Wearable Health Monitoring System

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Abstract : Cardiovascular disease is the world's leading killer. It accounts for 16.7 million or 29.2 percent of total global deaths. Heart diseases are the leading cause of increased mortality rate as this is an era of industrialization, changing lifestyles and dietary habits. The mortality rate reported in government hospitals show that there is an increase in death due to heart diseases and this trend is expected to continue in the coming decades. Since cardiac disorders are affecting human lifestyle, some practical devices based on modern technology are inevitable. Here we are trying to implement a portable monitoring system with wireless transmission where the detected ECG signals are processed in a controlling unit (Atmega328P) to detect for abnormalities. If there is any abnormality, an alarming notification is sent to the physicians mobile. The system will have the required database of the patients, stored in the memory of Arduino microcontroller. This solution not only give patients more freedom, but also provides early diagnosis of cardiac diseases. Our work also presents a system for a simultaneous non-invasive estimation of systolic (SBP) and diastolic (DBP) blood pressure using Photoplethysmography (PPG).

***Keywords* —Arduino Uno, Atmega328P, Einthoven's triangle, Electrocardiogram, Photoplethysmography, Modern healthcare**

I. INTRODUCTION

The proposed device is a 'Wearable Health Monitoring Device' which monitors the Electrocardiogram and blood pressure of patients. We use the commercial ECG three electrode lead method to detect ECG of the user and also their systolic and diastolic pressure by Photoplethysmography and sends data to the user's mobile via GSM module. If there is any deviation from the normal value (the patient suffers from any heart disease and requires immediate medical help), an alert message is sent to Doctor via GSM module with the obtained values.

The Proposed device is self operating which help the patients to monitor their health daily and omits the need for unwanted travel to nearby hospitals. A regular checkup and sending of data to concerned doctors helps in maintaining their health (Proactive decision making for doctors). Our device uses mobile phone and short message service, it is user friendly and cheap, compared to other similar systems. Thus our project increases life expectancy and upscales the health of users.

In the upcoming sections, we can see how the "Wearable health monitoring system" is implemented, the concept and theory, experimental setup, obtained results and conclusions from the project.

II. METHODOLOGY

A. *Electrocardiogram (ECG)*

Electrocardiogram (ECG) is a recording of electrical activity of the heart. It is totally painless and can be performed quickly. The electrical activity is detected by adhesive electrodes attached to the skin. The resulting measurements are taken from leads. Various electrode lead systems have been developed and improved over the past century from which electrocardiograms are transcribed[1]. These include the lead systems from Einthoven, Goldberger, and Wilson.

Steps:-

1. Connect the ECG leads to the electrodes by pressing the buttons together.
2. Place the ECG electrodes in the correct anatomical positions.
   Right arm = RA
   Left arm = LA
   Left leg = LL
3. Connect the ECG leads to AD8233CB-EBZ Board
4. Ensure there is a signal for all leads displayed. If signal is absent, double check connections and electrode contact with skin.
5. Switch on the board.
6. Heart beat detection starts.

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7. It detects every 100 beats, RR interval and Heart rate is displayed on the LCD.
8. The data is then sent to the user using a GSM module and if there is any deviation from the normal value, an alert message is sent to the doctor.

B. Einthoven's lead system

Einthoven recorded the first ECG in the year 1903. As there were no adhesive electrodes or intensifying systems available at this time, the only way to contact the body was to place the extremities in a bucket of salt solution. Einthoven produced a sufficient contact resistance to the body to make the first ECG visible with the help of a string galvanometer. Einthoven could measure the tension between the right and left arm (lead I), the right arm and left leg (lead II), and the left arm and left leg (lead III).

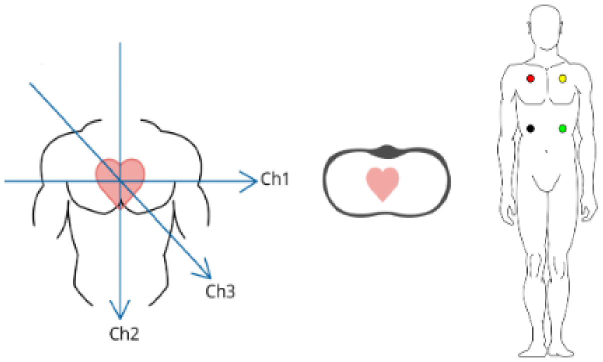

Fig 2.1:-Electrode position/visual axes

C. 3-Lead ECGs

3-lead ECGs are used most often for recording a 24-hour reading. A 24-hour reading is a frequently used tool for the diagnosis of heart problems and is reimbursed as a long-term reading. 3-lead electrode positions are shown in fig 2.1. Heart muscle contracts using the electrical signals from the heart. This is how the 3-lead ECG system works. In fig 2.2, signals from the individual leads are plotted in a graph.

