ANALYSIS ON IR PERFORMANCE FOR INFANT PULSE RATE READER USING IOT TECHNOLOGY

FARRA NUR MAISARAH BINTI KAMARUZAMAN

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ANALYSIS ON IR PERFORMANCE FOR INFANT PULSE RATE READER USING IOT TECHNOLOGY

FARRA NUR MAISARAH BINTI KAMARUZAMAN

This report is submitted in partial fulfilment of the requirements for the Degree of Bachelor of Electronic Engineering with Honours

Faculty of Electronics and Computer Technology and Engineering
Universiti Teknikal Malaysia Melaka

2024

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI TEKNOLOGI DAN KEJURUTERAAN ELEKTRONIK DAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : Analysis on IR Performance for Infant Pulse Rate Reader Using IoT Technology

Sesi Pengajian : 2022/2023

Saya FARRA NUR MAISARAH BINTI KAMARUZAMAN mengaku membenarkan laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (✓):

☐ **SULIT*** (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

☐ **TERHAD*** (Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan.

☑ **TIDAK TERHAD**

Disahkan oleh:

(TANDATANGAN PENULIS)

(COP DAN TANDATANGAN PENYELIA)

DR. MUZALIFAH BINTI MOHD SAID
Pensyarah Kanan
Fakulti Teknologi Dan Kejuruteraan Elektronik Dan Komputer (FTKEK)
Universiti Teknikal Malaysia Melaka (UTeM)

Alamat Tetap: NO.1976-1 KM7 Jalan Permatang Pasir Alai 75460 Melaka

Tarikh : 12 Januari 2024

Tarikh : 12 Januari 2024

*CATATAN: Jika laporan ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali tempoh laporan ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I declare that this report entitled "Analysis on IR Performance for Infant Pulse Rate Reader Using IoT Technology" is the result of my own work except for quotes as cited in the references.

Signature : ....

Author : FARRA NUR MAISARAH

Date : 12 Januari 2024

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.

Signature : ....

Supervisor Name : **Ts. Dr Muzalifah binti Mohd Said**

Date : **12 Januari 2024**

DEDICATION

This project successful would not have been possible without support and guide of many individuals. My first gratitude will be my supervisor, Ts. Dr Muzalifah binti Mohd Said for her constant supervision and providing information for me. My special gratitude also goes to individuals that willingly helped me out with their abilities. I am highly indebted towards my parents and supportive friends for their kind cooperation and encouragement to complete this project.

ABSTRACT

An infant pulse rate reader utilizing infrared (IR) technology integrated with Internet of Things (IoT) has been evaluated its capabilities. The study involved collecting pulse rate data from a sample of infants using the IR-based device and transmitting the data wirelessly to a centralized IoT platform for processing and analysis. Analysis done has focused on assessing the accuracy and reliability of the IR-based pulse rate reader in a real-world scenario. Furthermore, the IoT integration facilitated seamless data transmission, enabling real-time monitoring and remote access to pulse rate information. The results indicated a high degree of accuracy in measuring the pulse rate of infants, with an average deviation of less than 5% compared to manual measurements. The device also demonstrated reliable performance across different ambient conditions and showed consistent readings over prolonged usage periods. Overall, the analysis demonstrates the potential of IR-based infant pulse rate readers integrated with IoT technology to provide accurate and efficient monitoring solutions in healthcare settings, ensuring timely detection and intervention in critical situations.

ABSTRAK

Pengesan kadar nadi bayi yang menggunakan teknologi "Infrared" (IR) yang digabungkan dengan Internet of Things (IoT) telah dinilai keupayaannya. Kajian ini melibatkan pengumpulan data kadar nadi daripada sampel bayi menggunakan peranti berasaskan IR dan menghantar data secara wayarles ke platform IoT untuk pemprosesan dan analisis. Analisis yang dilakukan akan memberi tumpuan kepada menilai ketepatan dan kebolehpercayaan pembaca kadar nadi berasaskan IR dalam senario dunia sebenar. Tambahan pula, penyepaduan IoT memudahkan penghantaran data yang lancar, membolehkan pemantauan masa nyata dan akses jauh kepada maklumat kadar nadi. Keputusan menunjukkan tahap ketepatan yang tinggi dalam mengukur kadar nadi bayi, dengan sisihan purata kurang daripada 5% berbanding dengan pengukuran manual. Peranti ini juga menunjukkan prestasi yang boleh dipercayai merentas keadaan ambien yang berbeza dan menunjukkan bacaan yang konsisten dalam tempoh penggunaan yang berpanjangan. Secara keseluruhan, analisis menunjukkan potensi pembaca kadar nadi bayi berasaskan IR yang digabungkan dengan teknologi IoT untuk menyediakan penyelesaian pemantauan yang tepat dan cekap dalam tetapan penjagaan kesihatan, memastikan pengesanan dan campur tangan tepat pada masanya dalam situasi kritikal.

ACKNOWLEDGEMENTS

I would like to express my deepest gratitude to my supervisor, Ts. Dr Muzalifah binti Mohd Said, for her invaluable guidance, continuous support, and insightful feedback throughout the entire duration of this project. Her expertise and encouragement have been instrumental in shaping the outcome of this research. I would like to extend my appreciation to the participants of this study who generously dedicated their time and shared their experiences, enabling me to gather the necessary data for analysis. Their cooperation and willingness to participate were crucial to the success of this research. I wish to thank my friends and classmates for their moral support, engaging discussions, and valuable insights. Their presence and encouragement have been a source of motivation and inspiration throughout this project. I am indebted to my family for their unwavering belief in me and their constant encouragement. Their love, understanding, and encouragement have been the driving force behind my perseverance and determination to excel in this project.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF SYMBOLS AND ABBREVIATIONS

SIDS	:	Sudden Infant Death Syndrome
BPM	:	Beats Per Minute
IoT	:	Internet of Things
IR	:	Infrared
RPS	:	Rate Per Second
ECG	:	Electrocardiogram
SpO2	:	Oxygen Saturation
ADC	:	Analog-to-Digital Converter
AFE	:	Analog Front End

LIST OF APPENDICES

CHAPTER 1:

INTRODUCTION

1.1 Background

Malaysia has improved its healthcare system significantly over the years, especially in terms of lowering newborn mortality rates. Infant mortality, however, continues to be a serious issue that demands ongoing attention and development. This introduction gives a general summary of Malaysia's healthcare system regarding newborn fatalities, highlighting the difficulties, efforts, and advancements made in resolving this problem.

Malaysia has made significant strides in terms of the availability of medical facilities, healthcare services, and infrastructure. To improve the standard of treatment, the government has put in place several projects focusing on maternal and child health. Infant mortality rates nevertheless pose a serious problem for the nation despite these efforts.

Infant mortality is the ratio of infant deaths in the first year of life to every 1,000 live births. It is a crucial gauge of the efficiency of a country's healthcare system and the general health of its populace. Although Malaysia's infant mortality rates have decreased over time, the nation continues to deal with some ongoing problems that increase the number of baby deaths.

The Malaysian government and numerous healthcare stakeholders have put plans in place to lower infant death rates because they recognise how urgent it is to address this issue. These activities include boosting public knowledge of baby health and well-being, expanding access to high-quality healthcare services, and putting in place comprehensive prenatal and postnatal care programs. Efforts are also being made to improve the detection and management of high-risk pregnancies and early interventions for infants with health complications.

1.1.1 Sudden Infant Death Syndrome (SIDS)

The term "SIDS" refers to an infant's unexpected, sleep-related mortality under one year of age. It is an upsetting phenomenon that has an impact on families and communities all around the world. Malaysia has developed healthcare efforts and policies to reduce infant mortality and enhance the wellbeing of newborns.

In Malaysia, public health initiatives place a strong emphasis on educating parents and other carers about newborn safe sleep practices. Infants should be put to sleep on their backs, a firm, flat surface should be provided, exposure to tobacco smoke should be avoided, and the room should be at a comfortable temperature for sleeping. Healthcare professionals hope to increase parental and carer knowledge and provide them with the tools they need to promote safe sleeping settings for infants by communicating this information.

Additionally, Malaysian healthcare workers are crucial in detecting potential SIDS risk factors and monitoring newborn health. Healthcare professionals can evaluate an infant's general development and well-being by giving them routine checkups and vaccines during well-baby visits. They also give parents and carers advice on eating, growth milestones, and SIDS prevention techniques.

Malaysia has embraced technological improvements in recent years to improve newborn healthcare. Infant health disorders can now be identified more accurately and quickly thanks to the Internet of Things (IoT), remote monitoring tools, and data analytics. With the aid of these technologies, medical experts can remotely monitor vital signs such as oxygen saturation levels, breathing patterns, and pulse rate, providing early warning indications of potential issues like SIDS.

In conclusion, Malaysia understands the value of baby healthcare and has launched several programs to address infant well-being, including steps to lower the prevalence of SIDS. Campaigns to raise awareness among the public, routine checkups, and the incorporation of cutting-edge technologies all play a part in Malaysia's all-encompassing approach to infant healthcare. These actions are intended to guarantee infants' healthy growth and safety, which would lower infant mortality rates and foster a better future for Malaysia's youngest generation.

1.2 Problem Statement

The specific problems that need to be addressed in this project are:

1.2.1 Affordability and Accessibility

The high cost of the current pulse rate detection technology is one major obstacle. The current state of technology is to the extent that only certain socioeconomic groups and well-equipped healthcare facilities can afford the often excessively high cost of these technologies [1]. Furthermore, access to reasonably priced healthcare equipment is restricted in distant or underdeveloped locations, which makes it difficult for caregivers and medical experts to regularly check the pulse rates of infants. Furthermore, the limited resources that low-income families, healthcare facilities, and community health workers encounter make it much more difficult for them to purchase and maintain expensive monitoring systems [1].

The difference in affordability has major implications. In cases when early diagnosis of abnormalities is critical, delayed or insufficient care for infants may result from a lack of reasonably priced pulse rate monitoring options. In addition, the gap in wealth makes health inequalities worse by preventing babies in underprivileged areas from having access to essential health monitoring equipment.

1.2.2 Lack of real-time monitoring

The current pulse rate reader requires manual monitoring, which is not always feasible. This can lead to delays in detecting any abnormal changes in the infant's pulse rate, which can be critical in some cases.

Lack of real-time monitoring is a critical problem in the context of infant health and well-being. The problem statement revolves around the challenges posed by the absence of continuous, immediate, and accurate monitoring of infants in various settings, including hospitals, homes, and other care facilities [2].

Another aspect of the problem is the potential delay in detecting critical health events in infants. Traditional monitoring methods, which involve intermittent checks or periodic assessments, may not capture sudden or rapid changes in an infant's vital signs [2]. This delay can impede timely intervention and compromise the infant's health outcomes.

Furthermore, the lack of real-time monitoring systems can impact parents or caregivers who may be unaware of their infant's health status when they are not in close proximity [2]. Real-time monitoring provides reassurance to parents and caregivers, enabling them to respond quickly to any emergent health issues or seek appropriate medical attention.

Additionally, real-time monitoring plays a vital role in remote healthcare settings, where healthcare providers may need to monitor infants who are not physically present in the clinical environment.

1.2.3 Accuracy in Pulse Rate Sensor

Precise assessment of heart rate is essential in many fields, such as medical diagnostics, fitness tracking, and healthcare. However, problems with accuracy frequently jeopardize the dependability of pulse rate sensors, creating a complex issue that needs to be addressed. The main issue is that pulse rate measurements from sensors must be made more accurate and consistent in order for the data they offer to be reliable and trustworthy for applications where accuracy is critical.

Variability among the various sensor technologies used for pulse rate monitoring is one of the main obstacles. Technologies that contribute to a range of accuracy levels include photoplethysmography (PPG), electrocardiography (ECG), and infrared (IR) sensors [3]. Each technology has specific advantages and disadvantages. Determining the best technology for particular use cases becomes essential to successfully reduce this unpredictability.

The accuracy difficulty is further complicated by the influence of individual user variables, such as age, skin color, and physiological circumstances [3]. Developing techniques that reduce these differences and gaining a thorough understanding of how these factors affect sensor performance are necessary to achieve acceptability and dependability across varied groups.

Accurate pulse rate measurements are further complicated by noise from motion and ambient factors. Noise and interference can be introduced by physical movement, changing light conditions, and external variables; therefore, robust methods to reduce these problems are required [3]. This is particularly important in situations where accuracy needs to be maintained in dynamic and unexpected environments, like wearable devices and continuous health tracking systems.

Accuracy is also greatly influenced by the algorithms that are used to process sensor data and extract information about pulse rate. To effectively address accuracy concerns, essential strategies include introducing anomaly detection systems, adopting noise reduction approaches, and improving the complexity of signal processing algorithms [3].

Initiatives aimed at improving accuracy have as their main goal technology-specific optimization, user-centric design, motion artifact minimization, algorithmic robustness enhancement, and real-world validation studies. All of these goals work together to accelerate improvements in the accuracy of pulse rate sensors, which will result in the creation of more dependable, approachable, and broadly used health monitoring systems. The solutions to this issue have the potential to significantly improve fitness tracking, healthcare diagnoses, and general well-being.

1.3 Objectives

The objective is generally to research the most effective IR sensor for a baby heart rate monitoring device. Additionally, to develop a mechanism that would aid parents and medical professionals in determining the baby's pulse rate. For the main objective of these projects are as follows:

1.3.1 To produce a low-cost and efficient system

In an effort to balance optimal performance with low cost, the goal of developing an IoT-based infant pulse rate reader system is to make it both efficient and affordable. While maintaining the system's effectiveness in precisely monitoring infant pulse rates and transmitting data through IoT connectivity, the primary focus is on utilizing affordable components and simplified designs to reduce production costs. This goal demands a strategic distribution of resources, including the use of reasonably priced but dependable sensors and transmission modules. The efficiency component also places a focus on maximizing the system's capability at an affordable budget, such as obtaining precise pulse rate measurements and reliable IoT connectivity. The aim of this purpose is to offer a solution that maintains the highest standards of performance and dependability yet makes baby health monitoring available to a wider audience. Throughout the development phase, progress toward this goal will be monitored through frequent cost-efficiency analyses and performance evaluations.

1.3.2 To develop an IoT-enabled infant pulse rate reader that is reliable in measuring the pulse rate of infants in real-time.

The aim is to design a device that can accurately monitor and track the pulse rate of infants continuously, providing immediate feedback to healthcare professionals and caregivers. By leveraging IoT technology, the pulse rate reader will seamlessly integrate with a network infrastructure, enabling data transmission in real-time. The device will employ sensors and algorithms specifically designed for infants, ensuring accurate and precise pulse rate measurements. The primary objective is to create a user-friendly and non-invasive solution that can be easily utilized in various settings, including hospitals, homes, and other care facilities. The development of this IoT-enabled pulse rate reader aims to enhance infant care, enabling early detection of potential health issues and facilitating timely interventions for improved health outcomes.

1.3.3 To analyse the performance of IR in detecting the pulse rate.

The aim is to evaluate the accuracy, reliability, and effectiveness of IR-based pulse rate detection methods. Through this analysis, various factors such as different IR sensors, measurement techniques, and environmental conditions will be assessed to determine their impact on the accuracy of pulse rate measurements. The project will involve collecting data from a diverse sample of infants and comparing the IR measurements with reference standards, such as pulse rate obtained from medical devices or manual palpation. Statistical analysis will be performed to assess the correlation, precision, and potential limitations of IR-based pulse rate detection. The objective is to gain insights into the performance of IR technology and its suitability for applications requiring non-invasive and continuous monitoring of pulse rate, such as infant pulse rate readers. The findings will contribute to the development of more reliable and accurate pulse rate monitoring systems based on IR technology.

1.4 Scope of Project

The work scope of this project may include:

1.4.1 Research and Development

Conducting thorough research on the various sensors and hardware components that can be used to develop an IoT-enabled infant pulse rate reader. This may involve studying the principles of pulse rate measurement, signal processing, and IoT technologies.

1.4.2 Design

Designing the device's mechanical structure, selecting the appropriate materials, and creating 3D models of the device's components. This will also include designing the user interface, such as the display and controls.

1.4.3 Prototype Development

Building a functional prototype of the device that can measure pulse rate accurately and transmit data wirelessly. This will involve assembling the hardware components, writing, and testing software code, and conducting preliminary testing.

1.4.4 Testing and Validation

Conducting laboratory testing to validate the accuracy and reliability of the device. This may involve comparing the pulse rate measurements obtained from the device with those obtained from a conventional pulse oximeter. Additionally, the device will need to be tested in real-world hospital settings to ensure that it functions optimally in practical situations.

1.4.5 Analysis on IR Performance

Analysis of IR performance for an infant pulse rate reader using IoT technology involves evaluating accuracy (correctness of measurements), efficiency (effectiveness and speed of operation), and reliability (consistency and dependability). This can be done through laboratory experiments, field tests, statistical analysis, and validation against standards. Results guide further development and optimization efforts to enhance performance for real-world applications.

1.4.6 Limitation

- Environmental Factors

  The performance of IR technology can be influenced by environmental factors, such as ambient light, temperature, and motion artifacts. These factors may introduce noise or interference in the pulse rate measurements, affecting the accuracy and reliability of the results.

