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Design and Demonstration of Arduino based Low Cost Pulse Oximeter

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Abstract— One of the main reasons for the pushback of the pandemic in India was the awareness that developed in people during the crisis. The adapting mindset of the Indian populace helped turn the tides. The Pulse Oximeter proved to be an important tool that helped in identifying the affected, to get timely healthcare. A very simple information was shared among people that the BPM (heart rate in beats per minute) should be around 60 - 100 (resting) for an average adult and the SpO2, i.e., oxygen saturation must be above 95% for all age groups. Just this was able to counter an entire wave of the Pandemic with the help of early detections, timely isolations, immediate health care and much more. However, access to this was not available to everyone due to the high prices of these devices. This project aims to build a simple monitor module with an Arduino Nano board which can determine the Blood Oxygen level and Heart rate of a person by using the MAX30102 sensor.

Keywords- Arduino Nano; Heart rate; MAX30102; Pulse oximeter;

I. INTRODUCTION

The COVID-19 pandemic has made us realize the importance of monitoring our health at home, especially for those with underlying medical conditions. One such vital parameter that needs to be monitored regularly is the oxygen saturation level in the blood. One of the main symptoms of the disease was the sudden and sharp drop in Blood Oxygen levels which could be detected by Heart rate and SpO2 Sensors. With said sensors, we were able to see and detect falls in blood oxygen levels and take the necessaryaction to save ourselves and others by stopping the spread. But this sensor wasn't available to everyone which hindered our efforts in overcoming the pandemic. This project aims to develop a simple setup making a pulse oximeter and heart rate monitor that is accessible to everyone.

The oxygen saturation level of the blood signal is found using an Optical sensor and another physiological parameter is also measured using an Arduino Uno R3 microcontroller [1]. A pulse oximeter is a non-invasive medical device that measures oxygen saturationlevel as well as heart rate. The market for pulse oximeters has exploded in the past year with people buying them for personal use [2]. However, they can be expensive and difficult to obtain. Fortunately, with readily available components and a little programming knowledge, anyone can build their own pulse oximeter using an Arduino Nano and MAX30102 sensor [3].

The resulting pulse oximeter will provide an affordable, convenient, and effective way for personal health monitoring. This is a comprehensive guide on how to build a pulse oximeter using an Arduino Nano and MAX30102 sensor [4]. Byfollowing the step-by-step instructions and using the provided code, anyone with a basic understanding of electronics and programming can build their own pulse oximeter [5]. The final device is compact, portable, and easy to use, making it an ideal personal health monitoring tool for individuals with respiratory and cardiac conditions. The project also provides opportunities for medical researchers and engineers to explore further applications of the pulse oximeter in healthcare settings [6].

The system proposed for monitoring the diagnostic details such as humidity and pulse rate of a person by using a pulse sensor [7]. The pulse rate and blood oxygen saturation state (SpO2) are the measured data sent to a mobile device through the Internet of Things (IoT), and mobile apps using the EasyEDA software [8, 15]. The Pulse sensor used to measure the heart rate is done with module Arduino Uno and pro mini for ECG and PPG graphs [9]. Vital signs and pulse rate are

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measured using photosensitive techniques using Arduino and GSM [10].

Continuous heart rate and body temperature monitoring system designed using Arduino and its application [11]. Persons' physical characteristics are measured using sensors and broadcasted through ZigBee to PC [12]. The system to monitor the Healthcare of patients is designed and measured using wireless mobile to monitor remotely [13]. A Simple portable ECG monitor is designed using Arduino-Uno and HC-05 FC-114 as a Bluetooth antenna, an ECG display could be seen on a smartphone's monitor in real-time [14].

Remote health monitoring, based on non-invasive and wearable sensors, actuators and modern communication and information technologies offers an efficient and cost-effective solution that allows the elderly to continue to live in their comfortable home environment instead of expensive healthcare facilities[16]. The study focuses on designing a monitoring system that consists of an incubator equipped with a humidity sensor to measure the humidity level, and a pulse sensor that can be attached on an infant placed inside the incubator to monitor infant's heart pulse[17].

