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# Low Cost Heart Rate Monitoring Using Fingertips

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## Abstract

Body health monitoring is very important to us to make sure our health is in excellent condition. One of the vital parameter for this device under consideration is the heart rate (HR) data apart from other significant body monitoring parameters such as temperature, weight and blood pressure which are also significant to body health monitoring. In this project we describe the design of low cost heart rate monitoring device from fingertips based on the Bluetooth technology. The entire system is comprised of several parts such as Heart Rate module, Android application and Bluetooth module. The Heart Rate (HR) module picks up heart rate signal by a non-invasive technique (Photoplethysmography) from the subject (patients) and sends it (signal) wirelessly to computer or android application using Bluetooth module. This system can be embraced and combined as a part of telemedicine constituent. The data received from heart rate module can be saved and viewed for further medical usage. The result from this device prototype can be utilized for various clinical investigations, indeed these Bluetooth's signal can be transmitted between 15 to 20 meters radius.

**Keywords:** Hear Rate, Photoplethysmography, android application, bluetooth

## Introduction

Health monitoring is important to be checked regularly in order to make sure our body constantly remains in healthy and excellent condition. Generally the vital parameters observed for health monitoring namely, Heart Rate (HR), temperature, weight, blood pressure, glucose and ECG are of paramount importance. These parameters will interpret some important information relevant to body health, for example high temperature indicates someone having fever while unstable heart rate is a sign for heart problem. The objective of this device prototype is to provide an accurate heart rate measuring using a non-invasive technique which can monitored remotely through an android application.

One of the methods to do health monitoring is to use remote patient monitoring. Such device operates remotely by collecting and sending data to a monitoring station for display, interpretation and storage for patient history record. Such "home tells health" applications might include using telemetry devices to capture a specific vital sign. Such services can be used to reduce the use of visiting nurses or to get medical consult from the doctor.

In medical devices telemedicine is the method which allows devices to send data wirelessly through telecommunication such as GSM modem, using internet, Radio Frequency (RF), and ZigBee [2]. Due to increased health awareness & increasing incidences of sudden death at home or at area faraway from medical facility, telemedicine has gained importance. Therefore, continuous monitoring via telemedicine [1] for the elderly people, who suffer with chronic disease or poor health, is of utmost significance.

The Heart Rate is a basic health sign, beneficial in both medical measurements and home health care. Existing home care systems frequently require the attachment of electrodes [4] or other sensors to the body, which can be awkward to the patient. There are portable devices in which the cardiac activity is sensed through the noninvasively measurement of changes in blood volume in the forearm. The electrical properties of the body segment change, when blood volume arrives to the forearm from the left ventricle. These changes, which largely consist of the electrical impedance of the tissue, are measured through the injection of a safe and sound ac current and the detection of the voltage changes due to blood flow. Such a method is known as electrical impedance Plethysmography. But this technique is not suitable for the persons who are having some type of metal installment in their bodies. Passing ac current may cause magnetic interference in user's body. Also the setup for this technique is fairly complex and time consuming.

There are researches on various types of BCG (Ballistocardiogram) sensor including a force sensitive electromechanical film (EMFi) [7] sensor, weighing scales [8], and pressure pad and load cell [9-10]. These sensors are electronic and vulnerable to electromagnetic interference, which may be problematic in some medical applications, e.g., Medical Resonance Imaging (MRI). Fiber optic sensor [5] is an enhanced contender in medical applications because of its intrinsic resistance to electromagnetic interference. Fiber Bragg grating sensor based on wavelength modulation is a major alternative. There is a microbending fiber based BCG (Ballistocardiogram) sensor, in which a threshold algorithm is used to calculate the heart rate. The algorithm used to compute the threshold seems to be not robust, e.g. its accuracy is easily affected by motion of the user. This technique is fused in a cushion which calculates the heart rate through the change in the intensity of light which is caused due to the application of pressure over the fiber when the user sits on it. Therefore, it is not an accurate technique for the measurement of heart rate.

This prototype device uses a non-invasive technique for the measurement of heart rate and margin of error is very less.

Pulse oximetry [6] is a non-invasive method for monitoring a person's Oxygen saturation. In its most common (transmissive) application mode, a sensor device is placed on the user’s body, usually a thin body part like fingertip or earlobe, or in the case of a child, across a foot. The sensor device passes two wavelengths of light through the body part which is received by a photo detector. It measures the change in the amount of the absorbance at each of the wavelengths, allowing it to determine the absorbance due to the pulsing arterial blood alone, excluding venous blood, skin, bone, muscle, fat, and (in most cases) nail polish.