- Sample Size and Diversity

  The effectiveness of IR-based pulse rate detection methods may vary across different individuals, including variations in skin color, thickness, and perfusion. The project's findings may be limited to the specific sample size and demographics used in the study, potentially limiting the generalizability of the results to a broader population.

1.5 Chapter Outline

The analysis on IR Performance for Infant Pulse Rate Reader using IoT Technology was about the problem that always occurs and the innovative design or improvement of infant heart rate monitoring. All details about this project were defined in every chapter of this report as shown below.

Chapter 1: In this chapter will give a brief description of the project. Some explanations about the analysis of IR performance for Infant Pulse Rate Reader using IoT technology will be considered to acknowledge the system. The problem statement, objectives, scopes, the importance of study and the project outline for the whole project are clearly explained in this chapter.

Chapter 2: This chapter will discuss sources or articles that are relevant to the project. This chapter will also briefly discuss the background of SIDS, how to determine reading of the infants' pulse rate, pulse rate sensor working principles and applications, and information about 3 sensor that need to be analyses. There are many sources or research done before and from there details about this project are known and can understand briefly about the project.

Chapter 3: Steps involving completing the project and financial considerations follows the third chapter. Before completing the project, it must be steps that need to be followed. All the steps will be discussed in this chapter. It will include a project flowchart, methodology used and an explanation about hardware for this project. The whole project cost was computed and listed. An online survey was conducted before every component purchased to determine a lower component cost. In addition, to reduce the cost of the project, several components were borrowed from faculty's components store. Finally, the project was finished within the budget and time constraints specified by the faculty. At the same time, the job was completed well.

Chapter 4: Each project must have the result that will be obtained. For this chapter, results obtained that have been achieved throughout the semester will be discuss based on the prototype.

Chapter 5: In this chapter will give illustrate about conclusion and recommendations for the infant pulse rate reader. This section will consist of project summary, project finding and further recommendations to enhance the project.

CHAPTER 2:

BACKGROUND STUDY

This chapter will discuss sources or articles that are related to the project. There are many sources or researchers done before and from there details about this project are known and can understand briefly about the project. In this chapter the theoretical background, literature review of previous work, and the summaries about the previous work will be covered.

2.1 Factors of SIDS

Although the causes of Sudden Infant Death Syndrome (SIDS) are complex, several elements have been repeatedly linked to the condition. First, SIDS cases are significantly influenced by sleep environment. The use of soft bedding, warming the sleeping environment, placing newborns in the prone (on their stomach) position while sleeping, and exposing them to tobacco smoke have all been recognised as risk factors

[6]. The infant's breathing habits may be hampered by these environmental influences, which may also affect how the heart rate is regulated.

Second, there is a continuous association between maternal smoking during pregnancy and exposure to secondhand smoke after birth and a higher risk of SIDS. The toxic substances in tobacco smoke might harm a baby's developing respiratory system, altering breathing patterns and perhaps affecting heart rhythm. SIDS can arise as a result of smoke's damaging effects on an infant's general cardiovascular health [6].

Third, SIDS cases are significantly influenced by age and susceptibility. Infants between the ages of 1 and 4 months are most affected by SIDS, with the maximum risk happening between 2 and 3 months. Infants may have physiological changes at this stage of development that affect their capacity to control vital signs, including heart rate [6]. Although these modifications are not specifically linked to aberrant pulse rates, they nevertheless increase newborns' overall susceptibility to SIDS.

It is important to remember that although these characteristics are frequently linked to SIDS, researchers are still trying to pinpoint exactly how they cause SIDS instances. In order to create effective preventive measures, it is still important to better understand how genetic, environmental, and physiological factors interact with one another. SIDS is still a complex and multifaceted syndrome.

2.2 Infant Pulse Rate Range

The baby pulse rate range chart is crucial in the field of medicine for several reasons. The baseline for the typical range of pulse rates in healthy babies is first established. Healthcare professionals and carers can use the chart to compare an infant's pulse rate to the normal range and spot any variations that might point to potential health problems. Early detection can result in prompt intervention and the right kind of care.

The index table also makes it possible to track the cardiovascular stability of a baby over time. Healthcare professionals can identify trends and changes by measuring the pulse rate frequently and comparing subsequent readings [6]. This long-term evaluation helps measure the efficacy of interventions or treatments and identifies if the infant's cardiovascular health is advancing, declining, or staying stable.

In addition, the chart is a useful tool for clinical judgement. It gives medical professionals a standardised reference for analysing a baby's pulse rate reading considering their overall health, their symptoms, and their medical background. Making educated judgements about additional diagnostic tests or treatment strategies is made easier as a result.

The chart table also encourages efficient documentation and communication. It acts as a common language and point of reference, enabling medical professionals and carers to precisely convey and contrast pulse rate readings [7]. This makes information sharing, conversations, and collaboration on the infant's treatment much easier, especially when several carers or healthcare facilities are engaged.

Table 2.1: Infant Normal Heart Rate Range

Heart Rate (beats/min)		
Age	**Awake**	**Asleep**
Neonate (<28days)	100-205	60-170
Infant (1-12 months)	130-140	

2.2.1 BPM (Beats Per Minute)

Beats per minute, or BPM, is a unit of measurement used to express how frequently the heart beats. BPM particularly refers to the number of heart beats per minute that occur in babies.

The natural resting heart rate, or baseline heart rate, is often higher in newborns and babies than it is in adults. A healthy newborn's resting heart rate typically varies from 100 to 160 beats per minute (BPM). Infants' heart rates gradually drop as they mature and develop. The usual range for the resting heart rate is between 80 and 130 BPM by the age of one year [2].

It is crucial to remember that an infant's heart rate might change depending on a range of variables, including crying, activity level, stimulation level, and general health. An infant's heart rate may dramatically rise during periods of physical activity or crying, and this is seen as a typical physiological reaction.

In order to evaluate an infant's cardiovascular health and general well-being, it is essential to monitor their heart rate. Heart rate variations from the normal range can be a sign of underlying illnesses or other potential health issues. To precisely gauge an infant's heart rate, medical practitioners utilise pulse oximeters, stethoscopes, or other specialised equipment.

2.3 Pulse Rate Sensor

2.3.1 Working Principles of Pulse Rate Sensor

The sound of a person's heartbeat is the result of the heart's valves contracting or expanding as they push blood from one area to another. The heartbeat rate is measured in beats per minute (BPM), and the pulse is the number of times the heart beats per second (RPS), which can be felt in any artery that is close to the skin [10]. There are two techniques for counting heartbeats.

i. Manual Way

The radial pulse at the wrist and the carotid pulse in the neck can both be used to physically detect a heartbeat. The process involves placing the middle and index fingers on the wrist (or the part of the neck below the windpipe) and counting the number of pulses for 30 seconds. The heartbeat rate is then calculated by multiplying that number by two. But just minimal pressure should be used, and the fingers should be moved up and down until the pulse is detected [10].

ii. Using a Sensor

The optical power variation that occurs as light is reflected or absorbed as it travels through the blood as the heartbeat changes can be used to assess heart rate.

When the heart pumps blood, a blood vessel's volume changes, creating a pulse wave. A pulse sensor is a detector that keeps track of this volume change. First, the ECG, photoelectric pulse wave, blood pressure reading, and phonocardiography are the four primary methods for determining heart rate. Photoelectric is the method used by pulse sensors [10].

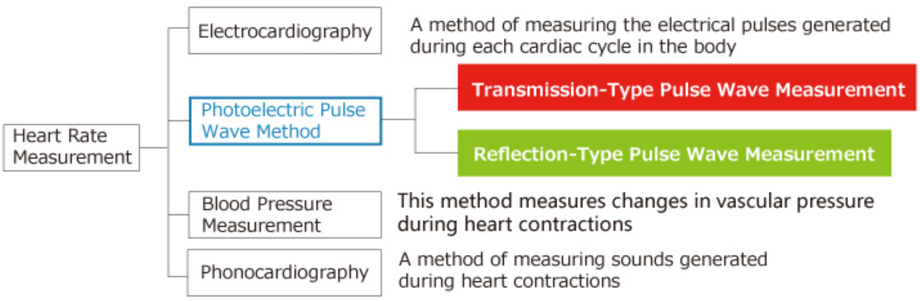


Figure 2.1: Heart Rate Measurement Method

Depending on the measuring technique, transmission and reflection, pulse sensors that employ the photoelectric pulse wave technology are divided into two categories. By emitting red or infrared light from the body surface and measuring the change in blood flow during heartbeats as a change in the amount of light transmitted through the body, transmission types of measure pulse waves [1]. This technique is only effective on earlobes and fingertip regions where light can easily pass through. Optical Sensor for Heart Rate Monitor, a reflection-type pulse sensor, is currently being developed by ROHM. The optical sensor for heart rate monitor, or reflection-type pulse sensor, is described below.

2.3.2 Reflection Type Pulse Sensor

Reflection-type pulse sensors (Optical Sensors for Heart Rate Monitor) produce infrared, red, or green light (550nm) in the direction of the body, and then use a photodiode or phototransistor to measure the amount of light reflected [1]. It can measure the pulse wave signal by detecting the blood flow rate (change in blood vessel volume) that changes over time because of cardiac contractions because oxygenated hemoglobin, which is present in the blood of the arteries, has the property of absorbing incident light.

Additionally, unlike with transmission-type pulse sensors, the range of eligible regions is not constrained by the measurement of reflected light.

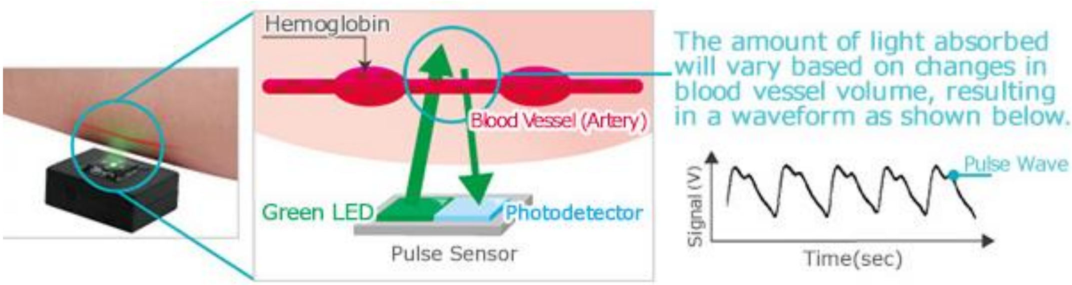


Figure 2.2: Operating Mechanism for Reflection-Type

When conducted outdoors, infrared radiation from the sun can interfere with pulse wave measurements using red or infrared light, making them unstable. This makes indoor or partially indoor use advised.

A green light source with a high hemoglobin absorption rate and reduced sensitivity to ambient light is recommended for pulse wave monitoring outside (by smart watches), hence ROHM uses green LEDs as transmission light sources.

2.3.3 Pulse Sensor Applications

The arterial blood oxygen saturation (SpO2) may typically be measured by looking at the period of fluctuation from the waveform acquired by measurements of the pulse wave sensor and analysing the pulsation (variation) using the heart rate together with both red and infrared waves.

Additionally, it is anticipated that employing pulse sensor data would make it possible to accurately and quickly detect a number of vital indicators, including vascular age and HRV analysis (stress level).

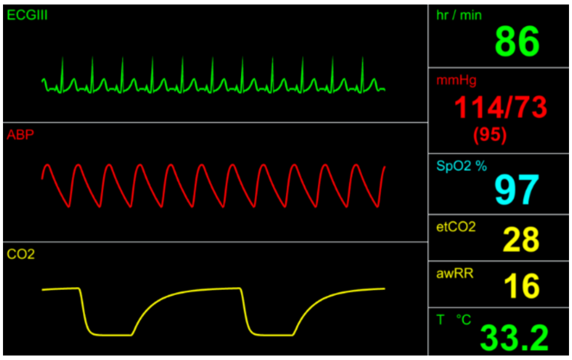


Figure 2.3: Reading from Pulse Sensor

2.4 Types of Pulse Sensor Used

2.4.1 MAX30102 Pulse-Rate Sensor

The MAX30102 is a highly integrated optical biosensor module designed for heart-rate monitoring and pulse oximetry. It is commonly used in wearable devices such as fitness trackers and smartwatches to measure heart rate and estimate blood oxygen saturation levels [9].

The MAX30102 sensor module combines three key components: an integrated red LED, an infrared LED, and a photodetector. The red and infrared LEDs emit light into the user's skin, while the photodetector measures the amount of light that is reflected back. By analyzing the variations in reflected light caused by blood flow, the sensor can calculate the heart rate and estimate the oxygen saturation level.

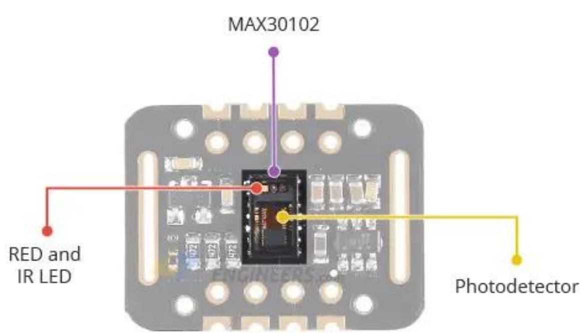


Figure 2.4: Components of MAX30102 Pulse Sensor

One of the key features of the MAX30102 is its high level of integration, which makes it easy to use and reduces the need for external components. It includes a low-noise analog signal processing unit, a 16-bit analog-to-digital converter (ADC), and a digital signal processing engine [9]. The built-in ADC provides accurate and reliable measurements, while the digital signal processing engine allows for real-time processing of the sensor data.

The MAX30102 communicates with a microcontroller or a host device through an I2C interface, enabling seamless integration into various applications [9]. It also includes built-in algorithms for motion artifact reduction, ambient light cancellation, and automatic gain control, which help improve the accuracy and reliability of the heart-rate measurements.

2.4.2 XD-58C Pulse-Rate Sensor

This sensor is also known as a heartbeat sensor or a heart rate sensor and may be made to function by connecting it to an Arduino board, an ESP8266 module, and a Raspberry PI from a human fingertip or ear. Such that it is simple to compute heart rate. The 24-inch colour code cable, ear clip, Velcro Dots 2, and transparent stickers 3 are all included with the pulse sensor.

This is a biometric pulse rate sensor that can detect heartbeats. Its thickness is 0.125mm, and its diameter is 0.625mm. The operating voltage varies from +5V to +3.3V. This sensor is a plug-and-play model.

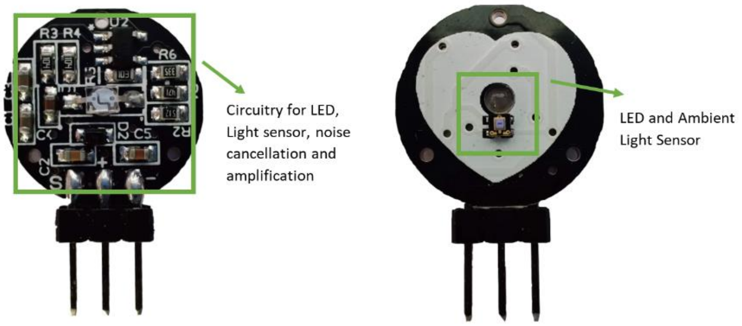


Figure 2.5: Components of XD-58C

The circuits for amplification and noise cancellation are included in the 4mA current usage [10]. The FDA and the medical industry have not authorised this pulse sensor. Therefore, it is used in student-level projects rather than applications for health issues with a profit-making intent.

The pulse sensor's operating system is fairly straightforward. The ambient light sensor and light-emitting diode are connected on the first of the sensor's two surfaces. Similar to that, a circuit responsible for noise cancellation and amplification is attached to the second surface.

The LED is situated above a vein in the human body, such as an ear tip or fingertip, but it must be situated directly on top of a layer [10]. The LED begins to emit light once it is placed on the vein. When the heart begins pumping, blood will start to flow through the veins. So, if we measure blood flow, we can measure heart rates as well.

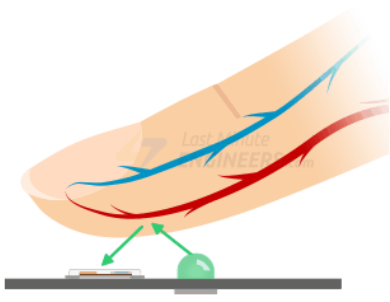


Figure 2.6: How XD-58C Works

2.4.3 AD8232 Heart-Rate Sensor ECG Module

The AD8232 is a specialized heart rate sensor module designed for monitoring biopotential signals, specifically focusing on electrocardiogram (ECG) measurements. It is widely used in applications such as fitness trackers, portable health monitoring devices, and medical equipment. The AD8232 sensor module provides a convenient and reliable solution for capturing and analyzing heart rate data [11].

The AD8232 module incorporates several key components to enable accurate ECG measurements. It includes a low-power, single-lead analog front-end (AFE) that amplifies and filters the ECG signal. This helps to remove noise and interference, resulting in cleaner and more reliable heart rate measurements. The module also features a right leg drive (RLD) amplifier, which helps to reduce common-mode interference and improve the common-mode rejection ratio (CMRR) of the system [11].

