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Design of Cost and Power Efficient Wireless Remote Cardiac Patient Monitoring System

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ABSTRACT

Electronics technology is innovating and finding applications in almost all the areas of life. The technology has greatly influenced human life. There is hardly any domain where telecommunication is not used. It is the diverse field of engineering finding applications in almost all areas of human life. One of the most important applications is in biomedical engineering. Recent medical sciences and association claims that the number of the patients suffering from heart diseases increasing day by day. This might be due to changing life style, work load, over tension, competition, lack of exercise etc. So timely monitoring of such a patient's heart activities like heartbeat, ECG is in demand now days. But this continuous monitoring increases rush in the hospitals and increases patient expenditure also. This encourage us to design such a system which can monitor patient at his home place continuously or whenever required and all the body parameters could be shared by the doctor at hospital in real time. Whenever any parameter value exceeds normal range then SMS is also sent to the doctor thereafter rapid treatment can be provided to the patient. This project used ARM 7 LPC 2148 development board. Patients body temperature, heart beat and ECG are acquired from body through various sensors such as LM 35 temperature sensor, LM 358 based IR heart beat sensor and AD 8232 ECG sensor and processed it and displayed on LCD as well as on NI LabVIEW through HC 05 Bluetooth module. It is then transmitted to doctors PC using team viewer which provides connectivity in both sides. SIM 900 GSM/GPRS Module is used for sending the SMS. ECG analysis can be achieved using various biomedical tools in LabVIEW The objective of this project is to design a configuration system which will require optimum power for its operation and should be cost efficient.

Keywords: HC 05, GSM/GPRS, LabVIEW, ECG, ARM 7 LPC, LM 35, AD 8232.

I. INTRODUCTION

As discussed earlier electronics technology is finding many applications in medical field and becoming popular in wireless remote patient monitoring which is in demand now days. The design purpose of our project is to monitor the parameters of patient's heart activity such as ECG, pulse rate along with body temperature wirelessly from a patient's location to the doctors section at hospital where investigations of this data could be achieved by cardiologist. Due to shortage of resources i.e. hospitals and physicians which does not meet with the requirement of tremendous increase in population of India. It is needed to healthcare professional to use electronics equipment's for monitoring and diagnosis of patient's data from outside of the hospital. This problem of shortage of resources and physicians becomes a challenge to the system which needs to provide the

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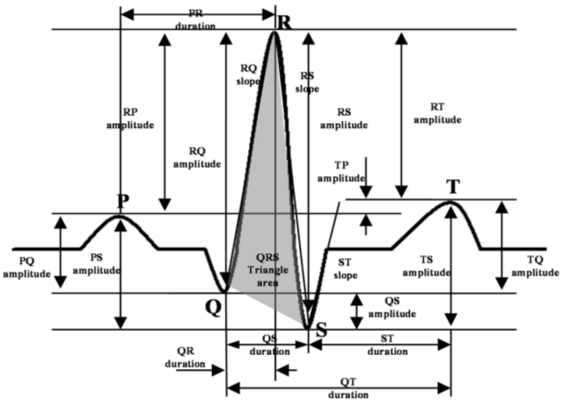
ways for workload easing so that many patients diagnosis and monitoring can be achieved simultaneously. This challenge encouraged the electronics technocrats and engineers to design and develop advance technology in biomedical field. Heart rate measurement can be done either by using pulse method which is carried out by examining the flow of blood into the finger or by the ECG waveform. The pulse method is simple and convenient. During the hearts systolic stroke blood flows into the body parts and into the finger via the radial artery on the arm. This flow of blood into the finger can be sensed photo electrically using IR sensor. Heart rate is detected when light intensity changes as blood flows into the finger. Early day's tape recording method was used for diagnosis for heart disease which typically based on of Electro Cardio Gram (ECG) signal which is then studied and analyzed using a microcomputer. In this method, the real time heart rate is measured by placing the finger in the IR sensor. At the same time, after the processing of heart rate any diseases can be detected such as, bradycardia or tachycardia either for adult or children. The ECG module is used to detect and plot the tiny potential changes in the heart which generates during atrial depolarization, ventricular depolarization and ventricular repolarization. The impulse generates in the Sinoatrial (SA) node and transmits to the Atrioventricular (AV) node as shown in figure 1. The one heart beat corresponds to the one ECG waveform. The time period of ECG waveform reduces as heart rate increases and vice versa. Figure 1 shows the P, Q, R, S and T waves on an electrocardiogram tracing (lead 1) illustrating the three normally recognizable deflection waves and the important intervals.



