Design and Implementation of a Compact Temperature, Heartbeat and ECG Measurement Module

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Abstract

In this work we designed a user friendly compact biomedical device that helps user to monitor and record change in general vital signs like- body temperature, heartbeat and ECG (electrocardiogram) with simple digital sensor models. Conventional biomedical devices are costly and requires expert personnel to operate the device. This device was designed to ensure portability, user-friendliness, reliability, ease of maintenance and cost optimization. The device also incorporates a computer interface software which will show real time ECG graphs and other measured biomedical data. This device can ensure user-friendly patient monitoring and better medication based on data statistics collected.

Keywords — *Biomedical Device, Patient Monitoring, Real Time ECG, Body Temperature, Heartbeat, Computer Interface, Biomedical sensors.*

I. INTRODUCTION

Day by day health conscious people are increasing and they urge for frequent monitoring of their health for a sound life. But this leads to exponential increase in cost and hazards for ensuring care of general mass. And in developing countries with less health care facilities and practitioners in comparison with popularity cannot cope up with this scenario. Therefore, people are heading to cheap, reliable and easily accessible health monitoring systems. This golden era of electronics with its rapid advancement opened up vast opportunities in this field. Measuring instruments are also getting more compact and user friendly. Newer and newer innovations are enriching medical sectors greatly and this plays crucial role in our civilization. Our work is a health monitoring system with user friendly computer interface can facilitate greatly as an easy household device. Such remote patient monitoring framework is quite common in technologically advanced countries in different models like clinical monitoring, wearable sensor network and so on [1]. These models save huge time, money and hazards and also encourage people to be more conscious of their own health. Moreover, treatments with statistical data and continuous monitoring can be achieved very easily which helps different physicians deeply. In developing countries such trend can have massive impact on social and health development of general mass.

II. OBJECTIVES

The objectives of this project are to design and implement a compact biomedical module facilitated with computer interface which can measure basic vital body signs like temperature, heart rate variability and electrocardiogram. The data can be viewed in real time via the interface both graphically and textually. The whole model can be divided into four sections shown in fig.1 below which are linearly connected and dependent.

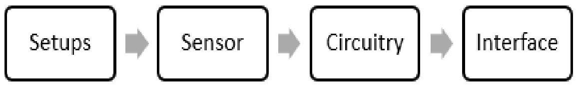

Fig. 1 System overview

III. METHODOLOGY

A. *Body Temperature Measurement*

1) Background Study: Body temperature is one of the oldest known diagnostic methods and is still a vital sign of healthiness [1]. Variation from normal temperature dictates disturbance in body system. Body temperature is body's measurement of generating and getting rid of heat. When heat rises the blood vessels in skin widen to carry the excess heat to skin's surface and helps cooling your body. Again, when heat in body falls, blood vessels get narrower and reduces blood flow to save body heat. Measuring one's body temperature is an initial part of a full clinical examination. Body's core temperature refers to the thoracic and abdominal contents, some muscles and brain, while the peripheral temperature relates to a relatively small amount of subcutaneous tissue and mostly the skin [2]. Generally, there exists thermal gradient between the body surface and the deeper tissues. It is seen that for each 4mm depth temperature rises about 1°C approximately [3]. Specifically, the pulmonary artery (PA) measures the temperature of mixed venous blood from the upper and the lower parts of the body as well as the core and the periphery and so considered as the gold standard of core temperature generally [4]. Usually in clinical and household practice non-invasive methods are popular [5].

2) Hardware: For measurement we used DS18B20 sensor which has a wide range of features other than the popular use of temperature measurement. In this sensor temperature measurements are made using two bandgap-generated voltage sources. It senses temperature by its unique 1-wire interface. Fig. 2 shows the waterproof model of DS18B20 sensor. In final model temperature circuitry needs only these following components:

- DS18B20 Digital temperature sensor
- Microcontroller (ATmega 328)
- Resistor (4.7K)

Fig. 2 DS18B20 sensor

3) Process Flow: Heartbeat detection model is implemented with different phase of actions. Fig. 3 illustrates the process flow comprising with the subdivisions to implement the total thing.

