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Review article about ELECTROCARDIOGRAM (ECG)

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Annotation: The electrocardiogram (ECG) is a crucial medical device for monitoring heart activity and detecting cardiovascular abnormalities. Despite advancements, traditional ECG devices often rely on non-rechargeable batteries, limiting their efficiency and long-term use. This study addresses the knowledge gap by integrating a rechargeable lithium battery and wireless Bluetooth technology into an ECG system for improved portability and real-time data transmission. A prototype was developed using Arduino, heart rate, temperature, and SpO2 sensors, enabling efficient monitoring. The findings indicate that the modified ECG device provides accurate heart rate and oxygen saturation readings while enhancing accessibility and ease of use. The results suggest that such innovations can improve remote patient monitoring, particularly in home-care settings. Future work includes optimizing energy consumption through solar power integration.

Keywords: Electrocardiogram, ECG monitoring, cardiac health, wireless ECG, biomedical engineering, heart rate, oxygen saturation, portable medical devices.

1.1. Introduction

A preliminary examination of attempts to record the electrical activity of the muscle was made by a number of scientists, starting in 1666 by (Franciscoridi), and in 1792 a report was presented and published by the Italian scientist (Luigi Galvani) who applied a preliminary recording of the muscle contraction until the year 1849 The scientist (Dobius and Raymond) showed the process of recording the activity of the voluntarily contracting muscle. Morey was also able to record the electrical activity of the working muscle. In 1922, the two scientists (Gasser, Ireland) used a screen to display the electrical signals that arise as a result of muscle contraction, then the methods of recording these electrical signals developed rapidly and on a large scale between the years 1930-1950. After developments in the electrocardiogram, Hardik and his assistants used the electrocardiogram in its current form in 1966. These devices are smaller in size, lighter in weight, and have other accessories such as electrical signal amplifiers, filters, and plotters [1].

And the first ECG device appeared in 1903 AD, which was invented by the scientist Einthoven, and it was called heart painter. After development and permanent improvements to this device, it became small, easy to use, and accurate in showing the result. We can define the heart as pumping blood within the circulatory system, and its work is similar to a pump, and it is the main organ in the cardiovascular system or what is known as the circulatory system. The heart is exposed to many diseases such as heart failure, open ductus arteriosus, angina pectoris, and arrhythmia. The electrocardiogram is an important medical device that gives a preliminary diagnosis of the work of the heart muscle and the heart's electrocardiogram [2]. The graph can show abnormalities, such as blocked arteries, and changes in the way electrical currents pass through heart tissue. Also called an EKG and electrocardiogram. It is a recording of these changes in electrical potential but from areas far away from the heart due to the human body's property of being a good conductor. Electrocardiogram is useful for diagnosing heart diseases, and it also helps us diagnose angina pectoris, heart attacks, and enlarged heart muscle [1].

1.2. Cases of using the electrocardiogram:[4]

1. Feeling of pain and tightness in the chest
2. Random, irregular heartbeat.
3. Feeling of tightness and difficulty in breathing.
4. Constant feeling of fatigue, exhaustion, and inability to move.
5. The issuance of abnormal heartbeats or beats.
6. Diagnosis of some diseases that affect the heart.
7. Follow-up of the heart while taking some types of medications.

1.3 The effect of the magnetic field on the heart:

The magnetic field has a great effect on the heart, as the heartbeat can be controlled by an electrical impulse by the instantaneous stimulation of a muscle cell located in the right atrium of the heart. It has become a routine daily business to test heart function with an ECG. Recent studies indicate that the application of magnetic fields to the heart leads to the emergence of new properties in the graph of the oscilloscope. New and important results have been reached in this field, as well as the presence of small holes placed in the regular magnetic field of different magnetic intensities. The first noticeable thing was that the T wave became blurred as a result of the instantaneous wave generated by the blood flow in the aorta. Also, the S wave changes to another one, while the direction of the T wave did not change, while the P wave showed a change in intensity and time as a result of the process of inhalation and exhalation. Recent research has indicated that prolonged exposure to strong magnetic fields is harmful to the heart [3].

1.4 Electrocardiogram components:

Electrocardiographs all share the same principle, but differ slightly in terms of components. The device generally consists of the following parts:

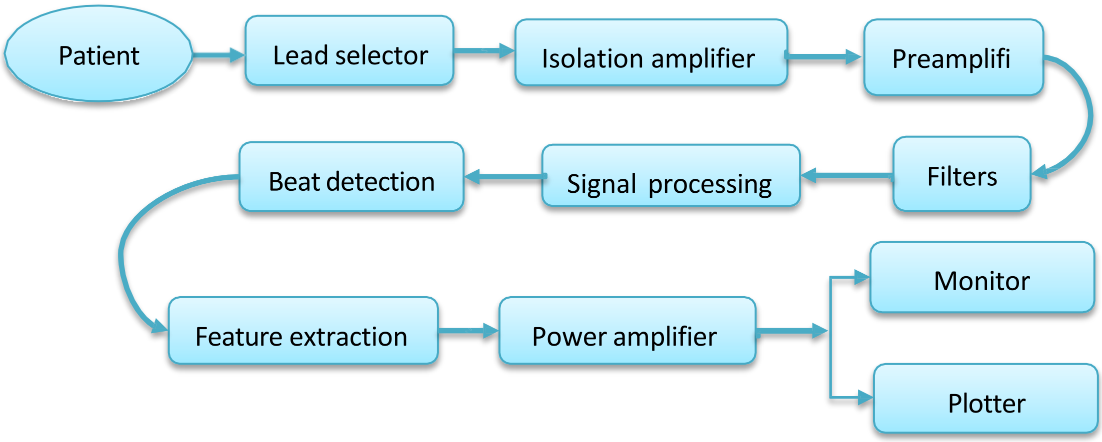


Fig. 1.1 : Block diagram of Electrocardiogram components[2]

1. **The battery and the transformer:** The battery is rechargeable and is connected directly to a low-voltage transformer to convert the voltage from AC to DC, where the entry voltage is 220 volts AC and after passing through the transformer it turns to 12 volts DC [2].
2. **The isolation amplifier:** It protects the patient from the flow of current 220/120 volts AC to the patient's body and blocks it. The circuit must contain this insulator to protect the patient and prevent high currents from reaching the patient's body [2].
3. **The diferential amplifier:** It is also known as the vital amplifier because it works to amplify the vital signals coming from the heart [5].
4. **Operational amplifier:** It also works to amplify the vital signal by measuring the difference between the incoming and outgoing signal [2].
5. **Filters:** Since the electrical signals coming from the heart of the device are weak and of low frequency, these signals are greatly affected by noise as a result of the movement of muscles and electrodes and the patient's breathing, so it is necessary to have filters to filter the signal from the interference. One of these types of filters is the frequency filter Low, high-frequency filter [5].
6. **Wire and Electrode:** It contains at least two electrodes and an initial amplification circuit for each one because the function of the device is to show a difference of the cardiac signal between two points of the body. (Electrode) It is the part that is in contact with the body and is divided into two types:

a) **Thoracic electrode:** (consists of two main parts: the contact surface, which is a metal surface with a high conductivity, to which one end is attached to connect the wire, and the other part is the rubber absorbent, which is often blue in color, and its function is to empty the air from the electrode before placing it on the surface of the body, in order to better contact with the body and often paint the skin with a fluid that increases its conductivity to preserve as much as possible the shape of the taken wave).

b) **The other type is the terminal electrode:** which comes with two tweezers and colored each color according to the tip on which it will be placed. In full planning, 6 electrodes are placed on the chest and 4 electrodes on the limbs, all of which take a signal except for the lower right limb electrode, which doctors consider the reference point. (Wires)The electrode wires are connected to the device. These wires are made of fine and shielded copper, so that the quoted signal is not affected by electrical noise waves [2].

