HEART RATE MONITORING AND ARRHYTHMIA DETECTION USING ARDUINO

A PROJECT REPORT

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BONAFIDE CERTIFICATE

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ABSTRACT

Our project presents implementation of a real-time heart rate monitoring system and detecting different types of Arrhythmias utilizing an Arduino Uno and a piezoelectric sensor. The primary objective is to create a user-friendly device capable of accurately measuring and displaying heart rate. The piezoelectric sensor detects the heartbeat through the vibrations of the pulse, which are then processed by the Arduino Uno microcontroller. The microcontroller translates these signals into beats per minute (BPM) and displays the results on the serial monitor of the Arduino IDE software for easy readability. This device is connected to a buzzer which rings and gives an alert if the heart rate is abnormal. Additionally, if the person has an abnormal heart rate, the type of Arrhythmia is also detected. This project demonstrates the integration of hardware and software components to provide a reliable health monitoring solution, potentially useful in both personal and clinical settings. The device's accuracy and cost efficiency offers significant advantages in monitoring cardiovascular health, making it a valuable tool for early detection and management of heart-related conditions.

Keywords: Heart rate monitoring, Arduino Uno, Piezoelectric sensor, Real-time monitoring, Cardiovascular health, Early detection, Arrhythmia detection.

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LIST OF ABBREVIATIONS

BPM	-	Beats Per Minute
IDE	-	Integrated Development Environment
LCD	-	Liquid Crystal Display
RoHS	-	Restriction of Hazardous Substances Directive
CE	-	Conformité Européenne
ECG	-	Electrocardiogram
LED	-	Light Emitting Diode
USB	-	Universal Serial Bus

CHAPTER 1

INTRODUCTION

1.1 AIM

To develop and implement a real-time heart rate monitoring system and to detect different types of Arrhythmia using an Arduino Uno and a piezoelectric sensor.

1.2 OBJECTIVE

The objective of this project is to create a user-friendly device that accurately measures and displays heart rate in real-time. By integrating the piezoelectric sensor with the Arduino Uno microcontroller, it captures heartbeat signals through vibrational changes and processes these signals to calculate beats per minute (BPM). The results are displayed on the serial monitor of the Arduino IDE software, providing an easy-to-read interface. Additionally, if the person has an abnormal heart rate, the type of Arrhythmia is also detected. The project aims to demonstrate the effective combination of hardware and software components to develop a reliable health monitoring solution suitable for both personal and clinical use.

1.3 MOTIVATION

The increasing prevalence of cardiovascular diseases globally underscores the need for accessible and reliable heart rate monitoring solutions. Traditional heart rate monitors can be expensive and may not be readily available to all individuals, particularly in resource-limited settings. This project is motivated by the desire to create a cost-effective and user-friendly device that can provide accurate real-time heart rate data, empowering individuals to take proactive steps in managing their cardiovascular health. By leveraging the capabilities of the Arduino Uno and piezoelectric sensor, this project aims to contribute to the early detection and management of heart-related conditions, potentially improving health outcomes and enhancing the quality of life for users.

CHAPTER 2

LITERATURE REVIEW

To understand the analytical concepts related to the study, several research papers were surveyed, yielding significant insights into the subject matter. Below are the key discoveries obtained from those studies.

Setyowati, V., Muninggar, J. and NA, M.R.S. (2017) "Design of heart rate monitor based on piezoelectric sensor using an Arduino" has used piezoelectric sensor, filter, amplifier, and Arduino microcontroller, it provides accurate measurements comparable to standard devices, with minimal error and no significant difference found in independent testing [4].

Park, D.Y., Joe, D.J., Kim, D.H., Park, H., Han, J.H., Jeong, C.K., Park, H., Park, J.G., Joung, B. and Lee, K.J. (2017) "Self‐powered real‐time arterial pulse monitoring using ultrathin epidermal piezoelectric sensors" has demonstrated a self-powered piezoelectric pulse sensor for continuous arterial pulse monitoring, crucial for early cardiovascular disease detection. The sensor, with high sensitivity and stability, achieves conformal skin contact and allows wireless real-time pulse monitoring via smartphone [2].

Bhuyan, M.H. and Hasan, M. (2020) "Design and simulation of heartbeat measurement system using arduino microcontroller in proteus" has designed and simulated an Arduino-based heart rate monitoring system using clipping sensors to detect heart rate from fingertip blood pressure changes. The system processes signals via a microcontroller and displays heart rate in bpm. Simulation results have been satisfactory across various age groups [1].

Patil, C. and Chaware, A (2021) "Heart (pulse rate) monitoring using pulse rate sensor, piezoelectric sensor and NodeMCU" has studied the development of a wireless heart monitoring system using IoT technology, enabling remote patient monitoring. Continuous tracking of pulse rate and resonance frequency has improved patient outcomes, with collected data analyzed for insights, showcasing the benefits of ICT-based healthcare [3].