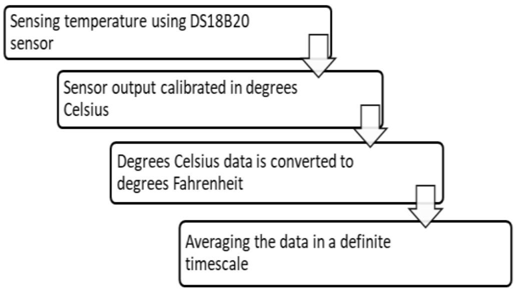

Fig. 3 Process flow of Temperature measurement

4) Schematic: The following Fig. 4 is the schematic diagram of the circuit designed for temperature measurement.

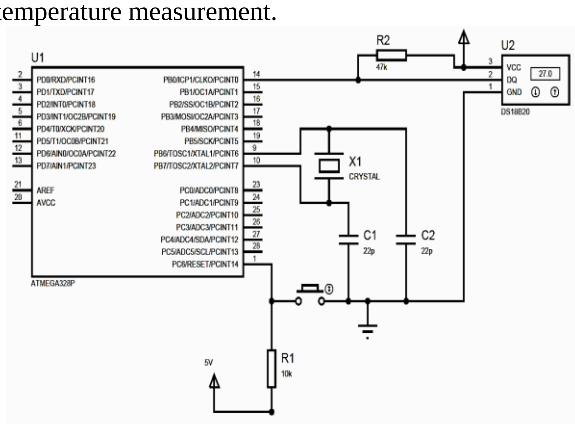

Fig. 4 Temperature measurement circuit schematic

B. Heart Rate Measurement

1) Background Study: In 2005, WHO (World Health Organization) reported that about seventeen million people died in heart disease around the world [6]. So, it is unquestionable that heart rate monitoring has a great importance in patient monitoring. Heart beat is a vital body sign which indicates the time duration of a cardiac cycle. It is related to the contraction of the muscles of the heart or a perceived effect of it. As the heart pushes blood through the arteries, the arteries expand and contract with the flow of the blood. Resting heart rate means when heart is pumping lowest amount of blood. It is usually within 60 to 100 BPM according to many test-cites [7]. Fast heart rate above 100 bpm at rest is defined as Tachycardia [8]. Heartbeat of irregular pattern is referred to as an arrhythmia. Heart rate pattern is important because abnormalities of heart rate can indicate different disease [9]. The heart rate monitor can find several types of applications. Such as they can be used in the hospitals, elderly health care, personal emergency response or sport training [10]. Heart rate variability (HRV) is a special parameter that can be measured during heart beat measurement. While heart rate measures average beats per minute, it measures the specific changes in time between successive heart beats. HRV is generally measured in milliseconds. HRV is best to measure at rest. At rest a high HRV is generally preferable. Whereas in an active state lower relative HRV is generally favourable.

The principle of operation is based on photoelectric plethysmography. There are two types of photoelectric plethysmography.

- Transmission based
- Reflection based

We used the reflection-based process. Haemoglobin of blood can absorb a substantial portion of light in our body and rest of them are reflected from the body parts. In each cardiac cycle blood concentration varies. This concentration variation changes the amount of light reflected back from the body parts. For our measurement we used green light from a solid-state LED lamp instead of IR. Green light has much less wavelength (about 525 nm) than IR light as seen from the relative absorbance of haemoglobin in Fig. 5 [11].

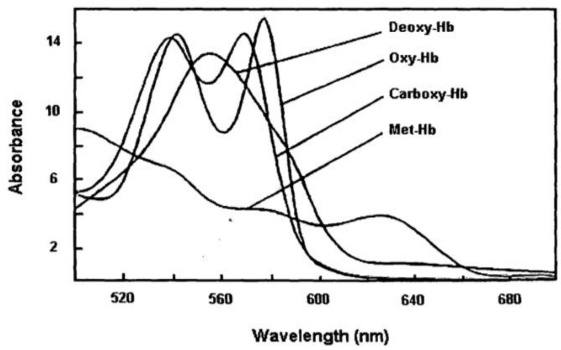

Fig. 5 Relative absorbance of hemoglobin

*2) **Hardware:*** To implement the heartbeat measuring circuitry we used following components.

- SEN-11574 pulse sensor
- Microcontroller (ATmega 328)
- Low power Op-amp
- Resistors and capacitors

SEN-11574 is integrated with a solid state green LED and an ambient light photo sensor, which fits our need.

