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Design and Implementation of Oxygenation part of the Heart Lung Machine Using Arduino

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Abstract:

The blood oxygenation component is regarded as a critical element of the open heart and lung system during open heart surgery. This is due to the fact that both the heart and lungs lose their fundamental functions during such procedures. Consequently, an alternative device or component is required to compensate for and replace these functions, thereby fulfilling several essential roles:

The device substitutes for the heart and lung functions during the operation, ensuring the circulation of blood between the heart and the body's organs to prevent clotting in the absence of a circulation mechanism. It regulates the volume of blood being pumped to the patient throughout the surgical procedure, with a pumping rate of 2.4 liters per minute for adults and 1.2 liters per minute for newborns.

Additionally, it facilitates the oxygenation of blood, which typically occurs through the lungs; however, during this type of surgery, lung function is compromised. The device also manages the temperature of the blood, maintaining it below 30 degrees Celsius. In this project, we have developed a system that encompasses all these functions, including the regulation of blood and body temperature. The device effectively lowers blood temperature to below 30 degrees Celsius, thereby diminishing the metabolic activity of the body's organs and subsequently reducing their oxygen requirements during the surgical procedure.

Keywords (Design. Implantation. Heart-lung machine. Oxygenation system. Arduino-based medical Devices. open-source medical technology.)

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Chapter one: Introduction

1.1Cardiopalmonary machine :

Cardiopulmonary bypass (CPB) is a medical procedure wherein a machine assumes the roles of the heart and lungs during surgical operations, ensuring the continuous circulation of blood and the adequate oxygenation of the patient's body. This machine is commonly known as a heart-lung machine or simply "the pump." The operation of CPB pumps is typically managed by perfusionists. CPB represents a type of extracorporeal circulation, while extracorporeal membrane oxygenation is primarily utilized for extended treatment durations. [1].

1.1.2 Aim of the CPM:

Cardiopulmonary bypass is commonly used in operations involving the heart. The technique allows the surgical team to oxygenate and circulate the patient's blood, thus allowing the surgeon to operate on the heart.[1]

In numerous surgical procedures, including coronary artery bypass grafting (CABG), it is necessary to arrest the heart to facilitate the operation, as working on a beating heart presents significant challenges. Procedures that involve accessing the heart's chambers, such as mitral valve repair or replacement, necessitate the use of cardiopulmonary bypass (CPB) to prevent systemic air embolism and to create a bloodless surgical field, thereby enhancing the surgeon's visibility. The CPB machine circulates blood and incorporates an oxygenator, which enables red blood cells to absorb oxygen while simultaneously reducing carbon dioxide levels.[2] This replicates the roles of the heart and lungs, respectively. Cardiopulmonary bypass (CPB) may be employed to induce total body hypothermia, a condition in which the body can be sustained for as long as 45 minutes without perfusion (blood circulation).[1] Should blood circulation cease at standard body temperature, irreversible brain injury typically manifests within three to four minutes, potentially leading to death shortly thereafter. Likewise, cardiopulmonary bypass (CPB) can be employed to rewarm patients experiencing hypothermia. This method of rewarming via CPB proves effective when the patient's core temperature exceeds 16 °C.[4]

Extracorporeal membrane oxygenation (ECMO) serves as a streamlined alternative to the heart-lung machine, incorporating a centrifugal pump and an oxygenator to temporarily assume the roles of the heart and/or lungs. This technique is particularly beneficial for patients recovering from cardiac surgery who experience cardiac or pulmonary dysfunction, as well as those suffering from acute respiratory failure, significant pulmonary embolisms, lung injuries due to infections, and various other conditions that compromise cardiac or pulmonary performance. ECMO provides essential time for the heart and/or lungs to heal or recuperate; however, it is important to note that it is a temporary measure. Patients with terminal illnesses, cancer, severe neurological damage, uncontrolled sepsis, and other similar conditions may not be suitable candidates for ECMO. [14, 15].

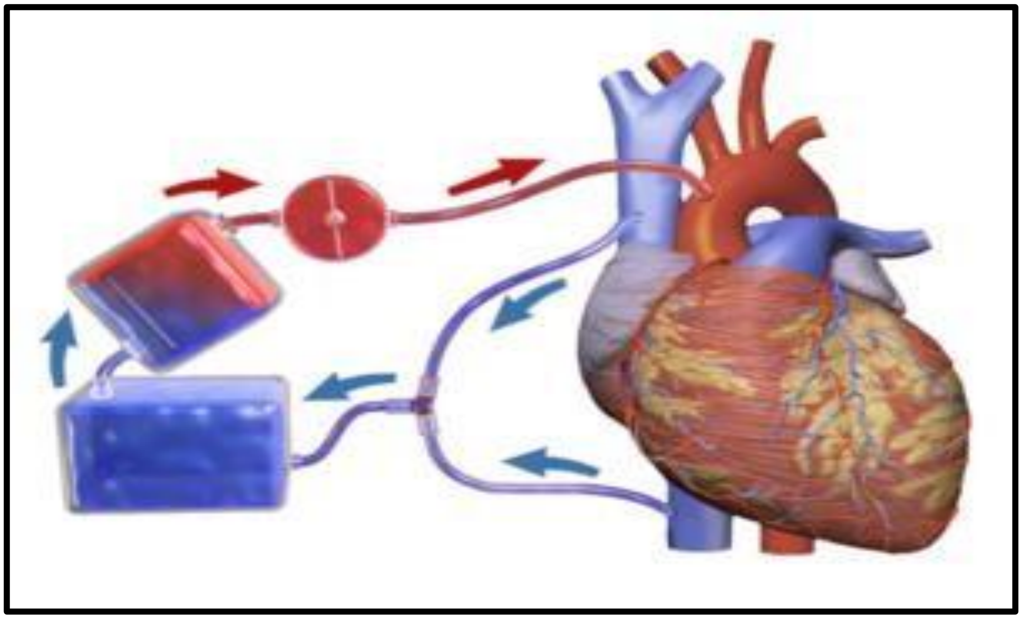

Fig (1.1) shows the typical way that a heart-lung machine may be connected to the veins and arteries near the heart.

1.1.3 CPM Components:

Cardiopulmonary bypass is comprised of two primary functional components: the pump and the oxygenator. The pump extracts blood that is relatively low in oxygen from the patient's body, while the oxygenator infuses it with oxygen-rich blood via a network of tubes. Additionally, a heat exchanger is employed to regulate the patient's body temperature by either heating or cooling the blood circulating within the system. To ensure the prevention of clot formation within the circuit, it is crucial that all internal surfaces of the components are treated with heparin or an alternative anticoagulant[1].

- **Tubing**

  The components of the CPB circuit are interconnected by a series of tubes made of silicone rubber or PVC.[5]

- **Pumps**

Centrifugal pump

Numerous CPB circuits currently utilize a centrifugal pump to regulate and maintain blood flow during cardiopulmonary bypass. The generation of blood flow is achieved through the centrifugal force created by varying the revolutions per minute (RPM) of the pump head. Many experts regard this pumping mechanism as more advantageous than that of the roller pump, as it is believed to mitigate issues such as over-pressurization, line clamping or kinking, and to cause less harm to blood components, including hemolysis)[6]

Roller pump

The pump console typically consists of multiple motor-driven pumps that operate in a rotating manner to peristaltically "massage" the tubing. This mechanism effectively moves blood through the tubing. Such devices are commonly known as roller pumps or peristaltic pumps. While these pumps are generally less expensive than centrifugal pumps, they are prone to over pressurization if the lines are pinched or obstructed. Additionally, they have a higher risk of causing significant air embolisms and necessitate continuous, vigilant monitoring by the perfusionist.[1]

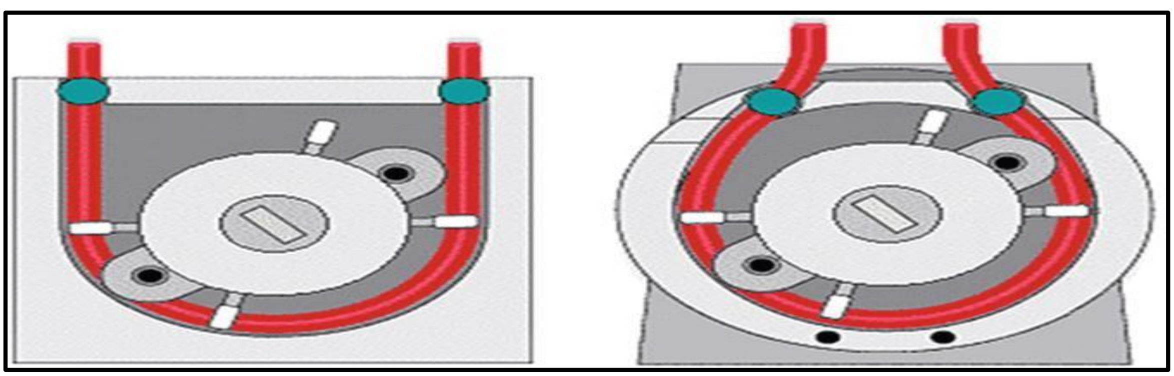

Fig (1.2) Shows the roller pump.

