

Universal design of a microcontroller and IoT system to detect the heart rate

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Abstract. Heart rate analysis provides vital information of the present condition of the human body. It helps medical professionals in diagnosis of various malfunctions of the body. The limitation of vision impaired and blind people to access medical devices cause a considerable loss of life. In this paper, we intended to develop a heart rate detection system that is usable for people with normal and abnormal vision. The system is based on a non-invasive method of measuring the variation of the tissue blood flow rate by means of a photo transmitter and detector through fingertip known as photoplethysmography (PPG). The signal detected is firstly passed through active low pass filter and then amplified by a two stages high gain amplifier. The amplified signal is feed into the microcontroller to calculate the heart rate and displays the heart beat via sound systems and Liquid Crystal Display (LCD). To distinguish arrhythmia, normal heart rate and abnormal working conditions of the system, recognition is provided in different sounds, LCD readings and Light Emitting Diodes (LED).

1. Background

The heart rate is one of the cardiac parameters for daily health care. Recently, heart pulse has been monitored by the Neonatal Intensive unit [1]. The first measurement of heart beat has been done by portrait of Herophilos (ca.335-280 BC) by means of water clock to time the pulse. Later in the nineteenth and early twentieth century Willem Einthoven measured the change in electrical activity of the heart using galvanometers [2]. The normal heart beat varies between 60-100 beats per minute and it is around 72 beats per minute for adult at resting state. The heart rate for older children is averaged as 90 - 120 for infants [3]. The condition in which the heart rate is lower than normal value is known as bradycardia and when it is higher it is known as tachycardia [4]. The value of heart rate varies depending on many factors such sex, age, emotional state, stress level, physical condition and activities [4, 5]. Even though these measurements are accurate, has some restrictions for being used by individuals themselves at their home as it is expensive and must be used by medical professionals [1]. These limitations are overcome by a use of volumetric flow change of blood through tissues measured using a light source and a detector [6,10]. This technique is known as Photoplethysmography (PG) and is classified as transmittance or reflectance depending on the part of the body where it is applied. The transmittance PPG is mostly applicable to the finger or the ear lobe while the reflectance PPG can be applied to any parts of human body [6] and is based on the light source placed on one side of measured volume and the photo detector is placed on opposite side for measuring transmitted light intensity. In reflectance PPG light detector is placed adjacent to the light source [6]. The individuals such as athletes can also monitor their rate in order to acquire maximum efficiency [1]. Advanced design trends are to be emerged to help individuals with blinded or low vision impaired eyes to manipulate heart rate measuring devices. The next section discuss the literature of the work conducted in the past.



2. Related works

Photoelectric plethysmography dated in the 1930s (Rolfe, 1979); is a method used to measure the change in blood flow in different parts of the body [1,2]. The technique concerned with external peripherals parts of the human body such as radial [7], toes, fingers, ear lobes and other vascular surface of the human body [8]. Over the years, research efforts have been carried out; thus vibration venous and arterial oximetry have been used to detect a plethysmographic signal to discriminate responses attributable to a specified blood vessel [15]. In 2014, Toshiyo Tamura, Yuka Maeda Masaki Sekine and Masaki Yoshida proved that the idea behind the working principle of the photoplethysmography is based on light to pass through the tissue and the flow change within the microvascular bed of the tissues [9]. The analysis of this light from photo diode detector indicates that the received light is varying with time in a direct synchronicity of the rhythmic beat of the heart [2]. Transmittance and reflectance are the main basic of Photoplethysmography [9]. Reflectance method is based on positioning the detector and the source on the same plane; it found a use in research to monitor various anatomical sites [2]. The illumination of the fingertip from the light source can result to the absorption, transmission and reflection of certain amount of light, the quantity of blood volume in the fingertip has a great impact on the intensity of reflected light [10]. The lower reflected light results in high blood flow and the higher reflected light indicates the lower. In this work, it has been proved that the output signal from PPG system has an AC and DC components that is from the contact force between the measurement area and the sensor unit and optical signals reflected or transmitted by the tissues [11, 12]. The heart rate is measured based on AC component while the DC component is removed by the low pass filter, the first stage of conditional circuit [11, 13, 16] while the Microcontroller has been used for counting the heart rate [6,10,14]. Index finger technology has been used to detect the heart rate especially in the area of personal and home-based care applications [6]. This paper is aimed to implement the design of a heart rate detection system that is friendly to all individual irrespective of their level of education and vision.

