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Emergency Patient Monitoring System for Cardiac Disorders

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Abstract—Nowadays, heart related diseases are on the rise. Cardiac arrest is quoted as the major contributor to sudden and unexpected death rate in the modern stress filled lifestyle around the globe. A system that warns the person about the onset of the disease earlier automatically will be a boon to the society. Remote patient monitoring is an alternative to regular home check-ups of patients with certain special medical conditions or the elderly who are unable to regularly visit a healthcare facility. This technology reduces the number of home visits which are now only required when special attention is needed. This paper presents the design and development of a patient monitoring system which monitors the cardiac activity of the patient. The system uses the standard Global System for Mobile Communication (GSM) technology for communication. In case of emergency, an SMS is sent to the cellphone of the physician, who can arrange for quick and necessary treatment of the patient. The system has been tested for accuracy and quickness in communicating emergency conditions to the physician and is found to be working satisfactorily.

Keywords-Electrocardiogram (ECG), Heart Rate, GSM, Wireless transmission.

I. INTRODUCTION

Worldwide surveys conducted by World Health Organization (WHO) have confirmed that the heart related diseases are on the rise. Many of the cardiac related problems are attributed to the modern lifestyles, food habits, obesity, smoking, tobacco chewing and lack of physical exercises etc. The post-operative patients can develop complications once they are discharged from the hospital. In some patients the cardiac problems may reoccur, when they start doing their routine work. Hence the ECG of such patients needs to be monitored for some time after their treatment. This helps in diagnosing the improper functioning of the heart and take precautions.. Some of these lives can often be saved if acute care and cardiac surgery is provided within the so-called golden hour. So the need for advice on first hand medical attention and promotion of good health by patient monitoring and follow-up becomes inevitable. Hence, patients who are at risk require that their cardiac health to be monitored frequently whether they are indoors or outdoors so that emergency treatment is possible. Telemedicine is widely considered to be part of the inevitable future of the modern practice of medicine. It is gaining more and more momentum as a new approach for patients surveillance

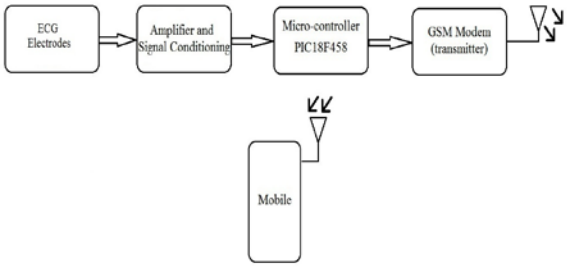

Figure 1. Tele-Alert system.

outside of hospitals (at home) to encourage public safety, a ciliate early diagnosis, treatment, and for increased convenience. Defined as the use of advanced Tele Communication technologies to exchange the information about the patients health care status and provide health care services across is now currently being used by doctors, hospitals and other healthcare providers around the world with conventional mode of treatment [1], [2]. Telemedicine systems are already available to enable the doctor to monitor a patient remotely for home care emergency applications. Nowadays, Wireless networking is an emerging technology that will allow users to access information and services electronically, regardless of their geographic topography.

The use of wireless communication between mobile users has become increasingly popular due to the advancements in computer and wireless technologies [3], [4]. Implementation of wireless technology in the existing ECG monitoring system eliminates the physical constraints imposed by hard-wired link and allows users to conduct own check up at anytime anywhere. The usage of mobile phone has been recognized as a possible tool for telemedicine since it has become a commercially available household article. In the recent past, it has been shown that a bio signal acquisition unit connected to a computer, vital signs can be transmitted from an ambulance [5] to a hospital in a store-and-forward mode or in real-time mode. Moreover, newer cellular access technologies, such as Third generation (3G), and others provide much higher data transmission speeds (rates) than basic second generation (2G) GSM cellular system offering future