- **Oxygenator**

  - The oxygenator is engineered to enrich infused blood with oxygen while simultaneously eliminating a portion of the carbon dioxide present in venous blood. The advent of cardiopulmonary bypass (CPB) facilitated cardiac surgery through the use of bubble oxygenators; however, since the 1980s, membrane oxygenators have replaced bubble oxygenators. This transition is primarily attributed to the fact that membrane oxygenators produce significantly fewer micro-bubbles, known as gaseous micro emboli, which are typically regarded as detrimental to patient health.[7] and reduce damage to blood cells,[8] The utilization of hollow-fiber oxygenators has gained increased popularity in recent times, particularly in comparison to bubble oxygenators. These membrane oxygenator derivatives minimize the formation of micro emboli by decreasing the direct interface between air and blood, all the while ensuring sufficient gas exchange.[7]

Another type of oxygenator gaining favor recently is the heparin-coated blood oxygenator which is believed to produce less systemic inflammation and decrease the propensity for blood to clot in the CPB circuit.[7]

Fig (1.3)Shows the oxygenator part.

- **Heat exchangers**

Hypothermia is commonly employed during cardiopulmonary bypass (CPB) to decrease metabolic requirements, including those of the heart. To facilitate the warming and cooling of blood within the circuit, heat exchangers are utilized. This process is achieved by routing the blood line through either a warm or ice water bath. Additionally, a distinct heat exchanger is necessary for the cardioplegia line.[1]

- **Cannula**

Several cannulas are inserted into the patient's body at various sites, contingent upon the specific surgical procedure being performed. A venous cannula is utilized to extract oxygen-depleted venous blood from the patient. Conversely, an arterial cannula is employed to deliver oxygen-rich blood into the arterial circulation. The primary factors influencing the selection of cannula size include the patient's dimensions and weight, the expected flow rate, and the caliber of the vessel being cannulated.[1]

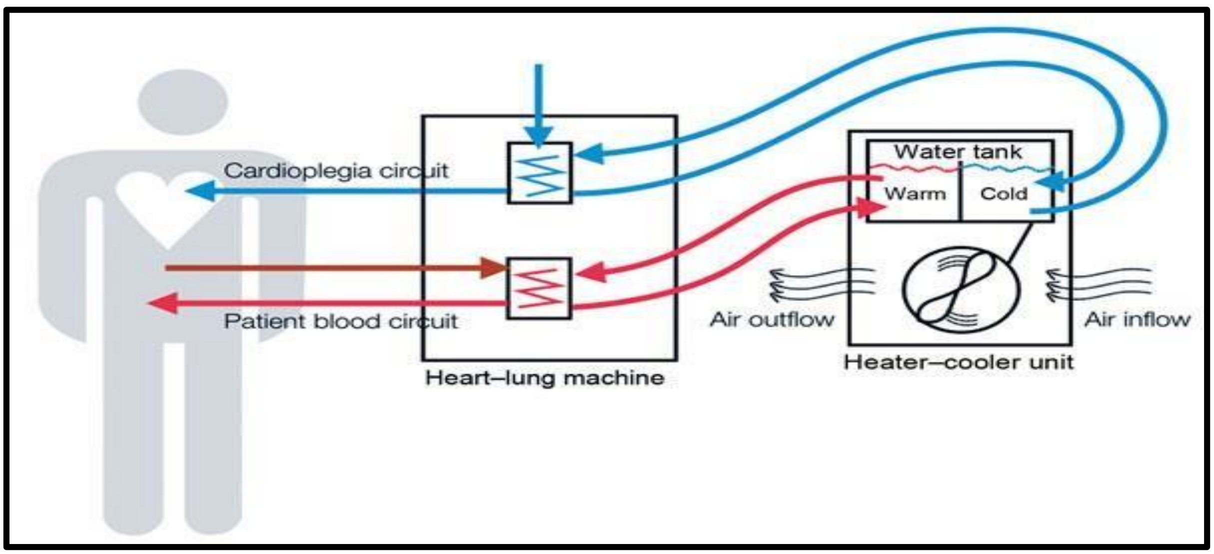

Fig (1.4) Show the working principle of the heat exchanger .

1.2 .1Arduino platform:

Arduino is an open-source electronics platform that utilizes user-friendly hardware and software. It can interpret various inputs, such as light detected by a sensor, a finger pressing a button, or a message from Twitter, and convert these into outputs, such as activating a motor, illuminating an LED, or publishing content online. Users can instruct the board by transmitting a series of commands to the microcontroller integrated within the board. This is accomplished through the Arduino programming language, which is derived from Wiring, and the Arduino Integrated Development Environment (IDE), which is based on Processing[9].

1.2.2 Arduino types:

The platform of an Arduino has become very famous with designers or students just starting out with electronics, and for an excellent cause, so there are different types of Arduino as follow below [10]:

- Arduino Uno (R3)
- Arduino Nano
- Arduino Micro
- Arduino Due
- LilyPad Arduino Board
- Arduino Bluetooth
- Arduino Diecimila
- RedBoard Arduino Board
- Arduino Mega (R3) Board
- Arduino Leonardo Board
- Arduino Robot

- Arduino Esplora
- Arduino Pro Mic
- Arduino Ethernet
- Arduino Zero
- Fastest Arduino Board

Each one differs from the according to the following:

- Type of the processor.
- Memory capacity.
- Number of Digital I/O.
- Number of Analog input.

In our project we will use the arduino UNO and explain it below.

1.3 Roller Pump:

A peristaltic pump, also known as a roller pump, operates by having a segment of flexible tubing pressed against a rigid outer structure, as illustrated in the accompanying figure. The rollers exert pressure on the tubing, which inhibits backflow and propels the blood in a forward direction. The output from a roller pump is characterized by a pulsatile flow, which can positively influence mass transfer. When the rollers fully occlude the tubing, the flow rate becomes primarily determined by the rotational speed of the roller head, showing a degree of independence from the back-pressure created by the flow resistance within the extracorporeal circuit[11].

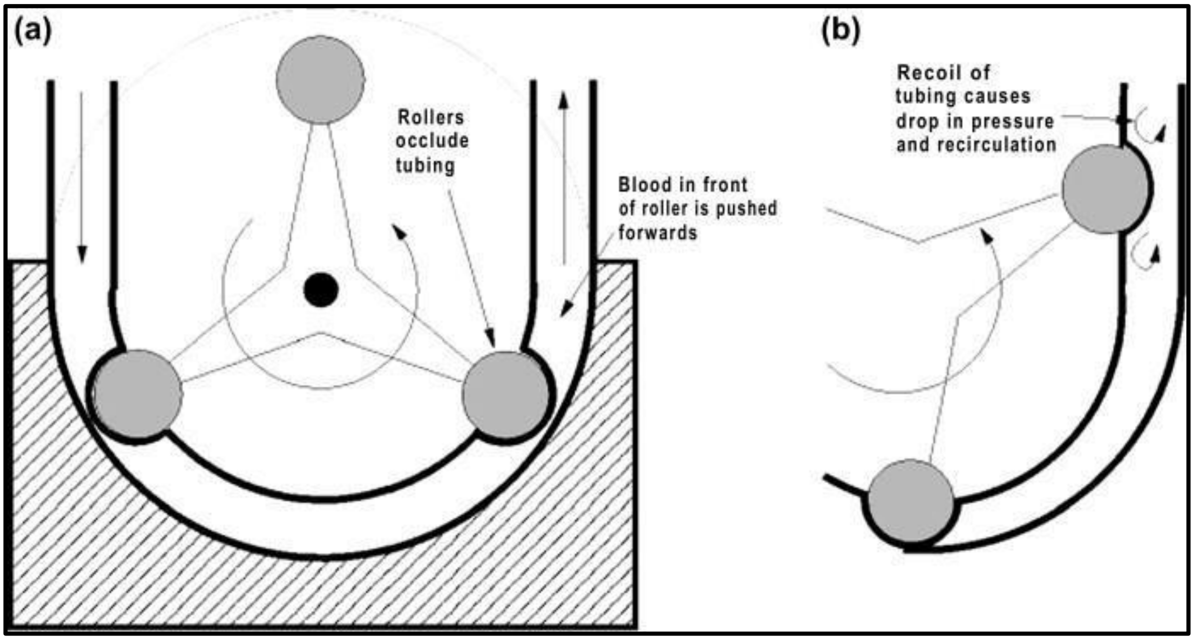

Fig (1.5) Show the working principle of the roller pump.

