PRINT: ISSN 0973-5070 ONLINE: 2456-6772
Ethno Med, 8(3): 305-315 (2014)
DOI: 10.31901/24566322.2014/08.03.13

VLSI Technology for Real Time Monitoring System of High Risk Cardiac Patients

G. Kavya[1] and V. Thulasi Bai[2]

Sathyabama University, Prathyusha Institute of Technology and Management, Chennai 602 025, Tamilnadu, India
E-mail: [1]<kavyavimal@gmail.com>, [2]<thulasi_bai@yahoo.com>

KEYWORDS Field Programmable Gate Array. Cardiopulmonary Resuscitation. Global System for Mobile Communication. Global Positioning System. Short Message Service. Soft-core Processors

ABSTRACT Recent developments in Cardiac surgery have led to increase in number of patients between the age group of 25 and 69 years of age who have survived Myocardial Infarction. Regular and continuous monitoring of these patients becomes essential as this age group of people is the real asset to a family. Hence this paper aims in design and development of low cost, light weight, portable real time monitoring system for cardiac patients. The proposed system employs a Field Programmable Gate Array (FPGA), a reconfigurable platform that performs online analysis of the acquired ECG signal continuously. FPGA based Arrhythmia detector, implemented on a DE0 Nano Altera Cyclone IV board is interfaced with GSM/GPS module to alert the physician or the caretaker on a mobile phone about the imminent fatal condition and location of the patient. If the portable system detects any arrhythmia, it automatically sends an alarm condition to the patient's care taker and doctor or ambulance centre. Through our proposed system the caretaker is immediately aware of the fatal condition of the patient, and hence immediate cardiopulmonary resuscitation (CPR) may be performed, because CPR can provide an efficient method for maintaining a flow of oxygen–rich blood to the body's vital organs before advanced emergency care is available for the patient.

INTRODUCTION

Nearly 20 million people die each year due to cardiovascular diseases and 22 million people are at risk of sudden failure at any moment. According to a study (Evans 1998) in UK, it is seen that among patient above 55 years old, who die from cardiac arrest, about 91% die outside hospital, due to a lack of immediate treatment. In case of acute myocardial infarction the survival is related to the "call to needle" time, which should be less than 60 minutes (David 1999). Patients, who have survived cardiac arrest, ventricular tachycardia or cardiac syncope, face an increased risk of sudden cardiac death. These patients with heart rhythm irregularities (arrhythmia) require some type of monitoring and it is a major part of many healthcare services. It can bring down the need for hospitalization. Today, the conventional method of monitoring a patient discharged from hospital is by using portable Holter monitor and in an emergency situation by using ambulatory ECG recording equipment. However these devices only record a serious rhythm irregularity or transmit the ECG recording to a hospital server, where the doctor has to go and make the analysis and then initiate a treatment. This is patently time consuming. Early detection and defibrillation is critical for survival.

In a patient with cardiac illness, the timing of medical intervention is crucial and dictates the outcome of treatment often proving to be the difference between life and death. The initiation of treatment early in a patient suffering a heart attack (golden hour) can save life and have an important bearing on the quality of life. With the advancement in science and technology, remarkable progress has been made in the field of medicine including diagnosis, treatments and pharmaceutics (Phurpa 2008).Earlier public switched telephone Networks (PSTN) was employed to implement telemedicine system. Wireless Access Protocol (WAP) based telemedicine system (Hung 2003), Wireless LAN and PDA based physiological monitoring system (Lin 2004), Bluetooth based ECG monitoring device (Daniel et al. 2006) were implemented in which patient's biosignals were transmitted to a remote central

Address for correspondence:
Ms. G. Kavya
No:1, Kalaignar Street,
Valasaravakkam, Chennai 600 087.
Tamilnadu, India
Mobile: +91-9884414438
E-mail: kavyavimal@gmail.com

management unit and no online analysis was performed. The criticality of a cardiac patient was analyzed using FPGA based smart diagnostic system (Roy and Saha 2006) but no wireless transceiver was interfaced with the system. A microcontroller based portable system (Mitra et al. 2006) capable of transmitting ECG signal to a remote PC for analysis has been implemented. A mobile Telecardiac system (Thulasi Bai and Srivatsa 2008) with GPRS transceiver was proposed and simulated in MATLAB environment and ECG signal analysis was performed using ARM microcontroller. Real time monitoring of ECG signal using PIC and web server were also implemented (Saurabh 2013). A virtual ICT training framework to support doctors have also been implemented to transmit data and to incorporate security (Coleman 2013). A Wireless Emergency Telemedicine System for Patients Monitoring and Diagnosis that integrates sensor unit, processing unit, and communication unit in one chip bounded to patient's body called mobile-care unit and the vital signs are transmitted through GSM/GPRS networks using sim900 GSM/GPRS module has been implemented in recent times (Abo-Zahhad et al. 2014).