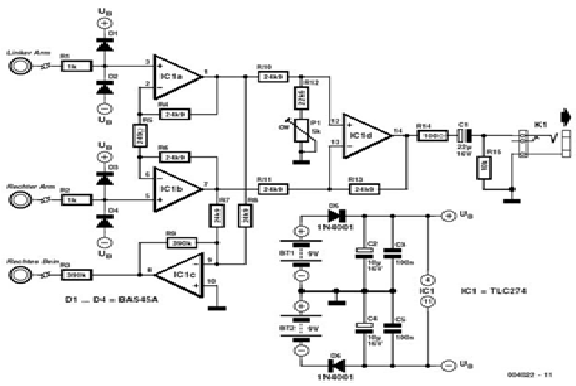


Fig. 1: The Electrocardiogram (ECG) plot **Fig 2 Circuit Diagram for ECG Amplifier**

The objective over designing of this system is to provide solutions to the problems which encountered during the transmission of ECG and other body parameters from a location to a remote site where this data could be investigated by a cardiologist. As like pulse method the patient's heart beat can also be measured by using the waveform of ECG. The pulse method for heart beat detection is easy and convenient. Many researches have done on patient monitoring. Telemedicine and telemonitoring have been used in several researches. Telemonitoring network is dedicated to medical teleservices; the people who live in isolated and rural areas are the main focus of it [1]. This system continuously aware and update doctor regarding health status of patient. Through this way physicians can also provide best health care after the diagnosis of proper disease. Hence it provides comfort to the patients, reducing rush in the hospitals thus saving time and money of the patient. In this Project the solution is provided to the problem which occurs during transmission of patient monitoring data such as pulse rate, ECG & temperature from a patient's remote site location to the hospital where this data could be monitored continuously by the cardiologist. This work mainly focuses on design and implementation of remote

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patient monitoring system in which continuous monitoring of the patient's body parameters is achieved wirelessly for a patient who is situated in his home or remote place and not in reach of hospital and inform and aware the doctor regarding any abnormal and fatal parameters values by sending SMS, so that rapid treatment can be provided to the patient.The system described here is a microcontroller-based portable system for diagnosis and controlling of heart rate, ECG and temperature on real time. The ECG signal recording using tape recording systems are large in size and prone to mechanical failure and it needs large batteries also. In order to reduce the weight, size and power consumption of the system, a single chip Reduced Instruction Set Computer (RISC) architecture ARM 7 family LPC 2148 microcontroller is chosen. The AD 8232 ECG sensor is used to examine the heart activity. LM 358 based IR heart beat sensor is used to provide pulse rate from body by placing the finger into the IR sensor to the Analog to Digital converter circuit which is mounted on LPC 2148 microcontroller. LM 35 Precision Centigrade Temperature Sensors is used to measure body temperature. 16*2 liquid crystal display is used to display the temperature in Fahrenheit, pulse rate in beats per minutes and ECG values. Different types of electrodes and sensors are used which is placed on desired locations of the patient's body to extract the raw data, filtered it and transmitted wirelessly through Bluetooth module to display graphically using LabVIEW software. The continuous recorded real time data is then shared with the doctor using team viewer to examine the ECG signals and further guides the patient for any emergency medical aid required.

II. LITERATURE SURVEY

Different ECG Monitoring system architecture is discussed in this section:

Various researchers have developed their own systems and have used various software and hardware architectures. In this section the methodology adapted by the researcher is discussed along with its limitations and scope of improvements.