In this article, we will discuss the process of building a pulse oximeter with Arduino Nano and MAX30102, including the hardware and software setup. Section 1 describes the introduction, section 2 explains the methodology used, section 3 illustrates the demonstration, section 4 explains the results and discussions followed by conclusion and references.

II. METHODOLOGY

The very first idea that originated leading to this article was the most integral part of this project: The Arduino Nano. The Arduino Nano is a small and versatile open-source microcontroller board based on the Atmel AVR microcontroller. While surfing for project ideas, research showed that the Arduino Uno was the most popular for project building in Microprocessors. Further study revealed that there are many types of Arduinos like the ArduinoUNO, MEGA, YUN, DUE, LEONARDO and much more. One such Arduino the study led to was the NANO. It was a compact and multifaceted computer that had wide-ranging functions. However, the Arduino UNO could still be argued as the better fit for a project like this; here are the main reasons the NANO was chosen over the UNO.

A. Arduino Nano vs Arduino Uno

Arduino Nano and Arduino Uno are both microcontroller development boards that are very popular in the maker community. While both boards have many similarities, there are some key advantages of Arduino Nano over Arduino Uno are size, cost, power consumption, compatibility, integrated USB and pin count. The Arduino Nano is a great choice for projects where size, cost, power consumption, and pin count are important factors. However, if the need for more processing power, more memory, or additional features like Ethernet or Wi-Fi connectivity is greater, the Arduino Uno may be a better option. When searching for possible use cases for such a computer that is small, low cost, effective and that has a wide range of applications, the recent pandemic came into sight. This was the origination of the concept that is the project today. The image of the Arduino Nano used in this project is shown in Figure 1.

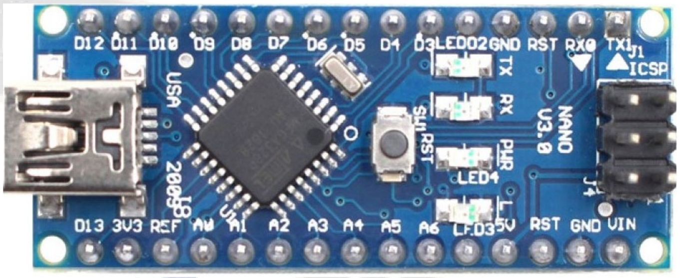

Figure 1. Arduino Nano

B. MAX 30102

The next step was to find a suitable sensor, the most important component of this setup that could collect the essential data for the Pulse Oximeter. A very short search led to the MAX3010X series of sensors. The MAX3010X sensors are a series of highly integrated optical sensor modules designed for pulse oximetry and heart-rate monitoring applications. The series includes the MAX30100, MAX30101, MAX30102, and MAX30105 sensors. Here is a brief overview of each sensor in the MAX3010x series.

- MAX30100: The MAX30100 is the first sensor in the series and features an integrated red LED and infrared LED along with a photodetector. It can be used to measure oxygen saturation and heart rate.
- MAX30101: The MAX30101 is similar to the MAX30100, but with added features such as an ambient light cancellation algorithm and aprogrammable FIFO buffer.
- MAX30102: The MAX30102 is the most advanced sensor in the series and includes features such as a high SNR photodetector, an integrated ambient light cancellation algorithm, and a programmable sample rate.
- MAX30105: The MAX30105 is a variant of the MAX30102 that includes an additional green LED for improved accuracy in heart-rate monitoring.

All sensors in the MAX3010X series use a similar

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architecture and are designed to be highly integrated, low- power, and compact. They are typically used in wearable health monitoring applications and are designed to provide accurate pulse oximetry and heart-rate monitoring in challenging environments. The MAX30102 is a highly integrated optical sensor moduledesigned for pulse oximetry and heart-rate monitoring applications. It integrates a red LED and an infrared LED along with a photodetector to provide accurate readings of oxygen saturation and heart rate. Here are five keyadvantages to using the MAX30102 highly integrated design, accurate readings, Low power consumption, flexible connectivity, and small form factor. The MAX30102 is an advanced optical sensor module that provides accurate pulse oximetry and heart-rate monitoring in a small and low-power package. Its highly integrateddesign, accurate readings, low power consumption, flexible connectivity, and small form factor make it an ideal choice for wearable health monitoring applications. The picture of the MAX30102 is shown in Figure 2.