Yuvaraj, T., Chandana, G.S., Shetty, D. and Sanil, H. (2021) "Development of Prototype Heart Pulse Rate Monitoring System" has emphasized the need for daily heart rate monitoring using a system that converts pulse action into electrical signals. It has explored various technologies, including IoT-based and MEMS-based sensors, aiming to create a portable and cost-effective solution for home use [5].

CHAPTER 3

MATERIALS AND METHODS

3.1 OVERVIEW OF THE HEART RATE MONITORING SYSTEM

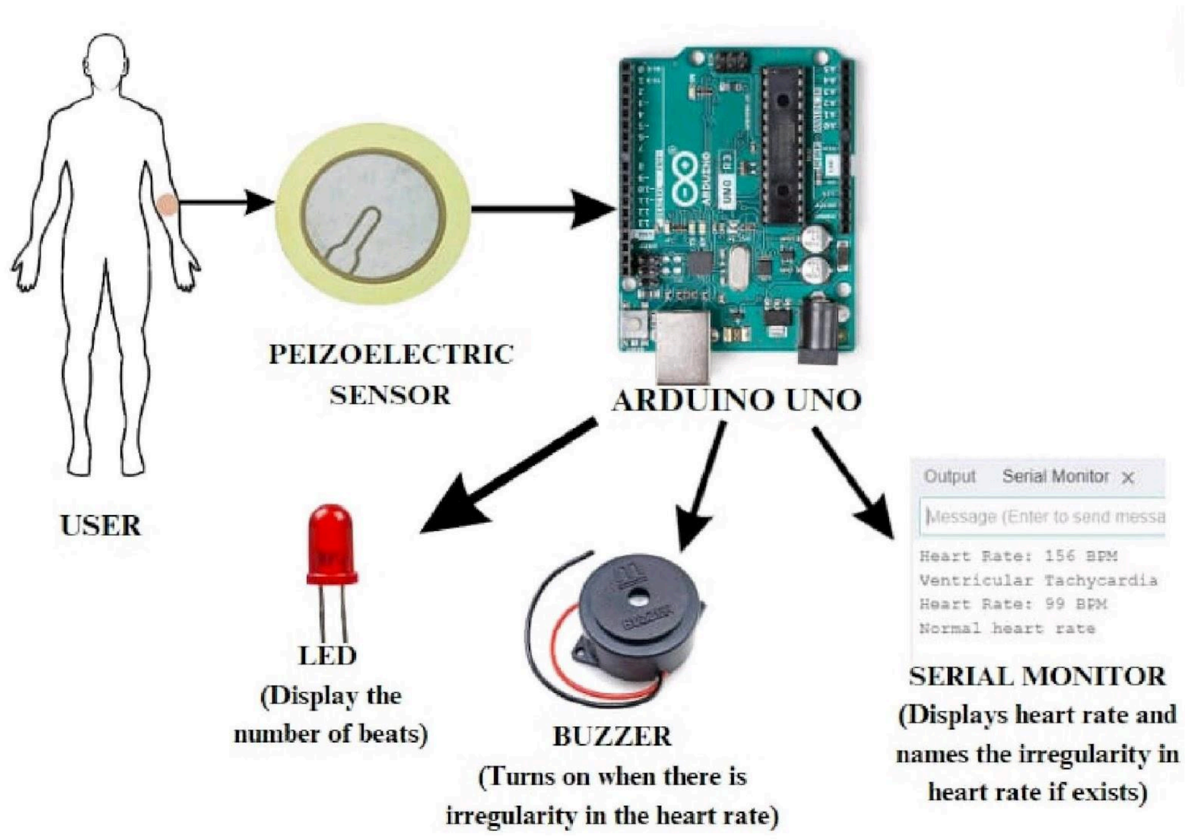

Fig 3.1 Block diagram

In this heart rate monitoring system, a piezoelectric sensor detects heartbeat vibrations, converting them into electrical signals. These signals are then processed by an Arduino Uno microcontroller. The Arduino calculates the heart rate and displays it in real-time on the serial monitor within the Arduino IDE. If the calculated heart rate deviates from normal ranges, the Arduino activates a buzzer to alert the user of potential abnormalities. This integrated approach ensures prompt detection and notification of irregular heart rhythms, facilitating timely intervention and care.

3.1.1 PIEZOELECTRIC SENSOR

A piezoelectric sensor is a device that converts mechanical stress or pressure into an electrical signal using the piezoelectric effect. It is commonly used for detecting vibrations, measuring force, and monitoring pressure changes.

