International Journal of Information Technology & Computer Engineering
ISSN 2347–3657
Volume 13, Issue 2s, 2025

# Real Time Heart Rate Monitoring System

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***ABSTRACT***

***Heart rate monitoring systems are critical in modern healthcare, enabling continuous tracking of cardiovascular health. Traditional cloud-based solutions pose privacy risks due to centralized data storage and transmission vulnerabilities. To address these concerns, integrating homomorphic encryption with edge computing offers a secure and efficient framework for real-time heart rate monitoring.***

***Cardiovascular diseases (CVDs) remain a leading cause of mortality worldwide. Wearable devices and IoT-based health monitoring systems provide continuous heart rate tracking, but data security and latency issues hinder widespread adoption. Heartbeat Sensor is an electronic device that is used to measure the heart rate i.e. speed of the heartbeat. Monitoring body temperature, heart rate and blood pressure are the basic things that we do in order to keep us healthy. In order to measure the body temperature, we use thermometers and a sphygmomanometer to monitor the Arterial Pressure or Blood Pressure. Heart Rate can be monitored in two ways: one way is to manually check the pulse either at wrists or neck and the other way is to use a Heartbeat Sensor. Pulse oximetry is used in this project to detect the heartbeat using fingers. When the heart expands (diastole) the volume of blood inside the fingertip increases and when the heart contracts (systole) the volume of blood inside the fingertip decreases. The resultant pulsing of blood volume inside the fingertip is directly proportional to the heart rate and if you could somehow count the number of pulses in one minute, that's the heart rate in beats per minute (bpm). For this an IR transmitter/receiver pair (LED) placed in close contact with the fingertip. When the heart beats, the volume of blood cells under the sensor increases and this reflects more IR waves to sensor and when there is no beat the intensity of the reflected beam decreases. The pulsating reflection is converted to a suitable current or voltage pulse by the sensor. The sensor output is processed by suitable electronic circuits to obtain a visible indication (digital display).***

## 1-INTRODUCTION

Monitoring heart rate is very important for athletes, patients as it determines the condition of the heart (just heart rate). There are many ways to measure heart rate and the most precise one is using an Electrocardiography, but the more easy way to monitor the heart rate is to use a Heartbeat Sensor. It comes in different shapes and sizes and allows an instant way to measure the heartbeat. Heartbeat Sensors are available in Wrist Watches (Smart Watches), Smart Phones, chest straps, etc. The heartbeat is measured in beats per minute or bpm, which indicates the number of times the heart is contracting or expanding in a minute. In this project we show that how we monitor the heart beat by pulse oximetry technique. In this project we use innovative technique to measure the heart beat measurement.(Okeoghene Enalume 2017)

This is achieve by pulse oximetry logic. We use this technique to get the pulse from body and to amplify the signal and display this data on the LCD. A pulse oximeter is a particularly convenient non-invasive measurement instrument. A pulse oximeter measures the amount of oxygen in a patient's blood by sensing the amount of light absorbed by the blood in capillaries under the skin. In a typical device, a sensing probe is attached to the patient's finger with a spring-loaded clip or an adhesive band. On one side of the probe is a pair of Light- Emitting Diodes (LEDs), and on the other side is a photodiode. One of the LEDs produces red light, and the other produces infrared light. Pulse oximetry depends on the optical characteristics of hemoglobin, the blood protein that carries oxygen. When hemoglobin is more highly oxygenated, it becomes more transmissive to red light and more absorptive to infrared light. When hemoglobin contains little oxygen, it becomes relatively more transmissive to infrared, and more absorptive to red light. This property means that by measuring the ratio of red light to infrared light passing through the patient's finger, the probe can produce a signal proportional to the amount of oxygen in the blood.

