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An Experimental Study and Design of A System and App To Measure Pulse Rate

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Abstract—The amalgamation of electronics with healthcare has been an inevitable and positive development that continues to aid people in leading longer and healthier lives. However, one of the major obstacles facing the penetration of these facilities into the third tier cities and villages in India is the cost that these systems entail. The research work aimed to provide a platform for economical and easy access to the usage of such devices. It entails the calculation of pulse rate of human beings using an oximeter probe and interpretation of the results obtained via a mobile application, thereby eliminating the need for expensive interpreters such as ECG machines. Further, information derived from these devices could be used as further health indicators like haemoglobin count and glucose levels. In this paper, the pulse rate is measured using a pulse oximeter probe. The photo detector current signals from the oximeter probe are converted to voltage. The signal is then processed by filtering out noise and by amplification. The microcontroller is responsible for peak detection and calculation of number of peaks in the processed signal. The result in beats per minute is displayed on a user friendly Graphical User Interface along with the interpretation of the reading. The results were then tested for accuracy.

Keywords-Pulse rate measurement, ECG, Oximeter, Microcontroller.

I. INTRODUCTION

THE heart rate is typically a measurement of the number of poundings of the heart per unit time (bpm). It is an indication of the soundness of the heart. Certain patients require continuous monitoring of heart rate. Also, several other activities and diseases can provoke a change in the heart rate. ECG, PCG, blood pressure wave forms and pulse meters are the clinical devices widely used for heart rate measurement. These devices are accurate but they are expensive, unhandy, and not built for domestic use [1]. Under such circumstances, a reliable, accurate, relatively inexpensive and portable device for measuring heart rate is the need of the hour. Pulse oximetry is a non-invasive method of measuring heart rate which is based on photo-plethysmographic pulses in two wavelengths, generally in the red and infrared regions [2].

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It is a procedure used to measure the oxygen level (or oxygen saturation) in the blood. It is considered to be a noninvasive, painless, general indicator of oxygen delivery to the peripheral tissues (such as the finger, earlobe, or nose). A subject's fingertip is exposed to monochromatic light (LED). Depending on the concentration of blood components (oxygen level), light is absorbed accordingly. The reflected light is then measured for further analysis. The absorption of light is dependent on the concentration of blood components (oxygen level) and also on the wavelength of light.[3] Using this concept of pulse oximetry, a device is designed to measure the heart beats per minute along with an app to provide a user friendly interface for the subject. Traditionally, the heart rate is measured using devices like ECG and PCG in clinical environments. These devices have a high level of accuracy but as discussed previously, they are difficult to operate for non-medical personnel and are not meant for domestic use. The system designed here tries to address these problems by being a portable device along with a user friendly app. With the help of this device, people who have to monitor their heart rate regularly will no longer need to make trips to their physician for a simple heart rate measurement. The proposed work has a lot of application in future in medical field. M.M.A. Hashem and et al in their paper "Design and Development of a Heart Rate Measuring Device using Fingertip" have briefly discussed the working principles and design of an economical and user friendly heart rate monitoring device. The proposed device uses optical technology to detect the flow of blood through the index finger. Pulses are detected using three phases: pulse detection, signal extraction and pulse amplification [4].

A. Pulse Rate

Heart rate or pulse rate is a measure of the speed at which the heart beats. It is measured in beats per minute (bpm). It is an indication of the soundness of heart and helps in assessing the health of the cardiovascular system. The normal resting adult human heart rate ranges from 50-70 bpm for men, 60-80 bpm for women. Bradycardia is a slow heart rate, defined as below 60 bpm. Tachycardia is a fast heart rate, defined as above 100 bpm at rest. Arrhythmia is a condition when the heart is not beating in a regular pattern. Such irregularities are caused by diseases. Other factors such as physical exercise, sleep, anxiety, stress, illness, and drugs can also cause variations in the heart rate.

B. Pulse Oximetry

The principle of pulse oximetry is based on the red and infrared light absorption characteristics of oxygenated and deoxygenated haemoglobin. Oxy-haemoglobin absorbs more infrared light and allows more red light to pass through.