3. Methodology and materials

The system involves a hardware and software Units. Hardware unit comprises processing steps. The first phase is a signal acquisition from a fingertip by means of infra red transmitter and unit receiver as shown in Figure 6 and 11. The amount of light transmitted is in direct proportion to the blood volume inside the finger tip. In the second phase, the acquired signal is processed by active low pass filter and amplified by a two stage high gain. The High gain resulting signal is feed in the microcontroller (Arduino Uno Atmega 328) to compute the heart rate and drive the LEDs and LCD to display and blink based on the result from the heart respectively. The third unit involves speakers from which sounds played are proportional to the LCD displayed values, which are indications of tachycardia, bradycardia, normal heart beat and abnormality of the system to detect input. The system uses IC LM324 dual operational amplifier, with a single operating power supply.

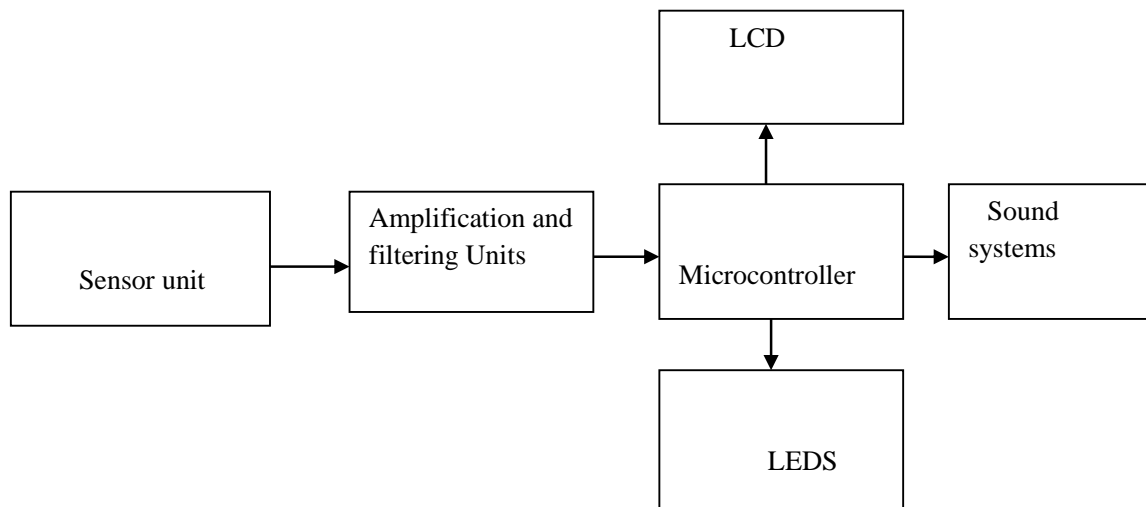


Figure 1. Block diagram of the system

3.1. Sensor Unit

The system sensor unit consists of a photo transistor (Receiver) and an infrared LED transmitter. The infrared LED transmitter emits infrared light into the fingertip whereas the photodiode receiver detects the refracted light and converts into voltage. The detected light depends on the blood volume pumped by the heart to the fingertip. To each heart beat corresponds a change in light detected by the photodiode. By use of an operational amplifier LM324, the slight change in the amplitude of the light detected by the photodiode is transformed into a pulse. Thus, the pulse is detected by the microcontroller to calculate the heart rate.

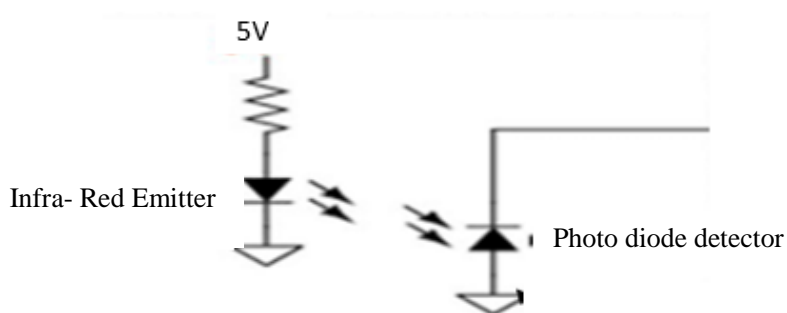


Figure 2. Infrared and Photo diode detector couple

3.2. Filtration and Amplification

The signal acquired from the sensor is too small to be detected by the microcontroller for heart beat rate calculation. The signal conditioning circuit consists of two stage active low pass filter and high gain amplifier to boost the low signal from the photodiode detector and converts it into a pulse.