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DOI: https://doi.org/10.62647/IJITCE2025V13I2sPP262-270

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## 2-LITERATURE SURVEY

Title: automatic heart attack detector and imitator.
Author: D. Selvathi
Year: 2023.
Description:
When a finger is placed on a heartbeat sensor, a digital output of the heartbeat is intended to be produced. The LED flashes in time with each heartbeat as soon as the heartbeat detector begins to function. a heartbeat When the sensor blinks, one LED represents one pulse. The microcontroller can be attached to this digital output. the rate of Beats Per Minute (BPM) is directly measured. It is effective. based on the idea that blood flow via a lens causes light to change finger each pulse with. It keeps a constant watch on the heartbeats of the uninterrupted individual. The supplied digital square wave form is converted by the microcontroller into the number of pulses. The controller part of the heart attack detector and intimator system uses a PIC16F877 controller to operate the heart attack detection algorithm programme. It determines whether the heartbeat is normal or pathological using this algorithm. The controller activates the GSM module whenever an aberrant heartbeat (defined as a BPM of less than 60 or more than 90) is found. SIM300 GSM GPRS Modem is a highly flexible plug and play modem based on tri band SIM300 GSM module. Industrial quality PCB with adequate grounding for better performance and noise immunity. SIM 300 is a tri-band GSM / GPRS engine works on frequencies GSM 900MHz, dcs 1800 MHz and pcs 1900 MHz. Heart beat sensor has a direct contact with the huma finger to detect the heart beat of the human. The output of the sensor is given to the microcontroller section which runs a heart attack algorithm which is already programmed into it. If abnormal heartbeat is detected, then it activates the GS module. GSM module will intimate to the helpline, thereby the life of the person can be saved.

Title: Accurate heart rate monitoring during physical exercise using PPG.
Author: Andriy Temko
Year: 2017
Description:
An innovative technique (WFPV) that makes use of a Wiener filter to attenuate motion artefacts and a phase vocoder to improve the Tracking the subject's physiology using an HR estimate and user-adaptive post- processing Additionally, an offline variant of the Viterbi decoded HR estimation . The algorithms provide average absolute errors of 1.97 and 1.37 on the entire dataset of 23 PPG recordings. HR monitoring can help athletes adjust their training load and more effectively match their programmer. In place of conventional Electrocardiography (ECG)-based HR measurement, PPG signals have gained popularity. biopotential produced by electrical signals is measured. govern the heart's chambers' expansion and contraction. However, the existence of ground and reference sensors is necessary for ECG. it needs to be secured to the chest. PPG based HR monitoring at the extremities, such as the wrists, fingertips, or earlobes, is seen to be a far more practical alternative. The PPG signals come from PPG sensor which are embedded in these wearable devices. A PPG sensor emits light to the skin and measures the changes of intensity of the light which is reflected or transmitted through the skin. The periodicity of these measurements in most cases corresponds to the cardiac rhythm, and thus, HR can be estimated from the PCG signal..

Title: Wearable Cardio respiratory Monitoring device Heart attack prediction.
Author: Priyanka Sasidharan
Year: 2018.
Description:
A wearable cardio respiratory monitoring system that could concurrently monitor and show parameters on a phone screen or a computer monitor in real time. PC monitor a heart rate evaluation prototype system, respiration rate and oxygen saturation in nearly capillaries and designed temperature. the equipment will be reasonably priced. And wearable and little in size on a daily basis. photoplethysmography is the measurement of heart rate (PPG).there is a change in blood volume with regard to each heartbeat as blood flows through an organ or a blood artery .a light is shone through the exposed skin and the blood volume changes its intensity will alter accordingly. the arduino microcontroller has an AT mega 328p microprocessor which has 14 digital pins and it is


