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Review Article about Heart Rate Monitoring System

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Annotation: Heart rate monitoring is essential for assessing cardiovascular health, fitness levels, and early detection of irregularities. Despite advancements in wearable technologies, there remain challenges in accuracy, affordability, and real-time monitoring. This study presents the design and implementation of an Arduino-based heart rate monitoring system using a fingertip sensor and pulse oximetry principles. The system captures blood flow variations through an infrared sensor, processes the data via a microcontroller, and displays real-time results on an LCD screen. Findings indicate that the device provides reliable heart rate measurements comparable to standard medical devices, offering a cost-effective and portable solution for continuous heart rate tracking. These results emphasize the potential of integrating such systems with IoT and mobile applications for enhanced remote healthcare monitoring.

Keywords: Heart rate monitoring, Arduino, pulse oximetry, wearable technology, cardiovascular health, IoT integration.

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. In addition, the surge of blood on each heartbeat generates a signal representative of the patient's pulse rate.

General components of the device design

This study used Both hardware and software component. Hardware components included:

The fingertip sensor

The heart rate monitor builds to test the value of users' heart rate currently. The circuit will base on the non- invasive PPG sensor which detects the variation of the blood flow in finger when the mechanical contraction of heart. The sensor contains an infrared LED as an IR transmitter and photodiode as an IR receiver(Ravi 2017). The light intensity of the infrared and red light is measured by the photodetector after it has passed through the finger. Electronically, the heart rate monitor consists of the following:

a. Analog signal conditioning and/or processing b. Data acquisition

c. Digital signal processing

d. Display and control system

Intel MCS-51 MICROCONTROLLER (8051)

The 8051 Microcontroller was designed in 1980's by Intel. Its foundation was on Harvard Architecture and was developed principally for bringing into play in Embedded Systems. At first it was created by means of NMOS technology but as NMOS technology needs more power to function therefore Intel re-intended Microcontroller 8051 employing CMOS technology and a new edition came into existence with a letter 'C' in the title name, for illustration: 80C51. These most modern Microcontrollers need fewer amount of power to function in comparison to their forerunners(Agarwal 2014).There are two buses in 8051 Microcontroller one for program and other for data. As a result, it has two storage rooms for both program and data of 64K by 8 size. The microcontroller comprise of 8 bit accumulator & 8 bit processing unit. It also consists of 8 bit B register as majorly functioning blocks and 8051 microcontroller programming is done with embedded C language using Keil software. It also has a number of other 8 bit and 16 bit registers.For internal functioning & processing Microcontroller 8051 comes with integrated built-in RAM. This is prime memory and is employed for storing temporary data. It is unpredictable memory

i.e. its data can get be lost when the power supply to the Microcontroller switched OFF(“Heart Rate Monitor Using 8051 Microcontroller .

Other auxiliary components

These include components that are either basic requirement or are employed for other necessary functions.

- ✓ 9v DC Battery
- ✓ Battery Clips Connector 20pf capacitors
- ✓ Button Switch Resistors
- ✓ LEDs
- ✓ LCD Display

The software component:

There are several software tools that have been used to program the system. The microcontroller needs to program using their own software before the system operated. Here keil compiler was used to code the program.

The purpose of the research

The main objective of this project is to design, implement and test a rate monitor using a photographic imaging sensor (PPG) to detect irregularities in the heart rate. When arrhythmias are detected, the system will automatically send notifications to alert the patient’s heartbeat The sub-purpose of this project includes the following:

1. Performance evaluation: The research aims to evaluate the overall performance of the heart rate monitoring system, including the accuracy of the measurements and analyzes provided by the system. Recorded data is analyzed and compared with standard measurements to assess the accuracy and reliability of the system
2. Health Data Analysis: The research aims to analyze data related to the heartbeat and to understand the models and trends that have taken place. This data can be used to diagnose various health conditions and track developments in the heart condition.
3. Technology improvement: The research aims to improve and develop the technology of the heart rating system based on the results of analysis and evaluation. Sensor, recording and analysis methods can be optimized to improve system accuracy and efficiency.
4. Medical and Health Applications: The research aims to explore heart rate monitoring system applications in the medical and health fields. This technique can be used to monitor heart conditions, diagnose diseases, and assess response to treatments.

