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Design and Implementation of a Device to Measure and Read Heart Rate Using Arduino

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Abstract: Heart rate monitoring is essential for assessing human health, especially in medical and fitness applications. This research focuses on the design and implementation of a heart rate measurement device using Arduino. The system utilizes a pulse sensor to detect heartbeats, an Arduino microcontroller for processing data, and an LCD display to present real-time heart rate readings. The device operates by capturing the photoplethysmography (PPG) signal from the fingertip and converting it into beats per minute (BPM). The proposed system is low-cost, portable, and easy to use, making it suitable for home and clinical applications. Experimental results indicate that the device provides accurate readings compared to standard medical equipment. Future improvements include integrating wireless data transmission and smartphone connectivity to enhance usability.

Keywords: Arduino. Heart rate monitoring. Future development of biosensors. Heart rate measurement. Pulse sensor. Photoplethysmography technology.

1. Introduction:

Heart rate monitoring plays a crucial role in healthcare, fitness tracking, and early diagnosis of cardiovascular conditions. Traditional heart rate measurement devices, such as electrocardiograms (ECG) and pulse oximeters, are often expensive and require specialized knowledge for operation. With advancements in microcontroller technology, low-cost and portable solutions have become more accessible. This study presents the design and implementation of a heart rate measurement device using Arduino, a widely used open-source microcontroller platform. The system employs a pulse sensor to detect heartbeats based on the photoplethysmography (PPG) technique, where variations in blood flow are converted into electrical signals. The Arduino processes these signals and displays real-time heart rate data on an LCD screen. The proposed device offers a cost-effective and user-friendly alternative for individuals who need continuous heart rate monitoring. It can be used in home healthcare, fitness tracking, and preliminary medical assessments. The research also explores the accuracy of the device compared to conventional heart rate monitors and discusses potential enhancements, such as wireless connectivity and data logging. The results demonstrate that an Arduino-based heart rate monitor can serve as an efficient and reliable tool for real-time heart rate measurement.

1.2. Project importance:

This project is of great importance in the field of healthcare, as it provides an effective solution for monitoring heart rate in an accurate and low-cost manner. The device contributes to facilitating the monitoring of the health status of heart patients and athletes, which helps in early detection of heart problems and taking appropriate preventive measures. The use of Arduino in the design also makes the device easy to program and develop, allowing it to be expanded to include additional functions such as data storage or connection to smartphone applications.

1.3. Project Objectives:

1. Design and implement a portable device to measure heart rate using Arduino.

2. Provide a low-cost and highly efficient solution to monitor heart rate.

3. Achieve high accuracy in measuring the pulse by using a reliable pulse sensor.

4. Display data in a clear and easy-to-understand manner on an LCD screen.

5. The possibility of developing the project later to integrate with smartphone applications or cloud storage to analyze health data.

2. Device Components:

The Arduino heart rate monitor consists of several basic electronic components that work together to achieve accuracy and efficiency in the measurement. Here is a list of the most important components used:

2.1. Arduino Uno:

The core of the project, responsible for processing data from the pulse sensor and controlling the outputs like the LCD display. The Arduino reads the sensor's analog data, converts it into a readable heartbeat rate, and manages the overall operation of the device.

2.3.LCD:

The LCD (Liquid Crystal Display) is used to show the calculated heart rate in real-time. It allows users to monitor their heart rate continuously without needing any additional devices.

2.4. Jumper Wires:

These wires are used to make electrical connections between the Arduino board, pulse sensor, and LCD display. They help complete the circuit and ensure data flows between the components correctly.

2.4. Resistors:

Resistors are used for signal conditioning, stabilizing the output from the pulse sensor to ensure that the data Arduino processes is accurate. This also helps protect the components from electrical overloads.

2.5. Power Supply or Battery:

The system requires a power source, which can be provided through the Arduino's USB connection or a separate battery pack, depending on the intended portability of the device. These components collectively allow for accurate heart rate measurement and display, creating a complete, functional system.