Hence the proposed system involves acquisition and real time analysis of the ECG signal using a FPGA board and the system also automatically sends an alarm condition to the patient's care taker and ambulance centre by sending a SMS that has information about the heart rate and location of the patient. The major tasks involved in the system implementation are filtering of ECG signal, QRS detection, Interpretation, GPS (Global Positioning System) acquisition and parallel tracking which are carried out by multiple Nios –II soft core processors implemented in ALTERA environment. Each core runs independently and coordinated with Avalon bus arbitration. A highly sophisticated area of medical science and technology is the practice of cardiopulmonary resuscitation (CPR), aimed at improving the survival of patients who are victims of sudden cardiac arrest (Walker 2008). At the same time, advances in resuscitation technology add to the complexity of caring for the dying patient and their family (Walker 2008).

METHODOLOGY

The main blocks of any remote monitoring system are data acquisition, processing module and a communication network. Hence the proposed telecardiac system includes three soft processor cores in FPGA for performing the above operations. Core 1 for ECG signal analysis, interpretation and for decision making; Core 2 performs GSM baseband operations like channel encoder, Interleaver and GMSK modulator; Core 3 have been implemented to perform operations of GPS receiver like signal acquisition, tracking and for synchronization of data received from the RF front end.

QRS Detector

An earliest and real time QRS detector algorithm was developed by Pan and Tompkins in the year 1985 and later the algorithm was enhanced by Hamilton and Tompkins in the year 1986.In this algorithm, the slope , amplitude and width of the QRS complex are analyzed to determine the R-peak. Many new approaches like genetic algorithms, Wavelets Transformation, Artificial Neural network have been proposed for QRS detection. But the basic steps involved in any algorithm remains the same as shown in Figure 1.

Normally, frequency range of QRS complex ranges from 10 to 25 Hz. Hence a preprocessing stage becomes necessary to suppress the baseline drift and other artifacts. A band pass filter with pass band frequency of 10 to 25 Hz well suits to extract the QRS complex and to suppress the various types of noises like Electromyogram (EMG) signal, Baseline Wander signal, 50/60 Hz Power Line Interference (PLI) etc.

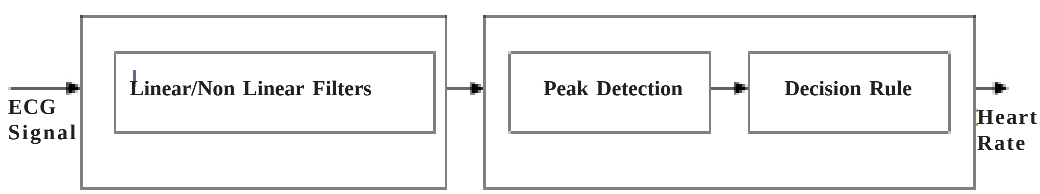


Fig. 1. QRS detector

that affects the ECG signal. The filtered signal is then passed to a decision stage which accomplishes the task of detecting the occurrence of QRS complex by comparing to a threshold value.

Bandpass Filter – Linear Filtering

A bandpass filter can be realized by cascading a lowpass filter and high pass filter. The difference equation and the transfer function of the lowpass filter is given below.

$$y(n) = 2y(n-1) - y(n-2) + x(n) - 2x(n-6) + x(n-12) \text{----------} (1)$$

$$H(z) = \frac{1-2z^{-6}+z^{-12}}{1-2z^{-1}+z^{-2}} \text{----------------------------} (2)$$

The difference equation and the transfer function that satisfies the required frequency response of high pass filter are given in equation 3 and 4.

$$y(n) = x(n-16) - \frac{1}{32}y(n-1) - \frac{1}{32}x(n) + \frac{1}{32}x(n-32) \text{------------} (3)$$

$$H(z) = \frac{1+z^{-16}+\frac{1}{32}z^{-32}}{1+\frac{1}{32}z^{-1}} \text{--------------------------} (4)$$

Derivative Operation – Non-linear Filtering

The slope information of the QRS complex is obtained by differentiating the signal using a derivative filter that has frequency response from dc to 30 Hz and its difference equation is given in equation 5.

$$y(n) = \frac{1}{8}[2x(n) + x(n-1) - x(n-3) - 2x(n-4)] \text{----------------} (5)$$

Rectifying Operation - Squaring Function

Squaring operation is performed after performing derivation of the filtered signal. This transformation helps to convert the entire data samples into positive values.

Moving – Window Integration Method

QRS detection cannot rely on only on slope of the R-wave. Many abnormal QRS complexes may come with larger amplitudes and long durations which may not be detected by using the R-wave only. Hence a moving window integrator is implemented that sums the area under the squared waveform over 150ms for the signal taken at 200 samples per second. The difference equation satisfying the above is

$$y(n) = \frac{1}{30}[x(n) + x(n-1) + x(n-2) + \dots\dots\dots + x(n-(N-1))] \text{-----} (6)$$

Decision Stage

A set of decision rules based on threshold levels are used to reduce the false detection and improve the accuracy of the QRS detector.