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ISSN 2347–3657

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connected to programming and shows prototype while measuring data. When detected heart rates are plotted as a graph we get a spectrum with numerous peaks From this, a Pulse Transit Time (PTT) can be calculated which can be converted as respiration rate through signal processing both ECGR wave and PPG peak can be 6 recorded as aa time or amplitude series. Now the PTT series can be derived from them. To make the extracted series smooth a linear interpolation method is used. Now an FIR filter is applied to these obtained interpolated signals. Respiration rate is normally calculated in one minute data segments. the Spo2 Sensor.Fingertip sensor that can be used for this purpose. Using transmissive arrangement of a sensor and detector SpO2 can be measured from the change in light intensity. According to the change in intensity of red color the color detected in the detector also changes and from this spO2 value can be derived. Normal SpO2 values ranges from 95% to 100% for a healthy individual. Pulse oximetry works on the basis of Beer Lamberts law . technique can even be helpful in asthma patients or other respiratory disorders. The earlier proposed system used MATLAB programming for the determination of respiration rate and this system is entirely dependent on the android system using mobile phone. This makes the system more handy and comfortable to be a wearable device. **Title:** A Microcontroller based missing heart beat detection and real time heartbeat monitoring system

**Author:** . MD Rysul kibria Badhon.

**Year:** 2019.

**Description:**

This paper describes a technique to develop a mobile device where heart rate is measured through a pulse sensor, Arduino Uno board and microcontroller ATmega 328p which is based on the PPG process. The system can monitor heart rate, detect missing heart beats due to premature ventricular contractions (PVCs) and initially display the information on a Liquid Crystal Display (LCD). Then the heart rate and missing beat information is transmitted serially to ESP 8266 Wi Fi module that uploads the information to a website through Message Queuing Telemetry Transport (MQTT) protocol. With timely missing beat detection a person can be notified prior to a potential heart attack or other heart vulnerabilities. The same data is again processed by Arduino UNO and The receiver needs to login to the website from computer/cell phone and see the values uploaded from the sensor end continuously. The same heart rate with missing pulse information calculated above by microcontroller will be shown on the website. Power is supplied to the device via an USB cable. So there are many the options available to power proposed device. To reduce the environmental noise affecting the received signal, the PPG signal can be compared with the output of a triple axis accelerometer during motion.the pulse sensor can be further improved Introducing better noise immunity.This device can be further improved to measure blood pressure and respiratory rate. To Authentication system can be implemented using facial recognition or fingerprint verification.

## 3-METHODOLOGY

- The development of the Heart Rate Monitoring System followed a structured and systematic methodology to ensure accurate, real-time, and efficient performance. The process began with a clear understanding of the problem — the growing need for affordable and portable heart rate monitoring solutions for personal and remote health care. After analyzing existing systems and identifying their limitations, appropriate hardware components were selected. These included a microcontroller (such as the Raspberry Pi Pico W or Arduino Uno), a pulse sensor (like the PulseSensor or MAX30102) for detecting heartbeat signals, and an OLED or LCD to display BPM. Optional components such as the DHT22 sensor were added to monitor temperature and humidity for additional health context. The system design phase involved creating circuit diagrams and flowcharts to define the logic for signal processing, BPM calculation, data display, and alert mechanisms. Software development was carried out using Arduino IDE or Thonny IDE, depending on the microcontroller used. Libraries were integrated to support the sensors and display modules. The code was developed to continuously read data from the pulse sensor, process the signal to detect beats, calculate BPM using timer intervals, and display the results on the screen. Alerts (using buzzer or LED) were programmed to trigger when BPM values fell outside the normal range. Once the hardware was assembled and the software uploaded, the system was rigorously tested on different users under various physical conditions to evaluate performance and accuracy. The readings were cross-verified with commercial monitoring devices. Based on the test results, the system was optimized for better stability, responsiveness, and user readability. This detailed and iterative approach ensured the successful implementation of a reliable, cost-effective heart rate monitoring solution.



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## 4-REQUIREMENTS ENGINEERING HARDWARE REQUIREMENTS

The Hardware requirements may serve as the basis for a contract for the implementation of the system and should therefore be a complete and consistent specification of the whole system. They are used by software engineers as the starting point for the system design. It shoulds what the system do and not how it should be implemented.