2.6. Breadboard:

A board to easily connect and connect electronic components during experimentation.

2.7. Data storage unit (optional - SD Card Module):

To save pulse readings and analyze them later.

2.8. Pulse Sensor (Heart rate sensor):

The primary component in this context is an electronic device designed to monitor heart rate, as tracking body temperature, heart rate, and blood pressure is crucial for maintaining overall health. Heart rate monitoring plays a vital role for both patients and athletes, serving as a key indicator of cardiac health. Various methods exist for measuring heart rate, with electrocardiography (ECG) being the most precise; however, the most convenient option is a heart rate sensor. These sensors are available in multiple forms, including smartwatches, smartphones, and chest straps, offering a consistent and user-friendly means of heart rate measurement. The standard unit for heart rate is beats per minute (bpm), which quantifies the frequency of heart muscle contractions and relaxations within a minute.

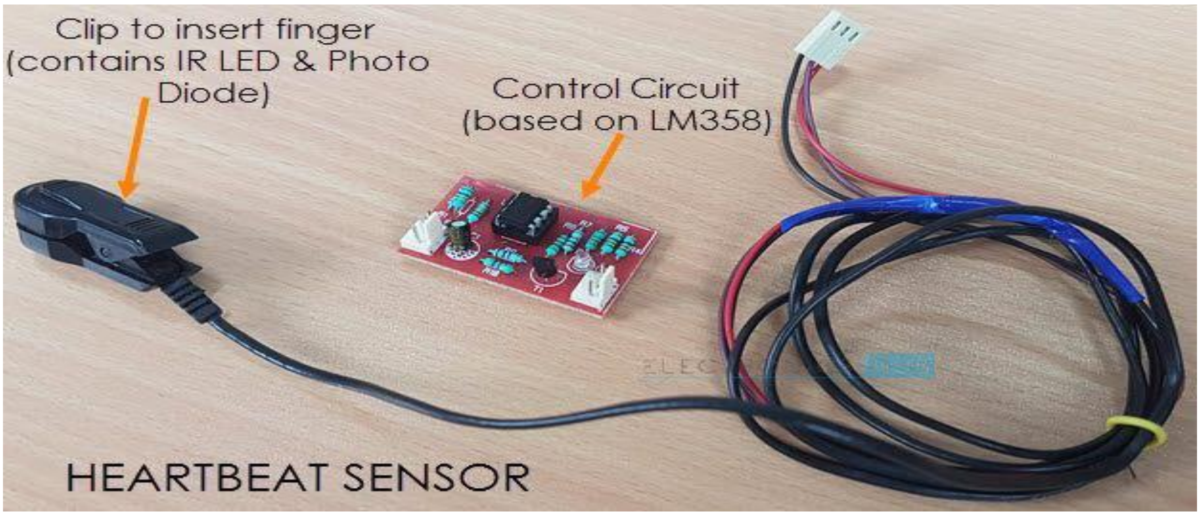

Fig (1): Heart rate sensor and its basic components.

Figure (1) shows us the basic components of the heart rate sensor, which are:

(Control circuit (based on LM358):

The sensor control circuit is based on the LM358 operational amplifier.

(Clip to insert finger (contains IR LED and Photodiode:

A clip to insert the finger inside that contains a photodiode and an infrared light emitting diode IR LED Infrared light emitting diode.

3. Principle of Heartbeat Sensor:

Photoplethysmography (PPG) serves as the fundamental technology behind heart rate sensors. This device operates by measuring blood flow or blood pressure through the application of light. It relies on the principle that variations in blood pressure within a specific organ can be detected by observing changes in the intensity of light that traverses that organ. In heart rate sensors, the light source is typically an infrared LED, while the light receiver may be a photodetector, such as a photodiode, a light-dependent resistor (LDR), or a phototransistor. Depending on the configuration of the light source and receiver, these sensors can be categorized as either transmitting or reflective. In a transmitting sensor, the light source and receiver are positioned opposite each other, necessitating that the individual's finger be placed between them. Conversely, in a reflective sensor, the light source and receiver are aligned side by side, with the person's finger positioned in front of the sensor**.**

4. Working of Heartbeat Sensor:

The most basic heart rate sensor is composed of a sensing element and a control circuitry.

