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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 aspect of the open heart and lung system during open-heart surgery. This is due to the fact that, during such procedures, the heart and lungs temporarily cease their fundamental functions. Consequently, it is essential to utilize an alternative device or component that compensates for and replaces the functions of the heart and lungs, thereby ensuring the following capabilities: The apparatus serves to substitute the roles of the heart and lungs during open-heart surgery, facilitating blood circulation between the heart and the various organs of the body. This function is crucial in preventing blood clot formation within the body tissues when the natural circulation mechanism is not operational. Additionally, it regulates the volume of blood being pumped into the patient's body throughout the surgical procedure, with a pumping rate of 2.4 liters per minute for adults and 1.2 liters per minute for newborns.

The process of oxygenating the blood typically occurs through the lungs; however, during this specific type of procedure, the lungs are unable to perform their usual functions. It is essential to maintain the blood temperature below 30 degrees Celsius. In this project, we have developed a system that not only fulfills these requirements but also regulates the temperature of both the blood and the body. The device effectively lowers the blood temperature to below 30 degrees Celsius, thereby diminishing the metabolic activity of all body parts, which subsequently reduces their oxygen demand during the surgical procedure.

Keywords: Blood oxygenation system. Heart lung machine. Design and Implantation of oxygenation part. Using Arduino in medical device.

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1. Introduction

Cardiopulmonary bypass (CPB) machines play an essential role in open-heart surgeries by providing continuous oxygenation and blood circulation. These devices temporarily take over the functions of the heart and lungs, enabling surgeons to perform procedures on a motionless and blood-free heart. The main components of CPB systems include pumps, oxygenators, and heat exchangers, each of which is crucial for maintaining the stability of the patient. Nevertheless, existing CPB systems are costly and necessitate intricate maintenance. This project aims to develop a cost-effective prototype for the oxygenation component of the CPB machine, utilizing commonly available parts. This paper discusses the design, implementation, and performance outcomes of the system, emphasizing its potential as a practical and accessible solution for medical use.

1.2 Objectives

The project aims to achieve the following:

1. Develop a low-cost oxygenation system using Arduino technology to replace the function of the lungs during open-heart surgeries.
2. Design a mechanism for controlled blood flow and temperature regulation to reduce metabolic activity during operations.
3. Integrate an air bubble detection system to enhance safety and prevent complications such as embolisms.
4. Demonstrate the feasibility of using widely available electronic components in medical applications.

2. Components

The prototype consists of the following main components:

1. Arduino Uno: A microcontroller for managing the system's operations.
2. Roller Pump: To simulate blood circulation with adjustable flow rates.
3. Oxygenator: A hollow fiber structure to facilitate gas exchange.
4. Heat Exchanger: Maintains blood temperature below 30°C.
5. Air Bubble Detector: Detects air bubbles using light sensors and alerts the system.
6. LCD Display: Provides real-time monitoring of blood flow and temperature.
7. Power Supply and Relays: To manage the electrical requirements of the components.

2.1 Working Principle of the Project

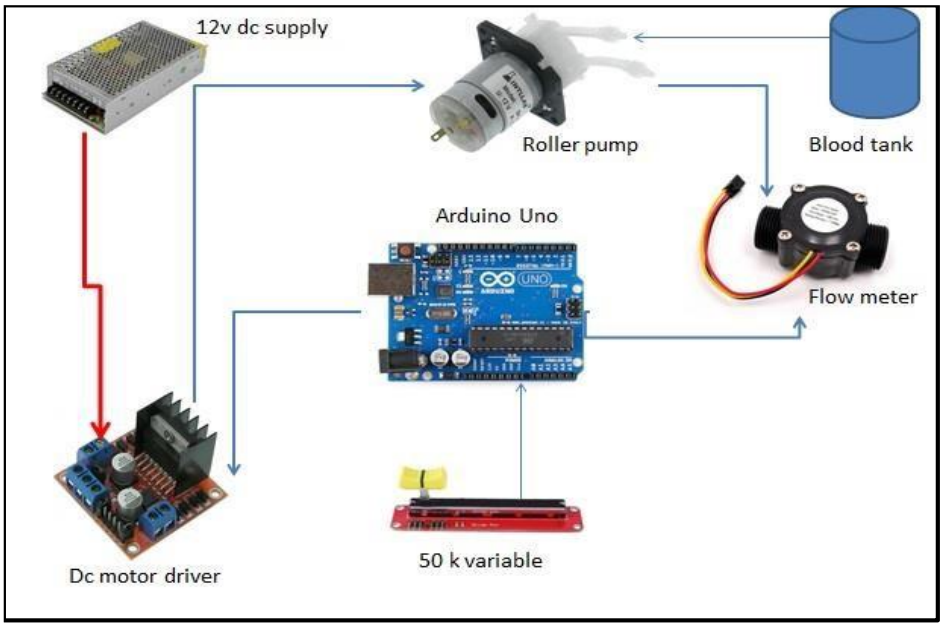
The operation of the device is based on the mechanism that withdraws and returns blood to the patient's body. Blood undergoes several critical stages, with the most significant being the removal of carbon dioxide and its replacement with oxygen. This essential function is performed by a roller pump that mimics the heart's activity. The flow rate can be adjusted according to the patient's requirements, while the oxygenation process employs a hollow fiber oxygenator to enhance gas exchange efficiency. A heat exchanger is also included to control the blood temperature, keeping it below 30°C to minimize the body's metabolic activity during surgical procedures. Furthermore, a bubble detection system is incorporated to safeguard the patient by preventing the occurrence of air embolisms. Together, these components ensure the system operates reliably and efficiently.