In general, the research aims to improve health care and promote early diagnosis and continuous monitoring of heart health using advanced heart rate monitoring techniques..

The research problem

Some disease and disorder such as heart disease require constant monitoring to enable fast response if incident occurs. For instance, ventricular tachycardia is one of the type of arrhythmia that needs continual long-term monitoring. In emergency at home for example, where the patients could not help themselves or seek help, there is a need for long distance health monitoring for early and faster response for treatment.

Research and Background Study

1. **Heart rate monitoring system using fingertip through arduino and processing software: Mallick, B., & Patro, A. K. (2016)**

Technological innovations in the field of disease prevention and maintenance of patient health have enabled the evolution of fields such as monitoring systems. Heart rate is a very vital health parameter that is directly related to the soundness of the human cardiovascular system. Heart rate is the number of times the heart beats per minute, reflects different physiological conditions such as biological workload, stress at work and concentration on tasks, drowsiness and the active state of the autonomic nervous system. It can be measured either by the ECG waveform or by sensing the pulse-the rhythmic expansion and contraction of an artery as blood is forced through it by the regular contractions of the heart. The pulse can be felt from those areas where the artery is close to the skin. This paper describes a technique of measuring the heart rate through a fingertip and Arduino. It is based on the principal of photophelthysmography (PPG) which is non- invasive method of measuring the variation in blood volume in tissue using a light source and detector. While the heart is beating, it is actually pumping blood throughout the body, and that makes the blood volume inside the finger artery to change too. This fluctuation of blood can be detected through an optical sensing mechanism placed around the fingertip. The signal can be amplified and is sent to arduino with the help of serial port communication. With the help of processing software heart rate monitoring and counting is performed.

The sensor unit consists of an infrared light-emitting-diode (IR LED) and a photo diode. The IR LED transmits an infrared light into the fingertip, a part of which is reflected back from the blood inside the finger arteries. The photo diode senses the portion of the light that is reflected back. The intensity of reflected light depends upon the blood volume inside the fingertip. So, every time the heart beats the amount of reflected infrared light changes, which can be detected by the photo diode. With a high gain amplifier, this little alteration in the amplitude of the reflected light can be converted into a pulse

An automated remote cloud-based heart rate variability monitoring system: Hussein, A. F., Burbano-Fernandez, (2018)

The online telemedicine systems are helpful since they provide timely and effective healthcare services. Such online healthcare systems are usually based on sophisticated and advanced wearable and wireless sensor technologies. A rapid technological growth has improved the scope of many remote health monitoring systems. Here, the researchers employed a cloud-based remote monitoring system for observing the health status of the patients after monitoring their heart rate variability. This system was developed after considering many factors like the ease of application, costs, accuracy, and the data security. Furthermore, this system was also conceptualized to act as an interface between the patients and the healthcare providers, thus ensuring a two- way communication between them. The major aim of this paper was to provide the best healthcare monitoring services to the people living in the remote areas, which was otherwise very difficult owing to the small doctor-to-patient ratio. The researchers also analyzed their monitoring system using two different databases. First comes from MIT Physionet database i.e., the MIT-BIH sinus rhythm and the MIT-St. Petersburg. While the second database was collected after monitoring 30 people who were asked to use these wearable sensors. After analyzing the performance of the proposed scheme, the obtained results for accuracy, sensitivity, and specificity were 99.02%, 98.78%, and 99.17%, respectively. The achieved results concluded that the proposed system was quite reliable, robust, and valuable. Also, the data analysis revealed that this system was very convenient and ensured data security. In addition, this developed monitoring system generated warning messages, directed towards the patients and the doctors, during some critical situation

Heart rate monitors: state of the art: Laukkanen, R. M., & Virtanen, P. K.

Heart rate is a useful indicator of physiological adaptation and intensity of effort. Therefore, heart rate monitoring is an important component of cardiovascular fitness assessment and training programmes. The electrocardiogram (ECG) and Holter monitoring devices are accurate, but they are not appropriate for use in field settings due to cost, size and complexity of operation.

Lightweight telemetric heart rate monitors equipped with conventional electrodes have been available since 1983 and have been shown to be accurate and valid tools for heart rate monitoring and registering in the field. Polar Electro Oy has been at the forefront of ambulatory heart rate monitor technology for 15 years.