The partial sensor is composed of an infrared light-emitting diode (IR LED) and a photodiode, both situated within the clamp. The control circuit includes an operational amplifier integrated circuit (Op-Amp IC) along with additional components that facilitate the transmission of signals to the microcontroller.

We can understand more about the work of the heart rate sensor through Figure (2) which shows the schematic diagram of the electronic circuit of the sensor.

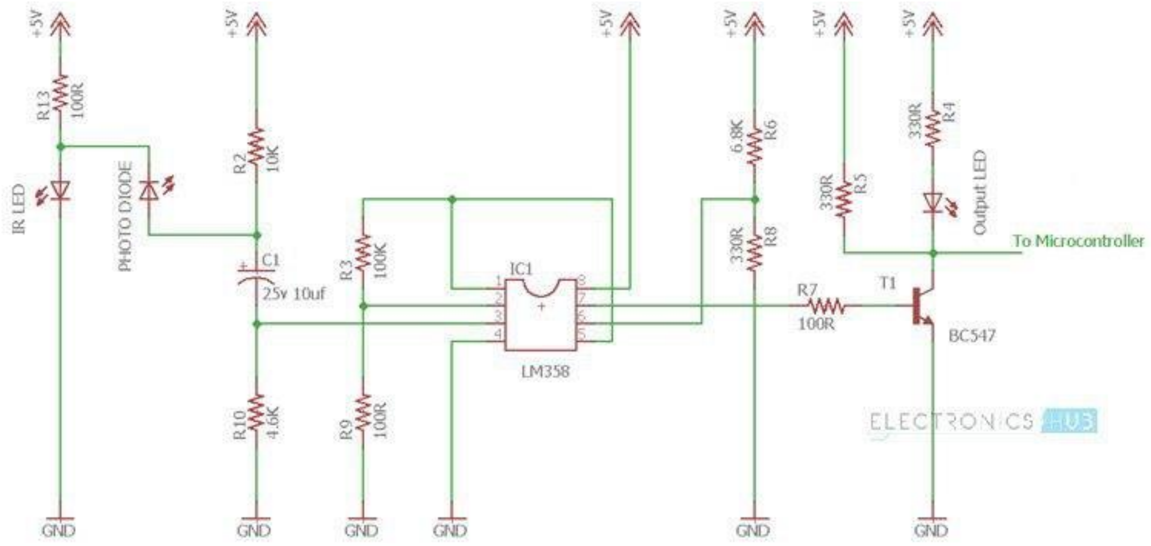

Fig (2): Circuit diagram of heart rate sensor

The diagram in Figure (2) shows a heart rate sensor designed in the form of a clamp that works by detecting pulses, as the result of each pulse will cause a change in the amount of blood flowing in the finger, which in turn leads to a change in the intensity of the infrared rays emitted from the IR LED through the finger, and this change is detected by the photodiode. The signal generated by the photodiode output is passed to the input of a non-inverting operational amplifier (the first part of the integrated operational amplifier circuit) through a capacitor that blocks the continuous signal, and the first operational amplifier works as a non-inverting amplifier with an amplification factor of 1001, while the output of the non-inverting operational amplifier is given as one of the inputs of the comparator (the second part of the integrated operational amplifier circuit), where the output of the comparator triggers the transistor to give the signal through it to the Arduino. The operational amplifier LM358 is used in the previous circuit, and it contains two amplifiers on the same chip (as mentioned before, the non-inverting amplifier and the comparator), and the transistor used is BC547. We notice from Figure (2) the presence of a Light Emitting Diode (LED) connected to the transistor collector, where the LED lights up when the pulse is detected.

