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Portable Health Monitoring Device

Dipika Vasava[1], Shripad Deshpande[2]
[1]GTU PG School-CDACACTS, Pune India, dipika4491@gmail.com, +91 9033505882
[2]SyncSpace Solutions Pvt. Ltd., Pune India, deshpande.shripad2@gmail.com

Abstract — With meticulous and quick development in Medical industry, the task of detecting irregularity in convalescent is very easy. The vital signs are useful in detecting or monitoring medical problems. The vital parameters routinely monitored by the medical professionals and healthcare providers comprises of body temperature, pulse rate, respiration rate and blood pressure. In environments such as multispecialty hospitals, most of the healthcare issues can be taken cared of under one roof. But with busy life styles and changing priorities visiting medical consultants at regular intervals has become time, money and more of productivity consuming for which, the reason lies in exponentially increasing number of patients and scarcity of specialists. Now with ever increasing growth in medical cost as well as the population, has led to need for cut priced and compact health gadget that help convalescent to determine the amount of various vital parameters in industrialize nation. In order to solve this problem, portable health monitoring device can act as preliminary assistants to notify the patient the actual need of visiting the hospital. In this paper, a cost effective, smart and portable health assistant's design and work flow in accordance is discussed along with suitable results. Manual probing IO and schematic/layout driven approach is considered for system design while sensing itself is handled using integrated on-chip-multi-functionality-sensors. The logic is to be governed by suitable ARM controller but for prototyping purpose, BeagleBone Black is used.

Keywords—*ECG, Portability, Pulse Oximetry, Chronic disease, ECG, Biomedical Embedded system, BeagleBone Black*

INTRODUCTION

With advancement in VLSI technologies and circuits becoming denser and smaller with time integration of analog components on chip itself has allowed mankind to experience many of the unseen paradigms and one of them is biomedical sensing frontend [16][17]. Advancement in the electronics and communication field has helped a lot in having great life, no problem is big enough to deal with. Despite of these advantages, human lives are getting busier. They do not have time for regular health check-up. In past 50 years at least 100 new diseases have been either triggered or identified. Chronic diseases are the prime cause of death [1]. According to a survey done by WHO (World Health Organization), it has been concluded that not only the chronic diseases are the prime cause of death but also for the disability worldwide [2]. But the good news is, timely diagnosis and proper treatment can still save patients' life. One of the healthy habits to remain physically fit is to keep track of our health on regular basis which generally involves attention of a medical consultant. Now the doctors have so many patients to be taken care of and this leads to an atrocious time load on the doctors. So in such case the patient who might actually require doctor's attention, might not get the attention that they require. In this case wearables help a lot for tracking the health parameters like heart beats. They also help in controlling our dietary. Moreover there are availability of glucometers which help to keep eye on the sugar content in the blood and so helps patients to take decisive steps to control the blood sugar. Now-a-days small blood pressure measuring devices are also available, so that patient can keep track of his blood pressure. While wearables can just notify with heart rates, for other so important parameters like ECG, blood oxygen saturation etc. one has to still visit the hospitals for their tests. But in this generation with people having busy schedule on going and the distance between their residential area to the hospital and of course the money are the main three causes that people fail to keep track of their health. One of the most highly proposed and buzzed solution is a portable health monitoring device which can act as an assistant and bridge the gap between doctor and patient without them having to see each other personally. The reason why such devices have not gained a bright view from the market window and pervasive acceptance is either high cost, poor performance or complicated user interface.

In this paper design and working of such a system is discussed elaborately. Section II describes brief literature review, section III discusses the design and specifications while section IV explains its working and section IV concludes the article. A brief introduction to such vital parameters is also given in tabular format.

LITERATURE SURVEY

Literature related to the research topic has been summarized in tabular form. The table 1 shows literature survey in tabular form. The table 2 shows checklist table of the review paper. The S in the table shows Sensors where S1 is temperature sensor, S2 is Blood pressure sensor, S3 is Heart rate sensor, S4 is ECG and S5 is Pulse Oximetry sensor.

Table 1. Summary table of Literature survey

Sr. No.	Title	Year	Key points	Remarks
1.	An open NFC based platforms for vital sign monitoring [3]	2015	Use of NFC	Too many dependencies
2.	Development of Algorithm for transmission of Electrocardiogram and its parameters [5]	2015	Lots Use of wireless transmission technologies	Lots of interference
3.	Remote monitoring of ECG and body temperature signals [7]	2014	Multiple sensors, good data exchange, efficiency	Very useful for implementation
4.	Design of a low cost BP and body temperature interface [18]	2013	New ways of sensing	Poor data exchange interface
5.	Accurate temperature measurements for medical research using BSN [19]	2011	Portability and temperature sensor	Limited and poor performance
6.	Human body respiration measurement using digital temperature sensor with I2C interface[20]	2013	Coding algorithm	Old interface