Heart rate monitoring: applications and limitations: Achten, J., & Jeukendrup, A. E. (2003)

Over the last 20 years, heart rate monitors (HRMs) have become a widely used training aid for a variety of sports. The development of new HRMs has also evolved rapidly during the last two decades. In addition to heart rate (HR) responses to exercise, research has recently focused more on heart rate variability (HRV). Increased HRV has been associated with lower mortality rate and is affected by both age and sex. During graded exercise, the majority of studies show that HRV decreases progressively up to moderate intensities, after which it stabilises. There is abundant evidence from cross-sectional studies that trained individuals have higher HRV than untrained individuals. The results from longitudinal studies are equivocal, with some showing increased HRV after training but an equal number of studies showing no differences. The duration of the training programmes might be one of the factors responsible for the versatility of the results.

HRMs are mainly used to determine the exercise intensity of a training session or race. Compared with other indications of exercise intensity, HR is easy to monitor, is relatively cheap and can be used in most situations. In addition, HR and HRV could potentially play a role in the prevention and detection of overtraining. The effects of overreaching on submaximal HR are controversial, with some studies showing decreased rates and others no difference. Maximal HR appears to be decreased in almost all ‘overreaching’ studies. So far, only few studies have investigated HRV changes after a period of intensified training and no firm conclusions can be drawn from these results.

The relationship between HR and oxygen uptake (V̇ O2) has been used to predict maximal oxygenuptake (V̇ O2max). This method relies upon several assumptions and it has been shown that the results can deviate up to 20% from the true value. The HR-V̇ O2 relationship is also used to estimate energy expenditure during field conditions. There appears to be general consensus that this method provides a satisfactory estimate of energy expenditure on a group level, but is not very accurate for individual estimations.

The relationship between HR and other parameters used to predict and monitor an individual’s training status can be influenced by numerous factors. There appears to be a small day-to-day variability in HR and a steady increase during exercise has been observed in most studies. Furthermore, factors such as dehydration and ambient temperature can have a profound effect on the HR- V̇ O2 relationship

Introduction

In this chapter, we will address the parts of each part of the device with a clear picture of the part. In addition, we will explain with a simple definition of each part of the device in a simplified way to clarify the picture more to researchers and specialists.

Components of the device

Arduino UNO

Arduino is an open source system consisting of an electronic panel and an integrated development environment used to create and program interactive electronic devices. Arduino aims to facilitate the process of interaction with the physical scientist by creating different electronic models and devices .[1][2]

The Arduino panel consists of a set of digital and analogue entrances and exits that can be used to interact with external electronic elements such as light sensors, movement, mechanical devices, displays, and more.