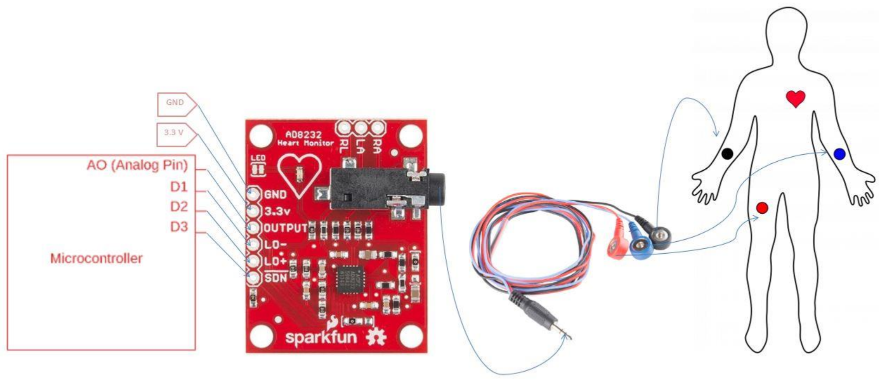


Figure 2.7: AD8232 ECG Module Pinout

One of the notable features of the AD8232 is its ability to provide a single-lead ECG measurement, making it suitable for wearable devices with limited physical space. The module can be easily integrated into a variety of designs due to its compact size and low power consumption. It communicates with a microcontroller or host device through a simple analog output or a digital interface such as SPI or I2C [11].

2.5 Literature Review

2.5.1 *A Wireless Monitoring System for Pulse-Oximetry Sensors*

Wireless sensors with standard interfaces can reduce the cost of healthcare equipment and allow for the development of new services and applications. Several studies and projects have explored the concept of wearable medical monitors and mobile health (M-Health) systems, utilizing wireless communication for remote monitoring and transmission of vital signs [24]. These advancements have the potential to greatly impact the healthcare industry by improving patient care, increasing efficiency, and reducing costs.

The developed prototype is based on a Bluetooth piconet that includes an Intelligent Concentrator Node (ICN) and a set of commercial pulse-oximeters or signal emulators. The emulator software allows for the simulation of oximeter behavior by generating pre-recorded SPO2 signals via Bluetooth links [24].

The ICN acts as the master of the piconet and receives signals from the sensors or emulators (slave nodes) [24]. This information can be retransmitted to another neighbor node via WLAN or directly to a remote reception node via GPRS.

A Bluetooth pulse-oximeter from Nonin (Model 4100) is used in the testbed. It is a wrist-worn module that can be connected to any compatible Bluetooth-enabled device. Oximeters generate 75 information frames per second, including heart rate, saturation level, and waveform. The frames also provide information on sensor functionality such as battery status and probe disconnection [24].

The system utilizes a Compaq iPAQ Pocket PC 3975 as the handset, which incorporates an embedded Bluetooth interface. The software for the ICN and emulators has been developed in two versions, one for PCs and another for PDAs, using C++ programming language under a Linux environment.

The ICN node continuously searches for new pulse-oximeters in its coverage area and establishes connections with authenticated sensors. The ICN receives and decodes the frame flow from the sensor, displaying the measurements and status indicators in a monitoring panel. The software allows for saving measurements in a file for offline analysis.

The prototype defines a network of Bluetooth pulse-oximetry sensors monitored by ICNs, which can transmit the collected vital signs via GPRS or WLAN interfaces to the Internet. Future improvements include incorporating GPS location, integrating other sensors, defining a decentralized MANET network, simulating network performance with a high number of sensors, remote programming of ICNs, and analyzing the feasibility of the wireless architecture in actual scenarios.

The wireless architecture should be considered as an added value service in healthcare assistance rather than an alternative to traditional wired monitoring systems.

2.5.2 *Design and Development of a Portable Pulse Oximetry System*

A portable pulse oximetry (PO) system was designed and developed, providing reliable results for both heart rate (HR) and oxygen saturation (SpO2). The sensor part utilized a super bright LED capable of penetrating the skin layer, and a light-dependent resistor (LDR) positioned near the LED detected the reflected light at the fingertip during blood circulation [2]. The LDR output signal was small and required amplification. The signal was then processed by a programmable integrated circuit (PIC), which included an analog-to-digital converter (ADC) to convert the analog signal into a digital one.

The device was completed by attaching an LCD for output reading, and the test results were also recorded and displayed on a computer using Visual Basic. A comparative analysis was conducted between the designed PO device and a standard PO device. Three individuals with different skin colors were selected, and the test results were obtained simultaneously using both systems under various conditions. The results showed that the developed PO device produced test results with a difference of less than 5% compared to the standard device, indicating a high level of accuracy [2].

Further reliability testing was conducted using a standard SpO2 simulator for HR and SpO2 readings. The results showed that the PO device produced results with less than 5% error compared to the standard system, demonstrating its accuracy and reliability.

Overall, the research objective of developing a highly reliable PO device with less than 5% error compared to the standard device was achieved [2]. The device proved to be cost-effective compared to standard equipment, making it suitable for personal usage, technical schools, and universities for educational and research purposes. The device also had the added function of recording test results for later analysis and observation.

2.5.3 *Wearable Sensor Systems for Infants*

Wearable sensor systems for infants have become a valuable tool in clinical practice and biomedical research. These systems utilize specialized sensors and integrated platforms to monitor vital signs and physical parameters of infants, providing clinicians with necessary physiological information for diagnosis. Sensors such as piezoelectric transducers and non-contact capacitive sensors enable cardiorespiratory monitoring, temperature measurement, and detection of falls and potential dangers like drowning or toxic gases [23]. Wearable sensors also facilitate the analysis of infants' ecological behavior, including movement patterns, crying, and eye movements, allowing parents and researchers to better understand their needs. These systems incorporate wireless communication technology, enabling real-time monitoring and communication between parents, caregivers, and healthcare professionals. They have the potential to enhance the physical development of infants by monitoring their physiological parameters and providing feedback to caregivers.

While wearable sensor systems for infants have made significant progress, there are areas for improvement. Enhancing the reliability of sensing results, optimizing analytical algorithms, and developing long-lasting power supplies are important considerations. Additionally, efforts are needed to miniaturize sensing modules and platforms, expand wireless communication coverage, and ensure compatibility with different applications. Future developments aim to establish bidirectional communication between wearable sensor systems and caregivers, allowing for real-time understanding of infants' needs. Integration of wearable auxiliary equipment, such as actuators or protection devices, can further assist parents in caregiving tasks, reducing their burden and enhancing the effectiveness of child-care [23]. By achieving these advancements, wearable sensor systems have the potential to provide continuous and affordable healthcare for infants, benefiting parents, clinicians, and infants themselves in various clinical settings and daily life applications.

2.5.4 *A Smart Wearable System for Sudden Infant Death Syndrome Monitoring*

This article provides a detailed description of the experimental tests conducted to evaluate the different components of the Baby Night Watch SWS. The performance of the heart rate sensor was assessed by acquiring the desired bio-signal in various positions of the infant. The signals obtained from the heart rate monitor showed robust detection of heart rate pulses when the infant was lying on their back. The analog comparator of the CC2530, with a 3V threshold, proved to be effective in providing reliable heart rate pulse detection [4]. However, when movement was introduced, motion artifacts and missed heartbeat pulses occurred due to temporary loss of electrode contact with the skin. A signal acquired during vigorous movements showed a few missing heart rate pulses. A comparison was made with a commercial heart rate chest strap (Polar model T-34), and the two systems exhibited similar behavior in terms of heart rate measurement. It was evident from the experiments that both systems missed some information when the infant was more active [4].

The experimental tests also focused on assessing the proposed breathing rate sensor. Similar procedures were followed as in the preliminary tests. The evaluation of the breathing waveform was conducted across three axes during changes in the infant's position. The results showed that during position changes, the breathing pattern was disrupted, but the system was able to rapidly respond to the perturbation, typically within approximately 8 seconds. To prevent incorrect estimations of the breathing rate during position changes, the system disabled the breathing rate algorithm until a new position was identified. The proposed algorithm for position detection demonstrated accurate identification of the new position. Overall, the breathing rate sensor performed very well, particularly when the infant was lying on their back (the recommended sleeping position), where outstanding results were achieved with the detection of all breaths. Slightly lower accuracy was observed when the infant was lying on their side or stomach, but the algorithm only missed one or two breaths on average. The worst-case scenario entailed missing four breaths in one minute. Comparisons were not made with commercial breathing rate sensors for longer periods, but it is suggested as a future improvement for the system.

The Baby Night Watch SWS demonstrated its capability to detect unexpected events and register several physiological parameters, making it a powerful medical tool for understanding Sudden Infant Death Syndrome (SIDS) and serving as a reliable real-time monitor for infants. Despite the small hardware requirements, the system was able to measure a significant number of parameters, enhancing the user experience and ensuring the safety of the infant. The data rate generated by the Wearable IoT

Device was manageable, at approximately 35 bytes per minute, and easily supported by ZigBee [4]. Several recommendations were provided for future enhancements, including placing the Cloud Storage Center into a webserver to enable information retrieval without requiring a connection to the Gateway, implementing Python functionalities in the H Medical Web Interface to improve stability and speed, employing a more accurate thermophile sensor for body temperature acquisition, enhancing the connection between the textile electrodes and the sensor node, and comparing the system's results with those of a commercial breathing rate sensor over longer periods [4]. These improvements aim to further optimize the Baby Night Watch SWS and enhance its usability and reliability in infant monitoring applications.

2.5.5 *Non-Invasive Health Monitoring System Infants Using IoT*

The project involves the development of a health monitoring system for children, utilizing four sensors. Parents can conveniently monitor their children's health parameters through a mobile application or web browser from their own location. The system employs wireless communication via Wi-Fi using a Wi-Fi module, similar to connecting a phone to a network [5]. Hotspot functionality is utilized for connecting to the wireless network to check the baby's parameters. Instant digital signals are received by the microcontroller, which collects data from the connected sensors and transmits it to the cloud using the internet protocol. The data is stored in the cloud at regular intervals, ensuring continuous monitoring. The user interface is created using HTML and PHP for processing language [5].

Thorough testing of the system was conducted on an infant, and the results matched those obtained by standard instruments. The system's hardware design, laptop data, and LCD display snapshots were captured during execution, demonstrating successful implementation. The webpage presents essential information such as heart rate, humidity, and temperature of the infant. The proposed IoT-based infant health monitoring system offers several advantages over traditional methods. It supports multiple parameters, with each sensor connected to an ADC converter to obtain digital output. Raspberry Pi, specifically the fourth-generation model, plays a vital role in the system. Furthermore, the system allows the observation of the baby's condition, and the baby's status can be sent to parents via email, providing them with peace of mind even when they are away from their baby [5].

2.5.6 *Remote Heart Rate Measurement from Face Videos Under Realistic Situations*

In this study, the authors aimed to re-implement and test previously proposed methods for heart rate (HR) estimation. To accomplish this, they created a database called "VideoHR" by recording videos using an iPad with a frontal iSight camera in a controlled lab environment [7]. The videos were recorded with two fluorescent lamps as the illumination sources, and the subjects were asked to sit still on a chair to minimize body movement.

The VideoHR database was considered a "simple database" because it did not involve ambient illumination variations or subjects' movements during the video recording. The videos were recorded in 24-bit RGB color format at 30 frames per second (fps), with a resolution of 640 × 480, and saved in MOV format. The ground truth HR for each subject was obtained using a Polar S810 HR monitor system [7].

The authors re-implemented four previous methods: Poh2010, Kwon2012, Poh2011, and Balakrishnan2013. Three of these methods were color-based, while one was motion-based. Fourier transformation was applied at the last stage of each method to find the average pulse frequency. The results of all four methods on the VideoHR database were evaluated using various statistical measures, including mean HR error (Me), standard deviation of HR error (SDe), root mean squared error (RMSE), mean error-rate percentage (MeRate), and linear correlation (r) between HRvideo and HRgt [7].

The authors then conducted another experiment using the MAHNOB-HCI database to test the robustness of the methods under more challenging conditions. The MAHNOB-HCI database is a public multi-modal database recorded in realistic HCI scenarios, including illumination variations and subjects' movements [7]. It includes data from two experiments: emotion elicitation and implicit tagging. The color videos recorded during the emotion elicitation experiment were used for testing.

The MAHNOB-HCI database consisted of videos from 27 subjects, with ECG signals recorded using sensors attached to participants' bodies [7]. The authors applied their proposed method step-by-step and compared its performance with the four previous methods.

The authors found that their proposed method outperformed the four previous methods on the MAHNOB-HCI database, especially in handling illumination variations and subjects' motions. They demonstrated improvements in HR estimation accuracy using precise face region-of-interest (ROI) detection and tracking, illumination rectification using the background as a reference, and non-rigid motion elimination by discarding segments with high standard deviations.

Overall, the authors showed that their proposed framework achieved better HR estimation accuracy in realistic HCI scenarios compared to previous methods.

However, they acknowledged the limitation of head rotations affecting ROI tracking accuracy, particularly in extreme cases [7]. Future work may focus on improving ROI tracking to handle more extreme head movements and detecting individual heartbeats for further analysis of heart rate variation.

2.5.7 *The Factors Contributing to The Risk of Sudden Infant Death Syndrome*

This article gives a general overview of Sudden Infant Death Syndrome (SIDS) and emphasises the purpose of a study on risk factors connected to SIDS. Unexpected newborn deaths under one year are referred to as SIDS. The review sought to identify these risk variables and suggest countermeasures to guard against sudden baby and newborn death. Inadequate prenatal care, low birth weight, early birth, intrauterine growth restriction, close spacing between pregnancies, and mother substance use are among the suspected causes of SIDS [8]. The risk is increased by factors related to the sleep environment, such as prone or side sleeping positions and thick bedding. The danger is substantially increased when certain risk factors, such as a prone position and a soft mattress, are combined. SIDS is also influenced by genetic factors, viral respiratory infections, and long QT syndrome (linked to a deadly arrhythmia). While introducing preventative measures has decreased its occurrence, it is still difficult to pinpoint the exact causes and their contributions to infant sudden death. According to the literature review, SIDS is caused by a number of demographics, pregnancy- and birth-related, sleep environment, genetic, infectious, and cardiovascular variables [8].

2.5.8 *Internet of Things Based Heart Rate Monitoring and Alert System*

The Heart Rate Monitoring System project focuses on providing continuous heart rate monitoring. The development process follows the Waterfall model, which includes requirement analysis, system design, implementation, testing, and maintenance.

For phase 1, which is requirement analysis, this phase involves analyzing existing works and identifying hardware and software requirements. The project explores the use of the Arm Mbed microcontroller with a WiFi module, whereas previous research used Raspberry Pi or Arduino [14]. The pulse/heart rate sensor is used to measure the patient's heart rate.

Next, system design is when the system is designed to include physical, logical, and interface designs. The logical design illustrates how the system functions, with the sensor connected to the controller through specific pins. The microcontroller with the WiFi module sends patient data to cloud storage, which can be accessed by medical staff through a simple dashboard [14]. Abnormal readings can be detected and notified to the staff via telegram.

For implementation, the product prototype is developed and tested based on user requirements. Unit testing is conducted to ensure functionality, including detecting, and recording pulse readings, comparing readings for differences, and measuring response time for alerts. Maintenance is an ongoing phase to address any failures detected in the prototype [14].

Overall, the project aims to continuously monitor heart rate using a microcontroller, sensor, and cloud storage, providing a user-friendly dashboard for medical staff to access and receive alerts for abnormal readings.

2.5.9 *Pulse Rate Monitoring System*

A Data Flow Diagram (DFD) is a graphical representation of data flow within a system. The system in question involves four processes: register, login, manage info, and manage pulse rate data. There are four data stores: user, doctor, admin, and record [15].

The system consists of four users: admin, doctor, and user. The admin manages the system and sensor, while the doctor can register, login, and monitor pulse rate data. Users can also register, login, and measure their pulse rate. The NodeMCU acts as the brain of the system, connecting the sensor to the system. The sensor detects the user's pulse rate at the wrist and sends the data to the NodeMCU, which, in turn, transmits the data to the Pulse Rate Monitoring System for monitoring by doctors and users [15].

The Pulse Rate Monitoring System comprises four entities: Admin, Doctor, User, and Microcontroller. Each entity needs to log in to access the system's interface. The admin can view and update user information, doctors can monitor users' pulse rate data, and users can measure their pulse rate and receive feedback from doctors [15]. The microcontroller sends the user's pulse rate details.

The NodeMcu serves as the central control. The pulse sensor detects the user's pulse rate beat and count, and the NodeMcu connects it to the system, displaying whether the pulse rate is normal or not. The system interface displays the measured pulse rate on a monitor, indicating whether it is in the normal or abnormal range. Users can restart the measurement process if needed.

The components used in the system: Pulse sensor, NodeMcu, and a breadboard. The NodeMcu is crucial as it connects the sensor to the system. The pulse sensor is placed on the user's wrist to detect the pulse rate, and the NodeMcu sends the data to the system.

2.5.10 *Remote Heart Rate Monitor System Using NodeMCU Microcontroller and Easy Pulse Sensor V1.1*

The aim of this project was to develop a low-cost heart rate monitoring system using IoT technology to provide early diagnosis and treatment for heart attacks in hospitals and healthcare centers in low-budget countries. Commercial heart monitors are expensive and not accessible to all hospitals, especially in remote areas. Remote heart rate monitoring is crucial for detecting emergencies and assessing the risk of heart failure [16].

