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A Smart Wearable System for ECG and Health Monitoring

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ABSTRACT

There are many situations where the patient needs regular or daily observation but this is difficult to do as it mingles with the life style of the patient. To solve this problem a system can be developed which is easy to carry and which checks the health parameters like temperature, heart rhythm, heartbeat and blood pressure of the patients continuously. This smart ECG can be worn by inpatients or outpatients and monitored in real-time. Healthcare professionals can access patients' data wirelessly in real time with their smart phones. This system can be useful especially for senior citizens who live alone or have a disability. Therefore, this proposed system can be utilized for remote medical systems to assist the elderly patients, for self-testing diagnostics, or for physicians to diagnose diseases of the circulatory system. The proposed system consists of electro cardiogram (ECG) which assesses the heart rhythm, diagnose abnormalities of heart and pulse oximeter which calculate the vital parameters of the patient and store this information using Arduino Mega. This system would be very helpful as the patient's health condition is regularly checked without the patient going to the hospital for regular checkups and this will also help the patient financially. In case of dire conditions like heart stroke and problems with blood pressure, the location of the patient is found using GPS and the patient can be treated immediately. The system is then connected to the smart phone through Bluetooth and the patient's health parameter information is displayed in an app. These kinds of systems are very promising in these cases due to the decrease in prices, increase in data storage capacity, availability of various sensors and standard communication interfaces, best user interface using touch screen.

Keywords: *Arduino Mega, ECG, GPS, pulse oximeter, Bluetooth, LM35, Smart phone, App***.**

1. INTRODUCTION

During the recent decade, rapid advancements in healthcare services and low-cost wireless communication have greatly assisted in coping with the problem of fewer medical facilities. The integration of mobile communications with wearable sensors has facilitated the shift of healthcare services from clinic-centric to patient-centric. In the larger perspective, it can be of two types:

- Live communication type, where the presence of the doctor and patient is necessary with additional requirements of high bandwidth and good data speed, and
- Store and forward type, which requires the acquisition of medical parameters such as vital signs, images, videos, and transmission of patient's data to a concerned specialist in the hospital.

According to existing medical surveys, telemedicine has been adopted to take care of the patients with cardiac diseases, diabetes, hypotension, hypertension, hyperthermia, and hypothermia. The most promising application is in real-time monitoring of chronic illnesses such as cardiopulmonary disease, asthma, and heart failure in patients located far from the medical care facilities through wireless monitoring systems. Heart diseases have become one of the leading causes of human fatalities around the world; for instance, approximately 2.8 million people die each year as a result of being overweight or obese as obesity can lead to adverse metabolic effects on blood pressure and cholesterol which ultimately increases the risks of coronary heart disease, ischemic stroke, diabetes mellitus, and a number of common cancers. According to WHO, it has been estimated that heart disease rate might increase to 23.3% worldwide by the year 2030. The treatment of such chronic diseases requires continuous and long-term monitoring to control the threat.

Usually, patients' vital parameters are continuously monitored during the stay in the hospital, to ensure complete supervision. For example, the medical monitor devices used in anesthesia applications show information such as the heart rate and the flow-meter results (O2, CO2). A complete monitoring helps to better understand the conditions of the patients both during operations and recovery period. For non-critical situations, patients can follow the rehabilitation process directly at their own homes, supported by portable devices for vital parameter monitoring. In that way, costs related to personnel and usage of the health accommodation facilities in hospitals is reduced. Such equipment are basically storage devices, which can acquire and memorize data for many days. A periodic procedure of data downloading and off-line processing, to evaluate the rehabilitation improvements or the detection of possible critical situations, must be performed by the medic.

The next frontier in the health care field is the in-home assistance. Beside cost reducing, due to the avoiding of stay in sanitary structures, in-home assistance solutions offer enduring monitoring and control as well as real-time data processing and communication. In that way, the promptness of critical situation diagnosis is improved. Since the typical end-users are elderly population, the so-called not-digital people, devices for in-home assistance applications need to be as simple and accessible as possible, in order not to obligate the patient to handle with instrumentation usage.

Systems already in the market and conceived for the continuous acquiring of data are usually expensive and not very comfortable for the patient. The Holter monitor is one of such portable devices, used for acquiring, elaborating and storing the electrocardiogram (ECG) trace, it offers an acceptable degree of comfort if worn for only 24-48 hours. However, its price (above 500 $ [1]) is still significantly high for a wide utilization, for example in deep control of the patients recovering from heart attack. In this case, the monitoring lapse of time should be extended as long as possible, but the current device price does not allow an exclusive instrument allocation to each patient.

