PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA

وزارة التعليم العالي والبحث العلمي

Ministry of Higher Education and Scientific Research

جامعة أبي بكر بلقايد – تلمسان –

Abou Bekr Belkaïd University – Tlemcen –
Faculty of TECHNOLOGY

Thesis Master's Degree

In: (College of Technology)

Specialty: (Biomedical Engineering- Instrumentation Biomedical)

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Pulse Oximeter and Heart Rate Sensor with Arduino and MAX30102

Publicly defended, on 05 / 06/ 2023, before the jury composed of:

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2022/2023

Quran Karim

بِسْمِ اللّهِ الرَّحْمنِ الرَّحيمِ

«نَحْنُ نَقُصُّ عَلَيْكَ أَحْسَنَ الْقَصَصِ بِمَا أَوْحَيْنَا إِلَيْكَ هَذَا الْقُرْآنَ وَإِن كُنتَ مِن قَبْلِهِ لَمِنَ الْغَافِلِينَ»

يوسف: [3]

Dedication

I praise to Allah, the one to whom all dignity, honor and glory are due, the unique with perfect attributes, who bigots not, nor is He begotten.

All praise to the prophet Mohammed, peace be upon him.

I am extremely grateful to my supervisor and committee Chairman **Dr. Kerai salim**, **Dr. Benali Redouane**, and **Kholkhal Mourad** for accepting to be my supervisor and the directions they gave me.

All deep thanks to my wife, Aya Makhlouf, who persistently stands by me from the beginning to the end of this scientific journey.

I warmly dedicate this work to my father, Ebeid,

to my mother Ibtesam,

I warmly dedicate this work to my brothers; Sara, Sami, and Ahmed,

and my sisters; Dema.

Hatem O.N Mansour

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Abstract

With the development of life and its complexities and the expansion of the circle of scientific progress and inventions that came to serve humanity ,it was necessary to see the effects and repercussions of some of these achievements negatively on nature and man .Hence the great achievement that came from the invention of electromagnetic wave devices ,which provided great services to humans .Especially in the field of medicine in the axial treatment and diagnosis .In the beginning ,electromagnetic waves were defined with their physical properties and biological effects on humans .It also reviewed the uses of electromagnetic waves in medical technology .The study concluded that research conducted so far in the field of radiation risk has not been able to prove damage to brain and nervous system functions ,let alone other parts of the body .However ,all users of electromagnetic wave devices must operate at frequencies below permitted to avoid any damage that may occur .This study therefore recommends that the use of these devices be continued until other results are produced that contradict what has been achieved.

Key Word: Spo2, BPM, Pulse Oximeter, Heartbeat, Sensor.

Chapter I
Introduction

Chapter I: Introduction

1.1 Introduction

Every system and organ in the body needs oxygen to survive. Without oxygen, cells begin to malfunction and eventually die. Cell death can cause severe symptoms and ultimately lead to organ failure. The body transports oxygen to the organs by filtering it through the lungs. The lungs then distribute oxygen into the blood via hemoglobin proteins in red blood cells. These proteins provide oxygen to the rest of the body.

Oxygen saturation (SpO2) reading is an estimation of the amount of oxygen in your blood. Normal oxygen saturation levels are between 95 and 100 percent. Oxygen saturation levels below 90 percent are considered abnormally low and can be a clinical emergency.

Your pulse rate is an estimation of the number of times your heart contracts per minute, normal pulse rate values for adults range from 60 to 100 beats per minute (bpm).

The device is usually placed around one of the fingers. On one side, the device emits red and infrared light, on the other side a light receiver. This receiver measures the amount of absorbed light. It is known that the physical properties of oxidized hemoglobin (Hbo2) are different from those of non-oxidized so that oxidized hemoglobin absorbs infrared radiation more than non-oxidized. While the non- oxidized hemoglobin (Hb) absorbs more red light and allows the infrared to penetrate. The device measures the amount of red and infrared light and analyzes the amount of oxygen in the blood . (Kaufman et, sl., 2018)

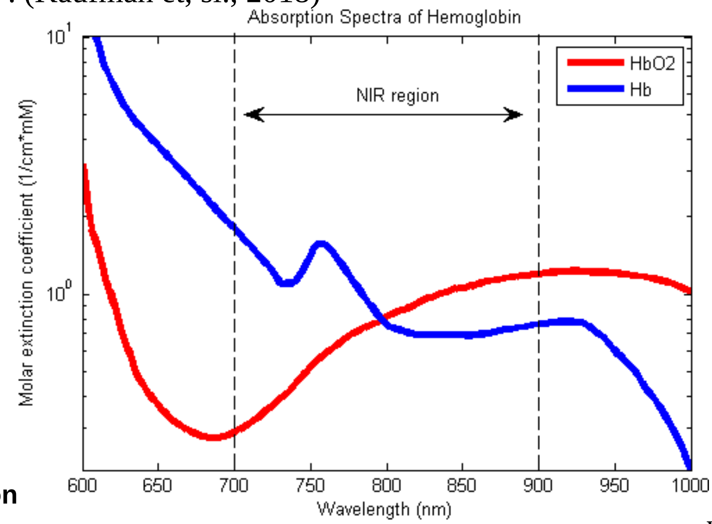


Figure 1-1:Absorption Spectra of Hemoglobin

Source: Wikimedia, Oxy and Deoxy Hemoglobin Near-Infrared absorption spectra, in url: https://commons.wikimedia.org/wiki/File:Oxy_and_Deoxy_Hemoglobin_Near-Infrared_absorption_spectra.png

1.2 Project Definition:

A Portable pulse oximeter is a small, lightweight device used to monitor the amount of oxygen carried in the body. This non-invasive tool attaches painlessly to your fingertip, sending two wavelengths of light through the finger to measure your pulse rate and how much oxygen is in your system. Once the oximeter finishes its assessment, its screen will display the percent of oxygen in your blood coming from your heart-as well as your current pulse rate and temperature synchronously and that typically sounds an alarm if the one of three parameters is abnormal. additionally, this device can send three parameters to Android application on mobile phone by Bluetooth module .

1.3 Problem Statement:

Patients in the intensive care unit were connected with equipment to monitor heart rate, temperature, and blood oxygen Levels.

Sometimes it is possible that their heart stops briefly and will trigger a warning, and the nurse will be sent to the rescue. And also, newborns. But how can families of patients know if this happened while they were at home? What they needed was heart rate and Spo2. We searched the Internet for a heart rate monitor that was affordable on average consumer. The few that I have not found are expensive and can be used with adults and cannot be used for children unless the child is supervised by an adult. This was due to the risk of choking of the connecting wires Child on screen. There is a need to have transmitter on the child who does not Interfere with the child's movements, such as on his foot. This device can also be used to alert people to other life-threatening conditions such as a sudden drop in heart beats; This led us to build a mobile pulse oximeter with fast technology and control and easy to use.

1.4 Objectives

In the light of the above, this project has the following objectives:

- Designing pulse oximeter that can measure oxygen saturation in the blood, heartbeat and temperature.
- Using infrared absorption technology by using two sources (red LED and infrared source) and a photodiode for detection.
- Calculating and studying the result of photodiode detection's by using software program.
- Using proteus for design the circuit.
- Design and implementation the device and make it ready to use.

1.5 Requirements

Requirements can be fit into two main categories: Hardware and Software requirements.

1.1.1 Software Requirements

- ARDINO IDE.
- Protues 8.7.
- SolidWorks
- App Inventor

1.5.1.1 Arduino software

The software consists of a standard programming language compiler and the boot loader that runs on the Uno Arduino board by C program. (Team Arduino)

Figure1-2: ARDUINO IDE

1.5.1.2 Proteus

Proteus is software for electronic and microprocessor simulation, schematic capture, and printed circuit board (PCB) design. (PCB Design and Circuit Simulator, 2023)

Figure 1-3: PROTEUS Simulation

1.5.1.3 SolidWorks

To create models and assemblies, SolidWorks, a solid modeler, employs a parametric feature-based method pioneered by PTC (Creo/Pro-Engineer). Parasolid-kernel is the foundation of the program's code.

The parameters of a model or assembly are the constraints whose values govern the model's or assembly's geometry. Line lengths and circle diameters are examples of numerical parameters; tangent, parallel, concentric, horizontal, and vertical are examples of geometric parameters. The application of relations between numerical quantities allows for the recording of design intent.