3.3. Microcontroller

The purpose of this unit is to condition and coordinate all the processing of the system. In this system, Arduino Uno Atmega 328P-PU has been used. The Arduino ATmega328 contains 14 digital

inputs/output pins, 6 of them can be used as Pulse Width Modulation(PWM) outputs, holds 6 analog inputs and crystals oscillator with 16 MHz operating frequency.

Table 1: Microcontroller (Arduino) specifications

Microcontroller	Atmega 328
Operating Voltage	5V
Supply voltage	7-12V
Acceptable Input Voltage range	6-20V
Digital I/O Pins	14
Analog input Pins	6
Direct current per I/O Pin	40 Ma
Direct Current (DC) for 3.3V Terminal	50 mA
Flash Memory	32 KB of which 0.5 KB used by booster loader
SRAM	2KB
EEPROM	1KB
Clock Speed	16MHz

Figure 3 shows the pin diagram of Arduino 328 specified in the table 1.

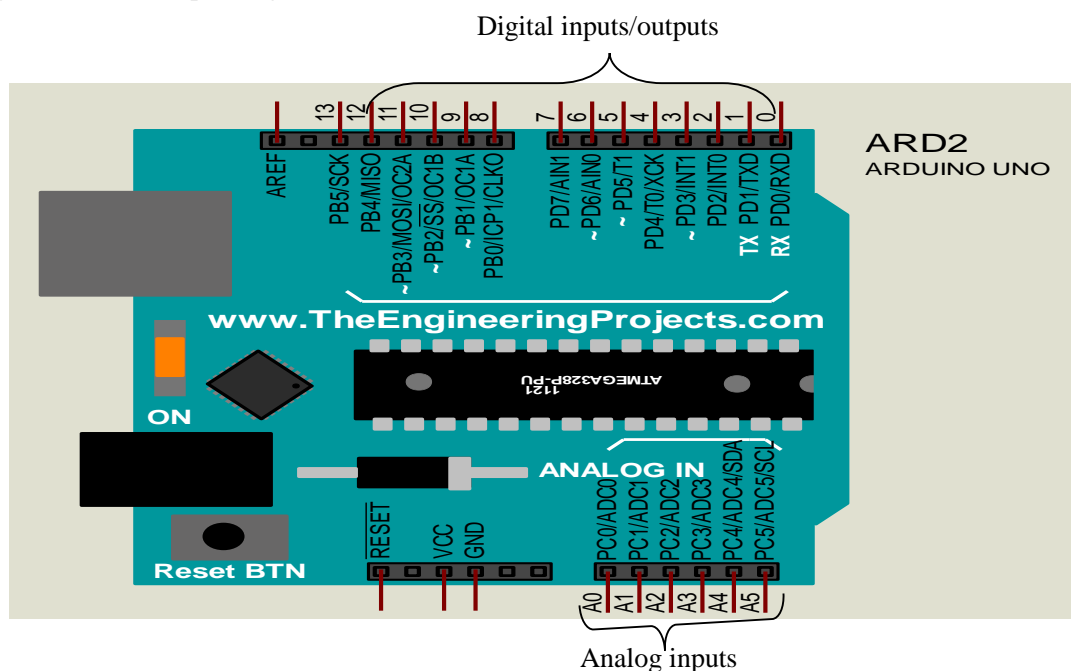


Figure 3. Arduino Uno ATMEGA328

3.4. Display unit

This unit involves a Liquid Crystal Display, 2 Light Emitting Diodes. The 2x16 line character LCD displays the output heart rate measured by the MCU. The two Light Emitting Diodes are indication of the Arrhythmia. The yellow LED indicates the Bradycardia (Heart beat rate lesser than **65**) and the green indicated the Tachycardia (Heart beat rate exceeds **100**). These help the low vision people to distinguish the Bradycardia to Tachycardia.



