Intelligent Patient Monitoring System for Emergency Conditions

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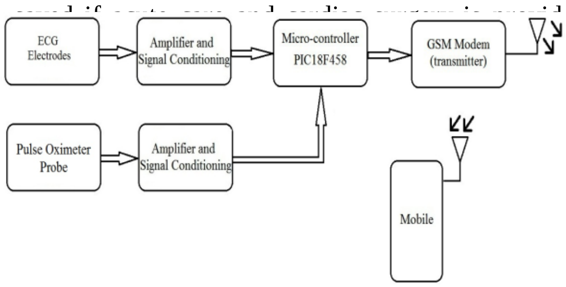
Abstract—Nowadays, heart related diseases are on the rise. Cardiac arrest is quoted as the major contributor to sudden and unexpected death rate in the modern stress filled lifestyle around the globe. A system that warns the person about the onset of the disease earlier automatically will be a boon to 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 blood oxygen saturation and 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 ...ed within ... on first ...health by ...e. Hence, ...alth to be ... outdoors ...dicine is ...re of the ...nd more



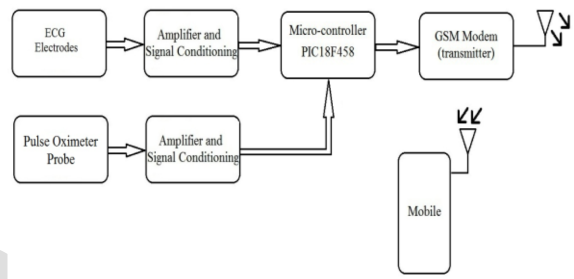


Figure 1. Tele-Alert system.

momentum as a new approach for patient's surveillance 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

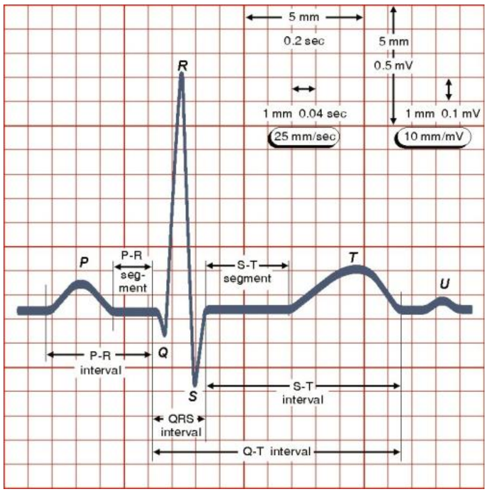


Figure 2. Graphical representation of ECG signal

second generation (2G) GSM cellular system offering future 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 system is shown in Fig.1 [7]. The system consists of an Pulse Oximetry and ECG monitoring system, with respective signal conditioning and amlpification units. Output is digitized by an A/D converter programmed in PIC18F4550 Micro controller [8], [9] 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 patient's cardiac activity if there is a chance that patient has cardiac problems such as an irregular heartbeat or arrhythmia, and lower blood oxygen saturation 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 [10]. 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.

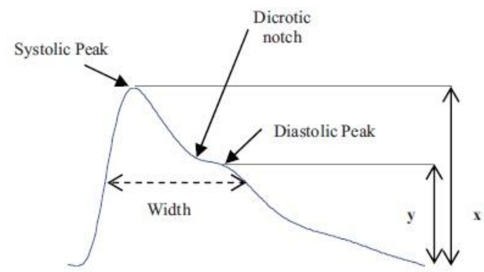


Figure 3. Graphical representation of pulse oximetry signal.

The durations of various components of the ECG are:

- 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.

A typical waveform of the PPG and its characteristic parameters is shown in Fig.3. The normal rhythmical constriction and dilatation of the heart during which the chambers are pumping and filling with blood is called systole and diastole respectively. The amplitude of the systolic peak is x while y is the amplitude of the diastolic peak.

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.4. 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.

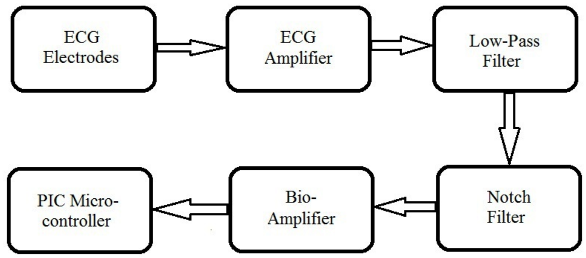


Figure 4. ECG signal conditioning.

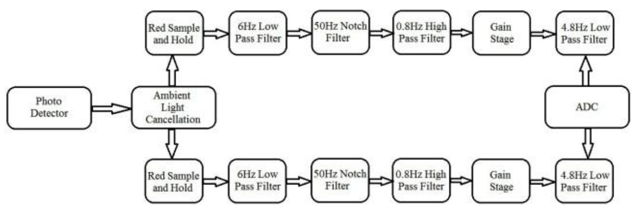


Figure 5. Pulse oximeter signal conditioning.