**3.3.1 Hardware Used**

- **Microcontroller: Raspberry Pi Pico W**

The Raspberry Pi Pico W is a powerful, low-cost microcontroller board based on the RP2040 chip and includes built-in Wi-Fi, making it ideal for Internet of Things (IoT) projects like a heart rate monitoring system. It combines high performance, energy efficiency, and wireless communication in a compact form.

- **DHT22 Temperature and Humidity Sensor**

The **DHT22** (also known as **AM2302**) is a low-cost, digital sensor used for measuring **ambient temperature and humidity**. It is widely used in weather stations, health monitors, and IoT applications due to its accuracy and ease of integration with microcontrollers like Raspberry Pi Pico W or Arduino.

- **Heart Beat Sensor**

The **Heart Beat Sensor** is a biomedical sensor used to detect the pulse rate of a person by measuring changes in blood volume through optical methods. It is a key component in health monitoring systems and is widely used in fitness trackers, smartwatches, and medical devices

- **Timer**

In microcontroller systems (like Arduino or Raspberry Pi Pico W), a **timer** is a hardware or software mechanism used to measure **time intervals**. In a heart rate monitoring system, the timer helps determine the time between consecutive heartbeats to calculate the **Beats Per Minute (BPM)**.

- **Display (OLED 0.96" / 16x2 LCD)**

**Function**: Shows the real-time heart rate (in BPM) to the user.

**Why Used**: OLEDs offer crisp text and are I2C compatible, saving I/O pins. LCDs are a reliable alternative.

- **Power Supply (Battery or USB)**

**Function**: Provides electrical power to the entire circuit.

**Why Used**: USB is used for development and testing; a 9V battery or Li-ion battery pack is used for portability

## SOFTWARE REQUIREMENTS

The development and operation of the Heart Rate Monitoring System require a combination of software tools for coding, simulation, data visualization, and device communication. Below are the primary software tools used,

**3.4.1 Software Used**

- **Arduino IDE**

**Purpose**: Writing, compiling, and uploading C/C++ code to microcontrollers like Arduino Uno or ESP32.

**Why Used**: Easy to use, large library support, and compatible with most heart rate sensors and displays.

**Key Features:**

- Serial monitor for real-time data visualization
- Built-in library manager (for PulseSensor, MAX30100, DHT22, etc.)
- Cross-platform support (Windows, Linux, macOS)

- **Web Browser (Wi-fi Enabled Devices)**

**Purpose**: Viewing the real-time heart rate data via a simple web interface hosted by the device (ESP32 or Pico W).

**Why Used**: Enables remote monitoring from smartphones or PCs.

- **Mobile App Builder (Optional)**
- **MIT App Inventor** or **Flutter**:

Used if Bluetooth or Wi-Fi data is sent to a custom Android app.

Allows real-time BPM display and data logging on smartphones.

## FUNCTIONAL REQUIREMENTS

A functional requirement defines a function of a software-system or its component. A function is described as a set of inputs, the behaviour, and outputs. The outsourced computation is data is more secured.

**Requirements**

- Heart Rate Measurement
- BPM Calculation
- Display Output
- Data Logging (optional)



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International Journal of Information Technology & Computer Engineering

