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Single- Lead Wearable Patch for Wireless Continuous Monitoring of ECG

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***Abstract*- The significance of the current research was mainly focused on implementation of attachable ECG sensor adhesive patch of low-power, inexpensive and relatively small form factor for continuous monitoring and recording of infrequent cardiac events in real time. The device was designed to maximize Comfort and minimize the footprint on the user. A single lead, home care electrocardiogram (ECG), are recorded while a user wearing the device carries out his/her daily activities. The patch is thin and flexible for comfortable wear on the person's chest for recoding of ECG provided simple self-administration. The patch incorporates a battery, dry electrode, ECG amplifier and microprocessor for recording events. A software algorithm converts analogue signal into digital signal by sampling at the rate of 500 samples per second and enables the RF transmission through BLE. It also includes android application to display ECG graphically on mobile phone. The patch is intended to be designed for continuous long term wear up to 3 days. This design can be used widely in home health care, community health care and sports training due to its characteristics of low power consumption, small in size and reliability.**

***Index Terms*- ECG, Blue tooth, Home care, ECG Patch, single Lead,**

I. INTRODUCTION

Today, personalized health monitoring devices are important for intensive care and diagnostic assessment. Developing countries often struggle to provide adequate healthcare to all of their citizens, especially in rural areas. Hence developing such approaches for continuous monitoring vital physiological parameters such as Electrocardiogram (ECG) is highly needed [3]. Electrocardiography or ECG is an important diagnostic tool for Medicine. ECG measures the electrical activity of the heart. To prevent cardiovascular diseases, early detection and diagnosis is essential. Continuous personal monitoring of chronic patients can reduce the number of heart failures significantly.

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Hence modern approaches for non-invasive ECG monitoring are required to perform continuous measurements, at home or in other non-clinical environments. Emerging wireless technologies and recent advances in sensor technology allow continuous, real-time ambulatory monitoring of electrocardiogram (ECG) [1].

This paper describes implementation of adhesive ECG sensor patch which is inexpensive, energy efficient, convenient & safe. A patch type wireless ECG measurement system is used to measure daily life ECG and a Smartphone monitoring through BLE. The system is capable of acquiring patient's ECG data in real-time over a period of 72 hours. It should be designed using low power electronic components, yet very efficient in giving excellent results. They must be extremely portable and light in weight, and simple for self- administration allowing the person to carry along [7]. Real time monitoring is very crucial and important feature for any medical device, allowing wirelessly transmitting of data to PC or cell phone in most secured mode, incorporated with digital data storage.

II. SYSTEM DESCRIPTION

It should be designed using low power electronic components, yet very efficient in giving excellent results. They must be extremely portable and light in weight, and simple for self- administration allowing the person to carry along. Real time monitoring is very crucial and important feature for any medical device, allowing wirelessly transmitting of data to PC or cell phone in most secured mode, incorporated with digital data storage.

A. *Hardware component:*

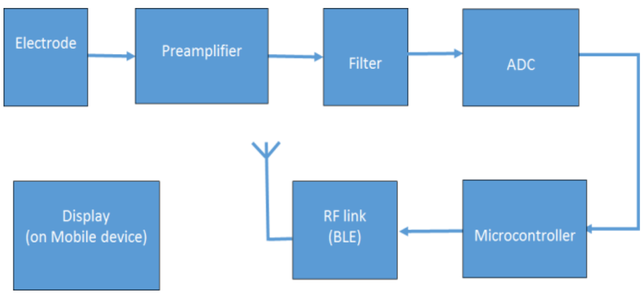


Fig. 1. Block diagram of ECG Device

Figure 1 illustrates the design architecture of the adhesive ECG sensor patch. The device consists of various hardware blocks (figure1) that are explained in the following sections with special attention to the CSR1010. This IC provides everything required to create a Bluetooth low energy ECG monitoring device with RF, baseband, MCU, qualified Bluetooth v4.1 specification stack and ECG application running on a single IC.

Signal Acquisition Using Dry Electrodes:

In recent years, however, the use of dry electrodes has become popular in many sports monitors, where the amplifier forms part of a larger custom integrated circuit. Clinical dry-electrode recording would be of benefit in applications where long-term monitoring of the ECG is required [10].

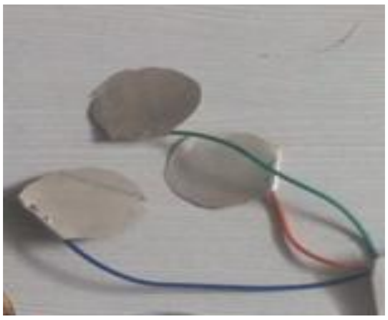
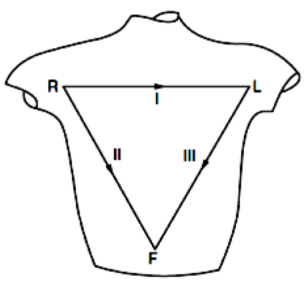


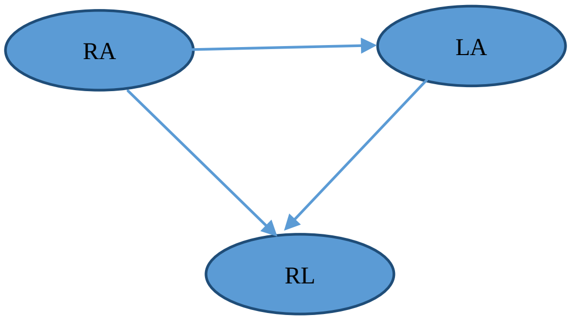
Fig. 2. Silver painted dry electrodes

The effect of skin irritation and dehydration caused from long term use of gel electrode can be minimized.

