

# Portable, Low Cost, Low Power Cardiac Interpreter

Avishek Paul

*Department of Applied Electronics and Instrumentation Engineering  
RCC Institute of Information Technology, Kolkata, West Bengal, India*

Jahnavi Jha

*Department of Applied Electronics and Instrumentation Engineering  
Techno India College of Technology, Kolkata, West Bengal, India*

**Abstract-** Electrocardiogram (ECG) is one of the most important tools for the diagnosis of disorders related to the cardiovascular system. The ECG signal is produced by the heart in form time varying potentials during the cardiac cycle. The signal contains some characteristic peaks, polarities and time periods which are used for detecting underlying abnormalities in the functioning of the heart. The aim of the project is to design an automatic, easy to read system as opposed to the manual techniques employed by physicians. The purpose is to acquire ECG signals from a patient's body, extract the parameters required and suggest a diagnosis with respect to the extracted parameters. This is low cost, consumes low power and is portable. The output is represented in a suitable way such that any individual with a very basic knowledge of computers, irrespective of their background can operate this and derive a basic understanding of one's heart condition. In this way one can approach close to a medical opinion by detecting the probable diseases before consultation with a doctor. Also, the outputs received after processing can be communicated between PCs via email.

**Keywords – ECG, ECG Signal Acquisition, ECG Signal Processing, ECG Diagnosis,**

## I. INTRODUCTION

The heart contains an electrical conduction system which produces an electrical potential during depolarization and repolarization of the myocardial fibers. These voltages produced due to spontaneous depolarization and repolarization can be measured by electrodes placed on the chest as well as the limbs. The electrodes act as a transducer which converts the ionic current in the body to electronic current in the wires. A differential recording between two electrodes is called a lead.

Several lead systems are present for measurement of ECG but for simplicity, we have considered the bipolar limb lead system which was first suggested by Willem Eithoven. According to Eithoven's theory, the instantaneous voltage measured from any one of the three limb lead positions is equal to the algebraic sum of the other two [2]. The electrodes placed for signal acquisition are on the Left Arm, Right Arm and Left Leg. The differential recording between Left Arm and Right Arm forms Lead I, Left Leg and Right Arm forms Lead II and Left Leg and Left Arm forms Lead III. The Right Leg is used as a ground reference. This signal is in the millivolt range and it consists of a number of characteristic peaks and time periods. The alphabetic designation given to the most prominent peaks are P, Q, R, S, and T [1]. These peaks along with certain time periods and polarities can be used for detecting abnormalities in the functioning and positioning of the heart.

## II. DESIGN SPECIFICATIONS

The system consists of a hardware module and a software module. The hardware or the data acquisition card is designed in order to acquire the ECG signal from a patient's body, amplify it, digitize it and communicate it serially to a PC. The signal is stored on the PC for processing and display. The software algorithm is designed to display the signal, extract the necessary parameters from it and suggest a probable diagnosis by comparing the extracted parameters with the known standard parameters for a healthy individual. The attempt has been made to keep the hardware design as cost effective as possible along with minimum power consumption.

### A. Hardware Design –

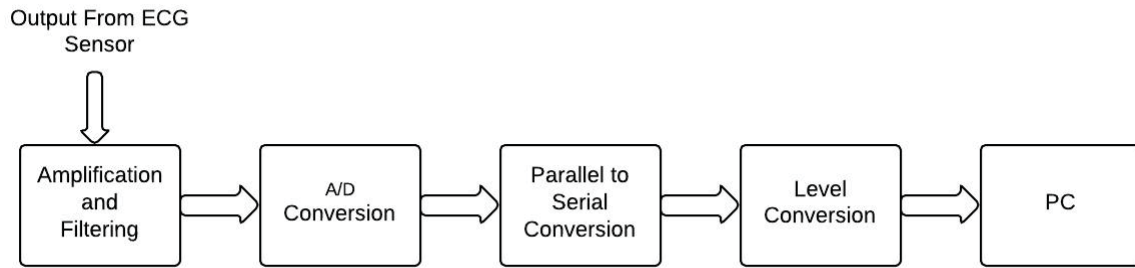


Figure 1. Block Diagram of Hardware

The ECG signal can be approximated to a periodic signal of maximum amplitude  $\pm 2.5\text{mV}$ . Thus, the sensor output has to first be amplified to the range of volts. This is done using an Instrumentation Amplifier of gain equal to 1000 [4]. The advantage of using an Instrumentation Amplifier is that it can also remove some of the noise from the acquired signal in form of common mode signals and thus perform a very basic filtering action at the input level. The amplifier is designed using IC OP07 which is an ultralow offset voltage operational amplifier. Three such instrumentation amplifiers are used for the three ECG leads. The output of the amplifiers is in the range of  $\pm 2.5\text{V}$ . In order to bring it to the range of 0-5V, a DC bias is applied.

