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An Embedded System for Monitoring Pulse Rate during Indoor Exercise

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Abstract—*In this paper we have presented the design, testing and results of a low cost heart beat rate measuring device. The proposed device is works on optical properties. Our system is non-invasive in nature and able to measure heart beat rate during different physical activities. We have developed an algorithm for counting the heart beat rate. The device can measure the heart beat rate in the interval of 5 second. The heart beat rate counted by the microcontroller has displayed in a LCD continuously. We have also measured the heart beat rate using a treadmill at different speed and compared with the result given by our device.*

1. INTRODUCTION

Heart beat rate (HBR) is the cardiac cycle per minute or beats per minute (bpm). The average HBR of adult person in rest is 72 bpm. Normal HBR of resting adult person lies between 60-100 bpm. The abnormality disease of HBR less than 60 bpm is called Bradycardia, above 100 bpm is called Tachycardia. Heart diseases occurs due to age, increasing blood sugar level, family history, lack of physical activity, social change, drug addiction etc.[1-7]. We can use a Treadmill as an exercise machine for walking or running at home regularly which provides a moving platform with a wide conveyor belt. Treadmill can be driven by electrically using a motor or manually [3, 7]. We can be aware of any heart related issues by checking the HBR regularly. For measuring the HBR we can use different portable device as well as a smartphone [11]. A treadmill can display the HBR at different speed while we are exercising on it [7-9].

2. WORKING PRINCIPLE

There are many handheld, portable devices are available in market using which we can easily obtain and check the HBR regularly by ourselves. Some smartphones also can measure the HBR using the inbuilt camera and flash light through dedicated application. Mainly there are two techniques to obtain the HBR namely, (a) Electrocardiography (ECG), and (b) Photoplethysomography (PPG). ECG uses two or more electrodes for measuring the HBR from the electrical changes occurs in our body [7]. It is used for medical purpose. PPG uses optical techniques for obtaining the HBR. The PPG signal can be obtained from our fingertip, earlobe etc. and using a data acquisition system we can process, calculate and display the HBR value.

3. PREVIOUS WORKS

In 2003, Q. George had proposed a HBR monitoring system using signal processing and Artificial Neural Network (ANN) techniques to detect and classify five cardiac conditions. He used real time processing, intelligence, cost effectiveness and efficient use of the ECG diagnostic system. He suggested the use of diagnostic medical systems remotely for diagnosing at home [1].

In 2008, Cheng, Savkin, Celler, Su, and Wang had described a nonlinear input–output relationship between the treadmill speed and the HBR. They employed a controller to regulate the HBR with well-defined input signal which is related to the predefined HBR value [2].

In 2009, Antonio Cuesta-Vargas, Jeronimo Carmelo Garcia-Romero, Raija Kuisma had studied the resting and maximum HBR in treadmill and deep-water running for male volleyball players [3].

In 2010, I. Dogan and B. Kadri had described the design of a simple, low-cost HBR measuring device using PIC16F84 microcontroller [4].

In 2010, M. Hashem, R. Shams, M. Kader and M. Sayed had presented the design and development using integrated microcontroller for obtaining the HBR from fingertip [5].

In 2011, F. Sharief, L. E. Abdel-Khair and S. M. Elbasheer had proposed a microcontroller based HBR monitor using fingertip sensors. The microcontroller acquires the signal and removes the zero-crossing problems of the digital signal which is obtained by Fourier transformation. He also employed one audible alarm to indicate the HBR status [6].

In 2015, C. R. Greeshma, Dr. N. P Ananthamoorthy had proposed a system to control the speed of treadmill automatically w.r.t. a person's HBR. This system is very helpful for the person who is suffering from heart disease [7].

In 2016, D. Ghose, V. Prasad, A. Singh had designed a treadmill exercise system which can control the speed of the treadmill comparing with the predefined HBR of a person [8].

In 2016, M. M. Asheghan, J. Míguez had studied the Stability and control of the HBR during treadmill exercise [9].

In 2016, L. C. Keat, A. B. Jambek, and U. Hashim had proposed a HBR measuring device using Nios II Soft-core Processor. The microprocessor signal flow is observed and analysed using Signal Tap II software from Quartus [10].

4. THE OBJECTIVE AND METHODOLOGY

We have proposed a system based on the PPG light reflection technique for measuring the HBR using infra-red (IR) light emitting diode (LED) and IR detector. In this method changes of light intensity is measured which is detected by the IR detector. As we place our finger over the sensor the IR LED emits light. Light can passes through the fingertip and some fraction of light reflects back which varies with the heartbeat. The reflected signal intensity varies person to person which results the HBR.