1.4 Oxygenator:

The oxygenator serves as the pivotal element within the CPB or ECMO circuit, fulfilling the role of the lungs by enriching the hemoglobin of venous blood with oxygen. It offers an extensive surface area for interaction between blood and the gas phase, utilizing either hollow fibers or a folded silicone membrane. An oxygen-rich gas mixture flows through the oxygenator in a direction counter to that of the blood, creating a countercurrent that enhances the diffusion of oxygen into the bloodstream. The total surface area, and consequently the capacity of the oxygenator, is determined by the patient's size and the volume of blood that requires complete oxygenation. Additionally, the exposure of blood to this substantial artificial surface is believed to contribute to various coagulation and inflammatory issues commonly observed in ECMO and CPB procedures[12].

1.5 Heat exchanger:

Heater-cooler devices are utilized in nearly all open-heart or open-chest bypass surgeries to manage a patient's body temperature. However, these machines have been associated with the transmission of non-tuberculosis mycobacteria (NTM), a type of bacteria that can lead to severe chronic lung infections in immunocompromised individuals, potentially resulting in death if not addressed appropriately[13].

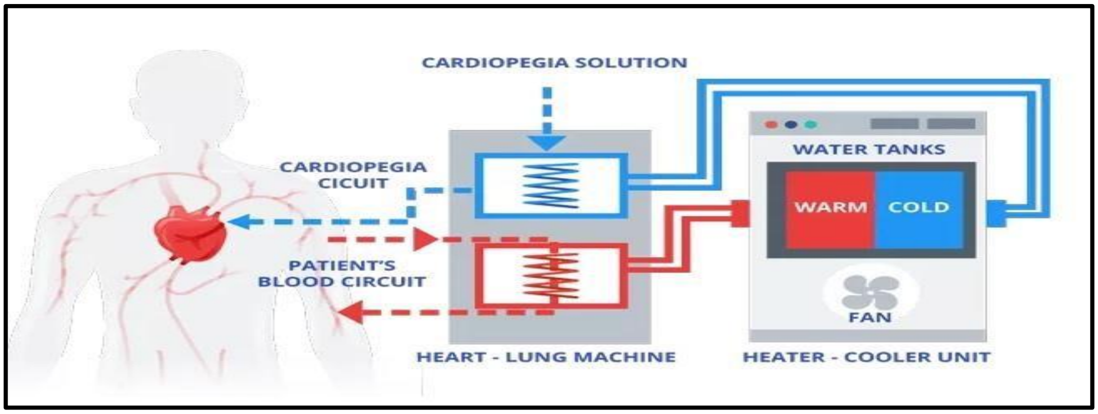

Fig (1.6) Shows the working principle of the device.

Heater-cooler devices, while regulated under cardiovascular guidelines, are also applicable in numerous other medical procedures. These machines consist of a water tank that keeps warm and cold water separate, along with a heating and cooling unit that facilitates the circulation of air. They deliver temperature-controlled water to external heat exchangers, such as heart-lung machines, or to warming and cooling blankets via closed water circuits that do not interact with open air. This mechanical operation aids in preserving an internal equilibrium against external fluctuations in a patient's body temperature.

The water within the heater-cooler apparatus is kept separate from the cardioplegia solution, which is employed to deliberately and temporarily halt the heart, as well as from the patient and the blood circulation systems.

1.6 objective of the study:

In our research, we will develop a prototype Continuous Perfusion Monitor (CPM). We will employ various electrical and electronic techniques to regulate the blood flow rate through a motor driver for the pump, utilizing an analog signal that can be measured with a potentiometer and controlled via Arduino code. Additionally, we will incorporate ultrasonic sensors along with a light-dependent resistor (LDR) to identify any bubbles that may enter the patient's tubing circuit, as these could potentially lead to blood clots in the bloodstream. The primary objective of our project is to create an affordable blood oxygenator using readily available components, suitable for use during open-heart surgeries for various applications.

2.1 Principle of the Device

The operation of the device is based on a mechanism that withdraws and returns blood to the patient's body, involving several critical stages. A key aspect of this process is the removal of carbon dioxide and its replacement with oxygen. The pump, specifically a roller pump, serves a function analogous to that of the heart. However, this research will focus on approximate values during the pumping process. In future developments, the device could be enhanced by incorporating a real pump that can achieve pumping rates aligned with the physiological requirements of the human body, as opposed to the pump utilized in this study, which delivers approximately 300 ml/min. The remaining stages involve oxygenation through an oxygenator and a heat exchanger, which is vital for maintaining the temperature within the range of 30-32 degrees Celsius, ensuring that the device meets the patient's needs during open chest surgery.

2.2 Device design stage

In this project, four main stages of design were relied upon, as follows:

- The pumping stage of the blood and its components.
- The oxygenation stage and tubing.
- The heat exchange stage and thermal transfer.
- The filtration stage and air bubbles detection.