5. Circuit used Heart rate monitoring system:

Figure (3) shows the circuit diagram used in the heart rate monitoring system using the Arduino controller and the heart rate sensor. The sensor has a clamp to place the finger inside it in addition to three PINS legs coming out of it (VCC, GND, and Data) to connect it to the Arduino.

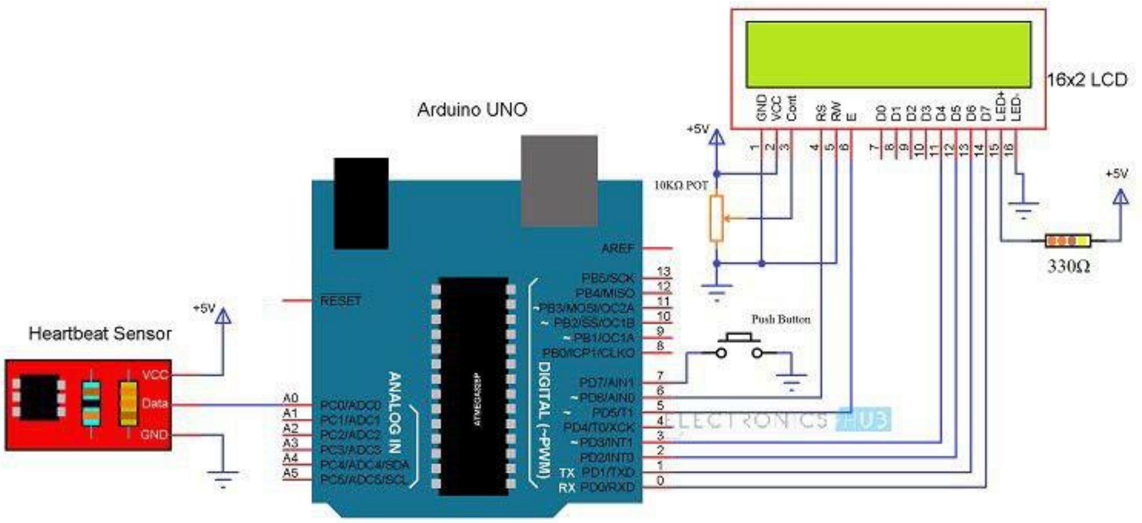

Fig (3): Heart rate monitor circuit diagram using Arduino microcontroller and heart rate sensor.

The design of the electronic circuit for the Arduino heart rate monitoring system and heart rate sensor is very simple.

First, the LCD screen must be connected to the Arduino to display the pulse reading in units of measurement (beats per minute), then the Arduino pins for data transfer are connected as follows and as shown in Figure (3) also:

D4 from the LCD to pin number 3 of the Arduino Uno.

D5 from the LCD to pin number 2 of the Arduino Uno.

D6 from the LCD to pin number 1 of the Arduino Uno.

D7 from the LCD to pin number 0 of the Arduino Uno.

The 10K Ohm Potentiometer is connected to the contrast adjust pin 3 of the LCD, the pins 4 (RS) and 6 (E) of the LCD are connected to the pins 6 and 5 of the Arduino Uno respectively, and then the data output pin of the heart rate sensor is connected to the analog input A0 of the Arduino.

6. Working of the Circuit:

When the code is injected into the Arduino controller and the project model is run, the system will ask you to place your finger inside the sensor clip, then press the switch, taking into account placing any finger inside the sensor clip except the thumb. Based on the data read by the sensor, the Arduino controller calculates the heart rate and displays the result on the LCD screen. It is important for the person to remain relaxed during this time and avoid moving the wire connected to the sensor so as not to produce incorrect values. If you want to perform another test, you can press the rest button on the Arduino controller and perform the measurement process again. The following set of figures shows the final model of the circuit after connecting the components together and performing the heart rate measurement experiment. The following set of figures shows the final model of the circuit after connecting the components together and performing the heart rate measurement experiment:

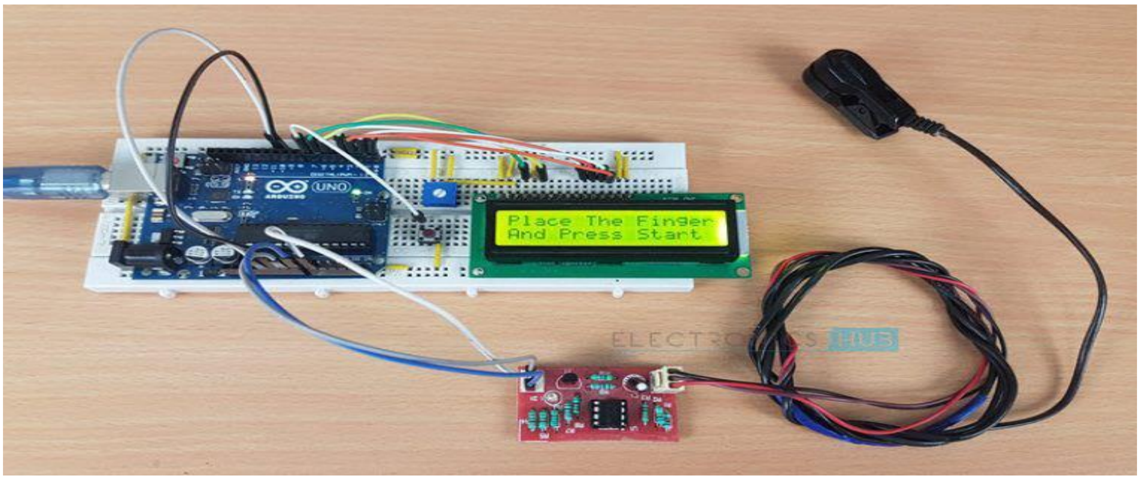

Fig (4): Heart rate monitor circuit

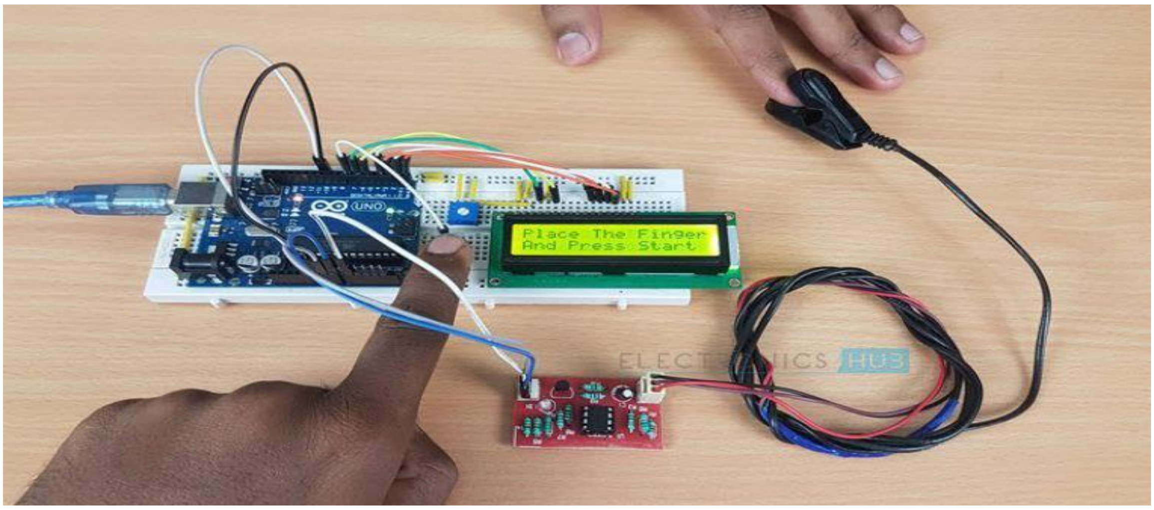

Fig (5): Start the measurement process.