7. **Signal processing:** ECG signal processing consists of, de-noising, Error correction, to extract useful information and arrhythmia detection. And ECG waveform consists of five basic waves P, Q, R, S, and T waves and sometimes U waves [5].
8. **Moniter:** When the doctor dispenses with paper or does not need it, to obtain a continuous reading of the heart [5].
9. **Earthed:** used as usual to leak excess charges, and to protect against electric shocks [2].

2.1.Working principle of the electrocadiogram:

Wires pass from the ECG machine to the electrodes, which are metal strips that conduct electricity. It works on the principle that the contracting muscle generates a small electrical current that can be detected and measured through these electrodes. Electrodes are placed on each arm and leg and at six points on the chest and above the heart. These electrodes pick up the currents produced by the heart at each heartbeat, and transmit them to an amplifier inside the electrocardiogram. The amplifying currents then flow through a coil of very thin wire suspended inside a magnetic field, and the wire moves due to the interaction of these currents with the magnetic field. The sensor records the movement of the wire on wavy graph paper, which produces an electrocardiogram in the form of images. Each heartbeat produces a series of wavelengths [6].

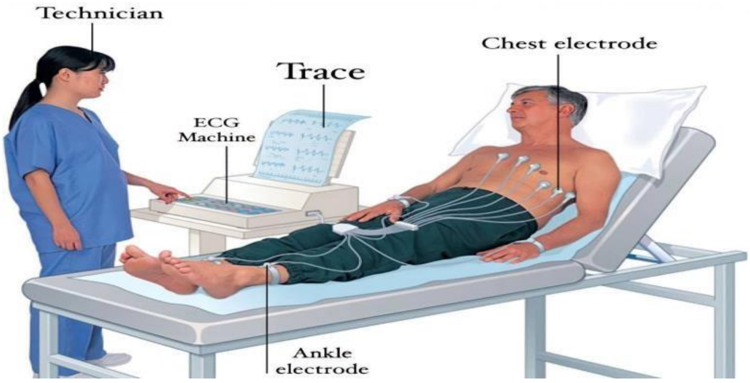


Fig 1.2 Electrocardiogram examination [6].

2.2 ECG interpretation:

Each electrode connected to the body is considered a camera, and we put 10 electrodes on the human body, one on each arm and each leg, and six electrodes on the chest, and thus we get 10 cameras (electrodes) from different directions , each camera produces a different image for us than the other camera, because each one captures a view of the heart From a different angle but the same view [8].

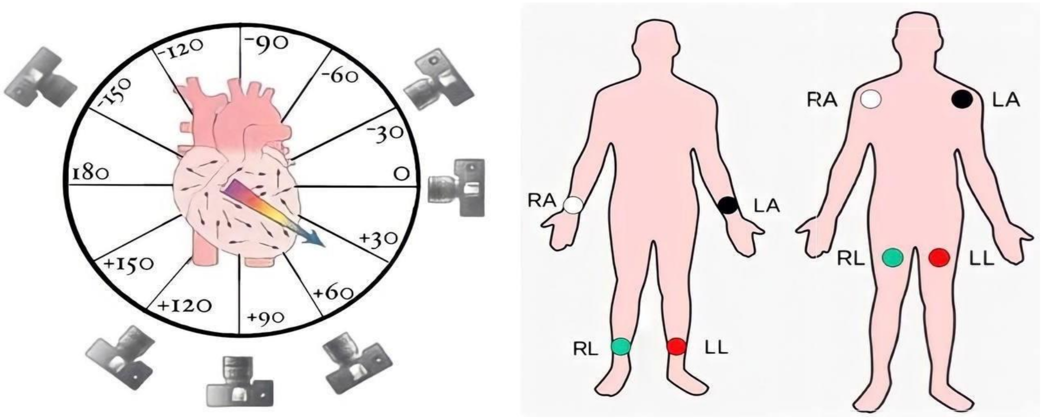


Fig 2.2 cardiac axis viewed by different leads and connect the electrodes [8].

2.3 The ECG produces 12 readings , which are: [9]

The six electrodes (cameras) on the chest produce 6 different readings V1 , V2 , V3 , V4 , V5 , V6.

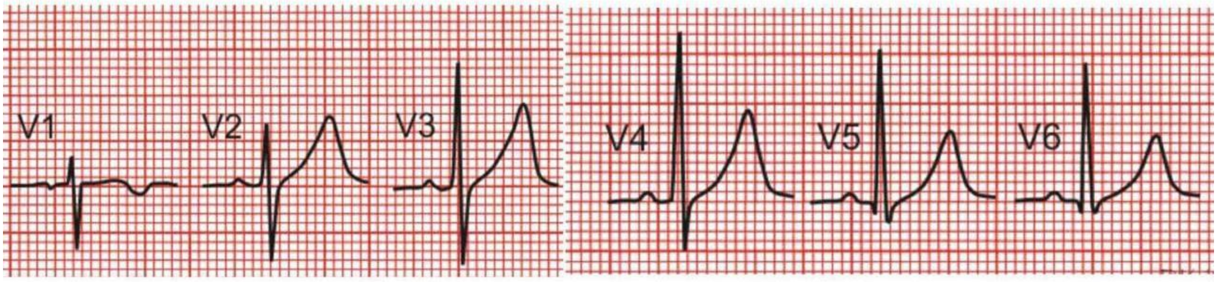


Fig 3.2 Electrodes on the chest [9].

1. **The locations of the electrodes on the chest are as follows :**

- V1: in the intercostal space on the right .
- V2: in the intercostal space on the left .
- V3: in the distance between V3 & V4
- V4: at the apex of the heart (peak) .
- V5: at the same level as the apex of the heart at the anterior axillary line .
- V6: at the same level as the apex of the heart at the mid-axillary line.

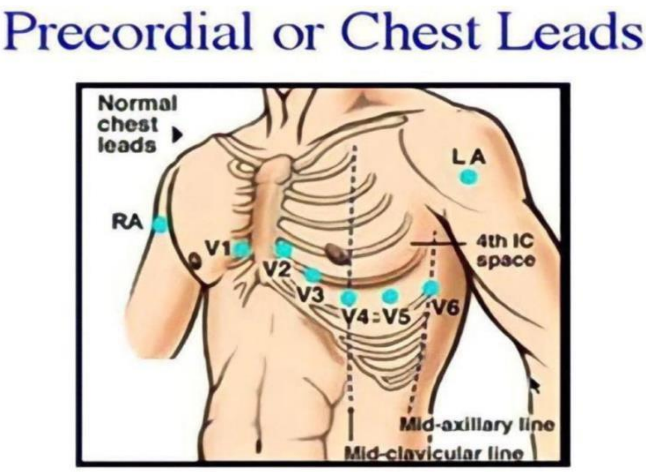


Fig 4.2 The locations of the electrodes on the chest [9].

2. As for the electrodes on the ends, each one produces a reading for us, except for the one at the right foot, which is only for the ground connection, for example: (At the right hand it is called AVR, Which at the left foot AVF, Which at left hand AVL).