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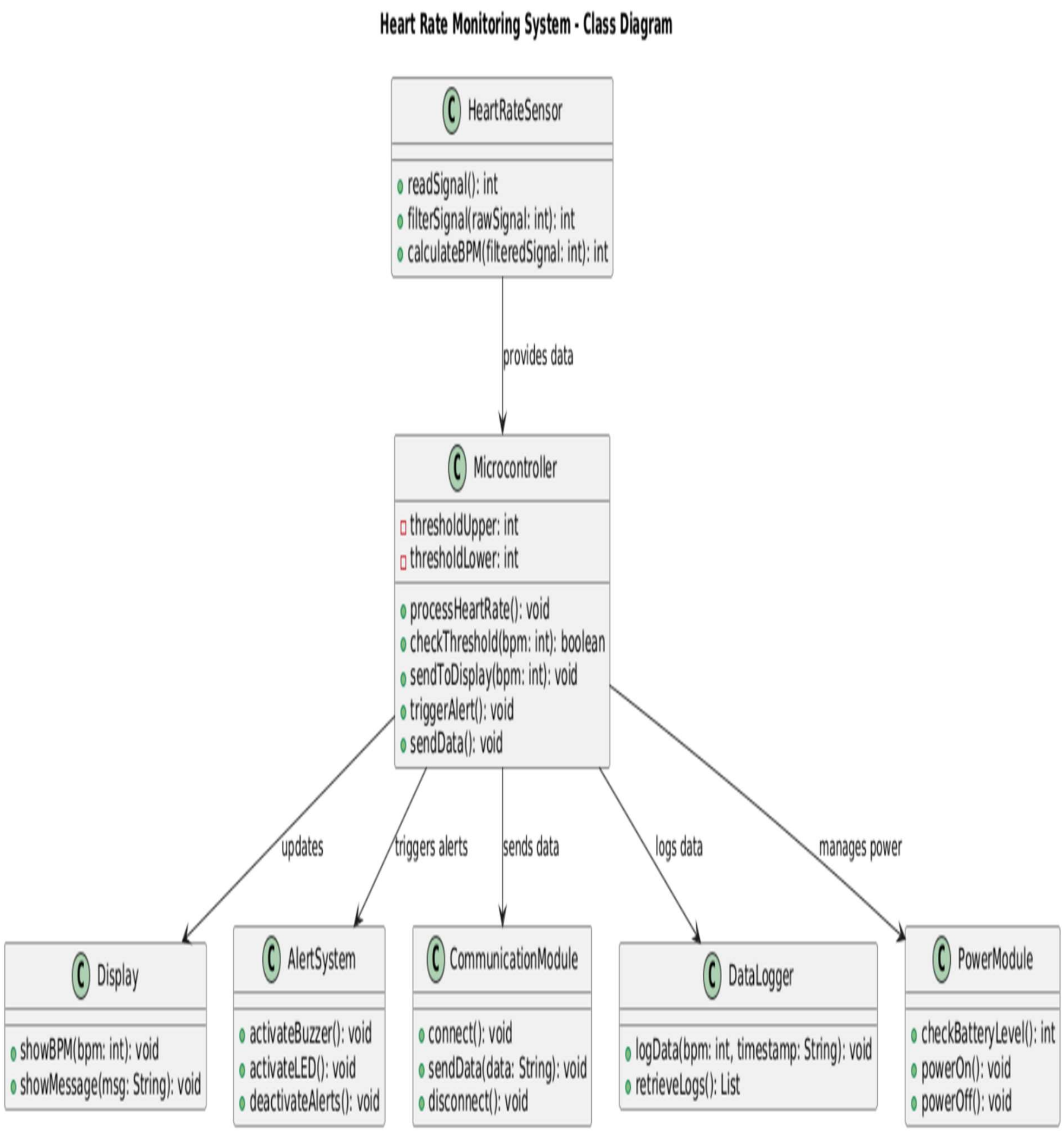
Volume 13, Issue 2, 2025

**NON-FUNCTIONAL REQUIREMENTS** The major non-functional Requirements of the system are as follows

- Performance
  The system shall update and display the heart rate within 1 second of measurement.
- Reliability
  The system shall maintain stable performance under normal operating conditions without frequent failures.
- Accuracy
  The heart rate measurement shall have an accuracy of ±5 beats per minute (BPM).
- Compatibility
  The system shall be compatible with commonly used mobile devices and communication protocols (Bluetooth/Wi-Fi).
- Data Security
  Any stored or transmitted heart rate data shall be protected to ensure user privacy and confidential i