Figure 4. (a) Bradycardia and (b) Tachycardia LED indicators

3.5. Sound player sub-system

A continuous alarm sound is played for normal heart beat. Different sounds are heard from Sound system to help blinded and low vision people to recognize among the normal, Tachycardia, Brodycardia and the abnormal working of the entire system.

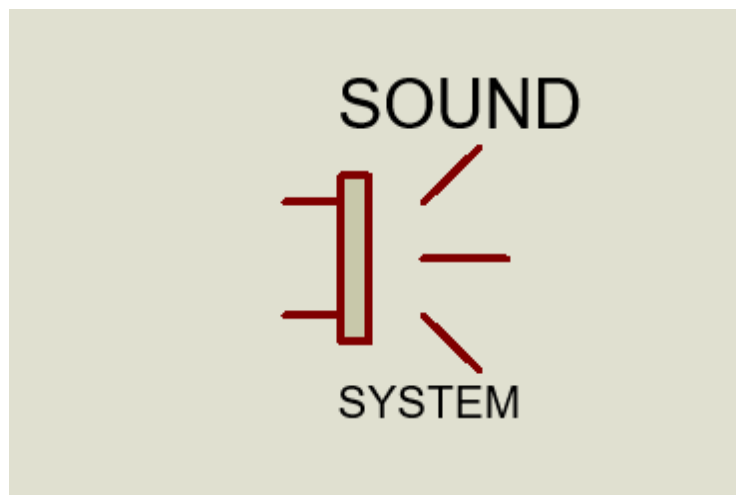


Figure 5. Sound System

3.6 Results and discussion.

An infrared link has been used as a diode emitter and detector. The input signal frequency under test has been adjusted to the ECG frequency range (1-100 Hz). The filtering is done in two high gain as shown on **figure 6**. The heart beat rate is determined by the software programming with Arduino Uno.

$$f_c = \frac{1}{2\pi RC} \quad (1)$$

Where **fc**: Cut-off frequency [Hz], **R**: Resistance [Ω], and **C**: Capacitance [F]

The system is designed to detect the bradycardia, tachycardia, normal heart beat rate and any malfunction in input instrumentation. LEDs, LCD, and Sounders are automatically operated based on the result from the Heart rate.