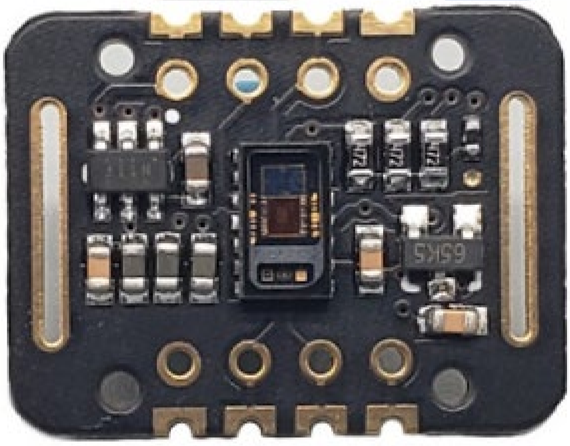

Figure 2. MAX30102

C. Algorithm of working principle

The working principle of the designed pulse oximeter is shown in Figure 3.

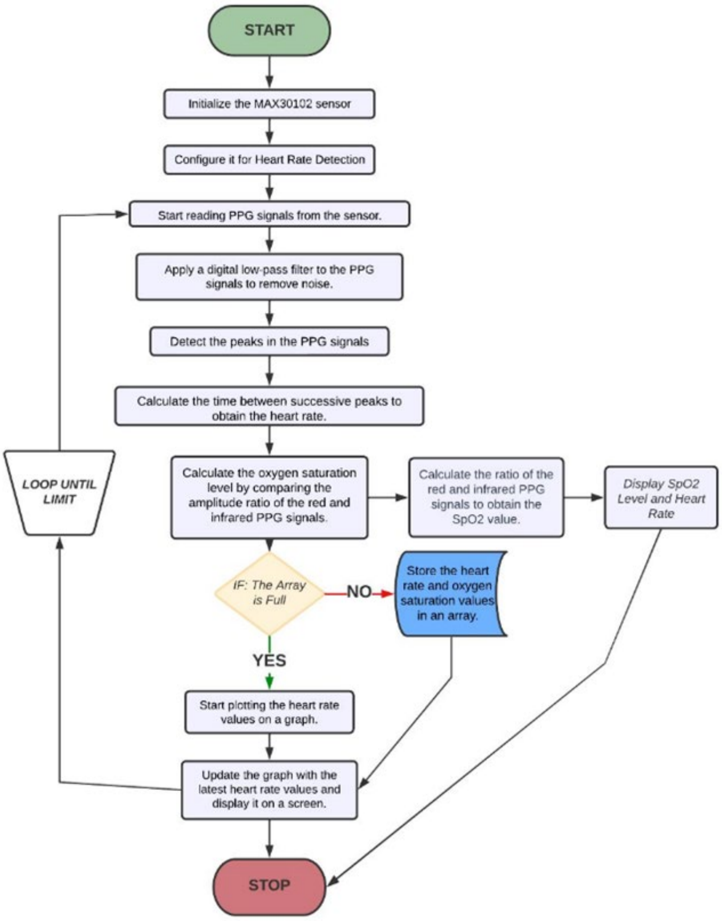

Figure 3. Flow chart of the working principle

- The algorithm for the MAX30102 sensor and Arduino Nano involves reading PPG data from the sensor, filtering the data to remove noise, detecting peaks in the data to identify heartbeats, and calculating the heart rate based on the time between beats.
- The program begins by including the necessary libraries for communicating with the MAX30102 sensor and calculating heart rate. The reporting period is set to 1000 milliseconds, or one second.
- In the ‘setup ()’ function, the MAX30102 sensor is initialized and the pulse amplitudes for red and green LEDs are set. The heart rate library is also initialized with a BPM range of 50 to 200.
- In the ‘loop ()’ function, PPG data is read from the MAX30102 sensor and passed to the heart rate library to calculate the heart rate. The calculated heart rate is then printed to the serial monitor. The loop waits for the reporting period before repeating the process.
- This program reads PPG data from the MAX30102 sensor, processes the data to calculate heart rate using

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the heart rate library, and outputs the heart rate to the serial monitor.