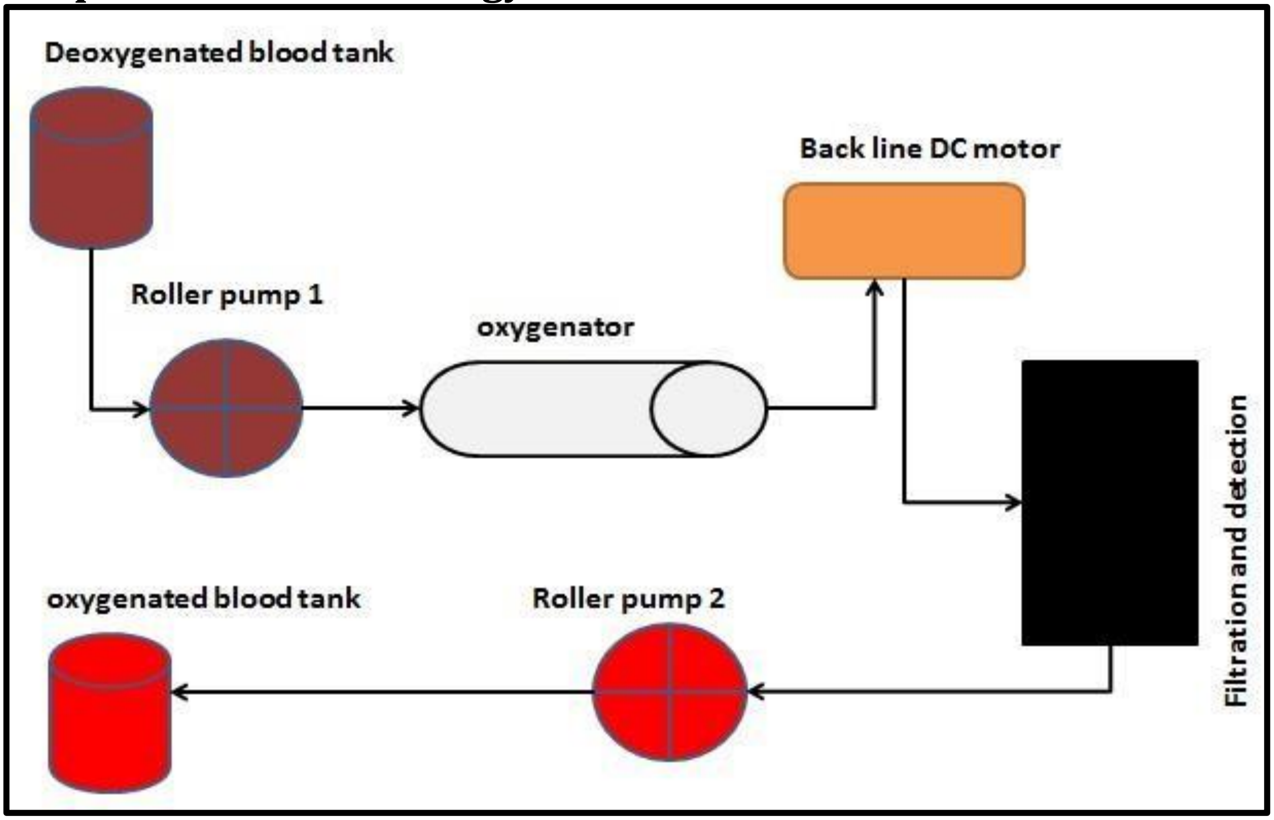

Fig (2.1) Show the main block diagram of the project.

In each phase of the aforementioned design, we will provide a comprehensive explanation of the components involved, their operational methods, and their interconnections. Additionally, we will detail the digital programming mechanism utilized to control the operational processes via the Arduino platform, accompanied by a block diagram for each phase of the device's practical design.

For our project, we have selected the most efficient and readily available components, specifically the Arduino Uno microcontroller, for several reasons. This board features numerous digital I/O pins, including 14 that can function as PWM outputs, along with 6 analog inputs, a reset button, a power jack, and a USB connection. It encompasses all necessary elements to support the microcontroller; simply connect it to a PC using a USB cable and provide power through an AC-to-DC adapter or battery. The abundance of pins makes the Arduino board particularly advantageous for projects requiring multiple digital inputs or outputs, such as numerous buttons. For further information about the Arduino Mega (R3) Board, please refer to the provided link[10].

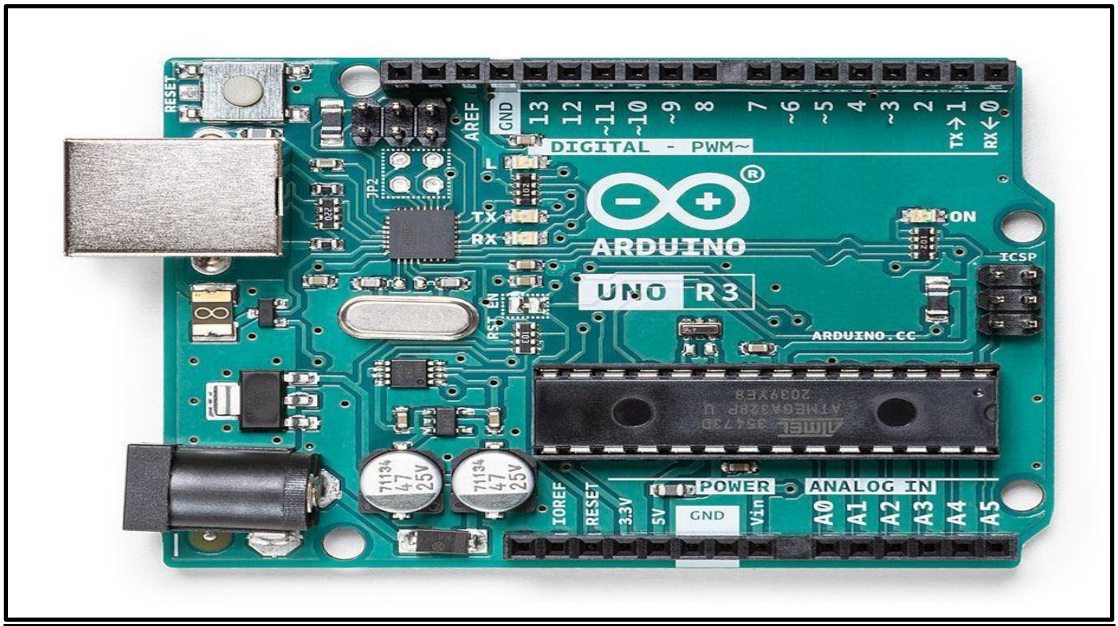

Fig (2.2) shows the Arduino Uno board.

2.2.1 Pumping stage

At this point, our objective is to develop a device capable of extracting blood from the patient's body in a rhythmic fashion, with a withdrawal and push rate of approximately 100-300 ml/min. This rate is ten times lower than that of the actual device; however, this design can serve as a reliable basis for the prototype. The unit comprises the following components:

1. Roller pump work on 12v DC/500 mA.

2. Relay switch 1 Ch type.
3. Slide potentiometer 50k ohm.
4. Bridge DC motor driver.
5. Variable power supply 1-12 v DC.
6. Mini 9v electronic flow meter.
7. LCD display unit.
8. I2C minimizing cct.
9. Arduino Uno.

(1) It represents the main part of the blood pumping process, as this pump operates on a constant current voltage as described above. The working mechanism and the amount of pumping are controlled by parts (2, 3 and 4), where Part (2) works to provide the source of electrical supply to the pump in case Receiving a signal from the Arduino microcontroller. As for the parts (3 and 4), they control the amount of pumping by converting the analog signal from the variable resistance to a digital signal that is controlled by the component (4). All these operations are controlled by the(9) Arduino software code, part 4. (6) Represents the actual measure of the flow of blood from the blood storage to the oxygenation portion in the first stage of the device's operation.

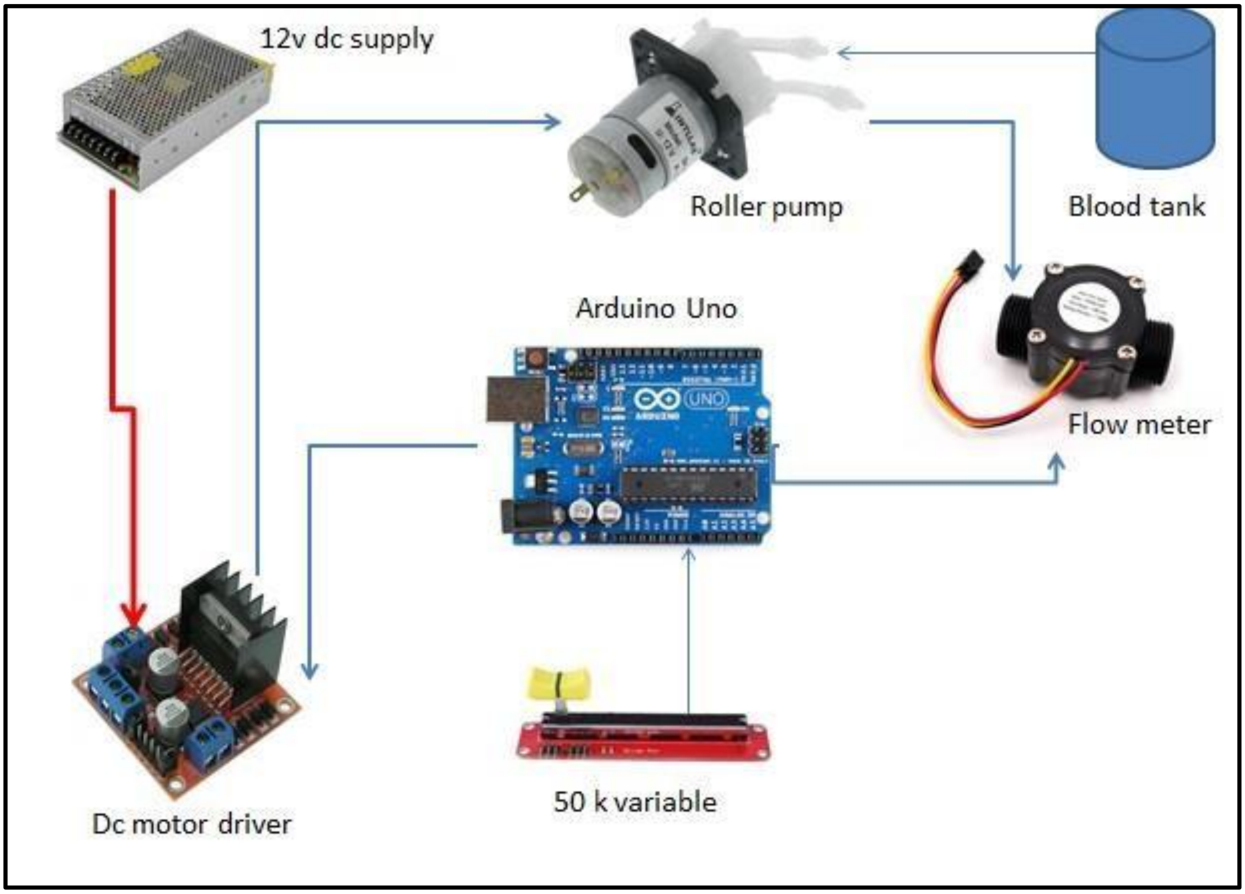

Fig (2.3) Show the working of the pumping unit.