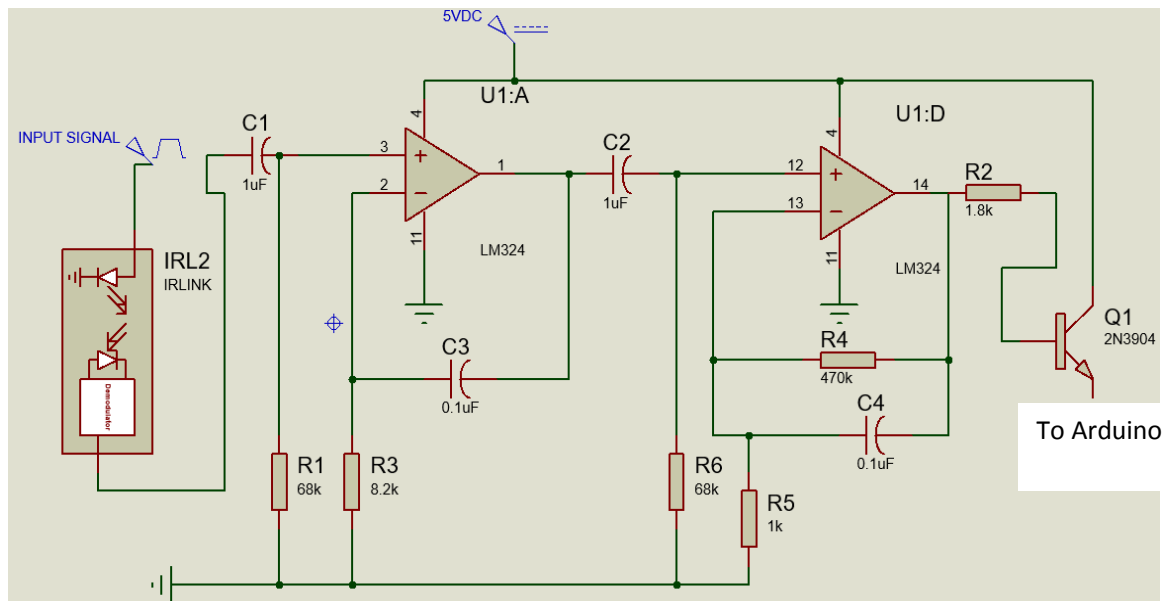


Figure 6. Instrumentation

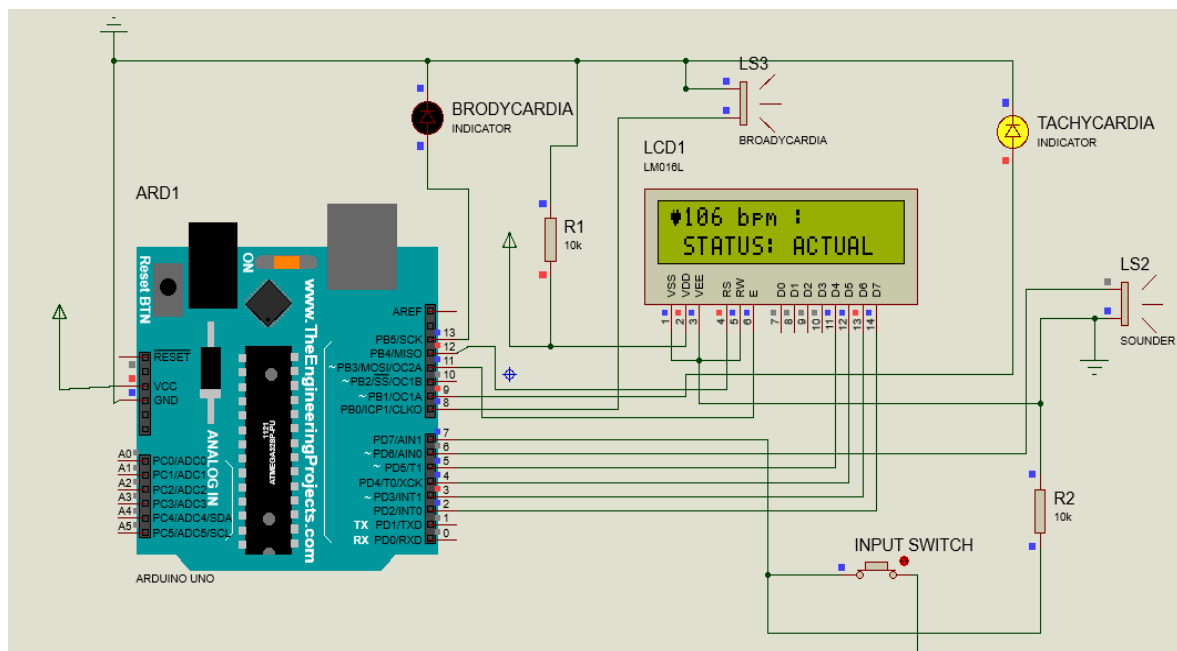


Figure 7. Tachycardia

From **Figure 7**, it is clear that the heart rate detected is 106 BPM, which exceeds the maximum range(100 BPM) . LCD displays the actual value, the sounder plays a defined alarm based on the result. The green LED shall be used by normal and low vision people to recognise the Tachycardia.