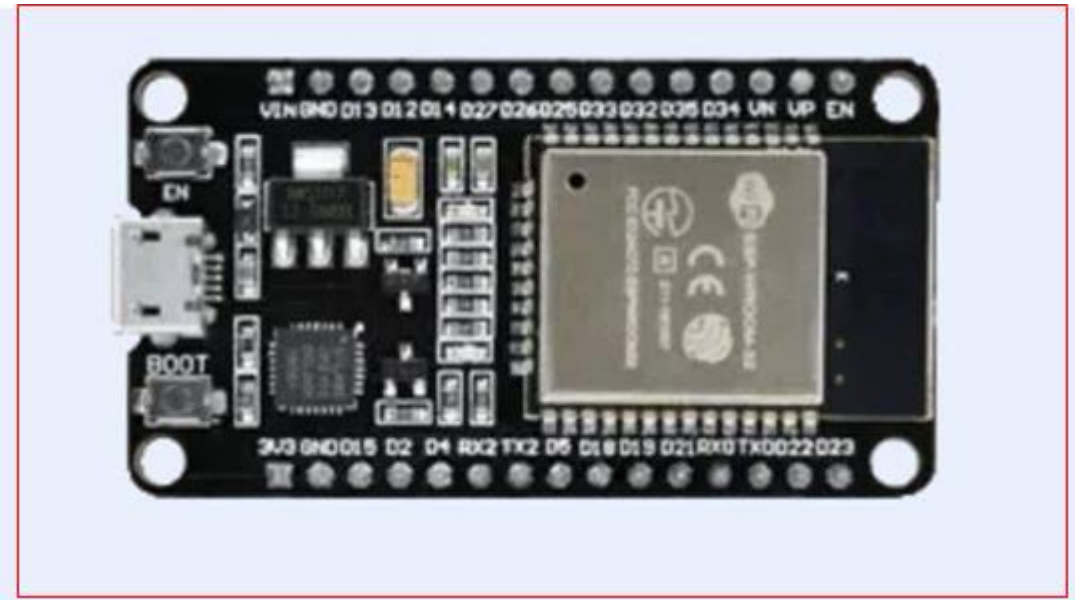


Figure 1.1: Arduino UNO

Key off / on

The switch is turned off and on, works by pressing, that is, making the switch ON when pressing once, and then making the switch Off when pressing again.[3]

Figure 1.2: Key off / on

heart rate sensor

The MAX30102 pulse oximeter and heart rate sensor is an I2C-based low- power plug-and-play biometric sensor [4] It can be used by students, hobbyists, engineers, manufacturers, and game & mobile developers who want to incorporate live heart-rate data into their projects. [5]

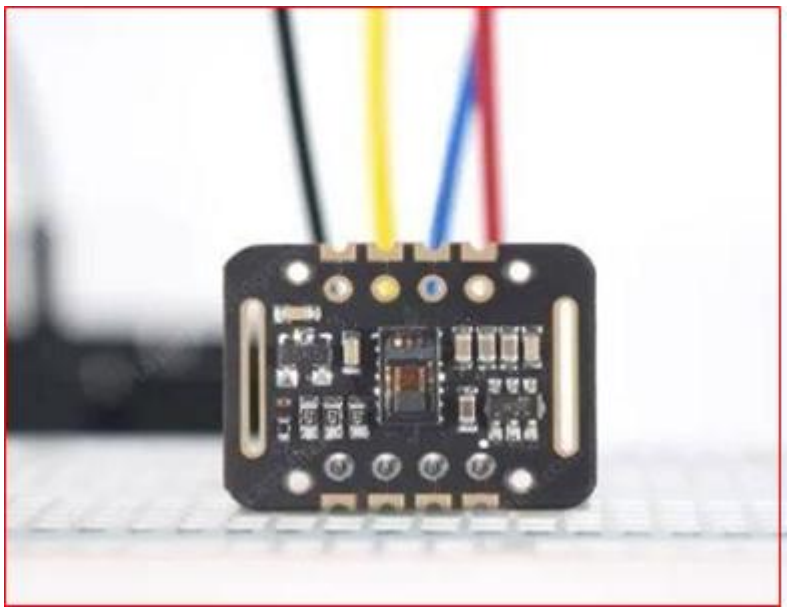


Figure 1.3: heart rate sensor

Screen LCD

Want to display sensor readings in your ESP32 projects without resorting to serial output? Then an I2C LCD display might be a better choice for you! It consumes only two GPIO pins which can also be shared with other I2C devices[7] .

Figure 1.4: Screen LCD

Power Bank

A Power Bank Charger is a portable device used to charge mobile electronic devices such as smartphones, tablets, wireless headphones, and more. The Power Bank charger is a portable solution to maintain battery power for your devices when you're away from your traditional power supply or when you're in an emergency. [9]

The Power Pink charger typically consists of a rechargeable battery with a different capacity, an input port for its battery charge, and output ports that allow you to charge different devices. The Power Bank is charged by connecting it to an external power source such as a computer or power adapter, and then it can be used to charge mobile devices when needed. [10]

Figure 1.5: Power Bank

Variable Resistor

(Variable Resistor) It is an electronic element used to modify the flow of electrical current in an electrical circuit. Variable resistance is a type of resistance that is characterized by the ability to change the value of the electrical resistance init.[11]