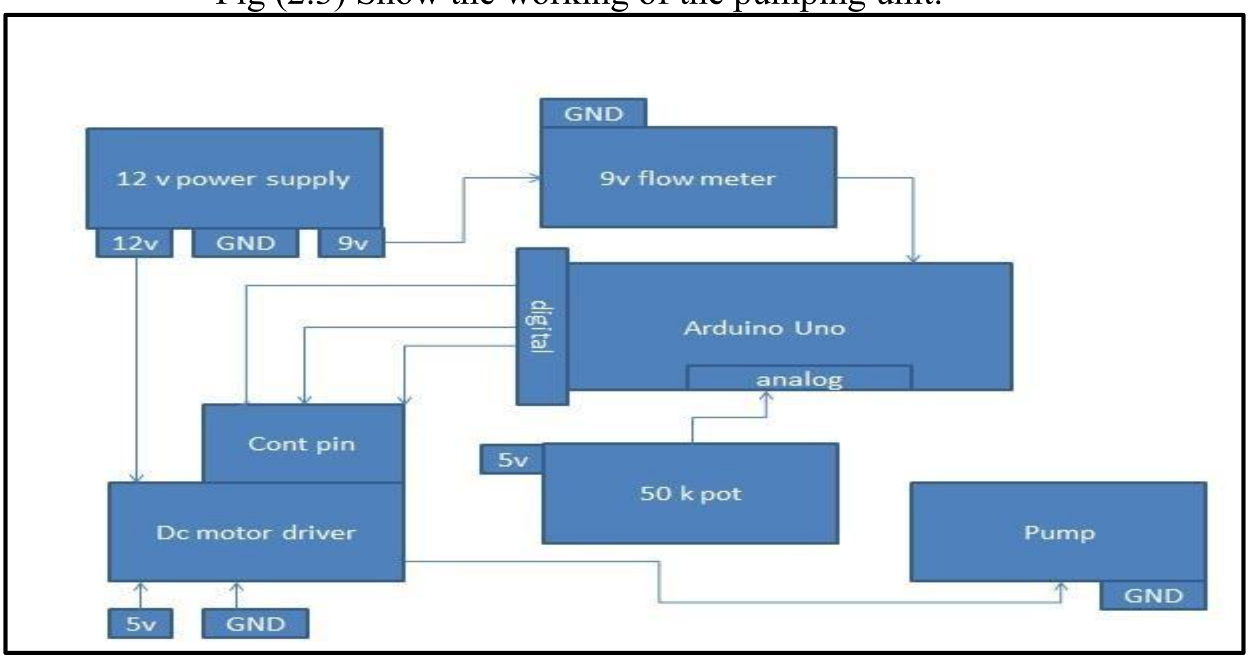

Fig (2.4) Show the schematic diagram of the pumping unit.

In our project, we utilize the most efficient and readily available components that ensure high stability and accuracy during operation. We will elaborate on this matter before proceeding to the next phase:

2.2.2 oxygenation stage

This phase is regarded as crucial in the procedure of extracting carbon dioxide from the bloodstream and substituting it with oxygen. It primarily relies on the key element known as the oxygenator, which is composed of extremely fine fibers that facilitate the movement of red blood cells and all other blood components, while effectively excluding carbon dioxide. The introduction of oxygen into the blood is managed through an external source, overseen by a specialist, and tailored to the patient's specific condition and biological factors, including age, weight, height, and overall physical health, all of which are assessed prior to the operation by the anesthesiologist.

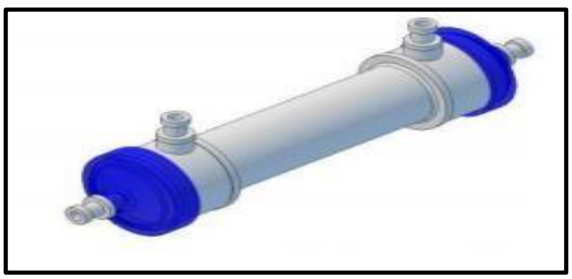

Fig (2.5) Show the oxygenator part of the CPM.

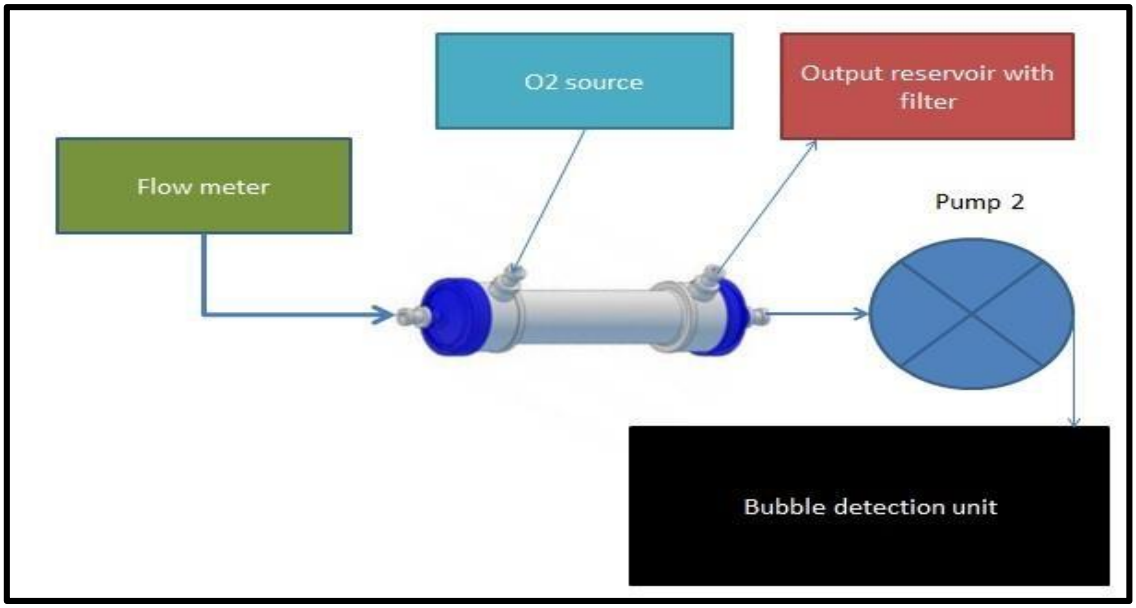

Fig (2.6) Show the working principle of the Oxygenator part.

2.2.3 heat exchanger stage

At this stage, the temperature of the blood returned to the patient is maintained below the normal level, where the temperature ranges (30-32 C), as this stage depends mainly on the following components:

1. Water proof heat sensor (DS18B20).
2. Heat Source (220/50HZ) Heater 2000W.
3. 1 Ch relay switch.
4. Tank architecture.
5. Arduino Uno. 6. Water source.

According to the parts above, the blood will be insert in tank section on the side and the water on the other side, the sensor will measure the temp of the blood using the arduino analog signal, the heater will work till reach the set point temp of the blood then will stop when the set point is reached, this procedure called physically connected and chemically disconnected.