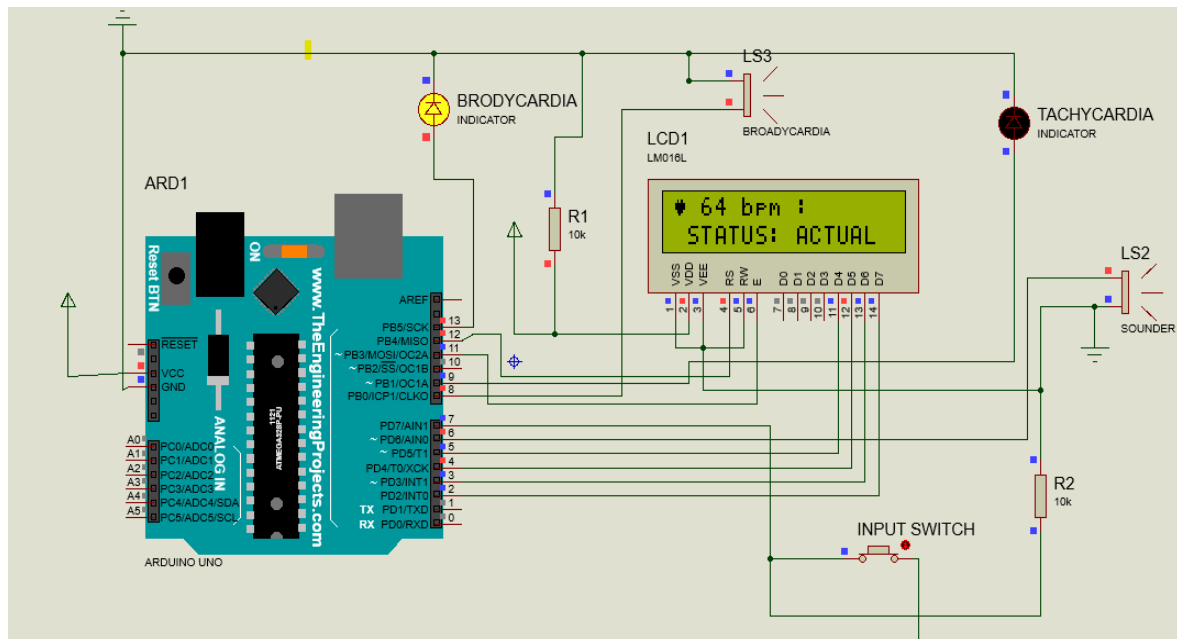


Figure 8. Bradycardia

When training the heart for fitness, we avoid pushing our heart but we chose a threshold heart value near the normal 60 BPM. The yellow LED indicated the Bradycardia, LCD indication (64 BPM) is lesser than 65 that has been set as threshold. A corresponding sound is produced and totally blind people can recognise the Bradycardia.