D. Fast Fourier Algorithm

The Fast Fourier Transform (FFT) algorithm plays an important role in building a pulse oximeter by enabling frequency domain analysis of the PPG signal. The PPGsignal is typically a time-varying waveform that represents the changes in blood volume in the fingertip caused byarterial blood flow. The FFT algorithm allows us to convert this time-domain signal into its corresponding frequency- domain representation.

In a pulse oximeter, the FFT algorithm can be used to analyze the periodicity of the PPG signal and extract the heart rate information. The FFT algorithm calculates the power spectrum of the PPG signal, which represents the distribution of signal power across different frequencies. The dominant frequency component in the power spectrum corresponds to the heart rate, as it represents the frequency at which the blood volume changes in the fingertip due to arterial pulsation.

By applying the FFT algorithm to the PPG signal, we can identify the heart rate frequency component and extract the heart rate information in a quantitative manner. This can be done using various signal processing techniques, such as windowing, zero-padding, and frequency peak detection. The heart rate information can then be used for further calculations, display, and output in the pulse oximeter system.

It's important to note that accurate heart rate calculationusing the FFT algorithm requires proper signal conditioning,noise reduction, and calibration to account for factors suchas motion artifacts, ambient light, and physiological variations. Careful implementation and validation of the FFT algorithm are necessary to ensure reliable and accurate heart rate detection in a pulse oximeter.

E. Fast Fourier Signal Processing

FFT is used in identifying the heart rate frequency component in the signal. The PPG signal consists of a pulsatile component, which corresponds to the changes in blood volume caused by the heartbeats, and a non-pulsatile component, which corresponds to the baseline tissue absorption. The heart rate frequency component can be isolated by filtering out the non-pulsatile component using a digital filter, and then applying FFT to the resulting pulsatilecomponent. The FFT algorithm works by breaking down the signal into a set of sinusoidal functions of different frequencies and amplitudes. These sinusoidal functions are called frequency components, or bins, and they represent the different frequency components of the original signal. The amplitude and phase of each frequency component can be computed using complex mathematical operations, and the resulting frequency-domain representation can be displayed as a graph of amplitude versus frequency. The gist is: FFT is used in PPG signal processing to isolate the heart rate frequency component from the PPG signal, which can be used to calculate the heart rate and othercardiovascular parameters.

III. HARDWARE DEMONSTRATION

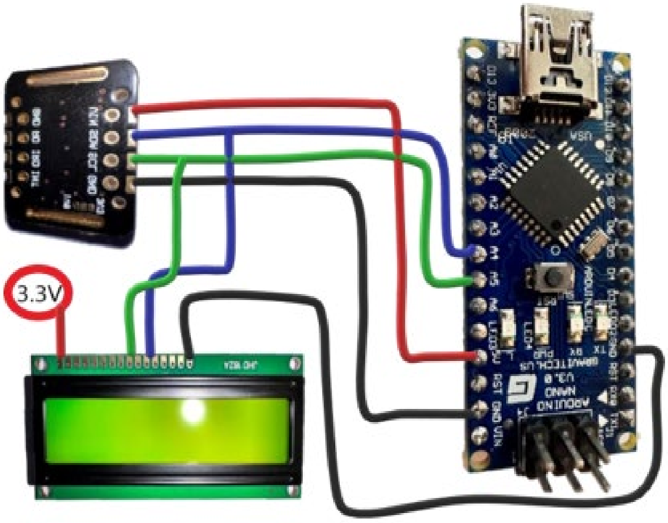

Figure 4. Circuit connection diagram

The circuit diagram with wiring connection of the monitoring system is shown in Figure 4. The working procedure is presented in different steps as follows.