The project implemented an IoT-based heart rate monitoring system using the NodeMcu board and Easy pulse sensor version 1.1. The Easy pulse sensor collected heart rate signals from the finger and amplified them to an observable scale. The NodeMcu board connected to a Wi-Fi router and transmitted the sensor data online, which could be accessed from anywhere over the internet [16]. An OLED display showed the heart rate in beats per minute (BPM).

The Arduino board used in this project required the addition of a Wi-Fi chip (Esp8266) to enable wireless network connectivity. The NodeMcu board, an open-source development board, provided built-in support for Wi-Fi, making it suitable for IoT applications.

The paper explained the specifications of the NodeMcu board, the installation process of Arduino IDE and Esp8266 with NodeMcu, and provided detailed information about the Easy pulse sensor [16]. It also demonstrated the simulation results for setting up the IoT connectivity via wireless networks.

A comparison was made between the heart pulse readings obtained from the traditional heart pulse measuring device and the readings from the Easy pulse sensor. The error rates for these readings ranged from 0% to 1.75%. Another comparison was made between the results displayed on the computer and the results displayed on the mobile device after establishing internet connections. The error rates for these readings ranged from 0% to 2.48% [16].

The proposed system showed higher accuracy and precision compared to the traditional heart pulse measurement device based on the Arduino Uno board. It was also more cost-effective, consumed less energy, and had a smaller size, making it suitable for a wide range of users, including elderly healthcare centers and small hospitals. The system provided reliable results to aid in making informed decisions for patients at a reasonable cost.

It was noted that there was a slight difference in readings between the computer and mobile devices due to the slower request processing time for mobile devices. The computer's connection to the router's MQTT was faster, resulting in a 20-millisecond delay in updating the mobile device's page, causing discrepancies in some readings [16].

2.5.11 *Virtual Heart Rate Monitoring System Using Node-MCU and Thing-Speak Cloud*

Pulse oximetry is based on the principle that two wavelengths of light can be used to assess arterial oxygen saturation. The absorption of light by different tissues and blood components can be measured to determine oxygen saturation. The Beer-Lambert law is used to calculate absorption based on the intensity of incident and transmitted light [17].

In this project, there was a focus on hardware implementation rather than a comparison between hardware and software. Sampling and amplification were performed using analog values, while a device with sufficient processing power, such as the Node MCU, was used for calculations and video generation.

Real-time service performance was tested, including the delay in transferring data from the device module to the website. A 15-second delay was observed during testing with a 10 Mbps Wi-Fi connection [17].

The developed IoT-enabled pulse oximeter successfully measures oxygen saturation and pulse rate, with the data being sent to the cloud and accessible through websites. Comparisons with mainstream pulse oximetry devices showed a difference of ±2.8 bpm for heart rate and ±1.5% for oxygen saturation. The 15-second delay in data transmission was considered acceptable [17].

Overall, the IoT-enabled pulse oximeter has proven to be a relative success compared to traditional devices. It offers accessibility, portability, and the ability for remote doctors to assess a person's condition through web-based results [17]. The system has been verified by comparing its readings with those of medical instruments used by healthcare providers. Multiple health parameters can be tracked and diagnosed simultaneously, and the device is available at a reasonable price.

2.5.12 *Realtime Health Monitoring System Design for Children with Cerebral Palsy Using Internet of Things*

The cerebral palsy monitoring system is designed with the aim of enabling health observation and vital sign checking at home. The architecture of the system incorporates the use of Arduino Uno R3 as the control unit. Arduino Uno is a microcontroller board that provides digital and analog pins, a USB port, ICSP header, and a reset button. It serves as the central component of the monitoring system [18].

To monitor vital signs, the system utilizes a pulse sensor that converts physiological signals into electrical forms for heart rate monitoring. This sensor plays a crucial role in detecting heart dysfunction, especially for children with cerebral palsy. Additionally, the system incorporates the use of the Myoware Muscle Sensor, which captures EMG signals generated by muscles. This sensor allows direct processing of muscle signals by the microcontroller.

For wireless connectivity, the system employs the ESP8266 Wi-Fi module. This module acts as an enhancement for the microcontroller, enabling direct Wi-Fi connection and establishing a TCP/IP connection. It operates on a power supply of around 3.3V and offers various Wi-Fi modes. The ESP8266 module is connected to the microcontroller using a USART serial connection [18].

The software system design of the application follows the principles of Unified Modeling Language (UML) [18]. It includes use case, activity, and class diagrams. The use case diagram depicts the menu options available to the users of the Android application. The activity diagram outlines the process flow of the application, starting from the user opening the app to displaying network information. The class diagram represents the structure of objects, classes, and their relationships within the system.

Cloud computing plays a significant role in the system, and Google Firebase is used as the cloud service provider. Firebase offers infrastructure as a service and facilitates the collection, storage, treatment, and sharing of data from medical sensors connected to patients. This cloud-based approach enables remote access to patient information and supports telemedicine services [18].

The system collects health condition data of children with cerebral palsy using synchronized sensors connected to the Arduino Uno board. The pulse sensor is typically mounted on the index finger, while the Myoware Muscle Sensor is placed between the thigh and knee using three electrodes [18]. The prototype of the system is designed to be portable, with the device attached to a pants or shirt pocket during gait activities.

To provide a user-friendly interface, the IoT4CP mobile application is developed for Android devices [18]. It allows users to select various menu options and displays relevant network information based on user selections. The system's response time is tested to measure how quickly it responds to user requests, with an average response time of 1.77 seconds per command request.

Overall, the IoT4CP framework aims to provide a portable and cost-effective solution for monitoring the health condition of children with cerebral palsy. By leveraging cloud computing and wireless connectivity, the system enables easy access to patient information from any location. The combination of Arduino Uno, pulse sensor, Myoware Muscle Sensor, and Google Firebase database ensures accurate monitoring and storage of vital signs data [18].

2.5.13 *IoT Based Infant Monitoring System*

The IoT-based infant monitoring system incorporates several important components for efficient monitoring and tracking of an infant's health. One key component is the sound sensor module, which detects sound intensity and finds applications in security, switch control, and monitoring [19]. It utilizes a microphone, amplifier, peak detector, and buffer to process sound signals and send them to a microcontroller for further analysis.

Another vital component is the LM35 series temperature sensor, which provides accurate temperature readings with a linear voltage output proportional to Celsius temperature. Unlike Kelvin-based sensors, it eliminates the need to subtract a constant voltage, simplifying temperature scaling. It offers high precision (0.25°C at room temperature) without requiring external calibration [19].

For heart rate monitoring, the Pulse Sensor Amped serves as a plug-and-play sensor specifically designed for Arduino projects. It integrates an optical heart rate sensor with amplification and noise cancellation circuitry, ensuring fast and reliable pulse readings. With low power consumption, it is well-suited for mobile applications.

To track motion, the system employs the MPU6050 sensor module, which combines a 3-axis gyroscope, 3-axis accelerometer, and temperature sensor in a compact package. It communicates through the I2C bus and can provide 9-axis motion fusion output when connected to additional sensor devices like a 3-axis magnetometer or pressure sensor [19].

The vibration motor plays a crucial role in providing silent feedback by vibrating, making it useful in applications such as cell phones and pagers. Its small size, low noise, and low power consumption make it a reliable and efficient component in the system.

By utilizing MQTT protocol and the Blynk platform, the proposed IoT-based infant monitoring system enables remote monitoring of infants' health. It collects data on vital signs like heart rate, temperature, and motion, and provides automated alerts to both parents and doctors in case of abnormalities [19]. This lightweight messaging protocol is well-suited for IoT applications with low bandwidth requirements, facilitating seamless communication between devices.

The system configuration includes voltage regulators and capacitors to stabilize and regulate voltage levels, ensuring proper operation of the Arduino and NodeMCU boards with their different voltage requirements. Additionally, the system allows for calibration and customization to adapt to each infant's body and activity patterns. This calibration step establishes tunable parameters for event detection and alert notifications. Periodic recalibration compensates for sensor drift due to aging and environmental variations, maintaining the system's accuracy and reliability over time [19].

In summary, this IoT-based infant monitoring system integrates a range of software components and hardware devices to enable efficient tracking and monitoring of an infant's health. By leveraging sound sensors, temperature sensors, heart rate sensors, motion sensors, and vibration motors, along with MQTT protocol and the Blynk platform, the system ensures real-time monitoring, timely alerts, and customizable parameters to meet the unique needs of each infant [19].

2.5.14 *A Novel Technique for Monitoring Infant Feelings Using IoT*

The NodeMCU is a low-cost, open-source IoT platform based on the Lua scripting language. It serves as a node microcontroller unit and facilitates wireless data transmission using IoT techniques through the Blynk app on an Android device. The NodeMCU incorporates firmware that runs on the ESP8266 Wi-Fi SoC from Espressif Systems and hardware based on the ESP-12 module. It features a 32-bit LX106 RISC microprocessor, supports RTOS, operates at 80MHz to 160MHz, and has 128 KB of RAM and 4MB of Flash memory. The NodeMCU supports UART, SPI, and I2C interfaces and can be powered via a Micro USB jack or an external supply pin [20].

The DHT11 sensor is a temperature and humidity sensor that provides temperature and humidity readings through a dedicated NTC to an 8-bit microcontroller [20]. It is easy to interface with other microcontrollers. The Pulse sensor is a plug-and-play heart rate sensor designed for Arduino, providing live heart rate monitoring. It can be attached to a fingertip and connected to an Arduino using jumper cables. The Pulse sensor also includes an open-source monitoring app that graphs pulse rates in real-time.

To maintain stable voltage outputs in a circuit, a transformer IC such as the 7805 IC, a member of the 78xx series of fixed linear voltage regulators, is commonly used. The 7805 IC regulates voltage fluctuations and provides a +5V regulated power supply with the option to add a conductor. In this proposed method, Wi-Fi is used instead of RF signals to minimize limitations faced in previous methods [20]. The system allows for monitoring infant feelings and conditions remotely using Wi-Fi and an Android app. The DHT11 and Pulse sensors are utilized to measure temperature, humidity, and pulse rate, providing insights into the infant's comfort and overall well-being [20].

Monitoring an infant's heart rate is crucial, as an irregular pulse rate may indicate a problem. Fast pulse rates can be caused by dehydration, stress, or other factors. Measuring the pulse rate gives valuable health information, and any deviation from the normal heart rate range can indicate a potential health issue. A fast pulse rate, along with symptoms like bluish color, pale skin, wheezing, or tiredness, may indicate breathing distress and the need for immediate attention.

The proposed system transfers continuous measurements of temperature, humidity, and heart rate over a wide range to one or more Android phones. The system provides alarms to parents in case of any danger and allows doctors to monitor the data and predict any potential issues. The microcontroller programming is done using the Arduino IDE software, which utilizes C language. The ESP8266 program, an essential part of the NodeMCU, is written in the Arduino IDE and transmits real-time sensor values using the MQ Telemetry Transport protocol [20].

To interface the sensors with the Android device, an interface program was developed, and a block diagram was created to illustrate the proposed method. The sensors, temperature, and humidity sensor along with the pulse sensor, are placed near the infant's body and connected to the NodeMCU with the ESP-12E chip [20]. The NodeMCU wirelessly transmits the collected data from the sensors, which is captured and displayed on an Android device preloaded with the Blynk app.

In summary, the proposed method offers a cost-effective, portable, and easy-to-use solution for monitoring infant health. It operates on battery power, utilizes Wi-Fi for data transmission, and provides real-time information about temperature, humidity, and heart rate [20]. The system allows for remote monitoring, alerts parents in case of danger, and enables healthcare professionals to analyze the data. It offers the advantages of affordability, portability, ease of use, and wireless information retrieval.

2.5.15 *IoT-Based Pulse Rate and Body Temperature Monitoring System*

The research work focuses on utilizing a smartphone as a reliable device for monitoring a subject's heart rate and body temperature over the internet. A literature review was conducted to analyze the available technology in the Android application market. The heart rate measurement was obtained through two methods: manual measurement and using a heartbeat detector to assess the accuracy of the circuit design. The circuit operates on a power supply of 3V, and positioning the finger or wrist close to the detector is crucial for accurate readings [21].

To evaluate accuracy, the output results were displayed as an electrocardiogram (ECG) on the serial plotter and output via the Serial Monitor. The manually calculated pulse values were compared with the Serial Monitor values to determine accuracy. The resulting average value was approximately 91, with an error calculated to be 3.41%. This indicates a result accuracy of around 96.5% [21].

The research project highlighted the need for filtering the heart rate signal to extract accurate values, as the signal can be noisy due to factors such as improper sensor placement or defective components. However, the output data showed significant improvement, achieving an accuracy of almost 96.5% [21].

The microcontroller NodeMCU was successfully implemented to detect and pair pulse values, receive data from pulse sensors, and monitor patients over the internet. The project aimed to use the open-source platforms Blynk and Adafruit IO to immediately alert medical and emergency contacts about the patient's health status.

The research explored different approaches for mobile devices to extract heart rate measurements and evaluated the accuracy of a smartphone application in retrieving non-contact heart rate values from the Adafruit IO server [21]. The study concluded that using a smartphone application for a heart-rate monitoring system is highly feasible and emphasized the device's non-contact monitoring capability.

The ongoing development involves creating a digital device and an application for continuous parameter monitoring, specifically detecting when the heart rate exceeds or falls below the required intensity. The portability of the device is highlighted as patients can carry it with them, reducing the need for hospitalization.

Alongside the heart rate monitor, an Android application was developed to enable user interaction, record data received from the heart rate monitor, and provide access to these records for doctors. The project encountered challenges related to the heart rate sensor's accuracy when placed with excessive or loose pressure on the body. Additionally, disturbances in the EKG signal were observed on the alphanumeric screen and serial monitor due to cable connections, which required proper grounding [21.

Challenges were faced with purchased components lacking datasheets, being copy products, and being highly unavailable in the researchers' country. Dependence on limited information provided by vendors' websites was necessary. The Android development environment also posed challenges, requiring time-consuming installations, and resolving Gradle errors [21].

Another limitation involved using the Firebase Database server for data storage, suggesting the potential benefits of building a customized web server for improved security and usability. Free notification services through actuators (email and phone text options) were utilized but had limitations, such as a limited number of notifications and occasional blocking [21].

Overall, the research demonstrates the feasibility and benefits of using a smartphone application for heart rate monitoring, but it also highlights challenges related to sensor accuracy, component availability, development environment setup, and server limitations.

2.5.16 *Heart Rate Monitoring Robot by Using Arduino and NodeMCU Esp8266*

The study presents a circuit diagram demonstrating the configuration of components used in the project. The circuit includes a NodeMCU ESP8266 microcontroller powered by a 9V battery, which connects to a switch, LED, LCD, and pulse sensor. The switch's pins are connected to the power supply and the LED, while the LED cathode is linked to a resistor that is grounded. The LCD has four pinouts: GND, VCC, SDA, and SCL. The VCC and GND pins are connected to the 5V supply from the NodeMCU ESP8266, while SDA and SCL are connected to specific pins on the microcontroller. The pulse sensor has three pinouts: VCC, GND, and signal. The VCC and GND pins are connected to the 3V supply from the NodeMCU, and the signal pin is connected to A0 on the microcontroller. Additionally, there are mechanical systems involved in controlling the motor. The NodeMCU's D6 pin is connected to pin two on the Arduino UNO, and the motor driver, with its eight pins, is connected accordingly. The 12V pin is connected to an external power supply, while the 5V and GND pins are connected to the Arduino UNO power supply. The pins IN1, IN2, IN3, IN4, ENA, and ENB are connected to specific pins on the Arduino UNO, and the pins OUT1, OUT2, OUT3, and OUT4 are linked to the motors A and B [23].

The complete circuit of the project, which encompasses both the electrical and mechanical systems.

The project is then evaluated using data collected from the system. The Blynk platform provides an interface, to monitor and interact with the project. The testing phase of the project involves single-person data. The software program "MONITORING BPM" is launched, attempting to establish a connection with Blynk. If the connection is successful, the LCD displays relevant information, but if it fails. To initiate the heart rate reading, the push button needs to be pressed. The accompanying green LED on the button lights up, and the system starts counting the heart rate. The counted heart rate is then displayed on the LCD and saved in Blynk. Control of the motor is done through a virtual switch on Blynk, with the LCD showing "motor = 1" when the switch is set to HIGH. The Blynk interface displays relevant information when the virtual switch is set to HIGH. Multiple data points collected in Blynk are depicted [22].

