Development of An Enhanced Microcontroller Based Heart Rate Measuring Device

ALIYU NUHU SHUAIBU[1], BAMSHAK N. JELTEN[2], PATRICK. N. JULIUS[3], DANJUMA D. DAJAB[4], EMMANUEL K. AKUT[5], MARYAM L. IMAM[6], KISHAK Z. CINFWAT[7], SOLOMON I. MOMOH[8], E. I. FELIX[9]

[1, 2, 3, 4, 5, 6, 7, 8, 9] *Department of Electrical and Electronics Engineering, University of Jos, Nigeria*

Abstract- ***Prevalent of cardiovascular diseases has led to the continuous development of devices and systems that can measure, detect and provides early warning symptoms and cardiovascular abnormalities. Recent studies have shown that cardiovascular diseases are amount the leading causes of death, thus the need to continuously develop systems that will monitor, observe and scrutinize cardiovascular properties such as pulse rate and blood oxygen concentration. In this paper, a non-invasive microcontroller-based oximeter for convenient measuring of heart rate and monitoring of blood oxygen saturation is developed. This will be very helpful to people at high risks of cardiovascular disorder and disease***

Indexed Terms- ***Heart rate, invasive and non-invasive, oximeter***

I. INTRODUCTION

This days, heart disorder and disease are leading causes of death for men, women, and people of most racial and ethnic groups. Global health estimates cardiovascular diseases on the list of top ten causes of annual global death. Regular assessment and constant monitoring of vital cardiovascular parameters, such as heart rate and arterial blood oxygen saturation is fundamental toward prevention, early detection, and treatment of cardiovascular disease.

Heart rate is the number of heartbeats per unit of time, typically expressed as beats per minute (bpm). Heart rate can vary as the body's need to absorb oxygen and excrete carbon dioxide changes during exercise or sleep. The measurement of heart rate is used by medical professionals to assist in the diagnosis and tracking of medical conditions must especially cardiovascular conditions. It is also used by athletes, who are interested in monitoring their heart rate to acquire maximum efficiency. Heart rate indicates the soundness of our heart and help in assessing the condition of cardiovascular system. In clinical environment, heart rate is measured under controlled conditions like blood measurement, heart voice measurement, and Electrocardiogram (ECG) [2]. As a source of information about a subject's physical and affective state, heart rate measurement is of interest to researchers and medical practitioners.

Most heart rate monitoring devices use a design where the signal is acquired from the subject, filtering function is applied to remove noise and high order harmonics from the signal and a hardware or software algorithm that uses a zero-crossing is employed to count the number of beats during a given time interval. The widely use zero-crossing algorithm may result in multiple local zero crossings which could be caused by local noise and might lead to false readings. Early models of heart rate monitor consisted of a monitoring box with a set of electrodes leads attached to the chest [3].

In this paper, the design and construction of a heart rate and blood oxygen concentration measuring system is presented. The system develop uses a non-invasive approach to measure the heart rate and blood oxygen concentration. Non-invasive method of measurement has the advantage of not posing any threat or harm to the user unlike the widely adopted invasive technique.

A. Relevance of Device Design

Heart rate monitoring devices is very useful, and finds applications in a vast area of medicine. From hospital equipment and ambulance equipment. It is also used to monitor out patients, reducing stress, and improving comfortability of delivering medical assistance. With

improvement made on this design, a remote monitoring and emergency alarm system can be included to alert medical personnel in case of emergency.

II. REVIEW OF FUNDAMENTAL CONCEPT

A pulse oximeter is basically a device which can measure pulse and oxygen saturation in the blood. In this section, mechanism of blood oxygenation, the heartrate theory, and the existing technology of measuring heart rate is conceded. Previous related works were review considering their scope, and proposing a solution that could make up for their limitations.