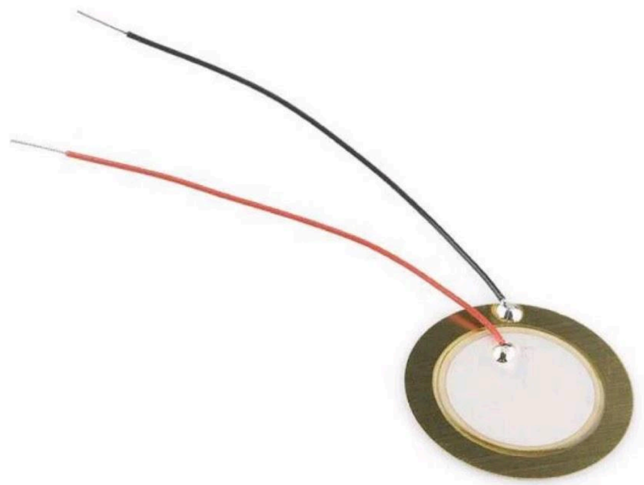

Fig. 3.2 Piezoelectric sensor

(Courtesy: https://robocraze.com/cdn/shop/products/10293_01_e52c33dc-1df2-4b82-a301-8aa4ef1ce69 1.jpg?v=1670583082&width=600)

3.1.1.1 SPECIFICATIONS OF THE SENSOR

Specifications of components provide crucial details about their characteristics, performance, and compatibility, guiding their selection and use in various applications. These specifications typically include parameters such as dimensions, material composition, electrical properties (voltage, current, resistance), operating temperature range, environmental resistance (to factors like moisture, dust, and shock), and regulatory compliance (e.g., RoHS, CE). Understanding these specifications is essential for determining how and where they can be used effectively.

The specifications of a piezoelectric sensor typically include:

1. Impedance:$\leq$500Ω;
2. Voltage:$\leq$30Vp-p;
3. Operating temperature:-20°C~+60°C
4. Storage temperature:-30°C~+70°C
5. Low Soldering temperature
6. Strain sensitivity: 5V/με
7. Material: Quartz (mostly used)

These specifications are essential in designing the heart rate monitoring system. They ensure the piezoelectric sensor's compatibility, reliability, and accuracy within various environmental conditions. Specifically, adherence to impedance, voltage, operating and storage temperature, low soldering temperature, and strain sensitivity specifications guarantees optimal sensor performance, seamless integration, and heartbeat detection, fulfilling the system's design requirements effectively.

3.1.1.2 ADVANTAGES OVER HEART RATE SENSORS

Piezoelectric sensors and heart rate sensors serve different purposes and have distinct advantages depending on the application. Here are some advantages of piezoelectric sensors over heart rate sensors:

Mechanical Sensing: Piezoelectric sensors excel at detecting mechanical phenomena such as vibrations, pressure, and force. They can be used in applications where direct mechanical interaction is involved, such as impact detection, structural health monitoring, and industrial machinery monitoring. Heart rate sensors, on the other hand, primarily measure physiological signals related to heart rate and blood flow.

Wide Range of Applications: Piezoelectric sensors have a wide range of applications beyond just heart rate monitoring. They can be used in various industries including automotive, aerospace, healthcare, and consumer electronics. Heart rate sensors are primarily used in healthcare and fitness applications for monitoring heart rate during exercise or medical diagnosis.

High Sensitivity and Accuracy: Piezoelectric sensors are known for their high sensitivity and accuracy in detecting mechanical stimuli. They can capture subtle changes in pressure or force, making them suitable for precision measurements. Heart rate sensors also offer accuracy, but they are optimized for measuring physiological signals related to heart activity.

Durability: Piezoelectric sensors are often more durable and robust compared to heart rate sensors. They can withstand harsh environmental conditions, vibrations, and mechanical shocks, making them suitable for rugged applications in industrial settings. Heart rate sensors may be more sensitive to environmental factors and physical movement.

Direct Contact Measurement: Piezoelectric sensors typically require direct contact with the object or surface being monitored, allowing for real-time measurement of mechanical parameters. In contrast, heart rate sensors can be non-contact or contact-based, depending on the technology used. Non-contact heart rate sensors, such as optical sensors, offer convenience but may have limitations in certain scenarios.

Cost-Effectiveness: Depending on the specific application, piezoelectric sensors can be more cost-effective than heart rate sensors. They often have simpler designs and lower manufacturing costs, especially for basic models used in industrial monitoring applications.

The choice between piezoelectric sensors and heart rate sensors depends on the specific requirements of the application, including the type of signal to be measured, environmental conditions, accuracy needs, and cost considerations.