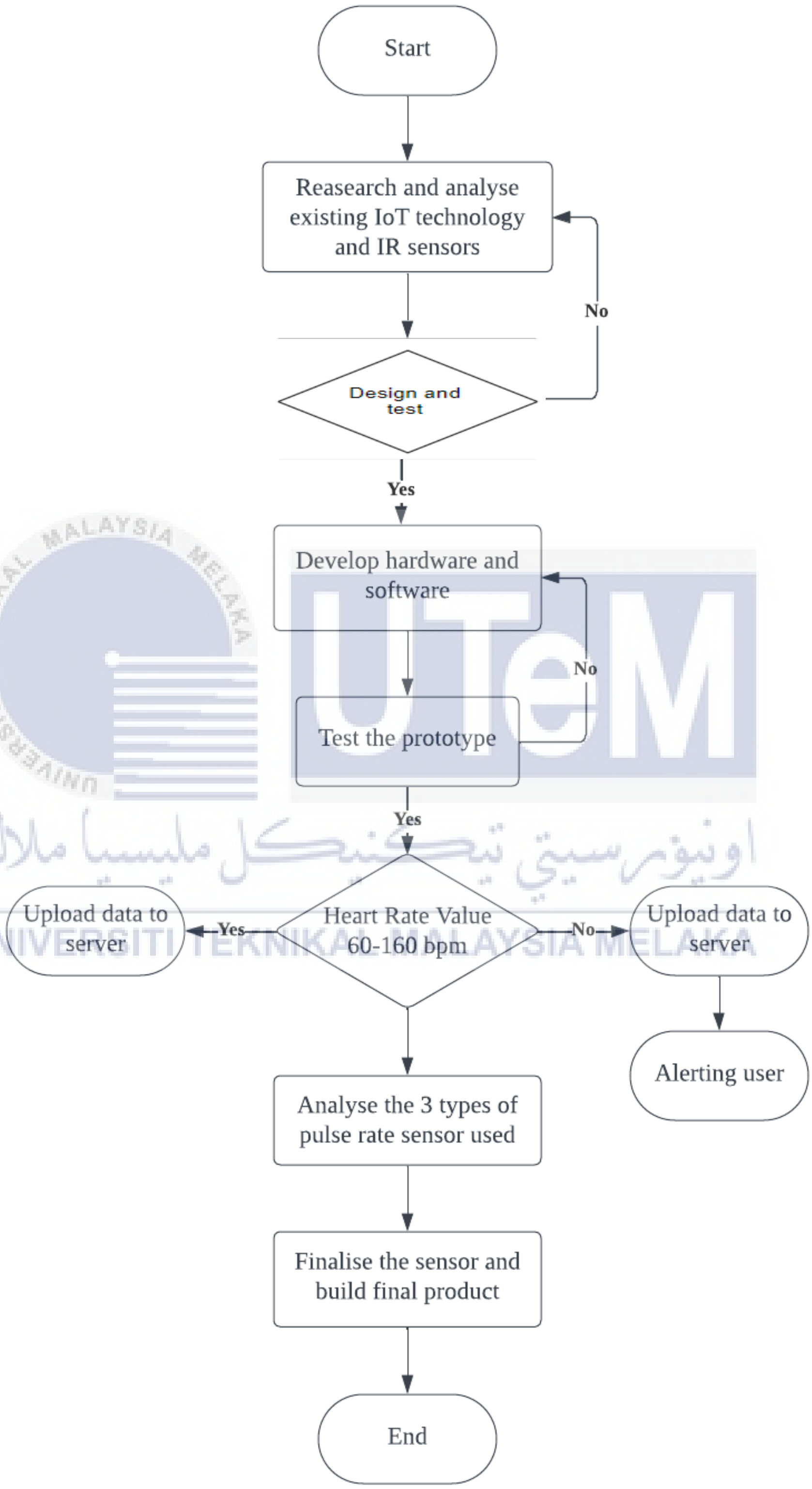
In summary, the successful development of a heart rate monitoring robot using Arduino UNO and NodeMCU ESP8266 is presented. The system, programmed with C language and Arduino IDE, effectively runs, analyzes data, and transfers data from the sensor to provide the desired output signal [22]. The pulse sensor serves as the primary input data source, while Blynk acts as the main output data platform. The construction of the project system fulfills the requirements and objectives, demonstrating successful implementation and achievement of the proposed project's goals.

CHAPTER 3:

METHODOLOGY

In this chapter will discuss every process or step which has been taken to complete the project. Besides, the tools and components used in this project are explained in more details such as functions, advantages and disadvantages of components used to perform the project successfully. Furthermore, the processes in designing the prototype are also shown.

3.1 Flowchart



Based on the flowchart above, there are steps required to complete the project. The first step is to do research and analyse existing IoT technologies and IR sensors. Perform a thorough analysis of existing technologies, such as pulse rate monitors, IoT devices, and OLED systems. This process assists to identify potential solutions and inform the design and development of the pulse rate reader. Analysis of the IR sensor in a heart rate monitoring project may include evaluating its accuracy by comparing measurements with a reference standard, assessing efficiency by analyzing response time, and evaluating reliability through repeated measurements. Other techniques such as sensitivity and specificity analysis can also be used. Results from these analyses validate the IR sensor's performance and suitability for the project.

There are several critical steps involved in designing and testing a pulse rate reader with software. The software's needs and goals are examined first. The user interface and data processing algorithms are then included in a design plan that is created. The relevant modules and functionalities are coded to create the software. Integration and testing guarantee proper accuracy and functionality. If the circuit is not working, research and analysis needs to be done again.

Construct the pulse rate reader's hardware, including the sensor, microcontroller, and buzzer. To construct a working device, this step includes putting the parts together and connecting them. Develop the software system for the pulse rate reader, including the user interface, data processing algorithms, and buzzer activation logic. This step involves writing code and testing the software to ensure it works correctly.

Do tests on the prototype in a controlled setting to make sure it satisfies the project's goals and performs as planned. In this step, the pulse rate measurements' precision and dependability are evaluated, and the buzzer feature is put to the test.

The Node MCU will get data when the pulse rate detects any pulse. Reading the sensor input and reading the sensor value are done by the Node MCU. Depending on the whether the pulse rate is in the range or not, the reading of the pulse will be shown on device, and buzzer will alert the user if the reading is not in the normal range. Additionally, the information will be uploaded to the server to alert the user.

Researching and choosing three different types of heart rate sensors, establishing an experimental setting, gathering heart rate data, analysing the data to assess accuracy and performance metrics, considering extraneous factors, drawing conclusions about sensor performance, and making recommendations are all part of the analysis. This process helps determine the most suitable heart rate sensor based on factors such as accuracy, usability, and compatibility with specific applications.

Lastly, finalise the sensor and the pulse rate reader's design. Construct the finished item based on the improved prototype.

3.2 Components and Software Used

The following components and software will be used to complete this project.

3.2.1 MAX30102 Pulse-Rate Sensor

The MAX30102 is a highly integrated optical biosensor module designed for heart-rate monitoring and pulse oximetry. It is commonly used in wearable devices such as fitness trackers and smartwatches to measure heart rate and estimate blood oxygen saturation levels [9].

The MAX30102 sensor module combines three key components: an integrated red LED, an infrared LED, and a photodetector. The red and infrared LEDs emit light into the user's skin, while the photodetector measures the amount of light that is reflected back. By analyzing the variations in reflected light caused by blood flow, the sensor can calculate the heart rate and estimate the oxygen saturation level.

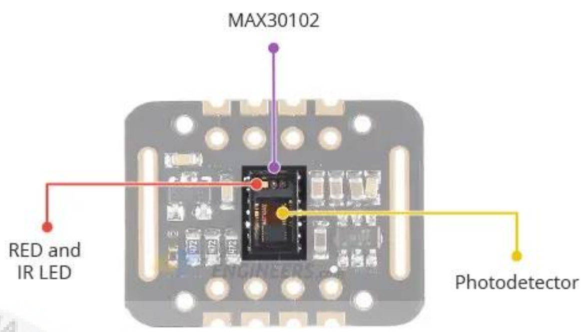


Figure 3.1: Components of MAX30102 Pulse Sensor

One of the key features of the MAX30102 is its high level of integration, which makes it easy to use and reduces the need for external components. It includes a low-noise analog signal processing unit, a 16-bit analog-to-digital converter (ADC), and a digital signal processing engine [9]. The built-in ADC provides accurate and reliable measurements, while the digital signal processing engine allows for real-time processing of the sensor data.

The MAX30102 communicates with a microcontroller or a host device through an I2C interface, enabling seamless integration into various applications [9]. It also includes built-in algorithms for motion artifact reduction, ambient light cancellation, and automatic gain control, which help improve the accuracy and reliability of the heart-rate measurements.

3.2.2 XD-58C Pulse-Rate Sensor

This sensor is also known as a heartbeat sensor or a heart rate sensor and may be made to function by connecting it to an Arduino board, an ESP8266 module, and a Raspberry PI from a human fingertip or ear. Such that it is simple to compute heart rate. The 24-inch colour code cable, ear clip, Velcro Dots 2, and transparent stickers 3 are all included with the pulse sensor.

This is a biometric pulse rate sensor that can detect heartbeats. Its thickness is 0.125mm, and its diameter is 0.625mm. The operating voltage varies from +5V to +3.3V. This sensor is a plug-and-play model.

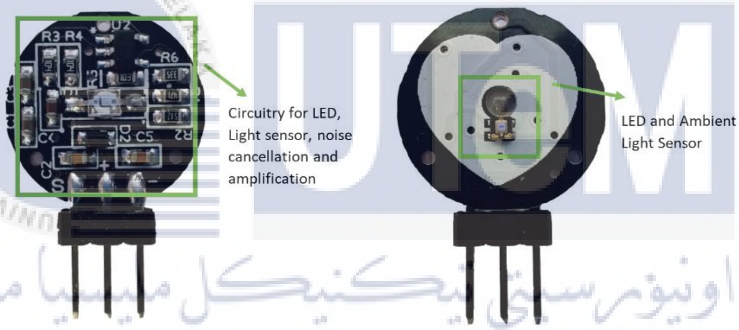


Figure 3.2: Components of XD-58C

The circuits for amplification and noise cancellation are included in the 4mA current usage [10]. The FDA and the medical industry have not authorised this pulse sensor. Therefore, it is used in student-level projects rather than applications for health issues with a profit-making intent.

The pulse sensor's operating system is fairly straightforward. The ambient light sensor and light-emitting diode are connected on the first of the sensor's two surfaces. Similar to that, a circuit responsible for noise cancellation and amplification is attached to the second surface.

The LED is situated above a vein in the human body, such as an ear tip or fingertip, but it must be situated directly on top of a layer [10]. The LED begins to emit light once it is placed on the vein. When the heart begins pumping, blood will start to flow through the veins. So, if we measure blood flow, we can measure heart rates as well.

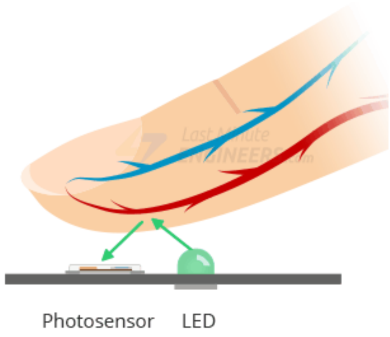


Figure 3.3: How XD-58C Works

3.2.3 AD8232 Heart-Rate Sensor ECG Module

The AD8232 is a specialized heart rate sensor module designed for monitoring biopotential signals, specifically focusing on electrocardiogram (ECG) measurements. It is widely used in applications such as fitness trackers, portable health monitoring devices, and medical equipment. The AD8232 sensor module provides a convenient and reliable solution for capturing and analyzing heart rate data [11].

The AD8232 module incorporates several key components to enable accurate ECG measurements. It includes a low-power, single-lead analog front-end (AFE) that amplifies and filters the ECG signal. This helps to remove noise and interference, resulting in cleaner and more reliable heart rate measurements. The module also features a right leg drive (RLD) amplifier, which helps to reduce common-mode interference and improve the common-mode rejection ratio (CMRR) of the system [11].

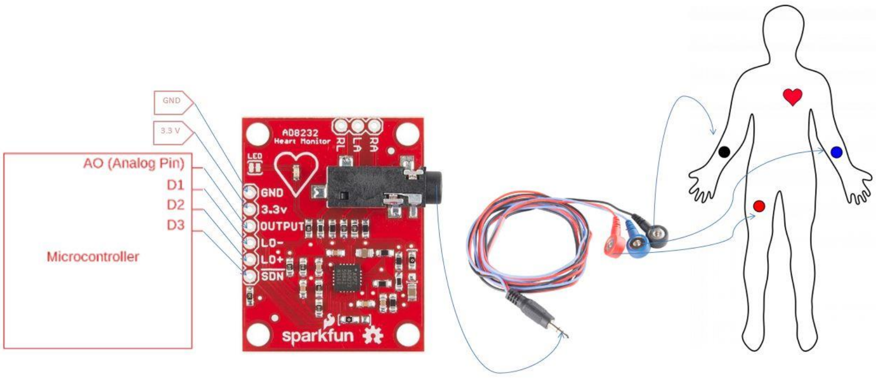


Figure 3.4: AD8232 ECG Module Pinout

One of the notable features of the AD8232 is its ability to provide a single-lead ECG measurement, making it suitable for wearable devices with limited physical space. The module can be easily integrated into a variety of designs due to its compact size and low power consumption. It communicates with a microcontroller or host device through a simple analog output or a digital interface such as SPI or I2C [11].

3.2.4 NodeMCU ESP8266

NodeMCU is an open-source development board based on the ESP8266 microcontroller. It provides a convenient platform for prototyping and developing Internet of Things (IoT) projects. The NodeMCU board integrates the ESP8266 Wi-Fi module, making it suitable for connecting to wireless networks and building IoT applications that require internet connectivity [12].

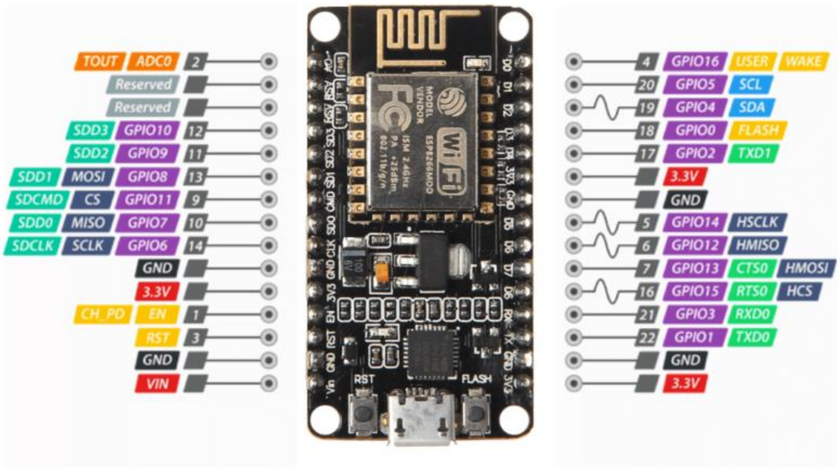


Figure 3.5: NodeMCU ESP8266 Pinout

The ESP8266 microcontroller at the heart of NodeMCU offers a powerful combination of processing capability and Wi-Fi connectivity. It features a 32-bit Tensilica L106 RISC processor with a clock speed of up to 80 MHz, providing sufficient computational power for running applications and interacting with the network. The built-in Wi-Fi module supports various Wi-Fi protocols, including 802.11 b/g/n, enabling seamless wireless communication [12].

NodeMCU offers a range of GPIO (General Purpose Input/Output) pins that allow for interfacing with sensors, actuators, and other electronic components. These GPIO pins provide flexibility and expandability, making it easy to interface with a wide range of devices and peripherals. Additionally, the board supports programming using the Lua scripting language, providing a simple and intuitive programming environment for rapid development.

The NodeMCU board can be programmed using the Arduino IDE or through other popular programming frameworks such as Micro Python. This flexibility allows developers to leverage their existing knowledge and libraries while working with

NodeMCU. The board also provides USB connectivity, enabling easy programming and power supply through a standard USB cable.

3.2.5 Blynk

Arduino, Raspberry Pi, ESP 8266, Intel Galileo, and other devices can be controlled via the Blynk platform, which has iOS and Android support. It is a smartphone app that enables us to create a project's graphic user interface by selecting the widget from the apps. To remotely access and manage IoT devices, the interface can be downloaded for free onto a smartphone. Users can access the Blynk application with an authentication code to avoid misuse and illegal access. There are three key components of the Blynk platform: the Blynk App, the Blynk Server, and the Blynk Library. By scanning the QR code or sharing the authentication code, the project can be shared. All project data will be kept on the Blynk Server and exported by the user as a csv file for additional analysis. Email and phone notifications are sent to the air monitoring widget. In addition, a labelling value must be added to enable real-time air quality monitoring by the user. To receive real-time notifications, the Blynk must be running in the background. In figure 3.6, it shows how architecture of Blynk cloud application.

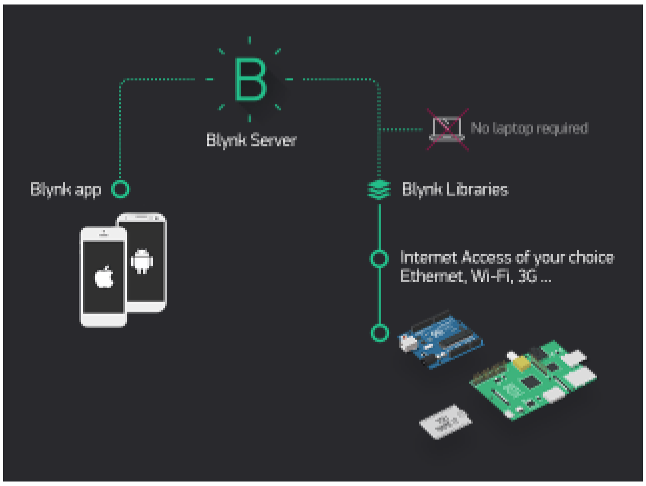


Figure 3.6: Blynk Cloud Architecture

3.2.6 Arduino IDE

The open-source electronic platform Arduino may be quickly and simply programmed, deleted, and reprogrammed at any moment. Since 2005, the Arduino platform has been developed and is now more reasonably priced. The Arduino platform comprises of a physical programmable circuit board as well as an Integrated Development Environment (IDE) that can be used to run the code that may be written and uploaded to the physical board on a computer. The Arduino software runs on Linux, Mac OS X, and Windows.