A possible solution is to develop a system for acquiring and analyzing vital signals exploiting smart phone devices. Nowadays, the continuous price decrease and an increase of computing capacity, united with the availability of various embedded sensors and standard communication interfaces, make these devices very versatile and several applications, also in the health and wellness field, can be found in the literature [2]-[12]. Usually, the smart phone embedded sensors are not suitable or sufficient for vital signals acquisition; for that reason, external sensing supports have to be realized.

In this paper, a single-lead electrocardiogram (ECG) trace acquisition system, based on and powered by a smart phone device is proposed and developed. It offers compactness, easiness of application on the patient under examination and high data storage capacity. Moreover, thanks to the high degree of configurability, offered by the touch screen for the user interface and software (Apps) development options, different strategies of data processing and communication could be implemented. In this way, new perspectives in the in-home assistance field could be effectively explored. The continuously decreasing smart phone price and the use of low-cost technologies for the implementation of the sensing support of the system make the proposed architecture particularly convenient, also from an economic point of view. Once suitably equipped with additional sensor systems for the acquisition of further vital parameters, the proposed approach could be largely employed also for a long-term monitoring of non-critical patients, elderly or fragile population, thus increasing the prevention level of hearth malfunction or other severe accidents.

2. BLOCK DIAGRAM

The aim of the proposed work is to provide a simple and wearable low-cost system for continuous ECG monitoring, possibly over long periods of time. In addition, at this stage of the project, only arrhythmia detection and other simple ECG trace processing are required. For these reasons a very simplified electrode setup, with respect to the traditional 12-lead ECG one is adopted.

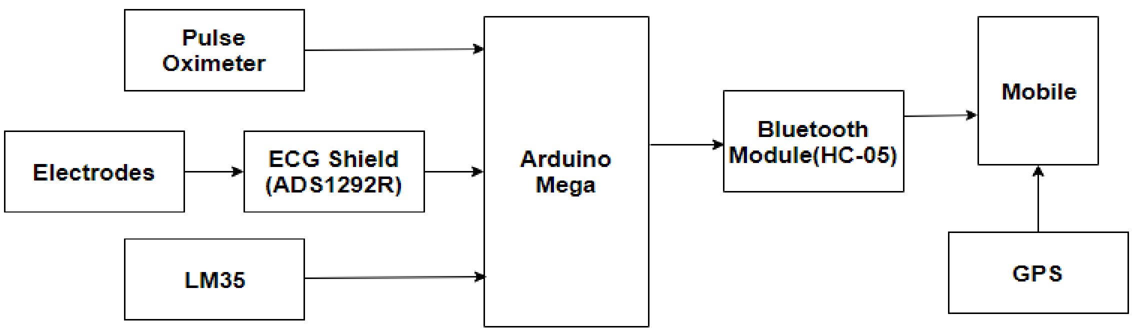

Fig -1: Block Scheme of Proposed System

2.1 Electrode System

In particular, the proposed system is designed to acquire a single ECG lead, thus only a pair of electrodes is employed. In accordance with the usually adopted electrode labeling [13], [14], limb electrodes RA and LA are used to create the single ECG lead (lead I = LA – RA) in addition, a third electrode, RL, is used to give a reference voltage to the body. Electrode positioning is also reconsidered. Normally, electrode RA and LA are supposed to be placed at the right and left arm, respectively, in a symmetric position between wrists and shoulders. Similarly, electrode RL is intended for application at the right leg, between ankle and hip. In this implementation, to facilitate the design of the wearable system and allow a less invasive measurement to be performed, electrodes are placed in a more compact distribution around the chest. In this way, artifacts due to the movements of arms and legs are also reduced. Two commercial cardio belts used for heart beat rate estimation in sport activities, each of which equipped with two electrodes, have been employed for the experimental setup. This choice assures a low cost of the electrode system and a good and stable placement, holding contact with the skin for all the period of observation. Fig. 2 shows the position of the cardio belts and the electrodes in the experimental setup. Electrodes of the upper cardio belt are RA and LA, in the lower cardio belt, only one electrode is employed as RL, whereas the second electrode is not used. Installation of the electrodes in a more comfortable structure to be worn is under evaluation for a future implementation.