Step 1: Initialize the Arduino Nano and MAX30102 sensor: Set up the Arduino Nano board and connect the MAX30102 sensor to the appropriate pins. Initialize the sensor and configure the required settings, such as LED brightness, sample rate, and pulse width.

Step 2: Read PPG data: Continuously read the PPG (Photoplethysmogram) data from the MAX30102 sensor. PPG data represents the changes in blood volume in the fingertip caused by arterial blood flow, and it contains information about the heart rate and oxygen saturation levels.

Step 3: Signal processing: Process the raw PPG data to extract the heart rate and oxygen saturation (SpO2) values. This typically involves filtering the raw PPG signal to remove noise, detecting the peaks and valleys of the waveform, and calculating the time intervals between the peaks and valleys

Step 4: Heart rate calculation: Use the time intervals between the peaks of the PPG signal to calculate the heart rate in beats per minute (BPM). This can be done using algorithms such as peak detection, thresholding, or autocorrelation.

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Step 5: SpO2 calculation: Use the ratio of the red and infrared PPG signal amplitudes to estimate the oxygen saturation (SpO2) level. This can be done using algorithms such as the Beer-Lambert law or empirical equations based on calibration data.

Step 6: Display and output: Display the calculated heart rate and SpO2 values on an output device, such as an LCD display or serial monitor. Additionally, the data can be logged or transmitted to other devices or platforms for further analysis or storage. Loop and update: Continuously loop through the PPG data processing steps to continuously update the heart rate and SpO2 values in real-time as new data is acquired from the MAX30102 sensor.

TABLE I. PIN CONNECTIONS

Arduino NANO Pin	*2-WAY*	*MAX30102 Sensor Pin*
GND (Ground)	←→	GND (Ground)
A5 pin (Analog Clock)	←→	SCL (Serial Clock)
A4 pin (Analog Data)	←→	SDA (Serial Data)
5V pin	←→	VIN (Voltage IN)

A. Computing the Output

- The output in the pulse oximeter setup calculated based on the PPG signals generated by the sensor.
- The MAX30102 sensor emits two types of light,red and infrared, through the skin and measures theamount of light that is absorbed or reflected back by the blood in the vessels.
- The sensor then produces an analog voltage signal that is proportional to the intensity of the reflected light, and this signal is read by the Arduino Nano using an analog-to-digital converter (ADC).
- The ADC converts the analog voltage signal to adigital value that can be processed by the Arduino.
- The Arduino processes the PPG signals using algorithms such as the fast Fourier transform (FFT) or the autocorrelation method to extract the heart rate and oxygen saturation values.
- The heart rate is determined by measuring the time between successive peaks in the PPG waveform, while oxygen saturation is calculated by comparingthe amplitude ratio of the red and infrared PPG signals.
- Once the heart rate and oxygen saturation valuesare calculated, they are displayed on a screen or transmitted wirelessly to another device for further processing and analysis.

IV. IMPLEMENTATION AND PROGRAMMING OF ARDUINO

The setup is constructed exactly according to the connection diagram as shown in Figure 4. The USB is connected to the laptop which acts as a power supply to the Arduino. The model is arranged in a bread board so as to organize and make access to parts easy for testing purposes. This in further stages will consist of only the Arduino Nano, the MAX30102 Sensor and a smaller display that makes the setup compact and portable. The top-down view ofthe setup is shown in Figure 5. A very important thing to note is the data transfer rate. It must be set at 115200 baud. Setting the data rate at 115200 baud is a commonly used and recommended choice for pulse oximeter projects using Arduino Nano and MAX30102, as it provides a good balance between data transmission speed, efficiency, compatibility with Arduino hardware, and sensor capabilities.