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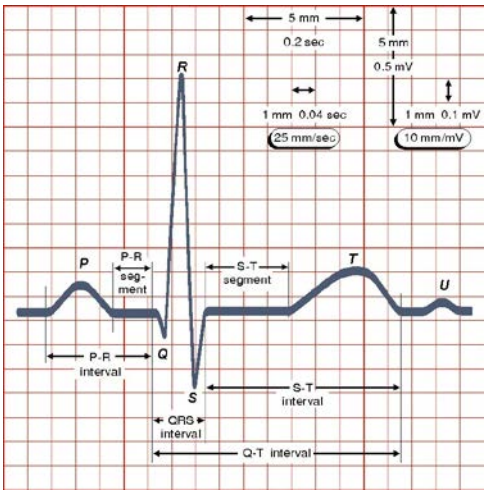

Figure 2. Graphical representation of ECG signal.

telemedicine solutions endless choices for high-end designs. These relatively new wireless technologies are deployed mostly in or around crowded high income metropolitan areas for our proposed scheme. We describe a telemedicine system based on mobile messaging service namely: Short Messaging Service (SMS), which is an integral part of the original 2G GSM cellular system and subsequent generations since all new phones are SMS capable [6]. Our project aims at detecting the cardiac disorder of the patient in advance thereby reducing the critical level of the patient by following precautionary measures at an earlier instant.

II. Methodology

The proposed ECG Tele-Alert system is shown in Fig.1 [12]. The system consists of an ECG amplifier that picks up the bio signal and then converts into electrical signal followed by a low pass filter. Output is digitized by an A/D converter programmed in PIC18F4550 Micro controller [7], [8] followed by the GSM MODEM. The patient (client) and the health-care professional can be located anywhere in the globe where there is 2G cellular network coverage. The primary purpose is to monitor patients cardiac activity if there is a chance that patient has cardiac problems such as an irregular heartbeat or arrhythmia that require close monitoring. The ECG is a graphical representation of electrical activities of the heart with respect to time. Cardiac cycle for ECG is shown in Fig.2. It is basic ECG waveform. The P, Q, R, S, T waves reflect the rhythmic electrical depolarization and depolarization of the myocardium [9].

The amplitudes of various components of the ECG are:

- P Wave = 0.25 mV.
- R Wave = 1.60 mV.
- Q Wave = 25% of R wave.
- T Wave = 0.1 to 0.5 mV.

The durations of various components of the ECG are:

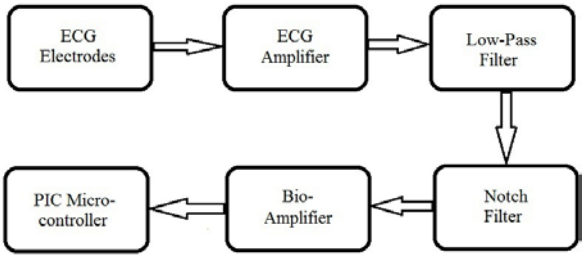

Figure 3. ECG signal conditioning.

- P-R Interval = 0.12 to 0.2 Sec.
- Q-T interval = 0.35 to 0.44 Sec.
- S-T segment = 0.05 to 0.15 Sec.
- P interval = 0.11 Sec.
- QRS interval = 0.09 Sec.

When the patients cardiac level goes beyond the threshold, our system alerts the patient by sending an alert SMS to the doctors mobile through the GSM MODEM.

A. ECG Signal Conditioning

Fig.3. shows the block diagram of ECG signal conditioning. The Electrocardiogram (ECG) is sensed by the clamp type sensors. The signal is achieved from clamp type sensor is very low (micro-volt). The maximum differential signal from the sensor at R wave is up to 1.2mV. Hence the signal should be applied to the instrumention amplifier for the faithful amplification and S/N level improvement. The suitable gain of the amplifier is decided by the resistance used in the circuit. The amplified signal is applied to low pass filter for the faithful nature of ECG signal. The cutoff frequency of the low pass filter is decided to be 150Hz to pass the element of all ECG signal. The signal is then applied to notch filter to filter the noise of line frequency 50Hz. One more stage of bio-amplifier is inserted and finally signal is applied to the comparator for the detection of R wave. This signal is applied to the comparator to detect the R pulses. After detection of the R pulses the signal is applied to mono-stable multivibrator. The output of mono-stable multivibrator is the sharp spike having very low on time with respect to off time. These pulses are regularly generated as the ECG nature is coming from the sensor part. The duration between two conjugative pulses is inversely proportional to the heart rate. If the duration is long, the heart rate will be slow. And if the duration is low then the heart rate will be very high. The normal heart rate is varying from 70-120 bpm. The microcontroller counts the heart rate from the number of R-wave peaks.