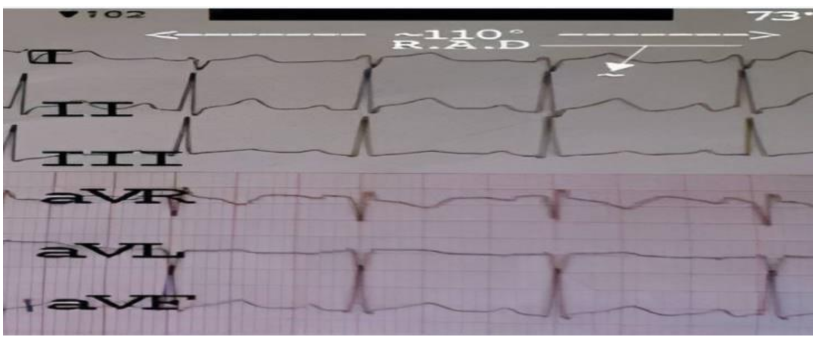


Fig 5.2 the electrodes on the ends [9].

3. As for the remaining three readings, they are the combination of each two readings resulting from the electrodes at the ends. for example: the merging of the reading from the pole at the right hand with the one at the left hand produces a reading called (lead l), and also the reading from the right hand with the left foot is called (lead ll), and also the reading from the left hand with the left foot (lead lll). Since these readings are a combination of more than one reading , they are therefore augmented. In order for the resulting reading to be equal, the device amplifies the other readings issued by the terminals (AVR , AVL , AVF). Where the letter (V) means the word (Vector), which means the electrode is destined for it , while the letter (A) means the word (Augmented), which means an amplifier. The readings are in the following order: (Lead l , Lead ll , Lead lll , AVR , AVL , AVF , V1 , V2 , V3 , V4 , V5 , V6).

2.4 Recording of ECG waves: [10]

In each cardiac cycle, a series of waves are observed in the electrocardiogram as shown in figure below einthoven names these waves P , Q , R , S and T waves:

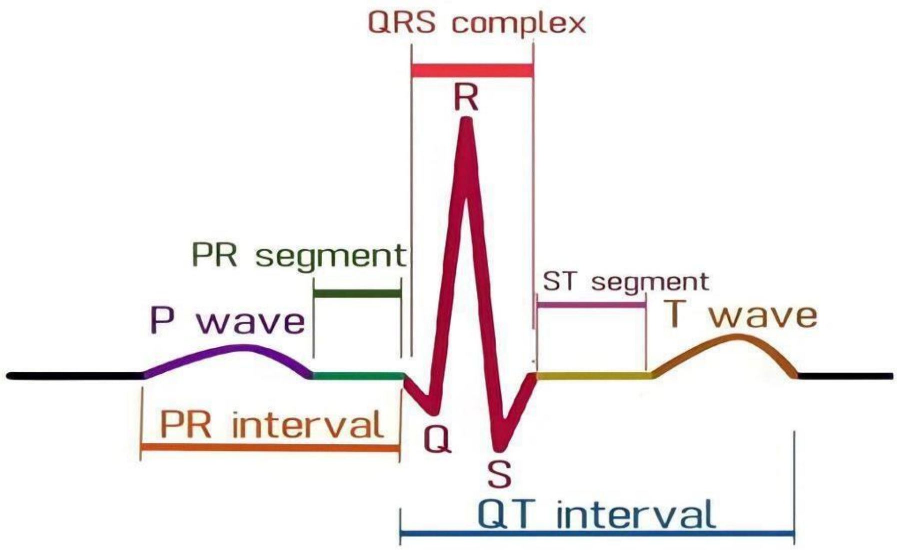


Fig 6.2 Electrocardiogram waves [10].

1. **P wave:** It is known that the muscles of the atria are very small compared to the muscles of the ventricles, so the electrical current accompanying the contraction of the atria will be very small and is symbolized by the electrocardiogram (P wave).
2. **R-wave:** It is the first upright wave after the P wave .
3. **Q-wave:** It is the negative wave that precedes the R wave .
4. **S-wave:** It is the negative wave that follows the R wave.
5. **QRS wave:** The QRS wave is always taken as single unit. It denotes ventricular activity. It is the polarization wave of the ventricle. It is most prominent wave in the whole cardiac cycle. As the electrode is moved from the right ventricle to the left ventricle the R wave increases in size and the S wave diminishes in size. And the systole of the ventricles stands for (QRS Complex).
6. **T wave:** Then it symbolizes the diastasis of the ventricles (T Wave).

Since the cardiac cycle begins with the contraction of the atria, then their diastole, then the systole of the ventricles, then their diastole, and all of this is recorded as waves in the ECG paper. According to the QRS complex, the first bend down the straight line is called Q Wave, the next bend is called R Wave, and then another bend is called S Wave. The picture above shows the normal ECG, but if there is any change in the shape of the waves, this reveals a problem that may be in the heart rate or as a result of an artery blockage or something else. With regard to the direction of the electric current in the heart, if the direction of the current is in the same direction as the electrode, then the wave will be bent downward (negative) on the ECG paper and vice versa. It has nothing to do with the direction of the poles, so the wave bends in any form.

If the direction of the electric current in the heart is in the same direction as the electrode (camera) directed, then the result will be a negative (downward) curvature on the ECG paper, and vice versa if the direction of the current is opposite the direction of the electrode, then the result will be a positive (upward) curvature on the ECG paper, and if the direction of the current had nothing to do with the direction of the pole, the signal (bending) would have any form [8].

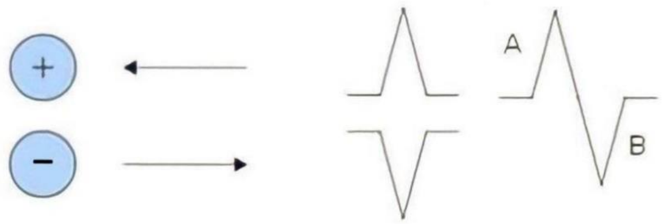


Fig 7.2 direction of electric current [8].

2.5 Signal amplification stage:

The signal amplification process starts after the signal is picked up from patient's heart. In the second stage, the signal will enter the amplifier (neutral or isolation amplifier) and through the electrodes (LL , LA , RA) represented by the triangle and chest points. The external signal from the three-pin amplifier is combined to compare with the ground voltage, usually the right leg (RL), and it is called the patient's voltage to eliminate interference to the plotting wave. These resistors, which are in the way of the incoming signal, are for the purpose of balancing the amplifier [13].

2.6 Anaiysis of the results: [12]

The results of the examination can be explained as follows :

1. **Correct result:** The waveform is normal.
2. **Incorrect result:** The ECG appears abnormal , as it may indicate the following:

- **Arrhythmia:** This is a condition in which the heart is too slow or too fast or shows any irregular pattern.
- **Coronary heart disease:** This occurs when the blood supply to the heart is blocked or cut off due to the accumulation of fatty substances.
- **Cardiomyopathy:** Cardiomyopathy is a condition in which the walls of the heart thicken or swell.
- **Heart Attacks:** When the blood supply to the heart is suddenly cut off , a heart attack occurs .