Although many programs, such Parallax Basic Stamp, Netmedia's BX-24, Phidgets, and MIT's Handyboard, perform similarly to Arduino software, Arduino is still a superior option than these programs. Additionally, the software for Arduino is open source and expandable. It can be released as an open-source tool and expanded by knowledgeable users. By comprehending the technical elements that can enable the transition from Arduino to the AVR C programming language on which it is based, the user can modify the code into C++ programming.

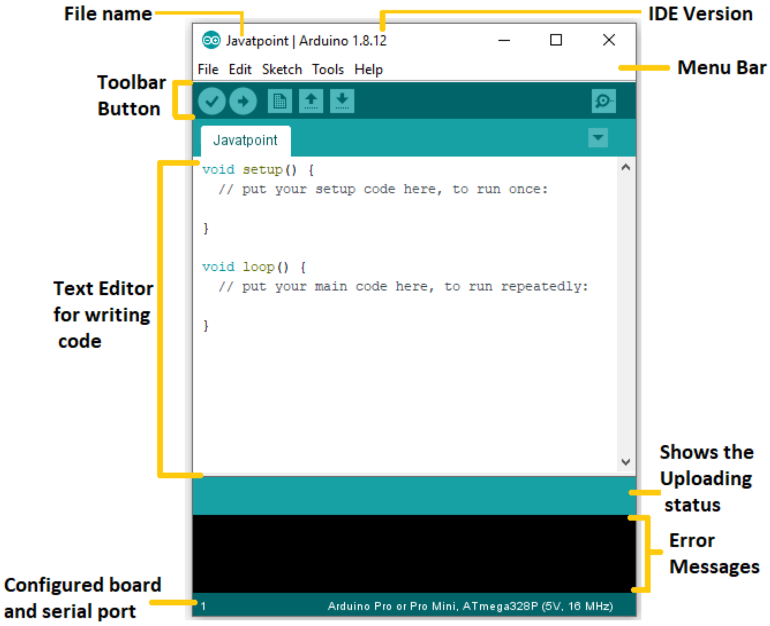


Figure 3.7: Script Codes of Arduino IDE

3.2.7 OLED

OLED (Organic Light-Emitting Diode) displays are a type of display technology that offers numerous advantages, including high contrast, wide viewing angles, and low power consumption [13]. These displays consist of organic compounds that emit light when an electric current is applied. OLED displays are widely used in various applications, including smartphones, televisions, wearable devices, and embedded systems.

OLED displays are known for their excellent contrast ratio and vibrant colors. Unlike traditional LCD displays that require a backlight, OLED displays emit their own light, which enables them to achieve deep blacks and infinite contrast levels. This results in vibrant and lifelike images with enhanced visual quality.

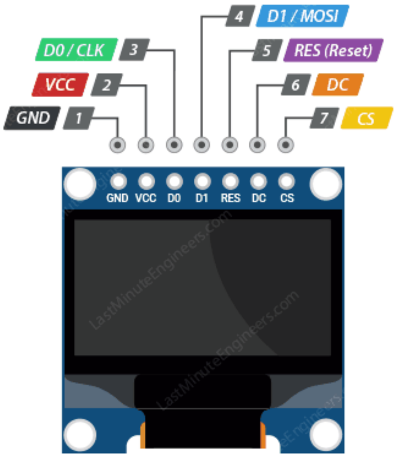


Figure 3.8: Pinout of OLED Display

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Final Product

Technical documentation is being put together, which includes schematic diagrams and fully functional prototypes of the XD58-C, MAX30102 and AD8232 sensors.

4.1.1 XD58-C

The schematic circuit for the XD58-C is quite simple, it just uses the sensor and a NodeMCU, an OLED is not included. To make the connections easy to understand and use, they are kept quite straightforward.

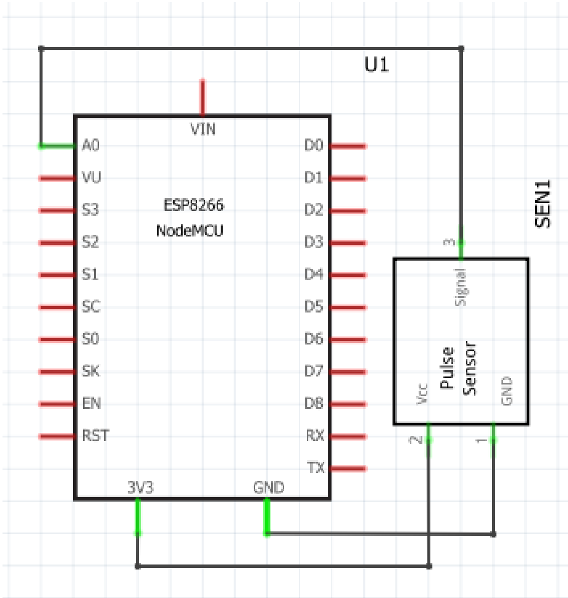


Figure 4.1: XD58-C Schematic Circuit

4.1.1.1 PCB Layout

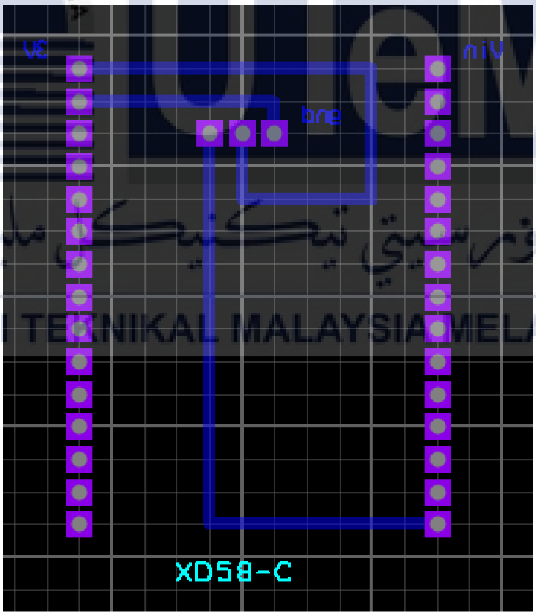


Figure 4.2: XD58-C PCB Layout

4.1.1.2 End Product

Figure 4.3: XD58-C Casing

Figure above show how the final look of XD58-C sensor, the sensor covered with soft fabric and adjustable strap. The small pouch is made in order to prevent any irritations towards infant.

4.1.2 MAX30102

On the other hand, the MAX30102 requires a more complex configuration of connections between the MAX30102 sensor, and NodeMCU. This sensor's wiring is somewhat more complex than that of the previous one, so extra care is needed to guarantee that all the parts are functioning properly and connecting to one another.

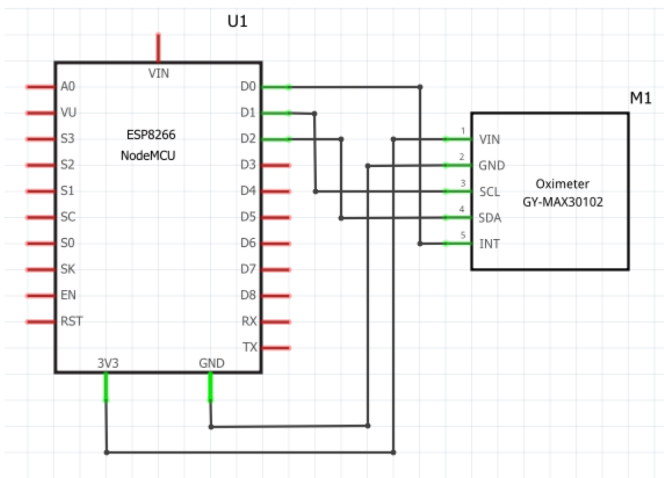


Figure 4.4: MAX30102 Schematic Circuit

4.1.2.1 PCB Layout

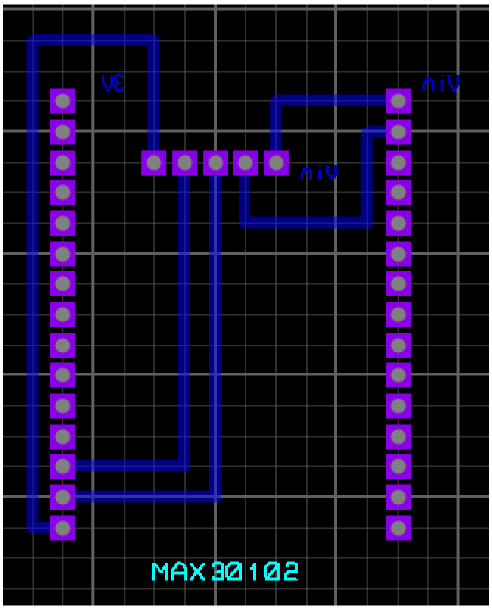


Figure 4.5: MAX30102 PCB Layout

4.1.2.2 End Product

Figure 4.6: MAX30102 Final Look

The casing for this sensor is similar to casing for XD58-C sensor. It has same fabric for the casing and adjustable strap, the aim of this protection are also the same.

4.1.3 AD8232 ECG

4.1.3.1 Schematic Circuit

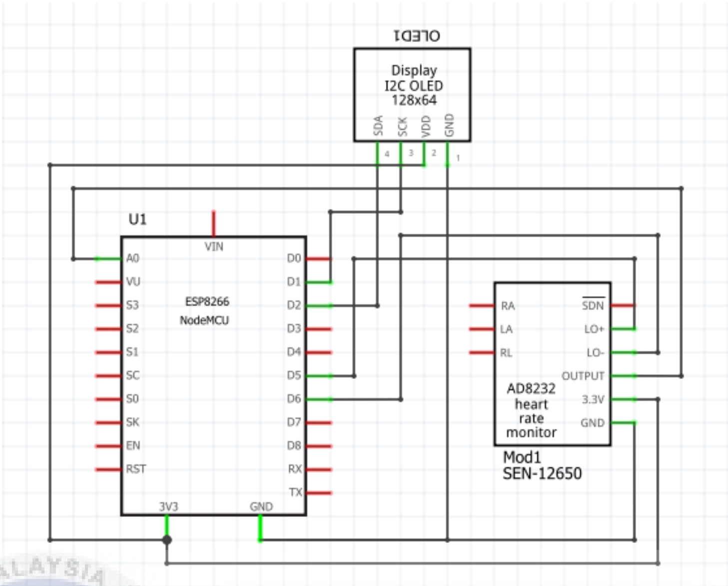


Figure 4.7: AD8232 ECG Schematic Circuit

4.1.3.2 PCB Layout

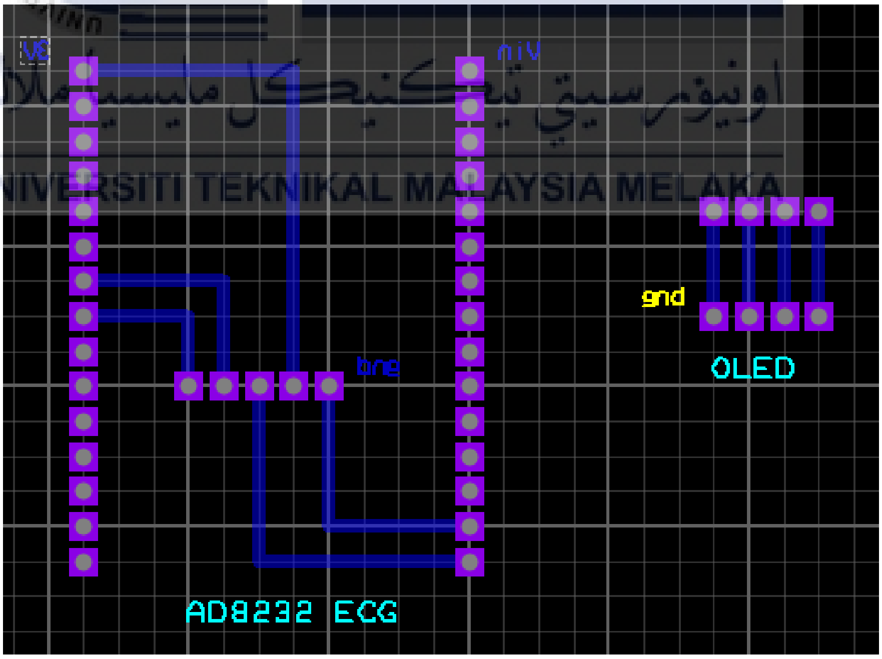


Figure 4.8: AD8232 ECG PCB Layout

4.1.3.3 End Product

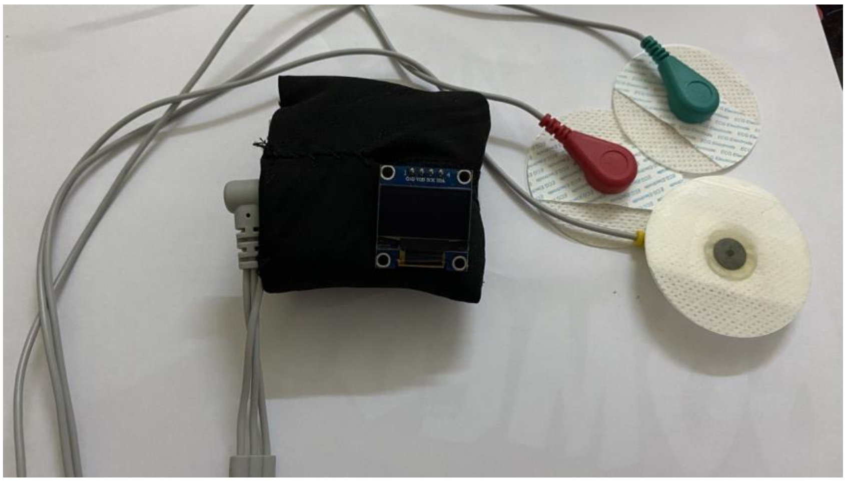


Figure 4.9: AD8232 ECG Final Look

For AD8232 ECG, it is a bit different from the other two sensors. It does not need any strap because it has 3 electrodes (Red, Green and Yellow) and require it directly patch it onto infant skin. However, for casing it used same fabric to prevent irritation.

Figure 4.10: Placement of Electrode AD8232

4.2 IoT Integration

The advanced features of the infant pulse rate monitoring device include an effortless Internet of Things (IoT) integration. For parents and medical personnel, this integration offers a new measure of accessibility and convenience by enabling the wireless transmission of critical health data. Utilizing the Blynk application as its cloud platform, the system offers a strong basis for remote accessibility, data analysis, and storage.

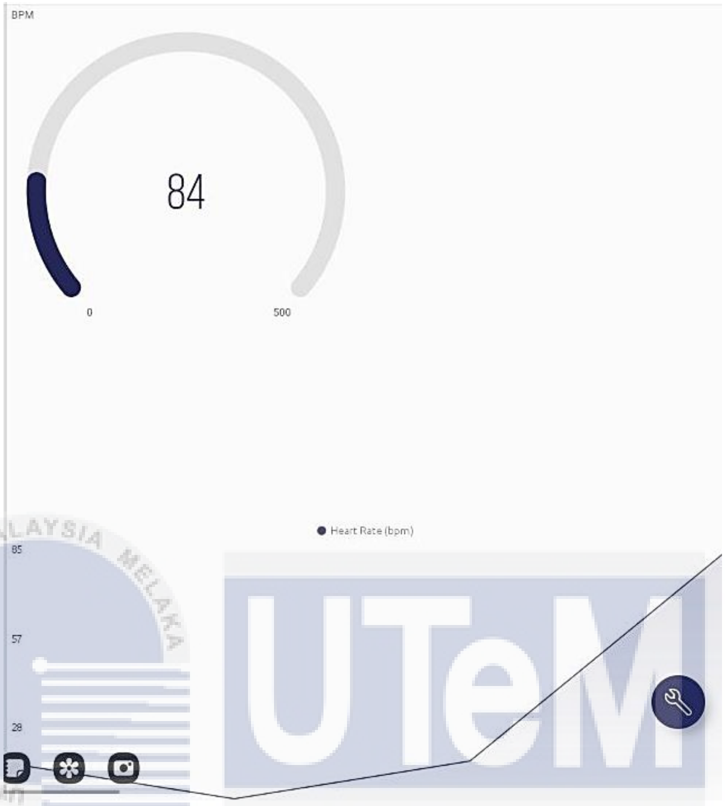


Figure 4.11: BPM Display for XD58-C and MAX30102

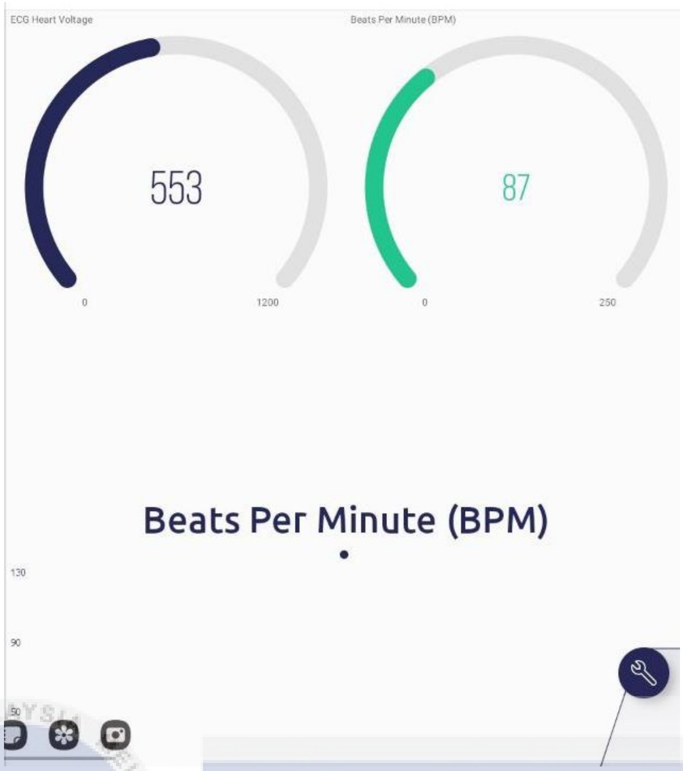


Figure 4.12: BPM and ECG Display for AD8232 ECG Module

The Blynk application allows parents and other caregivers to wirelessly and real-time monitor their infant's pulse rate. The Blynk application acts as a user-friendly indication by providing real-time, graphical updates on the infant's pulse rate. In addition to being more convenient, this real-time monitoring feature gives caretakers a useful tool for keeping checks on the infant's condition. In figure 4.11 and 4.12 above, shows the Blynk system display bpm value for sensor XD58-C and MAX30102. However for AD8232 ECG Module, it display values of ECG and bpm.