B. Microcontroller

The PIC18F4550 Microcontroller includes 32kb of internal program memory, 2048 bytes of RAM area and an internal EEPROM of 256 bytes. A 13-channel,10-bit A/D converter is included within the microcontroller, making

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it ideal for real-time systems and monitoring applications [7], [8]. All port connectors are brought out to standard headers for easy connect and disconnect. In-Circuit program download is also provided, enabling the board to be easily updated with new code and modified as required, without the need to remove the microcontroller.

C. Wireless Module

GSM MODEM provides full functional capability to serial devices to send SMS and data over GSM Network. The GSM MODEM is avaliable in 300/900/1800MHz frequency bands. It requires less than 3.5mA current during the idle mode. The GSM MODEM supports popular ”Attention (AT)” command set so that users can develop applications quickly. Some of the common AT commands are:

- AT-Attention Command. Alerts GSM module for communication.
- ATZ-Reset Command. Resets the GSM module.
- AT+CMGF-Sets SMS input mode as text mode.
- AT+CNMI-Sets the SMS indicator format.
- AT+CMGS-Sends text message.
- AT+CMGR-Receives text message.

Since this unit is the most sensitive part of the system, having direct contact with the sensors, special attention is given to design of the Printed Circuit Board (PCB) containing the components of the patient monitoring unit. Several ground planes have been defined and routing strictly enforced to avoid any noise coupling between the analog and digital sections. The analog and digital sections are located on different areas of the PCB, interfaced only at one point through digital isolators. The added number of components and traces increases the complexity of the board, thus introducing the need for a four layer PCB containing two inner layers in the addition to the two outer layers with components mounted on both outer layers.

III. Results

A. Placement of Electrodes

As a general principle the closer, the electrodes are to the heart, the stronger the ECG signal that will be obtained. In our Lead V formation, electrodes were placed on the right arm, left arm, right leg, left leg and chest with right leg electrode acting as the ground reference electrode for the body.

B. Observed Results

ECG samples from various patients were taken and ECG mean and heart rate were calculated and displayed. Fig.4. showas the observed ECG signal while Fig.5. shows the SMS received on the mobile phone.

Figure 4. Observed electrocardiogram (ECG)

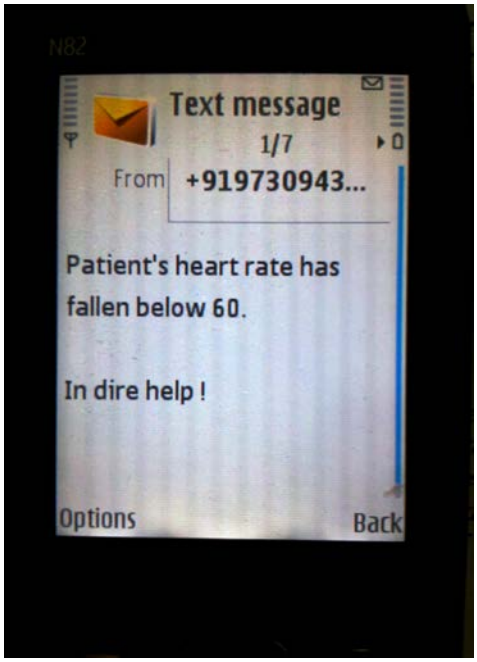

Figure 5. SMS received on the cellphone in case of emergency

IV. Conclusion

A mobile patient monitoring system was designed, developed and tested. The major value of this Patient monitoring system is in the detection of cardiac disorder of the patients who are located in the remote areas or in travel and are not in a position to report to the doctor for immediate treatment. An alert SMS can be transmitted using the GSM technology to the doctors and advises can be sought for saving the life of the patient. So far we have developed a model for enhancing the mobility of doctor alone and in future we will extend the prototype by providing mobility to both doctor and patient. The clinical evaluation reveals that this mobile patient monitoring system is user-friendly, convenient, and feasible for detecting and quickly communicating emergency cardiac conditions.

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