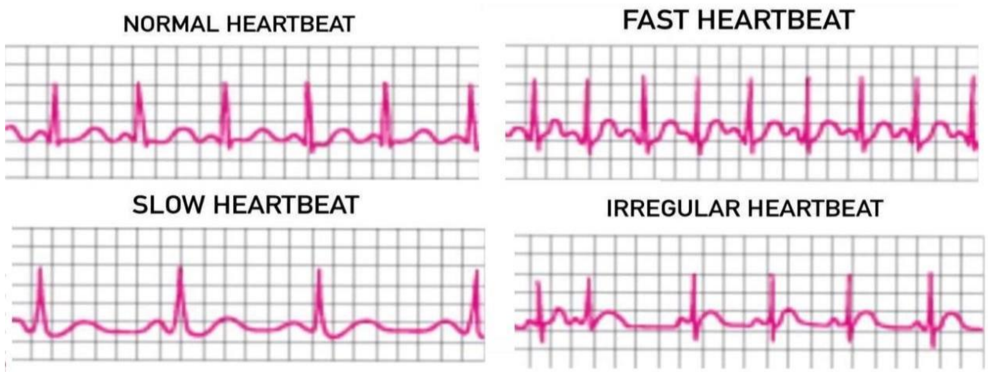


Fig 8.2 Various Heart beats [12].

2.7 Types of ECG:

Today, doctors use different types of ECG machines to provide detailed information about a patient's cardiovascular health, types of ECG include :

1. Resting ECG :

It is the measurement of the electrical activity of the heart while relaxing in a supine or semi-recumbent position so patients are simply asked to lie down or sit for the duration of the test - which takes about 5 to 10 minutes. The electrical activity of your heart is recorded from 12 electrodes on your chest, arms and legs at the same time. This is the most common type of ECG and is also one of the easiest types of ECG to perform . Because you are asked to remain still during the resting period of the ECG, the results it will record usually reflect your resting heart - hence its name [14].

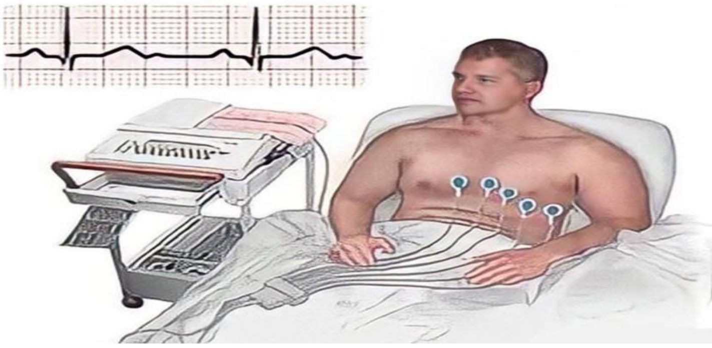


Fig 9.2 Resting ECG Test [14].

It provides information about heart rate and rhythm, and can also show if there is an enlarged heart, or evidence of a previous heart attack. However, it does not show if you have asymptomatic blockages in your coronary (heart) arteries, or predict your risk of having a heart attack in the future. The resting EKG differs from other types [14].

2. Exercise ECG :

An exercise ECG, also known as a treadmill test or stress test is an EKG that monitors the heart's capabilities and activity under conditions that require physical exertion, such as exercise. Typically, this test is performed in controlled settings with the patient connected to an ECG machine. Where the patient is asked to walk on a treadmill or to ride a stationary bike. For about 10 to 20 minutes, gradually increase exercise intensity while monitoring your breathing rate and blood pressure [14].

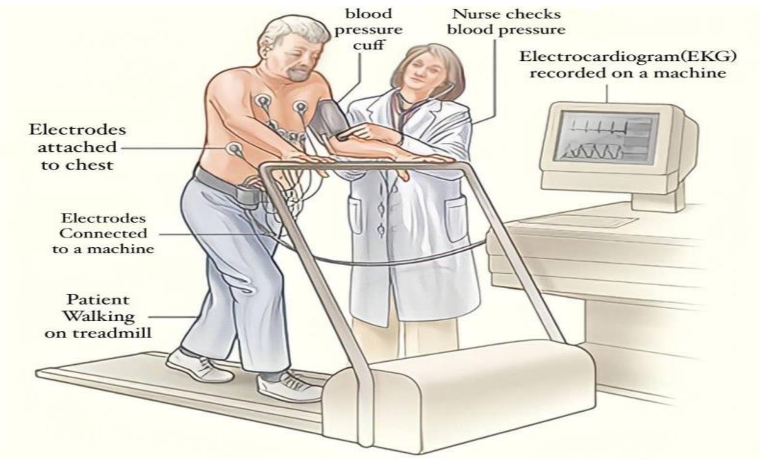


Fig 10.2 Exercise Stress Test [14].

This type of ECG is usually performed on people who have exercise symptoms, are being evaluated for surgery or angioplasty, or those who are at risk for a heart attack or coronary artery disease. In order for this test to provide a clear and unbiased result, Patients may be asked to fast and stop certain medications beforehand. This allows the ECG to record the heart without any external factors that might impair or improve its basic functioning [14].

3. Holter moniter :

Holter ECG OR mobile ECG is a type of ECG used to monitor, measure, and print an ECG continuously for 24 hours or more for future reference to a doctor . Small plastic patches or electrodes are placed on specific areas. Worn on the waist to monitor the heart at home for a day or longer An electrocardiogram (ECG) for stress or exercise is usually suggested if symptoms are caused by physical activity. In contrast, an ambulatory ECG is performed if symptoms are unexpected [7][14].

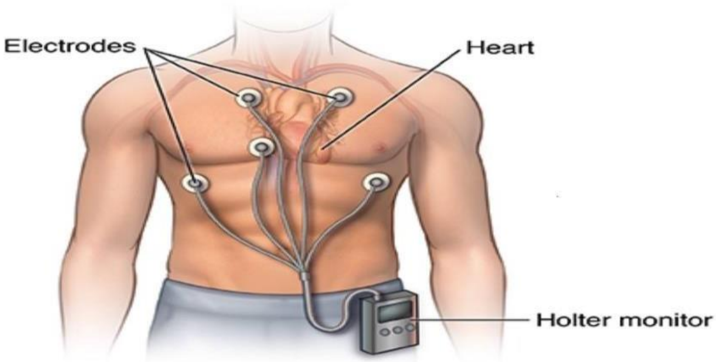


Fig 11.2 Holter Monitor [7].

4. Cardiac event recorder :

records an ECG over a longer period of time up to a year or more, records the electrical activity of the heart when symptoms appear, is implanted under the skin in the chest , and records the electrical activity of the heart continuously [14].

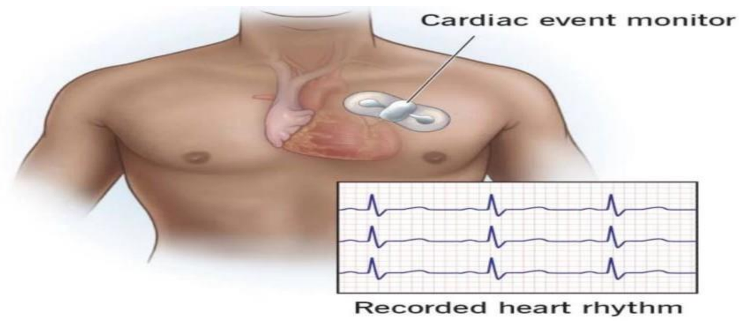


Fig 12.2 Cardiac event recorder [14].

