Design And Implementation Of Wireless Heartbeat Measuring Device For Remote Health Monitoring

Mr. Mayuresh Yeole (mayuresh.y@somaiya.edu), Prof. Rajashree Daryapurkar, Department of Electronics Engineering, K. J. Somaiya College of Engineering.

Abstract— This paper is based on development of a microcontroller based system for monitoring heartbeat and body temperature using fingertip and temperature sensor. The device uses the optical technology to detect the flow of blood through the finger and offers the advantage of portability over conventional recording systems. This design allows a network to be formed between the patient and doctor in order to enable remote monitoring by analysing the data of patients. The design consists of sensors like optical heartbeat sensor which counts the heartbeat per minute and oxygen saturation in the blood(SpO2) and temperature sensor which measures the temperature of the body. The readings from these sensors are further processed and sent via GSM module to a remote location where it is displayed on cell phone of medical experts or patient's family members or relatives. Thus doctors can monitor and diagnose the patient’s condition continuously and could suggest precautions for the patients. This will also alert the family members to quickly attend the patients.

Keywords- Fingertip Sensor; Temperature Sensor; Microcontroller; Opamp LM358; GSM Module SIM 900A.

I. INTRODUCTION

Cardiovascular disease is one of the main causes of death in many countries. The delay between the first symptom of any cardiac ailment and the call for medical assistance has a large variation among different patients and can have fatal consequences. One critical inference drawn from epidemiological data is that deployment of resources for early detection and treatment of heart disease has a higher potential of reducing fatality associated with cardiac disease than improved care after hospitalization. Hence new strategies are needed in order to reduce time before treatment. Monitoring of patients is one possible solution. Also, the trend towards an independent lifestyle has also increased the demand for personalized non-hospital based care. In this paper a device has been developed to measure vital signs like heart rate, oxygen saturation in blood(SpO2) and body temperature [1].

Heart rate measurement indicates the soundness of the human cardiovascular system. In clinical environment, heart rate is measured under controlled conditions like blood measurement, heart voice measurement, and Electrocardiogram (ECG) etc. Our heart pounds to pump oxygen-rich blood to our muscles and to carry cell waste products away from our muscles. The more we use our muscles, the harder our heart works to perform these tasks-means our heart must beat faster to
deliver more blood. A heart rate measurement means to take a sample of heartbeats and computes the Beats per Minute (bpm) so that the information can easily be used to track heart condition. The average resting human heart rate is about 70 bpm for adult males and 75 bpm for adult females. Heart rate varies significantly between individuals based on fitness, age and genetics. Endurance athletes often have very low resting heart rates. Heart rate can be measured by measuring one's pulse [2]. If heart rate is higher than normal the condition is known as tachycardia, in the opposite case it is known as bradycardia.

Measurement of heart rate and SpO2 concentration in the blood is based on the principle of absorption of light and transmittance/reflectance of light characteristics. Absorption of light takes place due to oxygenated blood and deoxygenated blood, where oxygenated blood contains different light absorption characteristics due to arterial blood vessels (AC component) than deoxygenated blood, because light absorption characteristics due to skin, tissue or muscle remains constant under red and infrared wavelengths of deoxygenated blood (called DC component). By considering the ratios of A.C and D.C components of red and infrared lights oxygen saturation in the blood can be measured. LM 35 is used to measure the body temperature which varies during the day. The measured data will be sent to medical expert’s phone as well as the relatives of patient through a sms. This device will help both the patient and doctor during emergency period by saving both time and cost of patient and physician.

II. LITERATURE REVIEW

Here the literature survey part is mainly dependent on contributions of significant papers which proved helpful in making this report.

A new integrated device for monitoring the heart rate using a finger-tip sensor is designed and implemented. There are many methods to measure heart rates like Phonocardiogram (PCG), ECG, pulse meters, stethoscope etc. but are clinical and expensive. The proposed Heart Rate Measuring (HRM) device is economical and user friendly and has used optical technology to detect the flow of blood through index finger. Three phases are used to detect pulses on the fingertip that include pulse detection, signal extraction, and pulse amplification. A microcontroller is used for counting the pulse rate and controlling a LED display. The microcontroller is programmed by developing an algorithm to count the pulse rate. Once a signal is detected, the algorithm will be executed according to the defined flow chart. The performance of the HRM device is tested with the output of ECG for some patients for its accuracy [2].