- Peaks that precede or follow the larger peaks within 150 ms are ignored.
- If a peak is detected, check for both positive and negative slopes, which represent the QRS complex. If consecutive positive and negative slope are not found then the peak may represent the baseline drift and hence the peak need to be ignored.
- A peak is said to occur within 150 ms only if its value is larger than the threshold value, otherwise it may be a noise signal.

GSM Baseband Processor Core

Global System for mobile communication (GSM) standardized by European telecommunication standard Institute has evolved as one of the most popular ICT in recent days. Commercial service of GSM has begun in the year 1991. From then onwards, the terrestrial and satellite network has grown to cover the whole world. The operation of frequency of GSM was originally 900 MHz and then adapted or changed to 1800 MHz and today it is brought down to 450 MHz.GSM not only transmits and receives speech signal but also provides variety of services like FAX, SMS and multimedia transfer. GSM, a circuit switching data network has a maximum data rate of 9.6 kbps and later extended to 14.4 to 115.2 kbps and in future data rate of 384kbps per user might evolve. Nowadays a sophisticated system that provides voice, high bit rate, video, image and multimedia capability are the demands of the customer. To meet the above requirements a highly flexible system that can adapt to new models and signal processing techniques are needed and FPGA finds its way into this because of greater performance, economically less cost, flexibility and low power consumption. The blocks implemented as a core in FPGA is shown in Figure 2.

Fig. 2. GSM baseband transmitter

Channel Encoder

Redundancy in data is introduced in channel coder for detecting and correcting errors that might occur during transmission. The 260 bit input to the convolutional encoder is divided into class Ia containing 50 bits, class II a containing 132 bits and class II with 78 bits. The class Ia bits are cyclic encoded using linear feedback shift register. The proposed work uses three registers to include 3 bits with 50 bit input pattern. Class Ia 50 bit data is fed to the cyclic encoder. Since the required bit pattern is of the form (53, 50), the generator polynomial used in this encoding process is $x^3 + x + 1$.Once the 50 bits are completely shifted the content of register 1 to 3 contains the three redundant bits which is added to the 50 bit input data to generate 53 bits. The generated 53 bit data is added with 132 class Ib plus 4 extra bits to form 189 bits. Next stage of convolutional encoding is to generate two bits for every input data. The output of the previous stage containing 189 bits is doubled to 378 bits. Convolutional encoder has been designed using the polynomial $G_1(x) = x^4 + x^3 + 1$ and $G_2(x) = x^4 + x^3 + x + 1$. The output of the convolutional encoder is 378 bits which is further added with class II 78 bits to generate the final 456 bits which is fed to the interleaver, next stage of GSM transmitter.

Interleaver

Fading is always one of the major impairment in RF channel that results in errors in consecutive bit patterns. Interleaver arranges the code word symbols in such a way that errors are spread among multiple code words. The first block is formed by taking every 8th bit that is selecting the 0th , 8th , 16th bits and so on. Similarly, the second block is formed by taking the 1st, 9th ,17th bit and so on. The same procedure is repeated to form the 8 blocks. The bits in the first four blocks occupy the even positions and the bits in the next 4 blocks are placed in the odd position for a total of 456 bits.

GMSK Modulator

An extension of Minimum shift keying (MSK) is Gaussian Minimum Shift keying (GMSK), a continuous phase modulation scheme. As shown in Figure 3 initial step in GMSK modulation is differential encoding in which the incoming binary sequence is expressed in (Non Return to zero) NRZ format

