

Heart Rate Monitoring Device

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ABSTRACT: In this paper, we presented the design and development of a new integrated device for measuring heart rate using fingertip to improve estimating the heart rate. As heart related diseases are increasing day by day, the need for an accurate and affordable heart rate measuring device or heart monitor is essential to ensure quality of health. However, most heart rate measuring tools and environments are expensive and do not follow ergonomics. Our proposed Heart Rate Measuring (HRM) device is economical and user friendly and uses 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. Qualitative and quantitative performance evaluation of the device on real signals shows accuracy in heart rate estimation, even under intense of physical activity. We compared the performance of HRM device with Electrocardiogram reports and manual pulse measurement of heartbeat of 90 human subjects of different ages. The results showed that the error rate of the device is negligible.

KEYWORDS: Biomedical; Microcontrollers; Heart Rate Measurement; Pulse Detection; Pulse Amplification; Signal Extraction.

I. INTRODUCTION

Heart rate indicates the soundness of our heart and helps 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) but it can be measured in home environment also. 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 monitor is simply a device that takes a sample of heartbeats and computes the Beats per Minute (BPM) so that the information can easily be used to track heart condition. There are two types of methods to develop heart monitors- electrical and optical methods. The electrical method has an average error of 1 percent and average cost of \$150.00. The optical method has an accuracy rating of 15 percent and an average cost of \$20.

The heart is one of the vital organs of the body, which works by pumping blood to all organs. The heart is located inside the fibrous pericardium. The heart generally has four chambers called the atrium and ventricle, which are divided into left and right. The heart also has four valves called mitral, tricuspid, aorta and pulmonary the first two valves, responsible for controlling the input Blood Flow and the next two valves, control the output blood flow (Figure 1). The heartbeat has two stages of systole and diastole, which is the systole phase of the contraction and diastole phase of the heart resting phase. Electric impulses are produced from the sinus node and released into the heart and emit blood in the organs of the body. Any irregularity in the heart rhythm that affects heartbeat is called arrhythmia, which is divided into two general types of tachycardia and bradycardia. In tachycardia, the heartbeat is fast and in the bradycardia, the heartbeat is slowed down

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. Endure athletes often have very low resting heart rates. Heart rate can be measured by measuring one's pulse. Pulse measurement can be achieved by using specialized medical devices, or by merely pressing one's fingers against an artery (typically on the wrist or the neck). It is generally accepted that listening to heartbeats using a stethoscope, a process known as auscultation, is a more accurate method to measure the heart rate. There are many other methods to measure heart rates like Phonocardiogram (PCG), ECG, blood pressure wave form and pulse meters but these methods are clinical and expensive. There are other cost-effective

methods that are implemented with sensors as proposed in and but they are susceptible to noise and movement of subject and artery.

In this paper, the design and development of a low powered HRM device is presented that provides an accurate reading of the heart rate using optical technology. The device is ergonomic, portable, durable, and cost effective. We incorporated the optical technology using standard Light Emitting Diode (LED) and photo-sensor to measure the heart rate within seconds using index finger. A microcontroller is programmed to count the pulse. The heart rate is digitally displayed on an LCD controlled by the same microcontroller that counts the pulse.

1.1 Motivation

The method of this device is to measure heartbeat with an optical sensor and with infrared light radiation on the fingertip and using a PIC microcontroller. This device displays the different heartbeat values in a maximum, medium, and minimum in a period of time. This device can be connected to a computer and store and analyze the obtained data.

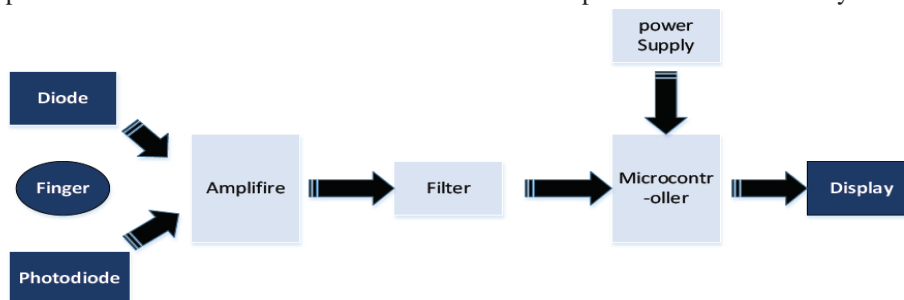


Figure 1: The block diagram of heartbeat measurement.