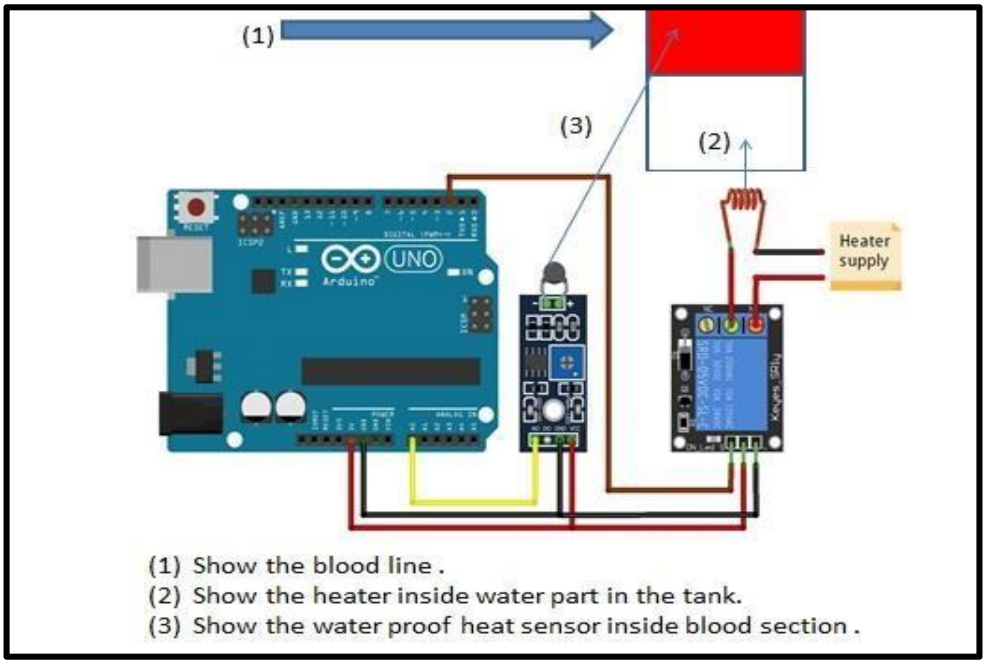

Fig (2.7) Show the block diagram of the heat exchanger .

2.2.4 Air bubble detection

At this point, any air bubbles linked to the oxygenated blood returning to the patient are identified, and the return process is halted if a defect is found. This phase incorporates an air filter designed to filter and separate the air from the blood. Additionally, a heparin line may be introduced in the future, with the necessary dosage determined based on the anesthesiologist's assessment. This stage comprises several components:

1. LDR sensor.
2. Totally black body cover.
3. Blood tube line .

4. Red led 25mm.
5. Arduino Uno.
6. Buzzer.

We programed (5) in order to detect the red light in wavelength (600-700)nm of the (4) after the tube line (3) , if there is change in the wavelength the Arduino will detect it using the LDR (1) because of the air bubble can change it , so we use this combination inside black cover in order to isolate all the other light wavelength.

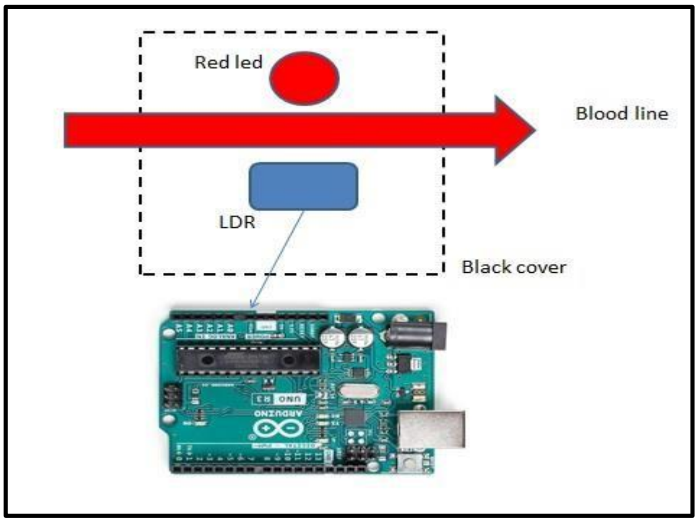

Fig (2.8) Show working principle of the air bubble detection unit.

2.3 Display unit

In every phase of the device's design, we incorporated methods for displaying and detecting the variables that arise during its operation. Primarily, we focused on the mechanism for displaying the volume of blood extracted from the patient via the pump, along with the blood temperature during the heat exchanger stage. We utilized an LCD with I2C compatibility, which is largely compatible with Arduino. One of the advantages of I2C is that it minimizes the number of wires required for connections and simplifies the process of obtaining addresses for transferring and printing information during programming.

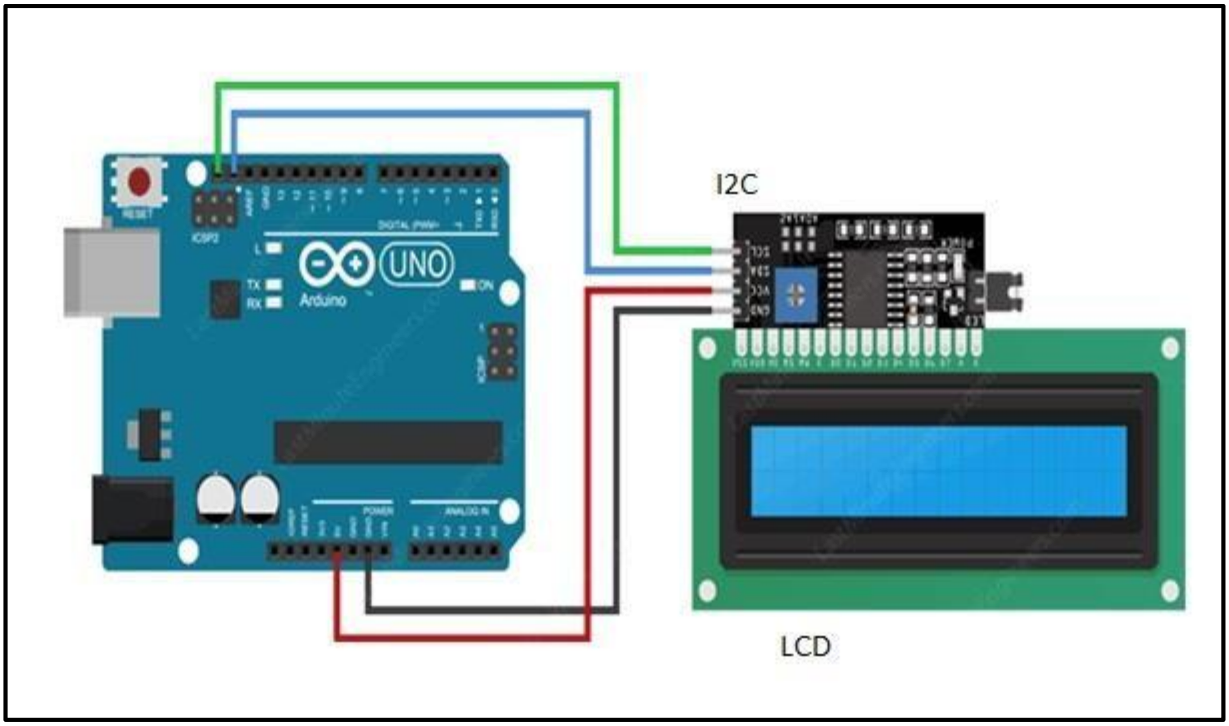

Fig (2.9) Show the display unit .

2.4 Programing and coding

Throughout every phase of our project, we rely on the Arduino IDE platform to execute all functionalities. Below, we will present the Arduino code corresponding to each phase.