The designer's goal for a component is its behavior in response to modifications. For instance, a beverage can's top hole should always be flush with the can's top surface, no matter how tall or wide the can is. Users may tell SolidWorks that they want the hole to be on the top surface, and the software will respect that preference regardless of the height they give the can. (Solidworks, 2023)

Figure 1-4: SolidWorks

1.5.1.4 App Inventor

App Inventor is an IDE for creating web applications that was first made available by Google and is currently supported by MIT. As of the 8th of July 2019, it is in its last beta testing phase before its general release this summer. It enables non-programmers to construct applications (apps) for both Android and iOS. It is open-source software that has been distributed under two different licenses: A combination of the Apache 2.0 License for the underlying code and the Creative Commons 3.0 Attribution ShareAlike Unported License. (Hardesty, 2010)

Figure 1-5: App Inventor (MIT)

1.1.2 Hardware Requirements

- Electrical components.
- Arduino Nano.

– SpO2 Sensor.
– LCD Display (LM016L).
– Battery.
– Buzzer.

1.5.1.5 Arduino Nano

If you're looking for a compact, full, and breadboard-friendly board, go no further than the ATmega328P-based Arduino Nano (3.x series). It's similar in function to the Arduino Duemilanove, but comes in a smaller form factor. It uses a Mini-B USB cable instead of a regular one and lacks just a DC power connector. (Arduino Official Store)

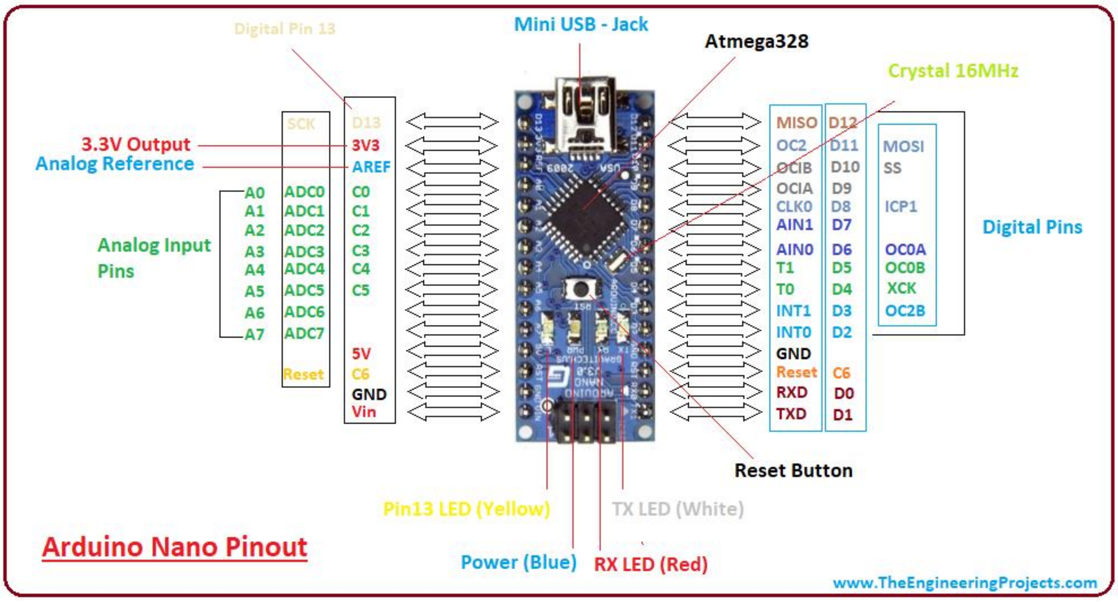


Figure 1-6: Arduino Nano

Source: from: https://store.arduino.cc/products/arduino-nano

1.5.1.6 Pulse Oximeter Sensor (Max 30102):

This sensor has been used because it contains the required components in a form that yields more accurate results. (Maxim Integrated Products, Inc, 2014)

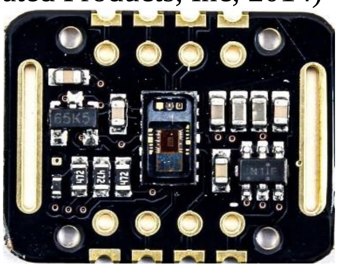


Figure 1-7: Max 30102 Pulse Oximeter Sensor

The sensor is an integrated pulse oximetry and heart-rate monitor sensor solution. It combines two LED’s, a photo detector, optimized optics, and low-noise analog signal processing to detect pulse and heart-rate signals. It operates from 1.8V and 3.3V power supplies and can be powered down through software with negligible standby current, permitting the power supply to remain connected at all times. (Maxim Integrated Products, Inc, 2014)

1.5.1.7 A liquid-crystal display (LCD LM016L)

translates to 16 characters per line and 2 lines total. This LCD displays each character in a 5x7 grid. This LCD has both a Command and Data register.

The command register records the LCD's received commands. LCDs may be instructed to perform a variety of predetermined functions—from initialization to screen clearing to pointer positioning to display control—via commands. The information for the LCD display is stored in the data register. The information is the character's ASCII value for the LCD to show. (Electronics For You, 2022)

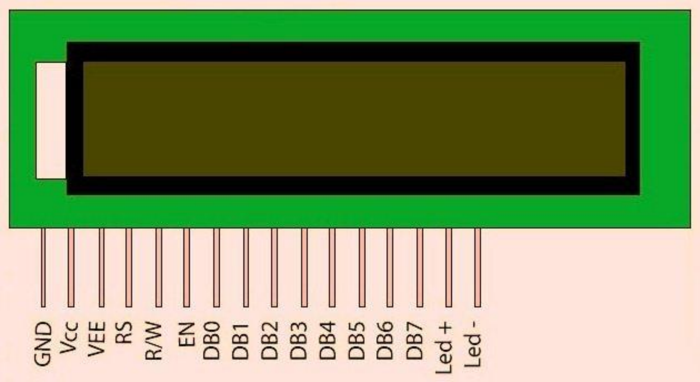


Figure 1-8: LM016L 16X2 LCD

1.5.1.8 Buzzer

A buzzer or beeper is an audio signaling device, which may be mechanical, electromechanical, or piezoelectric. Typical uses of buzzers and beepers include alarm devices, timers, and confirmation of user input such as a mouse click or keystroke. (Farlex, 2014)

Figure 1-9: Buzzer

1.5.1.9 Battery:

A battery is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices (9 volt). In our project it will be used instead of cables. (Harwood et al., 2007)

Figure 1-10: Battery

1.6 Project Block Diagram and Flow Charts

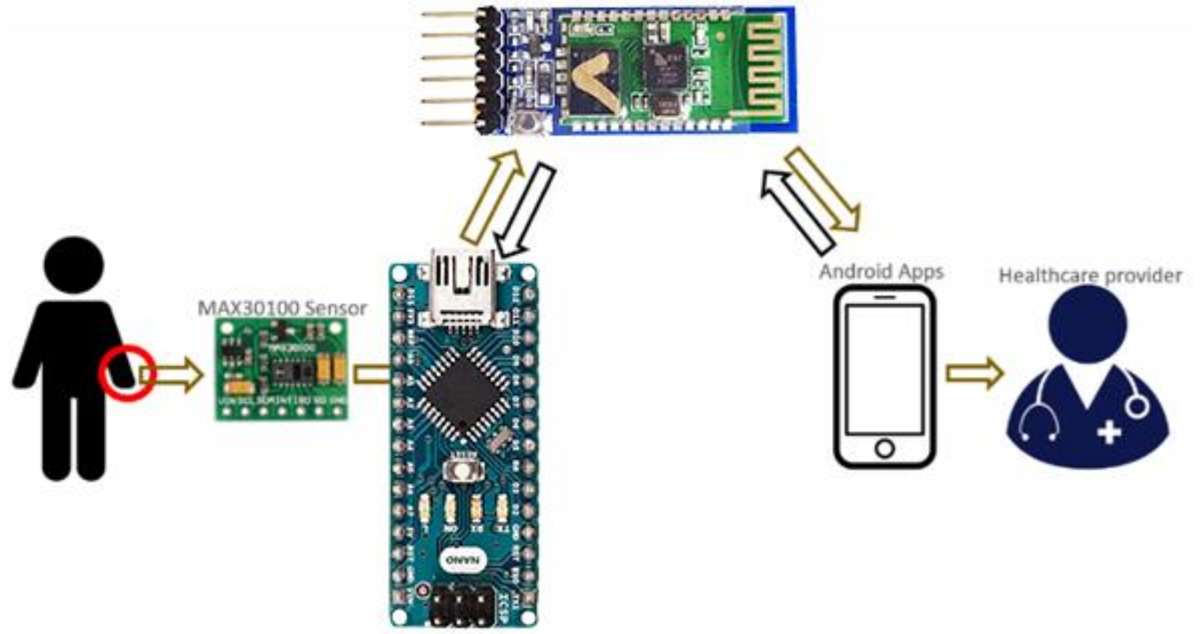


Figure 1-11: Block diagram of the system

The system, as shown in Figure (), comprises three subsystems: the hardware (module device), Transmit device (Bluetooth HC-05), and software (Android application).