Reflectance pulse oximetry may be used as an alternative to transmissive pulse oximetery described above. This method does not require a thin section of the person's body and is therefore well suited to more universal application such as the feet, forehead and chest, but it also has some limitations. In the reflectance pulse oximetry the change in the amount of wavelength received after reflecting from the tissue is calculated to measure the change in blood volume. This change in blood volume is synchronous to the heart beat thus providing us heart rate.

This above technique is also known as Photoplethysmography (PPG) which is a simple and low-cost optical technique that can be used to detect blood volume changes in the micro vascular bed of tissue. It is frequently used non-invasively to make measurements of heart rate at skin surface. Plethysmograph is a combination of the Greek word, ‘plethysmos’ meaning increase and ‘graph’ is the word for write. It is an instrument used mainly to determine and register the variations in blood volume or blood flow in the body. These transient changes occur with each heartbeat. There are several different types of Plethysmograph, which vary according to the type of transducers used such as air, impedance, photoelectric, and strain gauge Plethysmograph.

Mobile camera flash is also used for measuring heart rate based on the above technique [3]. But it is inaccurate due to the wavelength of light emitted by the camera flash.

This paper proposes a low cost heart rate monitoring device using Bluetooth technology. Bluetooth wireless technology is chosen because it is easy to find, low cost, and easy to communicate between devices such as computers and mobile phones. This prototype employs the concept of reflectance mode Photoplethysmography (PPG). The basic optical sensor of this proposed device consists of an infrared light emitting diodes (LED’s) and a photo sensor. This prototype uses components such as amplifier, filter, microcontroller, and employs serial interfacing using Bluetooth for wireless data transmission to computer or smartphone for displaying the result using Graphic User Interface (GUI) or an android application. The usage of Bluetooth transmission to computer or android application can be considered as Telemedicine function. All components used here can be bought easily and are inexpensive, intended to produce low cost and affordable heart beat monitoring device.

## Methodology

The block diagram shown in Figure 1 illustrates the overall picture of low cost heart beat monitoring device using Bluetooth. This system can be divided into several parts which are the sensor board, microcontroller, Bluetooth communication and computer/smartphone. Sensor board consist of the TCRT1000 sensor, filters and amplifiers which is interfaced with microcontroller (Arduino). At computer side consist of Bluetooth transceiver, communication module, monitor and server. The signal is taken from the human finger. This signal will be captured by IR diode and photodiode by applying the principle of Plethysmograph (PPG). The signal pickup from the sensor will be processed by microprocessor and the data will be passed to Bluetooth communication module and transmitted to computer/smartphone. The data will be captured by the microcontroller and heart rate will be calculated in beats per minute and then heart rate (in beats per minute) will be displayed in GUI at computer display and another display can be seen on android application which is received via Bluetooth. The data will also be stored for future use. Figure 1 gives the block diagram of the entire heart rate monitoring system.

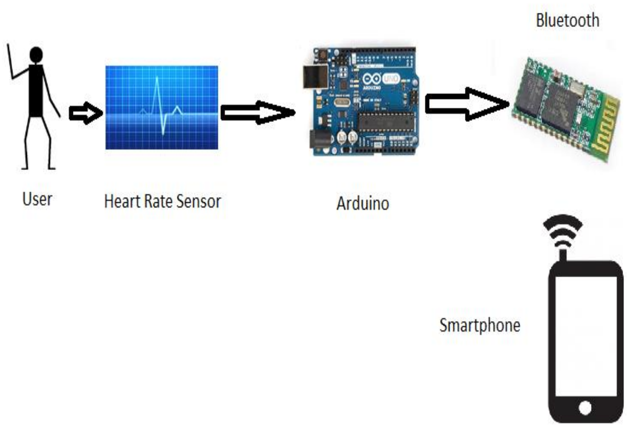


**Figure 1:** Block Diagram

*A. Microcontroller*

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. It's easily available and convenient in coding.

*B. Measurement of Heart Rate*

A Photoplethysmography sensor is used for the detection of volume change in the micro-vascular bed of tissue. The sensor used is TCRT1000 reflective optical sensor.

