reference of the bioelectric potentials. The ECG electrodes should be connected in the inner part of the left ankle and both wrists.

$$\text{Lead I:} \quad V_I = \varphi l - \varphi r \qquad (1)$$

$$\varphi l = \text{potential at the left arm}$$

$$\text{Lead II:} \quad V_{II} = \varphi f - \varphi r \qquad (2)$$

$$\varphi r = \text{potential at the right arm}$$

$$\text{Lead III:} \quad V_{III} = \varphi f - \varphi l \qquad (3)$$

$$\varphi f = \text{potential at the left foot}$$

Manipulation of the above results yields:

$$\text{Lead I + Lead III} = \varphi l - \varphi r + \varphi f - \varphi l = \varphi f - \varphi r = \text{Lead II}$$

Similarly:

$$\text{Lead II - Lead I = Lead III}$$

Figure 2: Three Leads Calculations

The Operational Amplifiers (Opamps) used are built with the JFET technology (TL084), hence they have a high input impedance and need a very small polarization current, giving an electrical safety margin for the patient. With the configuration shown in the figure 3, the gain of amplifier is given by
A= (1+2R1/R2)* (R7/R4)

The section C is Anti aliasing low pass filter, its job is to remove electrical noise picked up from fluorescent lights, computers and AC power lines. When ECG is amplified the noise is amplified too & after swaps the ECG signal. Luckily, the noised is usually of a higher frequency than the ECG this noise can be reduced by low pass filter. The amplifier takes input from self sticking electrodes that are attached to the body of the subject whose ECG is being taken. It is important for the cables connecting the electrodes to the inputs of the circuit to be as short as possible.

B. Anti Aliasing low pass filter

The next step is anti aliasing filter that ensures that the resulting signal contains only frequencies from 0.05Hz to100Hz[1]. Frequencies greater than 100Hz do not belong to heart signals, additionally, when the frequencies lower than 0.05Hz are filtered, we eliminate the difference of potential between the electrodes and the skin surface that can reach levels up to 300mV and may saturate the amplification devices. In the circuit used to implement the Anti Aliasing low pass filter (figure 3C).The filter is a simple low pass filter; its job is to remove electrical noise picked up from fluorescent lights, computers and AC power lines. ECG has amplitude of only about mV, so to detect it an amplifier is needed. There is a problem through electrical noise or electromagnetic interference.

HARDWARE DESIGN
A. Instrumentation Amplifier

The instrumentation amplifier is generally used for this purpose. The instrumentation amplifier is a type of differential amplifier that has been outfitted with input buffers which eliminate the need for input impedance matching and thus make the amplifier particularly suitable for use in measurement and test equipment. The instrumentation amplifier is useful for amplifying small differential signal which

may be riding n high common mode voltage levels. This amplifier is particularly useful in amplifying

signals in mili-volt range which is supplied from a high

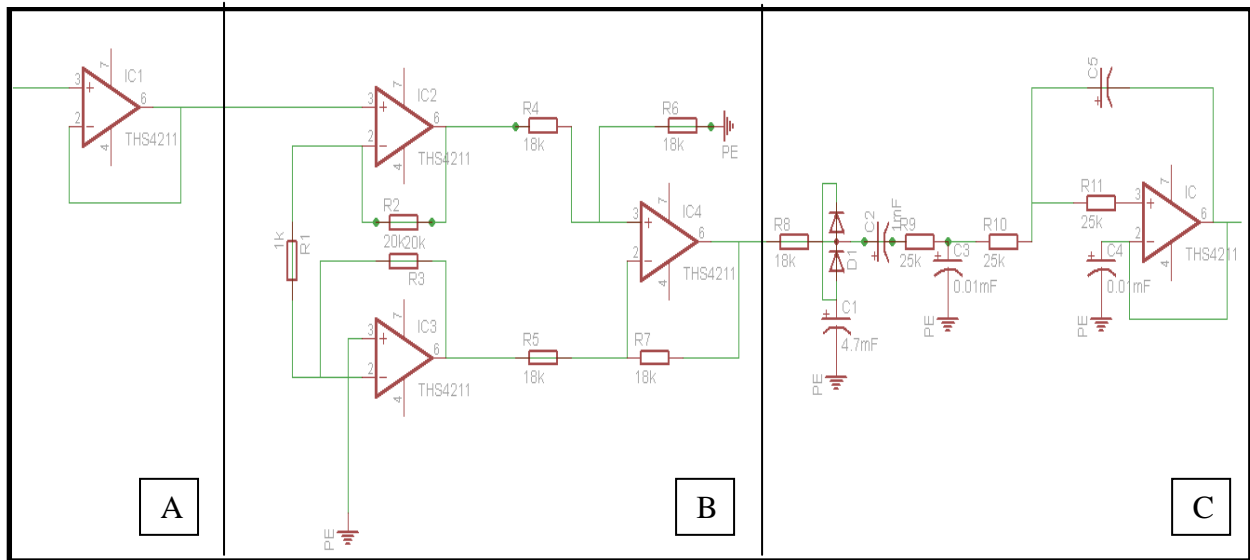Figure   3:   Circuit   Diagram   of   ECG

impedance source. Additional characteristics includes very low DC offset, low drift, low noise, very high input impedance.