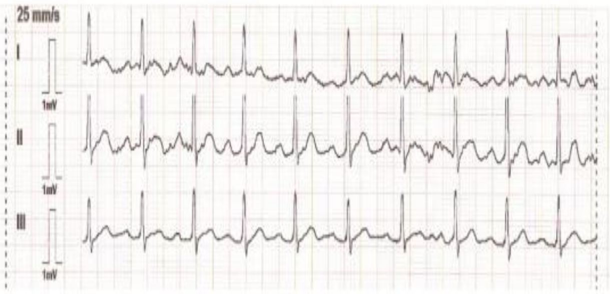

Fig 2.2:-ECG sample waveform

D. Blood Pressure(BP)

Blood pressure (BP) has been a major risk factor for cardiovascular diseases. Blood pressure measurement is one of the most and widely used parameters for early diagnosis, prevention, and treatment of cardiovascular diseases. At present, BP measurement mainly relies on cuff-based technique that causes inconvenience and discomfort to the patients. Even though some of the present prototype cuffless blood pressure measurement techniques are able to attain overall acceptable accuracies, we require an electrocardiogram (ECG) and a photoplethysmograph (PPG) that can make them suitable for wearable applications.[8]

Steps:-

1. The patient's finger tip is used for the measurement of blood pressure using TCRT5000 sensor.
2. PPG waveform is obtained from the sensor.
3. The difference between the dip of the PPG waveform and the peak value of QRS wave from the ECG signal is observed, which gives the pulse arrival time.
4. The pulse arrival time is inversely proportional to blood pressure and we get the blood pressure measurement.

E. Photoplethysmography

Photoplethysmography is a simple and low cost technique which is used to detect blood volume changes in the microvascular bed of tissue. In every cardiac cycle the heart pumps blood into the periphery[9]. Even though this pressure pulse is somewhat damped by the time it reaches the skin, it is enough to distend the arteries and arterioles in the subcutaneous tissue. If the pulse oximeter is attached without compressing the skin, a pressure pulse can be seen from the venous plexus, as a small secondary peak. The instantaneous change in volume of arteries caused by the pressure pulse is detected by illuminating the skin with the light from a light-emitting diode (LED) and then measuring the amount of light either transmitted or reflected onto a photodiode. The shape of the PPG waveform differs from person to person, and varies with the location and manner in which the pulse oximeter is attached.[4]