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Deoxy-haemoglobin absorbs more red light and allows more infrared light to pass through. Red light lies in the 660 wavelength band and IR light lies in the 940nm wavelength band [5,6]. The current work uses only red light of the pulse oximeter, as only this is required to measure the pulse rate.

II. METHODOLOGY

The block diagram of the proposed system is shown in Figure 1. There are four main components in the system, namely Measurement system, Microcontroller Unit, Graphical User Interface & Blue tooth Module.

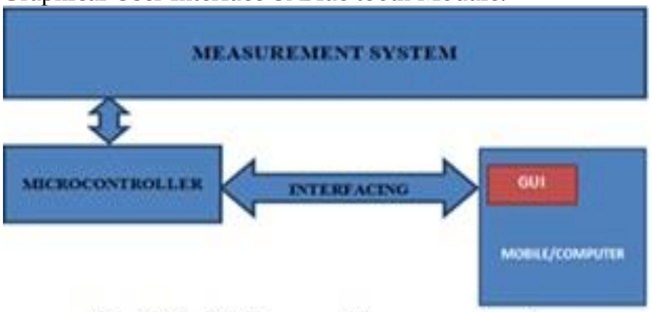

Fig.1. Block Diagram of the proposed system

2. A. Measurement system

Figure 2 shows the measurement system. It consists of oximeter probe, detection, filtering and amplification circuits. The amount of light passed through the measuring sites (subject's finger) is measured using the measurement system. The LED and Photo detector are placed opposite to each other in the oximeter probe [7]. When a subject places his finger in the probe, the pulsatile flow of the blood causes variations in the output current. The Photodetector generates a current proportional to the intensity of light absorbed by it. In oximeter probe, the photodiode's voltage response to incident light is more linear as compared to the current response. Hence an I-V converter is required. The current thus obtained from the Photodetector is fed to the current to voltage convertor. In this work IC LM 358 operational amplifier has been used for this task.

$$V_0 = I_d R_f \qquad (1)$$

The equation (1) shows the Input- Output relationship of I-V convertor. V_0 in the equation is the output voltage of I-V convertor which is proportional to the Photodetector current (I_d). R_f is the feedback resistor which is also equal to the transimpedence gain. Output of I-V convertor is passed through a band pass filter to eliminate the noise [8].

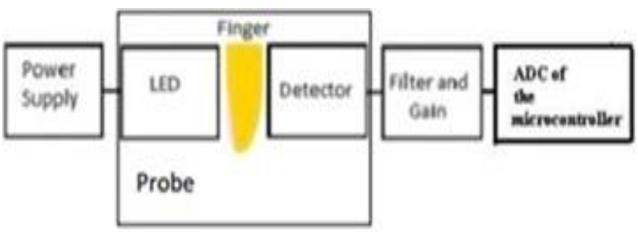

Fig.2.Measurement System

2. B. Microcontroller Unit

The measurement system provides a filtered Output signal which will be fed to the Microcontroller for further calculations. In this work, AVR ATmega 16 development board has been used [9,10,11]. The Microcontroller is programmed using USB programmer. Fig.3 shows the flow chart of the Microcontroller program. This program counts the pulses which it receives from the measurement system. The entire pulse rate measurement system can be enabled using Graphical User Interface (GUI), which is explained in the next section.

The programs starts off with the initialization of 2 variables bpm(beats per minute) and tcnt_cnt(variable to store TCNT count value). USART baud rate is initialized as 19200 for both, the microcontroller and the GUI to carry out an error-free wireless communication. Timer/counter1 is initialized to zero. Now, this counter is programmed to count incoming external pulses detected on T1(PB1 pin) of the microcontroller. The output of the measurement system is fed to the T1 pin. As soon as the start command is received from the user via the GUI, the counter starts counting the number of pulses and stores this value in tcnt_cnt variable. This process is carried out for a period of 1 minute after which the counter stops counting. The final beats per minute(bpm) value is transmitted via USART to the GUI by the Bluetooth Module.