3.1.1.3 DETECTION OF HEART RATE

In our heart rate monitoring system, the piezoelectric sensor detects mechanical vibrations produced by the heartbeat, converting them into electrical signals through the piezoelectric effect. These electrical signals are then fed into the Arduino Uno microcontroller for processing. Within the Arduino Uno, the signals are analyzed using programmed algorithms to extract heart rate information. The processed heart rate data is then displayed in real-time on the serial monitor within the Arduino IDE, providing users with immediate access to their heart rate readings. Additionally, in case of abnormal heart rates, an alert mechanism such as a buzzer is activated, alerting the user to potential health concerns and prompting timely intervention. This integrated approach combines signal processing, data presentation, and alert mechanisms, enhancing the functionality and usability of our heart rate monitoring system.

3.1.2 ABNORMAL HEART RATES

The normal heart rate, also known as the resting heart rate, is the number of times the heart beats per minute (bpm) when the body is at rest and not under any physical or emotional stress. For adults, a typical resting heart rate ranges between 60 and 100 beats per minute, although this can vary based on factors such as age, fitness level, and overall health.

The heart rate can be calculated using various methods, including manual pulse measurement, heart rate monitors, or electrocardiogram (ECG) readings. One common method for calculating heart rate manually is by measuring the pulse at a specific artery, such as the radial artery on the wrist or the carotid artery in the neck, and counting the number of beats felt within a certain time frame, usually 15 or 30 seconds, then multiplying by an appropriate factor to obtain the beats per minute.

Formula:

$$\text{Heart rate} = \left(\frac{\text{Number of beats}}{\text{Time interval (in minutes)}}\right) \times 60$$

Abnormal heart rates, or arrhythmias, can manifest in various ways and may present different symptoms depending on the specific type and severity of the arrhythmia. Some common symptoms of abnormal heart rates include:

1. Palpitations (feeling of rapid or irregular heartbeat)
2. Rapid heartbeat (tachycardia)
3. Slow heartbeat (bradycardia)
4. Fatigue or weakness
5. Shortness of breath
6. Dizziness or lightheadedness
7. Fainting or near-fainting episodes

8. Chest discomfort or pain
9. Irregular heartbeat (arrhythmias such as atrial fibrillation or ventricular arrhythmias)

These symptoms may occur intermittently or persistently and may vary in intensity depending on factors such as the underlying cause of the arrhythmia, the individual's overall health, and any concurrent medical conditions. In our project, when an abnormal heart rate is detected, such as tachycardia (rapid heart rate) or bradycardia (slow heart rate), an alarm system is triggered, typically in the form of a buzzer or auditory signal

3.1.3 SENSOR PLACEMENT

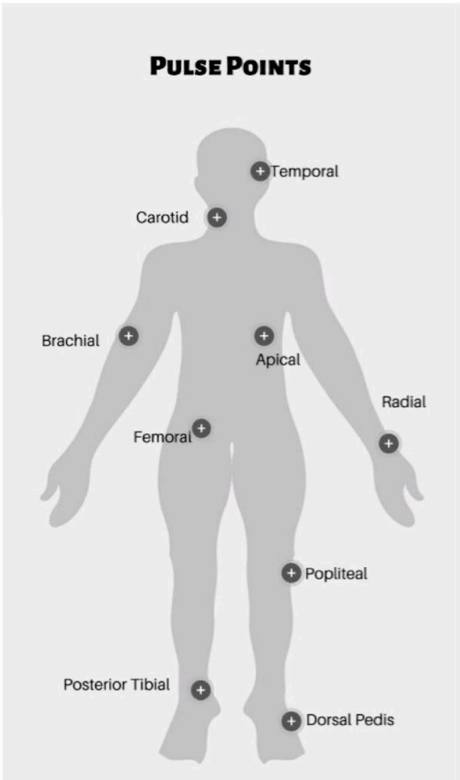

Fig 3.3 Pulse points

(Courtesy: http://surl.li/ttnep)

For pulse detection, the sensor can be strategically placed at anatomical locations where arterial pulsations are easily palpable or heard. Common sites include the wrist over the radial artery, the upper arm near the brachial artery, the chest aligned with the heart, and the neck over the carotid artery. Each location offers unique advantages and considerations, such as accessibility, comfort, and signal quality, depending on the specific requirements of the heart rate monitoring project

Placing the sensor in the cubital fossa, the region on the inner side of the elbow, provides precise values by positioning it near the brachial artery. This placement ensures optimal signal detection and consistent contact with the pulsatile blood flow, allowing for accurate and reliable heart rate measurements. The cubital fossa is easily accessible and offers stable positioning for the sensor, making it an ideal location for obtaining consistent and high-quality pulse readings in our heart rate monitoring system.