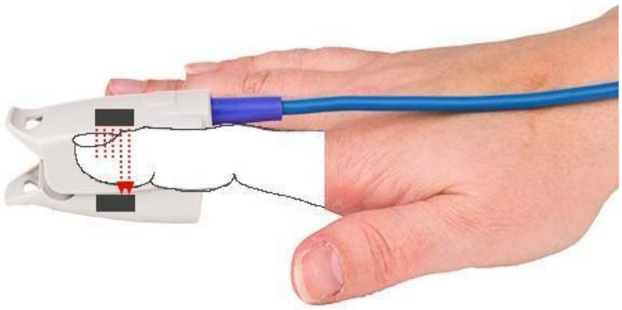

Fig 2.3:-Photoplethysmography setup

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III. PROPOSED SYSTEM

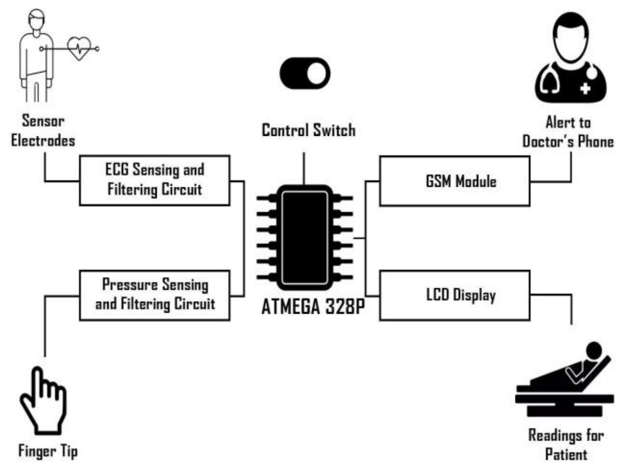

Fig 3.1:-Block diagram of wearable health monitoring device

The block diagram consists of ECG sensor electrodes to monitor heart rate and RR interval. The ECG sensing and filtering circuit is used to reduce noise and it consists of an instrumentation amplifier to amplify ECG signals. It also includes a pressure sensing and filtering circuit to filter and amplify PPG signals obtained from fingertip. We use Atmega328P microcontroller to process these signals. The measured data is sent to patient's mobile via GSM module. The LCD display is used to display the measured values. If there is any deviation from the normal value, an alert message is sent to the doctor with the measured values.

ECG electrodes used are foam type, which are stuck on to the body. They are connected using crocodile clips. These electrodes are then connected to AD8233CB-EBZ Board, which does the signal amplification and band passing. AD8233CB-EBZ is used for the initial evaluation in this application. AD8233CB-EBZ consists of 4 layers in which the primary side has all the components.

The gain versus frequency graph (fig 3.2) of AD8233CB-EBZ is centered at the frequency band 7.2-25 Hz, which efficiently improves the signal to noise ratio. The instrumentation amplifier has a fixed gain of 100, and the operational amplifier is set for a gain of 11. The overall gain is 1100, which limits the maximum differential input signal to approximately 2.7 mV peak to peak.

Blood pressure is sensed using TCRT5000, which is a transceiver. It includes an infrared emitter, with emitter wavelength 950 nm. The phototransistor is placed in a leaded package. This packaging will reduce the additional current produced due to daylight. The peak operating distance of TCRT5000 is at 2.5 mm, from where we can obtain the maximum output current. Output from TCRT5000 is then connected to a filtering and amplifying circuit.

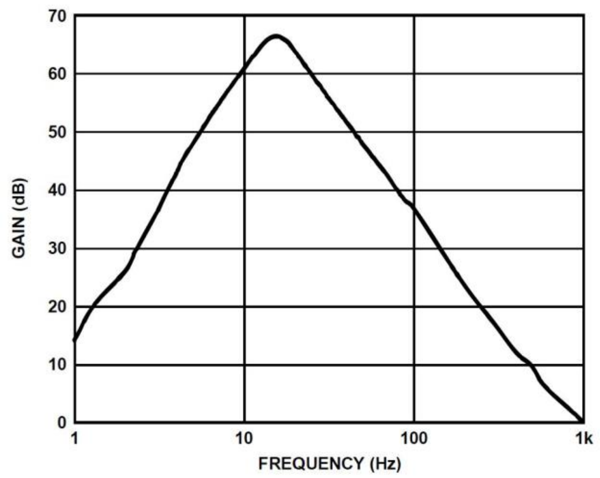

Fig 3.2:-Gain vs. Frequency curve of AD 8233CB-EBZ

LM324 is the component used to implement the filtering and amplification circuit.

IV. EXPERIMENTAL SETUP

A. ECG

ECG is first calculated using a simulator which is made using Arduino Uno and a low pass filter, by driving the DAC of Arduino Uno. The Database for simulating an ECG waveform is obtained from Physionet ECG Waveform Database (PhysioBank Databases). The Low pass filter is designed at 200 Hz, in order to reduce noise. Signals from ECG Signal Generator is given to Analog Input 0 (A0) Pin of ATMega328P. Sampled signals (After ADC) are cross checked so as to make sure that the required signal is sent to the Detection Phase. The RR Interval from ECG Signal Generator is calculated to find accuracy of the device. Regular comparison with this value and the calculated value is done as part of the experimental setup.