The change in blood volume is synchronous to the heart beat. Whenever oxygenated blood reaches the tips of the fingers, there is a surge in the volume of blood and when the de-oxygenated blood leaves through the vessels the volume decreases. The sensor has a light transmitter and a light detector. The light source and the detector are placed on the same side of the body part. The light emitted from the source is focused on the tissue and the reflected light is measured by the detector. The sensor is fed through a common-emitter configuration of 2N9304 transistor and thus it senses this change in volume of blood and gives out a voltage output which is further filtered and amplified using MCP6004 IC. The circuit (shown in Figure 2) depicts the heart rate measurement.

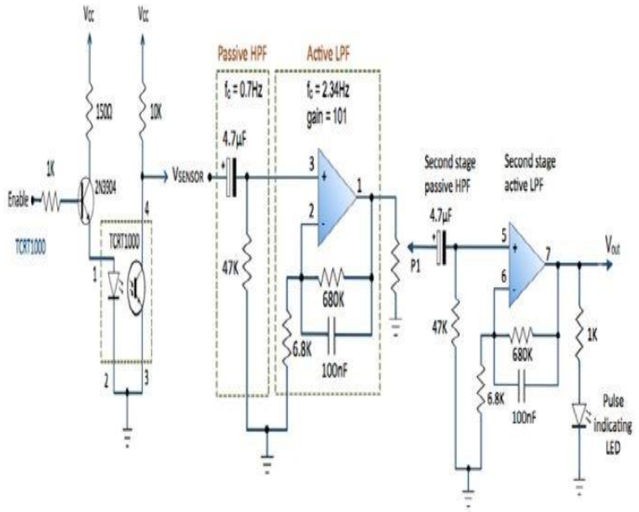


**Figure 2:** Circuit Diagram for Heart-Rate Measurement

The output from the sensor is obtained and filtered to suppress the large DC component and boost the pulsating AC voltage. This is the first stage filter i.e. the High-Pass Filter. The next stage filter is a Low-Pass Filter. The two-stage filters help in removing the DC component and the high-frequency noise signals. The output from the hardware set-up is a pulsating wave with amplitude of 1.8V.

Figure 3 consist of the bread board implementation of the heart rate module.

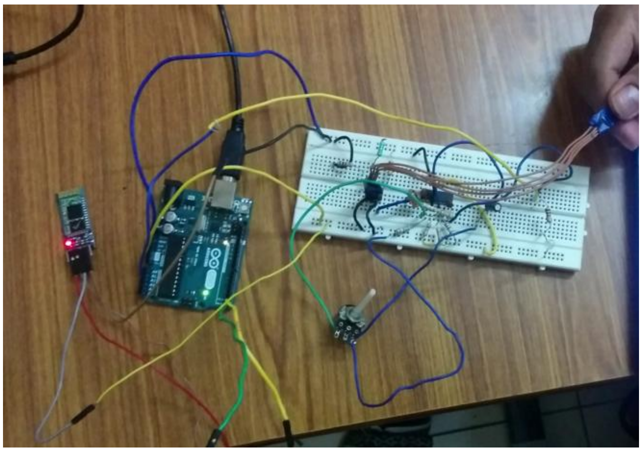

**Figure 3:** Bread Board Implementation

*C. Wireless Transmission of Heart Rate*

Proposed prototype uses HC-05 module which is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. The sensors that acquire the heart rate data need to be interfaced with the Bluetooth transmitter. This would ensure that the output of the sensors is in a format recognized and understood by the Bluetooth transmitter. The data is then sent from the transmitter to the Bluetooth receiver. Figure 4 shows its interfacing with Arduino Uno (Microcontroller).

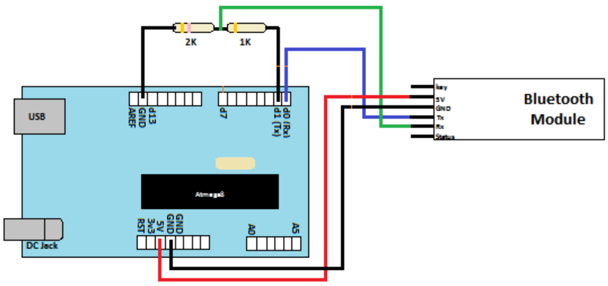


**Figure 4:** Interfacing with Arduino

*D. Analysis of received Heart Rate Data*

Next, this data needs to be passed on from the wireless receiver to the computer where the computations will be carried out. Interfacing is required here in order to send data to the computer. Here the change received in voltage is converted into beats per minute (beats per minute).