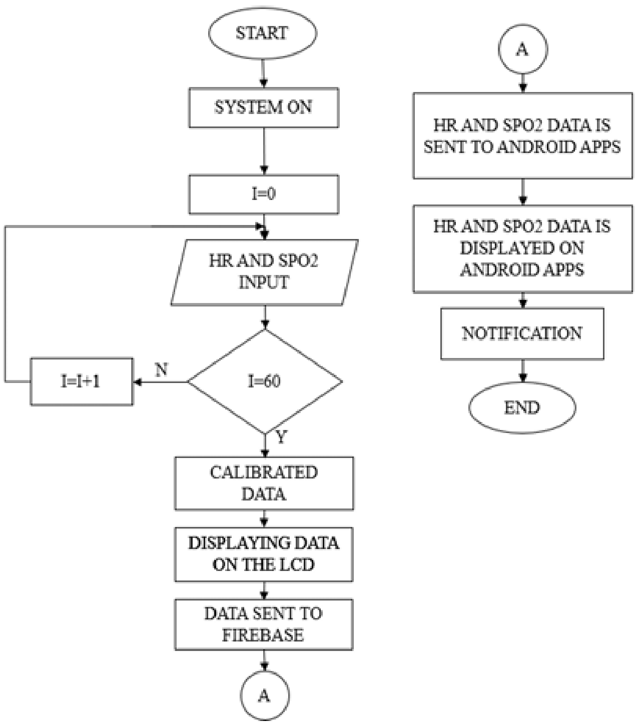
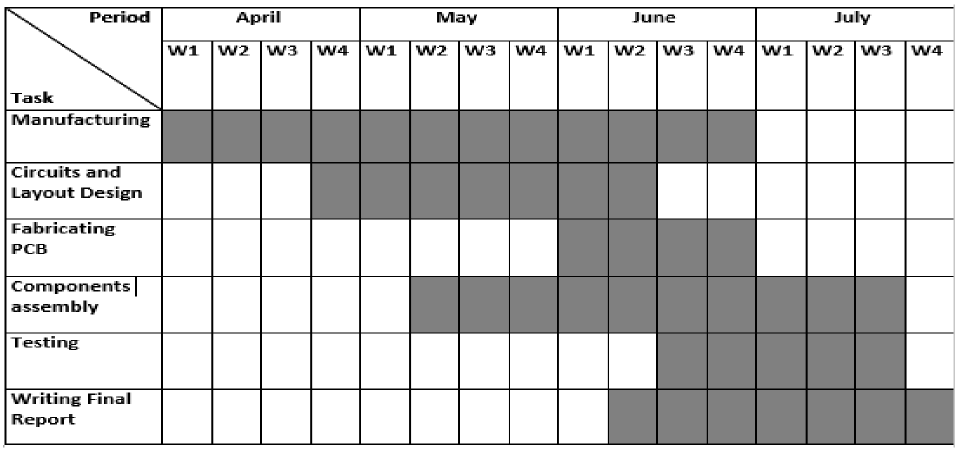


Figure 1-12: System flowchart

Figure () shows the flowchart of the system starting from the input (Max30100 sensor) to the output (the android application). When the system is on, the microcontroller continuously checks whether the sensor is collecting data (heart rate and SPO2), or not. Once the sensor is collecting data, the microcontroller calibrates the collected data and subsequently displays it in a 16x2 liquid crystal display (LCD) while also send it online to the database. In addition to such a calibrated data, the LCD also displays the timestamp based on the real-time clock module. Once the database received the real-time data, the Android application pops up a notification as a reminder that the sensor has sent the latest data and is ready to be displayed on the application.

1.7 Time Plan

The first step will be collecting information from many sources' internet, books, person with experience, specializing community institutions and others. The collected information then will be analyzed and the ideas that were noticed will be discussed in many brainstorming sessions to come out with decisions about the project. After that we decide what the appropriate components that we need in the project and buying it, then design and simulation of the required electronic circuits will be started using Proteus software. Finally, final report (part1) will be written.



After all that, by finishing the first semester, another time plan is used to ensure continuously work on the project.

Finally, documentation and writing the report with regard each step that records during both semesters for later attaching were completed.

1.8 Summary

Portable Pulse Oximeter (PPO) is an important type of SpO2 that uses in Medical to measured (BPM, SpO2, Temperature). In this chapter, a definition of the project is done for giving a good understanding of our project, objectives, requirements and time plans are demonstrated the main idea of the project and procedures.

Chapter II
Literature review

Chapter II: Literature review

The technique of oximetry and blood gas analysis has come a long way since its inception. When Lambert described the relationship between the light absorbed and the amount of absorbent. His experiments were reconducted by Beer in 1852, giving rise to the well-known Lambert-Beer law.

In 1864, by using the spectrometer; Hodde-Sevler identified the molecule of Hb. Shortly afterwards, Stokes shows that the Hb molecule is the O2 carrier in blood.

It was actually used later in hospitals These in-vitro analysis instruments were either blood gas analyzers or hem-oximetry. Nowadays; pulse oximetry quickly found its way into the operating rooms as one of the essential devices for patient monitoring. (Severinghaus & Honda, 1987).

2.1 Measurement oxygen saturation in blood

Measuring blood oxygen saturation (SPo2) is a very important parameter because oxygen is vital to life and reduced levels of oxygen circulating in the bloodstream can lead to very serious, even fatal, complications for the heart, lung, brain and other organ. People with severe lung or heart disease, who are unconscious or who have difficulty breathing, or who need oxygen treatment for any reason are at risk of reduced oxygen levels, and consequently are at risk of serious illness. In these days; There are two techniques to measure SpO2 parameter. (Walley, 2011)

2.1.1 Arterial blood gas (ABG) test (Invasive)

Invasive technique an arterial blood gas (ABG) test measures oxygen and carbon dioxide levels in your blood. It also measures your body's acid-base (pH) level, which is normally balanced when you are healthy. this test if you are in the hospital because you have a serious injury or illness. (Simpson, 2004)

2.2 DESIGN AND SIMULATION DESIGN AND SIMULATION

In this section, three models are proposed and described. Also, materials and control circuit are chosen and differentiated by taking into consideration best type, availability, cost and quality. Then, simulation is created to implement mathematical models that demonstrated in chapter 3. Based on that, we can display the project virtually. Finally, structure analysis and table of costs are created.

2.3 MAX30102 Component and Works:

The MAX30102, or any optical pulse oximeter and heart-rate sensor for that matter, consists of a pair of high-intensity LEDs (RED and IR, both of different wavelengths) and a photodetector. The wavelengths of these LEDs are 660nm and 880nm, respectively.

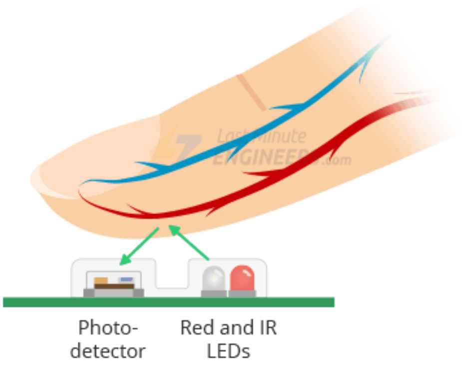


Figure 2-1: shining both lights onto the finger or earlobe

Source: https://lastminuteengineers.com/max30100-pulse-oximeter-heart-rate-sensor-arduino-tutorial/

The MAX30102 works by shining both lights onto the finger or earlobe (or essentially anywhere where the skin isn't too thick, so both lights can easily penetrate the tissue) and measuring the amount of reflected light using a photodetector. This method of pulse detection through light is called Photo plethysmogram.