B. Severnio Board

The hardware design is based on an embedded system implementation using ATMega8 AVR microcontroller within Severino Board. This was used to verify the various ideas and the requirements for final system design.

Figure 4: Severnio Board

Severnio Interfaces to digitize and introduce the ECG signal to the computer via a Bluetooth wireless connection. This system uses AVR microcontroller AT mega 8 as its brain. Eight channel ADC receives analog signal from ECG circuit and convert the data in to digital signal.

SOFTWARE DESIGN

The ECG signal's bandwidth is 100Hz, so according with the Nyquist's theorem; the minimum required sampling frequency is 200Hz. The program is

sampling with at 250Hz which is a sufficiently large frequency for acquiring the ECG signal.

The software consist of a Standard programming language & boot loader that runs on the board. Software for the microcontroller is designed in C language. Before writing a program, modes of serial communication are decided, baud rate is selected. & Take 100samples/sec. the microcontroller is   programmed   in   following   way:
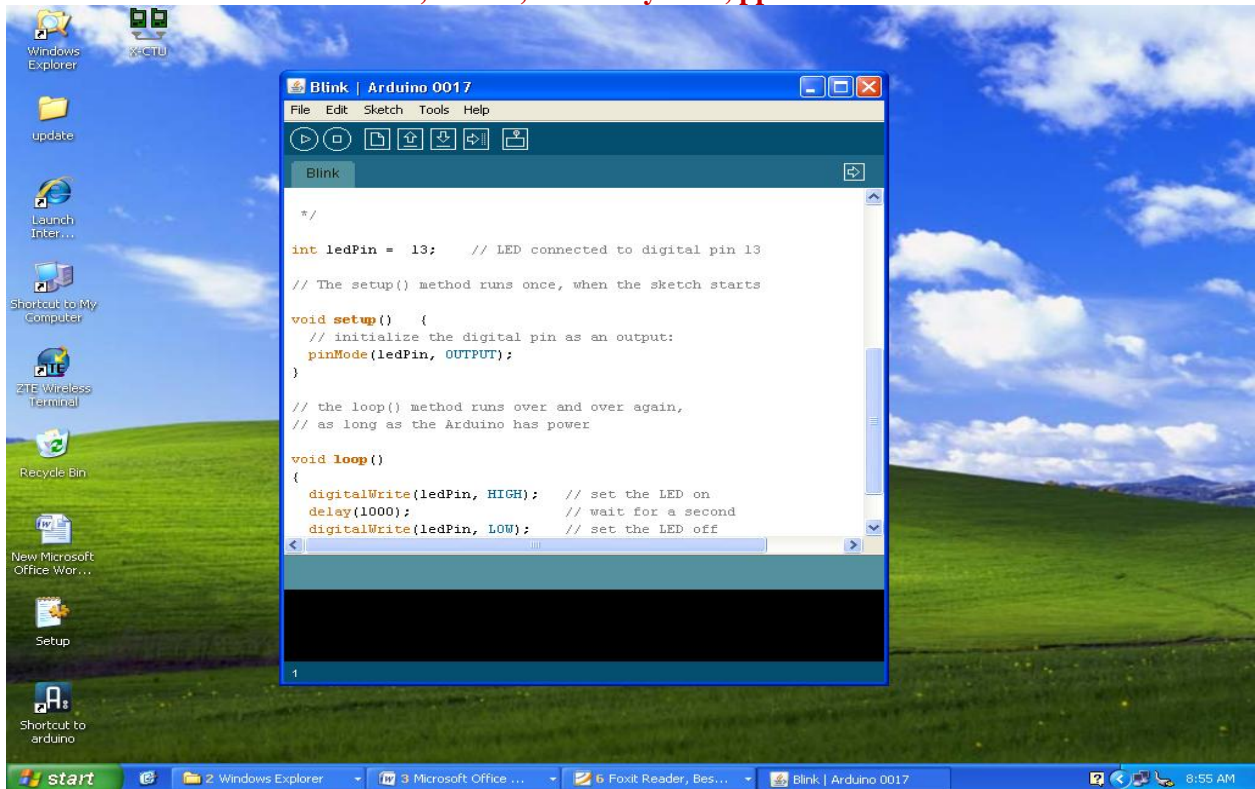
Figure 5: Severnio Software

Counter can be clock internally by the prescalar.
The prescalar is set by clock select bit CS20, CS21, CS22 equal to one.
Set counter value in Timer/Counter register 2.
Mask the AS2 bit in asynchronous status register
When AS2 is written to zero, Timer/Counter 2 is clocked from the I/O clock, clkI/O.
In Timer/Counter mask register
OCIE2: Timer/Counter2 Output Compare Match Interrupt
Timer/Counter2 Compare Match interrupt is disabled.
TOIE2: Timer/Counter2 Overflow Interrupt Enable
Timer/Counter2 Overflow interrupt is enabled.