*3) **Process Flow:*** Heartbeat detection model is implemented with different phase of actions. The process flow in the Fig. 6 shows the working process of heartbeat measurement.

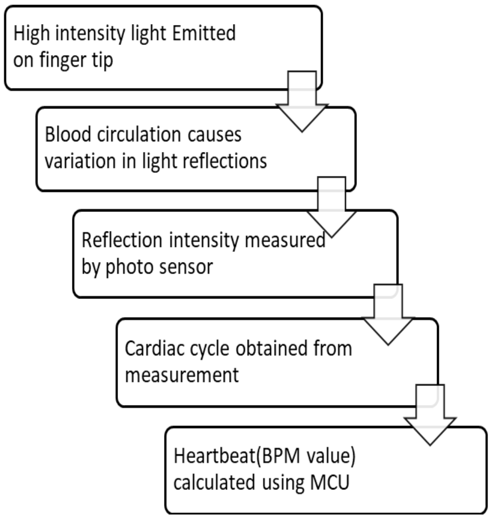

Fig. 5 Process flow of heartbeat detection

*4) **Schematic:*** There as three parts of the schematic for the heartbeat measurement circuit as shown in Fig. 6.

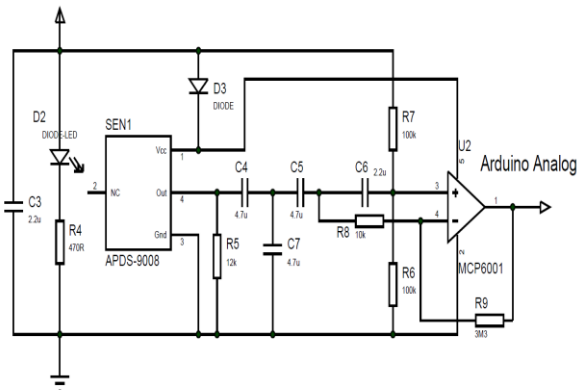

Fig. 6 Schematic of heartbeat measurement circuit

The first portion is named as 'Capturing reflection'. With necessary circuitry there are a green led and a photodetector. The light from the green led reflects due to blood volume variation and photodetector gets readings capturing the reflection. Photodetector output comes with noise that is managed by the filtering potion. The filtering portion is the second part that comes with necessary circuitry named as 'Filtering part'. The third and last part is 'Amplifying part'. This section amplifies the processed filtered output to a meaningful level. This output is feed to microprocessor analog read. The further processing is done through coding logics implemented according to this reading.

C. Electrocardiogram (ECG)

*1) **Background Study:*** ECG is short form for electrocardiogram or electrocardiograph, which is the measurement process of heart's electrical activity, the more appropriate term for which is the cardiac conduction system. There are several ways to measure ECG but mostly used and popular among them is standard 12 lead ECG. In this method 12 electrodes are placed along chest, abdomen, hand and leg and different signals are measured from these electrodes. Besides the standard 12 lead ECG there are several other methods in use [12].

- 3 channel ECG
- 5 channel ECG
- Vector electrocardiography
- Body surface mapping

In our thesis work we used a modified version of the 3-channel approach. This method is known as Wilson electrode system combined with right leg driven circuit. The right leg drive circuit works to reduce interference from the amplifier. Amplifying an ECG signal and creating a DC common mode bias off the inputs of the differential amplifier causes extreme susceptibility to common mode interference. Fig. 7 illustrates the right leg drive circuit [13].

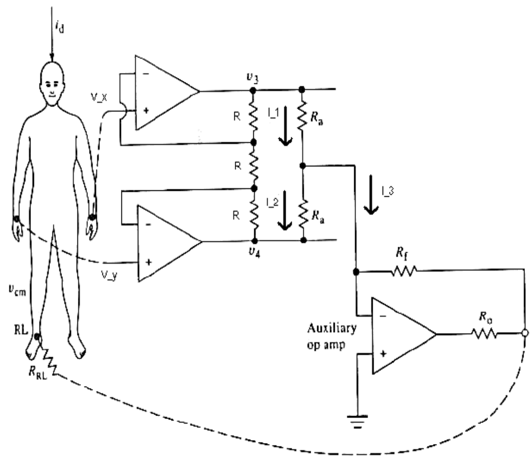

Fig. 7 Right leg drive circuit

*2) **Hardware:*** The following components are used for ECG measurement process:

- AD8232 sensor
- Microcontroller (ATmega 328)
- ECG leads

AD8232 sensor is a single lead ECG front end with common mode rejection ratio of 80 dB (dc to 60 Hz). It works with two or three electrode configurations. The integrated right leg drive amplifier is a major part of this sensor. It also provides leads off detection both for ac and dc. We used normal electrodes that are used to measure such biopotential signals. These are composed of a metal (usually silver for ECG measurement) and a salt of the metal (usually silver chloride). Additionally, some form of electrode grade or jelly is applied between the electrode and the skin.

*3) **Process Flow**:* ECG measurement needs several phases to operate. In the process flow we have subdivided the operations in simple three parts as shown as Fig. 8 below.

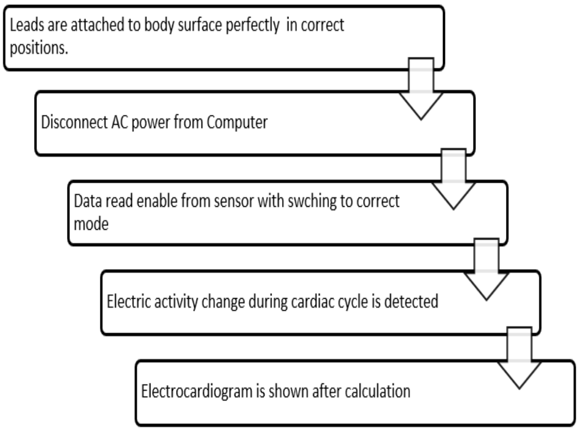

Fig. 8 Process flow of ECG measurement

3) Schematic: Schematic circuit for ECG measurement is shown in Fig 9.

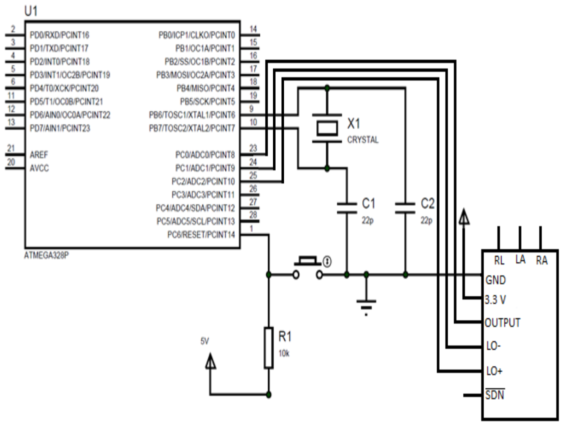

Fig. 9 Schematic circuit of ECG detection

The RL, LA, RA connection are for electrode placement. We used color coded ECG electrodes where RL, LA and RA are attached to right leg, left arm and right arm respectively.

IV. INTEGRATED SYSTEM

The integrated system combines all the measurement units together. With this major integration there comes some other implementations that paved the way to the final model.

We implemented a system interface for the project. The interface has been developed by Processing software. It incorporates following features:

- A window for showing graphical change of results over time. For special purpose two windows are also used. Like implementing heartbeat measurement one window shows the pulse variation and a smaller one beside it shows inter beat interval variation curve.
- Mode selection option for switching to different measurement. It is set as pressing ‘p’ key goes to previous mode and pressing ‘n’ key takes to next mode.
- Each mode is presented as user understand the state. Besides the name of the measurement a graphical presentation is made to show on the interface.
- Computer port selecting options for microcontrollers.
- Snapshot of the window can be taken anytime for storing the result curve by pressing ‘s’ key.
- Measurement result is averaged after a defined time and average value is shown as a continuous manner.
- Styling of the interface can be modified through coding for better look and feel. And other features or controls can easily be integrated.
- The interface is flexible to change it for measuring a single parameter or some parameters based on choice by some modification. This can help to meet varieties of need of patients.