The working of MAX30102 can be divided into two parts: Heart Rate Measurement and Pulse Oximetry (measuring the oxygen level of the blood). (Maxim Integrated Products, Inc, 2014)

2.3.1 Heart Rate Measurement

The oxygenated hemoglobin (HbO2) in the arterial blood has the characteristic of absorbing IR light. The redder the blood (the higher the hemoglobin), the more IR light is absorbed. As the blood is pumped through the finger with each heartbeat, the amount of reflected light changes, creating a changing waveform at the output of the photodetector. As you continue to shine light and take photodetector readings, you quickly start to get a heart-beat (HR) pulse reading. (Park et al., 2013)

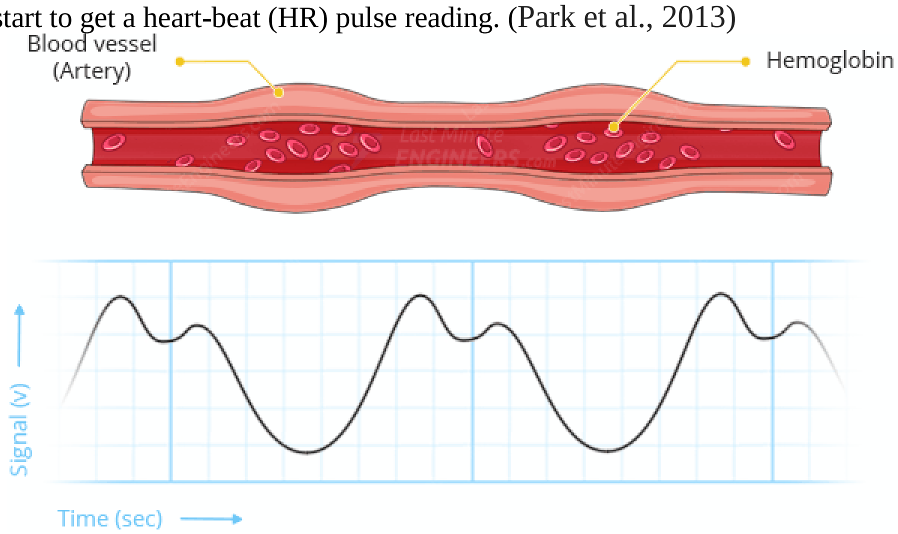


Figure 2-2: reflected light changes, creating a changing waveform at the output

Source: https://lastminuteengineers.com/max30100-pulse-oximeter-heart-rate-sensor-arduino-tutorial/

2.3.2 Pulse Oximetry

Pulse oximetry is based on the principle that the amount of RED and IR light absorbed varies depending on the amount of oxygen in your blood. The following graph is the absorption-spectrum of oxygenated hemoglobin (HbO2) and deoxygenated hemoglobin (Hb).

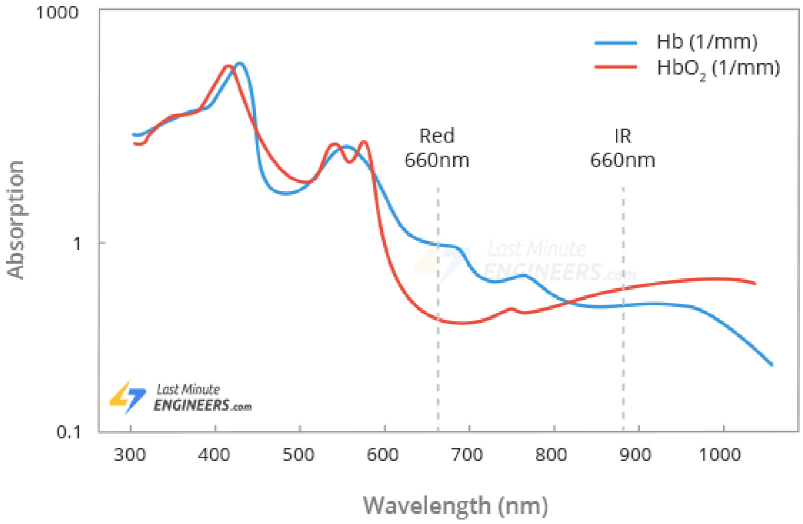


Figure 2-3: the absorption-spectrum of oxygenated hemoglobin (HbO2)

Source: https://lastminuteengineers.com/max30100-pulse-oximeter-heart-rate-sensor-arduino-tutorial/

As you can see from the graph, deoxygenated blood absorbs more RED light (660nm), while oxygenated blood absorbs more IR light (880nm). By measuring the ratio of IR and RED light received by the photodetector, the oxygen level (SpO2) in the blood is calculated. (Hoffman, 2017)

2.4 Methods

The peripheral oxygen saturation may be determined by measuring the time-varying absorption of oxyhemoglobin and deoxyhemoglobin at two separate wavelengths in the arterial blood, and this can be done using a modified pulse oximeter sensor to meet the compact size.

2.5 A pulse oximeter

The near infrared area of the light spectrum (about 940 nm) and the red region of the light spectrum (around 660 nm) are used by a pulse oximeter to detect the amount of light absorbed by blood. The LEDs in the SpO2 probe produce light at these wavelengths, and the PIN-diode on the other side of the probe detects it after it has traveled through peripheral tissue. An empirical link between relative absorption at the two wavelengths and arterial oxygen saturation SaO2 is used by the pulse oximeter to calculate SpO2.

Pulse oximeters get key information on arterial saturation from the component of light absorption giving fluctuations in time with the heartbeat.

One major drawback of pulse oximetry is that it can only distinguish between two kinds of hemoglobin since it uses only two wavelengths.

The fractional saturation SaO2frac or pulse rate is used for empirical calibration in current pulse oximeters. (Chan et al., 2013)

$$SaO_2frac = \frac{HbO_2}{HbO_2 + Hb + Dyshemoglobin} \qquad Formula 1$$

Or against functional saturation SaO_2func;

$$SaO_2frac = \frac{HbO_2}{HbO_2 + Hb} \qquad Formula 2$$

Changes in carboxyhemoglobin and methemoglobin concentrations have less of an effect on functional saturation.

The module uses functional saturation SaO2func as a reference to calibrate the oxygen saturation percentage SpO2. At relatively high carboxyhemoglobin concentrations in blood, the accuracy of SpO2 measurement relative to SaO2func may be maintained using this approach. At high amounts of carboxyhemoglobin or methemoglobin, oxygen content in the arterial blood cannot be accurately measured by pulse oximeters, regardless of the calibration technique used. (Nitzan et al., 2014)

2.6 Plethysmography pulse wave

The plethysmography waveform is derived from the IR signal and reflects the blood pulsation at the measuring site. Thus, the amplitude of the waveform represents the perfusion.

2.7 Pulse rate

Plethysmography relies on detecting the peak of the pulse wave in order to determine the heart rate. Noise is removed from the signals, and artifacts are identified and removed.

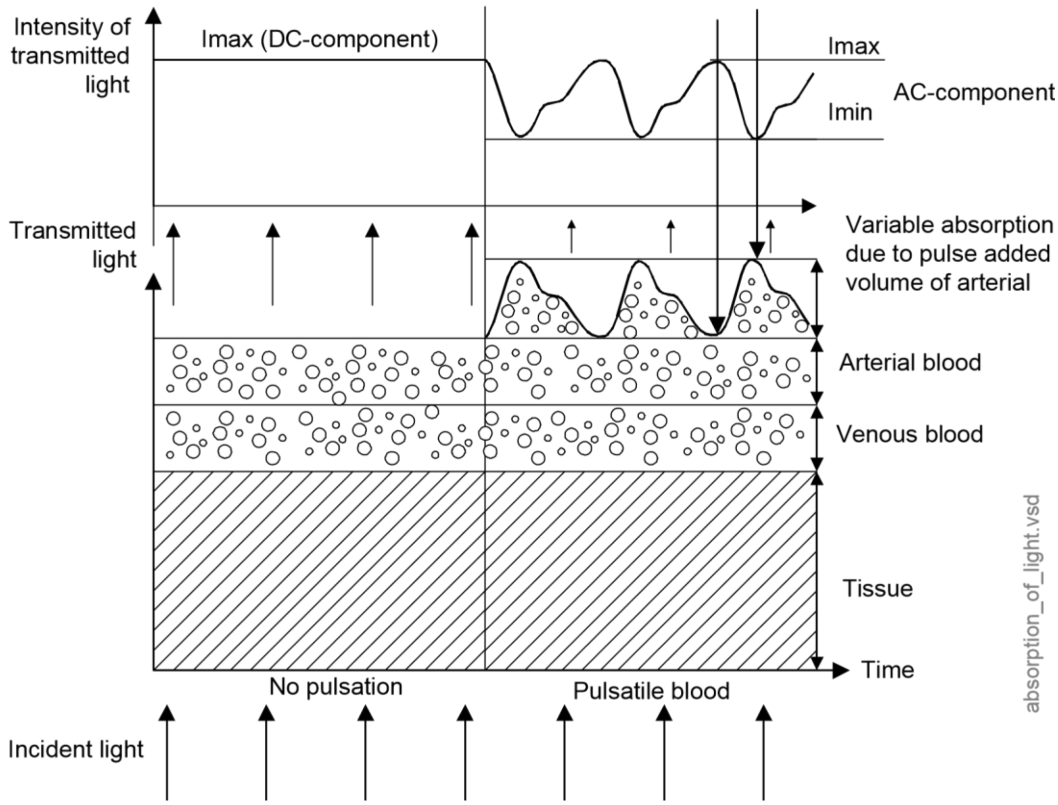


Figure 2-4: Absorption of infrared light in the finger. (Nitzan et al., 2014)