RESULT
      The design was successfully dissected into various modules. Each module with has been implemented.
The integration of the individual modules was achieved successfully. All the GUI functionality discussed in the report is operational.
The ECG signal can be sampled and analyzed in real-time.
The ECG data also can storage in SQL Database and transport the data to PC via Serial cable.
The storage of ECG data to the database has been implemented successfully.
The system consist of two section
1. Hardware Section
2. Software Section

Hardware Section:
      ECG signals captured by Electrodes are processed and filtered by signal conditioning block.
Now Filtered signals are given to MCU Board.
Microcontroller has in inbuilt 10-bit analog to digital converter, which convert analog signal coming from human body(Amplified by instrumentation amplifier) into digital signal .
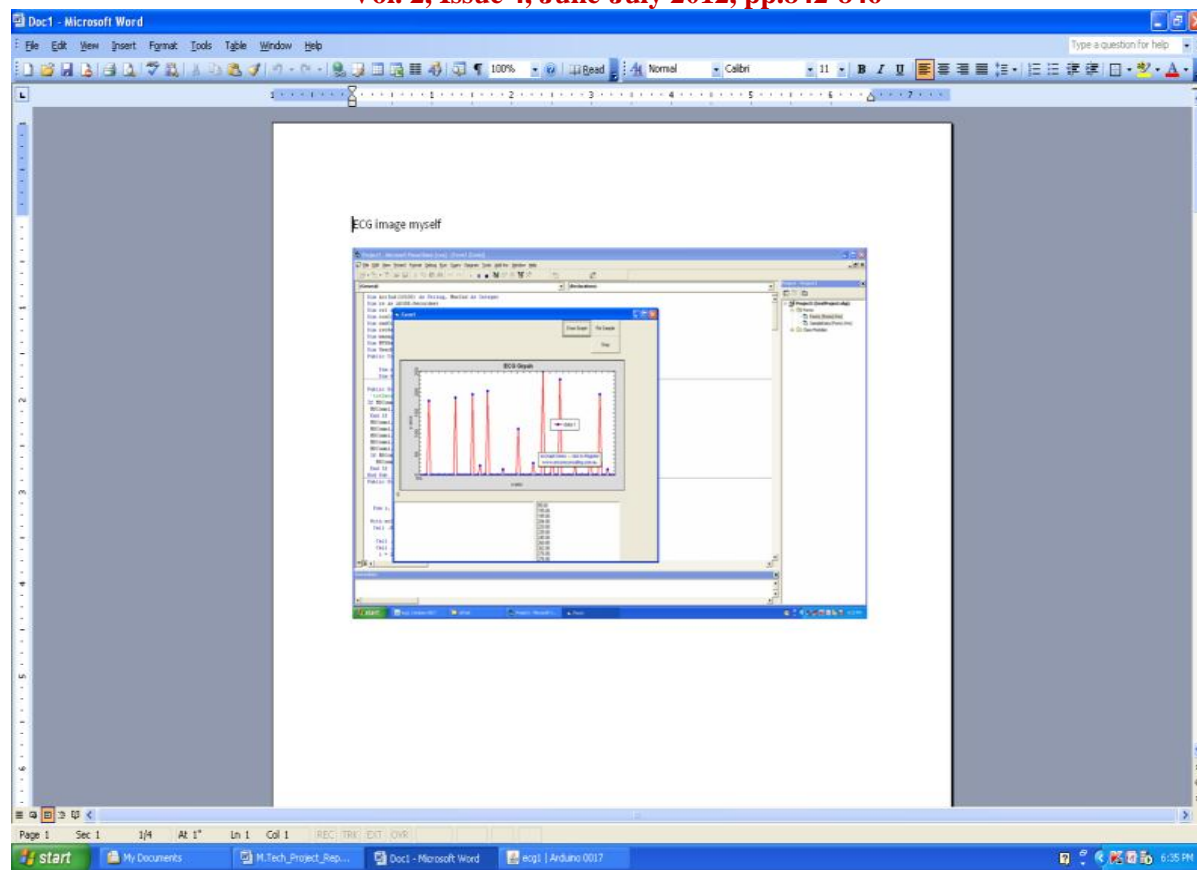Microcontroller is capturing 200 samples in one sec. from analog pin

Figure 6: ECG graph

Software Section:

> Received 200 samples(contain digital values) now stored in data base.

VB code used stored data from database and plot ECG waveform. In the figures 6 the plot of the data stored in the *.dat file after digitalizing and filtering the signal.

CONCLUSION

The implementation of the proposed system is entirely feasible, especially in those developing countries that have serious delays in the health systems, because the cost of an ECG study will inevitably decrease making the study reachable for most of the population.

As future work, one important characteristics of the heart disease detection system is that after some modifications, it can work as a mobile device, making the patient able to be almost in every place in the planet and still know his heart status. The patient would use our GSM system with a computer that receives the signal and then sends the data to a web server, in which the analysis is done. Once the web server gets the analysis results, they can be sent back to the patient along with some medical recommendations.

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