The ADC converts the analog signal into a digital signal. 8-bit 8-channel ADC0808 is used where the output of the three amplifiers is fed to three channels. The clock frequency of approximately 640 kHz with 50% duty cycle is applied using an LM555 timer operating in the astable mode [5]. The conversion is carried out using the successive approximation technique with a conversion time of  $100\mu\text{s}$  which is much higher than the time period of an ECG signal [6]. The output is a parallel stream of 8-bits.

AT89C51 microcontroller is used to convert the parallel output of the ADC to a serial form. The 8-bit parallel output of the ADC is fed to Port 0. Port 1 is used to select the ADC channels. The channels are selected in order and output from the channels is loaded on to the accumulator of the microcontroller. The accumulator contents are then loaded to the SBUF register for serial communication through the TXD line, in the RS-232 format [8-9]. The format consists of one start bit, 8 data bits, an optional parity bit and a stop bit. The start bit is a space (or zero) and the stop bit is a mark (or one) [7]. A Baud rate of 9600bps is chosen for fast and efficient communication with no data loss.

MAX232 level converter is used to interface between the microcontroller and the PC. This converts the data from the 0-5V range to the RS-232 logic levels. The voltage level of logic 1 is between -3V to -15V and the voltage level of logic 0 is +3V to +15V [10]. The use of serial asynchronous transmission is to ensure the cost effectiveness and the ease of implementation. The data is communicated to the COM port of the PC through a 9-pin connector.

### B. Development of Processing Algorithm–

The software platform chosen is MATLAB version 7.5.0.342 (R2007b). The reasons for selecting MATLAB is that it contains a large library of built in functions and it is fairly simple to develop a graphical user interface for user friendly representation of the output.

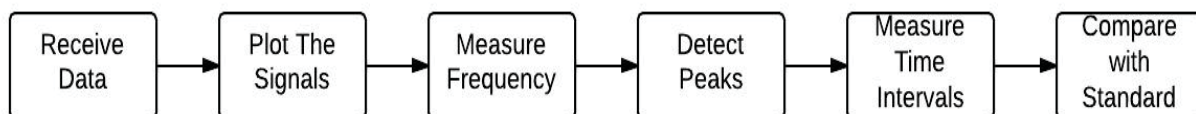


Figure 2: Steps Involved In the Algorithm

A simple linear search algorithm is used to process the signal. The high speed and minimum memory requirements are the advantages of this. The essential criterion for the implementation of the program is that a minimum of two complete time periods must be present for processing. The following steps are employed:

For Plotting and Measuring Frequency:

- The data is received through the COM port of the PC
- Data is separated into three channels corresponding to the three leads.
- A time array is constructed using the known sampling intervals
- The three signals are plotted against time
- For each channel highest value is located. This is one R-peak
- Locate the next R-peak adjacent to the first R-peak
- The time difference between the two R-peaks is the time period of the wave ( $T_p$ )
- Find the inverse of the time period which is the frequency of the signal. Find average frequency for three leads and express in beats/minute ( $60/T_p$ )

For Detecting Peaks and Time Intervals:

- Locate the highest value between the first R-peak and  $T_p/2$ . This is the T-peak.
- Locate the lowest value between the first R-peak and  $T_p/2$ . This is the S-peak.
- Locate the highest value between the T-peak and the next R-peak. This is the P-peak.
- Locate the lowest value between the P-peak and the second R-peak. This is the Q-peak.
- Locate the Q-peak to the left of the first R-peak. Time difference between this Q-peak and the S-peak is the QRS interval.
- The sum of absolute values of the R-peak and S-peak is the RS Amplitude

Final Display:

- Compare the obtained values to the known standard values for a healthy individual
- Create a text document and write the diagnosis to the text file
- Display name of disease if present, otherwise display 'normal'
- Display the text file containing the probable diagnosis