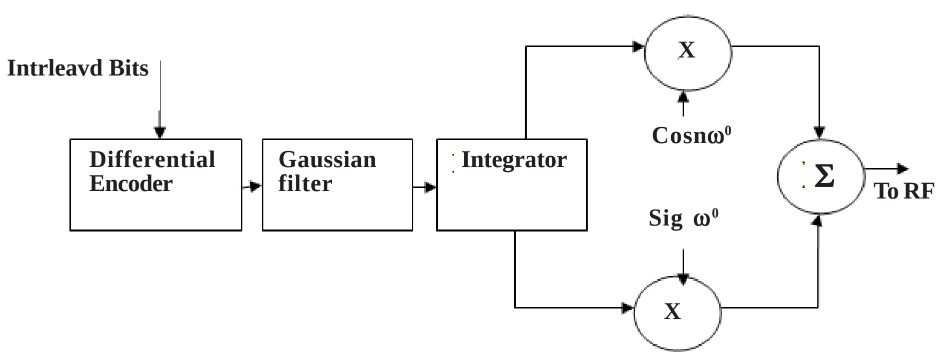


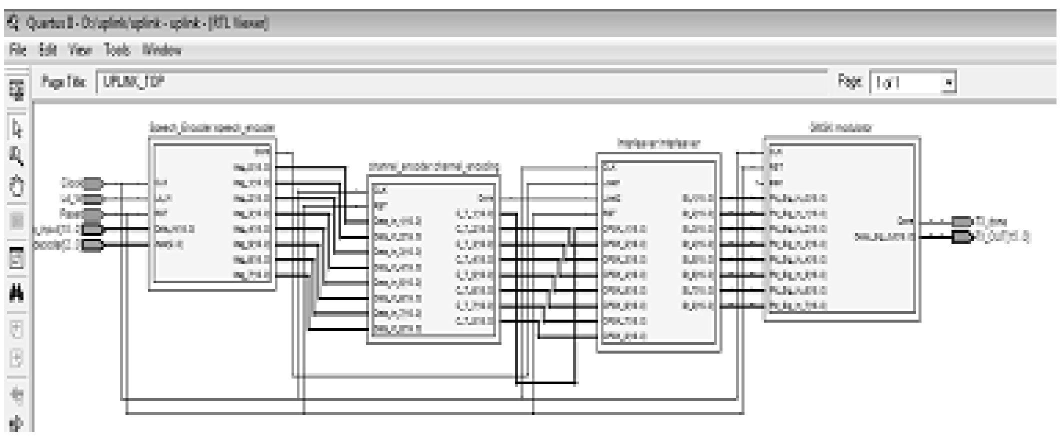
Fig. 3. GMSK modulator

followed by convolution with a Gaussian function that meets the following specifications: a function with narrow bandwidth and sharp cut off frequency and a small overshoot impulse response to avoid excess deviation. The bandwidth time product to design the filter has been chosen as 0.3, as per GSM standard.

The resulting signal is integrated and then multiplied with carrier signal represented by cos-$n\omega_0$ and - sin$n\omega_0$ to generate inphase component (I) and quadrature phase component (Q) respectively. Then the two signals (I and Q) are summed up to generate the resultant signal. The reason to prefer GMSK modulation in GSM is that the information to be transmitted is contained in phase variation rather than amplitude. This leads to higher signal to noise ratio that is the signal is more immune to noise. And also, a non linear amplifier that consumes less power can be used at the receiver to demodulate the signal leading to low battery usage an essential performance criteria in cellular technology. The output of the modulator feeds the RF circuit for transmission. Figure 4 shows the utilization summary and RTL schematic of the GSM Baseband Processor implemented in Altera DE0 nano FPGA board.

GPS Data Processing Core

Global Positioning System (GPS) is a space-based global navigation satellite system that provides time and location information to users anywhere on earth. All GPS satellites broadcast the signals in the same frequencies using Direct Sequence Spread Spectrum (DSSS) but use different ranging codes with low cross correlation properties. The signal received from the satellites consists of Code Division Multiple Access (CDMA) rang-



Flow Summary

Flow Status	**Succssful=Tue Jul 24 15: 12:54 2012**
Quartus II Version	**10.1 Build 153 11/29/2010 SJ Web Edition**
Revision Nam	**GSM_Uplink**
Top-level Entity Name	**UPLINK_TCP**
Family	**Cyclon IV C**
Device	**EP4CE22F 1718%**
Timing Models	**Final**
Total logic elements	**49/22,320 (< 1%)**
Total combinational functons	**49/22,320 (< 1%)**
Dedicated logic registers	**24/22,320 (< 1%)**
Total registers	**24**
Total pins	**83/154(4%)**

Fig. 4. Utilization summary and RTL Schematic of GSM Baseband Processor

ing codes that helps to determine the propagation time, navigation data and also provide satellite position and transmission time. These ranging codes and navigation data are modulated with the carrier signal using Binary Phase Shift Keying (BPSK).The ranging codes broadcasted by the GPS satellites are C/A codes (coarse acquisition code) and P(Y) code (military code). The C/A code signal frequency is 1.023MHz and carrier frequency [L1] is 1575.42 MHz. In this study as the GPS Receiver is used for civilian purpose, therefore only C/A codes are considered, as P(Y) codes are used for military application.

The right hand circular polarization antenna is used to receive the signals from GPS satellites. RF front end is used to convert the signal frequency into Intermediate Frequency (IF). The intermediate frequency is much lower so that it can be sampled by ADC. The IF signal is given as input to the software GPS baseband processor implemented in FPGA. The output of the GPS receiver from FPGA is in NMEA format, which is transmitted to a mobile through SIM 900A GSM modem.The designed RF front end takes the incoming signal at 1575.42 MHz with a received power of -163 dB. MAX 2742 has inbuilt low noise amplifier,mixer, Band Pass filter, automatic gain control, local oscillator, clock buffer and internal digital sampler. Using MAX 2742 in the design eliminates the requirement of costly SAW filter or bulky band pass filters at intermediate frequency. The main signal processing operations performed by the GPS Baseband receiver inside FPGA are acquisition, Tracking and Data processing.

Acquisition is a coarse synchronization process used to acquire the signal for removing code phase and Doppler Effect. Tracking, a fine synchronization process is the next step carried out to remove code and carrier frequency. At last data processing is done to recover the GPS data. The output of the GPS that is the location information is transmitted through a GSM modem to a mobile.

