Design and Development of Low Cost Real Time Heart Rate Monitoring System

[1]Rahul Dhod, [2]Swati
[1]*Centre for Development of Advance Computing, Mohali, Punjab, India*
[2]*Guru Nanak Dev University-RC, Gurdaspur, Punjab, India*

Abstract - The objective of this project is to develop a prototype for a portable system that detects the blood volume pulsation by optical radiation, displays photoplethysmograph (PPG) signals or by led blink. The prototype comprised primarily of infrared (IR) LED sensors, high and band-pass filters, an amplifier. An oscilloscope displays PPG signal. In this project, we used TCRT1000 (IR LED sensor) to convert the fluctuating reflected light intensity into electrical signals (voltages). The high-pass op-amp filter with cut-off frequency of 0.07Hz removes the DC component of the incoming PPG signals. The closed negative-feedback loop system with the filter drives a DC offset level to near zero value 29.5 mV. Signal is amplify in two stages. A multi stage operational amplifier LM324 is used to increases the incoming signal (1-3 mV) 10201 times (3- 5 V). A band-pass filter to pass signals between 0.7 Hz and 2.34 Hz was built to avoid the output signal DC level drift. Two voltage followers minimize the effects when the input voltage suddenly changes; for example, when a sudden pressure Change occurs on the LED sensor. Finally, Infrared AC PPG signals were obtained from second stage output and displayed on the oscilloscope and led is also connected at output, it will blink when heart rate is detected. In addition, this prototype produces clean dual PPG signals in real time such that PPG from different body locations can be used for PTT-based blood pressure estimation.

Keywords: *Heart rate, Heart rate variability, cost effective.*

I. INTRODUCTION

In this project modification in the existing heart rate monitoring system has been done. First of all heart rate is defined as number of bits per minute. Heart rate can vary with respiration system of body as absorption of oxygen and excretion of carbon dioxide. In medical profession, heart rate is measure to assist diagnosis and to tracking medical condition. It is also used by athletes, who are monitoring their heart rate to acquire more efficiency in games.

Today, because of change in lifestyle and unhealthy eating habit have increases the chance of diseases related to heart. Heart problems are being diagnosed on younger patients. Heart failure disease is leading cause of death in India. In medical field, heart rate is also measured with help of blood measurement, heart beat measurement. However, there is need of revolutionary change through which patients are able to measure their heart rate at home as well. Heart rate monitor is a device which are used to measure heartbeat signal and computes the bits per minute. With help of this, the information can easily be used to track heart conditions. Heart rate monitor device uses electrical and optical methods as means of detecting and acquiring heartbeats. Cardiovascular system depends on heart rate and it very important parameter. The heart rate of a adult in normal condition is around 72 beats per minute. The heart rate rises during exercises and it returns normal after exercise. The fitness of the person is defined by the rate at which the increased heart pulses returns to its normal rate. Bradycardia is a condition when heart beats less than 60 times a minute in adult, while tachycardia is a condition when heart beats more than 100 times a minute [5].

In this paper, we have designed and developed a low power heart rate monitor device which provides an accurate reading of the heart rate using optical technology. The optical technology uses TRCT1000 reflective type infrared sensor for heart rate measurement using the index finger. LM324 operational amplifier is used for signal amplification via using two cascaded stages. Finally, Infrared AC PPG signals were obtained from second stage output and displayed on the oscilloscope and LED is also connected at output, which will blink when heart rate is detected.

II. PREVIOUS DESIGN

The previous design group used a LED sensor as a way to obtain a digital (pulse) signal from the heart to be used for blood pressure measurement. Figure shows the Block Diagram of the Heartbeat Monitor of the previous group. The system consists of a LED sensor, a differential amplifier, and two potentiometers for adjustment of gain and DC offset. The first stage is a LED sensor, TCRT 1000. The sensor illuminates a tissue, the tip of a finger, with light, and the photo-detector measures the slight variations in light intensity associated with volumetric change in blood in the tissue. It converts the light into a corresponding voltage signal. The second stage is a differential op amp with a gain of 100. To avoid output saturation, the voltage from “DC offset control” is fed back into the differential amplifier’s inverting input. The amplifier’s non inverting input is supplied with incoming PPG signals which include the DC components (average light intensity) and the AC components (a small varying signal caused by changing blood pressure). At the third stage, the output signal from the amplifier connected to an analogy-to-digital converter (ADC). Being connected to the ADC, a microcontroller eliminates noisy components and then transmits the PPG signals to an oscilloscope. The figure shows the schematic of the block diagram of the system and the two variable potentiometers. The first pot cancels the DC off set from the incoming signal. The second pot adjusts the gain of the amplifier so that the amplifier would not be saturated. Trimming the knob stabilizes the operation of the circuit. The trimmer should be readjusted whenever we run the circuit, which was extremely difficult and frustrating [1].