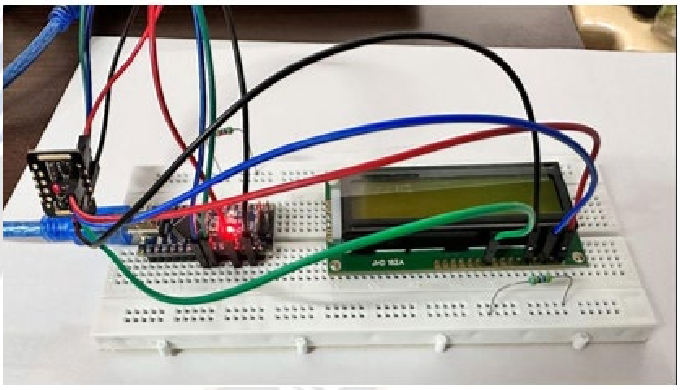

Figure 5. Hardware demonstration set up

Some of the key reasons and a brief explanation for each are listed below:

- *Efficiency:* The data rate of 115200 baud provides good balance between data transmission speed and efficiency. It allows for relatively fast data transfer without causing data corruption or loss due to excessive data rate.
- *Compatibility:* Many Arduino boards, including the NANO, are optimized for communication at 115200 baud. This baud rate is commonly supported by Arduino libraries and examples, making it a practical choice for pulse oximeter projects that use Arduino NANO and MAX30102.
- *Hardware limitations:* The NANO board, like other Arduino boards, has hardware limitations thatmay affect

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the stability of data communication at higher baud rates. Setting the data rate at 115200 baud helps to ensure reliable communication between the NANO board and the MAX30102 sensor.

- *Sensor capabilities:* The MAX30102 sensor, whichis commonly used in pulse oximeter projects, is capable of providing data at a rate that is easily handled by the Arduino NANO at 115200 baud. Higher data rates may
- result in data loss or corruption due to the limitations of the sensor orthe microcontroller.
- *Noise reduction:* Lower baud rates, such as 9600 or 4800, may result in slower data transfer and increased vulnerability to noise and interference. Setting the data rate at 115200 baud allows for faster data transfer, reducing the risk of noise or interference affecting the accuracy of the pulse oximeter readings.

V. RESULTS AND DISCUSSIONS

There are three important functionalities – added, tested and produced results such a Heart Rate measurement, Heart Rate Plot (a very rudimentary ECG), and SpO_2 (Blood Oxygen) measurement. These 3 measures (plots) are virtually displayed on the computer screen at 115200 bits per second. The results obtained as Heart rate measure is shown in Figure 6. The SpO2 measure and heart rate plots obtained from testing are shown in Figure 7 and 8 respectively.

Figure 6. Heart Rate Measure

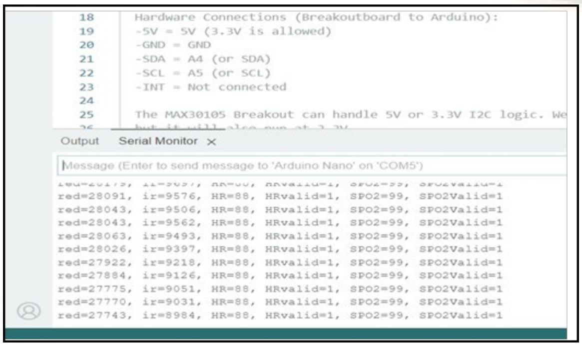

Figure 7. SpO2 Measure

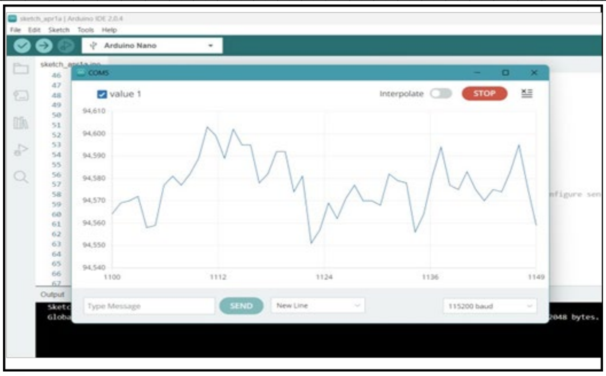

Figure 8. Heart rate plot

From the heart rate plot, it is observed that an average BPM of 81is recorded during experimentation. Similarly, the blood oxygen saturation level of 99 % is recorded. Both the values are confined to a normal value of human beings with less deviations. Since this set up is at preliminary stage, it need to be optimized to get more accurate results. But, still this technique can be used for preliminary measurement of heart rate and SpO2 if it is made as a portable prototype. The measured readings through practical experimentation also proved that the device is capable of measuring the parameters with minimal error. The merits of the proposed system is compared with the existing methods and is shown in Table II.