3.1 Introduction

Heart disease has become a major health killer disease for many years, and World Health Organization research has shown that most people die of heart disease. Therefore, this disease cannot be taken lightly. Thus, most healthcare equipment and monitoring system are designed to track disease. We also know that by analyzing or monitoring the ECG signal in the initial stage, this disease can be prevented. The electrocardiogram (ECG) is one of the most important non-invasive tools for monitoring and diagnosing heart-related diseases. An EKG provides insight into the electrical activity generated in the heart muscle. ECG machines allow easy and quick ECG monitoring for patients with symptoms of heart problems. There are many different ECG devices categorized based on features and intended use, but in general, ECG devices can be divided into two types. The first, used in hospitals, is very large and with a high resolution for detecting problems such as congenital cardiovascular problems [15].

The second type is smaller and can be used to monitor the patient individually. This type is suitable for the elderly. Choosing the device with suitable working mode, good signal quality, and cost of suitable equipment are still the main obstacles for these devices. To achieve efficient and operable features, individual patient monitors must adhere to several specific requirements: reduced size, mobility, and minimal power consumption. Portable ECG machines usually run on batteries. Due to the small size requirements, the batteries used in ECG machines often have a limited capacity and therefore must be replaced periodically. So, we put a battery charger to reduce the cost for the portable ECG device that charges at different times in order to keep it working for a longer time. And in all ECG devices, the results are displayed either on the screen of the device or on the computer, but in our device, this was dispensed with by placing a Bluetooth chip, and the results became visible via the mobile phone. In this chapter, we describe the hardware and software designs of our ECG model and provide images of the signals after testing [16]. The block diagram of the device is shown in Fig. 3.1.

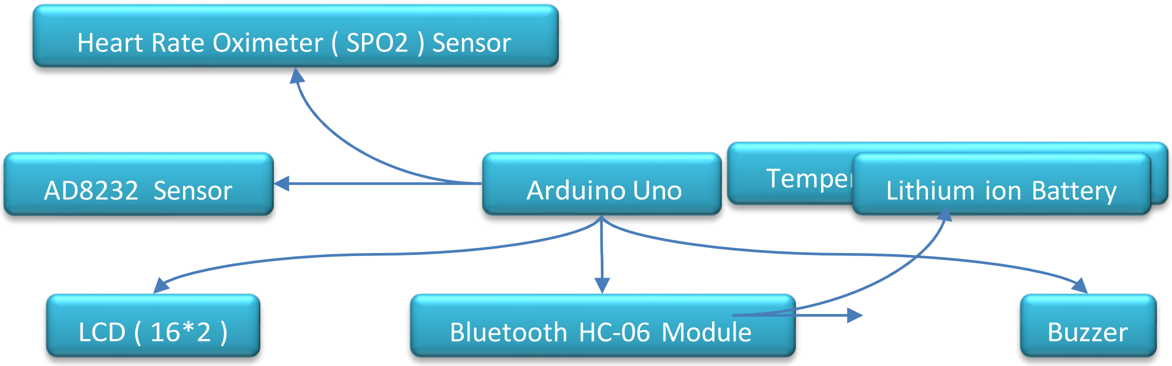


fig. 1.3: The block diagram of the device

3.2 Device components:

1. Arduino:

Arduino is an open source programmable circuit board that can be integrated into a wide variety of makerspace projects both simple and complex. This board contains a microcontroller which is able to be programmed to sense and control objects in the physical world. By responding to sensors and inputs, the Arduino is able to interact with a large array of outputs such as LEDs, motors and displays. Because of it's flexibility and low cost, Arduino has become a very popular choice for makers and makerspaces looking to create interactive hardware projects. Arduino was introduced back in 2005 in Italy by Massimo Banzi as a way for non- engineers to have access to a low cost, simple tool for creating hardware projects. Since the board is open-source, it is released under a Creative Commons license which allows anyone to produce their own board.

Arduino Uno: One of the most popular Arduino boards out there is the Arduino Uno. While it was not actually the first board to be released, it remains to be the most actively used and most widely documented on the market. Because of its extreme popularity. The Uno is a huge option for initial Arduino. This Arduino board depends on an ATmega328P based microcontroller. As compared with other types of arduino boards, it is very simple to use like the Arduino Mega type board. It consists of 14-digital I/O pins, where 6-pins can be used as PWM(pulse width modulation outputs), 6-analog inputs, a reset button, a power jack, a USB connection, an In-Circuit Serial Programming header (ICSP), etc. It includes everything required to hold up the microcontroller; simply attach it to a PC with the help of a USB cable and give the supply to get started with an AC-to-DC adapter or battery [17].

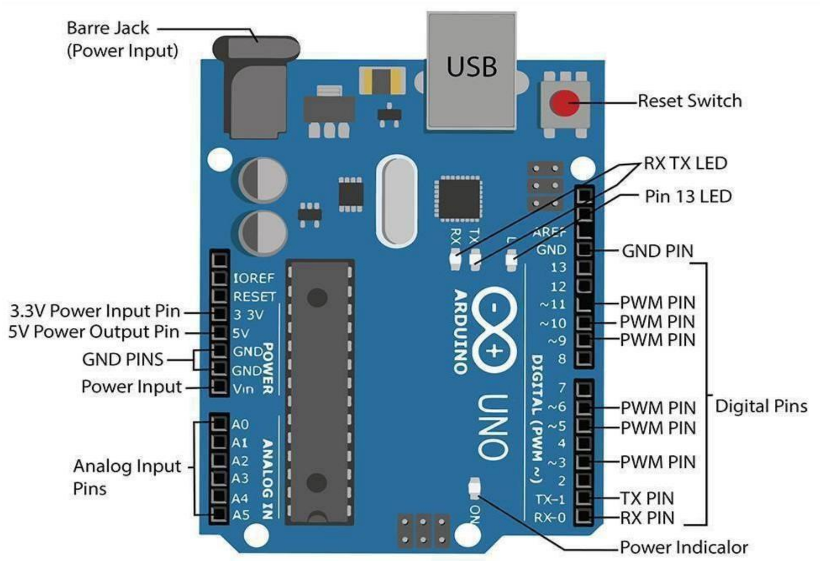


Fig. 2.3: Arduino Uno [17].

2. ECG Sensor:

This sensor is a cost-effective board used to measure the electrical activity of the heart. It is an integrated signal conditioning block for ECG and other bio- potential measurement applications. It is designed to extract, amplify, and filter small bio- potential signals in the presence of noisy conditions, such as those created by motion or remote electrode placement. This design allows for an ultralow power analog-to-digital converter (ADC) or an embedded microcontroller to acquire the output signal easily.The AD8232 can implement a two-pole high-pass filter for eliminating motion artifacts and the electrode half-cell potential. This filter is tightly coupled with the instrumentation architec-ture of the amplifier to allow both large gain and high-pass filtering in a single stage, thereby saving space and cost. An uncommitted operational amplifier enables the AD8232 to create a three- pole low-pass filter to remove additional noise. The user can select the frequency cutoff of all filters to suit different types of applications. To improve common-mode rejection of the line frequencies in the system and other undesired interferences, the AD8232 includes an amplifier for driven lead applications, such as right leg drive (RLD).The AD8232 includes a fast restore function that reduces the duration of otherwise long settling tails of the high-pass filters. After an abrupt signal change that rails the amplifier (such as a leads off condition), the AD8232 automatically adjusts to a higher filter cutoff. This feature allows the AD8232 to recover quickly, and therefore, to take valid measurements soon after connecting the electrodes to the subject [17].