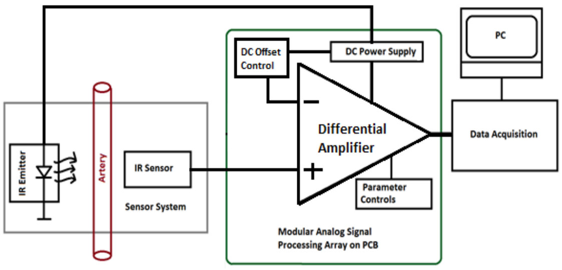

Figure 2.1 Block diagram of project

III. OBJECTIVES

We were recommended to improve those following items:

- Test different optical type sensors and find the particular type of senor, which is best suitable in converting the small variations in light intensity with volumetric change in blood.
- Design a high performance circuit, using op amp handling the output signal within 1-2 volts 5V single supply is preferred.
- Reduce the DC drift and output saturation, which is transient. The saturation appeared for a short while then went again.

To achieve those desired goals, we designed entirely new circuit board (PCB). The signal Conversion is implemented on seven stages as shown in the block diagram on figure given below.

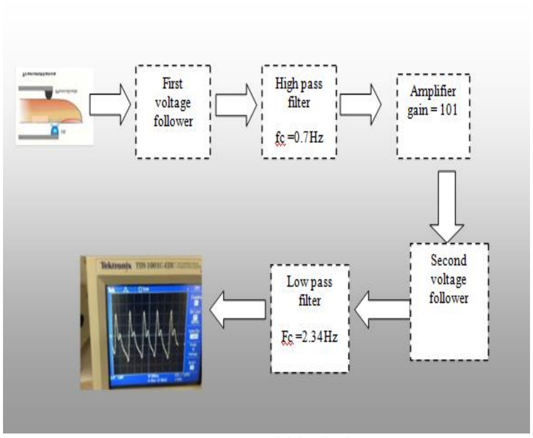

Figure 3.1 General block diagram

IV. SYSTEM DESIGN DESCRIPTION

The whole system has been designed to be used with a 5 V DC supply. The Complete system has been divided into three different parts. These are:

A. Input module
B. Amplification
C. Output unit

Input module is consisting of amplification circuit and sensor used for sensing pulse rate. Two major components of this module are:

1. TCRT1000
2. LM324

A. TCRT1000

TCRT100 reflective optical sensor is used in this project which has both the infrared light emitter and phototransistor. The sensor is packaged in leaded case to immune from external noise from surroundings.

Figure4.1 TCRT100 IR Sensor

The external biasing circuit of IR sensor is shown in figure 4.3. IR sensor is activated by pulling the enable pin high. A fingertip is placed over the photo diode which reflects incident light. The light reflected back from the fingertip is received by the phototransistor.