2.4.1 pumping control code

```
int in1 = 8;        //Declaring where our module is wired
int in2 = 9;
int EN = 10;     // Don't forget this is a PWM DI/DO
int speed1;
int potpin=A0;
void setup() {
  pinMode(8, OUTPUT);
  pinMode(9, OUTPUT);
  pinMode(10, OUTPUT);
}


void loop() {


  digitalWrite(in1, LOW);          //Switch between this HIGH and LOW to change direction
  digitalWrite(in2, HIGH);
  speed1 = analogRead(A0);
  speed1 = speed1 * 0.2492668622;      //We read thea analog value from the potentiometer calibrate it
  analogWrite(EN, speed1);          // Then inject it to our motor
}
```

2.4.2 flow meter code

```
#include<LiquidCrystal_I2C_Hangul.h>
#include<Wire.h>
LiquidCrystal_I2C_Hangul lcd(0x27,16,2);
int X;
int Y;
float TIME = 0;
float FREQUENCY = 0;
float WATER = 0;
float TOTAL = 0;
float LS = 0;
const int input = A0;
int relaypin=9;
void setup()
{
 pinMode(input,INPUT);
 Serial.begin(9600);
  pinMode(9,OUTPUT);
  digitalWrite(9,HIGH);
  lcd.init();
  lcd.backlight();
  //lcd.setCursor(0,0);
  lcd.print("welcome into");
  lcd.setCursor(1, 4);
  lcd.print("our project");
  delay(5000);
  lcd.clear();
}
```

```
void loop(){
digitalWrite(9,LOW);
X = pulseIn(input, HIGH);
Y = pulseIn(input, LOW);
TIME = X + Y;
FREQUENCY = 1000000/TIME;
WATER = FREQUENCY/7.5;
LS = WATER/60;
if(FREQUENCY >= 0)
{
if(isinf(FREQUENCY))
{
lcd.clear();
lcd.init();
lcd.backlight();
//lcd.setCursor(0,0);
lcd.print("VOL :0.00");
//lcd.setCursor(0,14);
lcd.print("L/M");
lcd.setCursor(0,1);
lcd.print("TOTAL:");
//lcd.setCursor(0,1);
lcd.print( TOTAL);
//lcd.setCursor(13,1);
lcd.print(" L");
```

```
}
else
{
TOTAL = TOTAL + LS;
Serial.println(FREQUENCY);
lcd.clear();
lcd.init();
lcd.backlight();
//lcd.setCursor(0,0);
lcd.print("VOL.: ");
//lcd.setCursor(0,7);
lcd.print(WATER);
//lcd.setCursor(0,12);
lcd.print(" L/M");
lcd.setCursor(0,1);
lcd.print("TOTAL:");
//lcd.setCursor(1,7);
lcd.print( TOTAL);
//lcd.setCursor(1,12);
lcd.print(" L");
}
}
delay(1000);
}
```

2.4.3 heat exchanger code

```
const int heater_out = 2;
int Ro = 50, B =  3950, Rseries = 10;
float To = 298.15;
int heater_on_temperature = 28, heater_off_temperature = 31;

void setup() {
  pinMode(heater_out, OUTPUT);
}

void loop() {
  float Vi = analogRead(A0) * (5.0 / 1023.0);
  float R = (Vi * Rseries) / (5 - Vi);
  float T =  1 / ((1 / To) + ((log(R / Ro)) / B));
  float Tc = T - 273.15;
  // float Tf = Tc * 9.0 / 5.0 + 32.0;
  if (Tc <= heater_on_temperature) {
    //Turn ON heater_out
    digitalWrite(heater_out, HIGH);
  }
  else if (Tc >= heater_off_temperature) {
    //Turn off heater_out
    digitalWrite(heater_out, LOW);
  }
  delay(1000);
}
```

2.4.4 Air bubble detection code

```
int LDR sensor=A0;
int buzz=3;
int led=6;
int pump=2;
void setup() {
 Serial.begin(9600);
 pinMode(6,OUTPUT);
 pinMode(3,OUTPUT);
}
void loop() {
  int ldrvalue=analogRead(A0);
  if(ldrvalue=600 && ldrvalue=700)
  {
    digitalWrite(2,HIGH);
  }
else
{
  digitalWrite(2,LOW);
  digitalWrite(3,HIGH);
}
}
```

3.1 Result

In this project, we will showcase the outcomes for various cases, which will be analyzed in accordance with the forms included in this research.

3.1 .1 Blood volume control:

The following results illustrate the volume of blood circulating through the tubing system via the roller pump, tailored to meet the varying needs of different patients:

Fig (3.1) Show the different type of the blood volume flow rate.

3.1.2 Blood oxygenation:

In our project, we focused on the hollow fiber tube, which plays a crucial role in blood oxygenation. This design is capable of extracting oxygen from an external source, while the structure of the fiber continuously eliminates carbon dioxide from the blood. Additionally, we incorporated a flow meter in conjunction with the hollow fiber to ensure a consistent supply of oxygen to the blood during the cycling process. The figures below illustrate the outcomes of this design:

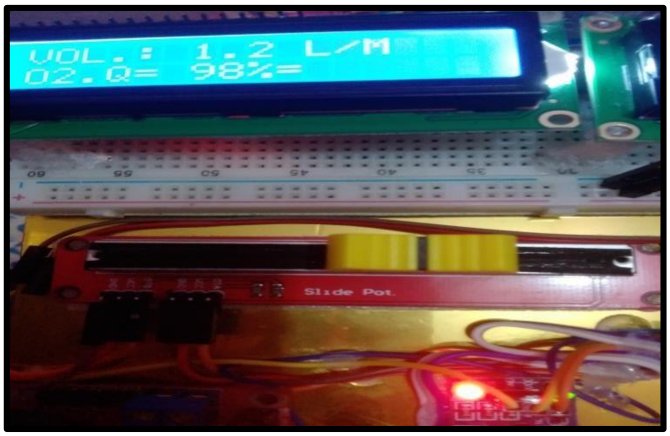

Fig (3.2) Show the oxygenation result process.

3.1.3 the temperature control result:

This design is founded on a waterproof sensor utilized for measuring the temperature of liquids, including blood. This capability enables the device to regulate the operation of the heater, ensuring that the blood temperature remains below 30°C, as illustrated below:

Fig (3.3) Show the working of the heat Exchanger unit .

Chapter FOURE

Four: Discussion

4.1 Discussion

In this section we will discuss some results and points according to the figures above .

1. According to the fig (4.1) the volume of the blood in L/M , its controlled by the slide variable resistor which has different value ranging from 0 to 1023 , this value can be the signal that control the volume of the blood , so after measure this value and calibrate it with the reading of the flow meter we design four type of the flow according to the type of the patients and them physiological body .

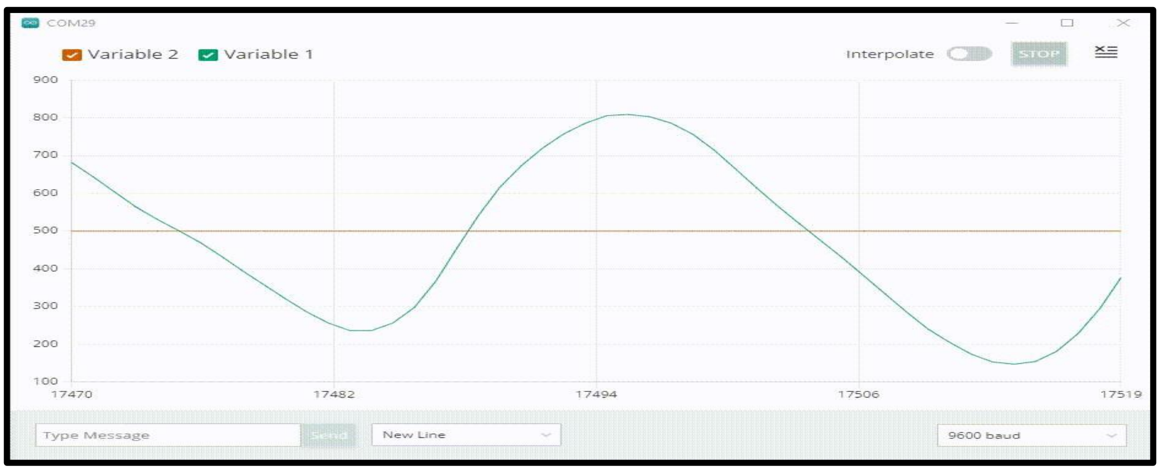

Fig (4.1) Show the behivaoure of the pot meter .

2. According to the fig (4.2), the hallow fiber mixed with flow meter provide blood oxygenation in time required about 20 sec to reach the 98% , so it can be start in 80% then 85% and so on to 98% as maximum..