5. HARDWARE SETUP

The proposed method has been illustrated in the block diagram as shown in **Fig. 1**.We have used one optical sensor (TCRT 5000, Vishay Semiconductors) to acquire the PPG pulse from the fingertip. This compact integrated circuit has an IR emitter and a phototransistor. The detected signal is very week and noisy. The noise sources are other sources of light, motion of arms, power supply noise etc. To remove the unwanted signal components a low pass filter with cut off frequency 2.4 Hz has employed. Then the required signal has been amplified using an amplifier with gain 100. We have used a double stage amplifier with overall gain ~10^4. The amplified PPG signal is converted to digital form using a comparator. The operational amplifier (IC 741) has been used to design the amplifier and the comparator. The sensor and the amplifier hardware connection are shown in **Fig. 2**. The comparator gives logic high or low level output comparing the input signal with a reference signal as shown in **Fig.3**. The digital output is fed to a 8051 µC as shown in **Fig.4** for processing and calculating the HBR where Timer 1 calculates the pulse while Timer 0 generates the delay. We have developed one algorithm of 5 sec duration to calculate the PPG pulse obtained from the fingertip during this interval. The HBR value per minute can be obtained by multiplying the result by 12. The PPG signal and the comparator output has been displayed in a Digital Phosphor Oscilloscope (DPO, Model: Tektronix, 4102B-L) and the HBR is displayed using LCD (JHD162A). Again we have used a manual treadmill (Aerofit, Model: AF-902M) for HBR monitoring during physical activities e.g. walking, running as shown in **Fig.5**. The treadmill has a 5 LCD display unit which is able to display time, speed, calorie, pulse and distance while we walk or run on it as shown in **Fig.6**.

6. SOFTWARE ALGORITHM

The algorithm used for calculating the HBR is given below:

Algorithm:

Step1: Start

Step2: Initialization

Step3: Set timer 1 high

Step4: Generate 5sec delay

Step5: Start timing and counting

Step6: Stop counting after 5sec

Step7: Multiply the result by 12

Step8: Convert the result from Hexadecimal to Decimal and Decimal to ASCII

Step9: Display

Step10: Repeat again

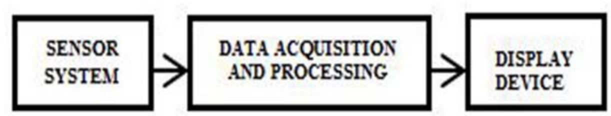

Fig. 1: Functional block diagram of the proposed system

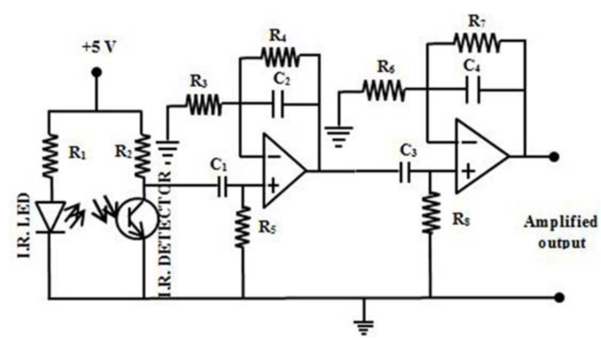

Fig. 2: Schematic of Sensor and Amplifier circuit

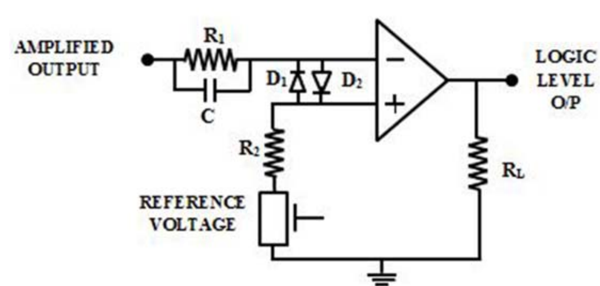

Fig.3. Schematic of comparator circuit

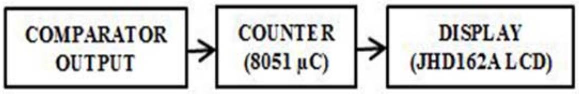

Fig. 4: Interfacing block diagram

Fig. 5: Snapshot of the Treadmill

Fig.6. 5 LCD display unit of the treadmill

7. RESULT AND DISCUSSION

We have taken the readings using our proposed device as well as a treadmill. The PPG signal vs. the

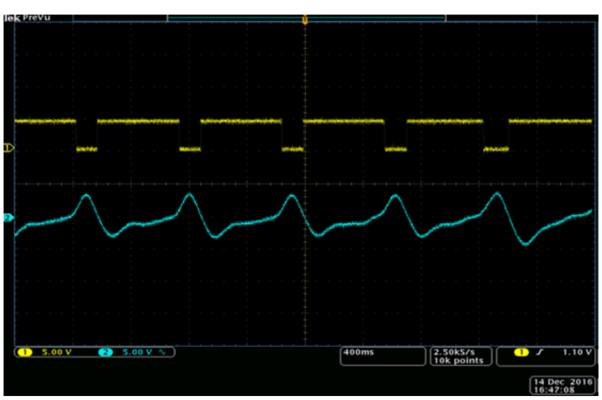

Fig. 7: Snapshot of sensor output taken from the DPO

Fig. 8: Snapshot of the LCD

comparator output has been displayed in **Fig.7**. The HBR displayed in LCD is shown in **Fig.8**. The HBR measured at different speed using treadmill and the proposed system is given in **Table 1**.

Table 1: HBR measured at different speed

Sl. No.	SPEED (Km/Hr)	HBR (Treadmill)	HBR (Proposed device)
1	1.2	62	60
2	1.8	65	60
3	2.5	70	72
4	2.8	72	72
5	3	73	72
6	3.5	75	84
7	4	78	84
8	4.2	80	84
9	4.5	85	96
10	5	90	96

8. CONCLUSION AND FURTHER IMPROVEMENT

In the present study of our proposed system we have displayed the HBR at rest as well as in motion. The HBR increases gradually as we increase our speed on the treadmill. After we stop it starts falling towards the normal HBR. The proposed system has affected by noise and became unstable due to motion. A proper filter should be employed to remove the motion effects.

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