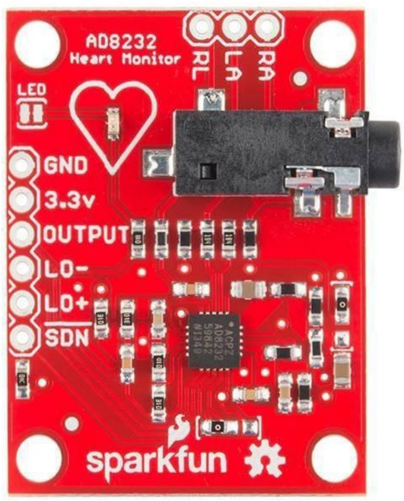


Fig. 3.3: ECG sensor [17].

3. Buzzer:

An buzzer is also called a piezo buzzer.In simplest terms, a piezo buzzer is a type of electronic device that's used to produce a tone, alarm or sound. It's lightweight with a simple construction, and it's typically a low-cost product. Yet at the same time, depending on the piezo ceramic buzzer specifications, it's also reliable and can be constructed in a wide range of sizes that work across varying frequencies to produce different sound outputs. The buzzer produces the same noisy sound irrespective of the voltage variation applied to it. It consists of piezo crystals between two conductors. When a potential is applied across these crystals, they push on one conductor and pull on the other. This, push and pull action, results in a sound wave. Most buzzers produce sound in the range of 2 to 4 kHz [18].

Fig. 4.3: buzzer [18].

4. Heart Rate and Oximeter (SPO2) Sensor:

is a way to measure how much oxygen your blood is carrying. By using a small device called a pulse oximeter, your blood oxygen level can be checked without needing to be stuck with a needle. The blood oxygen level measured with an oximeter is called your oxygen saturation level (abbreviated O2sat or SaO2). This is a percentage of how much oxygen your blood is carrying compared to the maximum it is capable of carrying. Normally, more than 89% of your red blood should be carrying oxygen. A pulse oximeter comes either as a small unit with a built in finger/toe clip, or a small hand held device that has a wire probe that can attach or be applied to your finger, toe or earlobe. The small unit is less expensive and more practical for home use.Beams of light from the device pass through the blood in your finger (earlobe or toe) to measure your oxygen. You will not feel this happen. The beams of light are “read” to calculate the percentage of your blood that is carrying oxygen. It also provides a reading of your heart rate (pulse).

To make sure the oximeter is giving you a good reading, count your pulse for one minute and compare the number you get to the pulse number on the oximeter. If they are the same, you are getting a good signal [18].

Fig. 5.3: Heart Rate and Oximeter (SPO2) Sensor [18].

5. Temperature sensor(Digital):

Intelligent temperature sensor, produced by DALLAS Semiconductor, belongs to a new generation of adaptive intelligent temperature sensor, and can directly convert temperature signal into serial digital signal. It is water resistant, great for measuring distant objects or in wet conditions. The sensor is good up to 125°C, and its accuracy is (±0.5°C), giving up to 12 bits of digital-to-analog conversion accuracy. And our temperature sensors are widely used in air conditioners, grills, refrigerators, ovens, aquariums and so on [17].

Fig. 6.3: Temperature Sensor(Digital) [17].

6. The HC-06 bluetooth module:

is a bluetooth module designed for wireless communication. It is a slave unit which means that it can receive the serial data when the serial data is sent from a master Bluetooth device (a device capable of sending serial data over the air: smartphones, PC).When the unit receives wireless data, it is sent through the exact serial interface when you receive it. No source code for the Bluetooth module is ever needed in the Arduino chip. An app on the phone is used to send the input to the module which receives this and then transmits it to the arduino. The arduino and the motors in turn respond accordingly, as specified in the source code. When the unit is not in pairing, the LED on the unit blinks quickly while when paired with the app on the phone, the LED on the unit is solid red.

The HC-06 module has four pins which are all required in order to make a connection with the arduino UNO. The VCC pin is where the module receives its input voltage and is thus connected to the 5V pin on the arduino. The GND on the module is the ground pin which connects to the ground pin on the arduino. In other words, it is the reference point from where all the other voltages are measured. The RXD and TXD are the recieve and the transfer pins respectively on the module. The module receives the serial data from the master device (smartphone) through the RXD pin and then transfers that data to the arduino using the TXD pin. The TXD pin on the module is connected directly to the RX pin on the arduino whereas the RXD pin of the module is connected to the TX pin on the arduino using a voltage divider circuit as the RXD on the module can only support voltage upto 3.3V [17].

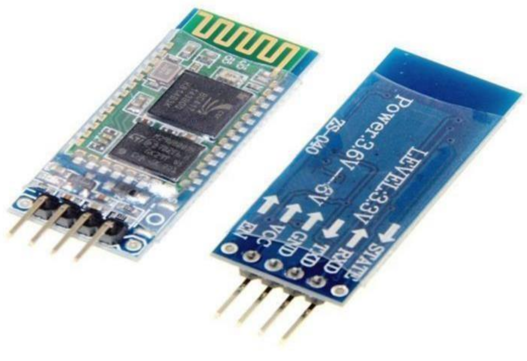


Fig. 7.3: The HC-06 bluetooth module [17].

7. LCD 16x2 Screen:

Liquid crystal display, abbreviated as LCD is an optical device composed of crystals arranged on a thin surface divided into many elements. And the 16 x 2 LCD is named because; It contains 16 columns and 2 rows. There are a lot of combinations available like, 8x1, 8x2, 10x2, 16x1, etc. But the most widely used is the 16 x 2 LCD screen.The monitor also requires a 5V power supply. Please be careful not to exceed 5V, as this will damage the device. And the liquid crystal screen uses almost the same system as the regular screen, but instead of the gas inside the large screen, a liquid is placed, which is known as liquid crystal. Among the advantages of these screens is their thickness, which is much less than that of regular screens. Lightweight and easy to move, hang or store anywhere. It does not require a high voltage of electricity, as in normal screens, and since it does not use high voltage, it is comfortable for the eyes compared to the normal screen [19].