Four: Discussion

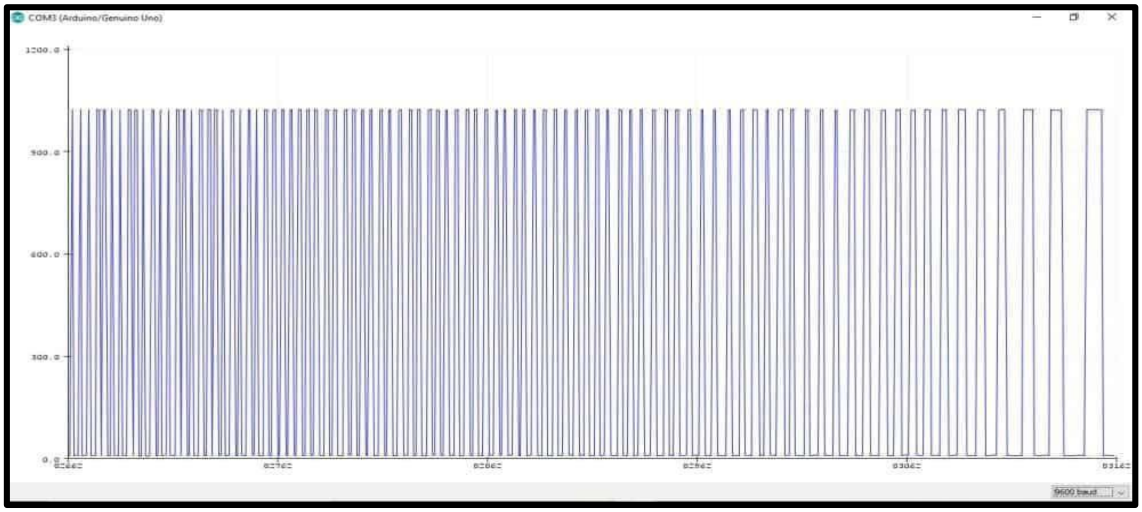

Fig (4.2) Show the working principle of the flow meter .

3. From the fig (4.3) we can see that the best fixer resistance its 4.7 k ohms in order to get in time reading (real time) reading for the temperature .

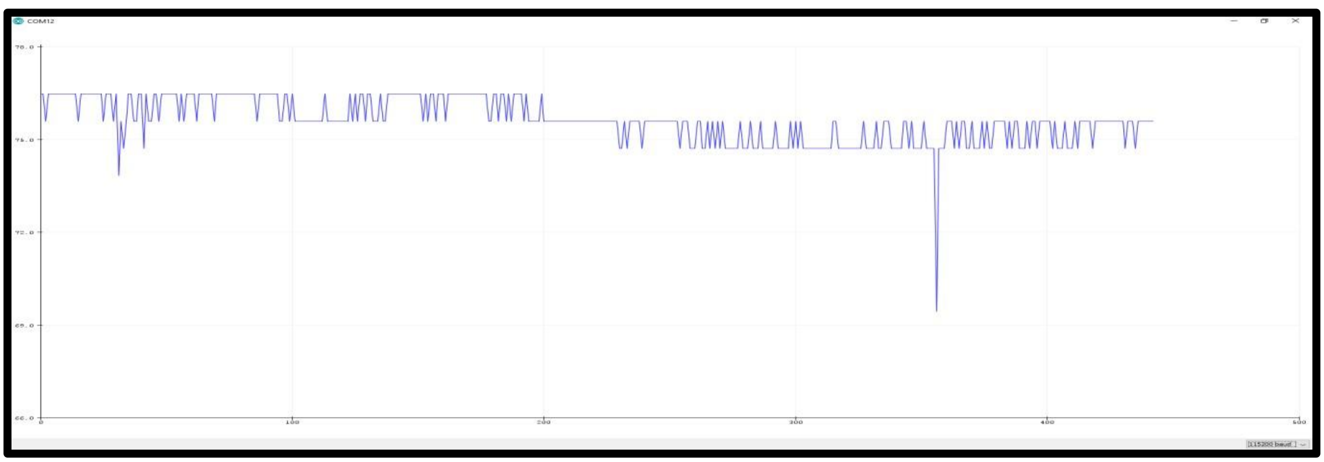

Fig (4.3) Show the working of the temp sensor with noise in reading .

4. From the fig (4.3) when the reading get above the 30 C the system will provide high temp alert and at the same time the heater will stop

working in order to return the temp to its acceptable value under the 30 C.

5.1 Conclusions

1. The roller pump is capable of accommodating various volume types depending on the current received from the relay circuit and the DC motor drive. Consequently, we offer flow rates of (0, 0.6, 1.2, 2.4) L/M in accordance with this current and electrical configuration.
2. The analog signal generated by the potentiometer operates based on the VDR principle, allowing for straightforward volume control of the blood flow rate.
3. The 4.7k ohm resistor, which is connected in parallel with the waterproof sensor, serves to enhance noise stability caused by overcurrent affecting the sensor during measurements. This noise can lead to unstable readings; therefore, the resistor functions as a stabilizing and noise-reducing component.

   To achieve precise measurements and optimal oxygenation, we have developed a fiber integrated with a flow meter. This configuration enables oxygenation to be accomplished within a mere 20 to 30 seconds, reaching a maximum level of 98% oxygenation.

5.2 Future Steps

1. The design can be using with data accusing monitor in order to monitor the vital sign of the patient under using of this device.
2. IOT arduino Cloud dashboard can be using according to the design below

:

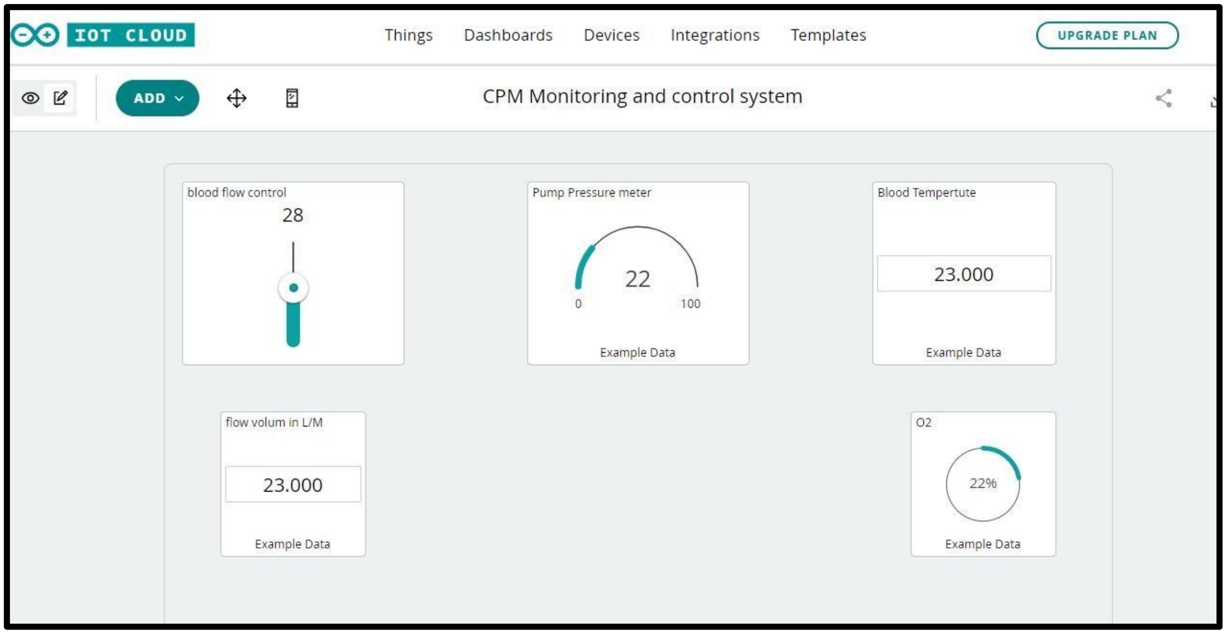

Fig (5.1) show IOT dashboard of the device.

3. This prototype can be in real using area if we using the compatible structure with human body like the roller pump or the hallow fiber oxygenator, but in our project we design the principle and not the real working state.
4. Ultrasonic air bubble detector can be using instead of the LDR sensor with some frequency calculation.
5. the outdoor monitoring and control can be adding for this project based on the xbee series protocol with frequency 2.4 GHZ or using the Wi-Fi cloud base.

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