2.1 Alauddin Al-Omary, Wael El-Medany, Riyad Al-Hakim, "Heart Disease Monitoring System Using Web and Smartphone" [2]

The system discussed in this paper consists of three subsystems which include patient subsystem, web server and database subsystem and android unit subsystem. Patient unit subsystem includes electrodes for acquisition of heart's electrical activity, it also includes instrumentation amplifier for signal amplification and conditioning and patients PC. The suitable timing can be set to send the data to patients PC.

Web Server and Database subsystem is used for storage of ECG signal data publish the result for any abnormality and it can be accessed by authorized person. This system includes following stages,

• Database Implementation

• Abnormalities Detections

The android based applications are used by the doctor to accessing the patient details using mobile. Here two applications are developed one for doctor called ECG Note and another for patient called My Note. The doctor application provide online information about the patient status such as the patient's heart beat rate, ECG, patient history and provides new reading every 30 minutes. The system enables doctors to remotely follow-up the status of their patient using their smart phones. The system was tested and checked by medical teams for validation and the system ECG generation and abnormality detection were certified. This system provides some sort of freedom to both doctor and patient since the results are shown at real-time on a website and the doctor will be

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alerted on his/her Android device in case of abnormality detection. Also, it can be deployed as part of a Decision Support System (DSS) in hospitals. As webpages needs to design this system costs more.

2.2 Cristian Rotariu, Hariton Costin, Dragoş Arotăriței And Bogdan Dionisie, "A Wireless ECG Module For Patient Monitoring Network" [3]

The system discussed in this paper is implemented by using a specially designed ECG amplifier and a low power microcontroller board of Texas instrument (eZ430-RF2500). The designed module of ECG is connected wirelessly to a personal server for receiving the information from ECG Module. This system could also be used as a warning system for monitoring during normal activity or physical exercise. In addition to monitoring of physiological signals, they are planning to use the proposed environment for development of a high performance user interface. New user inputs, including correlates of the user's physiological and emotional states could significantly improve human-computer interface and interaction.

2.3 S. Anusuya Dhandapani, Samiappan and P.R. Buvaneswari,"Design and Implementation of Motion Artifact Reduction Asic for Wearable ECG Recording" [4], [5]

The design of wearable wireless ECG monitoring system is proposed in this paper where motion artifact is reduced using adaptive filter with LMS algorithm. Also LUT is used to replace MAC unit in the LMS core. This LUT is optimized by using APC-OMS technique. The advantage of optimized LMS algorithm is that it consumes less power and small in size than the existing LMS algorithm. A novel VLSI architecture is developed and implemented for LMS algorithm for wearable ECG ASIC for size and power reduction. But again here cost parameter comes into the picture.

2.4 Prakashvidwan, Pradippanchal, Sachin Sharma," Real Time Portable Wireless ECG Monitoring System" [6]

The real time portable ECG monitoring system is implemented in this paper in which the acquired ECG data from the sensor are wirelessly transmitted using Zigbee-802.15.4 wireless module. The same module is used at the receiver to receive wireless signal transmitted by the transmitter and then send to the com port of PC for further processing of ECG signal. The disadvantage of this system is its complexity in design and cost.

2.5 I. Maglogiannis, L. Kazatzopoulos, K. Delakouridis, and S. Hadjiefthymiades, "Enabling location privacy and medical data encryption in patient telemonitoring systems" [7], [81]

The medical data encryption techniques discussed in this paper that are based on encryption and cryptographic algorithms. Such techniques can be used to secure data during the communication and storage. As a result, the final data will be stored in encrypted format. This system consists of many complicated algorithm hence simplicity in design is the major issue here.

2.6 H. Wang, D. Peng, W. Wang, H. Sharif, H. Chen, and A. Khoynezhad, "Resource-aware secure ECG healthcare monitoring through body sensor networks"[9],[10]

A novel steganography algorithm is proposed in this paper to hide patient information as well as diagnostics information inside ECG signal. This technique will provide a secured communication and confidentiality in a Point-of-Care system. 5-level wavelet decomposition is applied. A scrambling matrix is used to find the correct embedding sequence based on the user defined key. Steganography levels (i.e. number of bits to hide in the coefficients of each sub-band) are determined for each sub-band by experimental methods. In this system the

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diagnoses quality distortion is tested. It is found that the resultant watermarked ECG can be used for diagnoses and the hidden data can be totally extracted.