TABLE II. COMPARISON OF PROPOSED WORK WITH EXISTING WORKS

S. No.	Existing System	Proposed System
1	Expensive and difficult to obtain pulse oximeters	Affordable and accessible pulse oximeter using Arduino Nano and MAX30102 sensor
2	Limited availability of pulse oximeters for personal use	Enables individuals to build their own pulse oximeter at a lower cost
3	Lack of customization and experimentation options	DIY approach allows for customization and potential improvements
4	High accuracy commercial pulse oximeters	Lower accuracy but provides a gross idea about the user's condition
5	Designed for professional healthcare settings	Suitable for personal health monitoring and educational purposes
6	Higher cost for pulse oximeters in the market	Cost-effective solution with a lower bill of materials (BOM)
7	Limited scope for further applications	Provides opportunities for medical researchers and engineers to explore further applications

8	Dependency on external devices for programming and debugging	Integrated USB port in Arduino Nano for easier programming and debugging
9	Size, power consumption, and pin count limitations of existing boards	Arduino Nano offers a compact size, low power consumption, and higher pin count
10	Lack of extensive documentation and support for specific projects	Arduino IDE and Arduino-specific libraries offer a large community and extensive documentation

VI. CONCLUSIONS

This research work aims to make the pulse oximeter available for all. The Bill of Materials for just the main components (those that can together run the program the exact same way as this setup) is just 400 INR. This cost can further come down with increase in scale. Reliable and fast results in low cost is the crux of this work. Even if the accuracy is not as high as commercial pulse oximeters, this gives a gross idea about the current condition of the user, which can help in deciding a time to consult the doctor. This work is still at its early stages. There is a lot of optimizations left to do and a great deal of accuracy enhancement is also pending. These will be met in future iterations of the work. In conclusion, building a low-cost pulse oximeter using Arduino Nano and MAX30102 sensor can provide a cost-effective solution for monitoring blood oxygen levels and heart rate. By leveraging the versatility and ease of programming of Arduino IDE, along with the advanced features of MAX30102 sensor, a functional pulse oximeter can be developed at an affordable price point. This DIY approach allows for customization, experimentation, and potential for further improvements in design and functionality. With careful consideration of the BOM cost and efficient utilization of resources, a low-cost pulse oximeter can be a viable option for various applications, including home health monitoring, DIY medical projects, and educational purposes.

REFERENCES

[1] M.H. Bhuyan, & M.R. Sarder, "Design, Simulation, and Implementation of a Digital Pulse Oxygen Saturation Measurement System Using the Arduino Microcontroller," International Journal of Biomedical and Biological Engineering, vol. 15(2), pp.105-111, 2021.

[2] L. Surasura, & S. Patil, & M. Ayesha, Sattikar "IoT Based SPO2 and Temperature Monitoring Using Arduino Mega and GSM," 3rd International Online Conference on Emerging Trends in Multi-Disciplinary Research, Jan. 20-22, 2022.

[3] D. Fengzhi, & H. Wen, & J. Zhao, & H. Hao, & Qianqian Zhang, "Design of an Instrument for Measuring Heart Rate and Blood Oxygen Based on Arduino," Journal of Robotics, Networking and Artificial Life, Vol. 7(4), pp.275 – 278, 2021.

[4] H. Almimi, & A. A. Dahoud, & M. Fezari, & S. Mohammad, "A Study on New Arduino NANO Board for WSN and IoT Applications," International Journal of Advanced Science and Engineering, vol. 29(4), pp.10223-10230, 2020.