A. Blood Oxygenation

Body cells need oxygen to perform aerobic respiration. Respiration is one of the key ways a cell gains useful energy. The energy released in respiration is used to synthesize the adenosine triphosphate (ATP) to be stored. The energy stored in ATP can then be used to drive processes requiring energy, including biosynthesis, locomotion, or transportation of molecules across cell membranes. Oxygen transportation is performed through the circulatory system. Deoxygenated blood enters the heart where it is pumped to the lungs to be oxygenated. In the oxygenation process, blood passes through the pulmonary alveoli where gas exchange or diffusion occurs. This is illustrated in figure 1. Carbon dioxide (CO2) is released and the blood is oxygenated, afterwards the blood is pumped back to the aorta [4].

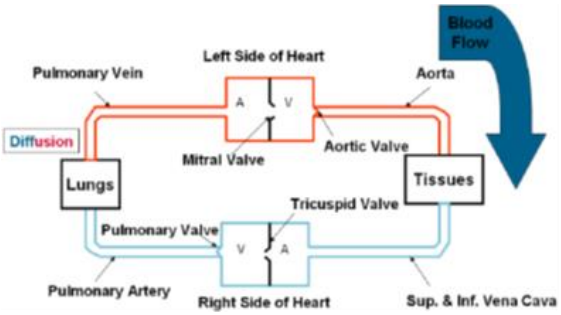

Figure 2: Blood circulation diagram [4]

B. Existing Technology for Heart Rate Monitoring

Most heart rate monitoring devices are design using one of the three widely employed methods, which includes optical, electrical and the radial method. The radial method involves placing finger over the artery which is close to the skin, either on the wrist, throat (carotid), head, or thigh. The heart rate is monitored by estimating pulses as blood flows in the artery. Blood oxygen saturation (SpO_2) is commonly measured by invasively drawing blood samples from the patient. The working and drawback of the various methods is explained in this section.

- Electrical Heart Rate Monitoring Technology

The electrical monitors consist of two elements: a monitor/transmitter, which is worn on a chest strap, and a receiver. When a heartbeat is detected a radio signal is transmitted, which the receiver uses to display/determine the current heart rate. This signal can be a simple radio pulse or a unique coded signal from the chest strap. The chest strap of a heart rate monitor uses electrodes to monitor the electric volts that occur when heart beats. The receiver detects this information from the electrodes via radio signal from the chest strap, the receiver uses this information to determine heart rate. Some monitors also include a "coded signal" which uses a special code in the radio signal, so that the receiver does not receive radio signals from other nearby transmitters. The receive radio signals from other nearby transmitters is not always a huge problem, but can be annoying or corrupt data [5].

Electro-cardiogram (ECG): Is the most widely adopted electrical heart rate monitoring technique to provide correct and reliable values for cardiac monitoring. However, this technique uses an invasive acquisition mode, since it requires the contact between the electrodes and the skin. An incorrect positioning of the electrodes on the skin can induce tissue irritation [6]. Also, electrical heart rate monitoring has the limitation of sometimes given inaccurate results, inconvenient and hectic wired connections over the body.

- Optical Heart Rate Monitoring Technology

Optical technique exploits the fact that tiny subcutaneous blood vessels (capillaries) in any patch of the skin (fingertip, ear lobe, etc.) furnished with a good blood supply, alternately expand and contract in time with the heartbeat. An ordinary infrared LED/phototransistor pair can sense this rhythmic change as small but detectable variations in skin

contrast. This method uses both transmittance and reflectance principles. It is a non-invasive method of finding heart rate i.e., no attachments or insertions on the body. It is precise and cost effective [4].

Photoplethymysography (PPG) is an optical, non-invasive heart rate monitoring method for the detection of cardiovascular pulse waves propagating across the human body. It is based on the determination of optical properties of vascular tissue using a probe, which consists of LED-photodiode configuration. The LEDs run as light emitters and the photodiodes (usually PINs, diode with a wide, lightly doped “near” intrinsic semiconductor region between a p-type semiconductor and an n-type semiconductor region) as light detectors (photo detectors, PDs). The probe can be placed on the periphery of human body, most commonly on a finger or a toe and can operate in reflectance or transmittance mode. The emitted light is reflected, absorbed or scattered by the blood and tissues. The intensity of the light reaching the PD is measured and the variations, caused by blood volume changes, are amplified, filtered and recorded as a voltage signal. This signal is extremely small, subject to noise and in addition to the PD, precise analogue amplifiers, high order filters and analogue-to-digital converters are required. Additional components not only increase the system complexity and cost, but also its size and power consumption. Additionally, the PIN detectors are not ideal as they are not spectrally selective and indiscriminately detect broad spectrum light ranging from near infrared to UV, and all that contributes to the noise and error levels [7].