2.7 Hyejung Kim, Member, IEEE, Sunyoung Kim, Member, IEEE, Nick Van Helleputte, Member, IEEE, Antonio Artes, Mario Konijnenburg, Member, IEEE, Jos Huisken, Chris Van Hoof, Member, IEEE, and Refet Firat Yazicioglu, Member, IEEE. "A Configurable and Low-Power Mixed Signal SoC for Portable ECG Monitoring Applications". [11]

The system discussed in this paper is a mixed-signal ECG SoC, which uses integrated AFE analog front-end and DSP back-end. Analog front end supports concurrent 3-channel electrodes for monitoring of ECG, with impedance measurement and band-power extraction. The system describes method for reduction of motion artifacts, accurate detection of the R peak analysis of HRV etc. The approach of this system is to design the wearable device using system on chip hence and complexity and cost of the system increases.

III. SYSTEM DESIGN METHODOLOGY

The designed system block diagram is shown in figure 3. The 64 pin IC ARM 7 family LPC 2148 microcontroller board is used which is mostly used for low power application and can be used to process the 16 as well as 32 bit data. The working principle of the system is divided into three parts i.e. hardware description, LabVIEW description and Team viewer. The interfacing diagram for developed system is shown in figure 4. A 64 pin IC ARM 7 family's LPC 2148 processor is used as a heart of the system. The LPC 2148 board contains RESET and ISP (In System Programming) switches. To dump the program into the system first press the ISP button and press and release RESET button then program will dump into the system through port 0.

