

## Arduino Microcontroller Based Heart Rate Monitor Using Fingertip Sensors

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### Original Research Article

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#### Article History

Received: 04.12.2017

Accepted: 14.12.2017

Published: 30.12.2017

#### DOI:

10.21276/sjeat.2017.2.12.4



**Abstract:** Medical devices can be categorized into two categories which is invasive and non-invasive method. Invasive method needs medical device to be inserted into patient body regarding to check or do the treatment on the patients. However, the non-invasive method is a way to check the health condition from the outside of the body. A common non-invasive medical device is Heart rate monitor. The function of the Heart rate monitor is determining heart rate (i.e.) beats per minute. The main aim of this work is to develop a portable device which helps to record heart rate of a person. The heart rate also referred as pulse rate, has been recognized as a vital parameter since beginning of medicine, and is directly related to person's cardiovascular health. Heart rate or pulse recording is the most important vital parameter which helps the individual as well as doctor to spot out developing health problems. Using Heart Rate Monitor (HRM) is a more accurate way to monitor heart rate than manually taking your pulse at carotid of radial pulse. A HRM detects the electronic signal of heart and automatically computes the heart rate in BPM. Infrared light emitting diode (LED) is used to transmit the light and phototransistor works as a receiver. The Infrared (IR) sensors used uses the principle reflectance plethysmography (PPG) to sense the pulse signal from finger tip. The sensor output is read from the Arduino board, computes the BPM and display the instantaneous heart rate on LCD display module. Based on the above principle, a portable heart rate device using Arduino microcontroller is developed.

**Keywords:** Heart rate monitor, plethysmography, Infrared light emitting diode, Infrared sensors, Arduino Microcontrollers.

## INTRODUCTION

Heart rate is the number of heartbeats per unit of time, typically expressed as beats per minute (bpm). Heart rate can vary from person to person. The recording of heart rate is used by medical professionals in diagnosis of various medical conditions mainly related to cardiovascular system [1]. The heart rate of a healthy adult at rest is around 72 bpm. Athletes normally have lower heart rates than normal people. Infants have a much higher heart rate at around 120 bpm, while older children have heart rates at around 90 bpm. The heart rate rises gradually during exercises and returns slowly to normal after exercise. The rate at which the pulse returns to normal is an indication of the fitness of the person. If the heart rate is below 60 bpm, it is termed as bradycardia, while heart rate is above 100, it is termed as tachycardia. Heart rate recording interests many individuals, especially athletes to acquire maximum efficiency [2, 3]. Cardiovascular diseases have been quite common these days due to modernization, lack of exercises and sedentary habits and life style especially in youngsters. Coronary Artery Disease (CAD) is now the leading cause of death worldwide [4]. In a clinical environment, heart rate is recorded by examining the patients by taking radial

pulse, carotid pulse, femoral pulse, poplital pulse [5]. Furthermore, it is also recorded in hospitals by Electrocardiogram (ECG) and Ecocardiogram and dopler studies. A HRM detects the electronic signal of heart and automatically computes the heart rate in BPM. Infrared light emitting diode (LED) is used to transmit the light and phototransistor works as a receiver. The IR sensors used uses the principle reflectance plethysmography (PPG) to sense the pulse signal from finger tip. The sensor output is read from the Arduino board, computes the BPM and display the instantaneous heart rate on LCD display module. Based on the above principle, a portable heart rate device using Arduino microcontroller is developed. Therefore, there is a great need that patients should be able to record the heart rate in the home environment as well. This effort has been made to design and develop an Arduino based heart rate recording device.

## MATERIALS AND METHODS

### System Hardware

The proposed HRM device is intended to have following features:

- System provides an optical mechanism to detect the modulation caused by electrical and physical changes in heart movements.
- The system provides an LCD screen to display instantaneous heart beat rate.

The system consists of an IR LED as transmitter and a phototransistor as receiver that acts a fingertip sensor. Figure shows the overview diagram of proposed HRM device.

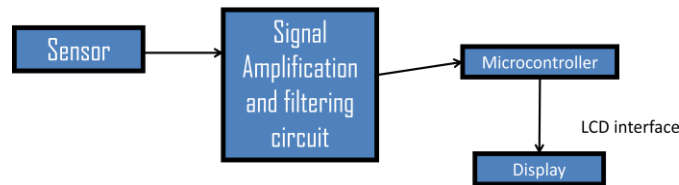


Fig-1: Overview diagram of proposed HRM device

**Fingertip Sensor**

The sensor (Infrared sensor) consists of an IR light emitting diode transmitter and an IR photo detector acting as the receiver. Infrared Sensors work by using a specific light sensor to detect a select light wavelength in the Infra-Red (IR) spectrum. By using an LED which produces light at the same wavelength as what the sensor is looking for, you can look at the intensity of the received light. Two methods can be used to do this.1.Reflectance PPG,2.Transmittance PPG.

In 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.