Acquisition

Acquisition is the process by which the receiver track and navigate the satellites in its view. To track the transmitted signal, the receiver must remove the carrier frequency and C/A code. It is used to identify the satellites for the users and determine the coarse values of the carrier frequency and the code phase of the signal. All satellites transmit the C/A code with carrier frequency equal to GPS L1 frequency. GPS receivers do not receive the signal exactly modulated by L1 frequency, because of the Doppler Effect. Hence in order to demodulate the signal and to remove the carrier frequency, the receiver must determine the Doppler shift of the satellite. The goal of acquisition is to perform a correlation with the incoming signal and a Pseudo Random Noise (PRN) code. Here the PRN code is generated using the Linear Feedback Shift Registers (LFSR). There are three standard methods of acquisition: serial search acquisition, parallel frequency space search acquisition and parallel code phase search acquisition. Compared to the three methods, the parallel code phase search acquisition

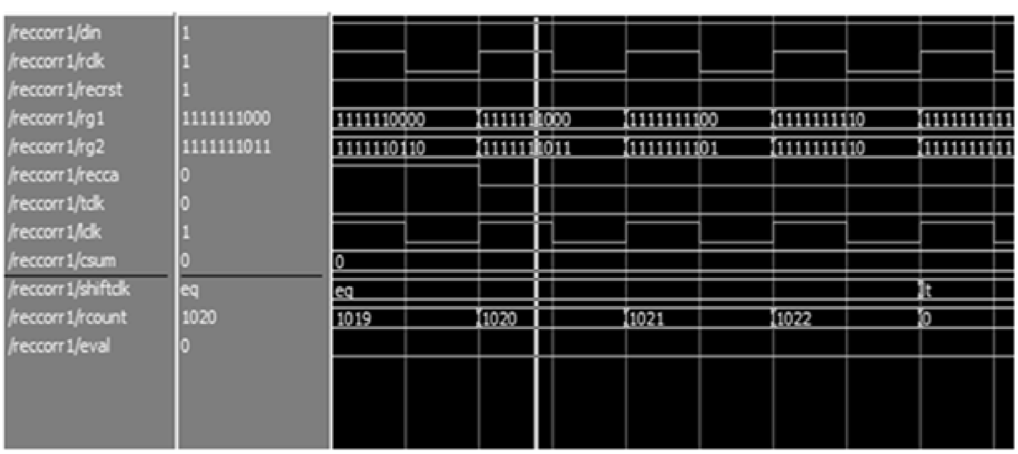


Fig. 5. Acquisition output in HDL environment

method reduces the search space only to the possible carrier frequencies. The accuracy of the carrier frequency is similar to the serial search method but the code phase is more accurate as it gives a correlation value for each sampled code phase.The output obtained for acquisition module is shown in Figure 5.

Tracking

Satellites constantly move in the orbit and the distance between the transmitter and receiver vary a lot. Once the signal is acquired, the tracking must be started by synchronization method of locally generated carrier and locally generated code. Two types of tracking need to be performed. They are Code tracking and Carrier tracking. The tracking is necessary to continuously follow the changes in frequency as a function of time. If the receiver loses the track of a satellite, a new acquisition must be performed for that particular satellite.

Code Tracking

Code tracking is the process of advancing or delaying the local replica code. Early code, Late code, Prompt code are the three replica been generated. These three types of code are compared with the transmitted signal. The code must be half of the chip distance from prompt code such that if the early or late code is increased than the incoming code, it is correlated with other PRN chip leading to error. Code tracking method is thus done using Delay Locked Loop (DLL).The code tracking method generates an exact code replica and it is correlated with the incoming signal.The incoming signal is multiplied with the local replica carrier wave. After that the signal is multiplied by three replica codes. Followed by this second multiplication, the three outputs are integrated and dumped giving a numerical value indicating how much the specific code replica correlates with the code of the incoming signal.

Carrier Tracking

To demodulate the navigation data successfully, an exact carrier wave replica has to be generated. To track a carrier wave signal, Phase Lock Loops (PLL) or Frequency Lock Loop (FLL) are often used. The problem with using an ordinary PLL is that it is sensitive to a 180 phase shift of the input signal carrier wave. Due to navigation bit transitions, the PLL used in a GPS receiver has to be insensitive to 180 phase shifts.The Costas loop is used for carrier tracking process. Costas loop is insensitive to 180 phase shifts. Hence both frequency and phase offset are removed by this tracking loop. Tracking output obtained in MODELSIM environment is shown in Figure 6.

Data Processing For Position

After removing the carrier and PRN code (gold codes) the remaining bits are given as data.