The dry electrode (Figure2) is made from the silver conductive ink, screen printed on poly urethane sheet and dried for two days and the desired shape and size of electrode is cut from the screen printed sheet. (above shown electrode size is 4cm in diameter). The following are major advantages of dry silver electrode for long-term ECG measurement. The skin electrode contact area and skin properties between each subject are directly related to the skin-electrode impedance. The contact area should be increased to keep lower impedance. However, the proposed dry silver electrode, made by the conductive silver ink, can provide an easy design process, very reliable and reusable. Three dry electrodes have been used to acquire ECG in lead I configuration. Placing of Electrodes over the surface of a skin is shown in figure3. RL Electrode is connected below the left pectoral muscle near the apex of the heart.



(a)



(b)

Fig. 3. Placement of electrodes (a): Einthoven triangle. Source [8]. (b) Placement of electrodes in proposed project.

In this project lead I configuration have been chosen providing more comfort to user whereas in lead II configuration the wires or electronics might have to cross over the pectoral muscles and breast tissue making uncomfortable to user.

B. Analogue Front-End

This block include instrumentation amplifier, high pass filter, low pass filter, reference buffer, and right leg drive amplifier integrated in a single chip IC AD8232 manufactured by analog devices in order to condition the signal. It is designed to extract, amplify, and filter small bio potential signals (ECG) in the presence of noisy conditions, such as those created by motion or remote electrode placement. The AD8232 extracts the common mode voltage from the instrumentation amplifier inputs and makes it available through the RLD amplifier to drive an opposing signal into the patient. The third electrode is driven for optimum common mode rejection. The two-pole high pass filter having cut off frequency of 0.5Hz and two pole low pass filter having cut-off frequency of 40Hz is designed to obtain an ECG waveform with minimal distortion [1]. The overall gain set to 1100 db 2].

C. CSR1010 MCRO-CONVERTER and Blue tooth Low Energy Module.

CSR1010 is a CSR µ Energy platform device which operates on single-mode Bluetooth low energy modules. CSR µ Energy enables ultra-low-power connectivity and basic data transfer for applications previously limited by the power consumption, size constraints and complexity of other wireless standards. CSR1010 QFN provides everything required to create a Bluetooth low energy ECG monitoring device with RF, baseband, MCU, qualified Bluetooth v4.1 specification stack and ECG application running on a single IC with high performance.

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The operating voltage lies between 1.8v to 3.6v providing 7.5dBmmax TX output power and -92.5dBm RX sensitivity [8]. It carries out the analogue to digital conversion of ECG signal acquired by the front-end block(correctly conditioned for getting the most out of 1.35V input range of ADC) with a sampling frequency of 500 Hz. CSR's protocol stack runs on the integrated MCU. The sampled digital packets are transmitted through BLE. Since the application is in real time, there is a chance of loss of data at the receiver end. To avoid this, the sampled data are buffered before transmitting and 10 samples are transmitted at a time (20ms duration), the real time ECG is continuously monitored on smart phone with the support of android application.

The code is developed in CSR µ Energy xIDE graphical code development environment platform. The software part includes two programs written in' C' language which converts analogue signal into digital signal by sampling 512 samples per second and the program for RF transmission of digitized data in a form of packets. The android application is written in Java script to obtain ECG signal graphically on mobile phone.

D. Bluetooth Transmission Link

In this wireless ECG monitoring system, the signal processing unit serves as an intermediate node between the ECG signal acquisition module and the smart-phone ECG Analysis platform. The signal processing unit consists of a microcontroller and a Bluetooth v4.1 module. The main task of the microcontroller is to format the ECG data into the specific data types in the Bluetooth 4.1 specification and control the flow of this ECG monitoring System. It is programmed to receive the digital output through RS232 from the signal acquisition module and further manipulate the data for the ease of wireless transmission [4]. The microcontroller is also responsible for the Bluetooth connection establishment and wireless communication. The interaction between Master and Slave is illustrated as in Fig.5.

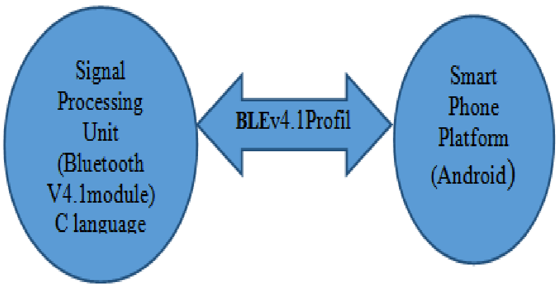

Fig. 4. The interaction between Master and Slav

E. Display Unit:

The display unit are smart phones or tablets with android operating system (version 4.1 and above). The android application is developed in order to display an ECG signal graphically.