[5] K. Mahesh, "Density Based Traffic Light Controller using Arduino – Nano," International Journal for Research in Applied Science & Engineering Technology, vol.11(I), 2023.

[6] R. Sameh, & M. Genedy, & A. Abdeldayem, "Design and Implementation of an SPO2 Based Sensor for Heart Monitoring using an Android Application," Journal of Physics: Conference Series,1447 012004, 2020.

[7] Kumar, D., Vertivendan, L. ., Velmurugan, K. ., M., K. ., Toradmalle, D. ., & Vajid Nabilal, K. . (2023). Semantic Marginal Autoencoder Model for the Word Embedding Technique for the Marginal Denoising in the Different Languages. International Journal of Intelligent Systems and Applications in Engineering, 11(3s), 204–210. Retrieved from https://ijisae.org/index.php/IJISAE/article/view/2562

[8] B. N. Karthik, & L.D. Parameswari, & R. Harshini, & A. Akshaya, "Survey on IOT & Arduino Based Patient Health Monitoring System," International Journal of Scientific Research in Computer Science, Engineering and Information Technology, vol. 3(1), pp. 1414-1417, 2018.

[9] M. H. Bhuyan, & M. Sheikh, "Designing, Implementing, and Testing of a Microcontroller and IoT-Based Pulse Oximeter Device," IOSR Journal of Electrical and Electronics Engineering, vol. 16(5), pp. 38-48, 2021.

[10] D. T. Harjono, & A. S. Tamsir, "Biomedical Sensor ECG, PPG, and spO2 based on Arduino Which Result from Comparison with Portable," Technical Report, pp. 1-9, 2020.

[11] R. Austin, & F. Lobo & S. Rajaguru, "GSM and Arduino Based Vital Sign Monitoring System. The Open Biomedical Engineering Journal, vol. 15(1), 2021.

[12] M. A. Miah, M. A, & M. H. Kabir, & M. S. R. Tanveer, & M. A. H. Akhand, "Continuous Heart Rate and Body Temperature Monitoring System using Arduino UNO and Android Device," 2nd International Conference on Electrical Information and Communication Technologies, pp. 189-194, 2015.

[13] R. Rákay, & M. Višňovský, & A. Galajdová, & D. Šimšík, "Testing properties of E-health System based on Arduino," Journal of Automatic Control, vol. 3(3), pp. 122-126, 2015.

[14] S. K. Pahuja, & N. Sethy, "Real time measurement of heart rate and it's variability, " Innovations in Power and Advanced Computing Technologies, pp. 1-6, 2017.

[15] W. J. Iskandar, & I. Roihan, & R. A. Koestoer, "Prototype Low-Cost Portable Electrocardiogram (ECG) Based on Arduino-Uno with Bluetooth feature," AIP Conference Proceedings, vol. 2193(1), pp. 050019-1- 050019-7, 2019.

[16] S. Basu, & S. Saha, & S. Pandit, & S. Barman, "Smart Health Monitoring System for Temperature, Blood Oxygen Saturation, and Heart Rate Sensing with Embedded Processing and Transmission using IoT Platform,"

Computational Intelligence in Pattern Recognition: Proceedings of CIPR, pp. 81-91, 2020.

[17] Mei Chen, Machine Learning for Energy Optimization in Smart Grids , Machine Learning Applications Conference Proceedings, Vol 2 2022.

[18] Mr. Kankan Sarkar. (2016). Design and analysis of Low Power High Speed Pulse Triggered Flip Flop. International Journal of New Practices in Management and Engineering, 5(03), 01 - 06. Retrieved from http://ijnpme.org/index.php/IJNPME/article/view/45

[19] S. Majumder, & T. Mondal, & M. J. Deen, "Wearable Sensors for Remote Health Monitoring Sensors," vol. 17(130), pp. 1-45, 2017.

[20] D. N. F. M. Ishak, & M. M. A. Jamil, & R. Ambar, "Arduino Based Infant Monitoring System," IOP conference series: Materials Science and Engineering, vol. 226(1), pp. 012095, 2017.