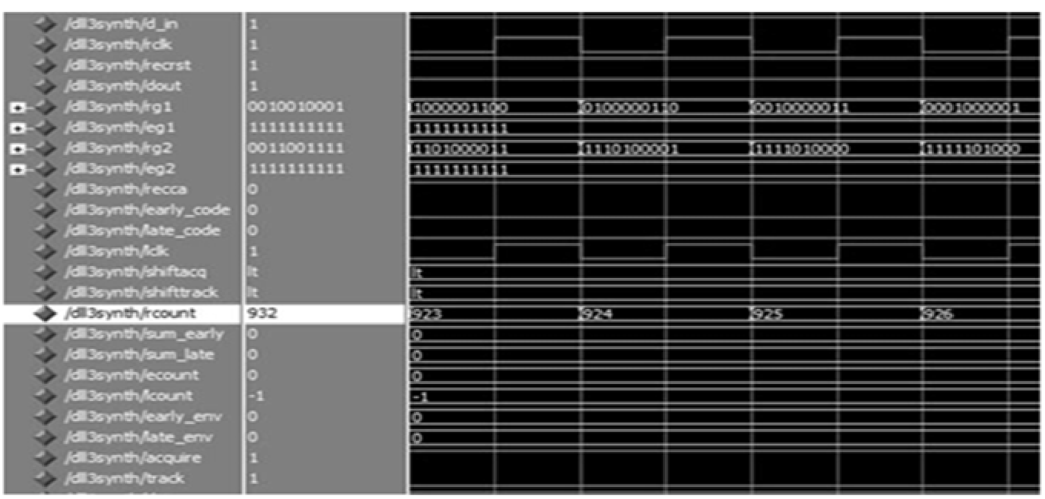


Fig. 6. Tracking output in MODELSIM environment

The data is divided into frames. An entire frame is transmitted within 30 sec. The data are encoded as 1. Each sub frame starts with 30-bit telemetry word (TLM). The TLM word consists of 22 preamble bits followed by telemetry message and parity bits at the end. The receiver considers the preamble data to determine the start of sub frame. Sub frame provides the ephemeris data (satellite orbital position), satellite constellation information, atmospheric modeling parameters (for correcting positioning errors) and almanac data of long term coarse satellite orbital parameters.From the data output date information, approximate time and position of satellite is obtained. Figure 7 shows the GPS data obtained in a mobile phone.

Fig. 7. GPS Data received in a mobile phone

IMPLEMENTATION AND RESULTS

Processor core implemented in FPGA with custom hardware is referred as System on programmable chip (SoPC).Nios II, a 32 bit embedded processor have been specifically designed for the Altera FPGA family. Architecture of the implemented hardware is shown in Figure 8. Arrhythmia detector, GSM baseband processor and GPS data processing modules as discussed in previous sections are implemented in Altera DE0 Nano FPGA board that contains Altera Cyclone IV EP4CE22F17C6N FPGA device; Altera serial configuration device EPCS64; onboard USB blaster for programming; 32 Mbytes of SDRAM; 4Mbytes of flash Memory and RS-232 Transceiver.

The communication between the host computer and the DE0 board is achieved using Altera USB Blaster Driver software. Philips ISP1362 USB controller provides an interface between the host and the device. Configuration data for the cyclone – IV FPGA is stored in E^2PROM chip on DE0 board. Each time power is applied to the board, the configuration data gets automatically loaded from E^2PROM into FPGA. User programming can be downloaded into FPGA by two methods – JTAG programming (Joint Test Action Group) and Active Serial Programming (AS). The disadvantage of JTAG programming is that configuration is lost when the power is turned off whereas in AS programming, the information can be retrieved even when the power supply to the DE0 is turned off. EPCS64, the on board configuration device loads the data into Cyclone IV FPGA. Hence, AS programming is used for programming the FPGA.

The inbuilt SoPC builder option in Quartus is used to build the processor core along with set of peripherals like timers, on chip/off chip memory elements and bus architecture interconnected with Avalon Bus Protocol for interface purposes. As shown in Figure 8 the proposed system is implemented with three processor cores: cpu_0 for ECG analysis; cpu_1 for GSM Baseband processes and cpu_2 for GPS data processing application.

The system was designed in Altera's Quartus software and targeted on Cyclone. The phone number and the calculated information about the ECG signal are stored in the on – chip memory (Configurable ROM) of FPGA. For normal person, bpm ranges between 60 and 100. Decision making circuit declares a panic situation if bpm is not in the normal range and automatically sends an AT command to SIM 900A through UART. SIM 900A is a compact Dual band GSM/GPRS module that can deliver voice, data, and fax. The default baud rate is 9600 with 8-N-1.This module contains a SIM card holder to plug in a valid SIM card for the purpose of accessing the GSM network. The power supply to the GSM modem is +4.1 V, which is obtained by LM7805 voltage regulator. It has LED display to indicate the status of the GSM module