3.1.4 CONNECTIONS

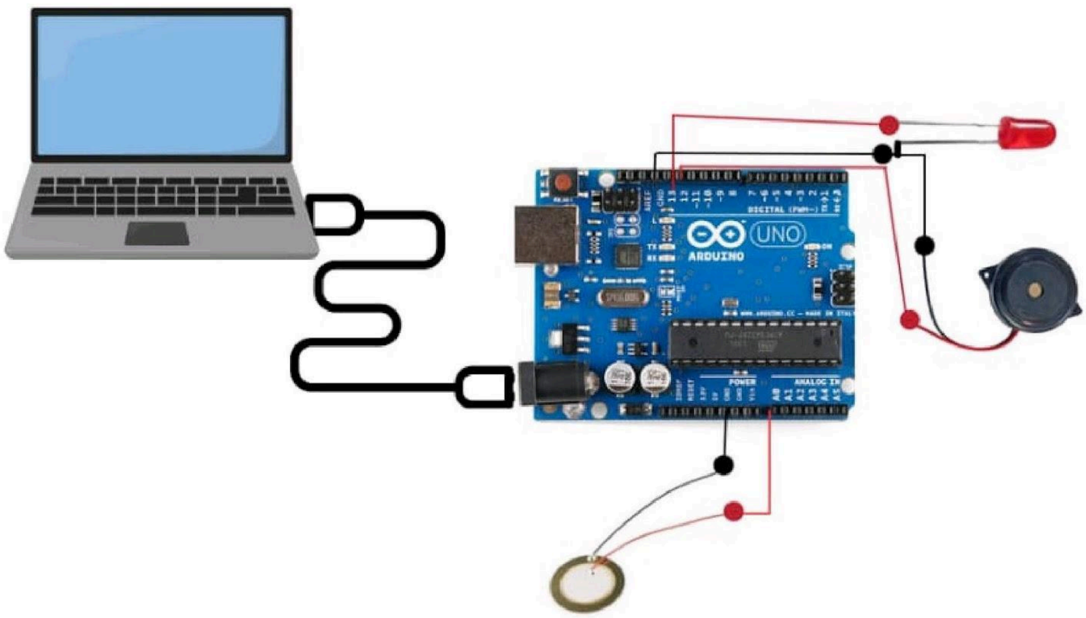

Fig 3.4 Connection Diagram

The positive of the piezoelectric sensor is connected to the A0 pin and the negative is connected to the Ground of the Arduino UNO. The anode(longer) terminal and cathode(shorter) terminal of the LED are connected to the 13th pin and ground pin of the Arduino UNO respectively. The positive of the buzzer is connected to the 12th pin and the negative is connected to the Ground of the Arduino UNO. The USB cable connects the Arduino board and the computer by which power is given to the Arduino board.

3.2 DETECTION OF DIFFERENT TYPES OF ARRHYTHMIA

Arrhythmia refers to an irregular heartbeat, where the heart may beat too fast (tachycardia), too slow (bradycardia), or irregularly. In our project, we focus on detecting specific types of arrhythmias, including bradycardia and tachycardia, both ventricular and atrial.

Types of Arrhythmia:

Bradycardia is an abnormally slow heart rate, typically below 60 beats per minute, which can lead to symptoms like dizziness and fatigue and may require medical attention depending on severity. **Mild bradycardia** the heart rate less than 60 beats per minute (BPM), **moderate** as less than 40 BPM, and **severe** as less than 20 BPM.

Tachycardia is an abnormally fast heart rate, typically exceeding 100 beats per minute, which can lead to symptoms like palpitations, dizziness, and shortness of breath, and may indicate underlying medical conditions.

Ventricular tachycardia is a rapid heart rhythm originating in the heart's lower chambers (ventricles), often exceeding 100 beats per minute, and may lead to symptoms such as palpitations, dizziness, chest pain, or loss of consciousness, potentially requiring immediate medical intervention.

Atrial tachycardia is a rapid heart rhythm originating in the heart's upper chambers (atria), typically exceeding 100 beats per minute, often presenting with symptoms like palpitations, shortness of breath, chest discomfort, or lightheadedness, and may indicate underlying heart conditions.

Atrial fibrillation (AFib) is a specific type of arrhythmia characterized by irregular and often rapid heart rate. In AFib, the heart's upper chambers (atria) beat chaotically and out of coordination with the lower chambers (ventricles). The heart rate in atrial fibrillation can range widely, typically from 100 to 175 BPM.

S. NO	TYPE OF ARRHYTHMIA	HEART RATE
1.	Mild bradycardia	<60 bpm
2.	Moderate bradycardia	<40 bpm
3.	Severe bradycardia	<20 bpm
4.	Ventricular tachycardia	Ranges from 120 bpm to 200 bpm
5.	Atrial fibrillation	Ranges from 160 bpm to 180 bpm

Table 3.1 Types of Arrhythmia

CHAPTER 4

RESULTS AND DISCUSSIONS

In this section, the outcomes of the heart rate monitoring project are presented. To validate the results, heart rate measurements obtained from the system were compared with those obtained from other commercially available heart rate detection devices. The following figure represents the circuit connection of the system.