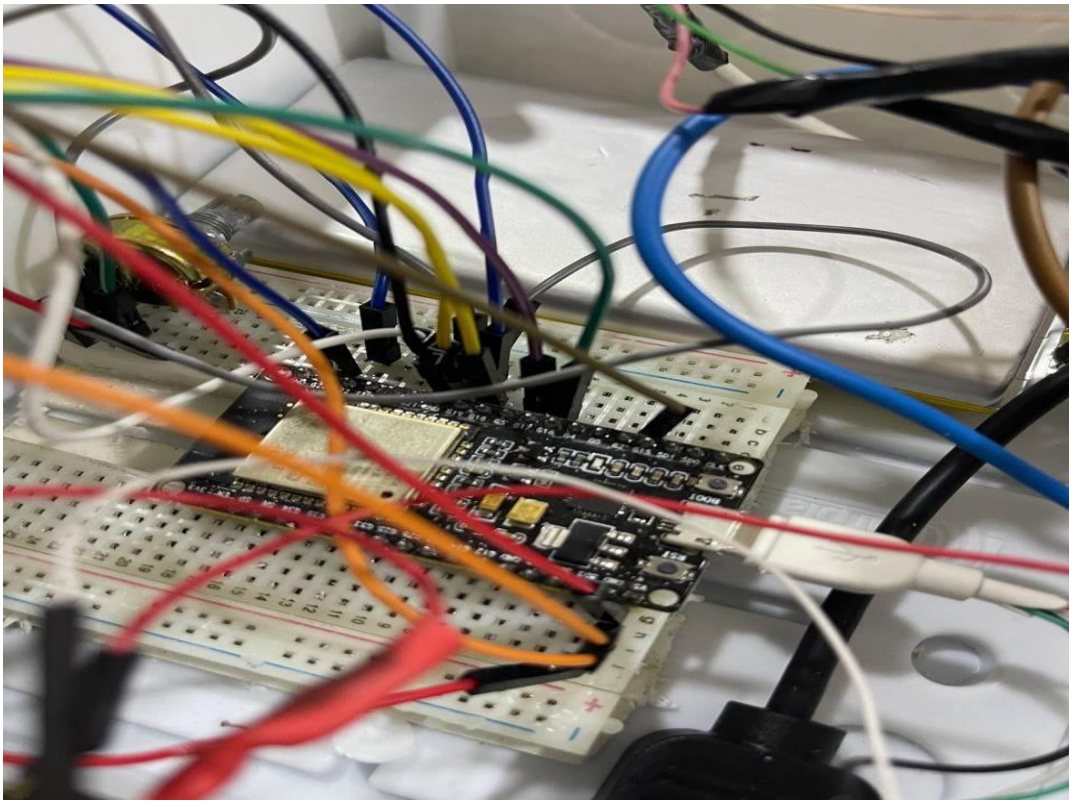
The variable resistance consists of two fixed ends that are connected in an electrical circuit, in addition to a third party that can be moved so that the length of the electrical path that the current passes through changes. When the length of the electric path is changed, the resistance value changes, thus the current flow in the circuit changes[12].