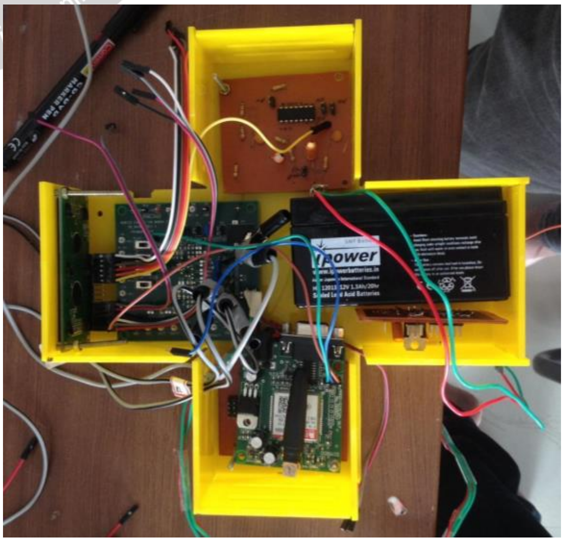

Fig 4.1:-Experimental setup

The next phase of Experimenting is to analyse and calculate ECG Vitals from a live subject. In order to achieve the above goal, we designed three ECG Lead wires and connected it to the electrode patch. These Electrodes were

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stuck on to the Subject on his Right Chest, Left Chest and Right Abdomen.

At first, the experiment was conducted in a room where power supply noise was high, and we found distorted waveforms in DSO. To reduce the power supply noise, we moved to a room where AC supply was minimum and only used DC Power sources as Supply for all Boards. Thus we could get a good quality ECG waveform from a Live Subject. The ECG Signal from AFE is interfaced to the A0 pin of ATMega. After Beat Detection and Processing, the results are displayed on the LCD Screen, and Report messages are sent via GSM Module. The values which are calculated is noted and compared with table (table 4.2), to detect any abnormalities.[7]

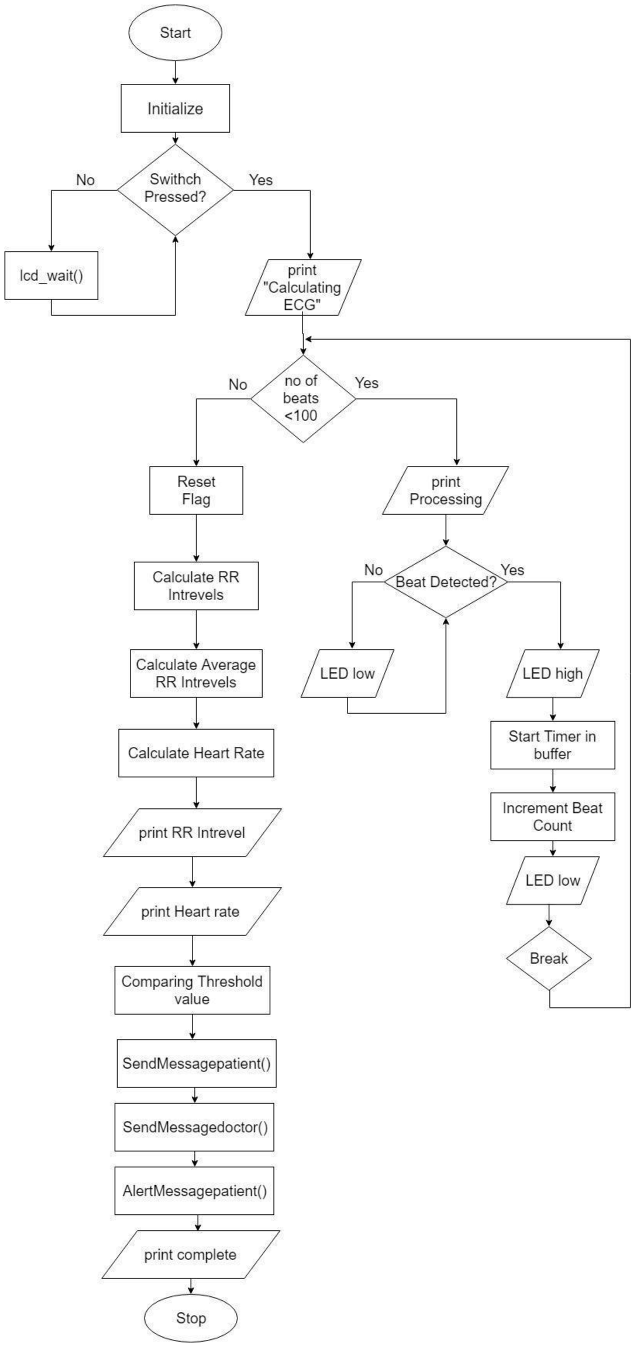

Fig 4.2:-Flowchart of ECG detection

	RR-interval	Heart rate
Normal value	0.6-1.2 sec	60-100 bpm
Low value	Below 0.6 sec	Below 60 bpm
High value	Above 1.2 sec	Above 1.2 bpm