An alert system for detecting heart beat rate with integrated GSM modem is proposed. The heart beat rate is detected using a band consisting of LDR and LED and finger is placed inside the band. AT89S52 microcontroller is used to calculate the heart beat rate per minute and is displayed on a LCD screen. GSM module is used to communicate this data to the doctor or the patient’s relatives via SMS. Thus doctor can monitor the patient’s condition continuously and could suggest earlier precautions for the patient. This will also alert the family members to quickly attend the patient [3].
Photoplethysmography (PPG) is used to measure heart rate of the human body. Plethysmograph an instrument mainly used to determine and register the variations in blood volume or blood flow in the body which occur with every beat of the heart. There are two basic types of photoplethysmography ie. Transmittance and reflectance. Reflectance photoplethysmography is used in this design. The optical sensor used for sensing is TCRT5000. Microcontroller used is PIC16F648A. This device is tested and compared with actual measured heart rate and is checked for accuracy by calculating the error. [4]

This paper describes about the design of simple heart rate monitor system based on Arduino board which displays the output on a LCD display and simultaneously transmits the data to a smart phone via Bluetooth. Unlike the conventional method, the doctor doesn’t need to be present at the time of measuring the heart rate. The system takes the physical input from pulse sensor by placing the patient’s finger on the sensor and then the input is processed by Arduino UNO SMD R3 to count the number of pulses and displaying the output. Interfacing of Bluetooth module Blue LINK-Silver with Arduino board is done to transmit the data that is to be sent to the Bluetooth enabled smartphone. [5]

This work proposes the design and implementation of a single Microcontroller based heart rate measuring device as a means of making monitoring systems cost effective and flexible. The device is compact in size, energy efficient, portable, capable of data storage and well suited for communicating with an external remote device via Bluetooth and cellular communication in case of a medical emergency or routine. It is based on a single Microcontroller chip that utilizes change in amount of reflection of light sensed by a photo transistor. A photo transistor is used to sense the reflected light. Signal received by the photo transistor is very weak and perturbed by high frequency noise. For this signal to be processed in the microcontroller, noise was to be eliminated. The signal level was raised to a satisfactory level so that the spikes coming from the transistor during each time the heart beats can be distinguished properly by the Microcontroller. After noise being properly attenuated, the signal is fed to the Microcontroller where the data processing is done by converting the analog signal to digital signal. It is designed to respond during medical emergencies via Bluetooth and cellular communication. [6]

In the work titled “Microcontroller Based Heart Beat Monitoring and Alerting System”, it explains how a single-chip microcontroller can be used to analyze heart beat rate in real-time. In addition, it allows doctors to get the heart beat and location of the patient by GSM every twenty-four hours. The hardware design is based on an embedded system implementation using the PIC16F877 microcontroller from microchip. This system consists of Microcontroller, heart beat sensor, GSM modem, GPS receiver. For measuring Heartbeat, input is taken from the finger. Heart beat sensor will generate digital pulse corresponding to each beat. This pulse is counted by interfacing heart beat sensor to microcontroller to pin no. 15 and programming the microcontroller in counter mode. After counting of pulse for one minute, value of heart beat will be displayed on LCD and if value is beyond the normal range then location of patient will be messaged to doctor or health attendant personnel using GSM. [7]

This paper demonstrates the design of a Pulse Oximeter using 8 bit Atmel Microcontroller. The Oxygen Saturation of blood (SpO2) and Pulse Rate are the two important parameters for monitoring patient’s health condition. The method that has been used to measure pulse rate is widely known as photoplethysmography (PPG). The Pulse Oximeter is one of the
medical device used to measure SpO2 and pulse rate of a person and its readings is analyzed using developed algorithm. The proposed system consists of Fingertip sensor, Analog device, 8 bit Atmel Microcontroller circuit and display unit (PC). The oxygen saturation of blood can be calculated by measuring different intensities of red and infrared lights operating at different wavelengths of 660nm and 940nm. The pulse rate can be calculated by measuring the peaks of IR signal between the elapsed time. All these parameters are measured and then transferred to PC via Bluetooth for displaying the results. [8]

### III. PROPOSED DESIGN

![Block Diagram of the proposed system](image)

Figure 1 shows the block diagram of the complete system.

#### A. Finger Tip Sensor –

![Arrangement of Fingertip sensors](image)

The sensor unit consists of an infrared light-emitting-diode (IR LED) (940nm) and a Red Led (660nm) and a photo diode placed side by side and the fingertip is placed over the sensor assembly as shown in the figure above. The IR LED transmits an infrared light into the fingertip, a part of which is reflected back from the blood inside the finger arteries. The photo diode senses the portion of the light that is reflected back. The intensity of reflected light depends upon the blood
volume inside the fingertip. So, every time the heart beats the amount of reflected infrared light changes, which can be detected by the photo diode [10]. Plethysmograph is an instrument mainly used to determine and register the variations in blood volume or blood flow in the body which occur with every beat of the heart. The change in blood volume is synchronous to the heart beat, so it can be used to detect heart rate.

Photoplethysmography is just a means of plethysmography that uses optical techniques. There are two basic types of photoplethysmography i.e. transmittance and reflectance.

Reflectance photoplethysmography:- A light source and a light detector are placed on the same side of a body part.

Transmittance photoplethysmography:- In this light source and light detector are placed on the opposite side of the body part [4].