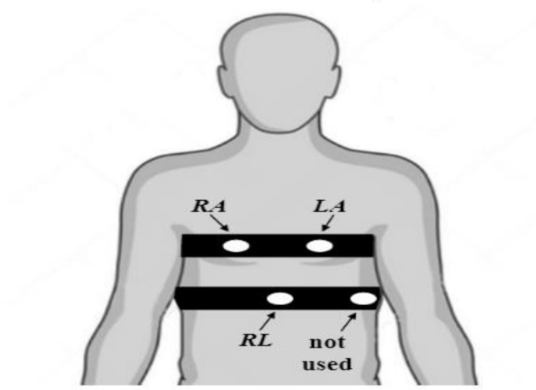

Fig -2: Positioning of Cardio Belts and Electrodes in the Proposed Setup

2.2 Pulse Oximeter

A typical pulse oximeter uses an electronic processor and a pair of small light-emitting diodes (LEDs) facing a photodiode through a translucent part of the patient's body, usually a fingertip or an earlobe. One LED is red, with a wavelength of 660 nm, and the other is infrared with a wavelength of 940 nm. Absorption of light at these wavelengths differs significantly between blood loaded with oxygen and blood lacking oxygen. Oxygenated hemoglobin absorbs more infrared light and allows more red lights to pass through. Deoxygenated hemoglobin allows more infrared light to pass through and absorbs more red lights. The LEDs sequence through their cycle of one on, then the other, then both off about thirty times per second which allows the photodiode to respond to the red and infrared light separately and also adjust for the ambient light baseline. The amount of light that is transmitted (in other words that are not absorbed) is measured, and separate normalized signals are produced for each wavelength. These signals fluctuate in time because of the amount of arterial blood that is present increases (literally pulses) with each heartbeat. By subtracting the minimum transmitted light from the peak transmitted light in each wavelength, the effects of other tissues is corrected for. The ratio of the red light measurement to the infrared light measurement is then calculated by the processor (which represents the ratio of oxygenated hemoglobin to deoxygenated hemoglobin), and this ratio is then converted to SpO2 by the processor via a lookup table based on the Beer-Lambert law.

2.3 ADS1292R

ADS1292R Arduino shield that will let you read ECG and respiration data using processing in real time. The Version 2.0 of this shield adds a new SPI pin header making it compatible with newer Arduino variants including the Arduino Yun. The shield also sports a 3.5mm interface to connect the electrodes. Plug in the shield on to an Arduino, attach the cables and electrodes, power up the Arduino and you are all set to read ECG data in real time. The cable accepts two ECG electrodes and one DRL (Driven Right Leg) electrode for common mode noise reduction. The ADS1292R uses "impedance pneumography" to measure respiration. The method uses the change in chest impedance to arrive at respiration measures.

2.4 Arduino Mega

The Arduino Mega is a microcontroller board based on the ATmega1280. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.

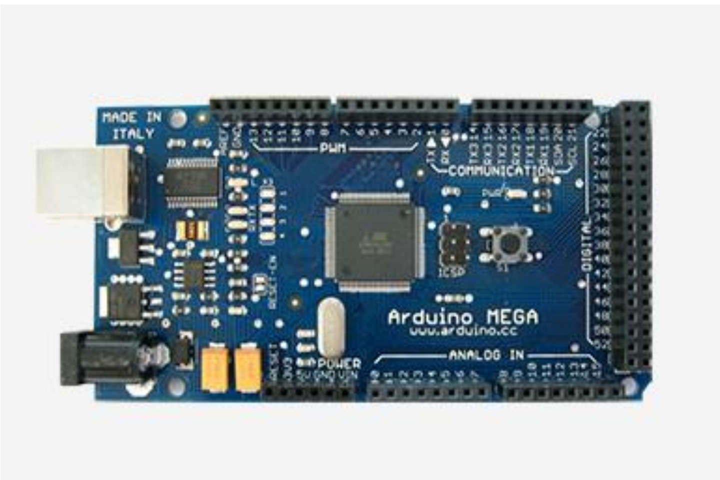

Fig -3: Arduino Mega Board

2.5 Bluetooth

Bluetooth is a wireless technology standard for exchanging data over short distances (using short-wavelength UHF radio waves in the ISM band from 2.4 to 2.485 GHz) from fixed and mobile devices and building personal area networks (PANs). Invented by telecom vendor Ericsson in 1994, it was originally conceived as a wireless alternative to RS-232 data cables. It can connect several devices, overcoming problems of synchronization.