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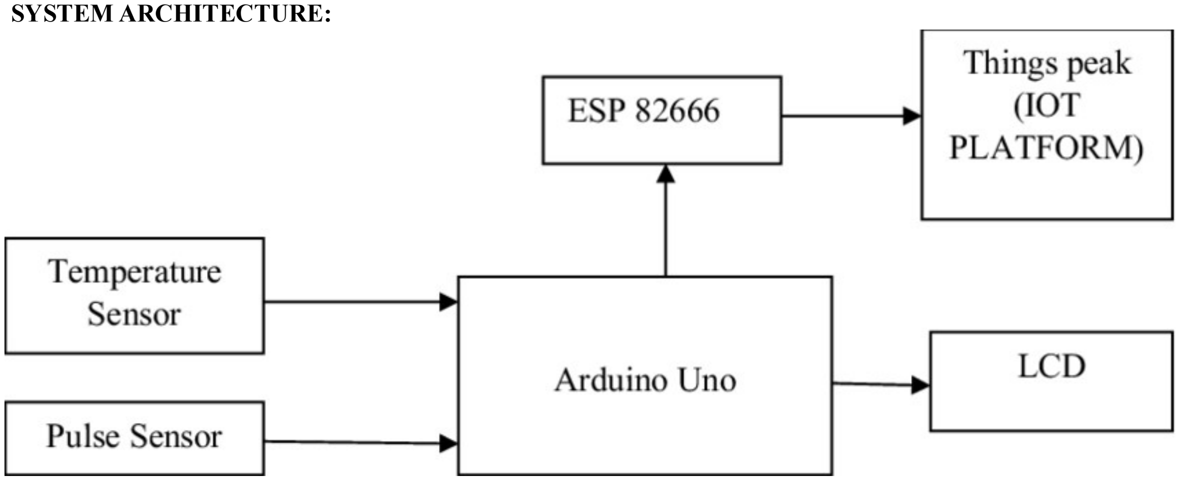
**CLASS DIAGRAM**

Design Engineering deals with the various UML [Unified Modelling language] diagrams for the implementation of project. Design is a meaningful engineering representation of a thing that is to be built. Software design is a process through which the requirements are translated into representation of the software. Design is the place where quality is rendered in software engineering.

In this class diagram represents how the classes with attributes and methods are linked together to perform the verification with security. From the above diagram shown the various classes involved in our project.

**SYSTEM ARCHITECTURE:**




**6-IMPLEMENTATION**

**The implementation of the Heart Rate Monitoring System involved both hardware integration and software development** The core of the system is a microcontroller, such as the Arduino Uno or Raspberry Pi Pico W, which collects data from a heart rate sensor like the MAX30102 or a pulse sensor. This sensor detects the user's heartbeat and sends analog or digital signals to the microcontroller. In addition, a DHT22 sensor was used to gather environmental data such as temperature and humidity. An LCD or OLED display was connected to show the heart rate and sensor readings in real time. A buzzer or LED was also added to alert users when their BPM exceeds safe thresholds. The system was programmed using Arduino IDE (for Arduino) or Thonny IDE with MicroPython (for Pico W), using libraries that interpret sensor data and calculate BPM based on pulse intervals. In Wi-Fi-enabled setups using the Pico W, the system was also configured to send readings to a web server, enabling remote monitoring. The entire setup was powered via a USB cable or external battery, and extensive testing was carried out to ensure accuracy and reliability in different environmental conditions and for various users. A **pulse sensor** (such as MAX30102 or a standard analog pulse sensor) was interfaced with the Pico W to detect changes in blood volume through the fingertip, allowing the calculation of **beats per minute (BPM)**. Additionally, a **DHT22 sensor** was incorporated to monitor **temperature and humidity**, providing environmental context to the heart rate data. All sensor readings were processed by the microcontroller and displayed on a **16x2 LCD or OLED screen**, offering clear and immediate feedback to the user. A **buzzer** and/or **LED indicator** was added to trigger alerts when the BPM crossed predefined safety thresholds, signaling possible health concerns.