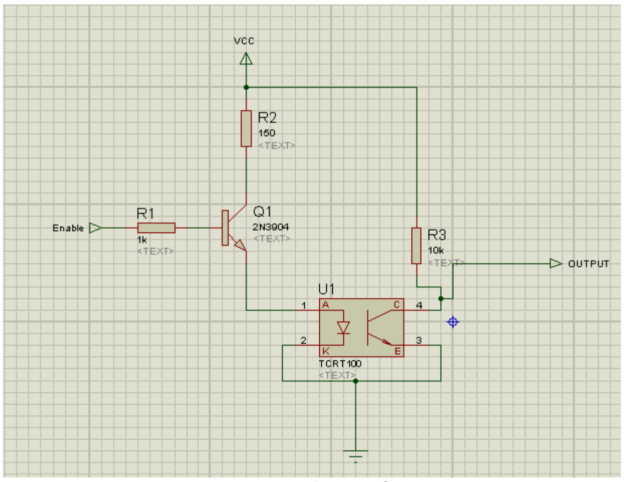

Figure 4.3 Proteus design of IR sensor

B. LM324

It is a Dual-in-Line Packaged Quad processor which consists of four independent, high gains; internally frequency compensated operational amplifiers which are specifically designed to operate on single power supply over a wide voltage range. Three of them have been used to amplify the signals from the IR. Figure 2.2 is the internal circuit diagram of the IC [6].

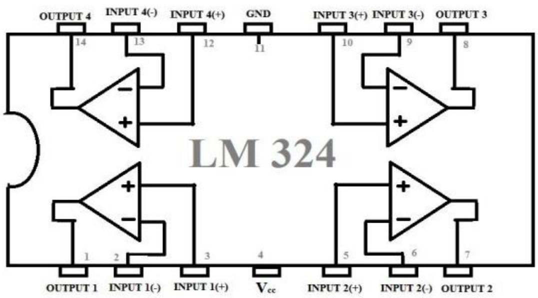

Figure 4.2 Internal diagram of LM324

The output from the sensor is a periodic waveform which is caused by pulsatile tissue blood volume inside the finger. This waveform is synchronous with the heartbeat. The following circuit diagram describes the first stage of the signal conditioning which has two operations, first will be the suppression of large DC component and second is to amplify the weak pulsatile AC component, which carries the desired information.

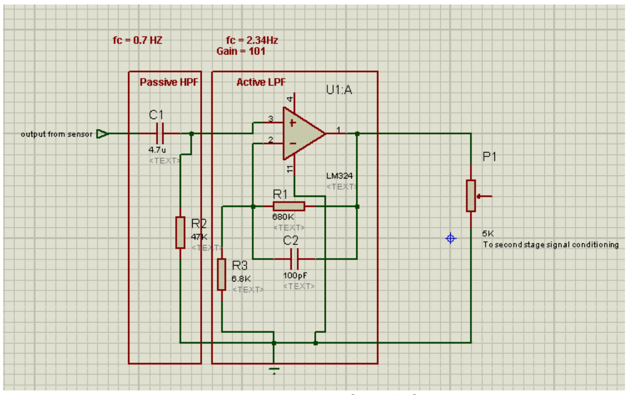

Figure 4.4 First stage of amplification

To get rid of the DC component, the sensor output is first passed through a passive high pass filter which has the cut off frequency of 0.7Hz. Next stage is an active low pass filter of gain and the cut off frequency 101 and 2.34Hz respectively the output from the first signal conditioning stage to a similar HPF/LPF combination for further filtering and amplification. So, the total voltage gain achieved from the two cascaded stages is 101*101 = 10201. The two stages of filtering and amplification convert the input PPG signal to near TTL pulses and synchronous with the heart beat. The heart rate is related to the frequency of TTL pulses according to following relation

Beats per minute (BPM) = 60*f

A 5k variable resistor is placed at the output of the first signal conditioning stage to adjust the total gain of two stages. When the heart beat is detected, it will blink the LED connected at the output of the second stage of signal conditioning [2].

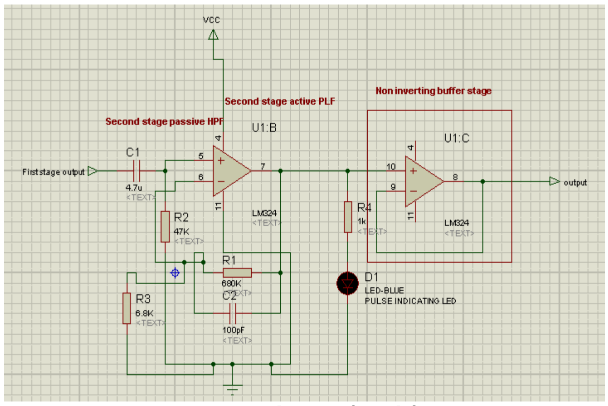

Figure 4.5 second stage of amplification

The final stage constitutes a non inverting buffer to lower the output impedance which will be needed if an ADC channel of a microcontroller is used to read the amplified PPG signal.