2.3 Design with Final System Diagram

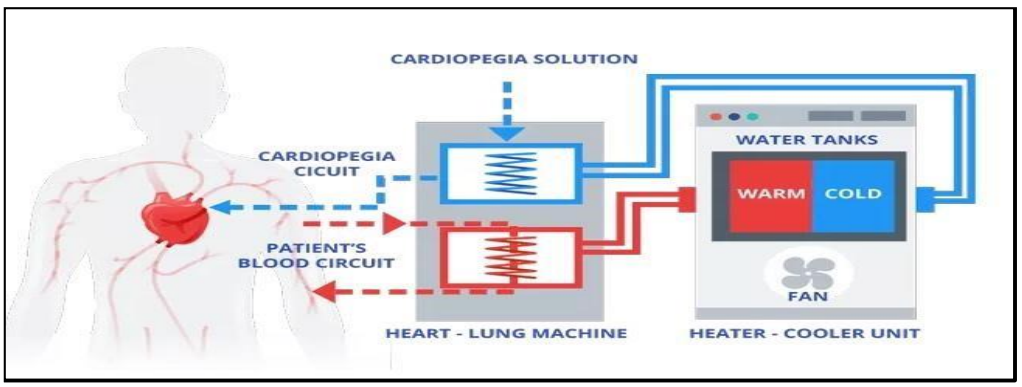
The design includes four primary stages, which are implemented using the following mechanisms:

1. Pumping Stage: Employs a roller pump controlled by Arduino for precise blood circulation.

2. Oxygenation Stage: Utilizes a hollow fiber oxygenator for effective gas exchange.
3. Heat Exchange Stage: Maintains blood temperature using a water-based heat exchanger controlled by sensors.
4. Bubble Detection Stage: Detects air bubbles in the blood and triggers alerts to prevent complications.



the working of the pumping unit



the working principle of the device

4. Results:

The results of the prototype's operation are summarized as follows:

1. Blood Flow Control: The roller pump successfully regulated blood flow at rates suitable for adults (2.4 L/min) and newborns (1.2 L/min).
2. Oxygenation Efficiency: The hollow fiber oxygenator achieved 98% oxygenation within 20–30 seconds.
3. Temperature Regulation: The heat exchanger effectively maintained blood temperature below 30°C, reducing metabolic activity and oxygen demand.
4. Bubble Detection: The system accurately identified air bubbles and activated safety measures.

5. Conclusion:

1. The roller pump can be using for different types of volume according to the current receive from the rely circuit and the DC motor drive, so we provide (0, 0.6, 1.2, 2.4) L/M based on this current and electrical structure.
2. The analog signal from the pot meter work as the VDR principle, so this analog signal able to make volume control of the blood flow rate easily.
3. The 4.7k ohm Resistance that connect in parallel with the water proof sensor, its provide noise stability that caused by the over current come to the sensor during the measuring, and this noise make the reading instable, so this resistance work as fixer and noise removal.
4. In order to obtain accurate measurements and high effect oxygenation we design the fiber mixed with flow meter; this structure can provide the oxygenation in just 20 to 30 sec to reach the maximum 98% of the oxygenation.

6. References

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