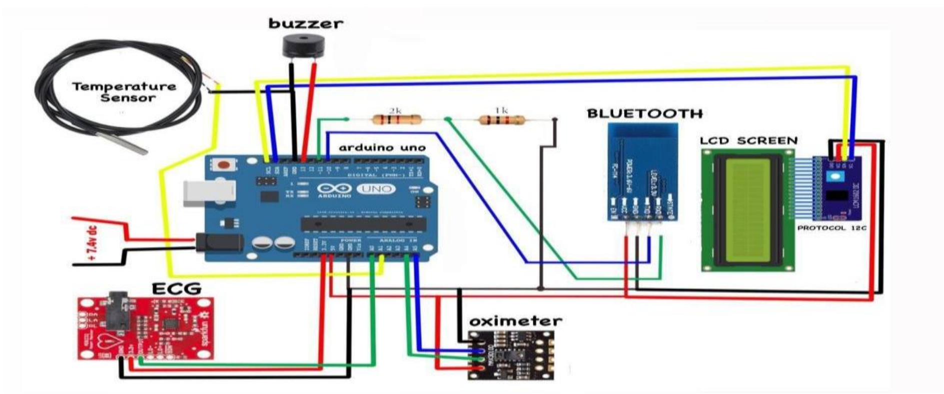
Fig. 8.3: LCD 16x2 Screen

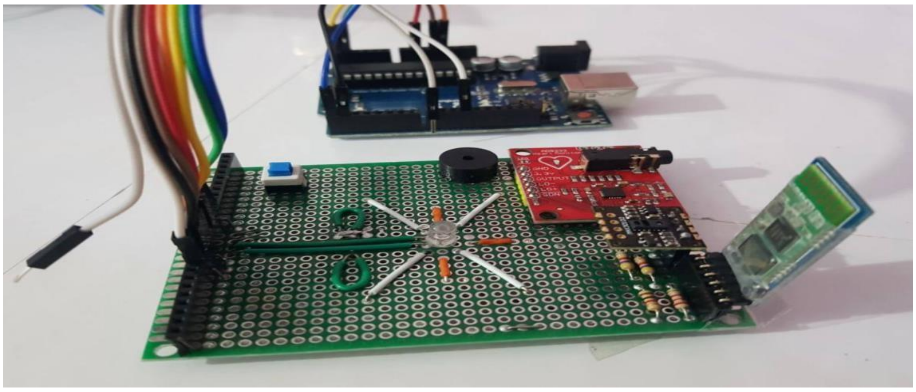
8. lithium ion battery:

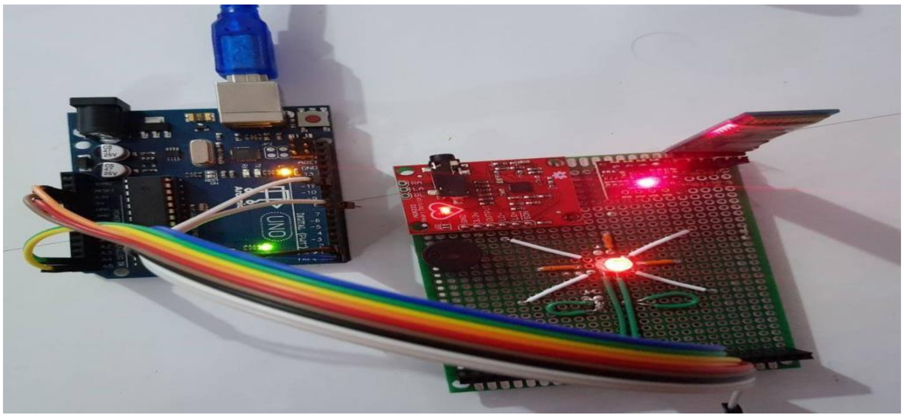
It is a family of rechargeable battery types in which lithium ions move from the negative electrode to the positive electrode during discharge and back when charging. It is one of the most popular types of rechargeable batteries for portable electronic devices, with one of the best energy-to-weight ratios, high open circuit voltage, no memory effect, and slow loss of charge when not in use. And in a lithium-ion battery, lithium ions (Li+) move between the cathode and the anode internally. Electrons move in the opposite direction in the outer circle. This is why the battery powers the device - because it generates electric current. As the battery discharges, the anode releases lithium ions to the cathode, generating a flow of electrons that help power the device. When the battery is charged, the opposite happens. Lithium ions are released by the cathode and received by the anode.The single lithium battery used in his device is 3.7 volts [20].

Fig. 9.3: Lithium ion Battery [20].

3.3 Circuit diagram for ECG device design and implementation:







3.4 Table 1.3: Bill of Materials Table

S.N	COMPONENTS NAME	QUANTITY
1	Arduino Board	1
2	ECG Sensor	1
3	Oximeter (SPO2) Sensor	1
4	Temperature Sensor	1
5	LCD 16x2 Screen	1
6	The HC-06 bluetooth	1
7	Lithium ion Battery3.7V	2
8	Connecting Wires	20
9	Disposable Electrodes	3
10	Buzzer	1
11	LED	1
12	Resistors	5
13	Lock Push button Switch	1

3.5 Software Requirements(Code):

```
#include <Wire.h >
#include <LiquidCrystal_I2C.h>                LiquidCrystal_I2C lcd(0x27, 16, 2);

#include <Thermistor3.h>                      Thermistor temp(1); double resistor = 10000;
                                              double average =0;  int sample = 100;  int j=0;

#include <Wire.h>                             #include "MAX30100_PulseOximeter.h"
```

```
#define REPORTING_PERIOD_MS 1000                    #define   REMOTEXY_MODE
___________________________HARDSERIAL

#include <RemoteXY.h>     #define REMOTEXY_SERIAL Serial

#define REMOTEXY_SERIAL_SPEED 9600                   #pragma   pack(push,   1)
Uint8_t RemoteXY_CONF[] =

{ 255,0,0,37,0,87,0,16,24,0,68,17,0,33,100,30,8,36,6,7,4

2,14,20,5,2,26,11,67,4,38,14,20,5,2,26,11,67,4,77,14,20,5,2,26,11,129,0,2,7,90,5,3

5,72,101,97,114,11,6,32,82,97,116,101,32,32,32,32,32,32,116,101,109,112,101,11

4,97,116,117,114,101,32,32,32,32,32,32,32,32,32,83,80,79,50,32,0};

float onlineGraph_1;                  char spo2[11];

char text_2[11];                      char heartrate[11];

other variable                        Uint8_t connect_flag; else =0

;RemoteXY } #pragma pack(pop)

pulseOximeter pox;                    Uint32_t tsLastReport = 0; (Void onBeatDetected){

Serial.println("Beat!");              digitalWrite( 11 , HIGH); delay(50);  digitalWrite( 11
,LOW);} void setup() {

(Lcd.init);

(Lcd.backlight);                      (RemoteXY_Init);

pinMode (11, OUTPUT);                      pinMode  (11,  OUTPUT);  Lcd.setCursor(0,0);
                                      Lcd.print("ELECTROCARDIOGRAM              ");
Lcd.setCursor(0,1);                   Lcd.print("| *ECG* |");               delay(1000);
(Lcd.clear);

Lcd.print("LECTROCARDIOGRAM  ");

Lcd.setCursor(0,1);   Lcd.print("| *ECG* |");     delay(1000); (Lcd.clear);


Lcd.setCursor(0,0);                   Lcd.print("| AL-Hikma |");

Lcd.setCursor(0,1);                   Lcd.print("| University |");           delay(2000);
(Lcd.clear);

Lcd.setCursor(0,0); Lcd.print("|Medical device|");

Lcd.setCursor(0,1);                   Lcd.print("| engineering |");           delay(2000);
(Lcd.clear);

Lcd.setCursor(0,0);

Lcd.print("| THIS PROJECT |");

Lcd.setCursor(0,1);                   Lcd.print("| WAS MADE BY |"); delay(2000);

(Lcd.clear);

Lcd.setCursor(0,0);                   Lcd.print("|HAJER MAKI ALI|");

Lcd.setCursor(0,1);                   Lcd.print("ALI FARIS RADHI"); delay(2000);

(Lcd.clear);

Lcd.setCursor(0,0);                   Lcd.print("| HADEER EMAD |");
```