Table 4.1:- Comparison of RR-interval and heart rate

B. BLOOD PRESSURE

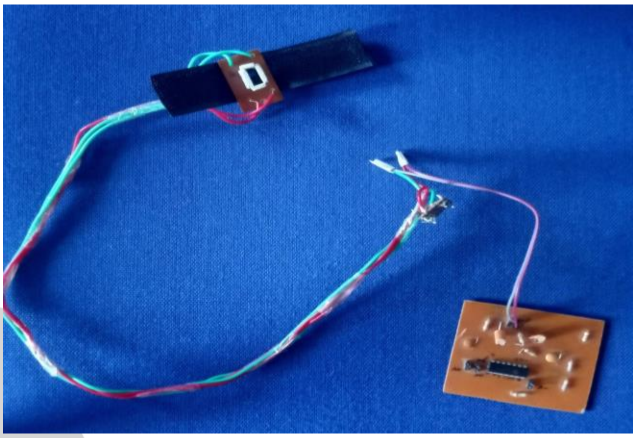

Fig 4.3:-Blood pressure setup

On completion of ECG calculation, a delay of five second is given to start pressure detection. The pressure sensor probe is placed on the index finger of right hand and pressure calculation starts which lasts for about 10 seconds. The waveform is obtained on DSO (Digital Storage Oscilloscope). The time at which the dip of the obtained PPG signal is annotated, and stored in an array. The time at which succeeding peak of QRS wave is also annotated and is stored in another array. Now, we find the difference between these values to find the pulse arrival time[4].

By calculating the pulse arrival time or PAT, we will get an idea about the pulse wave velocity or simply PWV. The obtained pulse wave velocity is inversely proportional to blood pressure. The proportionality constant between these values can be calculated by taking data from multiple subjects, and plotting the PWV v/s BP curve. The values which are calculated is noted and compared with the table given below, to detect any abnormalities.[9]

	Systolic BP	Diastolic BP
Normal value	90-140 mm Hg	60-90 mm Hg
Low value	below 90 mm Hg	below 60 mm Hg
High value	above 140mm Hg	above 90 mm Hg

Table 4.2:- Comparison of Systolic BP and Diastolic BP

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V. .RESULTS

A. ECG

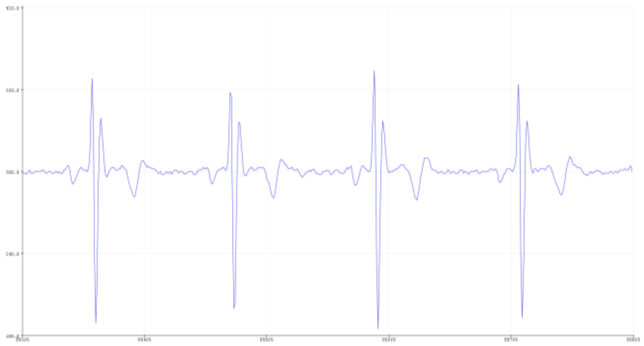

Fig 5.1:-Waveform obtained from serial monitor

ECG is measured by placing the electrodes according to the 3-Lead system on the subject's body and the output is observed in the serial monitor (fig 5.1). The main program is done in Arduino IDE. The ECG signal from the body is detected and processed for abnormalities. RR interval and the Heart rate is then displayed on the LCD display(fig 5.2 & 5.3). The obtained data is sent to the user's phone number via GSM module. If there is any change in the normal value, then the message is sent to the doctor's phone via GSM module.