constraint of two hemoglobin species, $c_{RHb} + c_{HbO2} = tHb$, is included, the equation can be rewritten in form

$$R = \frac{\varepsilon_{HbO_2,red} \cdot SpO_2 + \varepsilon_{RHb,red} \cdot (1 - SpO_2)}{\varepsilon_{HbO_2,ired} \cdot SpO_2 + \varepsilon_{RHb,ired} \cdot (1 - SpO_2)}, \quad (9)$$

which can be solved for SpO_2 as presented in equation

$$SpO_2 = -\frac{\varepsilon_{RHb,red} - R \cdot \varepsilon_{RHb,ired}}{(\varepsilon_{HbO_2,red} - \varepsilon_{RHb,red}) - R \cdot (\varepsilon_{HbO_2,ired} - \varepsilon_{RHb,ired})}. \quad (10)$$

Theory presented above is based on the Beer-Lambert assumptions that in reality are not valid in *in vivo* tissues. Other substances are present in blood and the incident light is partially scattered, refracted and reflected. The detected light at the photodetector consists of photons that travel different routes. Some of the photons travel through the tissue without migrating from the line that emitter and detector form and some scatter farther from the line and still reach the detector at the other end. When the absorption increases the detected light tends to come more from the shorter paths. Because of this path lengths vary with different wavelengths. Because of these deviations from the Beer-Lambert law conventional pulse oximeters are empirically calibrated to give better estimation of oxygen saturation. [2, 24]

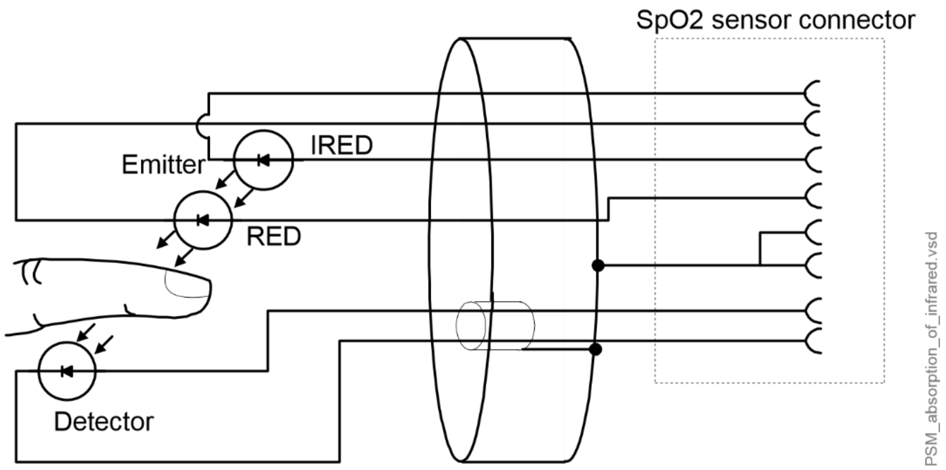


Figure 2-5: Pulse oximetry probe parts layout and schematic diagram. (Nitzan et al., 2014)

The typical probe is a finger clamp style that houses the LED light source and photodiode detector on opposite ends. GE Healthcare offers a wide variety of probe types.

2.8 Mathematical model:

Assuming a monochromatic light source, a uniform distribution of hemoglobin, no light scattering, and a contemporaneous measurement, one may develop, beginning with the Beer-Lambert equation, a calculation formula for the peripheral blood hemoglobin concentration. (Aigner et al., 2013)

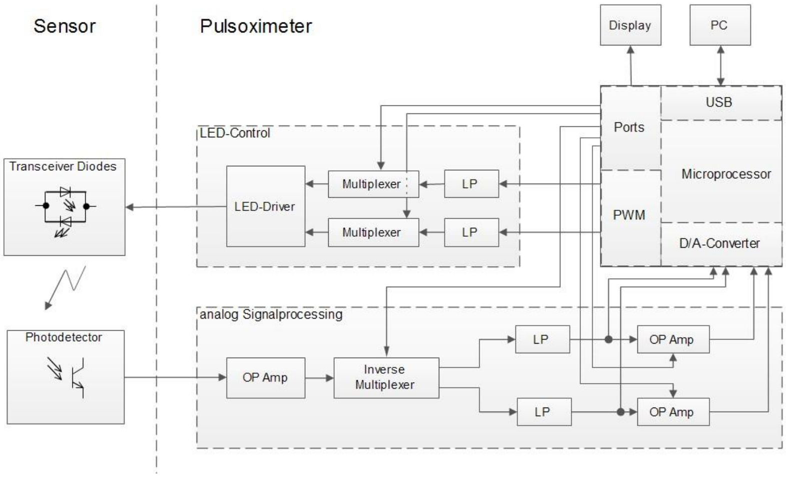


Figure 2-6: Block diagram of the pulse oximeter hardware. (Nitzan et al., 2014)

oxygen saturation as it is given in Eq. 1 (reproduced from [2]).

$$SpO_2 = \frac{\epsilon_{Hb}(\lambda_R) - \epsilon_{Hb}(\lambda_I R)R}{\epsilon_{Hb}(\lambda_R) - \epsilon_{HbO_2}(\lambda_R) + [\epsilon_{HbO2}(\lambda_I R) - \epsilon_{Hb}(\lambda_I R)]\ R} \qquad (1)$$

This theoretical equation is made up of the differential ratio between the observed pulse amplitudes (R), the hemoglobin and deoxyhemoglobin extinction coefficients (), and their evaluations at the visible red (R) and infrared (IR) wavelengths of the light sources.

Due to non-linearity and lacking conditions for the employment of the beer-lambert rule, the behavior of the formula presented in Eq. 1 must be fitted by equation 2 in order to prevent substantial mistakes, particularly in low saturation regions. (SpO2 < 80%).

SpO2 = k1- k2R =110.28 - 17.51R (2)

The model parameters (k1 = 110.28 and k2 = 17.51) are fitted from literature data to map the oxygen saturation regarding the amplitude-ratio that is calculated out of the measured and preprocessed data from the alternating infrared signal (IvrAC) and the alternating visible red signal (IirAC) as it is demonstrated in Eq. 3.

$$R \approx \frac{I_{vr_{AC}}/I_{vr_{DC}}}{I_{ir_{AC}}/I_{ir_{DC}}} \overset{I_{vr_{DC}} \equiv I_{ir_{DC}}}{\cong} \frac{I_{vr_{AC}}}{I_{ir_{AC}}} \qquad (3)$$

2.9 Summary

This section describes how blood oxygenation can be measured by pulse oximetry. First the basis of oximetry, Beer-Lambert law, is explained, then the theory of pulse oximetry and calibration methods are described. At the end accuracy and limitations of pulse oximetry are reviewed.

Chapter III

DESIGN AND SIMULATION

Chapter III: DESIGN AND SIMULATION

3.1 Introduction

In this chapter, three models are proposed and described. Also, materials and control circuit are chosen and differentiated by taking into consideration best type, availability, cost and quality. Then, simulation is created to implement mathematical models that demonstrated in chapter 3. Based on that, we can display the project virtually. Finally, structure analysis and table of costs are created.

3.2 Modeling

3.2.1 Model Designing

Figure 3-1 : Portable Pulse Oximeter.

In figure above is a demonstration of "Portable Pulse Oximeter (PPO)". As well, our prototype of the Portable Pulse Oximeter is inspired by the mechanism of this pulse oximeter.