For the transmittance PPG, a light source is shone through the tissue using an LED and a light detector is placed in the opposite side of the tissue to

measure the resultant light. Reflectance PPG is used here. Even though both the signal contains information pertaining to the changes in blood volume in the tissue, the relationship is not same. As example, increasing the blood volume in the tissue decrease the light enable to transmit through the tissue, but has opposite effect on the reflected light. It also can be described as more blood there in the tissue, more light passing through the tissue. As an effect, the signal observed in the reflection effect will increase. Similar with the light when getting block, the light reaches the photo detector in transmittance configuration. So, a decline in signal is observed.

Moreover, the term configuration is more suited to the areas of the body that lend themselves better to light transmittance through them such as fingers or ear lobes. But, the transmittance configuration is not suitable to use at muscle or bones because it is significantly less in transmittance of light.

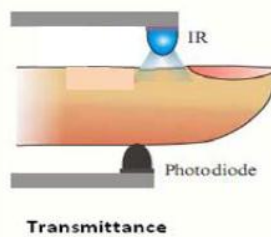


Fig. 2. Illustration of fingertip sensor

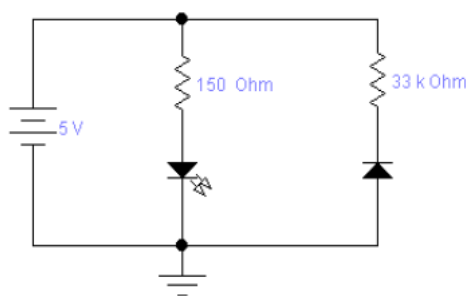
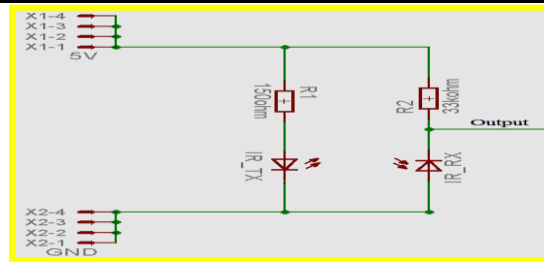


Fig. 3. The fingertip sensor circuit



**Fig-4: Pulse detection circuit**

Figure shows pulse detection circuit. The IR LED is forward biased through a resistor to create current flow. The values of resistors are chosen such that maximum amount of light output can be obtained. The photo transistor is placed in series with the resistor to reduce the amount of current into it and to prevent short circuit in power supply where no light is detected by photo transistor.

**Signal amplification and Filtering**

The plethysmograph word has been derived from two Greek words - ‘plethysmos’, meaning increase; and ‘graph’, meaning write [6]. It is an instrument mainly used to determine and register the variations in blood volume or blood flow in the body which occur with every beat of the heart [7, 8]. This work is based on the principle of Photo plethysmography (PPG) which is a non-invasive method of measuring the variation in blood volume in tissues using a light source and a detector [9]. 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 photo plethysmography. 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 pulsating blood flow caused by the beating of the heart. For this project I used the reflectance PPG. Here, the heart of the system is Arduino Microcontroller. The output signal of the sensor is very small. So, amplification is necessary in order achieve desired output. The PPG signal has two components, frequently referred to as AC and DC [10]. The AC component is mainly caused by pulsating 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 [11, 12] This AC component is superimposed onto a large DC component that relates to the tissues and to the average blood

volume [13]. The DC component must be removed to measure the AC waveform with a high signal-to-noise ratio. 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. And the output of the signal filtering and amplification circuit is connected to the Arduino microcontroller. Arduino is interfaced with LCD and the BPM is displayed on LCD display module.

**Circuit Operation**

There are two circuits used in this project 1) Signal Processing Circuit, 2) LCD Display Circuit.  
1) Signal Processing Circuit:

The sensor used in this project is IR sensor set, with both the infrared light emitter and phototransistor placed side by side and is enclosed inside a cap so that there is minimum effect of surrounding visible light. A fingertip placed over the sensor set 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 the sensor is a periodic physiological waveform attributed to small variations in the reflected IR light which is caused by the pulsating tissue blood volume inside the finger. The waveform is, therefore, synchronous with the heartbeat. This weak signal contains a lot of noise superimposed on the useful AC signal which is then thoroughly filtered a series of signal processing circuits via a Quad OP-AMP LM324N.

The signal 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. The 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 including 50 Hz mains interference, while amplifying the low amplitude pulse signal (AC component) 101 times. The output from the first signal conditioning stage goes 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 converts the input PPG signals to near Transistor –

transistor Logic (TTL) pulses and they are synchronous with the heartbeat.

An LED connected to the output of the second stage of signal conditioning will blink when a heartbeat is detected. The output is then connected to Digital Pin

8 of ARDUINO UNO. The microcontroller measures the frequency of the PPG signal and returns the value of heart rate in BPM. The frequency (f) of these pulses is related to the heart rate (BPM) as, Beats per minute (BPM) = 60\*f An Arduino program is written to calculate the BPM by using formula:  $BPM = 60 * f$ .