V. RESULTS

We built a portable four-channel PPG monitoring device, and each of them comprised of analogy filters and an amplifier. Therefore, it does not require both A/D convertor and digital filters. It is also operable with a single 5volts supply. Each channel is independently operable and can be connected to an IR-LED sensor as well as an oscilloscope. First, place the tip of an index finger hands gently over the sensor on its face. Second, the finger should be still and should not be pressed too hard on the sensor.

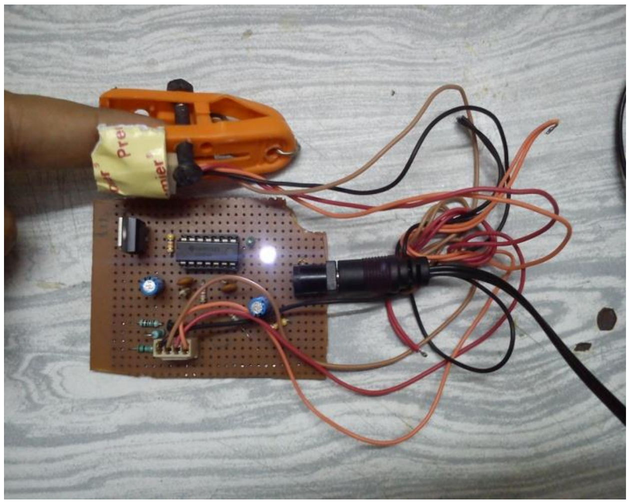

Figure 5.1 Image of circuit

The detected PPG waveforms will appear in an oscilloscope in real time.

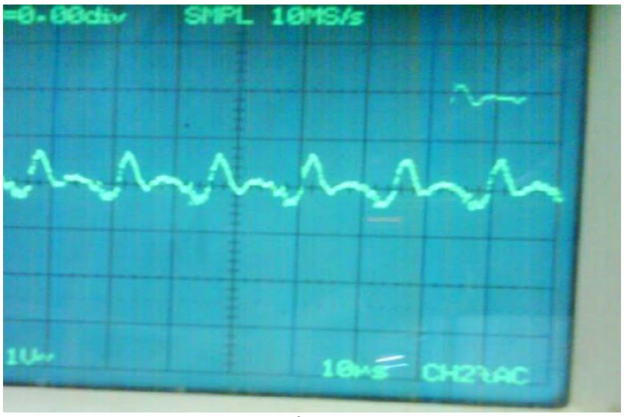

Figure 5.2 waveform appear in CRO

Table 1 Test Result of the device

S.No.	Heart Rate Measurement		Error %
	Standard Machine	Our Device	
1.	92	90	2.2%
2.	95	93	2.1%
3.	96	94	2.1
4.	81	85	-4.9%
5.	75	78	-4.0%

VI. CONCLUSION

We built a new compact HRM device. The improvements are following:

- We eliminated the potentiometers with a high pass filter. We used a couple of resisters to maintain constant gain, and eliminated the need of trimming the potentiometers. This makes HRM device easy to control.
- We significantly reduced the power supply to 5 Volts from 15 Volts, and as a result, the device need not be connected to an electrical outlet.
- The proposed two-channel PPG signals operate well, measuring pulse signal from the tip of the index fingers from both hands.
- The dual PPG signal detected at two different body sites is a useful reference for obtaining PTT (pulse transit time method) for blood pressure assessment.

VII. REFERENCES

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Rahul Dhod is pursuing his Master's degree in "Electronic Product Design and Technology" from C-DAC, Mohali, Punjab. He received his bachelor's degree (Electronics& communication) from RIEIT ropar, Punjab. His research interests include embedded system, biomedical product design, Telecommunication. At present, He is engaged in infrared radiations technology and design techniques which will helpful for blind persons in future.

Swati is pursuing her Master's degree in "Wireless communications" from Guru Nanak Dev University RC, Gurdaspur, Punjab. Her area of interest includes Environmental Sustainability in Wireless Communication Networks, Mobile Communications System.