This design is used for many reasons, the first reason is light weight and the ability to navigate with the patient, the second reason is the flexibility of the design where vital signs can be monitored through the application running on the smartphone, the shape is consistent. Finally, quality and low cost.

In this project, PROTEUS 8.7 CAD Connected is used to design the Circuit of our Pulse Oximeter as following bellow, And Arduino IDE is used to Programming it.

3.2.2 Sensor selection

There are many types of Pulse Oximeter Sensor used medical field. So, a differentiation will be made between the most common types that used in SPO2 applications. Accordingly, a comparison will be made between these types.

3.2.2.1 MAX30100 Pulse Oximeter

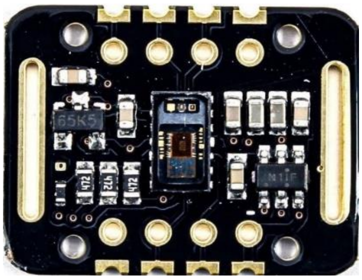


Figure 3-2: Max 30102 Pulse Oximeter Sensor

The sensor is an integrated pulse oximetry and heart-rate monitor sensor solution. It combines two LED's, a photo detector, optimized optics, and low-noise analog signal processing to detect pulse and heart-rate signals. It operates from 1.8V and 3.3V power supplies and can be powered down through software with negligible standby current, permitting the power supply to remain connected at all times. (Maxim Integrated Products, Inc, 2014)

Features

1. Consumes very low power (operates from 1.8V and 3.3V)
2. Ultra-Low Shutdown Current (0.7µA, type)
3. Fast Data Output Capability

3.2.2.2 Pulse Oximeter (SPO2) Heart-Rate Sensor Module MAX30100

The MAX30100 is an integrated pulse oximetry and heart rate monitor sensor solution. It combines two LEDs, a photodetector, optimized optics, and low-noise analog signal processing to detect pulse oximetry and heart-rate signals. The MAX30100 operates from 1.8V and 3.3V power supplies and can be powered down through software with negligible standby current, permitting the power supply to remain connected at all times.

3.2.2.3 Applications:

– Wearable Devices
– Fitness Assistant Devices
– Medical Monitoring Devices

3.2.2.4 Features & Specifications:

- Operating Voltage: 1.8v – 5.5v
- Interface Type: I2C Serial Interface
- Complete Pulse Oximeter and Heart-Rate Sensor Solution
- Simplifies Design Integrated LEDs, Photo Sensor, and High-Performance Analog Front-End
- Tiny 5.6mm x 2.8mm x 1.2mm
- Optically Enhanced System-in-Package.
- Ultra-Low-Power Operation Increases Battery Life for Wearable Devices
- Programmable Sample Rate and LED Current for Power Savings
- Ultra-Low Shutdown Current (0.7µA, typ)
- Advanced Functionality Improves Measurement Performance
- High SNR Provides Robust Motion Artifact Resilience
- Integrated Ambient Light Cancellation
- High Sample Rate Capability
- Fast Data Output Capability
- Module Weight: 1.2g (Header + module)

3.2.2.5 Pinouts:

VIN	1.8V – 5.5V Power Input
SCL	I2C Serial Clock
SDA	I2C Serial Data
INT	MAX30100 Interrupt
IRD	IR LED Cathode and LED Driver
RD	Red LED Cathode and LED Driver
GND	0V / Reference Voltage

3.2.3 control circuit

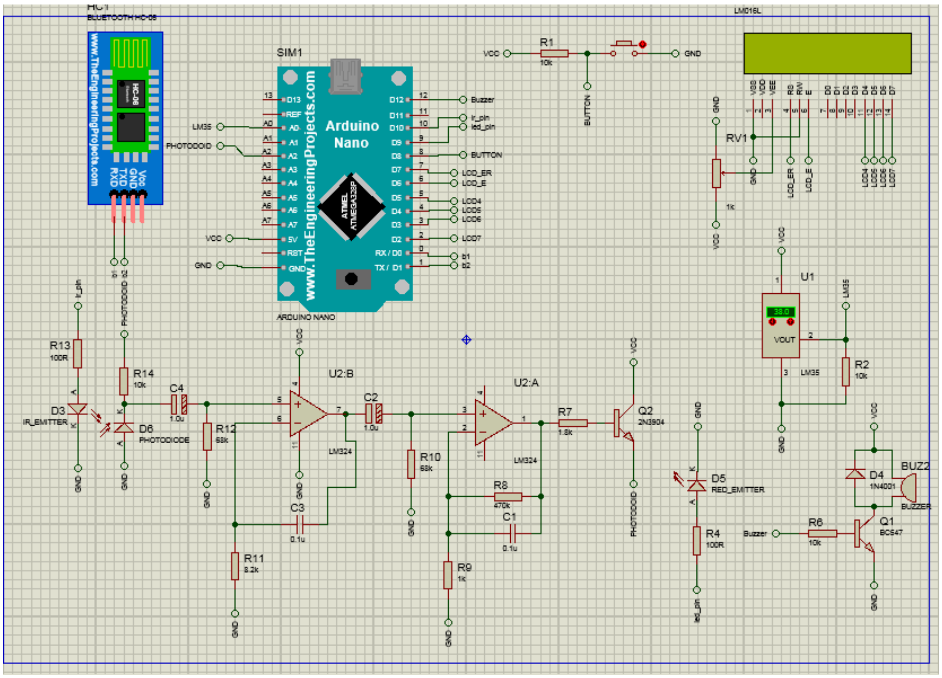


Figure 3-3: Final Circuit Simulated Diagram

This circuit is built with main controller Arduino which has serial communication port enable us to connect it directly in the computer and control of another component. Besides, other necessary component called Bluetooth to Transmit data between Arduino and Mobile App.

3.2.4 Final Design

Finally, we have our Portable Pulse Oximeter Design, we show it follow

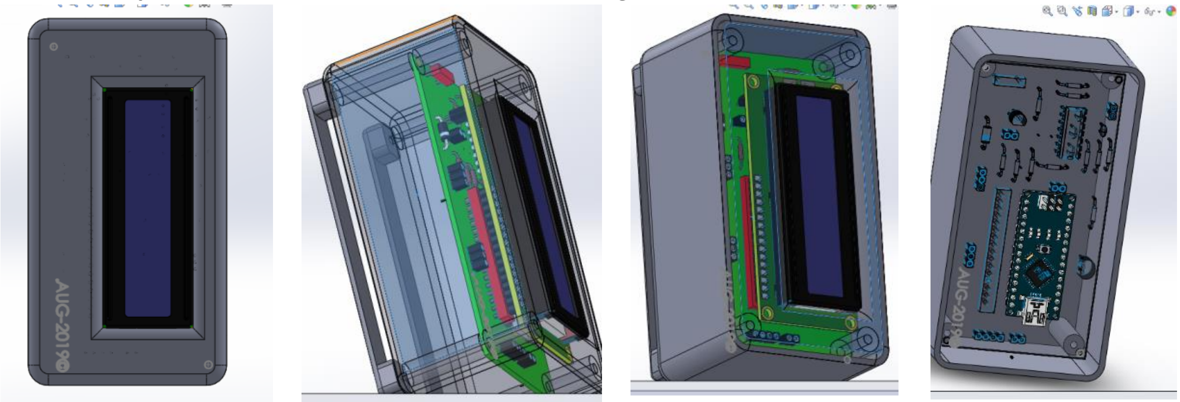


Figure 3-4: SolidWorks Design

3.2.4.1 Arduino

Arduino hardware and software are Open Source, and the designs and software are available to be copied and changed. Moreover, Arduino is a small circuit board with an Atmel Micro-Controller chip and other parts.

It is a "Rapid Electronics Prototyping Platform" which consists of two main parts:

- HARDWARE: An Arduino Open-Source Microcomputer board.
- SOFTWARE: The free Arduino IDE that runs on PC, MAC, or Linux.

It has many types as Arduino Uno, Arduino Due, Arduino Mega, Arduino Leonardo, etc. As a result, Arduino Nano will be chosen.

Arduino Nano is a small, compatible, flexible and breadboard friendly Microcontroller board, developed by Arduino.cc in Italy, based on ATmega328p (Arduino Nano V3.x) / Atmega168 (Arduino Nano V3.x).

It comes with exactly the same functionality as in Arduino UNO but quite in small size.

It comes with an operating voltage of 5V; however, the input voltage can vary from 7 to 12V. Arduino Nano Pinout contains 14 digital pins, 8 analog Pins, 2 Reset Pins & 6 Power Pins.