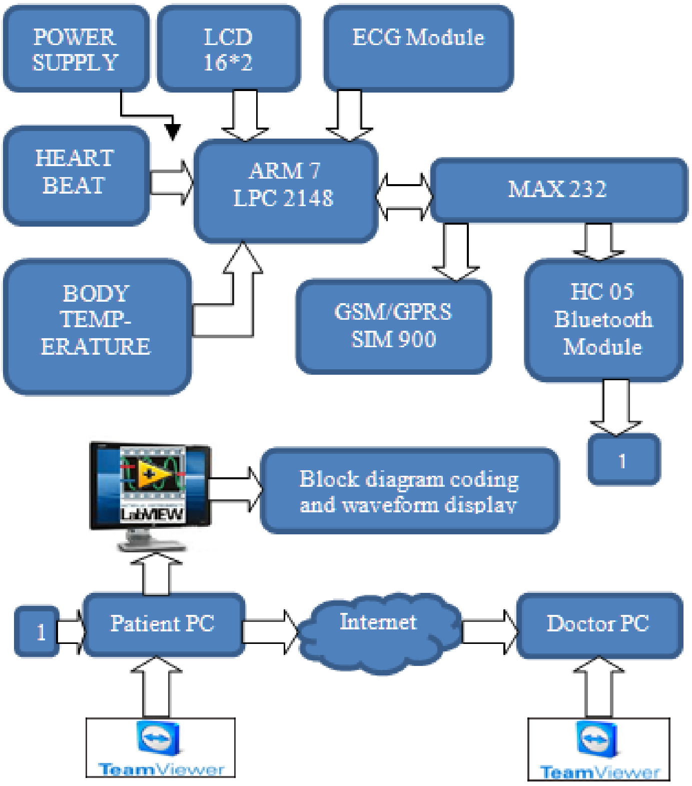

Fig. 3 Block diagram of designed system

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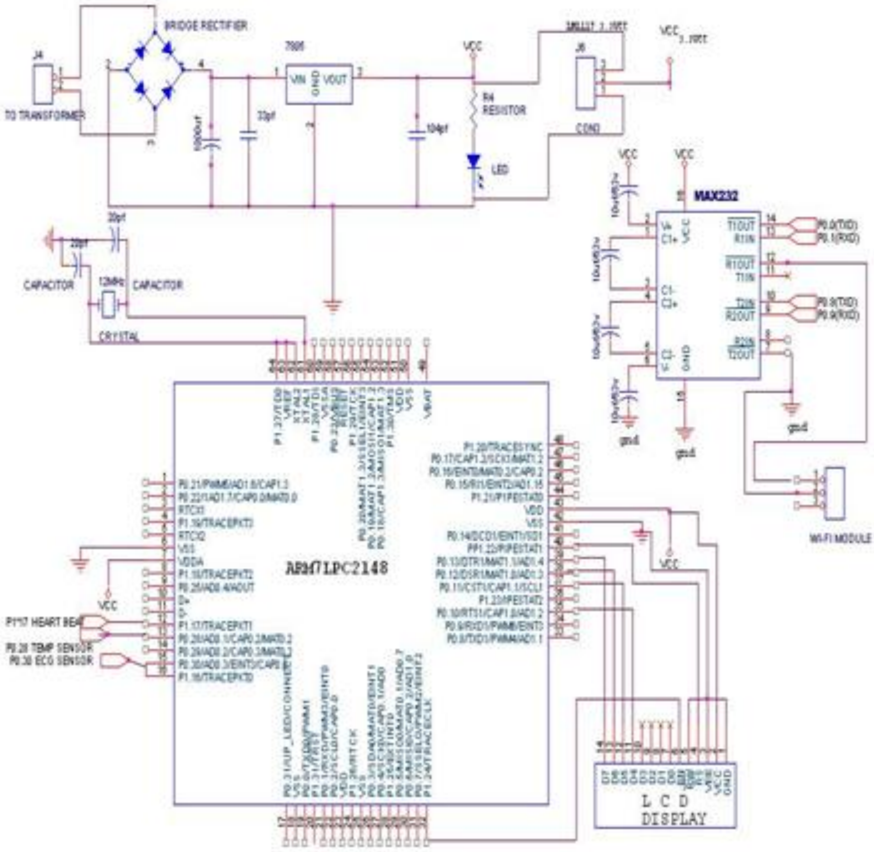

Fig. 4 System interfacing diagram

The system is supplied by the 230 V/9V transformer having 750 mA current supplying capability. The transformer supply is provided to the processor, heart beat sensor, ECG sensor and temperature sensor while SIM 900 GSM/ GPRS module is supplied by the 5V adaptor. Here two ports UART 0 and UART 1 are used. UART 0 is connected to the Bluetooth module and UART 1 to the SIM 900 GSM/GPRS module. MAX 232 voltage level converter IC is used to for matched stabilization purpose. For temperature measurement LM 35 precision centigrade temperature sensor is used which can measure the temperature of atmosphere and patient body as well if placed properly on a body. LM 35 is interfaced to the pin P0.28. Here ECG module AD 8232 is selected which consists of three electrodes which are connected to the Right Arm (RA), Left Arm (LA) and Right Leg (RL) on the body of the patient who's ECG has to be examined. The output of IR sensor output is provided to the LM 358. After amplification high low pulses are provided to pin number P1.17. Number of pulses are detected in 10 seconds which is then multiplied by 6 to give number of pulses per minute i.e. beats per minutes (BPM). ECG module is connected to the ADC port P0.28 third channel. The electrical signal generated at sinoatrial (SA) node and travels towards Atrioventricular (AV) node, in this duration one ECG wave having P, Q, R, S, T sub waves are generated with specific time interval and amplitude. The LM 358 based IR heart beat sensor is used to measure the heart beats of the patient which is measured in beats per minutes. The finger is placed in between the LED and Photo detector of the IR sensor which counts the number of beats by interrupting the light ray from LED to photo detector as blood force through the veins during each heartbeat.

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This data is send to the UART 0 to Bluetooth module HC 05 with 9600 baud rate and 2.4 GHz frequency. SIM 900 GSM/GPRS Module is used to send the SMS to doctor when temperature goes above 1050 F and heart beat goes above 100 beats per minute through UART 1. The system works according to the instructions given in embedded C program which is written in Keil uVision4 and dumped into the system using flash magic. The body parameters values are extracted from the body with the help of sensors and provided to the ARM 7 LPC 2148 processor after amplification; it is then processed and transmits wirelessly through Bluetooth to the Laptop/PC for display where NI LabVIEW 2013 is installed. The values are also displayed on 16*2 LCD display.