Table 2. Sensor availability in the Review paper

Sr. No.	Title	S1	S2	S3	S4	S5	Performance	Portability
1.	An open NFC based platform for vital signs monitoring [3]	✓						✓
2.	Remote monitoring of ECG and body temperature [7]	✓		✓	✓		✓	
3.	Design of a low cost BP and body temperature interface [18]	✓	✓				✓	✓
4.	Accurate temperature measurements for medical research using BSN [19]	✓						✓
5.	Human body respiration measurement using digital temperature sensor with I2C interface [20]	✓				✓		✓

SYSTEM DESIGN

This section discusses the block diagram of portable health monitoring device, its internal schematic and the program flow. The following figure shows the block diagram of the system. Here the controller used is BBB and the sensors are interfaced with BBB [13].

BBB comprises of 64 GPIOs which are more in number compared to that of Raspberry Pi. The 1GHz ARM Cortex A8 is sufficiently capable of collecting all of the patient's data, having a smooth user interface and transport the data over a communication channel that is secure and reliable. Furthermore the large amount of GPIOs make sensor interfacing easier and the inbuilt Debian is almost a full-fledged OS having a complete wiring library for direct terminal access, sophisticated compiler collection (GCC) which makes building, installation and running of any module easier and full network stack which allows programmer to exploit any kind of connectivity he desires in form of wired (Ethernet, SPI etc.) or wireless protocol. The built-in flash is what ultimately makes it the reason behind achieving portability and the USB interface is also very handy as it also provides secure shell communication from it thus laptop can be used as a display without having HDMI or networked interface like Raspberry Pi. As for the display, technically

any display and any wireless module can be used but for the sake of simple prototyping 16x2 LCD as well as Bluetooth module to send abnormality report to host's cell phone.

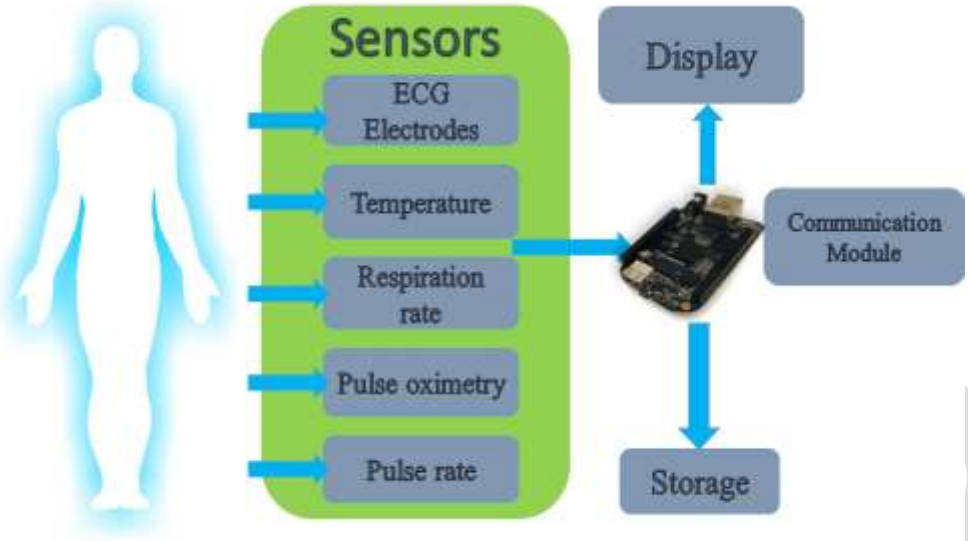

Figure 1. Block diagram of the portable health monitoring device

The interface of sensor ICs involves design of a single, small and expandable module which encompasses both the ICs in such a way that sensing and signal communication can be done without any hindrance. For achieving so, both SMD sensors ADAS1000-4 (ECG Sensor) and Max30100 (Pulse Oximetry sensor) are mounted on a custom designed PCB which is then expanded to be connected to GPIO of BBB [14] [15]. In the following figures customized Eagle symbols and the schematic is presented.