1.2 Materials & method

As previously mentioned, heartbeat is a unit for counting the intensity of cardiac function, and shows the rate of contraction and expansion of the heart, whose unit is beats per minute (BPM). The heartbeat can be measured by an electrocardiograph device. When blood passes through the heart and enters the veins, a pressure wave is applied to the veins, which causes pulses to arise in the blood vessels. In fact, the pulse is a contraction and expansion in the veins that occurs when the blood passes out of the left ventricle. The pulse can be touched and measured by placing fingers on the points where the vein passes through the bone.⁹ The main points for measuring pulse are radial pulse and carotid pulse which the radial pulse on the wrist and the carotid pulse on the neck.¹⁰ There is also a pulse meter device that can measure the pulse with infrared light to the earlobe. Under normal circumstances, heartbeat is similar to pulse, because pulse rate is related to heartbeat.

II. LITERATURE SURVEY

SumitaMulik et al. In this paper, a low cost and portable method is proposed and implemented to measure heartbeat, blood pressure and temperature from human body using the microcontroller device with LCD output. Heart rate of the subject is measured from the finger using infrared sensors. Blood pressure using wrist band and temperature by temperature sensor. The heart rate is a parameter most significance to medicine, physics and many other fields. The heart rate is closely related to the function and status of the human heart. More than two million people are at high risk of having heart attack. It would be helpful if there was a way for these people to monitor their heart. So, we have a problem. That is the way our project focuses on how we can utilize this problem and find a solution. The heart rate of a person is different depends on the age. The most heart rate measuring tools and environments are expensive and do not follow ergonomics. Here heart is measured by employing the pulse method i.e. blood flow in to the finger.

Bandana Mallick et al. This paper focuses on the heart rate monitoring and alert which is able to monitor the heart beat rate condition of patient. The system determines the heart beat rate per minute and then sends short message service (SMS) alert to the mobile phone. It is portable and cost effective. 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 and alert systems.

Mr. MayureshYeole et al. 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.. 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.

III. SYSTEM OVERVIEW

A. Pulse Detection

A pulse (heartbeat) detector in heart rate monitors consist of the two parts: a pulse sensing unit and a heart rate displaying unit. Our device uses two red LEDs and a photo-sensor to measure ones heart rate through the change of blood reflectivity on the index finger. The power transmitted by the LEDs is matched with the photo sensor in such a way that the resistance will vary within the range of the photo sensor after attenuations through the index finger. Since attenuations vary depending on the person using the device, our specifications assume that the attenuation is, 80 percent, on average, of the light transmitted. Fig. 2 shows a clip sensor which consists of two high intensity LEDs that illuminate the tissue and a Light Detecting Resistor (LDR) whose resistance changes according to the amount of light transmitted from the tissue.

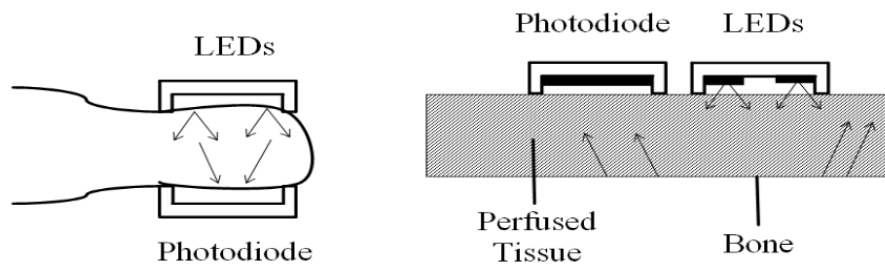


Figure 2. Finger positioning on the HRM device

The LED and LDR are mounted in a spring loaded device that can be clipped into the fingertip. The light emitted by the LED is diffusely scattered through the fingertip tissue. An LDR or photo sensor positioned on the surface of the skin on the opposite side can measure light transmitted through it. Light is absorbed well in blood and weakly absorbed in tissue. Any changes in blood volume will be registered since increasing (or decreasing) volume will cause more or less absorption.

B. Signal Extraction

We used a band pass filter to remove any interference caused by ambient light and level detection distortions. The filter used will have a cutoff frequency of 2.5 Hz to allow a maximum heart rate of 125 BPM to be measured by the device with accuracy. This roll off provides an attenuation of 60Hz, by 23.5dB. The pulse has a -14 dB Signal to Noise Ratio (SNR) before it passes through the filter. The pass-band frequencies are amplified by a factor of 40 dB with a small signal amplifier.

C. Pulse Amplification

The extracted signal is analyzed by an amplifier to provide a pulse of high amplitude to be fed into the microcontroller input. The amplifier detects the peak of each pulse and creates a corresponding pulse of high amplitude. The time between each successive rising of high amplitude pulse edge is interpreted by the microcontroller as the period between each heart pulse. To detect signal amplification an LM358 is used and the heart signal is amplified twice after passing through band pass filter (Fig. 3). Finally, we get the amplified output that the microcontroller uses it as its input and calculates the heart rate.