IV. SIMULATION USING LabVIEW

National Instruments NI LabVIEW is used in this project for simulation. The LabVIEW block diagram coding is shown in figure 5. The block coding is performed in NI LabVIEW to display the real time values and waveforms of Temperature, Heart Beat and ECG. The different elements are selected from tool palettes. The data received by the Bluetooth receiver of the Laptop/PC through COM Port transmitted by the Bluetooth transmitter HC 05.

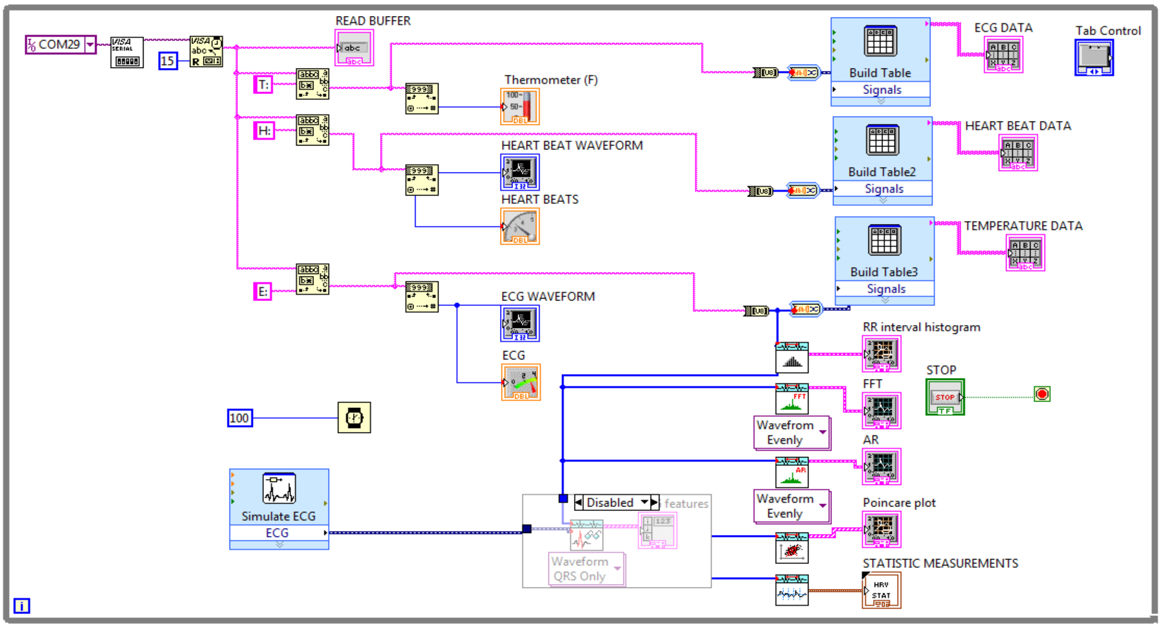

Fig 5. LabVIEW graphical programming for HR, Temp. & ECG analysis

The data through Com port is provided to the VISA (Virtual Instrument Serial Architecture) serial port; it is a string that uniquely identifies the resource to be opened and written to as well as read from. This data is then provided to the VISA configure serial port where length is provided to the data to display which is taken 15 where 15 represent number of characters and here 5 characters are assigned to each parameter for display. For example T: 084 H: 077 E: 126. After the separation of the data it is stored in the buffer. The data is displayed separately on garage and meters after segregation.