The microcontroller counts the heart rate from the number of R-wave peaks.

B. Pulse Oximeter Signal Conditioning

A pulse oximeter is essentially a portable, non-invasive monitoring of oxygen saturation which enables prompt recognition of hypoxemia [11]. Pulse oximetry basically measures oxygen saturation (SpO_2) i.e. the percentage of hemoglobin saturated with oxygen. The Nellcor DS-100 finger probe is used as sensor [12]. It consists of two narrow band LEDs as sources of light. One is red LED of 660 nm wavelength and other one is an infrared LED of 940 nm wavelength, placed on one side and a photo detector placed on opposite side of the probe. The output of the photo-detector is given to the signal conditioning and amplification circuitry. Fig.5. shows the block diagram of the signal conditioning and amplification circuitry.

The first filter is a low pass filter with a cut-off frequency (f_0) of 6Hz designed to eliminate high frequency noise. The filter cut frequency of 6Hz is calculated using (1), by selecting the appropriate values of resistor and capacitor.

f0 = 1/2πRC ………………… (1)

Gain (Av) = 1+(R_F /R_1) ………………… (2)

The second filter is a 50Hz notch filter. The purpose of this filter is to eliminate the 50Hz power-line interference. The notch filter is designed as a passive filter in the twin-T configuration. The notch filter is referenced to Vcc/2 to add an offset voltage. The third filter is a 0.8Hz high pass fourth filter is a first order active 6Hz low pass filter that also provides a gain of 31. The cut-off frequency of this filter is set by calculating the value of components using the (1). The values of components are calculated using Equation (3) to set the desired gain of 31. The fifth and last one is a 4.8 Hz low pass filter. The cut-off frequency of this filter is also calculated using (1). The last stage is an active amplifier with variable gain to adjust the amplitude of the derived photoplethysmogram [12]. The values of components are calculated using (2). The result at this point is a noise-free photoplethysmogram. This photoplethysmogram is further fed to the microcontroller for the calculation of SpO_2.

C. 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 it ideal for real-time systems and monitoring applications [8], [9]. 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.

D. 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 filter. The desired cut-off frequency is calculated using (1). This filter separates the DC component of the signal. The 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.

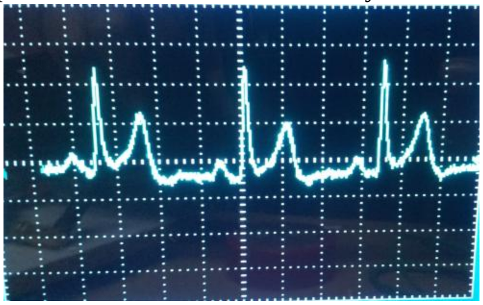


Figure 6. Observed electrocardiogram (ECG)

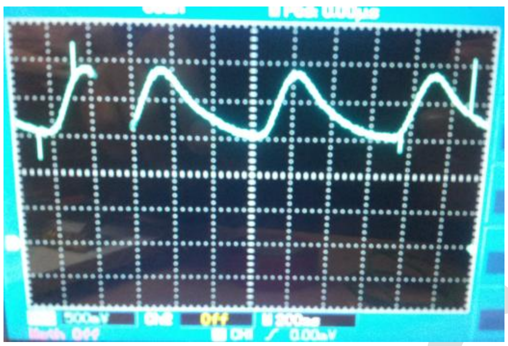


Figure 7. Observed pulse oximeter wavefrom.

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

The system was tested in the R&D laboratory of Medion Healthcare Pvt. Ltd. before testing on real-time patients. The results obtained from the lab tests are presented. Fig.6. shows the Electrocardiogram (ECG). Fig.7. shows the pulse oximeter wavefrom obtained after the signal conditioning and amplification block i.e. the photoplethysmogram. Fig.8. shows the SMS received on the mobile phone received by the physician 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

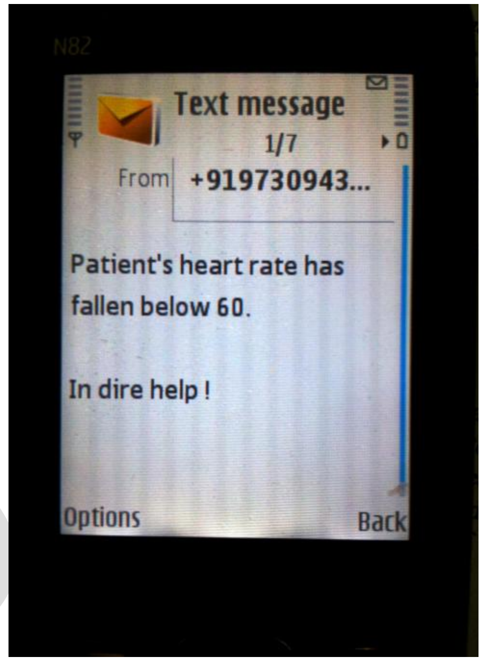


Figure 8. SMS received on the cellphone in case of emergency

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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