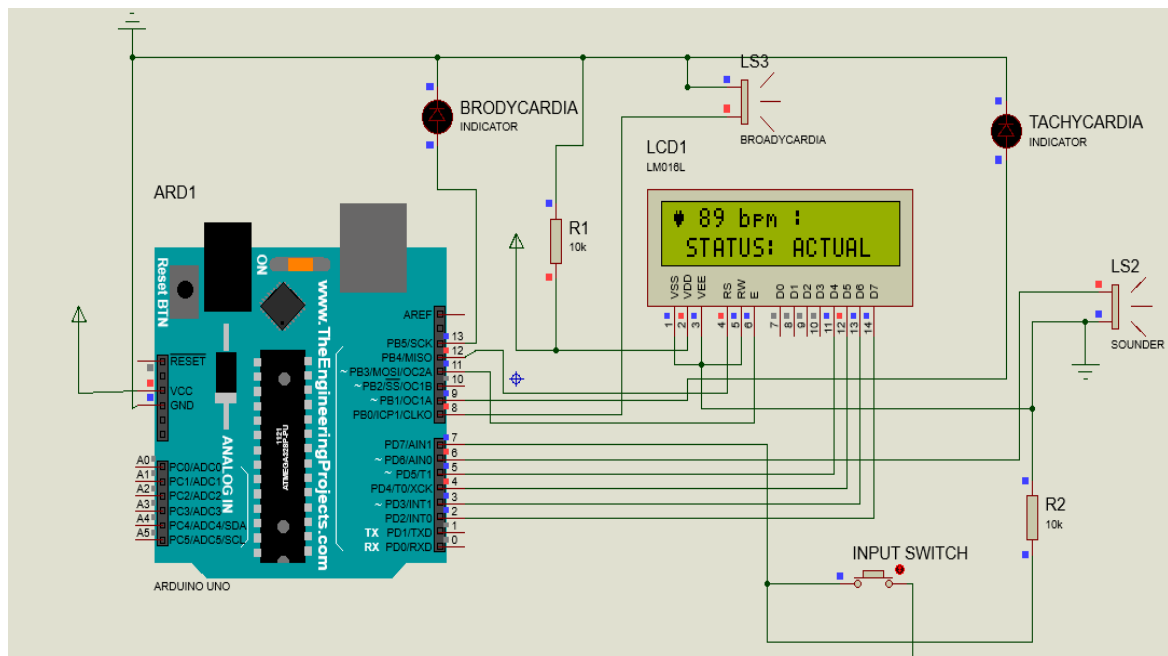


Figure 9. Normal Heart Rate

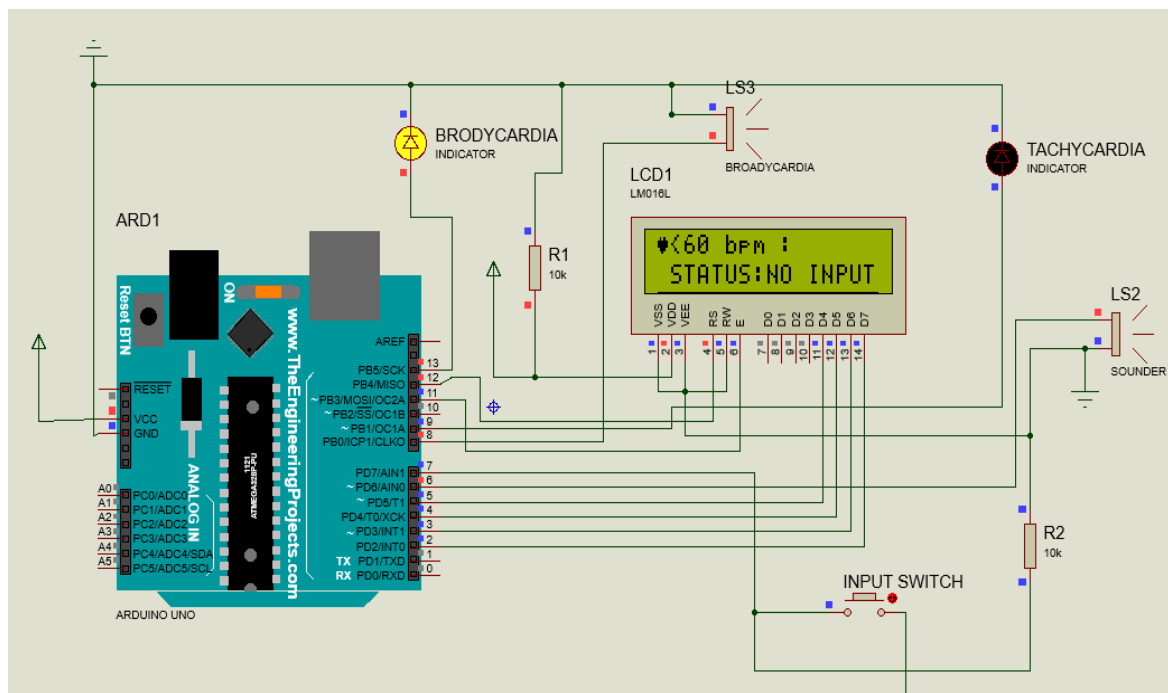


Figure 10. Break in Input

A wrongly finger placement on the detector, a cut in input to the microcontroller or any malfunction of the system can be determined by both normal and abnormal vision people. The system will wait for six seconds to detect if the problem and make a decision as displayed on LCD from **Figure 10**. A sound is produced in different rhythm from other sounds. The yellow LED lights as an indication of the Bradycardia. **Table 2** shows a brief explanation of the results gathered from the system.

Table 2: Summary of result interpretation

S/N	MEASURED VALUE [bpm] ON LCD	Indication	DECISION
1	106	Green Red ON , Corresponding sound is heard	Tachycardia
2	64	YELLOW Red ON , Corresponding sound is heard,	Bradycardia
3	89	All LED off, continuous bip sound ON	Normal heart beat rate
4	< 60	High sound heard	No input detected

3.7. Implementation results

From the **figure 11**, the system measures 75 Beat per minute (BPM). The green LED changes from its OFF to ON state. When the fingertip is released from the infra-red link, the system will recognize the change and displays on LCD, from **figure 12** the Green LED is switched OFF whereas the Red LED becomes ON.