Team Viewer is a proprietary computer software package which can be used for various applications such as desktop sharing, remote control, online meetings, web conferencing and file transfer between computers. The software operates with the Microsoft Windows, Linux, Android, Windows RT and Windows Phone operating

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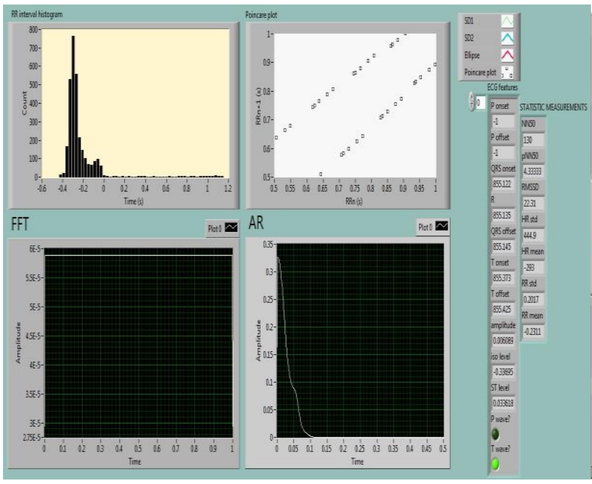
systems. It is also possible to access a machine running Team Viewer with a web browser. While the main focus of this app is remote control of computers, collaboration and presentation features are included. As an aim of this project to remotely monitor the patient from his residential place team viewer is needed. Here it is needed to install the team viewer in both the PC's of patient as well as doctor. To achieve the connectivity in both side internet connections is required. Through this way whatever the values of patients body parameters displaying on the desktop of the patient can be shared by the doctor. Hence continuous monitoring of the patient can be achieved by the doctor remotely and wirelessly.

V. RESULTS AND DISCUSSION

The results in the form of values and waveforms are displayed in NI LabVIEW 2008 simulating software. The results meet the standard values. The screenshot of the real time waveforms are shown below in figure 6. The voltage of QRS is obtained up to 0.5 to 1 mV from the body of the patient and it is then amplified by using Instrumentation Amplifier which is designed by using LM 324 quad Op-Amp whose open loop gain is 100V/mV and also AD 8232 ECG module have been used whose operating voltage is 3.3 V. The closed loop configuration is used in an instrumentation amplifier whose gain is decided by the values of resistors. Here the gain so selected to get the ECG output voltage to 1V. One ECG cycle is generated according to the beat rates i.e. we measured one ECG cycle in time duration of 0.8 seconds for a 75 bpm heart beat reading. Heart beats of person in normal condition are measured which ranges from 72 to 77 beats per minutes. Heartbeats are measured immediately after heavy exercise i.e. by running and push-ups which exceeded 100 bpm and SMS was sent to the mobile.

The temperature of the atmosphere in normal condition is measured by LM 35 the precision centigrade temperature sensor which was varying around 27^{o}C with a tolerance of 1 to 1.5^{o} C. The temperature increases as the LM 35 subjected to the high temperature and message is sent to the mobile when temperature exceeds 105^{o}F. Here temperature is rated in Fahrenheit. The degree to Fahrenheit conversion can be achieved by following formula. **T (°F) = T(°C) × 9/5 + 32.**



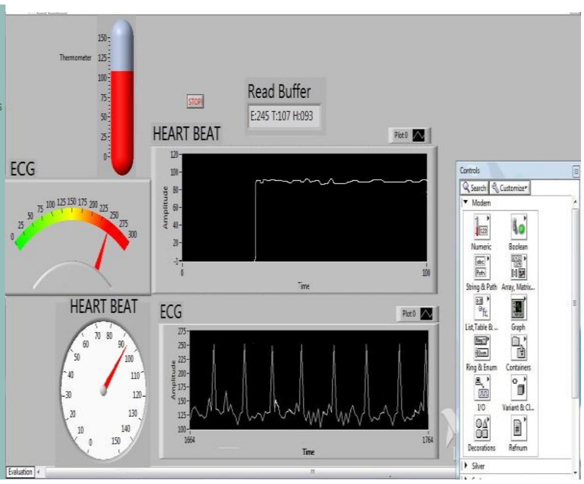


Fig 6 ECG Feature Extraction **Fig 7 LabVIEW front panel displays parameters graphs**

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The overall Power requirement to the system is less as it is supplied by the 230V/9V transformer with 9V output and 750 mA current carrying capability. The whole system is supplied by this power except SIM 900 GSM/GPRS module which is supplied separately by the adaptor having 5 V DC output.