Each of these Digital & Analog Pins are assigned with multiple functions but their main function is to be configured as input or output.

There is one limitation using Arduino Nano i.e., it doesn’t come with DC power jack, means you cannot supply external power source through a battery.

This board doesn’t use standard USB for connection with a computer, instead, it comes with Mini USB support.

Tiny size and breadboard friendly nature make this device an ideal choice for most of the applications where a size of the electronic components is of great concern.

Flash memory is 16KB or 32KB that all depends on the Atmega board i.e Atmega168 comes with 16KB of flash memory while Atmega328 comes with a flash memory of 32KB. Flash memory is used for storing code. The 2KB of memory out of total flash memory is used for a bootloader . (Arduino Official Store)

Figure 3-5: Arduino Nano

3.3 Simulation

3.3.1 Proteus Professional 8.7 Simulation

In this section, a **Proteus Professional 8.7** is demonstrated to do many functions. Initially, the electronic board was designed using the software, as well as the connection of the board that was designed with Arduino, then the code was loaded on the Arduino to make a complete simulation of the circuit.

The final step was to design the printed circuit board using the software itself to reach the final shape of the circuit and print it.

Besides, in addition, Bluetooth Module has been added to the circuit design to allow wireless connectivity with an application running on the Android platform. (PCB Design and Circuit Simulator, 2023)

Figure 3-6 : Proteus Professional 8.7.

3.3.2 Arduino IDE

Developed in Java, the Arduino IDE is available for several operating systems. This includes Windows, macOS, and Linux. It's primarily meant for usage with Arduino-compatible boards, but may be used with other vendor development boards through 3rd-party cores.

The IDE's source code is available for download under version 2 of the GNU General Public License. The Arduino IDE is compatible with C and C++ and has its own set of standards for how code should be structured. The Wiring project's software library is included in the Arduino IDE, and it contains several frequently used input and output routines. The GNU toolchain, which is included with the IDE, compiles and links the user's code with a program stub called main (), turning it into a cyclic executive program that can be run. The software in question is used by the Arduino IDE to compile source code into a hexadecimal text file, which is then loaded into the Arduino board by a loader program in the firmware. (*Arduino Integrated Development Environment (IDE))*

Figure 3-7 : Arduino IDE.

3.3.3 The Android App

The Pulse Rate and Blood Oxygen concentration that is displayed on OLED Display can be transferred wirelessly to Android device using Android App over a Bluetooth Connection.

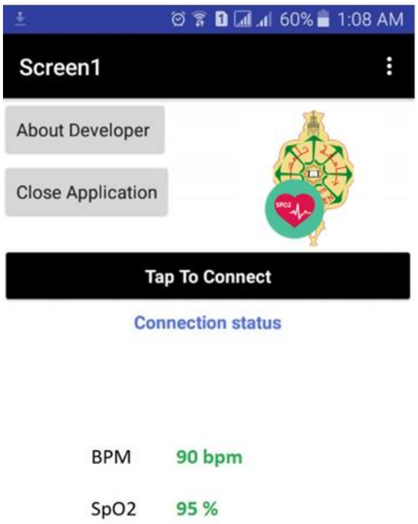


Figure 3-8 : The Android Application foe (PPO).

This App has been designed using **MIT App Inventor2**. The app can be installed on any Android device and can be connected to HC-05 Bluetooth Module.

3.4 Cost analysis

Cost is one of the important factors which considers the project optimality.

Table 3-1 : Shows cost in NIS for parts and quantities of materials.

ITEM NO.	PART Name	QTY.	Cost
1	resistor	1	-
2	LCD LM016L	1	1600 DA
3	Bluetooth Module	1	800 DA
4	Arduino UNO	1	1800 DA
5	Bread Board	1	-
6	Variable resistance	1	20 DA
7	PCB 1 Layer	-	450 DA
8	3D printing	80 g	350 DA
9	MAX 30102	1	1000 DA
Total Amount			6020 DA

3.5 Summary

This chapter discussed designing models, selecting Sensors, implementing simulation and analysing cost.

Chapter IV
Prototyping

Chapter IV: Prototyping

3.1 Prototyping

In the previous chapter designing and simulation processes are completely done after the equations are calculated and verified. Moreover, by starting manufacturing process and design building many things are going to be obvious, details will be revealed and the design will be manufactured and assembled. Also, challenges and problems are demonstrated, implementation process, calibration and testing procedures are displayed.

3.2 Components collection

This section will introduce all the components that used in the project. This component will help to assemble the design after manufacturing process, so every part has its function in the Portable Pulse Oximeter.

3.2.1 Electronic Components

1- **Arduino Nano:** this type is used due to its flexibility and availability which considered simple and cover the project requirements.

Microcontroller	Atmega328p/Atmega 168
Operating Voltage	5V
Input Voltage	7 – 12 V
Digital I/O Pins	14
PWM	6 out of 14 digital pins
Max. Current Rating	40mA
USB	Mini
Analog Pins	8
Flash Memory	16KB or 32KB
SRAM	1KB or 2KB
Crystal Oscillator	16 MHz
EEPROM	512bytes or 1KB
USART	Yes

Arduino Nano Specifications

www.TheEngineeringProjects.com

Figure 4-1 : Arduino Uno.

2- **HC-05 Bluetooth Module:** HC-05 Bluetooth Module is an easy-to-use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Its communication is via serial communication which makes an easy way to interface with controller or PC. HC-05 Bluetooth module provides switching mode between master and slave mode which means it able to use neither receiving nor transmitting data.

Specification:

- Model: HC-05
- Input Voltage: DC 5V
- Communication Method: Serial Communication
- Master and slave mode can be switched

Bluetooth Module Pin Definition

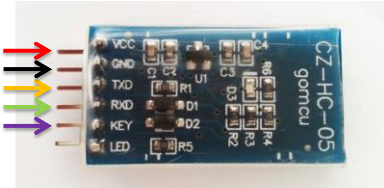


Figure 4-2 : Bluetooth Module.

3.2.2 Collection:

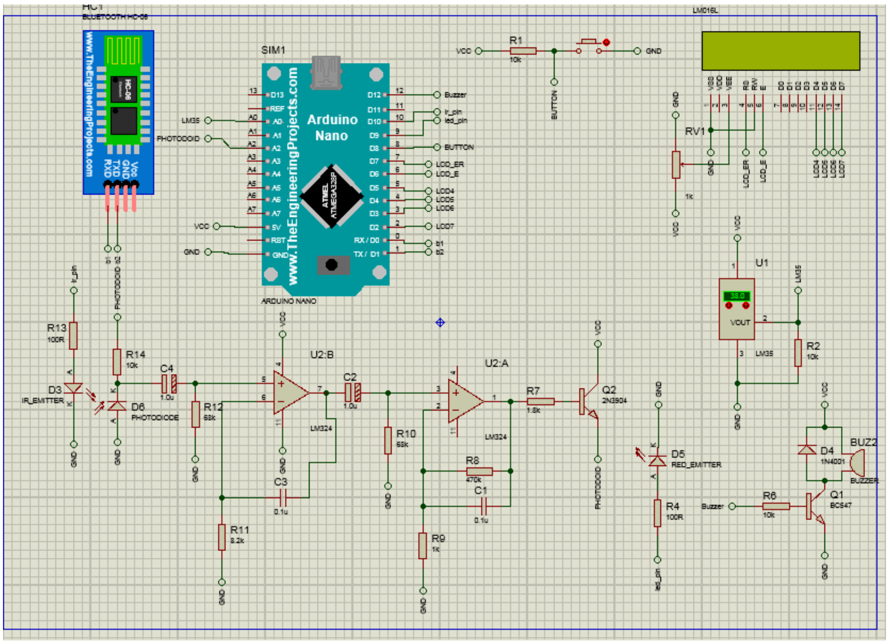


Figure 4-3 : Proutes simulation.

Here we have assembled the circuit components together in parallel using the Proutes Program. From this stage, the transition from simulation to the practical application of the system is made, and due to the complexity of the previous circuit, most of the components of the previous circuit have been dispensed with an electronic cat called (MAX30100).

The Circuit in Figure 4-3 is based on the absorption principle, where the infrared emitting diode (IR) corresponds to the receiver (Photodiode), unlike (MAX30100) which relies on the reflection principle where (IR) and (Photodiode) are all straight.

3.3 Manufacturing and Assembly

In this section, manufacturing and assembly processes are completed.