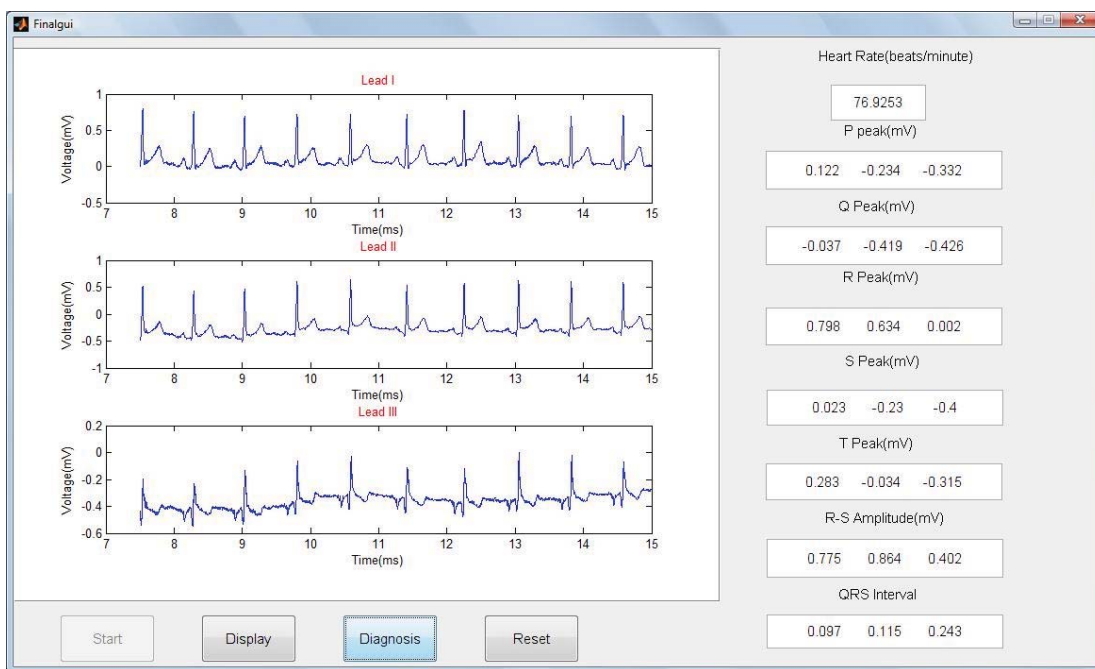
The Graphical User Interface Development Environment (GUIDE) is used to build a GUI [11]. The GUI consists of a 'Start' button which prompts the user to select a file containing sampled ECG data. The file is processed using the software algorithm. After processing the 'Display', 'Reset' and 'Diagnosis' buttons are enabled. On pressing the 'Display' button, the extracted parameters along with the signal plots are displayed. The 'Diagnosis' button when pressed displays the name of the probable disease [13-15] in a message box. The more details diagnosis can be obtained in the text file created by the program named 'diagnosis.txt'. The 'Reset' button can be used to return to the blank GUI and a new file can be processed again by pressing the 'Start' button.

### III. EXPERIMENT AND RESULT

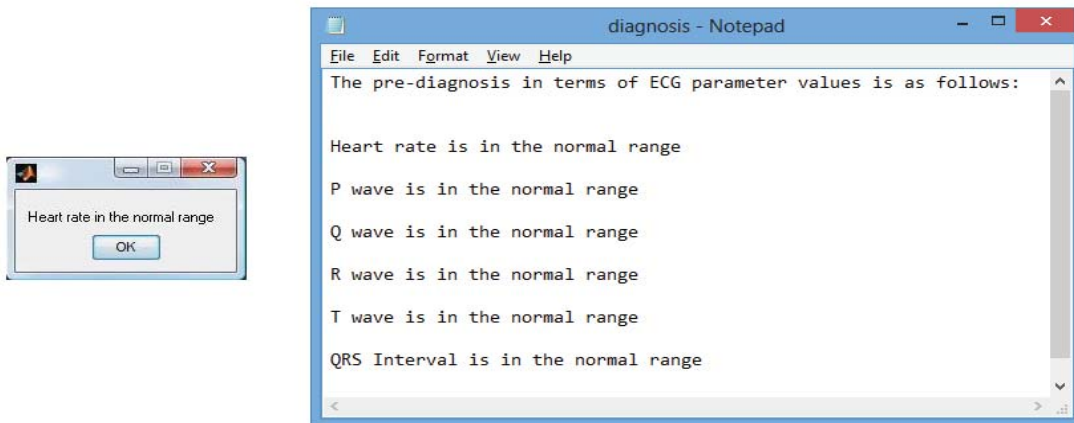
The hardware was tested with an AC signal of amplitude equal to  $\pm 2.5\text{mV}$  and a bit pattern was obtained at the output. The software was tested by using a data downloaded from an ECG database.

