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Digital ECG Data Acquisition System

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Abstract— **Today, the quality of life of the patients is improved by the health information technology which includes the design and development of telemedicine solutions that provides the patients various medical services. The advancements in technology in the field of wireless communication and integrated circuits have led to the design and production of the small sized, low cost and low power smart physiological data acquisition devices. An Electrocardiogram (ECG) is a bioelectric signal of the heart which detects and records the heart's electrical activity over a time period.The aim of the study is to design and develop a wearable, portable, small size and cost effective digital ECG Data Acquisition System (DAQ). The system transmits the ECG data wirelessly from the device to the smartphone. The acquired data is plotted using MATLAB.**

Keywords—**Data Acquisition, ECG, ESP8266, Bluetooth Module, ADS129X**

I. INTRODUCTION

Food, clothing and shelter are the basic needs of human beings wherein healthcare can also be added as a basic need in these days. The improvement in the technology has made new innovations in the field of various health care devices. The innovation of such handy portable devices which make use of technologies like wireless communications has made people to use them anywhere and monitor their health continuously.

Electrocardiogram (ECG) signals plays a vigorous role in clinical identification particularly for diagnosing diseases and disorders related to heart.ECG refers to measuring the bioelectrical signals generated by cardiac cells involved in heart activity. The ECG is identified by electrodes attached to the outer surface of the body. ECG signals are recorded by a device external to the body. The contraction and relaxation mechanisms of the heartproduce an electrical potential difference on various point of the heart. The electrical signals produced will propagate to all neighbouring soft tissues and lets the physician to measure the differences between these potentials using particularhardware. The rhythmicity of the heart can be evaluated precisely using the ECG and the morphology of ECG waveform providesessential information about the functioning of the cardiac muscle. ECG signal acts a significant part in the early diagnosis, prognosis and survival analysis of heart diseases [1].

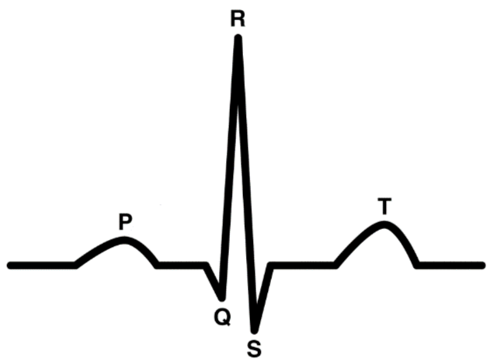

Fig 1: The ECG waveform

A usual ECG signal of a regular heartbeat consists of a P wave, a QRS complex and a T wave (Fig 1).P wave is the outcome of contraction of heart muscles which will represent the atrial depolarization. Q wave is the representation of any downward deflection after P wave. R wave indicates the big upward deflection also called as R peak which comes after the P wave. The downward wave after R wave is the S wave. T wave denotes ventricular repolarization. The QRS complex symbolizes ventricular depolarization. The ECG signal that is acquired from the human body has a very low potential and it is tough to evaluatethe signal. The amplitude of the ECG signal is comparatively low of about 10uV~5mV with a frequency spectrum comprising of frequency components ranging between 0.05Hz to 100Hz of frequency. The amplification of the acquired ECG signals is necessary to get any information about the abnormalities of heart.

The aim of the project is to acquire data from the patient wirelessly through Bluetooth using a smart phone and plot it in MATLAB to get the ECG waveform.The system involves Analog Front End (AFE) chip from TI (ADS129x) which is specially designed to obtain biomedical samples upto8 electrodes to obtain the raw ECG data with 24 bit Analog to Digital Converters (ADC) with variable gain amplifier and an on-board oscillator. Tensilica Xtensa is the microcontroller used is ESP8266 from ESPRESSIF. ESP8266 chip has an integrated Wi-Fi module with full TCP/IP protocol stack.The communication between the ADS129x chip and ESP8266 is

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through Serial Peripheral Interface (SPI). ESP8266 will be the master and ADS129x will act as a slave.

The data acquisition system is controlled by a smart phone. The Android application developed for the smart phone will be sending the control commands wirelessly to the data acquisition system through Bluetooth using a standard Bluetooth module. The data acquired wirelessly from the Data Acquisition System is sent to the smart phone for display.

II. RELATED WORKS

Kho et al [2] presented a paper Wireless monitoring system which uses Bluetooth. 2-lead ECG sensor is created and the ECG data is acquired through the Bluetooth. The acquired ECG data is transferred to the PC using Bluetooth module. After processing the data, it is displayed on PC.J Yoo et al [3] have proposed a wearable ECG acquisition system. This system is employed using planar-fashionable circuit board which also designs a shirt. The wires for attaching the electrodes on the body are embedded within the shirt and have less harmful effects with low cost. D Gawali et al [4] proposed a system on real time system based on microcontroller. For the purpose of additional processingECG data is stored as a text file. Hardware system encompasses of a front end amplifier, optical isolator, and filters and uses Visual basic.Takash Handa et al [5] designed a system where Low frequency digital ECG (DAQ) is executed. This 2 or 3 ECG leads system is low cost, small in size and reliable. Design includes ECG data analogies, sensor block, ADC IC and software for driving, visualization, storing and processing of the acquired data.R Dozio et al [6] proposed a paper where Front end analog high pass filter for ECG monitoring system. Filter parameters obtained from constraint optimization which rejects noise & distortion.