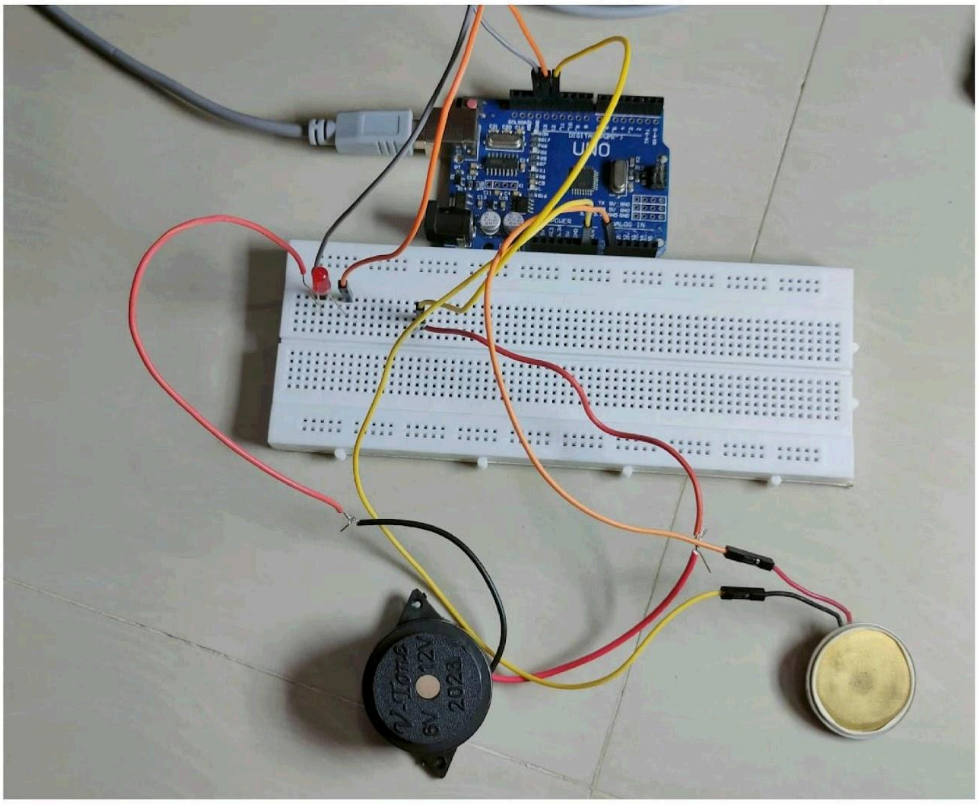

Fig 4.1 Circuit connection

This visual depiction of the circuit connection offers insight into the physical configuration of our setup, showcasing the interconnection of key components including the piezoelectric sensor, Arduino Uno microcontroller, and buzzer alert mechanism. By presenting the circuit connection in this manner, we aim to offer a clear understanding of the hardware layout and structural organization integral to our heart rate monitoring system.

The following figure represents the results obtained using our device which is depicted on the serial monitor within the Arduino IDE