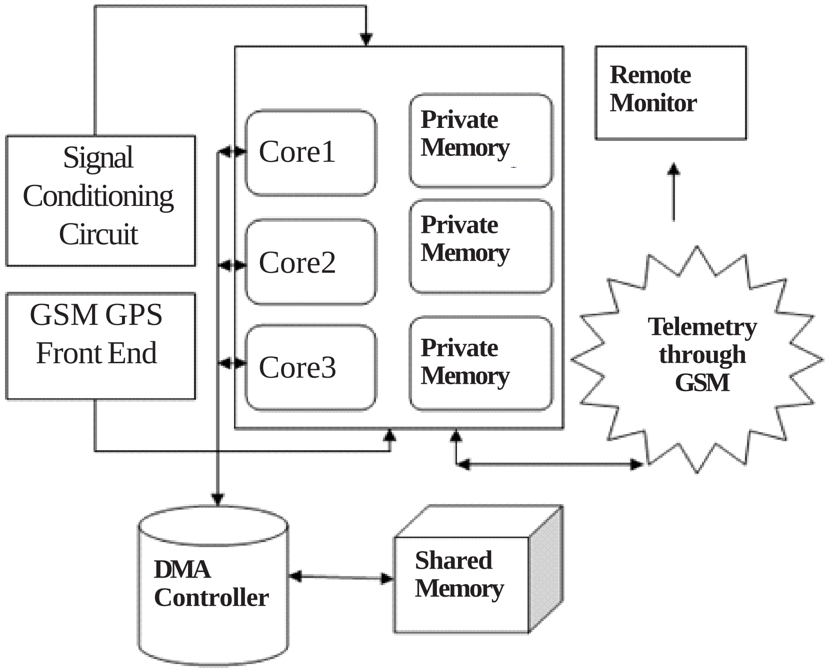


Fig. 8. System architecture in PSoc

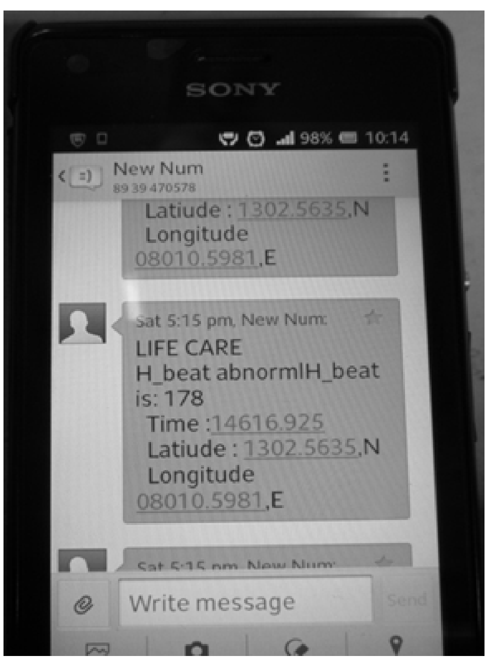


Fig. 9. Heart beat per minute with location received in a mobile phone

like power on, Network access and registration, GPRS connectivity etc. Once the board is powered ON and if valid SIM card is available the corresponding LED will blink in step of 3 second which indicates that GSM modem has registered its connectivity in the network and ready for the application. Figure 9 shows the alerting SMS received in the mobile phone along with abnormal heart beat rate and the location of the patient.

DISCUSSION

Sudden cardiac death (SCD) refers to a natural death from cardiac causes (Myerberg and Wellens 2005). SCD generally occurs 61 h from the onset of symptoms (Zipes and Wellens 1998) and in the absence of any prior condition that would appear fatal. Therefore, some of the existing ECG monitoring systems that are commercially available for monitoring of the cardiac patients are

Systems that record signals and perform offline analysis : These systems only record the vital signals and no real time classification is done, for example, Holters, Medtronic Reveal

Insertable Loop recorder, Adhesive patch monitor(Barett 2014). Later, the recorded signals are analyzed. Hence no real time classification is performed.

Systems that perform remote real time monitoring: Here the ECG signals are acquired and sent to a remote monitoring centre through mobile phones. The limitation here is that the analysis is not performed in the place where the signal is acquired, for example, Vita phone (Daja 2001), QRS diagnostic, Cardio control, MobiHealth Project.

Systems that provide local real-time classification: These systems use intermediary local computers between sensors and the control centres or a hospital. These computers perform local real time monitoring. If some anomalies are detected, it sends alarms to the hospital, for example, @Home (Sachpazidis 2002), TeleMediCare and PhMon (Kunze et al. 2002).This solution that makes use of PCs to perform local analysis, the mobility of the patients is restricted and it is almost reduced to their homes.

Systems that performs real time monitoring: These systems are mobile or real-time cardiac telemetry systems (MCOT). With these devices, cardiac activity is continuously monitored and the collected data is transmitted to a portable monitor that has a built-in cell phone and needs to be in proximity to the patient to receive signals. The monitor is equipped with software that analyzes the rhythm data continuously. If an arrhythmia is detected the monitor automatically transmits recorded data transtelephonically (by wireless network or land phone line) to a central monitoring station for subsequent analysis. No alert signal or location of the patient is transmitted to the caretaker (Zimetbaum and Goldman 2010).Use of a novel device applied at emergency department (ED) discharge that provides continuous prolonged cardiac monitoring has also been suggested (Schreiber et al. 2014)

Therefore the proposed system performs real time classification at the patient side and FPGA based real time monitoring system declares panic situation in any of the following cases:

1. The beat per minute value is not between 60 and 100.
2. Relatively fluctuating bpm for every heartbeat.
3. The R-amplitude falls below the minimum required by a healthy heart.