III. METHODOLOGY

A. *Block Diagram*

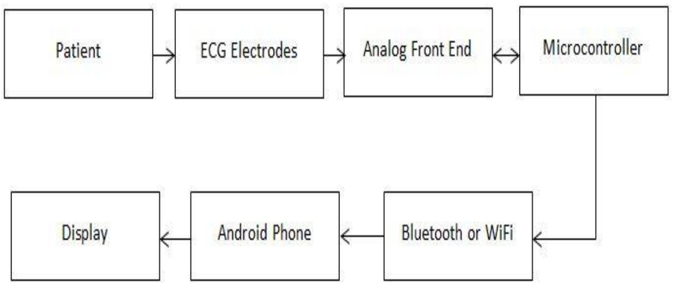

Fig 2: Block diagram of data acquisition system

A cable with 10 electrodes is interfaced to the body of the patient to acquire 8 lead ECG data as shown in figure 3. The Data Acquisition System (DAQ) acquires data from the body and the raw ECG is filtered, amplified and digitized in AFE Module. The android application from the smart phone sends the commands to acquire the ECG data wirelessly from DAQ and stores the digital ECG. The acquired data is plotted using the Matlab. Figure 2 shows the block diagram of the data acquisition system.

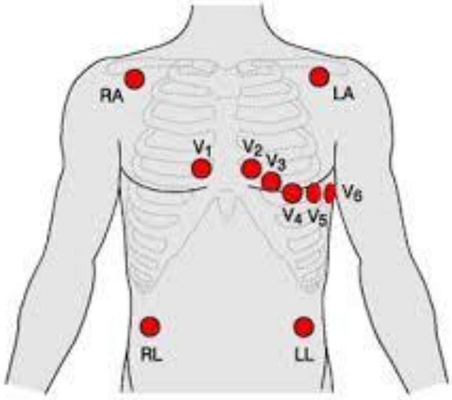

Fig 3: Electrode placements in the body.

An ECG signal displays the bioelectric signal attained from the human body. An ECG waveform is made up of five different component waves namely P, Q, R, S and T wave followed by conditional U wave. 12 lead ECG signals are derived from 10 electrode positions for full lead ECG records. A low input leakage current less than 1 µA and High Common Mode Rejection Ratio is essential for proper acquisition of the ECG signals [7]. Silver chloride (Ag cl) material is used as ECG electrodes which are attached to the patient's body after considering all the above requirements.

Texas Instruments ADS129x ECG signal acquisition chip have been used as the Analog front end to acquire 12 lead ECG data. It helps in achieving fine performance with a small size. ADS129xdelivers application oriented functionality than simple signal conditioning. The major applications of the chip are in Electromyography (EMG), Electrocardiography (ECG), Electroencephalography (EEG) applications. 8 low noise Programmable Gain Amplifiers (PGAs) and 8 high resolution 24-bit Analog to Digital Converters are incorporated in the chip for the simultaneous sampling including an on-board oscillator and a voltage reference. It also encompasses of the amplifiers for Right Leg Drive (RLD), Wilson Central Terminal (WCTs) and Goldberger Terminals (GCT). Pacing pulses by a cardiac pacemaker within an ECG signal can be identified. The ADS129x also includes few features like low power consumption of 0.75 mW and have flexible input multiplexer per channel attached to internally generated signals for test, temperature and lead off detection. ADChas different data rates from 250 SPS to 32 KSPS. SPI interface is used for data transmission between the device and ESP8266. The chip will be functioning with 1.65-5.25V on digital side and 2.7- 5.25V on analog side.

The microcontroller used is Tensilica Xtensa in ESP8266 chip. The small size and the low cost of the chip make this DAQ cost effective. There are various versions of ESP8266 and the version used here is 12E. General Purpose Input

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Output (GPIO) pins are used for communicating with ADS129x and 17 GPIO's available for use in ESP8266. For programming the ESP8266 Arduino IDE is used and it supports all the Arduino libraries.

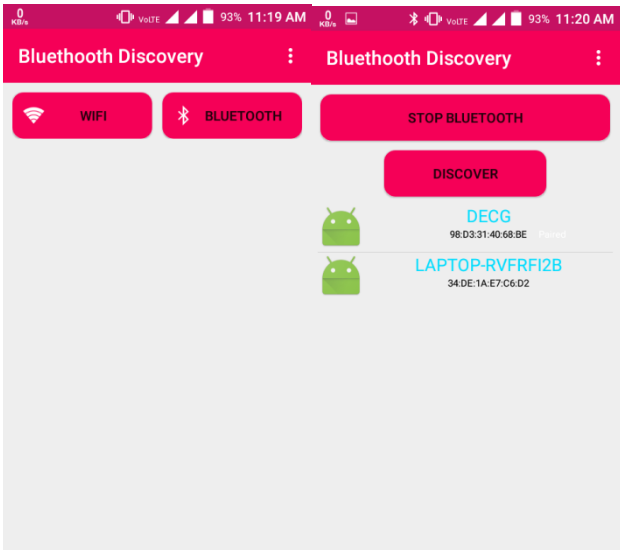

Fig 4: Screenshot of Data Acquisition android application.