The device includes notification alerts which appear up on the phone screen in a situation that the infant's pulse rate drops below 60 or increases above 170 as a proactive safety measure, the notification shown below at figure 4.13 and 4.14. When a potentially dangerous scenario arises, the instant alert system makes sure that caregivers are promptly notified, enabling them to respond quickly and take appropriate action.

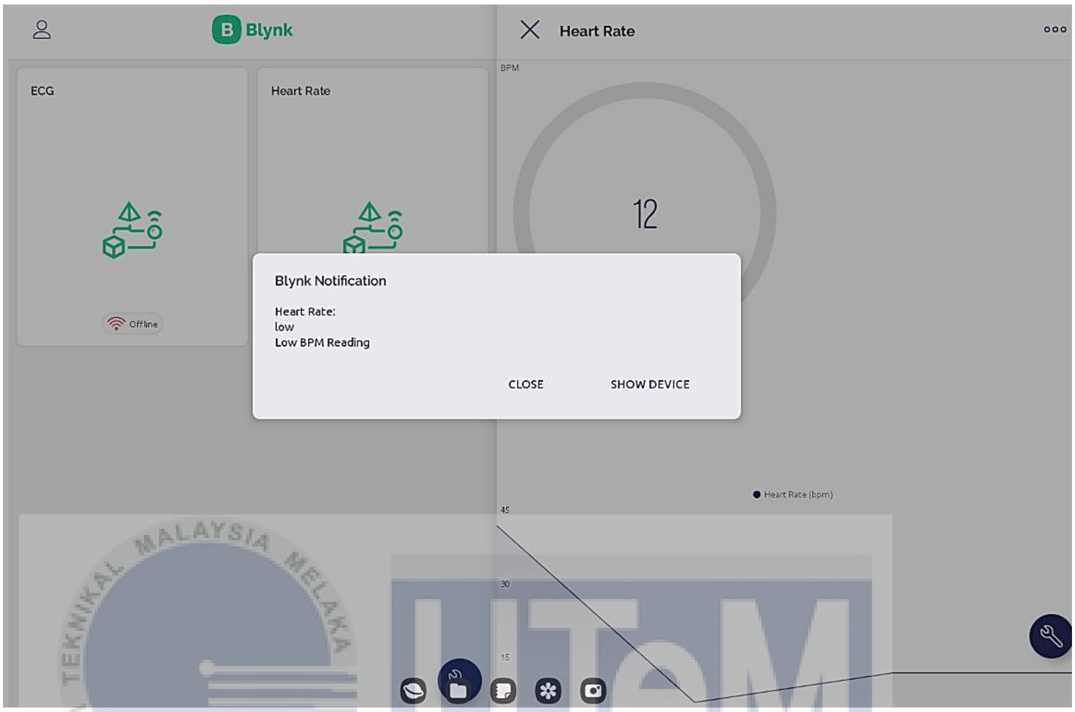


Figure 4.13: Notification appear on Blynk App

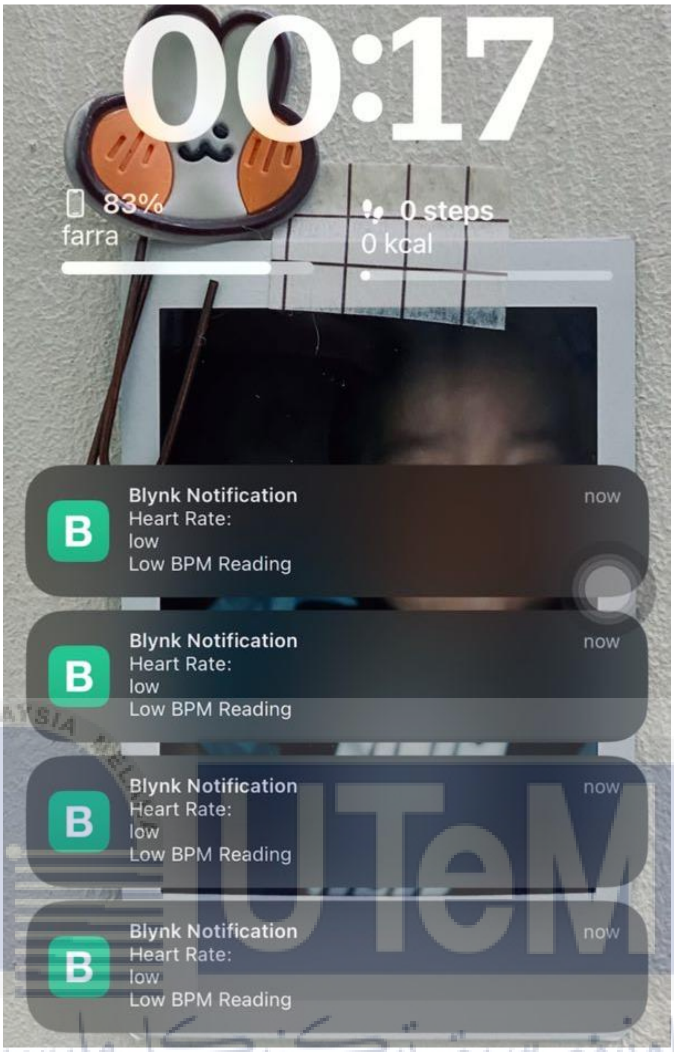


Figure 4.14: Notification When Phone is Locked

Additionally, the technology is made to make collaborative monitoring easier. Real-time, secure access to the the infant's BPM data is accessible to authorized individuals, such as family members and medical experts. This inclusive approach promotes a sense of shared responsibility and care by enabling different stakeholders to be updated about the infant's health state at the same time.

In a nutshell the infant pulse rate monitoring system guarantees the security and promptness of information delivery, enabling caregivers and authorized users to effectively monitor and respond to the infant's health needs. It also provides real-time health data through IoT integration and the Blynk application.

4.3 XD58C, MAX30102 and AD8232 Sensor Comparison

4.3.1 Accuracy and Precision

When infants are peaceful, the XD58C gives a good estimate of their heart rate with an accuracy of 98.61%. However, keep in mind that this accuracy can be impacted by movement, skin tone and sensor placement. With its outstanding 98.46% of accuracy and, the AD8232 is an excellent tool for monitoring baby's heart rate, even in the smallest changes. This accuracy is useful for tracking playtime reactions and examining sleep patterns, giving a thorough picture of infant's health. Despite there are few requirements regarding precise accuracy, the MAX30102 has a accuracy of 94.59%, making it suitable for simple heart rate monitoring. Formula (4.1) is used in order to calculate the value of accuracy [4]:

$$Accuracy\ (\%) = \left(1 - \frac{Absolute\ Error}{Reference\ BPM}\right) \times 100 \qquad (4.1)$$

4.3.2 Signal Quality

The XD58C may have trouble with noise in demanding situations, even though its accuracy suggests high quality for casual monitoring. The signal may be impacted by electrical interference, motion, and ambient light, which could lead to errors. MAX30102 sensor provides excellent signal quality. This gives piece of mind when keeping an eye on baby's playtime or sleep because it guarantees precise and dependable data, even in somewhat noisy surroundings. In a similar way, the AD8232, which was designed for ECG signals, provides exceptional signal quality and accurately records the complex electrical patterns of the heart since it has advanced processing and cancellation of noise built right in.

4.3.3 Movement

When the infant is moving around a lot, the XD58C sensor is not the best choice because it could shift and provide values that are not precise. It is crucial to ensure that it is properly attached in order to obtain accurate data. Because of its sensitivity to movement, it must always be secured carefully, especially while the baby is active. However, in comparison to the XD58C, the MAX30102 sensor functions slightly better when there is movement. However, for it to function properly, just like the XD58C, it still needs to be firmly connected. This is especially crucial if your infant is engaging in physically demanding activities. The AD8232 sensor is an excellent option if your infant moves around a lot because it has amazing features that make it good at detecting motion.

4.3.4 Power Consumption

The XD58C guarantees a longer battery life thanks to its low power consumption which is less than 4mA. This minimizes any potential disturbance to the infant's routine and is perfect for wearable devices that provide continuous monitoring without the need for regular battery changes. Despite using a bit more power (8mA) than the XD58C, the enhanced features of the MAX30102 frequently make up this downside. Perhaps the ease of constant monitoring justifies a little more regular battery replacement. The AD8232 have low power consumption, balancing energy efficiency and performance. Although all sensors may have different particular power descriptions, neither much exceeds the other in terms of energy efficiency. This feature guarantees reasonable power consumption, which supports longer operating times and improves the feasibility of all sensors for battery-operated applications.

4.3.5 Time Taken

The XD58-C sensor demonstrates exceptional efficiency in acquiring reliable measurements, taking less than 10 seconds to produce data. Its quick reaction time ensures that users may get dependable data quickly, which adds to a smooth monitoring experience. Conversely, the MAX30102 sensor responds even faster, delivering accurate readings in less than 7 seconds. Applications requiring almost instantaneous data for real-time monitoring scenarios benefit from this quick performance. In a comparable way the AD8232 ECG sensor demonstrates remarkable speed, taking less than 3 seconds to provide precise results. Because of its fast response time, the AD8232 is a useful sensor for applications where low latency is essential for accurate and rapid data collection.

4.3.6 Cost

The price of the MAX30102, XD58C, and AD8232 sensors varies, with the MAX30102 typically being thought of as the least expensive choice, followed by the XD58C and AD8232. Among the choices that are offered, the MAX30102 sensor is particularly cost-effective and offers dependable performance for applications involving pulse rate monitoring at a reasonably priced range. Although it is reasonably priced, the XD58C sensor is in the middle of the range, making it a well-rounded choice that combines usefulness and affordability. The AD8232 sensor is often more costly, falling on the upper end of the price range. This is often credited to its expertise in electrocardiogram (ECG) monitoring, which makes the need for further elements for thorough evaluations of heart health necessary.

The comparison of the XD58-C, MAX30102, and AD8232 heart rate sensors in several aspects is displayed in the table below.

Table 4.2: Comparison of XD58C, MAX30102 and AD8232

Aspect	XD58C	MAX30102	AD8232
Accuracy	Accuracy of 98.61%	Accuracy of 94.59%	Less accurate than the XD58C with 98.46% accuracy.
Signal Quality	Struggle with noise	Might not be able to tolerate noise in complicated applications.	Offers complex algorithms and integrated noise cancellation.
Movement	Not optimal for high-movement activities	Requires proper attachment	Offer advanced motion detection features
Power Consumption	Most energy-efficient alternative (less than 4mA).	High power consumption at 8mA.	Moderate power consumption.
Time Taken	<10 seconds	<7 seconds	<3 seconds
Cost	± RM44.60	±RM33.60	±RM58.40

4.4 Stability of BPM Reading

For data to be precise and dependable in the context of physical monitoring, sensor stability is essential. BPM (beats per minute) variability over time is a critical statistic for evaluating stability. Based on the figure 4.15 below that shows the BPM values, the stability of three sensors the AD8232 ECG sensor, the XD58-C sensor, and the MAX30102 sensor compared with value of oximeter was evaluated in this research.

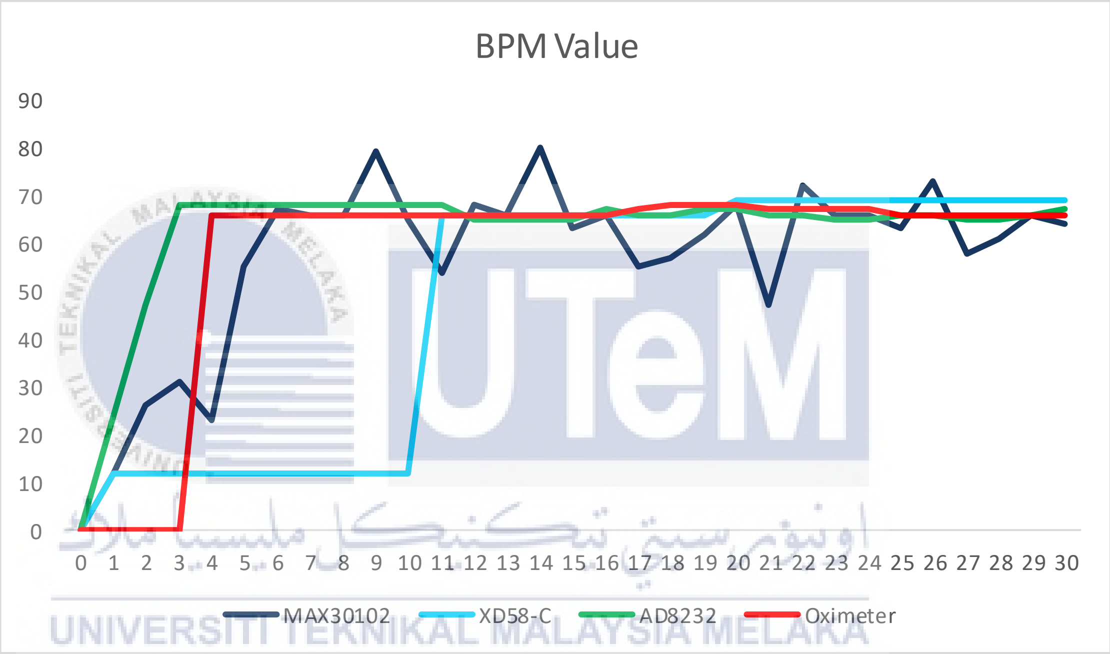


Figure 4.15 BPM Value of Different Sensors

Refer to Figure 4.15, out of the three, the AD8232 ECG sensor proves to be the most stable. The BPM readings from this sensor are very stable over the duration of the measurement time, indicating an excellent level of reliability. In situations where accurate and reliable heart rate monitoring is required, this constancy is critical.

In contrast, the XD58-C sensor demonstrates stability as well, but with a slightly higher degree of variability in its BPM readings than the AD8232. It is a dependable option for applications where a small amount of fluctuation is acceptable because it retains a respectable level of stability in spite of this.

However, in this evaluation, the MAX30102 sensor displays the least stability. When compared to the other sensors, the BPM readings from this one shows an unacceptable amount of periodic fluctuation, indicating a poorer degree of reliability. This fluctuation could provide problems in situations when reliable and accurate heart rate measurements are critical.

In addition to stability, one of the most important aspects of real-time monitoring is the time it takes for each sensor to give an accurate measurement. The AD8232 sensor is remarkable for its quick response time, providing an accurate reading in around three seconds. In situations where precise and timely data collecting is crucial, this quick response time is beneficial.

The MAX30102 sensor, on the other hand, takes a little longer to stabilize and provides an accurate reading in the range of five to seven seconds. There is a trade-off between response time and stability, even if this delay might be acceptable in some applications. In the final analysis, the XD58-C sensor demonstrates the slowest response time, requiring around 10 seconds to produce an accurate reading, despite its stability. This slower response may limit its suitability in applications demanding swift and real-time monitoring.

CHAPTER 5

CONCLUSION AND FUTURE WORKS

5.1 Conclusion

In conclusion, the AD8232 ECG sensor proves to be the best choice out of all the sensors examined for the specific requirements of an infant pulse rate reader project. Its remarkable stability which is illustrated by the steady and comparatively constant BPM readings over the duration of the measurement period is essential to guaranteeing precise and trustworthy heart rate monitoring for infants.

Moreover, the quick response time of the AD8232 sensor which yields an accurate measurement in around three seconds is consistent with the dynamic character of an infant's physiology. The quick response is necessary to record changes in an infant's pulse rate in real time, allowing for precise and timely monitoring.