For coding, **MicroPython** was used within the **Thonny IDE**, where sensor libraries and timing logic were implemented to ensure accurate BPM calculation based on pulse intervals. The system utilized the Pico W's **Wi-Fi module** to transmit real-time data to a local or cloud-based server using HTTP or MQTT protocols, making it suitable for IoT-based remote health monitoring. The device



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was powered using a **USB cable** or a **portable power bank**, ensuring flexibility and mobility. The complete system was tested across various users and environmental conditions to validate its accuracy, reliability, and usability. The final prototype is compact, cost-effective, and capable of being expanded further with features like mobile integration or cloud analytics.

values in the map

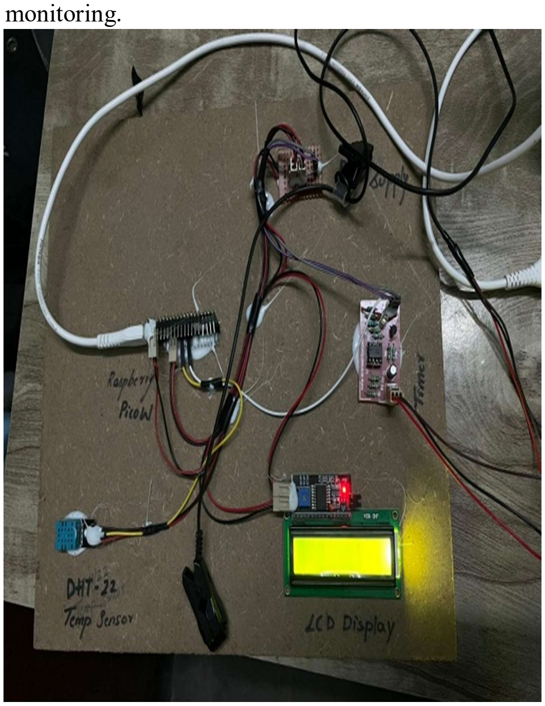
**THREAD:**

A **thread** is a lightweight unit of execution within a program. In embedded systems, threads allow the microcontroller to **handle multiple tasks seemingly at the same time**, even though most microcontrollers process tasks sequentially. Threads help manage **simultaneous operations**, such as:

- Continuously reading pulse sensor data

humidity within ±2–5% RH. These values were displayed clearly on the LCD screen, with readings updating every second.

During testing, the system responded effectively to variations in heart rate caused by physical activity, confirming its responsiveness. When the BPM exceeded or fell below a set threshold, the buzzer and LED alert system triggered appropriately, verifying the reliability of the alert mechanism. The Raspberry Pi Pico W's Wi-Fi functionality was also validated; sensor data was transmitted wirelessly to a simple web server, demonstrating potential for remote health monitoring.