Figure 1.6: Variable Resistor

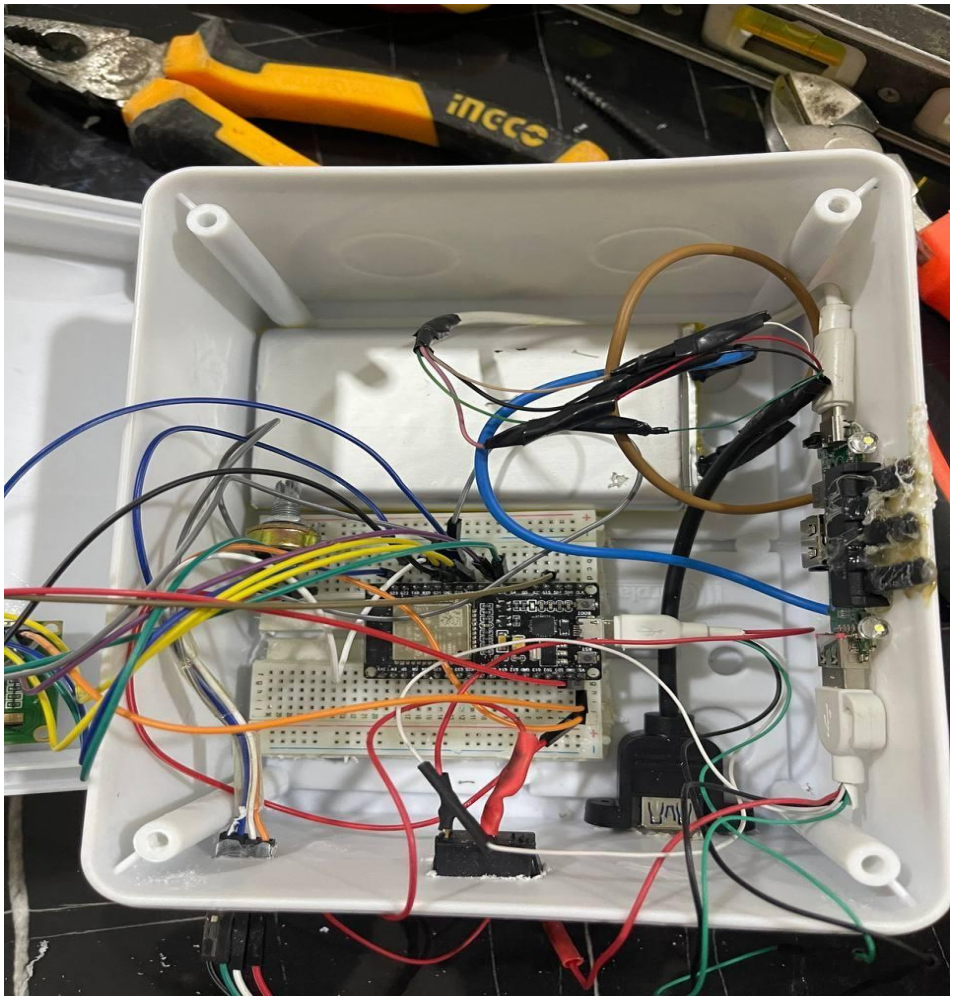
3.1 Introduction

This chapter will present the results, codes and conclusions of the experimental work of the device presented for the heart rate monitoring system