Time Interval	Lead I	Lead II	Lead III
0	0.245	-3.04	-3.287
0.001	0.243	-3.04	-3.284
0.002	0.244	-3.035	-3.28
0.003	0.245	-3.036	-3.281
0.004	0.245	-3.034	-3.279
0.005	0.248	-3.03	-3.278
0.006	0.253	-3.026	-3.278
0.007	0.255	-3.022	-3.277
0.008	0.258	-3.022	-3.28
0.009	0.261	-3.025	-3.285
0.01	0.261	-3.023	-3.284
0.011	0.255	-3.022	-3.276
0.012	0.252	-3.025	-3.277
0.013	0.254	-3.026	-3.28
0.014	0.256	-3.023	-3.279
0.015	0.257	-3.024	-3.28
0.016	0.257	-3.03	-3.287
0.017	0.26	-3.027	-3.288
0.018	0.26	-3.026	-3.284
0.019	0.258	-3.029	-3.285
0.02	0.255	-3.03	-3.285

Figure 3. Test Data Consisting of Time Intervals (Column 1) and Data For Each Lead (Column 2,3 and 4)

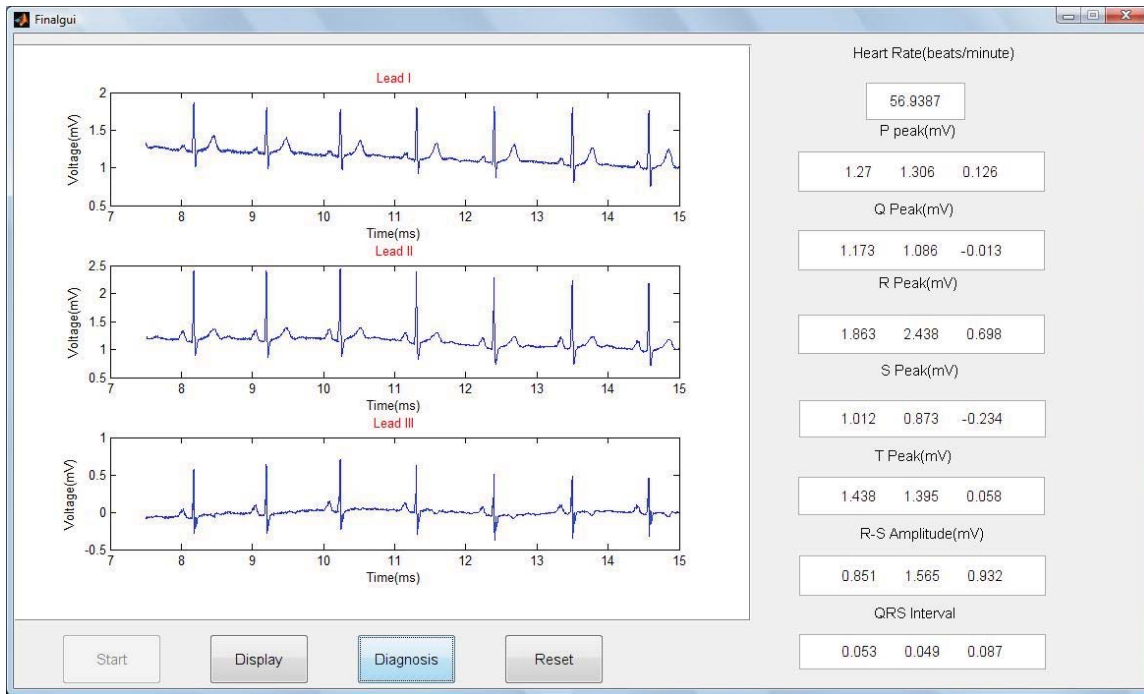


(a)