The PPG signal consists of different components like AC and DC due to arteries, blood volume, skin, tissues, muscles, blood vessels etc. and noise which are caused by motion artifacts, respiration rate, thickness of the skin etc. Absorption of light takes place due to oxygenated blood and deoxygenated blood. Oxygenated blood contains different light absorption characteristics due to arterial blood vessels (called AC component) than deoxygenated blood, because light absorption characteristics due to skin, tissue or muscle remains constant under red and infrared wavelengths of deoxygenated blood (called DC component) [8].

AC and DC component from each of the LED is calculated in the measurement. Oxygen Saturation (SpO2) in the blood can be calculated using the following formula

$$SpO2 = 110-(25*R)\% \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots$$  (1)

Where R is ratio between AC component and DC component of red and infrared light. Therefore by using a single medical device both oxygen saturation and Pulse rate of a volunteer can be measured [8].
B. Temperature Measuring Unit –

This temperature sensor is an analog sensor which produces an analog voltage by sensing the temperature. This sensor is held by the finger for a while (about 15 sec) in order to measure the body temperature. The electrical output voltage of LM35 is linearly proportional to the celsius or centigrade temperature. Reason for using LM35 is that it accurately measures the temperature in comparison to thermistor and it is not subjected to oxidation as the sensor circuitry is sealed. The low output impedance, linear output and precise inherent calibration of the LM35 make its interfacing to control circuitry very easy.

LM35 is rated to operate over a -55°C to +150°C temperature range. The output voltage varies by 10 mV in response to every °C rise/fall in ambient temperature, i.e. its scale factor is 0.01 V/ °C. The output pin of LM35 is connected to the PIC18F4520 at port A for further processing. The microcontroller has ADC in it and it keeps the digital data in the memory [2].

C. Signal Conditioning and Filtering –

The photodiode detects the infra-red light reflected by the finger and generates a pulse at the output of the photodiode. The signal produced by the photodiode is very small and weak and cannot be detected by the microcontroller directly. Thus this signal is amplified using an operational amplifier LM358.

This operational amplifier is provided with two of the independent high gain, frequency compensated operational amplifier which is designed to function from a single supply over a wide range of voltages which means that this amplifier is capable of amplifying the signal in two stages making the device able to detect the signal and in turn measure the heartbeat. The signal generated from the photo diode also contains noise which is required to be filtered. Also the interference produced due to the movement of artefacts and the mains supply of 50Hz can also affect the signal. A low pass filter can be used to block higher frequency noise components that are present in the signal [2].

D. PIC 18F4520 Microcontroller-

PIC 18F4520 Microcontroller used is a 40 pin I.C. It is used for analog to digital conversion purpose as well as for counting the heart rate of human body and displaying it on different forms of displays. In this design output of LM
35 sensor is connected to any one of the analog input channels (RA0 pin) which gives the digital temperature in °C as output. Signal detected from the fingertip sensor after amplification and filtering is given to the microcontroller for counting the number of pulses using a counting algorithm.

E. GSM Module –

The GSM module used in this project is SIM 900A. It is a quad-band GSM/GPRS engine that works on frequencies GSM 850Hz, EGS 900MHz, DCS 1800MHz and PCS 1900MHz. This module has a 68-PIN SMT Pad which provides all hardware interfaces between the module and the customer board. It consists of a serial port and a debug port that can help users to easily develop the user’s applications. The SPI and Keypad display gives the flexibility to develop customized applications. Moreover, this module comes with power saving technique so that the consumption of current is as low as 1.5 mA during sleep mode. The SMS storage is on SIM card. The sim interface supports a SIM card of 1.8V and 3V. The physical characteristics include the size of 24mm x 24mm x 3mm. The weight of this module is 3.4g [14].

Basically this GSM Module SIM 900A is used for displaying the body related parameters like heart rate, Oxygen saturation and Body Temperature to the mobile phones of medical experts and patient’s relatives. Thus sitting at any remote location doctor can monitor the patient’s condition.

IV. RESULTS

We have interfaced LM 35 Temperature sensor with PIC 18F4520 microcontroller and displayed it on 16x2 LCD display.
LM 35 temperature sensor is analog in nature which means that it gives a voltage output that varies directly and linearly with the sensed quantity. In this sensor, the output voltage is 10mV Per Degree Centigrade. For example if output is 300Mv then the temperature is 30 degrees. When this interfacing was implemented at the output we got 30 °C.

V. CONCLUSION

This research led to the development of a system which measured heartbeat, oxygen saturation in the blood and temperature of a patient and sent it to a remote end by the use of a microcontroller at a reasonable cost with great effect. It utilized remote patient monitoring system technology which enabled the monitoring of patients outside of clinical settings and leads to increasing access to health care as well as decreasing the health care delivery costs. Accuracy will be tested by comparing these parameters with actual measured ones. By measuring the heart rate we can predict the type of heart rate condition of the person.
REFERENCES