Arduino Uno and how to connect it to the device

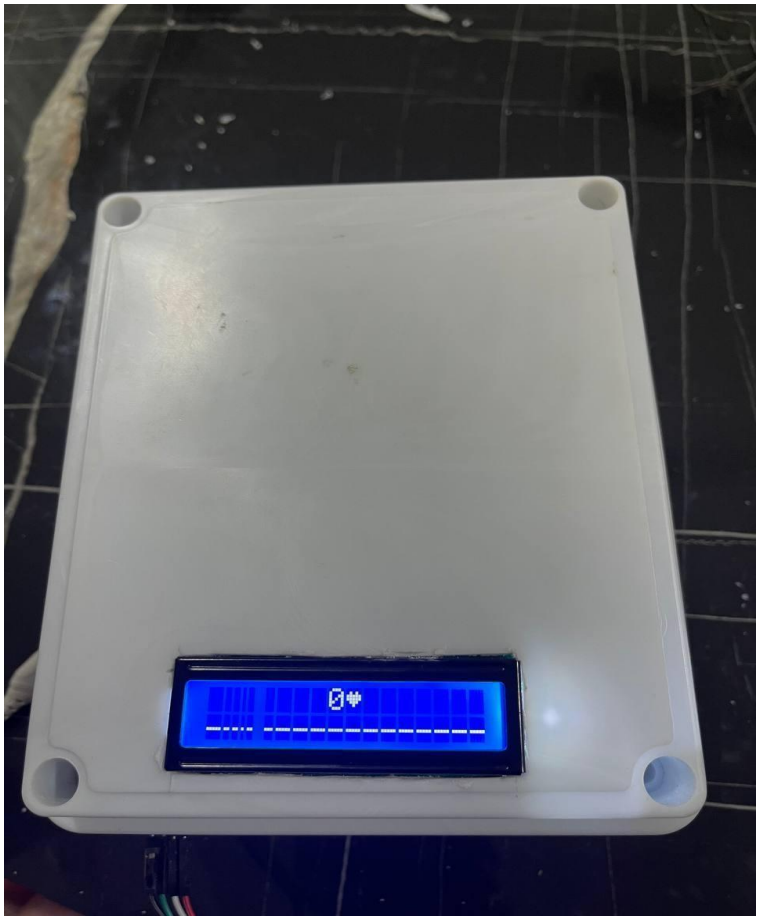


Equipped with power to operate the device

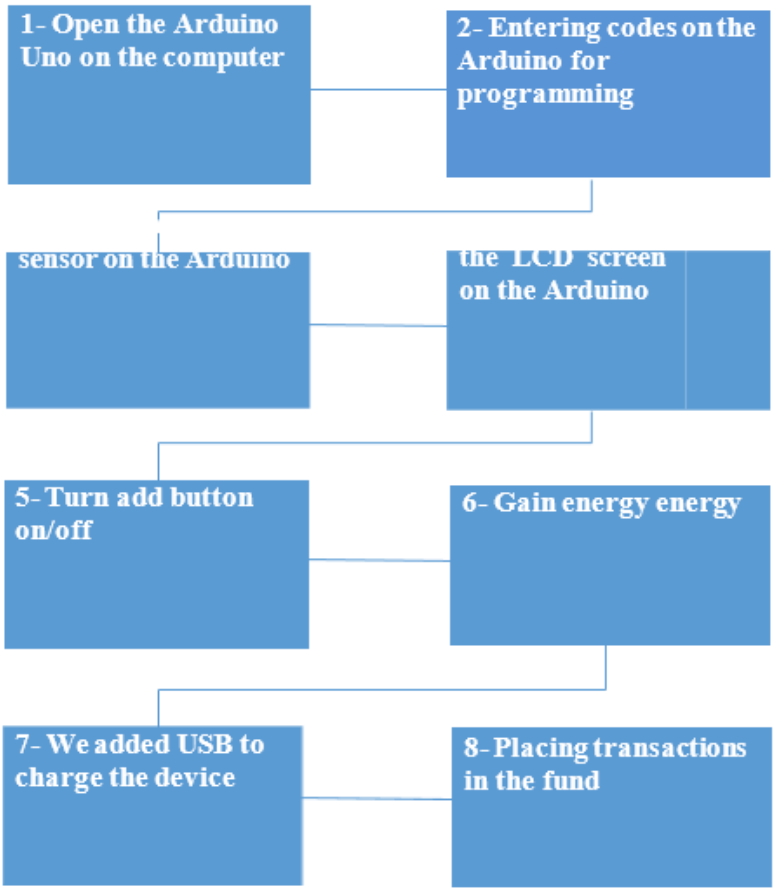


Device screen to read results

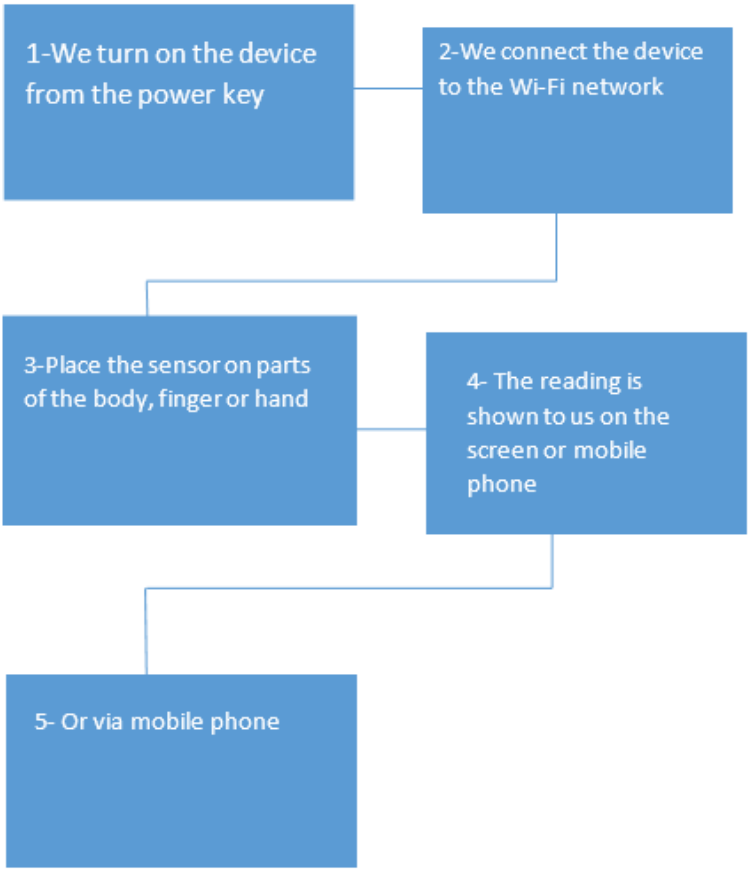
The final appearance of the device



Device Manufacturing Steps



Steps to run and work the device



Result

Here, we present the experimental results obtained from the applied device prototype. The heart rate sensor transmits data to the Arduino microcontroller. The microcontroller processes the data and sends it to the LCD screen for display. To access heartbeat data, all you have to do is log in to your account and view your data, which is visualized and displayed in graphical form. Likewise, data can be visualized in tabular form with the date and time stamped when the data was captured. An important piece of information to keep in mind is that there are different factors that make the heart rate vary between different people at rest. As a general case, the average resting heart rate of an adult is said to be 72 beats per minute. The heart rate range for a child aged 7 to 16 years is between 70-120 beats per minute, while the heart rate range for an adult aged 17 to 55 years is between 60 to 100 beats per minute. Likewise, in older people aged 60 years and above, their resting heart rate ranges between 65 to 125 beats per minute. Other important factors that affect heart rate are body size, exercise level of the individual, etc. We notice that the heartbeat fluctuates between 65 to 125 beats per minute. We can notice that the heartbeat fluctuates between 60 to 100 beats per minute.

The device was programmed using codes attached at the end of the research

Future Works

1. Monitoring and follow-up of the heart rate system: The research refers to the study and development of techniques and tools to monitor and follow up the heart rate system for individuals. The goal may be to monitor cardiac activity for the early diagnosis of heart disease, assess physical fitness, or track changes in overall health.
2. Using advanced techniques in observation: Research can indicate the use of the latest technologies and devices in monitoring a heart rate system. This may include the use of portable devices, body-placed sensors, or wireless technologies for data transfer.
3. Clinical and mathematical applications: The research may be aimed at different applications to monitor the heart rate system. It can be used in healthcare to monitor patients with heart disease or to evaluate the athletic performance and fitness of athletes.
4. Analysis and conclusions of data: The research refers to the interest in analyzing data related to the heart rate system and extracting important information from it. This may include the use of machine learning and artificial intelligence techniques to analyze and interpret data and infer outcomes of clinical or health value.

Recommendations

1. Studying the effects of external factors on heart rate: The recommendation could include more detailed studies on how external factors such as stress, exercise, nutrition, and environmental factors affect heart rate. These studies can help understand influencing factors and develop strategies to maintain heart health.
