A Non Invasive Method for Calculating Calories Burned during Exercise using Heartbeat

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Abstract— **In this paper, we presented the novel design and development of a non-invasive new integrated device for measuring calories burnt from the heart rate in Arduino environment. By using the heart rate, a relation for calories burnt will be calculated. As obese people are most concerned about losing their weight, they regularly need to check the weight they lose during exercises. This calorie estimator helps in calculating calories burnt by using raise in heartbeat during am exercise. In this project, heart rate is measured using Heartbeat sensor (IR sensor). However, most heart rate measuring tools and environments are expensive and do not follow ergonomics. Our proposed IR sensor is economical and user friendly and uses optical technology to detect the flow of blood through index finger. In this project, Arduino is used in which microcontroller ATmega328 is embedded into it, suitable codes have been written to detect and count the heartbeat and also to calculate the calories burnt.**

Keywords- **Bio-electronics, Microcontrollers, Arduino, IR sensor, Heartbeat, Calories**.

I. INTRODUCTION

Heart rate specifies the healthiness of our heart and body fitness. Heart rate helps assessing the condition of cardiovascular system [1]. 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. Healthy athletes often have very low resting heart rates. In clinical environment, heart rate is measured under controlled conditions like blood measurement, heart voice measurement [4]. 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 [3]. There are many other methods to measure heart rates like Phonocardiogram (PCG), ECG, blood pressure wave form [5] and pulse meters [6] but these methods are clinical and expensive, but heartbeat can be measured in home environment also using sensors[2].

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.

An IR sensor is simply a device which consists of an IR LED and photo diode. 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. With a high gain amplifier, this little alteration in the amplitude of the reflected light can be converted into a pulse. There are other cost-effective methods that are implemented with sensors as proposed in [7] and [8] but they are susceptible to noise and movement of subject and artery.

In this paper, the design and development of a low powered IR sensor 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. This is given as an input to the microcontroller ATmega328. Microcontroller is programmed to detect and count the pulses. The heart rate thus obtained is used to measure the calories burnt after performing exercise. The organization of the paper is as follows. In Section II, we discuss the system overview. Section III describes the methodologies by which IR sensor works. Section IV discusses the methodology for calculating calories

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burnt. Section V shows the experimental results. Section V concludes the paper.

II. OVERVIEW OF HEART BEAT SENSOR MODULE

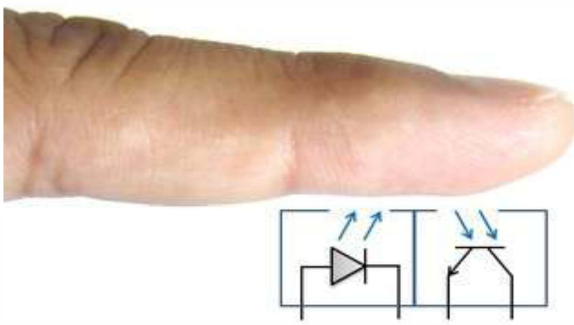

Figure 1. Finger positioning on the HRM device

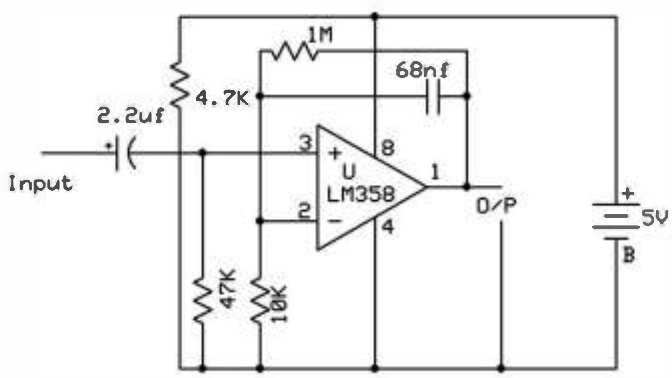

Figure 2. Portion of the pulse amplifier circuit using LM358[9]

Heart beat sensor module is based on the principle of Photoplethysmography (PPG) which is a non-invasive method of measuring the variation in blood volume in tissues using a light source and a detector. Since the change in blood volume is synchronous to the heart beat, this technique can be used to calculate the heart rate. Transmittance and reflectance are two basic types of photoplethysmography. For the transmittance PPG, a light source is emitted in to the tissue and a light detector is placed in the opposite side of the tissue to measure the resultant light. Because of the limited penetration depth of the light through organ tissue, the transmittance PPG is applicable to a restricted body part, such as the finger or the ear lobe. However, in the reflectance PPG, the light source and the light detector are both placed on the same side of a body part. The light is emitted into the tissue and the reflected light is measured by the detector. As the light doesn't have to penetrate the body, the reflectance PPG can be applied to any parts of human body. In either case, the detected light reflected from or transmitted through the body part will fluctuate according to the pulsatile blood flow caused by the beating of the heart [9].