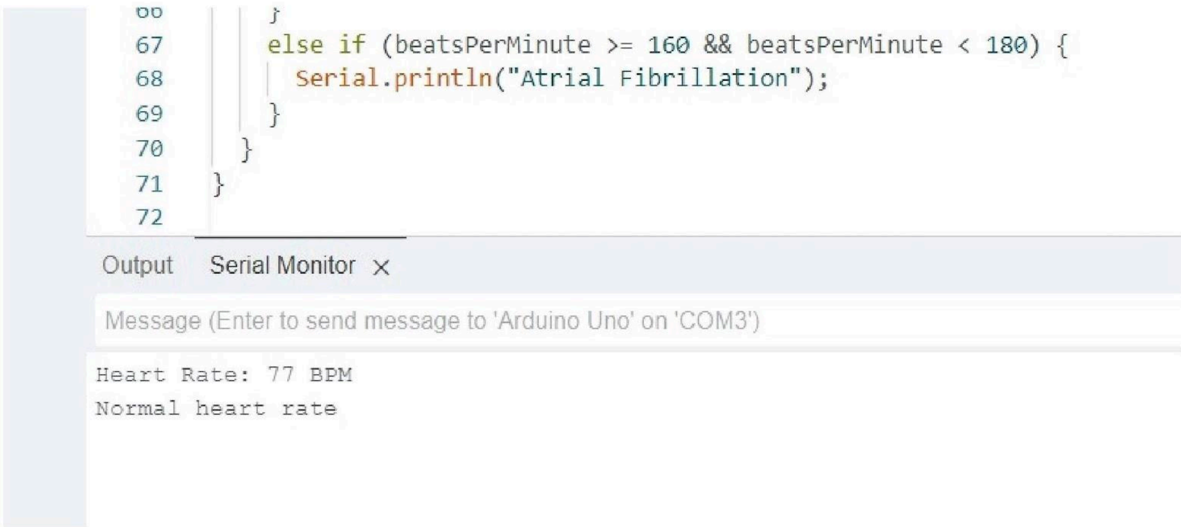

Fig 4.2 Normal heart rate displayed on serial monitor

To validate our findings, we compared results obtained from our device with those from various other heart rate monitoring devices. The following figure illustrates the results obtained from a digital blood pressure monitor, providing further validation of our device's accuracy and reliability.

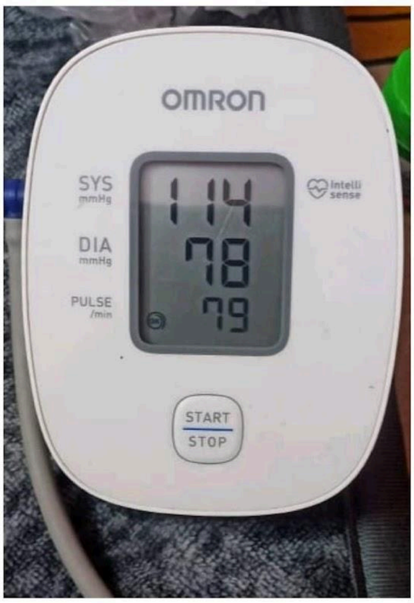

Fig 4.3 Normal rate obtained using Digital Blood Pressure Monitor

After conducting exercises, we employed our heart rate monitoring device to assess the post-exercise heart rate. The results revealed a notable increase in heart rate immediately after exercise, indicative of the body's physiological response to physical exertion. The figure below represents the result obtained using our device.

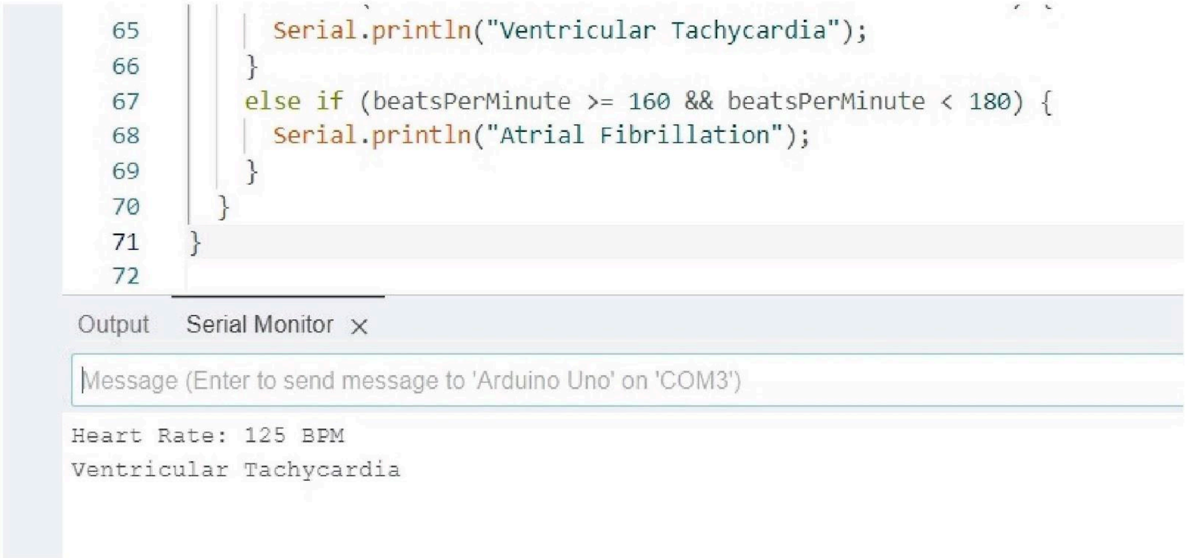

Fig 4.4 Ventricular tachycardia displayed on serial monitor

The results obtained from the pulse oximeter corroborated the findings from our device, showing a similar trend of increased heart rate post-exercise.

Fig 4.5 Pulse Oximeter displaying increased heart rate

The consistency between the results obtained from our device and those from the pulse oximeter post-exercise strongly corroborates the reliability of our heart rate monitoring system. The parallel increase in heart rate measurements observed in both devices demonstrates our system's ability to effectively capture and reflect physiological changes. This alignment with a widely recognized medical device underscores the validity of our readings and dependability of our heart rate monitoring device for both regular and post-exercise applications.