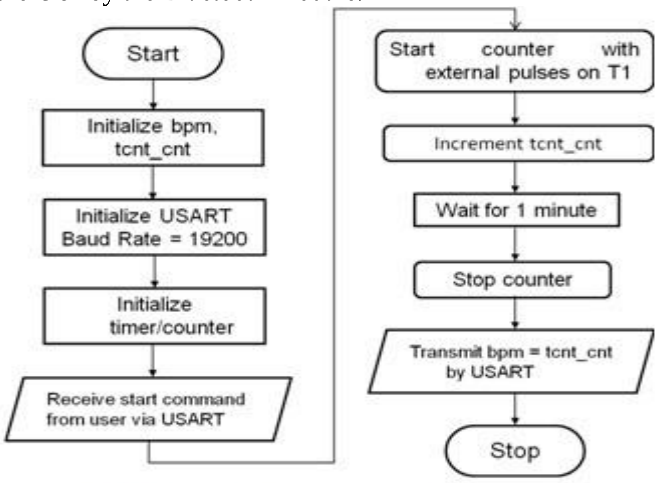

Fig 3: Flowchart of the Microcontroller Program

2. C. Graphical User Interface (GUI) using Visual Basic (VB)

This project makes use of Visual Studio Express 2012 for creating the GUI. Visual Studio Express 2012 IDE comprises of few windows: the form window, the code window, the solution explorer window and the properties window. VB consists of a tool box which contains many useful controls that allows the programmer to develop VB programmers.

In this work, the serial code control is used to communicate with the Microcontroller via a Bluetooth module to send the start and stop commands as well as to display the final heart rate reading [12,13]. Figure 4 shows the screenshot of the Graphical User Interface. "Measure My Pulse Rate" button is created in the GUI for sending the character to the Microcontroller using serial port control via the COM port. The baud rate for the serial port is set as 19200. The "Measure My Pulse Rate" button triggers a timer to start the measurement system and the progress of which is indicated to the user through a progress bar in the GUI.

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The Microcontroller has been programmed to work as a timer for one minute in order to count the heart beats of the user. This count is then sent back to the interface for the display.

The GUI also has the text box which shows the heart beat range (Low, Normal or High) depending on the selected gender.

Fig. 4: Screenshot of Graphical User Interface

2. D. Bluetooth Communication

User can communicate with the entire proposed system wirelessly using desktop/laptop. The Bluetooth module HC-05 has been used for the wireless communication.

III. RESULTANALYSIS

This chapter discusses the results attained in the entire course of the project. The results have been analyzed and their significance has been explained.

3. A. Testing of Oximeter Probe

As part of the initial testing of the probe, varying levels of voltages were given to the Red LED. The LED started glowing at around 1.8V and increase in intensity as the voltage level was increased.

Table 1 shows the difference in voltages across the photo detector in finger-in and finger-out condition. Finger out condition is when there is no finger-tip in the probe. Finger-in condition is that condition when the finger is inside the probe, between the LED and the photo sensor. In finger-out condition all the light emitted by the LED reaches the photo detector resulting in higher photo detector voltage as compared to finger-in condition where only the light that is unabsorbed by the finger reaches the photo detector. The table is thus a clear demonstration of Beer-Lambert's Law.

TABLE 1.COMPARISON OF PHOTODETECTOR VOLTAGES

LED (v)	Photo detector Voltage	
	Finger out	**Finger in**
1.5 V	140 mV	0.03 V
2 V	0.44 V	0.28 V
2.5 V	0.42 V	0.27 V
3 V	0.38 V	0.26 V
3.5 V	0.31 V	0.23 V

3. B. Graphical User Interface

The GUI is designed on Visual Basic and as the user clicks on 'Measure My Pulse Rate' button, a start command is sent to the microcontroller to start counting the pulses. GUI has been programmed to create various buttons and text boxes for the measurement of heart rate, for the display of heart rate ranges and for the display of patient's history. Figure 5 shows the two waveforms obtained before and after the filtering circuit in the measurement system. First waveform is embedded with noise which is filtered using filtering circuit and waveform below shows the filtered signal. As seen from the waveforms, the second waveform is free of noise. Each section of the waveform in the figure comprises of two peaks corresponding to systolic and diastolic phase of heart.