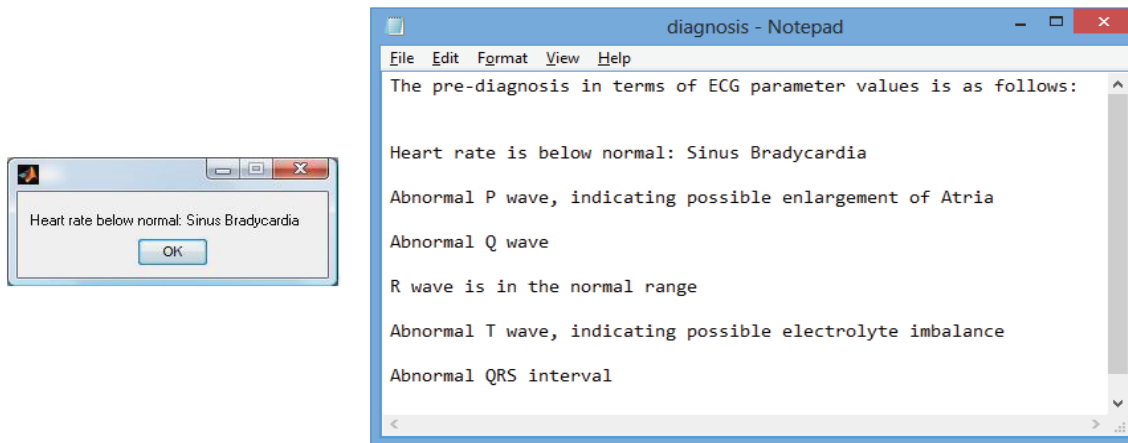


(b)

Figure 4. (a) GUI Output for Test Data-1 (b) Diagnosis for Test Data-1

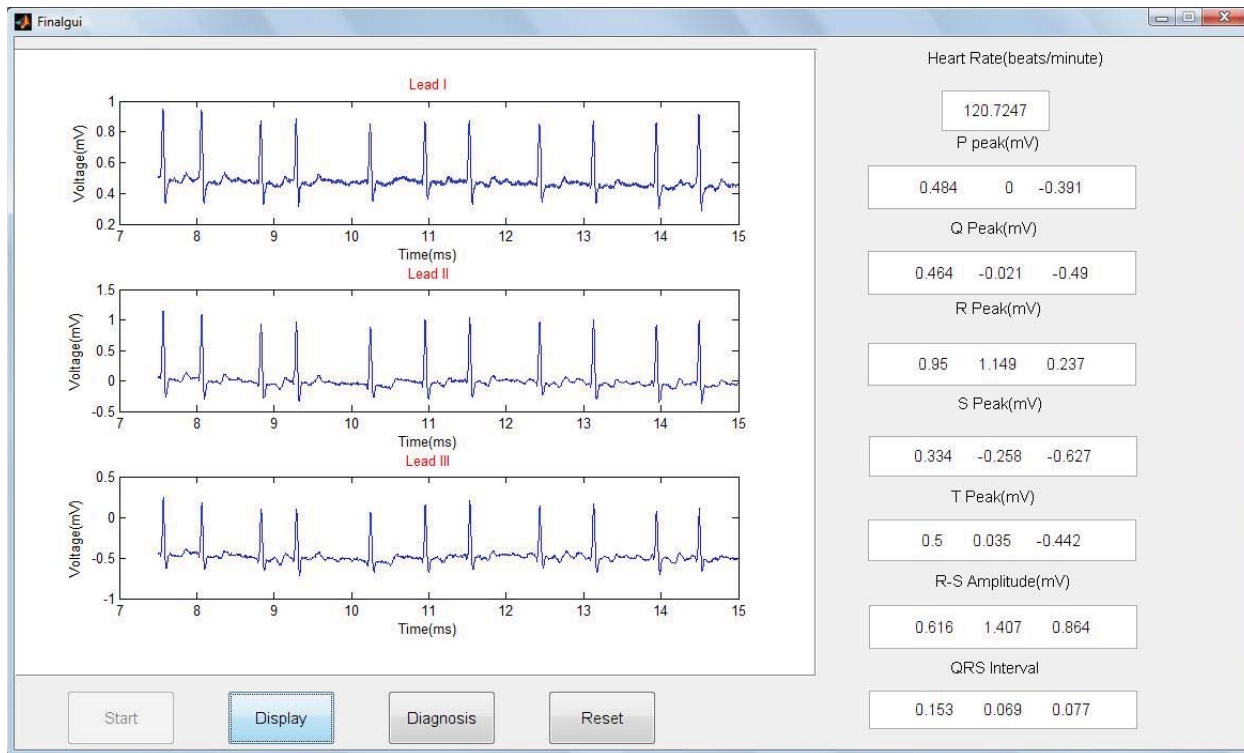


(a)