Bluetooth is managed by the Bluetooth Special Interest Group (SIG), which has more than 19,000 member companies in the areas of telecommunication, computing, networking, and consumer electronics. Bluetooth was standardized as IEEE 802.15.1, but the standard is no longer maintained. The SIG oversees the development of the specification, manages the qualification program, and protects the trademarks. To be marketed as a Bluetooth device, it must be qualified to standards defined by the SIG.

2.6 Power

The Arduino Mega can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.

2.7 Global Positioning System

A GPS receiver calculates its position by precisely timing the signals sent by GPS satellites high above the Earth. Each satellite continually transmits messages that include

- The time the message was transmitted
- Satellite position at time of message transmission

The receiver uses the messages it receives to determine the transit time of each message and computes the distance to each satellite. These distances along with the satellites locations are used with the possible aid of trilateration, to compute the position of the receiver. This position is then displayed, with a moving map display or latitude and longitude. Many GPS units show derived information such as direction and speed, calculated from position changes.

2.8 LM35 (Temperature Sensor)

LM35 is a precision IC temperature sensor with its output proportional to the temperature. The sensor circuitry is sealed and therefore it is not subjected to oxidation and other processes. With LM35, the temperature can be measured more accurately than with a thermistor. It also possesses low self-heating and does not cause more than 0.1^{0} C temperature rise in still air.

2.9 Arduino Software (IDE)

A program for Arduino may be written in any programming language with compilers that produce binary machine code for the target processor. Atmel provides a development environment for their microcontrollers, AVR Studio and the newer Atmel Studio.

The Arduino project provides the Arduino integrated development environment (IDE), which is a cross-platform application written in the programming language Java. It originated from the IDE for the languages Processing and Wiring. It includes a code editor with features such as text cutting and pasting, searching and replacing text, automatic indenting, brace matching, and syntax highlighting, and provides simple one-click mechanisms to compile and upload programs to an Arduino board. It also contains a message area, a text console, a toolbar with buttons for common functions and a hierarchy of operation menus. The Arduino IDE supports the languages C and C++ using special rules of code structuring. The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures.

2.10 MIT APP Inventor

App Inventor for Android is an open-source web application originally provided by Google and now maintained by the Massachusetts Institute of Technology (MIT).

It allows newcomers to computer programming to create software applications for the Android operating system (OS). It uses a graphical interface, very similar to Scratch and the StarLogo TNG user interface, which allows users to drag-and-drop visual objects to create an application that can run on Android devices. In creating App Inventor, Google drew upon significant prior research in educational computing, as well as work is done within Google on online development environments.
App Inventor and the projects on which it is based are informed by constructionist learning theories, which emphasizes that programming can be a vehicle for engaging powerful ideas through active learning. As such, it is part of an ongoing movement in computers and education that began with the work of Seymour Papert and the MIT Logo Group in the 1960s and has also manifested itself with Mitchel Resnick's work on Lego Mindstorms and StarLogo.

MIT App Inventor is also supported with the firebase database extension. This allows people to store data on google's firebase.

3. RESULTS

Experimental tests have been conducted by using MIT App Inventor that is used to acquire the traces of heart beat, blood pressure, Temperature, and ECG. The Hardware support for the wearable ECG is as shown in Fig- 4.