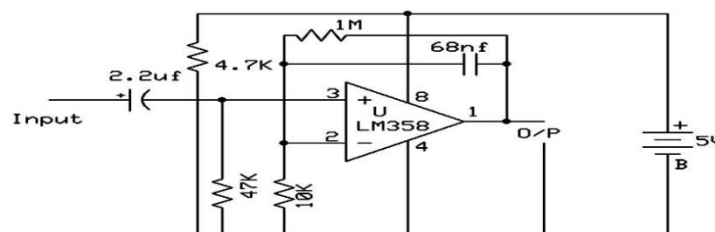


Figure 3. Portion of the pulse amplifier circuit

D. Physical Properties

The heart rate is displayed on an LCD controlled by a microcontroller. As improper finger placement may take place, a flashing segment on the LCD will be used to help the user identify when a heart rate is measured. A character LCD is used to show the formatted result of heart rate. The accuracy of our device is controlled primarily by the amount of

time used to average the pulse rate from the user. The more time used means more samples and thus greater accuracy. Our device uses a method that has a dynamic time for pulse gathering. The pulse is averaged after a set number of pulses are obtained, five in our case, by the microcontroller. This allows a better distribution of accuracy over the range of pulses that can be measured by the device. The battery should last one year under normal use; however, this will vary based on the use. Typical usage of 15 minutes per day will allow the device to operate for two months. The package is small and lightweight and hence portable.

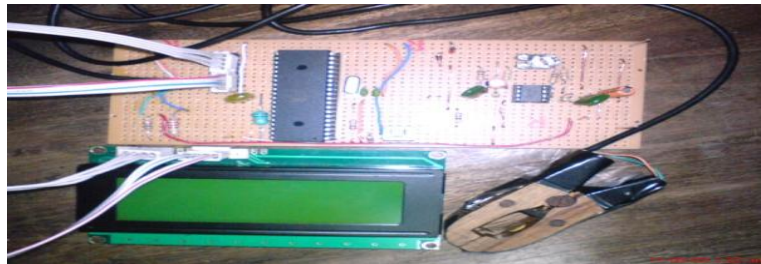


Figure 4. Physical appearance of HRM device

IV. METHODOLOGY

A. Optical Transmitter and Receiver Circuit

HRM measures the pulse rate through changes of blood flow through an index finger. Each pulse of blood from the heart increases the density of blood in the finger pulsatile tissue and causes a decrease in light power received by the photo-sensor. The circuit in Fig. 5 shows our pulse -rate to voltage converter and our source of constant red light that is designed and constructed to gather real-world data. The red LED is forward biased through a resistor to create a current flow. The calculated value is approximated to a resistance value that is commonly available. The photo-resistor is placed in series with a resistor to reduce the current drawn by the detection system and to prevent shorting the power supply when no light is detected by the photo resistor.

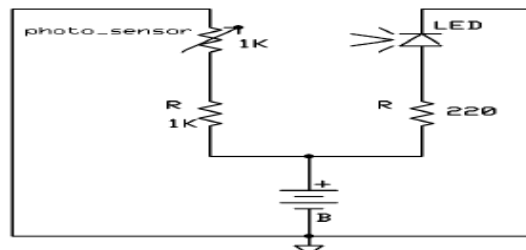


Figure 5. Pulse receiving circuit used in HRM device

B. Amplification of Pulse Rate Signal

To let the microcontroller counting the pulse rate, the signal must be amplified. An amplifier is used to find rising edges of the filtered signal received by the photo-sensor. This allows one pin of the microcontroller to be used as an n input. The time between rising pulse edges is determined by the microcontroller so that the frequency of the heart rate can be measured. The designed circuit is shown in Fig. 6. The signal frequencies are boxed in by movement artifacts at the low end (generated by the peg moving and distorting the underlying tissues; light pegs are better) and at the top end by mains-hum interference.