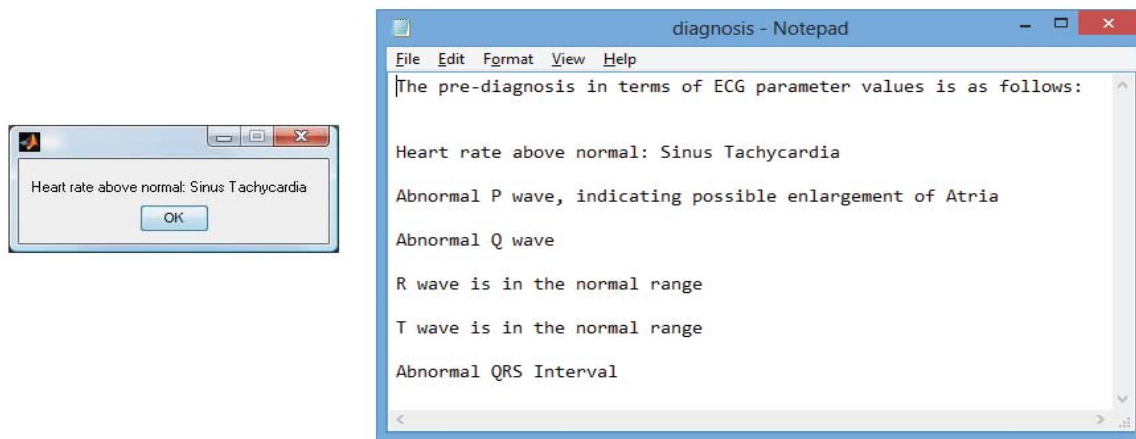


(b)

Figure 5. (a) GUI Output for Test Data-2 (b) Diagnosis for Test Data-2



(a)



(b)

Figure 6. (a) GUI Output for Test Date-3 (b) Diagnosis for Test Data-3

Table-1: Comparison of Standard Parameter Values [12] with Obtained Values

PARAMETRS	STANDARD VALUES	OBTAINED VALUES: TEST DATA-1	OBTAINED VALUES: TEST DATA-2	OBTAINED VALUES: TEST DATA-3
Heart Rate (average)	60-100 beats/min	76.9253 beats/min	56.9387 beats/min	120.7247 beats/min
P Peak (Lead I)	0.03-0.15 mV	0.122 mV	1.27 mV	0.484 mV

Q Peak (Lead I)	<25% of R peak	-0.037 mV	1.173 mV	0.464 mV
R Peak (Lead I)	0.5-2.5 mV	0.798 mV	1.863 mV	0.95 mV
T Peak (Lead I)	0.1-0.5 mV	0.231 mV	1.438 mV	0.5 mV
QRS Interval (Lead I)	0.06-0.10 sec	0.097 sec	0.053 sec	0.153 sec

Figure 3, 4 and 5 show the results of testing the GUI. The obtained values can be confirmed with the help of the datatips tool available in MATLAB. The diagnosis has been restricted to certain common diseases and critical diseases have been omitted for simplicity. Table-1 shows the comparison of the obtained values with the standard values. Common diseases like Tachycardia (faster heart rate), Bradycardia (slower heart rate), probable enlargement of atria or ventricles, electrolyte imbalance, excess body weight, etc can be indicated by the output. Though the analysis cannot be restricted to these diseases alone and it is not absolute, a basic idea can be received.

#### IV.CONCLUSION

In this way, the ECG signal can be acquired and processed in order to get a basic idea about common diseases that occur in human systems. This process is limited to a number of diseases because the diagnosis of most diseases and disorders is a more complex process and requires the expert opinion of an experienced doctor. Also, ECG is not a conclusive test for most diseases because the signal varies in accordance with age, gender, extent of physical activity, temperature, etc. Nevertheless, one can come close a medical opinion which must be confirmed by a doctor.

The diagnosis provided by this algorithm is purely in terms of the ECG parameters and heart rate. This can be further extended to recognize the characteristic changes in wave shape for various diseases, as one of the future prospects.

The hardware is being further developed in order to eliminate noise as far as possible by the use of hardware as well as software filters. Several ECG artifacts such as baseline wander are also to be taken care of. The communication between the hardware and the PC can be made wireless.

The utility of this device is in the low cost, low power and ease of implementation. The work may be extended to those areas, especially rural areas, where the availability of a doctor may be a problem. The major advantage also lies in the fact that the obtained data and diagnosis can be communicated between computers through email. The text file as well as the GUI output in form of screenshots can be emailed to a doctor for better understanding of the abnormalities.

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