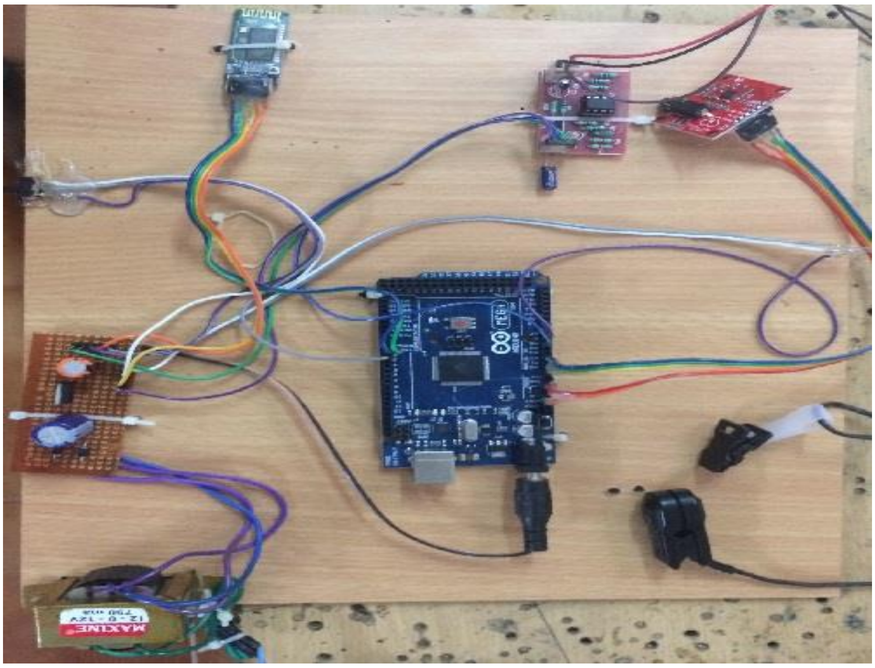

Fig -4: Hardware Structure of the Proposed System

The pulse oximeter readings such as hear beat traces are displayed in the form of a graph as shown in Fig-5.

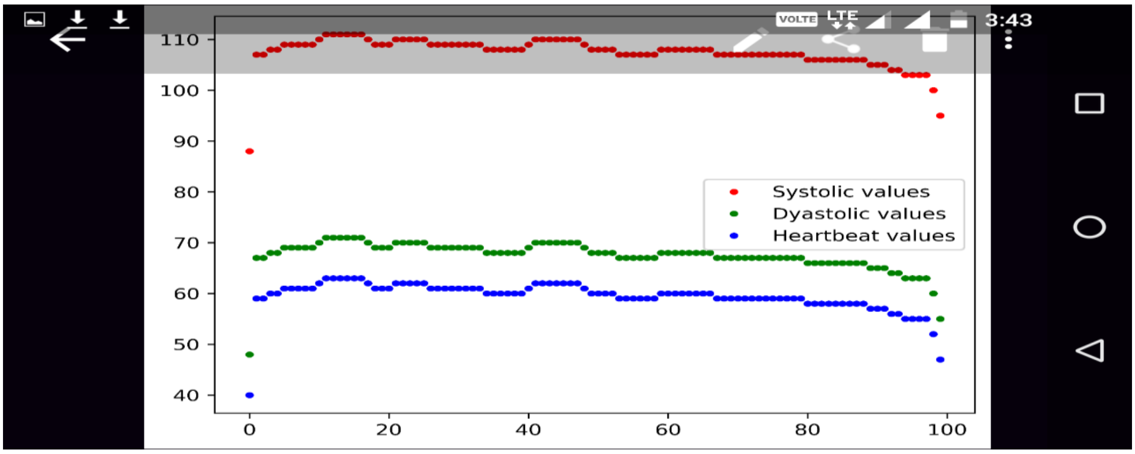

Fig -5: Screenshot of Proposed App While Acquiring the Heart Beat Trace

The readings from ECG shield such as ECG traces are displayed in the form of graph as shown in Fig-6

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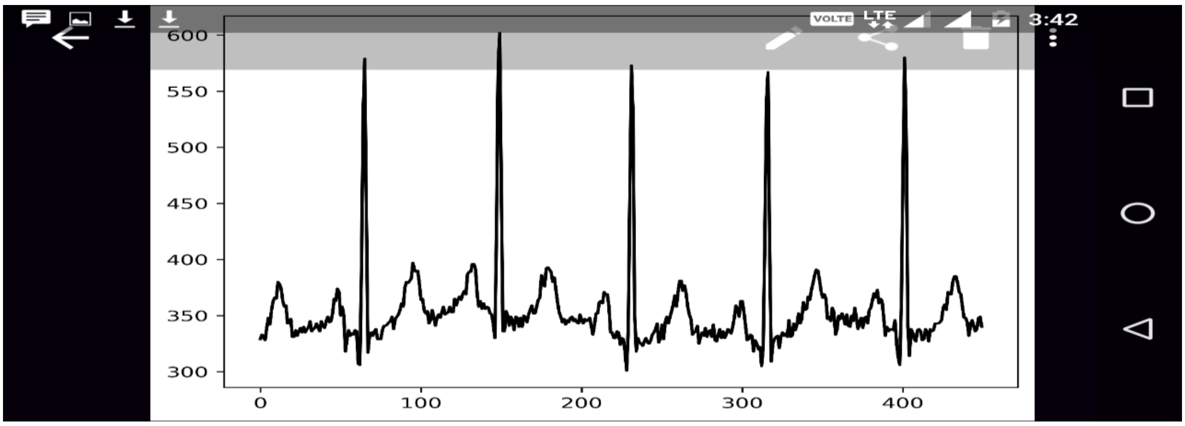

Fig -6: Screenshot of Proposed App While Acquiring the ECG Trace

The readings from Pulse oximeter such as Blood Pressure traces are displayed in the form of a graph as shown in Fig-7.