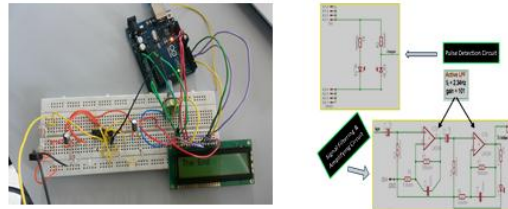


Fig-5: Interface with LCD and arduino

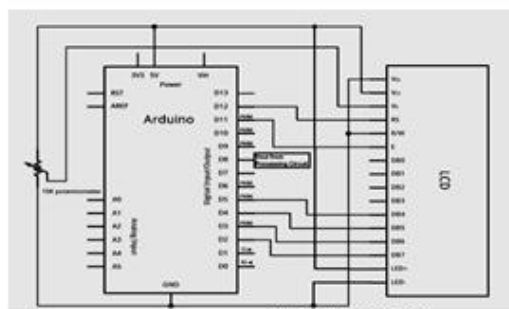
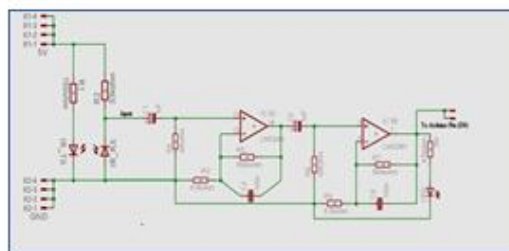


Fig-6: Circuit diagram of connections of arduino with LCD

## SOFTWARE

```

void loop()
{
  lcd.setCursor(0, 1); // set the cursor to column 0, line 1
  // print the number of seconds since reset:
  if (FreqMeasure.available())
  {
    sum = sum + FreqMeasure.read(); // average several reading together
    count = count + 1;
    Serial.println(count); //for arduino serial monitor (ctrl+shift+m)
    lcd.print(count);

    lcd.setCursor(0, 1);
    if (count > 15)
    {
      double frequency = F_CPU / (sum / count);
      double BPM=(frequency*60);
      Serial.print("freq");
      Serial.println(frequency);

      Serial.print("BPM"); //for arduino serial monitor (ctrl+shift+m)
      Serial.println(BPM); //for arduino serial monitor (ctrl+shift+m)
      a[count]=BPM;
      sum = 0;
      count = 0;
      countl++;
    }
  }
}

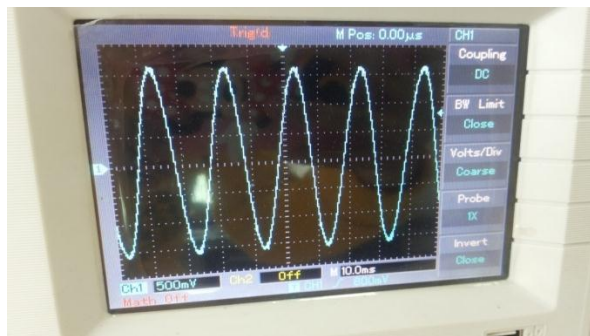
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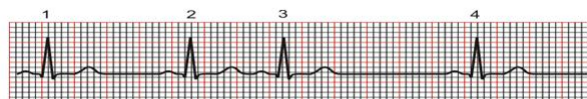
        if (count1>1)
        {
            for(int i=0;i<3;i++)
            {
                sum2+=a[i];
            }
            Serial.println(sum2/2);
            FreqMeasure.end();
            delay (5000);
            lcd.print(sum2/2);
            lcd.print(" BPM");
            delay(5000);
            lcd.clear();
            lcd.print("The End");
        }
    }
}

```

**RESULTS AND DISCUSSIONS**  
**Output**



**Fi-7: Output of sensors**  
**Expected**



**Fig-8: Final output of the circuit in oscilloscope**  
**Output**



**Fig-9: Final output of the circuit in oscilloscope after decreasing times/div**

Figure 6 is the output of the sensors in Signal Amplification and filtering circuit Figure 7 and Figure 8 are the final output of the circuit. In figure 7 the output doesn't seem similar to PQRST waves of heartbeat waveform, so in order to achieve this, time per division is decreased in order to observe waveform similar to PQRST waves of Heartbeat which is expected.

**CONCLUSION**

Health problem solving skill of biomedical engineering helps the doctors to improve patient's health care and the quality of life, Heart disease are the major causes of deaths in world, Recording of heart rate

useful for early detection of cardiac vascular accidents [13]. By using IR sensors we can measure heart rate through fingertip. This paper focuses on the heart rate monitoring and alert which is able to monitor the heart beat rate condition of patient. Arduino Based heart monitor is built and is able to measure heart rate of the person and display BPM on LCD display module. Based on the results obtained, the objective of this project is achieved. The main component to detect them is by using Arduino microcontroller. 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.

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