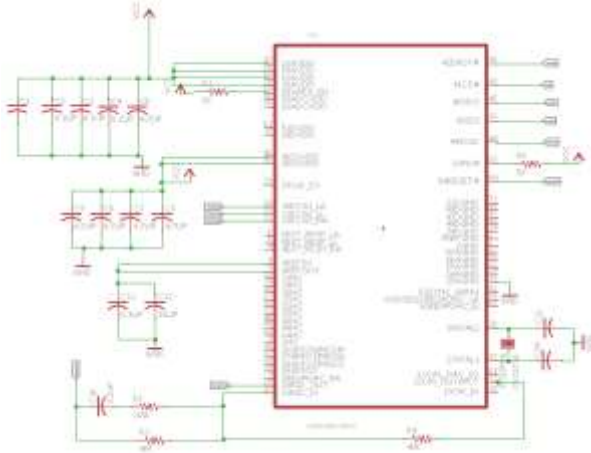

Figure 2. Schematic of ADAS1000-4

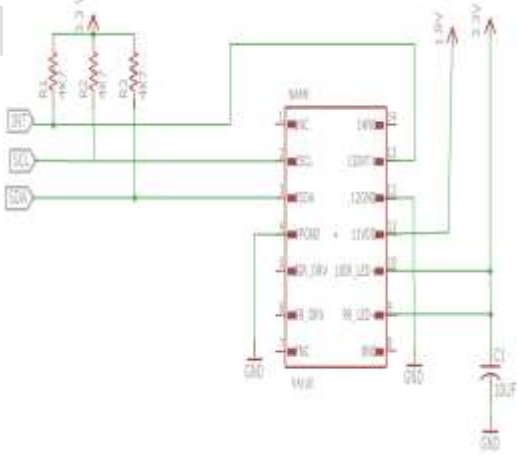

Figure 3. Schematic of Max30100

THE WORKING

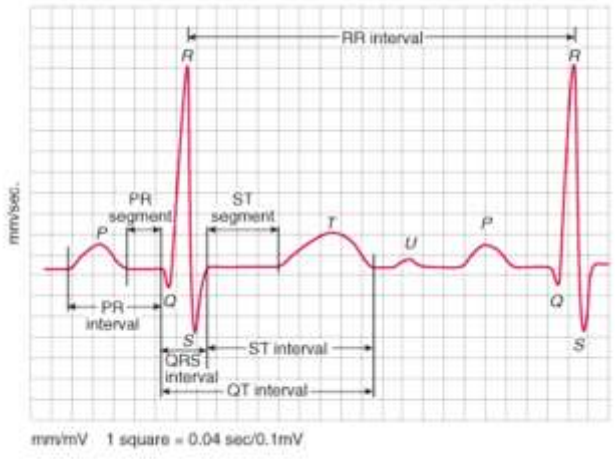

Figure 4. ECG waveform

Annotation	Type	Semantics	Value (ms)
P	Wave	Sequential Activation of Atria	<80
PR	Interval	Travel time from sinus to AV node	120-200
QRS	Segment	Depolarization of ventricles	60-100
QT	Segment	Bridge b/w QRS & T	<380 @80bpm <420 @60bpm
T	Wave	Repolarization of ventricles	180

Table 1. ECG Waveform explanation [7] [8]

To comprehend the working of any system, one must understand the functionalities, parameters and logic lying within. Figure is a typical graph of ECG. ECG also known as EKG is a process that records the activity of heart when the electrodes are placed over a patient's body for a given period of time. ECG can be measured through 12 lead, 5 lead and with recent advancements, with 3 lead as well. And from 3 or 5 lead one can recover the values that can be obtained via 12 lead ECG. The leads measure the tiny changes on the skin that are electrical in nature due to heart polarization and depolarization. Through 12 lead ECG, 10 leads are placed on patient's hands and legs and also on chest surface. This is recorded for 10 seconds to get the heart's electrical potential measured from 12 different leads. ECG is a repetitive cycle that comprises of 2 electrical quantities. One is the P wave that denotes atrial depolarization, QRS segment that denotes the ventricular depolarization and T wave that shows ventricular repolarization [4]. Table 1 shows various sections of ECG and their interpretation along with value in time. It is important to note that the monitor's task is just to ensure that there is no critical condition. In other work it will not act like a full-fledged ECG measuring machine but will only serve the warning purpose. The flowchart describes ECG abnormality detection in terms of process in the BBB.