3.3.1 Manufacturing

After completing the final design of the circuit using **Proteus**, we collect the component with kiteboard, then we testing it in next section.

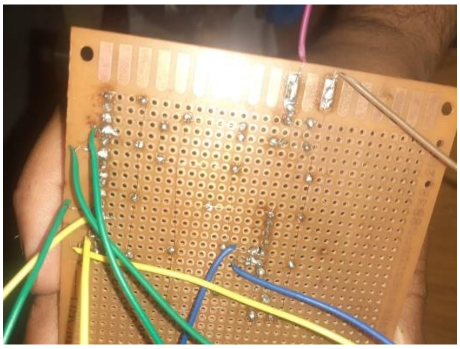


Figure 4-4 : PCB Collection.

Here we have assembled the components of the circuit together on the printed circuit board using soldering iron, tin and insulated wires to assemble the components of the circuit according to the design prepared for the circuit and tested using simulation

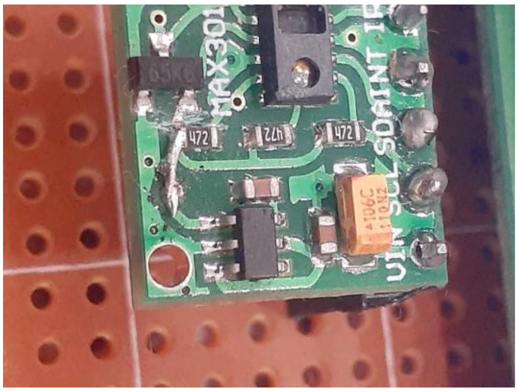


Figure 4-5 : Component Collection.

In this Stage we collect and connect component to the PCB Board.

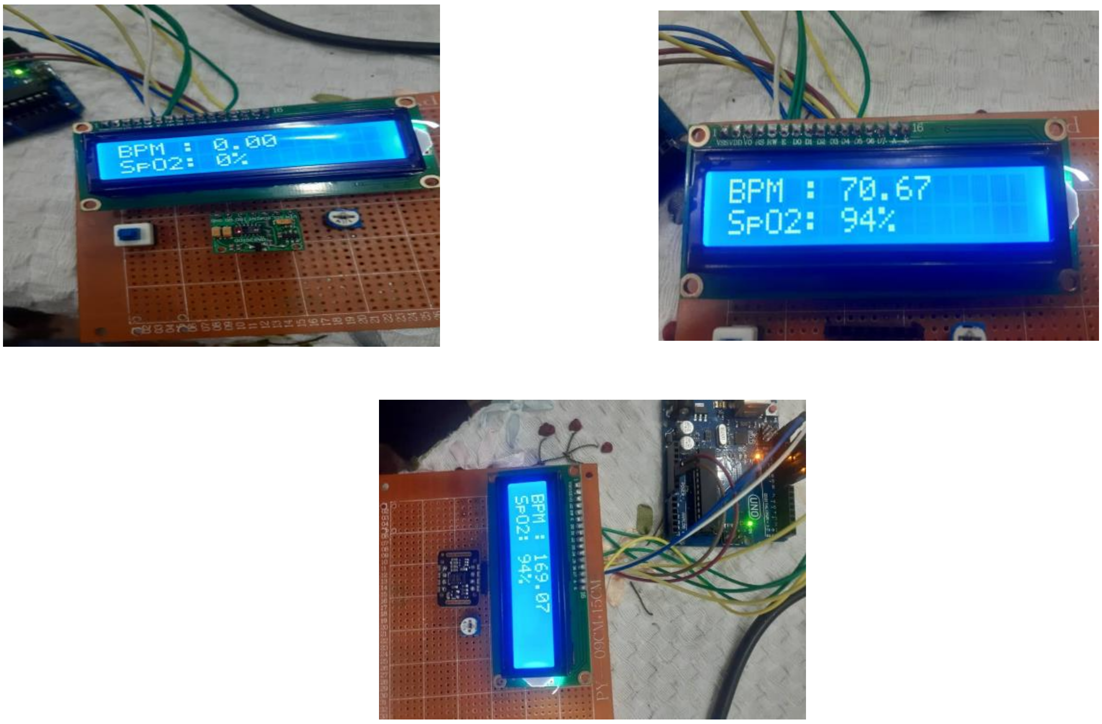


Figure 4-6 : Testing Stage.

In this Stage we Upload the code to the Arduino, then we turn off the System and testing it.

3.3.2 Testing

In this sub section, we test our Final Design and its results.

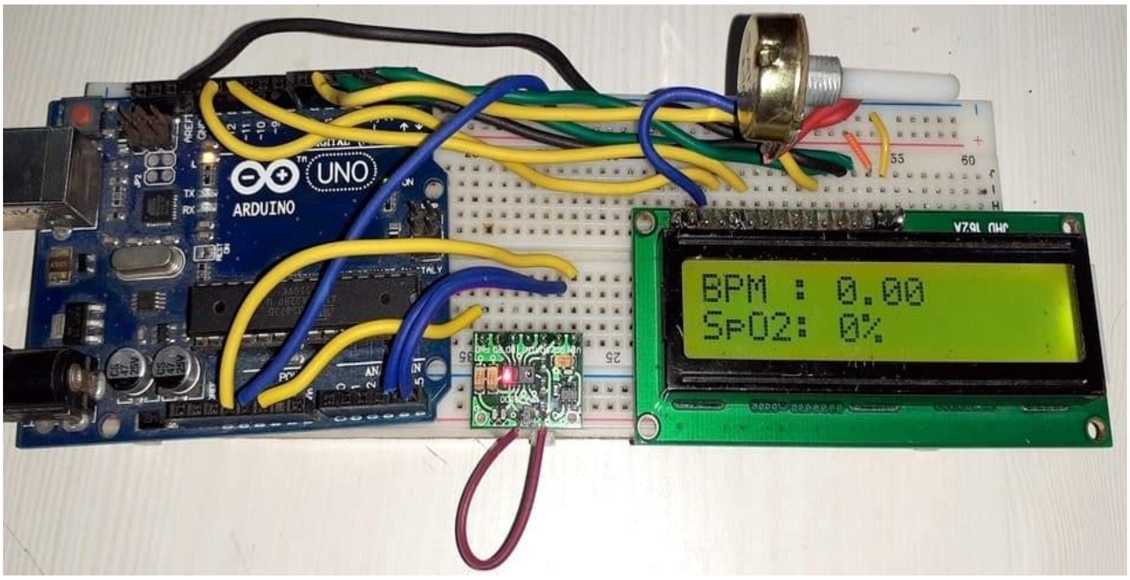


Figure 4-7 : Testing Device (PPO).

3.4 Summary

In this chapter, components are shown after collecting them; then, manufacturing and assembly of all parts are done sequentially. Both challenges and problem are mentioned. Implementation of Portable Pulse Oximeter is made accompanied with calibration, validation and testing.

Chapter V
Conclusion and Future Work

4 Chapter V: Conclusion and Future Work

5.1 Conclusion

In this project, many things were completed starting by simple explanation of the problem that will be solved. Moreover, the objectives of the whole project were demonstrated with requirements and well thought time plan.

On the other hand, the searching step is implemented to get familiar with palletizing (PPO) and to bring the proper way to apply this project as prototype, trying to gather the best solutions to deal with the problem by divided it into sub problems. As known, a brief history is presented to get a little sense about the idea; also, pros and cons of SPO2 Sensors are shown.

Besides, to deep the knowledge, an application of (PPO) are demonstrated. After that, equations are solved and verified mathematically.

Modeling and simulation part are done by using software programs. Such as, Proteus Professional 8.7, Arduino IDE. Those programs helped us to bring the design to reality and make it more obvious when the equations are applied and the design controlled. Besides, a simulation.

Subsequently designing process is done, our prototype is manufactured piece by piece with take into consideration the accuracy needed for each part. Required components are collected to start the assembly process. Among that, Sensors are chosen with a proper driver to control them.

5.2 Future Work

There are many (PPO) and methods can be used and applied in this pulse oximeter with some Improvements on the project. Such as:

- **Applications:**

  Using Android and database server to save data.

- **Control methods:**

  We can use a wi-fi module to transmit data via network.

Appendix A: Final Circuit and Arduino Code:

The Full Final Graduation Project is in Google Drive Link Below:
https://drive.google.com/drive/folders/1NGnnZewv12abaNMNgfnFgAuZw3lFj3KD?usp=share_link

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