Table 1 Comparison of system results with normal values for different age group person

Parameters		Sex	Age Group (Age in Years)							
			11-20	20-29	30-39	40-49	50-59	60-69	70-79	80+
QRS Duration (ms)	Normal Values	M	100	100	100	100	100	100	101	98
		F	92	90	92	90	92	92	92	92
	System Result	M	101	110	108	106	101	110	103	103
		F	100	98	93	94	93	95	99	91
R-R Interval (ms)	Normal Values	M	821	923	923	909	895	895	895	810
		F	833	895	909	895	869	845	833	833
	System Result	M	845	833	845	833	833	833	821	779
		F	821	833	833	833	821	810	810	821
Heart Beat (bpm)	Normal Values	M	73	65	65	66	67	67	67	74
		F	72	67	66	67	69	71	72	72
	System Result	M	71	72	71	72	72	72	73	77
		F	73	72	72	72	73	74	74	73
Body Temp. (^oF)	Normal Values	M	96.0	96.6	97.7	97.6	98.5	99.1	98.1	96.7
		F	94.0	95.1	94.7	96.6	95.5	95.1	94.1	97.7
	System Result	M	96.3	97.5	96.5	96.6	99.5	97.3	98.0	98.5
		F	96.0	97.1	96.7	95.6	97.2	96.1	96.3	98.4

Table 2 System Accuracy of individual parameters age wise

Parameters	Sex	Age Group (Age in Years)							
		11-20	20-29	30-39	40-49	50-59	60-69	70-79	80+
QRS Duration (Accuracy in %)	M	99.00	90.90	92.59	90.90	99.00	90.90	98.05	95.14
	F	92.00	91.83	98.92	95.74	98.92	96.84	92.92	98.91
R-R Interval (Accuracy in %)	M	97.15	90.24	91.54	91.63	93.07	93.07	91.73	97.23
	F	98.55	93.07	91.63	93.07	94.47	95.85	97.23	98.55
Heart Beat (Efficiency in %)	M	97.26	90.27	91.54	91.66	93.05	93.05	91.78	96.10
	F	98.63	93.05	91.66	93.05	94.52	95.94	97.29	98.63
Body Temp. (Accuracy in %)	M	99.68	99.07	98.77	98.97	98.99	98.18	99.89	98.17
	F	97.91	97.94	97.93	98.96	98.25	98.95	97.71	99.28

Table 3 System's average accuracy of individual parameters

Parameters	Sex	Average Accuracy (M/F) in %	Average Accuracy (Parameters) in %	Average Accuracy (System) in %
QRS Duration (ms)	M	94.56	**95.16**	**95.57**
	F	95.76		
R-R Interval (ms)	M	93.20	**94.25**	
	F	95.30		
Heart Beat (bpm)	M	93.08	**94.21**	
	F	95.34		
Body Temp. (^oF)	M	98.96	**98.66**	
	F	98.36		

VI. CONCLUSION

The system can be used for real time wireless remote patient monitoring. For any emergency situation i.e. when body parameters (Heart Beat and Temperature) exceeds normal values then SMS is sent to the doctor using SIM 900 GSM/ GPRS module which further helps to alert the doctor to take immediate action to diagnose the patient. With the implementation of this system will reduce the hospital rush and patient expenditure as well. The system used hardware modules LM 358 based IR Heart beat sensor, LM 35 temperature sensor and ECG Amplifier as well as AD 8232 module. The LPC 2148 is the advance RISC machine used for signal processing and providing the output in real time. Use of Bluetooth module allows ease of communication between hardware system and PC/Laptop of patient section. The system also require less power for operation as it is supplied through adaptor of 5V and Power supply of 230 V/ 9V having 750 mA current supplying capability. In software part the embedded C is used for program which is written in Keil uVision4 and dumped into the system using Flash Magic. LabVIEW is used for simulation and waveform display. The use of Team viewer allows the connectivity between patient and doctor PC which is then used for continuous monitoring of patient from his hometown by the doctor at hospital. The overall designed system is configurable, low power and cost efficient.

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