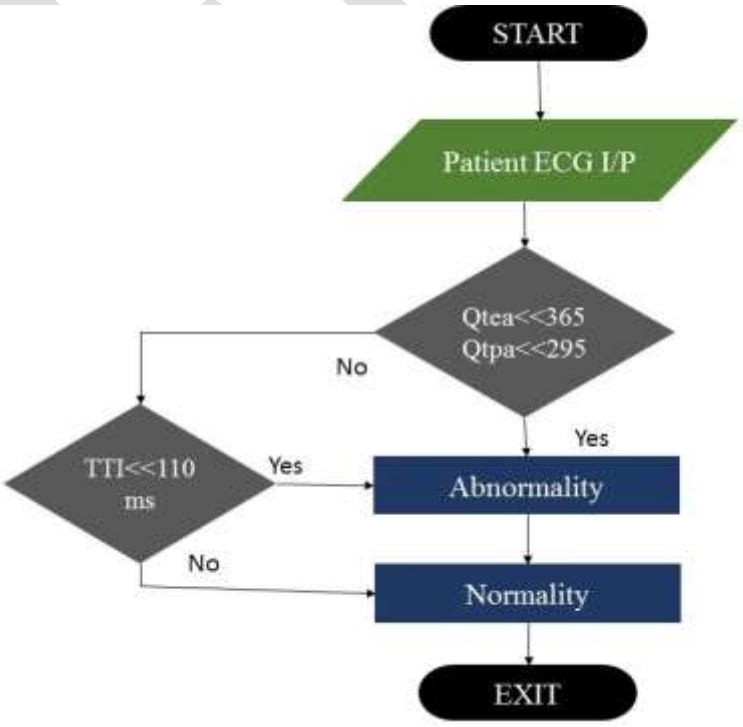

Figure 5. Flowchart of ECG Peak detection

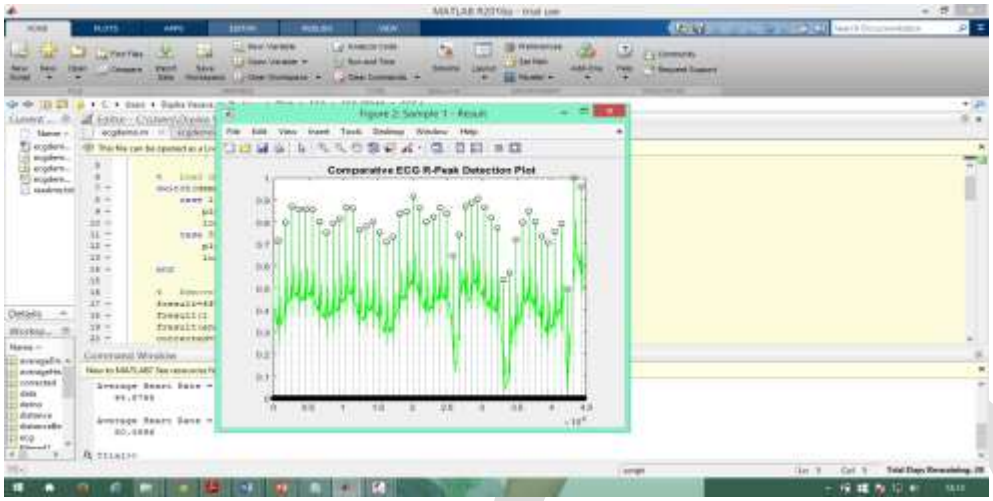

Figure 6. R-peak detection plot

Figure 6 shows graphical representation of ECG peak detection in MatLab. The trick here is simple. Physicians measure abnormalities in ECG by looking at the graph because different waveforms suggest different values and rationally apart from the disease the patient is suffering from, rest of the possibilities are least of his concern unless eitheer he himself is a medico or the diseases are inter-related[6] [12]. Thus, for a patient, just knowing whether he is having a regular cardiogram or not is enough of a signal to get serious. This is exactly what this device achieves. Detecting Quarturnery abnormality and letting the user know if he is doing well or not (if not, then how well is not the evice's issue because it is not designed to replace physicians in the first place). To ensure that the abnormalities signalled by the device are actually abnormalities, the waveforms are created as a matter of verification. This approach keeps the portability parameter to on utmost priority and on a sufficiently satisfactory level. The device also measures other parameters which are descriebed below.

The table 2 shows various vital parameters and their normal ranges. If the parameter values are lesser than or higher than this range then it shows that there is abnormality.

Table 2. Normal ranges of vital parameters [3] [9] [10]

Sr. No.	Vital parameter	Normal ranges
1.	Temperature	96.6-98.6 °F
2.	Pulse Rate	60-100 beats per minute
3.	Respiration rate	16-20 breaths per minute
4.	Oxygen Saturation	96-99%

The figure 5 shows the flowchart of the program. Qtea and Qtpa are the values already stored in the memory. The input ECG wave values that are the QT peak time and QT amplitude are compared with the stored values. If the values exceed the stored quantity then it shows the abnormality in the display.

The device uses MAX30100 for measuring the heart rate and pulse oxygen saturation values, ADAS1000-4 for measuring the ECG and respiration rate and TMP36 for body temperature measurement. By pressing the push button of the related parameter to be measured, the process starts accordingly. The related parameter value is shown on the display. If the parameter value exceeds the limit then red LED gets ON. For ECG parameter, the value is not shown on the display. Anyway he is not able to understand it. It just shows that if it is normal or not on the display. The data can be shared via blue-tooth or also through the BBB's USB [5] [11].

CONCLUSION

From the design, algorithm and results mentioned in this paper we can conclude that the portable health assistant serves its purpose as a cost effective, time saving and easy to use interface between biomedical technology and patients and can simplify their lives in cardiovascular and respiratory diseases.

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