The ECG data received at the microcontroller is transmitted wirelessly to Android phone. By using Bluetooth, the lossless wireless data transmission is done (Fig 4). For transmission through Bluetooth, the Bluetooth module is used [8]. The ESP8266 microcontroller and the Bluetooth module are connected through RS-232 interfacing. After receiving the data from the data acquisition system in the smart phone, the 8 leads are displayed on the mobile phone in real time. The smart phone also streams the data to the web using 3G/4G mobile internet links on the phone. Matlab is used to plot the acquired data.

B. Serial Peripheral Interface (SPI) Communication

SPI communication is done between ADS129x and ESP8266. ESP8266 module is used as a master. It will always control the ADS129x chip. ADS129x will be acting as a slave. It receives the commands from the master.

The communication between ADS129x and ESP8266 is through a four wire SPI interface and three GPIO's. SPI includes four connections. They are namely Slave Select (SS), Master Out-Slave IN (SPI OUT), Master IN- Slave OUT (SPI IN) and clock (SCLK). RESET, SPI START and DRDY are the three GPIO's included. The communication that takes place between the master and slave is shown in Figure 5.

The slave at any time can be selected using the Slave Select (SS) pin. The data conversion starts by sending the SPI START command. When the data is ready, the DRDY pin will be interrupted which is an active low pin. The registers of ADS129x are reinitialized by the RESET pin. The data from the master is sent to the slave with the SPI OUT pin. The SPI IN pin is used to send data from the slave to the master.

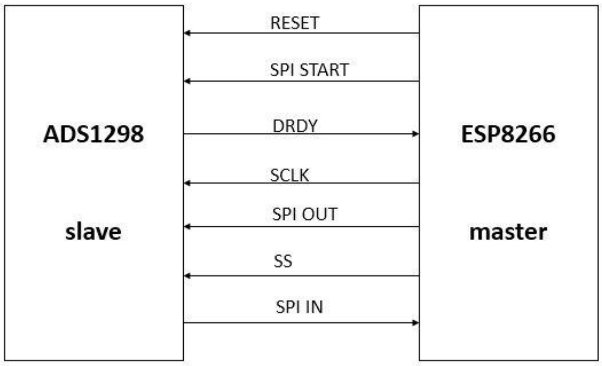

Fig 5: SPI Communication between ADS129x and ESP8266

IV. RESULTS

The wireless ECG Data Acquisition system described above requires very low power and is small in size.The digital data acquisition is managed by the android application in the smart phone. In the application Bluetooth is selected as the wireless transmission mode. DISCOVER button is pressed after selecting the transmission medium to find the available devices within the range.DECG is selected in the application which will connect the android phone with the data acquisition system. After selecting, START button is pressed to begin the transmission of ECG data from the data acquisition system to the android smart phone wirelessly. The data acquisition can be stopped by pressing the STOP button. After stopping the data acquisition, the ECG data is stored in the file in the smart phone. Screenshots of the application is shown in Figure 3.

After storing the acquired digital ECG data in a file, it is plotted using the Matlab. The 8 channel data will be plotted separately. The waveforms from the Matlab plot is shown in figure 6. The first graph in the plot represents the status bits. The next eight graphs are of the ECG data acquired from eight leads.

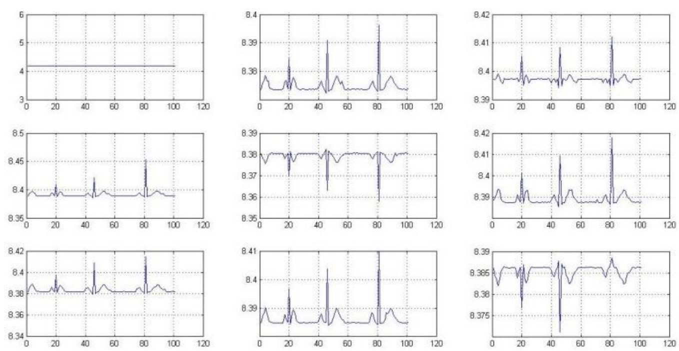

Fig 6: Digital ECG plotted in Matlab.

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V. CONCLUSIONS

In this paper, a digital ECG data acquisition system is designed and developed. The system is small in size and portable. It is also cost effective. This device helps the patients to acquire the ECG data wirelessly and store it in a file using the smartphone android application. The acquired ECG is plotted in Matlab. The plotted ECG waveform can be used to detect the abnormalities of the heart.

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