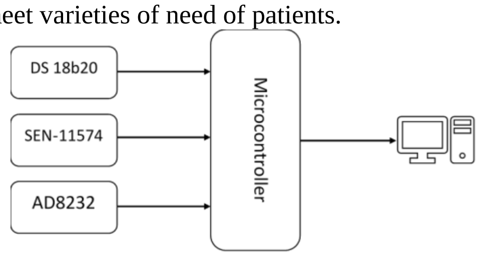

Fig. 10 Block diagram of the final prototype

V. RESULT

After completion of the prototype, all the data were measured on different subject to compare our measurement with other conventional technique or instruments.

For temperature measurement waterproof DS18B20 sensor was used. In the GUI the temperaure was plotted to show the change of temperature over time. The Fig.11 shows the comparision of our temperature measurement with conventional mercury thermometer and digital thermometer.

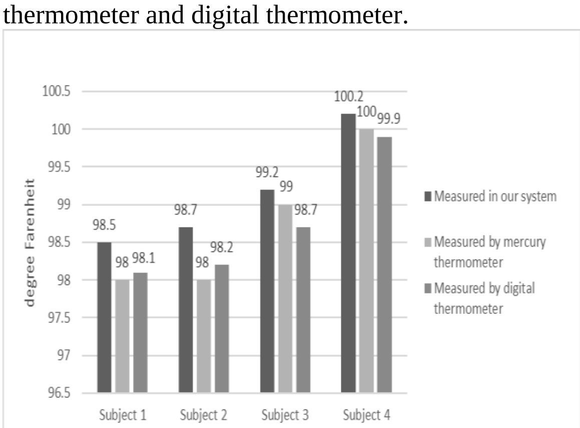

Fig. 11 Comparison of different temperature measurement

The graph in figure 12 below compares the heart rate of 4 different subjects measured using our heart rate sensor and by conventional manual method. For heart rate measurement the GUI shows the pulse variation with a smaller window showing inter beat interval variation curve.

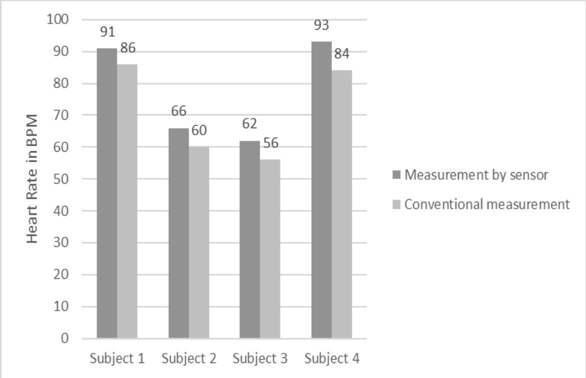

Fig. 12 Comparison of different Heart Rate measurement

The three lead ECG used in our prototype is not similar to traditional twelve lead ECG. Our goal was to implement a simple system that will be easy to use but will provide an useful data for quick diagnosis. The figure 13 below shows how the GUI shows the ECG wave.

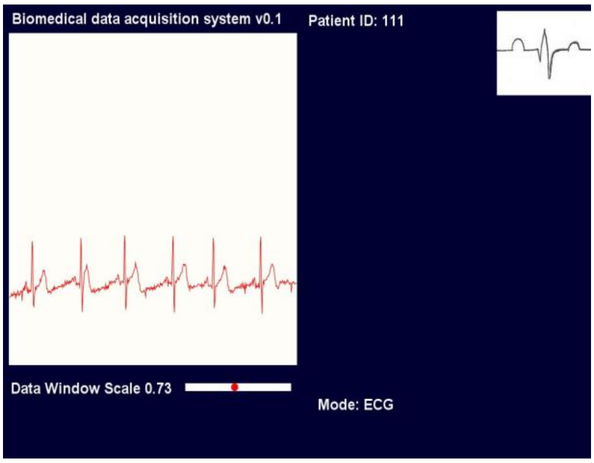

Fig. 13 ECG data on the GUI

VI. CONCLUSION

Rapid innovations in electronics and biomedical field are revolutionizing the research fields. These tacky devices are finding their path in consumers market and making self-health monitoring a common day's work for ordinary people. Our designed module presents a new approach in health monitoring. One of the main perk of our design is that, the device is compact and integrable. It is very easy to incorporate other forms of biomedical sensors with our device. In future, this compact device will incorporate sensors which will help to monitor and record change in vital signs like- respiratory rate, blood oxygen saturation, blood pressure etc. In near future, compact heath monitoring devices like this will revolutionize our everyday life.

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