The AD8232 is an excellent sensor for applications that monitor the pulse of infants because of its reliability and quick reaction time. The success of the project depends on the sensor's ability to quickly and reliably obtain readings, and the AD8232 sensor performs exceptionally well in this regard. The AD8232 ECG sensor is therefore suggested as the best sensor for a project involving an infant pulse rate reader based on the factors that were examined. This sensor guarantees the timeliness and reliability needed for efficient monitoring of an infant's cardiovascular health.

Furthermore, the AD8232 sensor guarantees accuracy in its measurements with an outstanding precision rating of 98.46%. This high level of precision is essential, particularly when handling the delicate task of monitoring an infant's health.

The AD8232 sensor also has advanced characteristics including integrated noise reduction and complex algorithms. These features improve the sensor's effectiveness in settings where precise and distinct signals are necessary for trustworthy readings of pulse rate.

Another remarkable benefit of the sensor is that it has advanced motion detecting features, which makes it ideal for applications involving infants who might move subtly. This guarantees that motion-related artifacts can be properly filtered out by the sensor, preserving the accuracy of the pulse rate values.

The AD8232 sensor strikes an agreement between usability and energy efficiency with its minimal power consumption, even with its extensive features. This is especially crucial for projects involving little ones, as reducing down on power consumption is frequently a top priority.

The pricing of the AD8232 sensor, which is RM58.40, is acceptable. Despite being the most expensive of the three sensors under consideration, the advanced functionality, excellent accuracy, and dependability make the investment worthwhile. With its many features and capabilities, the AD8232 sensor is a great option for the infant pulse rate reader project because it is reasonably priced.

In conclusion, the AD8232 ECG sensor has excellent stability and quick response time, along with high accuracy, advanced functions, and an affordable price. After taking these things into consideration, the AD8232 sensor becomes the best option for making sure that a project involving an infant pulse rate reader is successful and efficient.

5.2 Future Works

5.2.1 Integration of Additional Vital Signs

A development toward an improved health monitoring system is shown by the infant's pulse rate monitoring system's enhancement to include additional vital signs, such as temperature and oxygen level. The system gains the capacity to present an improved view of an infant's health state by integrating various vital indicators. Tracking temperature provides important information about possible indicators of infection or anomalous bodily conditions, while monitoring oxygen levels is essential for evaluating respiratory function. This extension helps with early detection and intervention in a wider range of health problems in addition to improving the system's clinical worth. Nonetheless, this integration poses difficulties with regard to data synchronization, sensor compatibility, and the creation of algorithms that can process several vital signs at once.

5.2.2 Clinical Validation and Certification

A crucial step in guaranteeing the dependability and security of the infant pulse rate monitoring system is working together with regulatory agencies and medical professionals for clinical validation and certification. Clinical validation include thorough testing and assessment in actual healthcare environments, enabling healthcare professionals to evaluate the system's functionality in a variety of scenarios. Regulatory authorities' certification guarantees that the system complies with rules and regulations by ensuring that it meets strict healthcare requirements. Through this partnership, the monitoring system gains credibility and cultivates confidence with end users, caregivers, and healthcare providers. Additionally, it sets up the system for broad clinical environment adoption, which will enhance the outcomes of newborn healthcare. Overcoming obstacles related to data privacy, legal compliance, and preserving consistency in a variety of clinical contexts is essential for the successful clinical validation and certification of the system.

5.2.3 Biometric Authentication and Security Measures

Adding biometric verification for caregivers and setting robust safety protocols in effect to protect private health information are two ways to improve the security features of the infant pulse rate monitoring system. By adding a second level of identity verification, biometric authentication makes sure that only caregivers with permission can access the monitoring system. Strong security measures guard against illegal access and possible breaches of health data. These methods include safe data storage, encryption, and user authentication. To strengthen the system against potential threats, it is necessary to address difficulties relevant to secure implementation, user-friendly authentication processes, and ongoing security protocol monitoring. The system encourages trust among parents, caregivers, and healthcare experts by emphasizing modern security features and biometric verification, thereby creating a safe and reliable environment for monitoring newborn health.

REFERENCES

[1] Larson CP. Poverty during pregnancy: Its effects on child health outcomes. Paediatr Child Health. 2007 Oct;12(8):673-7. doi: 10.1093/pch/12.8.673. PMID: 19030445; PMCID: PMC2528810.

[2] Mohamed A. Zaltum, M. Shukri Ahmad, Ariffuddin Joret and M. Mahadi Abdul Jamil. "Design and Development of a portable Pulse Oximetry system," Faculty of Electrical & Electronic Engineering, University Tun Hussein Onn Malaysia, July 2011.

[3] Chow HW, Yang CC. Accuracy of Optical Heart Rate Sensing Technology in Wearable Fitness Trackers for Young and Older Adults: Validation and Comparison Study. JMIR Mhealth Uhealth. 2020 Apr 28;8(4):e14707. doi: 10.2196/14707. PMID: 32343255; PMCID: PMC7218601.

[4] André G. Ferreira, Duarte Fernandes, Sérgio Branco, João L. Monteiro and Jorge Cabral. "A Smart Wearable System for Sudden Infant Death Syndrome Monitoring," Center of Textile Science and Technology (2C2T) University of Minho Campus of Azurém, 4800-058, Guimarães, Portugal, March 2016.

[5] Prof. Thiyagarajan. N., Mohana M., Kanimozhi A. and Shanmuga Priya K. “Non-Invasive Health Monitoring System Infants Using IoT,” Department of Medical Electronics Engineering, Sengunthar College of Engineering, Tiruchengode, India. March 2020.

[6] Amanda Ruggeri, “The search for what causes SIDS”, Article of BBC news, October 2022. Retrieved from https://www.bbc.com/future/article/20221024-the-search-for-what-causes-sids.

[7] Xiaobai Li, Jie Chen, Guoying Zhao and Matti Pietikainen CM. “Remote Heart Rate Measurement from Face Videos Under Realistic Situations”, University of Oulu, Finland. 2014.

[8] Athanasakis E, Karavasiliadou S, Styliadis I. “The factors contributing to the risk of sudden infant death syndrome”. Hippokratia. *2011 Apr*;15(2):127-31. PMID: 22110293; PMCID: PMC3209674.

[9] MAX30102 datasheet, Maxim Integrated, Maxim Integrated Products INC. 2018. Retrieved from https://datasheets.maximintegrated.com/en/ds/MAX30102.pdf

[10] EL Pro Cus. “Pulse Sensor: Working Principles and Its Application”. Retrieved from https://www.elprocus.com/pulse-sensor-working-principle-and-its-applications/

[11] AD8232 datasheet, Analog Devices, Inc. Retrieved from https://www.analog.com/media/en/technical-documentation/data-sheets/AD8232.pdf

[12] "NodeMCU - An open-source firmware based on ESP8266 Wi-Fi SoC", NodeMCU GitHub repository. Retrieved from https://github.com/nodemcu/nodemcu-firmware

[13] "OLED Display Technology and Capabilities", Samsung Display. Retrieved from https://www.samsungdisplay.com/solution/oled-technology/

[14] Wahidah Md Shah, Mohd Hazman Yaakob, Norhayati Harun, Aslinda Hassan, Mohd Fairuz, Iskandar Othman & Isredza Rahmi A. Hamid. (2020). Internet of Things Based Heart Rate Monitoring and Alert System. Universiti Teknikal Malaysia Melaka.

[15] Nurul Fatiha binti Muda. Pulse Rate Monitoring System. (2021). Universiti Sultan Zainal Abidin.

[16] Abdullah, Salam. (2019). Remote Heart Rate Monitor System using NodeMcu Microcontroller and easy pulse sensor v1.1. IOP Conference Series: Materials Science and Engineering. 518. 052016. 10.1088/1757-899X/518/5/052016. (9)

[17] Sinha, Suryakant & Nandagawali, Pratik & Rai, Anubhav & Channi, Harpreet. (2021). Virtual Heart Rate Monitoring system using Node-MCU and Thing- Speak Cloud. 8. 171-176.

[18] R Fadhlillah, S Susmartini & L Herdiman. (2019). Realtime Health Monitoring System Design for Children with Cerebral Palsy Using Internet of Things. doi:10.1088/1742-6596/1450/1/012119.

[19] Aswathy R Nair, Eshana Mariam John, Lakshmi R Menon, Nivitha Teresa & Unnikrishnan L. (2019). IoT Based Infant Monitoring System. Department of Electrical and Electronics, Rajagiri School of Engineering and Technology.

[20] Saurabh Prasad & Ramjee Prasad. (2022). A Novel Technique for Monitoring Infant Feelings Using IoT. Aarhus University.

[21] Md. Rasheduzzaman & Md. Monirul Awal. (2019). IoT-Based Pulse Rate and Body Temperature Monitoring System. Daffodil International University.

[22] Mohamad Nur Aiman Jam, Lilywati Bakar & Zurina Abdul Wahab. (2022). Heart Rate Monitoring Robot by Using Arduino and NodeMCU ESP8266. Universiti Tun Hussein Onn Malaysia.

[23] Zhihua Zhu, Tao Liu, Guangyi Li, Tong Li 1 and Yoshio Inoue. "Wearable Sensor Systems for Infants," The State Key Laboratory of Fluid Power Transmission and Control, Department of Mechanical Engineering, Zhejiang University, Hangzhou, February 2015.

[24] María J. Morón, Eduardo Casilari, Rafael Luque and José A. Gázquez, "A Wireless Monitoring System for Pulse-oximetry Sensors," Dpt. Technology Electronic, University of Málaga, Spain, September 2005.

APPENDICES

1. XD58-C CODING:

```
#define BLYNK_TEMPLATE_ID "TMPL6508ReYm_"
#define BLYNK_TEMPLATE_NAME "Heart Rate"
#define BLYNK_AUTH_TOKEN "gHSCIlxSM9QgXsJembXa0rKg9ZBBQ1Rn"

#include <ESP8266WiFi.h>
#include <WiFiClient.h>
#include <ESP8266WebServer.h>
#include <BlynkSimpleEsp8266.h>
#include <SimpleTimer.h>
SimpleTimer timer;
#define ON_Board_LED D4

const long intervalGetHR = 10; //Interval for reading heart rate (Heartbeat) = 10ms.
const long intervalHR = 10000; //Interval for obtaining the BPM value based on the sample is 10 seconds.

const int PulseSensorHRWire = A0; //PulseSensor connected to ANALOG PIN 0 (A0 / ADC 0).
const int LED_D1 = D1; //LED to detect when the heart is beating. The LED is connected to PIN D1 (GPIO5) on the NodeMCU ESP12E.
int Threshold = 850; //Determine which Signal to "count as a beat" and which to ignore.

  if (currentMillisGetHR - previousMillisGetHR >= intervalGetHR) {
    previousMillisGetHR = currentMillisGetHR;

    int PulseSensorHRVal = analogRead(PulseSensorHRWire);

    if (PulseSensorHRVal > Threshold && ThresholdStat == true) {
      cntHB++;
      ThresholdStat = false;
      digitalWrite(LED_D1,HIGH);
    }
```

```
    if (PulseSensorHRVal < Threshold) {
      ThresholdStat = true;
      digitalWrite(LED_D1,LOW);
    }
  }
  unsigned long currentMillisHR = millis();

  if (currentMillisHR - previousMillisHR >= intervalHR)
  {
    previousMillisHR = currentMillisHR;

    BPMval = cntHB * 6;
    Serial.print("BPM : ");
    Serial.println(BPMval);
    Blynk.virtualWrite(V0,BPMval);
    cntHB = 0;

    if (BPMval<60)
  {
    Blynk.logEvent("low","Low BPM Reading");
  }
  else if (BPMval>170)
  {
    Blynk.logEvent("high","High BPM Reading");
  }
}

void setup() {
  Blynk.begin(auth, ssid, password);
  delay(500);


  pinMode(ON_Board_LED,OUTPUT); //On Board LED port Direction output
  digitalWrite(ON_Board_LED, HIGH); //Turn off Led On Board

  pinMode(LED_D1,OUTPUT); //Set LED_3 PIN as Output.

  WiFi.mode(WIFI_STA);
  WiFi.begin(ssid, password);
  Serial.println("");

  Serial.print("Connecting");
  while (WiFi.status() != WL_CONNECTED) {
    Serial.print(".");

    digitalWrite(ON_Board_LED, LOW);
    delay(250);
```

```
    digitalWrite(ON_Board_LED, HIGH);
    delay(250);
  }
  digitalWrite(ON_Board_LED, HIGH);
  Serial.println("");
  Serial.print("Successfully connected to : ");
  Serial.println(ssid);
  Serial.print("IP address: ");
  Serial.println(WiFi.localIP());
  Serial.println();

  Serial.println();
  Serial.println("Please wait 10 seconds to get the BPM Value");
}
void loop() {
  // put your main code here, to run repeatedly:
  GetHeartRate(); //Calling the GetHeartRate() subroutine
}
```

2. MAX30102 CODING:

```
#define BLYNK_TEMPLATE_ID "TMPL6508ReYm_"
#define BLYNK_TEMPLATE_NAME "Heart Rate"
#define BLYNK_AUTH_TOKEN "gHSCIlxSM9QgXsJembXa0rKg9ZBBQ1Rn"

#include <ESP8266WiFi.h>
#include <WiFiClient.h>
#include <ESP8266WebServer.h>
#include <BlynkSimpleEsp8266.h>
#include <SimpleTimer.h>
SimpleTimer timer;
#define ON_Board_LED D4

unsigned long previousMillisGetHR = 0;
unsigned long previousMillisHR = 0;

const long intervalGetHR = 10;
const long intervalHR = 10000;

int cntHB = 0;
boolean ThresholdStat = true;
int BPMval = 0;

void handleHeartRate() {
  digitalWrite(ON_Board_LED, LOW);
```

```
    int PulseSensorHRVal = analogRead(PulseSensorHRWire);

    if (PulseSensorHRVal > Threshold && ThresholdStat == true) {
      cntHB++;
      ThresholdStat = false;
      digitalWrite(LED_D1,HIGH);
    }

    if (PulseSensorHRVal < Threshold) {
      ThresholdStat = true;
      digitalWrite(LED_D1,LOW);
    }
  }

  if (currentMillisHR - previousMillisHR >= intervalHR)
  {
    previousMillisHR = currentMillisHR;

    Serial.print("BPM : ");
    Serial.println(BPMval);
    Blynk.virtualWrite(V0,BPMval);
    cntHB = 0;

    if (BPMval<60)
  {
    Blynk.logEvent("low","Low BPM Reading");
  }
  else if (BPMval>170)
  {
    Blynk.logEvent("high","High BPM Reading");
  }

  }
}
//void setup()
void setup() {
  Serial.begin(115200);
  Blynk.begin(auth, ssid, password);
  delay(500);


  pinMode(ON_Board_LED,OUTPUT); //On Board LED port Direction output
  digitalWrite(ON_Board_LED, HIGH); //Turn off Led On Board

  pinMode(LED_D1,OUTPUT); // Set LED_3 PIN as Output.

  WiFi.mode(WIFI_STA);
```

```
  WiFi.begin(ssid, password);
  Serial.println("");

  Serial.print("Connecting");
  while (WiFi.status() != WL_CONNECTED) {
    Serial.print(".");
    //Make the On Board Flashing LED on the process of connecting to
the wifi router.
    digitalWrite(ON_Board_LED, LOW);
    delay(250);
    digitalWrite(ON_Board_LED, HIGH);
    delay(250);
  }

  digitalWrite(ON_Board_LED, HIGH);
  Serial.println("");
  Serial.print("Successfully connected to : ");
  Serial.println(ssid);
  Serial.print("IP address: ");
  Serial.println(WiFi.localIP());
  Serial.println();

  Serial.println();
  Serial.println("Please wait 10 seconds to get the BPM Value");
}

//void loop()
void loop() {
  GetHeartRate(); //Calling the GetHeartRate() subroutine
}
```


3. AD8232 ECG MODULE CODING:

```
#define BLYNK_TEMPLATE_ID "TMPL6-VxopjgQ"
#define BLYNK_TEMPLATE_NAME "Heart RateCopy"
#define BLYNK_AUTH_TOKEN "oJZGaforiwWlYlB9oDM-vtWsivWRaDOJ"

#include <BlynkSimpleEsp8266.h>
#include <ESP8266WiFi.h>
#include <Wire.h>

#include <SimpleTimer.h>
#include "heartRate.h"

SimpleTimer timer;
```

```
const int ecgPin = A0; // Analog pin for ECG sensor
const int ledPin = 13; // LED pin for visualizing heartbeats

int threshold = 650;   // Adjust this threshold based on your sensor
and environment
int prevValue = 0;
unsigned long prevTime = 0;
int heartRate = 0;
}

void loop() {
  Blynk.run();
  timer.run(); // Initiates SimpleTimer
  int sensorValue = analogRead(ecgPin);


    // Update previous time for the next calculation
    prevTime = currentTime;

    // Blink the LED to visualize heartbeats
    digitalWrite(ledPin, HIGH);
    delay(100);
    digitalWrite(ledPin, LOW);
  }

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

  // Update previous sensor value
  prevValue = sensorValue;
}

void getSendData()
{
  int sensorValue = analogRead(ecgPin);
  Blynk.virtualWrite(V0, sensorValue); //in voltage
  if (heartRate<60)
  {
    Blynk.logEvent("low","Low BPM Reading");
  }
  else if (heartRate>170)
  {
    Blynk.logEvent("high","High BPM Reading");
  }


}
```