*E. Heart Rate Display*

The heart rate in beats per minute will be displayed in form of graph through LabView Software through interfacing with Arduino Uno.

Apart from that same Heart Rate can be monitored via an android application (which will be compatible with android 4.x and above devices.)

## Result and Disscussion

This prototype is working when the user put their finger on TCRT1000 sensor, the luminous of IR will be block by the flow of blood pumped in out when heart pumping the blood to the entire body. This signal is capture by the heart beat sensor and sends to Arduino microcontroller. Figure 5 shows the status of heart rate when the patient puts the finger on the heart rate sensor. Data collected will be transferred to the Arduino microcontroller and will be display on the android application.

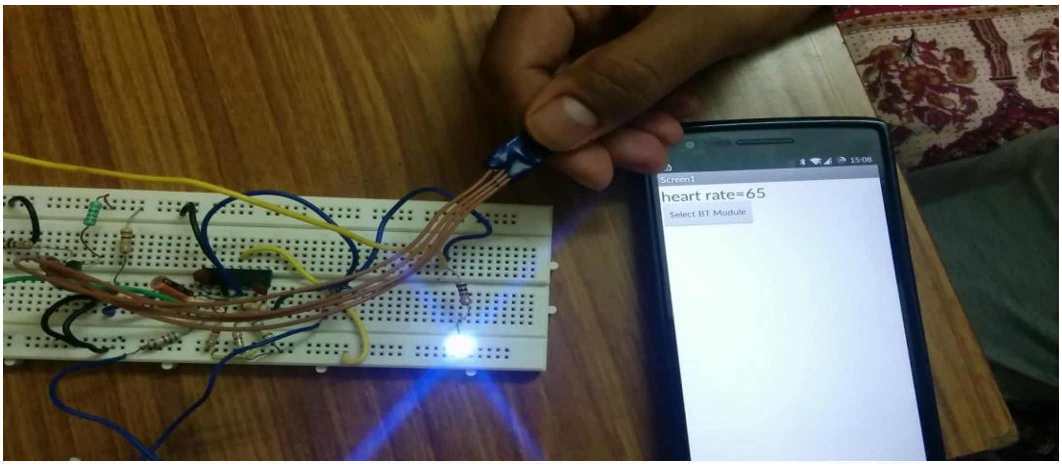


**Figure 5:** Android Application Display Result

Figure 5: Displays the heart rate of user in in beats per minute in android application. The data collected from the heart rate sensor is transferred to the Arduino microcontroller where received data is converted heart rate in beats per minute so that it can be easily understood by the user. This heart rate is then transferred to the android application via Bluetooth module attached with the device. For that first a connection is established between the Bluetooth module and android smartphone. After the connection is established the heart rate is displayed on the android application.

Result presented in Table 1 and Table 2 are obtained from 5 persons who are participate in this examination using this developing prototype device with different tension activities like sitting, walking. These groups are from different age between 20 to 30 years old and all of them in good health condition and were engaged with tension activities (e.g. walking.).

**Table 1:** Person Sitting

| | Heart rate obtained from prototype | Heart rate obtained from ECG |
|---|---|---|
| Subject 1 | 68 | 69 |
| Subject 2 | 75 | 75 |
| Subject 3 | 71 | 73 |
| Subject 4 | 81 | 79 |
| Subject 5 | 72 | 72 |

**Table 2:** Walking person

| | Heart rate obtained from prototype | Heart rate obtained from ECG |
|---|---|---|
| Subject 1 | 72 | 74 |
| Subject 2 | 78 | 73 |
| Subject 3 | 76 | 77 |
| Subject 4 | 83 | 85 |
| Subject 5 | 72 | 70 |

The result obtained from the prototype device was then compared with the ECG values. It was that the margin of error was within permissible range (i.e. 2-3 per cent).

Therefore, it can be concluded that device work properly and provide accurate heart rate values.

The Bluetooth module has some limitations of its own like the maximum range it can work is within a radius of 15-20 meter. So the android device should be within this radius.

## Conclusion

This project was developed successfully and run smoothly where all parts functioned and achieved according to the objective, even though this prototype used inexpensive components purposely to target the low cost high end product but quality of this device is make sure to be remain. This prototype can support in Telemedicine application because it have capability to communicate with computer/smartphone using Bluetooth technology. For future development this system is converted into a wearable device which can be used by anyone, anywhere. Along with that more functionality will be included in the android application to make it a complete fitness device.

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