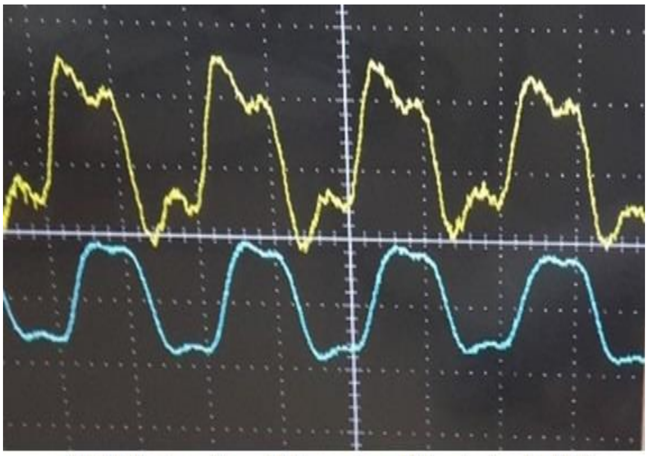

Fig.5: Output waveforms of I-V converter and Filter circuit on the CRO

The program code written for the ATmega16 microcontroller was first tested on the software Proteus 7 Professional. The following Figure 6 depicts the result obtained for implementation of the code for duration of 30 seconds. The code gave accurate results for sine waves as well as square waves given as input to the T1 pin of the microcontroller.

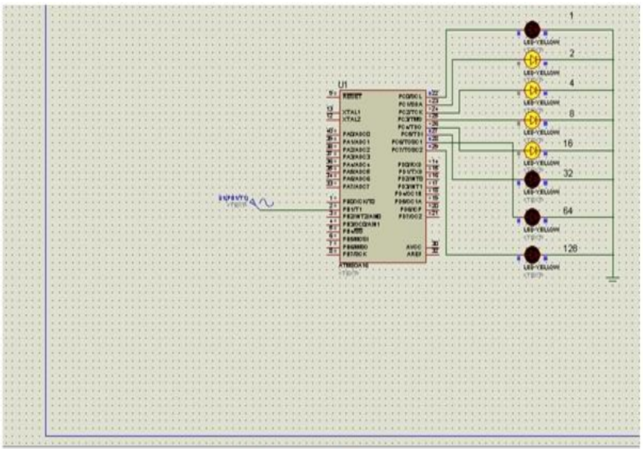

Fig. 6: Result on Proteus

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GUI has been programmed to create various buttons and text boxes for the measurement of heart rate, for the display of heart rate ranges and for the display of patient's history. Table 2 compares the actual readings taken from the help of oximeter with the experimental reading of different subjects. It is clear from the table that percentage error observed was 3.11.

TABLE 2: COMPARISON OF ACTUAL READINGS AND EXPERIMENTAL READINGS.

Age Group	Gender	Experimental Reading	Actual Reading
Below 20	Male	82	84
	Female	78	76
20-30	Male	63	68
	Male	77	75
	Female	78	80
Above 30	Female	89	92
	Male	71	69
	Female	84	83

IV. CONCLUSIONS & FUTURE WORK

The objective of this work was to design and develop an ergonomic heart rate measuring device which made use of optical technology using standard LED and photo-sensor for quick measurements using the index finger which would work on a user friendly app. The goal was to design and implement a device that would prove to be portable, durable and cost effective. Nellcor DS 100 oximeter sensor was powered by the AVR ATmega16 microcontroller, and used for the successful monitoring of the photodetector current signal. The signal was then studied in context of Beer Lambert's law applied in the field of pulse oximetry. The current signals were successfully converted into voltage values using a transimpedance amplifier. The result thus obtained suffered from noise interference and this consequently led to the designing and testing of a filter circuit to eliminate this noise and extract the relevant output signal.

The processed signal was fed back to the AVR micro controller for peak detection and calculation of heart beat rate (in beats per minute). A Graphical User Interface was designed using Visual Basic. The GUI and microcontroller were successfully interfaced via a Bluetooth Module using Serial Communication thus making the device wireless. The GUI was linked to a database to add an additional 'Patient History' feature.

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