With the optical method, if the tip of the index finger is pressed too hard over camera or infrared LED/phototransistor pair, the circulation will be cut off which will result in an inaccurate reading. Devices with optical sensors that read the wrist (instead of the fingertip) had the most trouble tracking heart rate because, in this method the light has to penetrate through several layers and so darker the person, the more difficult it is for light to bounce back. The skin color issue is something that this technology compensates for [8].

- Other Heart Rate Monitoring Technology

Other devices in the form of wrist watches are also available for the instantaneous measurement of the heart rate. Such devices include:

1. Wearables with optical heart-rate monitors: This device have small LEDs on their undersides that shines green light onto the skin on your wrist. The different wavelengths of light from these optical emitters interact with the blood flowing through your wrist. When that light refracts (or reflects) off your flowing blood, another sensor in the wearable captures the information. That data can then be processed, along with motion information detected by the device's accelerometer, with algorithms to produce understandable pulse readings.
2. Android based heart rate monitor: This device uses the camera and its flash to determine the user’s heart rate in beats per minute. It uses data smoothing in an Integer array to figure out the average red pixel value in the image. Once it figures out the average it determines a heartbeat when the average red pixel value in the latest image is greater than the smoothed average. [8].

The above methods of heartbeat reading might seem to provide a solution, but these methods have limitation and are not always sustainable. The traditional invasive method of measuring heart rate and blood oxygen level offers a limited solution toward cardiovascular monitoring as it takes a long time to perform, limitation for continuous monitoring and it can be uncomfortable for the patient. Thus, there is a dire need to come up with a safer and non-invasive way of measuring blood oxygen saturation with more accuracy.

C. Review of Related Projects

Reference [9], implemented two PPG based heart rate monitoring systems; the first method used Green LED as a light source whereas the second method used an infrared light emitting diode (IR LED) and a phototransistor instead of Green light source for pulse detection. The project also includes a Bluetooth interface to enable communication between the heart rate monitoring systems and an android phone. This design has the limitation in that the devices design centered on monitoring heart rate alone, blood oxygen level monitoring was not achieved.

Reference [10], developed a reflectance-based pulse oximeter for chest and wrist. Reflectance-based pulse oximetry allows measurements to be taken from areas of the body in which transmittance-based pulse oximetry cannot be applied. In reflectance-based pulse oximetry, the incident light is passed through the skin and is reflected off the subcutaneous tissue and bone.

In their of developing a functional and portable device to detect heart rate, Reference [11] design heart rate measuring device for adults, equipped with a finger sensor and adopting an optical, non-invasive heart rate monitoring method. The design was able to provide good software accuracy, and work of the total system operation. This design has the limitation of not been convenient for children heart rate monitoring.

Heart rate measurements using photoplethysmography was studied by Reference [12]. The work examine photoplethysmography method of measure heart rate. The work highlight that if the tip of the index finger is pressed too hard over camera or infrared LED/phototransistor pair, the circulation will be cut off which will result in an inaccurate reading.

The reviewed work indicate the most design of heart monitoring devices are centered toward monitoring heart rate alone, blood oxygen level monitoring are hardly considered or achieved. There is a need to have all these functionalities in a single system, to reduce cost while increasing the ease of operation as there will be a single system that performs the functions of pulse rate and blood oxygen concentration measurement.

III. PROPOSED SYSTEM

The system proposed in this research comprises of a pulse oximeter that measures pulse rate and blood oxygen concentration in the body. This is an all-in-one solution for measurements of pulse rate and blood oxygen concentration using optical, non-invasive heart rate monitoring method. A microcontroller (ATmega 328) is at the center of the system. The microcontroller receive data from the pulse sensor, process the raw data into reasonable, comprehendible heart rate and blood oxygen values. The pulse sensor consists majorly of a red LED and an IR LED which sends light through the skin, and is reflected by blood, and sensed by the light sensor. An OLED is used to display the results.