Here, every beat of the heart in a minute is counted which is used for further calculations. We use the interval between two successive QRS peaks which is equal to the RR interval. Heart rate is obtained by the equation:

$$Heart\ rate = 60000/RR\ interval(ms)$$

The accuracy of this project is measured by interfacing the ECG simulator, in which the RR interval can be defined in the program using the database of a normal ECG signal. Thus we obtain more accurate data by comparing the calculated and programmed values. The strap-on device is implemented by designing a casing for the project (can be seen in fig 4.1). The casing is designed using acrylic and cut using Laser (Epilog laser). This casing helps in developing a standalone product, also fulfilled the aspect of wearability of the project.

Fig 5.2:-RR interval displayed on LCD screen

In the messages sent to patient (when the vital parameters are normal) contains RR interval, heart rate and the comment oh his/her condition(fig 5.5). While the message sent to doctor (only when abnormal condition occurs), contains an "ALERT" so that he can quickly view from his mobile, and take necessary actions (fig 5.4).

Fig 5.3:-Heart rate displayed on LCD screen

Fig 5.4:-Alert message

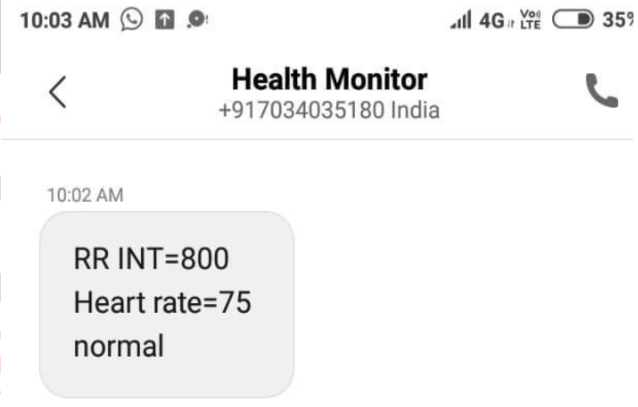

Fig 5.5:- Report message

B. BLOOD PRESSURE

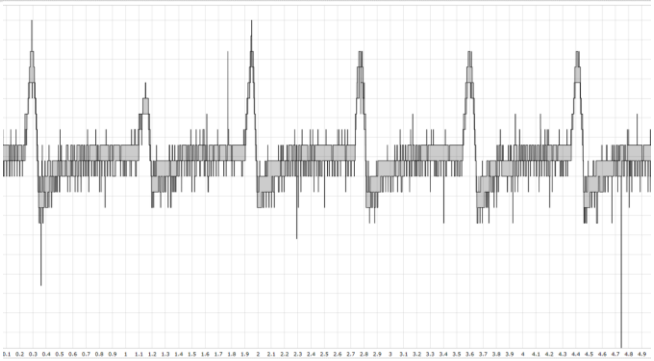

Fig 5.6:- Blood pressure waveform

Blood pressure is measured by using TCRT5000 sensor. Measurement of blood pressure is made hassle free as we do not use inflating cuffs but what we use is a finger probe, which can be clipped or strapped on to the finger tip. The obtained waveform is displayed on the DSO. The vibrations from finger tip is recorded instead of fluctuations in blood vessel.

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VI. CONCLUSIONS

ECG is estimated and displayed on the LCD screen. The obtained results are then sent to the user's phone via GSM module to keep the necessary records of the variations in their heart rate and blood pressure. If any abnormality is detected, the data is sent to the doctor's phone, so that necessary actions can be taken as fast as possible. This helps the doctor to have a clear idea of the progress or regress of his patient's health. Thus it eliminates the problem of undetermined condition of patient's health and increases life expectancy. Blood pressure sensing is implemented using TCRT5000 sensor. The limitation of our project is that since the EEPROM capacity of Atmega328P is only 1KB, our project consists of only QRS wave detection, RR interval and heart rate monitoring. Interfacing an external EEPROM can improve the memory capacity and include additional features like P wave detection and T wave detection.

We obtained accurate measurement while comparing with the simulated value. Even though the reports are more accurate than conventional heart rate monitors using heart rate sensors, the accuracy can be further increased if a 24 bit Analog to digital converter is used. And also, if the time for calculation is reduced, the number of beats that is detected can be reduced from 100 to 50. Currently it takes around 2 minutes for complete calculation, thus reduces to half.

The battery is heavy (around 2 Kg) and it consumes most of the weight and size of "Wearable Health Monitoring Device". Significant improvement in the compactability of 12v battery can be improved by substituting the SLA (Sealed Lead Acid) with a Li-ion battery.

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