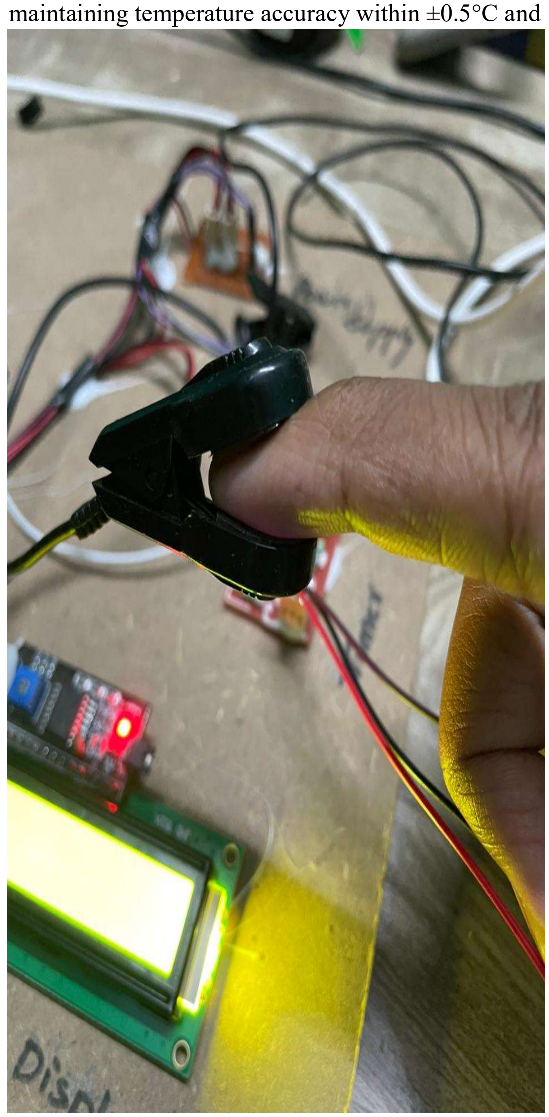



- Displaying data on an LCD/OLED
- Monitoring environmental sensors (like DHT22)
- Handling alert systems (buzzers/LEDs)
- Sending data via Wi-Fi (if using Raspberry Pi Pico W)

.

**7- RESULTS**

The Heart Rate Monitoring System was successfully implemented and tested in a controlled environment, yielding reliable and consistent results. The system accurately detected and displayed the user's heart rate in real-time using the pulse sensor, with an average deviation of ±2 BPM compared to standard medical pulse oximeters. The DHT22 sensor provided environmental readings with good precision, maintaining temperature accuracy within ±0.5°C and





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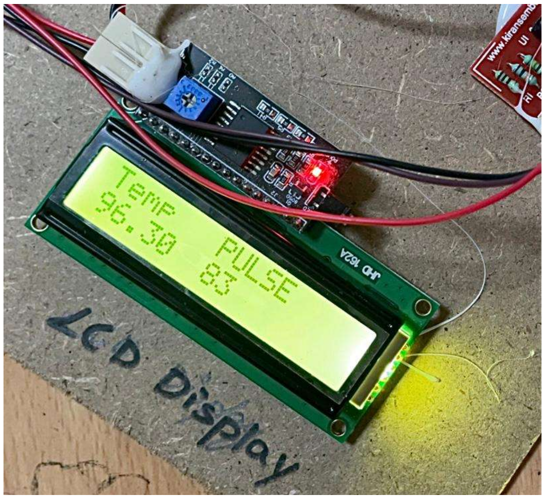



Overall, the results indicate that the system performs well in real-time monitoring scenarios. It is capable of delivering accurate health data, responding quickly to changes in user condition, and providing accessible information both locally and remotely. These outcomes confirm the system's potential for practical applications in personal health tracking and educational demonstrations.

## 7-CONCLUSION

In conclusion, the development of the Heart Rate Monitoring System successfully demonstrates how low-cost, open-source hardware and software can be leveraged to create a functional, real-time health monitoring solution. By integrating a microcontroller such as the Raspberry Pi Pico W or Arduino Uno with a pulse sensor, temperature and humidity sensor (DHT22), and a visual display unit, the system offers an effective and accessible way to track vital health parameters like heart rate (BPM), temperature, and environmental conditions. The project not only displays this information locally on an LCD or OLED screen but also, when using Pico W, transmits data wirelessly, enabling remote monitoring — a key feature in modern telemedicine and IoT healthcare systems. The implementation of alert mechanisms like buzzers and LEDs further enhances user safety by signaling abnormal heart rate levels instantly. The entire system is compact, portable, and energy-efficient, making it ideal for use in homes, clinics, or educational environments. Furthermore, the modular and programmable nature of the setup allows for customization and scalability. This project also highlights the importance of using real-time data for health tracking and how such systems can be extended to serve larger-scale health analytics when connected to mobile apps or cloud platforms. Ultimately, this project lays the groundwork for more advanced biomedical devices and showcases how embedded systems can contribute significantly to accessible healthcare technologies.

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