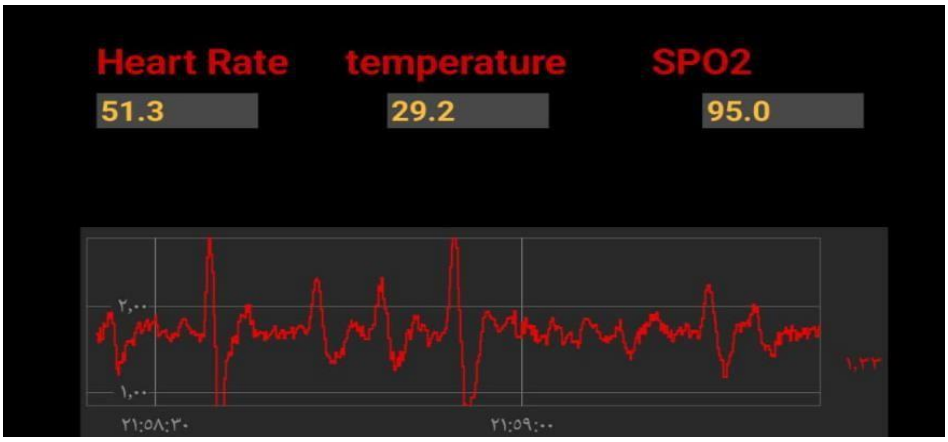
```
Lcd.setCursor(0,1);                 Lcd.print("| ATHMAR JAMAL |"); delay(2000);
(Lcd.clear);
Lcd.setCursor(0,0);                 Lcd.print("| AMEEN EMAD |");
Lcd.setCursor(0,1);                 Lcd.print("| MARYAM HAMEED|"); delay(2000);
(Lcd.clear);
Lcd.setCursor(0,0);   Lcd.print("| supervised |"); Lcd.setCursor(0,1);    Lcd.print("|   by   |");
      delay(2000);

(Lcd.clear);
Lcd.setCursor(0,0);                 Lcd.print("Assist. Prof. Dr.");
Lcd.setCursor(0,1);                 Lcd.print(" Saad Mohammed"); delay(2000);
(Lcd.clear);
Lcd.setCursor(0,0);                 Lcd.print("starting");            delay(200);
Lcd.setCursor(0,0);                 Lcd.print("starting .");          delay(200);
Lcd.setCursor(0,0);                 Lcd.print("starting ..");         delay(200);
Lcd.setCursor(0,0);                 Lcd.print("starting …");           delay(200);
Lcd.setCursor(0,1);                 Lcd.print(" welcome   □"); delay(1000);
(Lcd.clear);                        delay(500);
{ If (!pox.begin())                 Serial.println("FAILED");;);;(For
{ else }                            Serial.println("SUCCESS");}
Pox.setIRLedCurrent(MAX30100_LED_CURR_7
;_6MA) //Pox.setOnBeatDetectedCallback(onBeatDetected);}
```

3.6 Results:

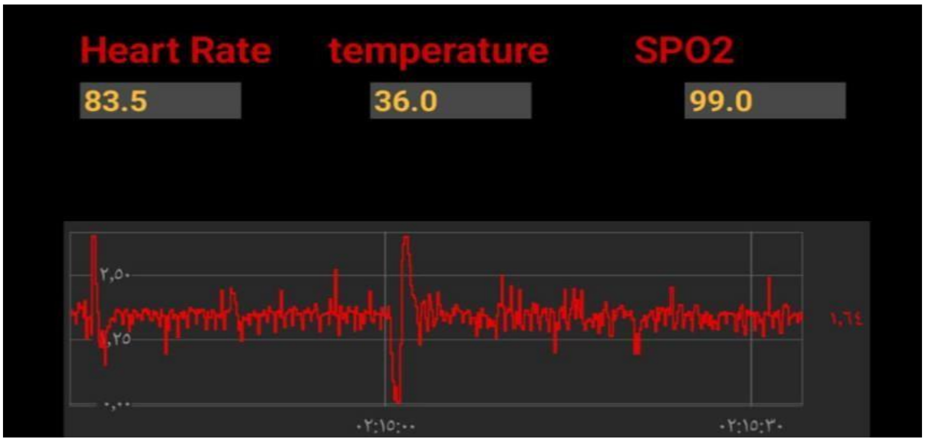
Table 2.3: The table below is test for four people:

Persons	Gender	The age	SPO2	Temperature	Heart rate
1. First Person	Female	53 Years	95.0	29.2	51.3
2. Second person	Male	20 Years	99.0	36.0	83.5
3. Third Person	Female	13 Years	96.0	37	94.7

First Person



Second person



Third Person

4.1 Discussion

According to the results of the test in the third chapter, we use the ECG device, the temperature sensor, the oxygen saturation sensor in the blood, and the heart rate in order to monitor of the heart. We did Procedure the test for three people from different age groups in order to notice the difference between one age group and another.

First, we measured the percentage of oxygen saturation in the blood, and the measurement process is done by sending infrared light to the capillaries in the finger. The reading of the blood oxygen level indicates the percentage of saturated blood, and this test contains an error rate of 2%, meaning that the reading is 2% higher or lower than the actual oxygen level in the blood, and it may be less accurate than others, but it has advantages such as ease of use and giving a close percentage And quick. When conducting the test on the first person, who was 53 years old, we noticed that the blood oxygen saturation rate was 95%. As for the second person who was 20 years old, the percentage of oxygen saturation in the blood was 99%, and for the third person who was 13 years old, the percentage of oxygen saturation in the blood was 96%. And when comparing the test percentages with the normal percentages, the percentage is 95 to 100%, which is a normal percentage, but for people with lung diseases, Almost normal ratio from 88 to 92%. After comparing the results of the test with the normal ratios, it was found that the three persons had their ratios within the normal range.

Second, we measured heart rate, which measures the number of times the heart beats or contracts per minute. Heart rate varies with physical activity and emotional responses. The normal heart rate varies according to age, as the normal heart rate for the elderly is different from the normal heart rate for children. When conducting the test on the three people, we noticed changes in the results from one person to another due to the different age groups, as the first person had a heart rate of 51.3 beats, the second person 83.5, and the third person 94.7. And when comparing these results with normal percentages, the percentage for people after the age of ten years is between 60 to 100 beats. After comparing the test results with the normal percentages, it was found that the first person had a slowdown in heart rate, while the second and third person had their percentages within the normal range. Note that the normal heart rate decreases gradually with the growth of the person and his transition from childhood to adolescence or older stages, and as it was found for the first person that his heart rate is low due to his age group. Heart Rate and Oximeter (SPO2) Sensor are both in one chip.

Third, as for the temperature sensor, the normal body temperature varies depending on a number of factors, including age, gender, and activity levels, as this temperature may rise or fall to varying degrees. Also, when measuring the temperature of the same three people, it was found that the first person had a temperature of 29.2, the second person 36.0, and the third person 36.9. When comparing the results, the percentage of the temperature of the first person is below normal (low), while the second and third person are within the normal range. In women, body temperature is often influenced by hormones.

4.2 Future work:

Most ECG machines usually operate on batteries due to the small size requirements. The batteries used in ECG machines often have a limited capacity and therefore must be replaced periodically. This often leads to problems in emergency situations, especially for elderly patients. To deal with this problem, we can develop a portable ECG device by using solar energy as the main source of energy so that there is no need to replace the battery, and solar energy is a secondary source for charging the device. The benefit of developing the design is to obtain low energy consumption and to store electricity from solar cells, which is a semi-conductor device with a simple structure, and its function is to convert solar energy into electrical energy that can be utilized. In this case, the sun played the role of electric generators [21][22].

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