Fig. 5. Graphical display of ECG

III. RESULT AND DISCUSSION

The parameters given in table (1) satisfy the requirements of the device and can be used for three days for continuous monitoring of ECG.

Table. 1. Specification of proposed project

Power consumption	Cost of system	Size of system	Usage of lithium cell
<7mw	< Rs1000	6cm x 3.5cm	73 hours (nominal capacity=220mah).

The ECG waveform at the output stage of AFE is shown in Fig (6). The waveform is captured on CRO for lead I configuration. Figure (7) illustrates the graphical representation of ECG on mobile phone. Placement of electrode and patch is shown in fig (8).

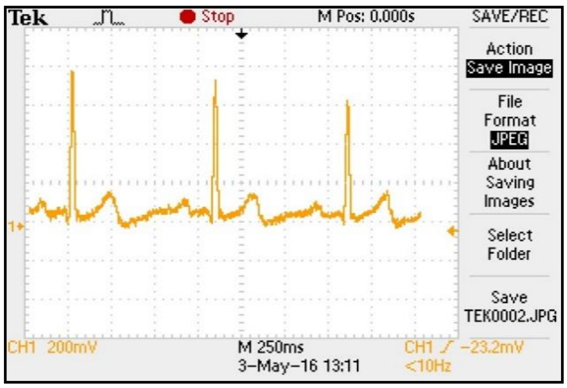

Fig. 6. Signal measured at o/p of AFE for subject1

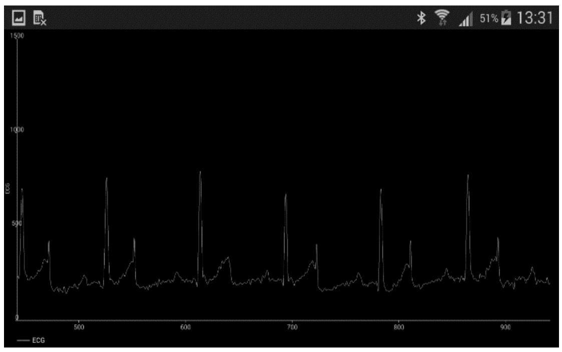

Fig. 7. ECG on mobile for subject1

Purpose of the design, which is to acquire lead I ECG using single channel is fulfilled. Prototype has been made and tested against standard clinical ECG. The lead I ECG acquired on the subjects, has similar shape with the standard device .The amplitude of the signal is subjective. Maximum amplitude that can be allowed is1.35v. Morphology of real-time ECG captured on CRO and on mobile are compared.

From the result we can conclude that Bluetooth graphics display the real-time data satisfactorily without losing data samples while monitoring continuously for three days. Accuracy needs to be improved. Motion artifacts to be minimized using software. Provision for storing of data through software is possible.

ECG Patch

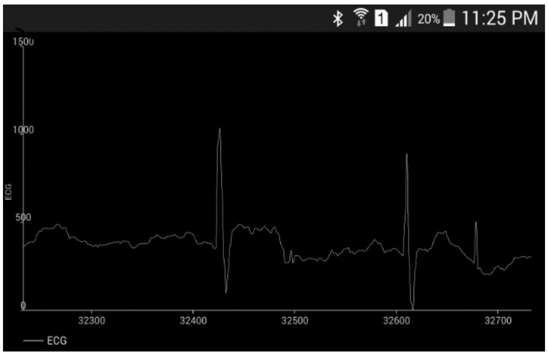

Fig. 8. ECG on mobile-subject

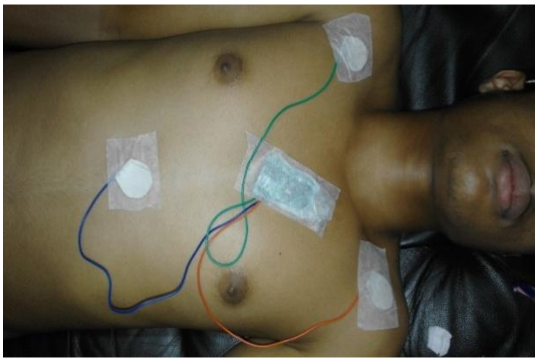

Fig. 9. placement of electrodes and ECG patch

IV. CONCLUSION

In this project, a patch type wireless ECG measurement system is developed to measure daily life ECG and displayed on smart phone through BLE. The design and selection of the electronic components and an efficient software implementation provide a device with great autonomy, reduced dimensions and minimum weight. The device is designed for Low cost and Low power for continuous monitoring of ECG (72 Hrs). The Project has been developed using single power supply for Lead I configuration. A newly developed Dry Electrodes has been used for comfort & effective result. The device can be upgraded to 3 lead configurations. The software can be upgraded to eliminate motion artifacts.

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