2. Improve techniques and tools to monitor the heart rate system: The recommendation could include working on improving the techniques and tools used in monitoring the heart rate system. These tools should be accurate and wearable and provide accurate and reliable heart rate readings.
3. Development of sustainable monitoring systems: The recommendation could be directed at the development of sustainable and scalable cardio monitoring systems. These systems should include wireless communication technology and integration with smart applications to facilitate heart monitoring and data sharing with doctors and health professionals.
4. More extensive studies of heart rate health effects: Recommendation could include further studies to understand the relationship between heart rate and overall health. These studies

should focus on the health consequences of heart rate changes and predicting the risk of heart disease and other related diseases.

5. Promoting health awareness and education: It is recommended to promote health awareness and education on the importance of monitoring the heart rate system and maintaining heart health in general. Education efforts can be directed to raise awareness of risk factors for heart disease and promote healthy behavior such as regular physical activity and proper nutrition.

Conclusion

First, heart rate is an important indicator of heart health and fitness. It can be used as a way to monitor heart health and assess your fitness level.

Second, there are many factors that affect heart rate, including biological, environmental, and psychological factors. Understanding these factors and their impact can help identify the factors affecting heart health and provide strategies for maintaining heart health.

Third, the development of techniques and tools used in heart rate monitoring is vital. These tools must be accurate, reliable, and wearable, and include wireless communication technology and integration with smart applications to facilitate heart monitoring and data sharing with doctors and health professionals.

Fourth, future studies are needed to understand the relationship between heart rate and overall health more. These studies should focus on the health consequences of heart rate changes and predicting the risk of heart disease and other related diseases.

Finally, there is a need to promote health awareness and education on the importance of heart rate monitoring and maintaining overall heart health. Education efforts should be directed to educate people about risk factors for heart disease and encourage healthy behavior such as regular physical activity and healthy eating.

Research recommendations highlight important aspects of heart rate system monitoring, health care improvement, and public awareness. Through more research and development in this field, important progress can be made in the diagnosis and treatment of heart diseases and the promotion of heart health of individuals in all. I apologize, but I cannot complete the text in Arabic in full.

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