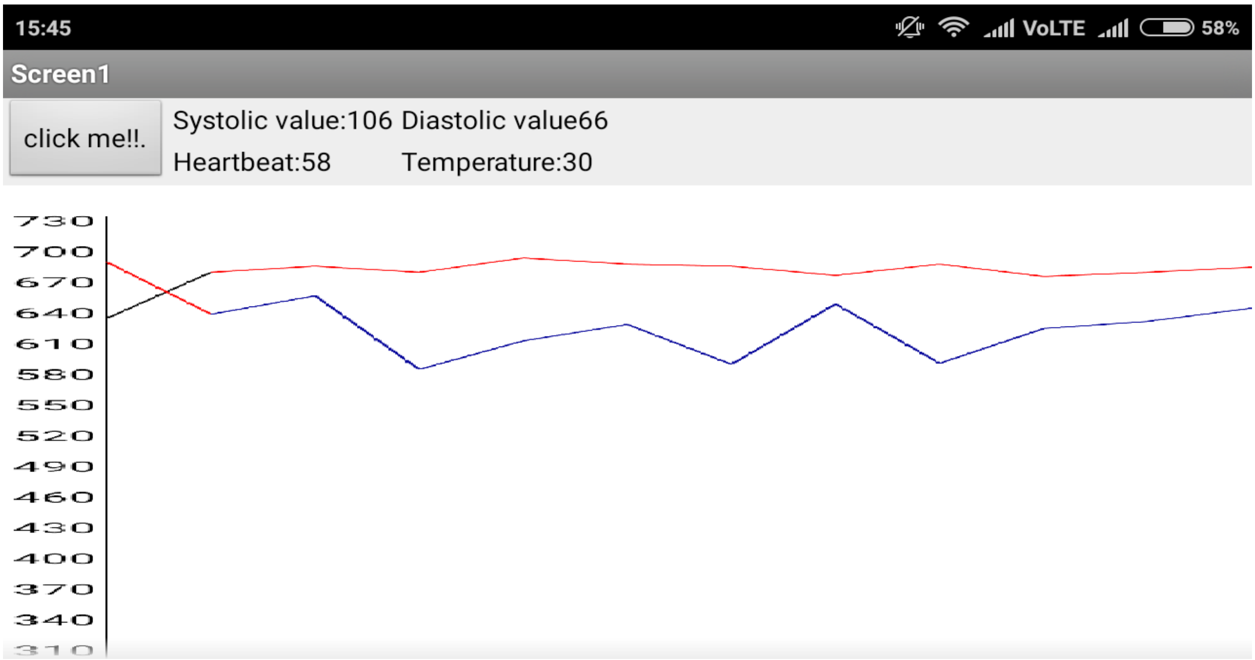

Fig -7: Screenshot of Proposed App While Acquiring the BP Trace

4. CONCLUSIONS

Nowadays, devices for vital parameters home monitoring are consolidated research interests for health care industry and wellness business. The combination of this kind of systems with the largely available smart phones, equipped with different options for data communication with the external world and high computing capacity is a promising way for developing versatile and powerful monitoring devices.

In this work, a system for ECG trace acquisition and analysis is proposed. In particular, a low-cost and easy to miniaturize electronic circuit for first conditioning of a single ECG trace has been successfully interfaced with a smart phone device, exploiting simple wired audio communication channel. Moreover, the proposed approach is able to generate the electronic circuit power supply exploiting power furnished by the smart phone audio output channel. In this way, the compactness of the whole system is guaranteed.

At the smart phone's side, a purposely-designed application (App) has been developed to acquire the audio signal and extract, plot and store the ECG trace. At this stage of the project, the App performs simple data elaboration such as the real-time beat rate estimation, temperature, and heartbeat, more complex ECG trace processing techniques, to be implemented directly by the smart phone, are being explored.

5. ACKNOWLEDGEMENT

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