The Fig.1 shows a basic reflectance PPG probe to extract the pulse signal from the fingertip. An infrared light-emitting diode illuminates light into the human finger. More or less light is absorbed, depending on the tissue blood volume. Consequently, the reflected light intensity varies with the pulsing of the blood with heart beat.

The PPG signal has two components, frequently referred to as AC and DC. The AC component is mainly caused by pulsatile changes in arterial blood volume, which is synchronous with the heartbeat. So, the AC component can be used as a source of heart rate information. Since the useful AC signal is only a very small portion of the whole signal, an effective amplification circuit is also required to extract desired information from it. Portion of signal amplification circuit is shown in Fig. 2.

Heartbeat sensor module uses a reflective optical sensor with both the infrared light emitter and phototransistor placed side by side. A fingertip placed over the sensor will act as a reflector of the incident light. The amount of light reflected back from the fingertip is monitored by the phototransistor.

The output from this module is a periodic waveform attributed to small variations in the reflected IR light which is caused by the pulsatile tissue blood volume inside the finger. The waveform is, therefore, synchronous with the heartbeat.

The IR sensor output is first passed through a RC high-pass filter (HPF) to get rid of the DC component. The cut-off frequency of the HPF is set to 0.7 Hz. Next stage is an active low-pass filter (LPF) that is made of an Op-Amp circuit. The gain and the cut-off frequency of the LPF are set to 101 and 2.34 Hz, respectively. Thus the combination of the HPF and LPF helps to remove unwanted DC signal and high frequency noise.

The output from the first signal conditioning stage goes to a similar HPF/LPF combination for further filtering and amplification. Further the amplified signal is sent to microcontroller to detect and count the heartbeat.

III. METHODOLOGY FOR HEARTBEAT MEASUREMENT

A. Optical Transmitter and Receiver Circuit

IR sensor 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 photodiode. The photo-diode does not pick up a purely AC signal as there are some DC components received from other non-pulsatile tissues and ambient light levels. The varying light levels received are converted into a varying resistance in the photo-sensor. The varying resistance is converted into a varying voltage by using a resistance network and power source. In order to do this, an LED is used in combination with a photo diode to detect and transmit the pulse rate. Since the tissue in the human body acts a filter, LED is chosen to allow the maximum amount of light energy to pass through the index finger. The circuit shown in Fig. 3 is designed to achieve this.

The circuit in Fig. 3 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 value of R2 is chosen in a way so that it produces a maximum amount of light output. The calculated value is approximated to a resistance value that is commonly available. The photodiode 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 pulse is detected by the photo transistor.

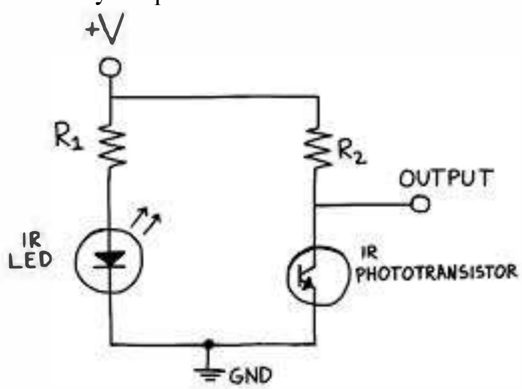

Figure 3. IR transmitter and receiver

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 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. 4.

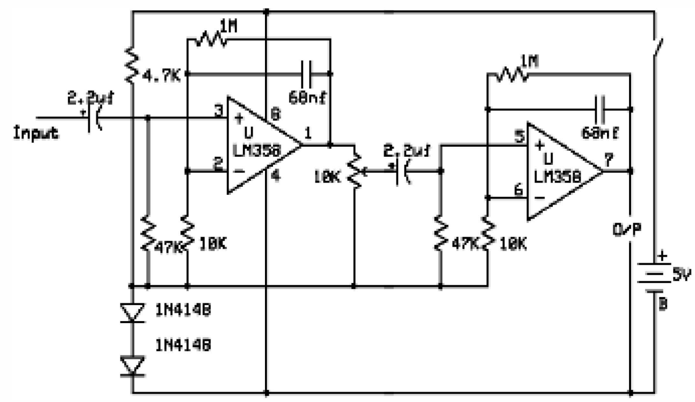

Figure 4. Amplifier Circuit used in HRM devices [9]

The amplifier uses an LM358 dual op amp to provide two identical broadly-tuned band pass stages with gains of 100. Again, the type of op amp is not particularly critical, as long as it will work at 5V. The circuit runs from a single 5 Volt battery and the output zero is offset by about 1 Volt by referring everything to an internal common line at a voltage set by a pair of forward-biased silicon diodes. This is convenient for interfaces with a 0-5 Volt input. The potentiometer allows the overall gain to be adjusted so as to prevent clipping on large signals. Components are not critical but the two 2.2 µF capacitors must be able to stand some reverse bias so they should be non-polarized. The circuit can easily be made up on a small piece of strip board [9].

C. Microcontroller

A microcontroller is an economical means of counting the pulse rate and controlling the output that is to be used to calculate the calories burnt from heart rate value. The microcontroller ATmega328 is used for this purpose. The connection between the IR sensor and the photodiode is as shown in the Figure 5.