Once the panic situation is declared by the processor core, an automatic call function is triggered to the care taker or the doctor. Once the alert signal is received by the care taker, even before emergency medicine starts, the following CPR actions may be performed. Care taker may start chest compressions by putting the heel of one hand in the centre of the victim’s chest and covering the first hand with the other hand. At a rate of 100 compressions per minute may be performed. Even if the caretaker is not trained in CPR, continuous chest compression may lead to consciousness recovery of the patient until emergency medical personnel arrives.

CONCLUSION

Monitoring systems that perform a complete ECG analysis in a local device near the patients are of great interest because they allow us to improve the quality of life for those who suffer from cardiac disorders. For ‘an anywhere at any time’ monitoring system, devices used have to be actually mobile. Hence the implemented system may be a life caring system for cardiac patients as continuous monitoring becomes possible.

RECOMMENDATIONS

Based on the findings, it is recommended that the proposed telecardiac system may be validated with ECG signal taken from real time patients followed by doctor’s opinion. The pilot implementation should take into account the installation of high speed GSM and GPS network connectivity in rural areas.

REFERENCES

Abo-Zahhad M, Sabah M, Elnahas O 2014. A Wireless Emergency Telemedicine System for Patients Monitoring and Diagnosis. International Journal of Telemedicine and Applications: From <http://dx.doi.org/10.1155/2014/380787.>

Barrett PM, Komatireddy R, Haaser S 2014. Comparison of 24-hour Holter monitoring with 14-day novel adhesive patch electrocardiographic monitoring. *Am J Med*, 127(1): 95.e11-7.

Coleman Alfred 2013. Using a virtual ICT training framework to support doctors in rural hospitals in South Africa. *Ethno Med*, 7(3): 137-141.

Daja N, Relin I, Reljin B 2001. Telemonitoring in cardiology-ECG transmission through mobile phones. *J Annals Academy Studenica*, 4: 63-66.

Evans T 1998. Cardiac arrests outside hospital. *BMJ*, 316: 1031-1032.

Hung Kevin 2003. Implementation of a WAP based telemedicine system for patient monitoring. *IEEE Transactions on Information Technology in Biomedicine,* 7(2): 101-107.

Kunze C, Grossmann U, Stork W, Muller-Glaser 2002. Application of ubiquitous computing in Personal Health Monitoring Systems. *Proc 36 Annu Meeting German Society for Biomed Eng,* pp. 360-362.

Lin Yusan-Hsiang 2004. A wireless PDA based physiological monitoring system for patient transport. *IEEE Transactions on Information Technology in Biomedicine,* 8(4): 439-447.

Lucani Daniel Cataldo, Giancarlos Guillermo Villegas 2006. A Portable ECG Monitoring Device with Bluetooth and Holter Capabilities for Telemedicine Applications. *IEEE EMBS Annual International Conference,* pp. 5244-5247.

Mitra S, Bera J, Mitra M, Sengupta S 2006. Wireless communication based portable telecardiolog system for rural health care. *IETE Technical Review,* 23(5): 277-282.

Myerberg Wellens 2005. Epidemiology of cardiac arrest. In: S Priori, D Zipes (Eds.): *Sudden Cardiac Death: Oxford: A Handbook for Clinical Practice.* England: Blackwell Publishing, pp. 3-20.

Roy Chowdhury S, Saha H 2006. Development of an FPGA based smart embedded system for rural telediagnostic applications. *IETE Technical Review,* 23(5): 297-304.

Sachpazidis I 2002. Home: A Modular Telemedicine System. *Proc. 2nd Workshop Mobile Computing in Medicine,* Germany.

Sandler David A 1999. Call to needle times after acute myocardial infarction *BMJ,* 318: 1553.

Saurabh Prakash Venkatesh 2013. Real time monitoring of ECG signal using PIC and web server. *International Journal of Engineering and Technology (IJET),* 5(2): 1047-1053.

Schreiber D, Sattar A, Drigalla D, Higgins S 2014. Ambulatory cardiac monitoring for discharged emergency department patients with possible cardiac arrhythmias, *West J Emerg Med* ,15(2): 194-198.

Thulasi Bai V, Srivatsa S K 2008. Design and implementation of mobile telecardiac system. *J Sci Ind Res,* 7: 1059-1063.

Wangchuk Phurpa 2008. Health impacts of traditional medicines and bio prospecting : A world scenario accentuating Bhutan perspective. *Journal of Bhutan Studies,*18: 116-134.

Wendy M 2008. Dying, sudden cardiac death and resuscitation technology. *International Emergency Nursing,* 16: 119-126.

Zimetbaum P, Goldman A 2010. Ambulatory arrhythmia monitoring: Choosing the right device. *Circulation,* 22(16): 1629-1636.

Zipes DP, Wellens HJJ 1998. Sudden cardiac death. *Circulation,* 98: 2334-2351.