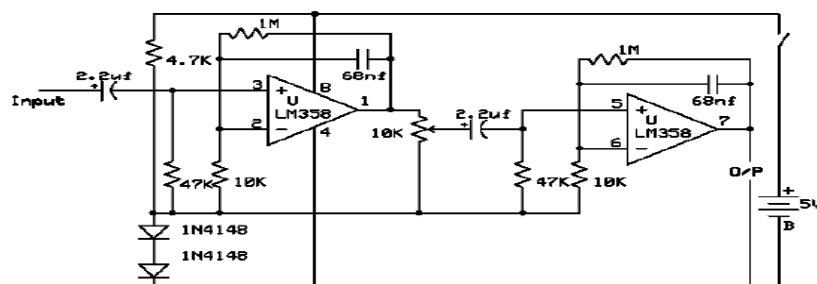


Figure 6. Amplifier Circuit used in HRM device

C. Microcontroller

A microcontroller is an economical means of counting the pulse rate and controlling a LED display. The displays are set and refreshed by multiplexing the segment lines to the same I/O pins on the microcontroller. Programming the microcontroller involves developing a calculation algorithm to count the pulse rate. The calculation algorithm for counting the pulse rate will be easy to develop using Firmware. The microcontroller will continuously be checking if a signal is fed into it. Once a signal is detected, the algorithm will begin according to the flow chart in Fig. 7.

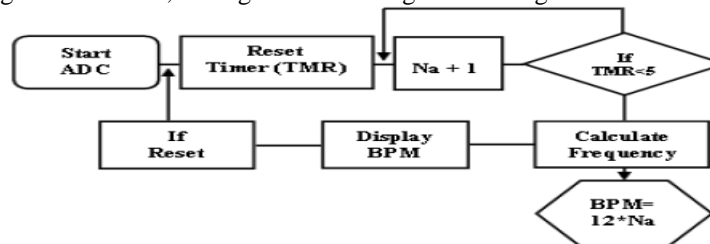


Figure 7. Algorithm for detecting pulse rate

Once each stage of the design has been simulated to prove their unit efficiency, they are integrated and in Fig. 8, the working principle is illustrated.

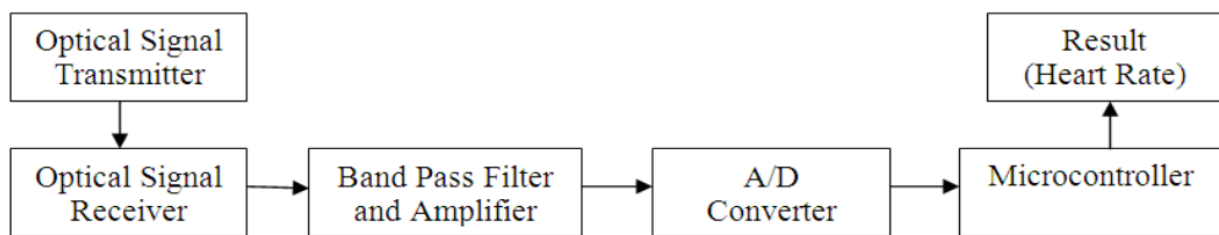
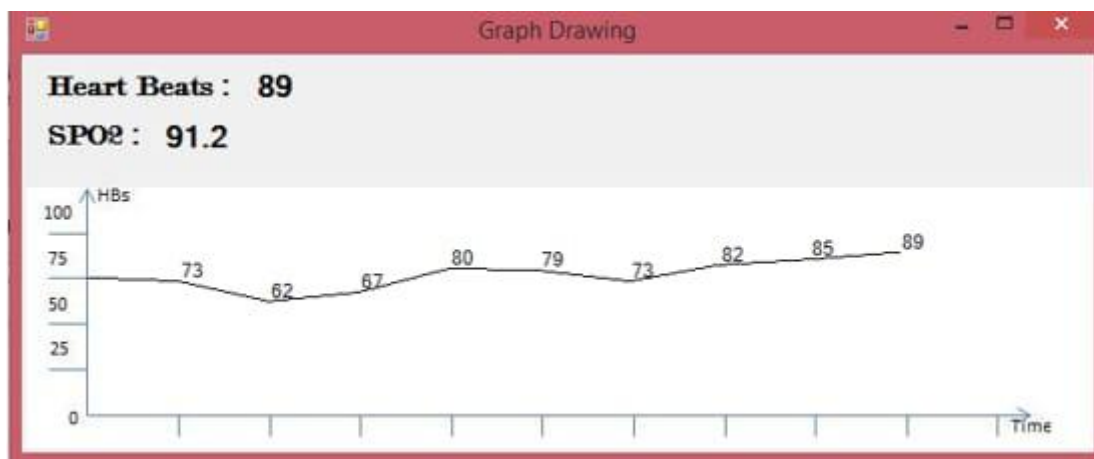


Figure 8. Working principle of HRM device

V. RESULTS



VI. CONCLUSIONS

In this paper, the design and development of a Heart Rate Measuring device is presented that measures the heart rate efficiently in a short time and with less expense without using time consuming and expensive clinical pulse detection systems. Both analog and digital signal processing techniques are combined to keep the device simple and to efficiently suppress the disturbance in signals. Simulations showed that heart rate can be detected from changes of blood flow through an index finger.



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