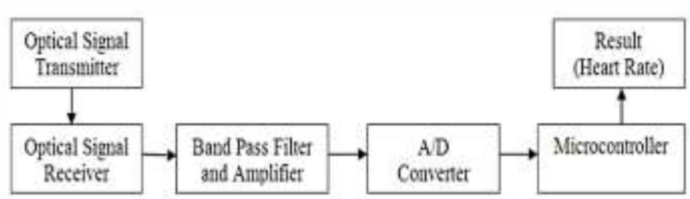

Figure 5. Working principle of IR based Heartbeat sensor

IV. METHODOLOGY FOR CALCULATING CALORIES BURNED

The calories burning have some association with heart rate. After large amount of research and investigation, the Journal of

Sports Sciences developed a formula to count for calories burned during exercises [10]. This calories burned by heart rate calculator is used to calculate calorie expenditure, and have different version for men and women. Besides weight, age and durations, we need Heart Rate during exercises.

The first phase of the device, the optical receiver and transmitter, is constructed and tested. The output of the receiver is connected to Arduino-Uno to count the heartbeat pulses. Arduino uno is programmed in such a way to estimate the calories burned, based on the heartbeat count and other human specific details such as age, weight.

The Arduino-Uno is programmed to count the number of peaks of the input signal in 5 or 10 seconds, and the result is further multiplied correspondingly by 12 or 6 to obtain the total number of peaks per minute. The LCD is connected to the microcontroller and a known frequency pulse signal is fed into it. The correct number of peaks per minute value is showed on the LCD. When the microcontroller is integrated into the entire design circuitry, it is able to count the number heartbeats per minute and drive the LCD to display the counted value.

Then the Arduino is programmed to estimate the calories burned based on the value of heart beat, age, weight and sex. The equations 1 & 2 show the relation between calories burned and heartbeat [10]. The equations correspond to both male and female. Fig. 6 shows the basic block diagram of calculating calories

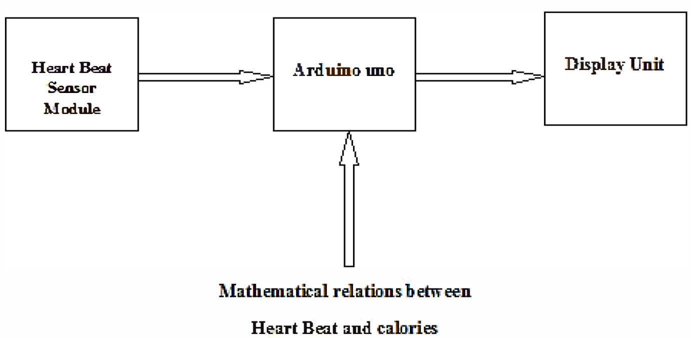

Figure. 6 Block diagram of calculating calories

$$\text{Male: } \frac{((-55.0969 + (0.6309 \text{ x HR}) + (0.1988 \text{ x W}) + (0.2017 \text{ x A}))}{4.184) \text{ x } 60 \text{ x T}}$$

Equation-(1)

$$\text{Female: } \frac{((-20.4022 + (0.4472 \text{ x HR}) - (0.1263 \text{ x W}) + (0.074 \text{ x A}))}{4.184) \text{ x } 60 \text{ x T}}$$

Equation-(2)

where

HR	=	Heartrate (in beats/minute)
W	=	Weight (in kilograms)
A	=	Age (in years)
T	=	Exercise duration time (in hours)

V. EXPERIMENTAL RESULTS

Calories burned can also be calculated in a gymnasium using a treadmill, where a tread mill shows the calories burned based on number of kilometres or duration a person has done exercise.

But the measurement is calibrated based on duration and number of miles run. This measurement of calories by treadmill is not accurate and not human specific, a person has different BMI index than others.

Whereas by calculating the calories from heartbeat it is accurate and it is completely depending on the person basal metabolism rate, heartbeat, weight and age.

Experiments have been done on a male and female during an exercise for 1 hour task is to run for 6 kilometres, the following table 1 show the experimental results. The experiment results shows the calories spend during an exercise for both male and female. For determining accuracy of this device, the results have been compared with the calorie estimator present in treadmill.

Table1: result of calories estimated from heartbeat

Gender	**Weight**	**Age**	**Heartbeat during exercise (BBM)**	**Calories measured from heartbeat**	**Calories measured from treadmill**
Male	65	22	160	906	465
Male	60	22	155	847	465
Female	50	22	145	728	465
Female	47	22	145	719	465

VI. CONCLUSION

In this paper, the design and development of a calorie estimator from 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, and then calculates the calories burned during an exercise from measured heartbeat. Both analog and digital signal processing techniques are combined to keep the device simple and to efficiently suppress the disturbance in signals. Experimental result shows that calories estimated from measured heartbeat are accurate and results have been compared with the tradition calorie estimator treadmill.

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