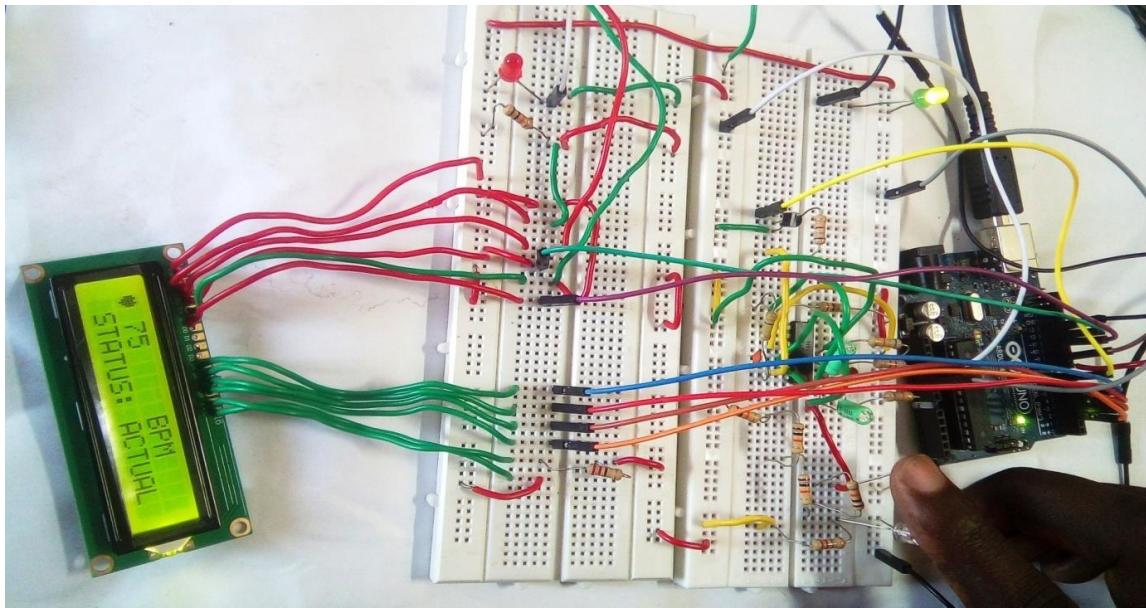


Figure 11. Indication of the normal heart beat

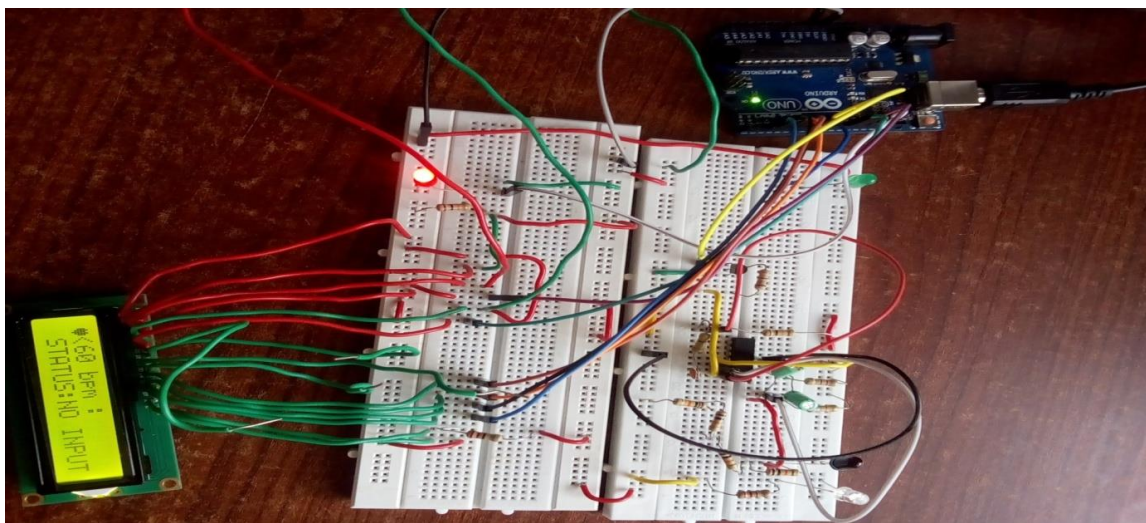


Figure 12. System indication when no input is detected

4. Conclusion

With the advent of IoT decreasing cost of technologies, the use of IoT based healthcare monitoring systems is growing rapidly to provide health care access to more people at affordable costs. To illustrate the concept of IoT based heart rate monitoring in this research, the heart beat detector circuit has been simulated using Microcontroller and proteus and implemented using Arduino Atmega 328. Arrhythmia, normal and abnormal working of the heart have been displayed and played in sound via sound systems. The system is able to detect the also any abnormal working. Vision impaired people are able to manipulate this system.

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