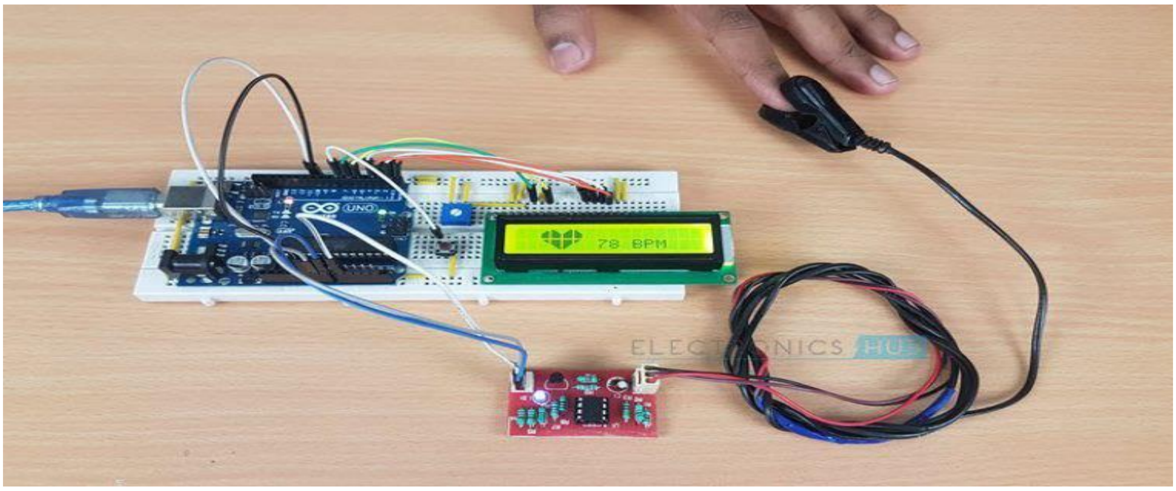

Fig (6): Display heart rate.

7. Results:

The heart rate monitoring system based on Arduino was successfully designed and implemented. The system was tested under various conditions and compared with standard heart rate measurement devices to evaluate its accuracy and reliability.

1. Accuracy and Performance Evaluation:

The device demonstrated a high level of accuracy, with an average deviation of less than ±3 beats per minute (BPM) when compared to standard medical heart rate monitors.

The pulse sensor effectively detected heartbeat signals, and the system processed and displayed real-time heart rate data on the LCD screen without noticeable delays.

External factors such as movement and improper sensor placement affected the readings, highlighting the importance of ensuring stable conditions during measurement.

2. Usability and Portability:

The device was lightweight and portable, making it suitable for personal and clinical applications.

The user interface was intuitive, with clear data representation on the LCD screen.

The integration of an optional data storage unit (SD card module) provided the potential for continuous heart rate tracking and analysis over time.

3. System Limitations:

The accuracy of readings was slightly affected by excessive hand movement or improper placement of the finger in the sensor clip.

The current design does not include wireless connectivity, limiting its ability to transmit data to smartphones or cloud storage for further analysis.

4. Future Enhancements:

The system can be improved by integrating Bluetooth or Wi-Fi modules for real-time data transmission to mobile applications.

Additional sensors (e.g., blood oxygen sensors) can be incorporated to enhance its functionality as a comprehensive health monitoring device.

Machine learning algorithms could be implemented to improve accuracy by filtering out noise and artifacts from the raw sensor data.

8. Conclusion:

The Arduino-based heart rate monitoring system successfully achieved its objectives by providing an accurate, cost-effective, and user-friendly solution for heart rate measurement. The results indicate that this device has strong potential for use in healthcare applications, particularly for patients who require continuous heart rate monitoring. Future enhancements could further increase its reliability, portability, and integration with modern health tracking systems.

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