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CHAPTER 5

CONCLUSION AND FUTURE WORKS

In summary, this discussion has covered the core components and objectives of the heart rate monitoring system. The importance of piezoelectric sensors in capturing pulse vibrations and converting them into electrical signals for heart rate measurement has been highlighted. Through meticulous sensor placement and signal processing, our project aims to deliver precise, real-time heart rate data to users, empowering them to monitor their cardiovascular health effectively. Additionally, our project addresses the detection and alerting of specific arrhythmias like bradycardia and tachycardia, potentially enabling early intervention for cardiac conditions.

Looking forward, several avenues for future development and enhancement of the heart rate monitoring system emerge. Firstly, there is scope for refining the system's hardware components to optimize performance and durability. This could involve exploring alternative sensor technologies, improving power efficiency, and enhancing signal processing capabilities. Additionally, integrating advanced features such as activity tracking, sleep monitoring, and stress detection could broaden the system's utility and appeal to users seeking comprehensive health monitoring solutions. Furthermore, leveraging emerging technologies such as artificial intelligence and machine learning algorithms could enable predictive analytics and personalized health insights, enhancing the system's ability to detect and prevent cardiovascular issues proactively. Moreover, expanding the system's connectivity options to include wireless communication protocols like Bluetooth or Wi-Fi would facilitate seamless data transmission and remote monitoring capabilities, catering to the evolving needs of users in an increasingly connected world. Finally, collaborating with healthcare professionals and researchers to validate the system's effectiveness in clinical settings and conducting longitudinal studies to assess its long-term impact on health outcomes could further strengthen its credibility and adoption in the healthcare ecosystem.

APPENDIX

ARDUINO CODE

```
const int sensorPin = A0;  // Piezoelectric sensor connected to A0
const int ledPin = 13;     // LED connected to digital pin 13
const int buzzerPin = 12;  // Buzzer connected to digital pin 12
int threshold = 40;        // Threshold value for detecting a pulse
unsigned long lastBeat = 0; // Time of the last beat
int beatCount = 0;          // Number of beats detected
unsigned long startTime = 0;

void setup() {
  pinMode(ledPin, OUTPUT);
  pinMode(buzzerPin, OUTPUT);
  Serial.begin(9600);
  startTime = millis();   // Initialize start time
}

void loop() {
  int sensorValue = analogRead(sensorPin);

  // Detect a beat
  if (sensorValue > threshold) {
    if (millis() - lastBeat > 300) { // Debounce time to avoid counting the same beat multiple
times
      lastBeat = millis();
      beatCount++;
      digitalWrite(ledPin, HIGH);  // Turn on the LED to indicate a beat detected
      delay(50);                   // Keep the LED on for a short duration
      digitalWrite(ledPin, LOW);   // Turn off the LED
    }
  }
```

```
 // Calculate heart rate every 60 seconds
 if (millis() - startTime >= 60000) {
   int beatsPerMinute = beatCount; // Beats per minute is the number of beats counted in 60
seconds
   beatCount = 0;               // Reset beat count
   startTime = millis();         // Reset start time

   // Print the heart rate to the Serial Monitor
   Serial.print("Heart Rate: ");
   Serial.print(beatsPerMinute);
   Serial.println(" BPM");

   // Activate the buzzer if heart rate exceeds 100 BPM
   if (beatsPerMinute > 100) {
     digitalWrite(buzzerPin, HIGH);  // Turn on the buzzer
     delay(1000);                  // Keep the buzzer on for 1 second
     digitalWrite(buzzerPin, LOW);   // Turn off the buzzer
   }
   if (beatsPerMinute < 60) {
     digitalWrite(buzzerPin, HIGH);  // Turn on the buzzer
     delay(1000);                  // Keep the buzzer on for 1 second
     digitalWrite(buzzerPin, LOW);   // Turn off the buzzer
   }
   if (beatsPerMinute >= 60 && beatsPerMinute < 100) {
     Serial.println("Normal heart rate");
   }
   else if (beatsPerMinute >= 40 && beatsPerMinute < 60) {
     Serial.println("Mild Bradycardia");
   }
   else if (beatsPerMinute >= 20 && beatsPerMinute < 40) {
     Serial.println("Moderate Bradycardia");
   }
   else if (beatsPerMinute < 20) {
     Serial.println("Severe Bradycardia");
```

```
    }
    else if (beatsPerMinute >= 120 && beatsPerMinute < 200) {
      Serial.println("Ventricular Tachycardia");
    }
    else if (beatsPerMinute >= 160 && beatsPerMinute < 180) {
      Serial.println("Atrial Fibrillation");
    }
  }
}
```