A. System Design

Mainly, the implementation consists of two parts: reading the pulse with IR LED only, and calculating SaO2 using both RED and IR LEDs. As shown in the system block diagram of figure 6 below, the design consists of two LEDs emitting light: one in Red spectrum (650nm) and the other one in Infrared (950nm). The sensor is placed on the finger or earlobe, essentially anywhere where the skin is not too thick so both light frequencies can easily penetrate the tissue. Once both of them are shined through the finger for example, the absorption is measured with a photodiode. And depending on the amount of oxygen in the blood the ratio between the absorbed red light and IR led vary. From this ratio it is possible to calculate the oxygen level in the hemoglobin.

The design of this system involves the use of a pulse oximetric sensor to sense heartrate and blood oxygen level, and send the information to a microcontroller illustrated in figures 7. The microcontroller converts these readings to standard units: beats per minute (BPM) for heartrate and SpO_2 for blood oxygen level. These processed values are then displayed on a screen. The heart rate measurement obtained with the device based on age differences is presented in the Table 1.

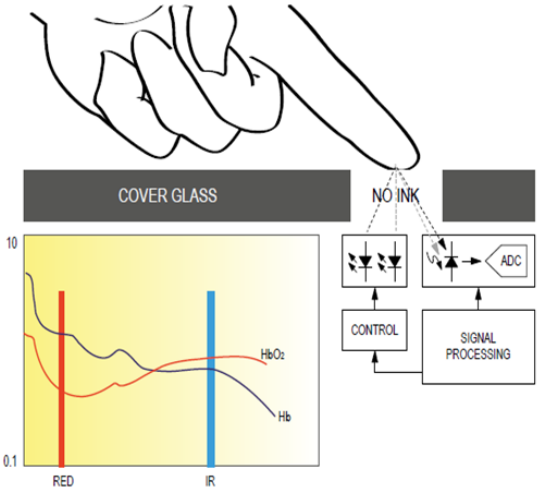

Figure 6: System block diagram

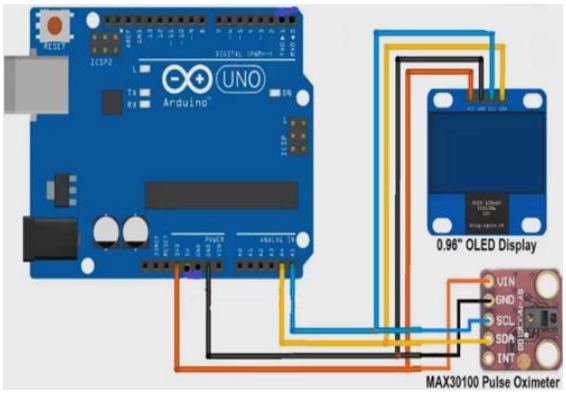

Figure 7: Circuit diagram of the system

Table 1: Normal heart rate measurement obtained with the pulse oximeter.

S/No.	Age Range (Years)	Heart Rate (Bpm)
1.	3 - 5	80 - 120
2.	6 - 10	70 - 110
3.	11 - 14	60 - 105
4.	15 and above	60 - 100

The results obtained in Table 1 was grouped based on four categories of age differences. The recorded heart rates correspond with the conventional heart rate obtained with ECG devices used in hospitals.

CONCLUSION

In this research, the design and developed of a non-invasive heartrate and blood oxygen reading system using embedded systems and pulse sensor techniques is presented. This system measures heartrate efficiently in a short time and with less expense without using time consuming and expensive clinical pulse detection systems. It is a very efficient system and very easy to handle and thus provides great flexibility and serves as a great improvement over other conventional monitoring system.

RECOMMENDATION

The device can be further improved by interfacing various other biomedical sensors with the microcontroller. These sensors should be capable of measuring body temperature, blood pressure and blood sugar level. The data obtained can also be logged and sent through the internet, or any other cloud storage, where doctors can access and monitor.

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