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SpO2 BASED OXYGEN DELIVERY SYSTEM

Anand subramaniam*, Anandhakumar M, Naveenprasad R***, Ayyappan G******

*(Department of Biomedical Engineering, Sri Ramakrishna Engineering College, Coimbatore
Email: anandsubramaniam.1407003@srec.ac.in)
** (Department of Biomedical Engineering, Sri Ramakrishna Engineering College, Coimbatore
Email:anandhakumar.1407004@srec.ac.in)
***(Department of Biomedical Engineering, Sri Ramakrishna Engineering College, Coimbatore
Email: naveenprasad.1407028@srec.ac.in)
****(Department of Biomedical Engineering, Sri Ramakrishna Engineering College, Coimbatore
Email: ayyappan.1407007@srec.ac.in)

Abstract:

Oxygen therapy is a very common procedure performed in both hospital and personal care which involve a controlled oxygen gas delivery for victims of respiratory disorders. Handling this system in personal care has been a challenge over the years, since patients may not be well aware of the system and their conditions. However, the hospital care also face some challenges that include, lack of proper monitoring by the authorities for a periodic assessment of the patients and fail to regulate the supply even after target oxygen saturation is achieved that may lead to hyperoxia. A system is proposed to solve the problems mentioned above by continuously monitoring a target saturation level that is user definable based on the clinical guidelines and automatically control the flow of oxygen delivery to the patient.

Keywords — **Oxygen therapy, personal care, controlled oxygen delivery, respiratory disorder, oxygen saturation, hyperoxia.**

I. INTRODUCTION

Oxygen is the most essential gas for the functioning of human body. The air inhaled contains 21% oxygen, this might be sufficient for people with healthy lungs and may not be enough for those suffering from COPD, hypoxemia or hypoxia. Oxygen therapy refers to the administration of supplemental oxygen for those patients who are suffering from these respiratory disorders or unable to take in desired amount of oxygen on their own. Oxygen therapy is being widely used in both paediatric and adult care both in hospitals and home. Many adults are even subjected to a 24x7 administration of oxygen supply due to their inability of breathing and for their prolonged risk of turning hypoxemic.

Oxygen saturation is the critical parameter that defines the oxygen content inside a patient's body and is used to monitor them from respiratory disorders. The oxygen saturation is commonly denoted as the SpO2 value and is acquired with the help of a pulse oximeter or SpO2 probe connected with the finger of the patient. The probe consist of a red LED and an IR diode that is connected to a driver that simultaneously drives them. The absorbance value of both the Red LED and IR diode is used for the calculation of SpO2 value. For a normal person the range of SpO2 can vary from 94% to 99%. For patients with mild respiratory disorders the SpO2 value should 90% or above. Supplementary oxygen should be used if SpO2 level falls below 90%, which is unacceptable for a prolonged period of time.

Oxygen therapy is prescribed by the doctor or clinician according to the type of disorder the patient faces. The clinician mainly prescribes the target oxygen saturation, target flow rate of oxygen supplement delivery and the mask to be used. This classification is purely based on clinical guidelines followed universally as mentioned in Table 1. Then the procedure of oxygen therapy is administered to the patient where, the oxygen saturation of the patient is monitored periodically and the flow rate is adjusted manually by either the patient themselves or by the bystanders. The flow rate shall be increased in case if the saturation value falls below the target value specified by the clinician and the flow rate is decreased if the saturation value exceeds the target saturation. The flow is uninterrupted when the saturation value is in range of the specified target range.

Since oxygen is a drug, too much or too little of it can be life threatening. If the required oxygen concentration is not met, it leads to a condition called hypoxemia where the tissues does not receives the adequate amount of oxygen for metabolism leading to cell degeneration in the entire body which is potentially dangerous. The overdose of Oxygen can lead to yet another life threatening disease named hyperoxia which affects the brain tissues initially and may lead to paralysis. So improper attention given to the patient can prove vital and is a problem demanding a solution. Excess delivery of unwanted oxygen after meeting the target saturation leads to its wastage which is not appreciating because oxygen gas is not abundant and requires energy and resource for its extraction. So conservation of the gas is crucial for sustenance and hence prove to be another demanding factor requiring solution.

TABLE I
OXYGEN PRESCRIPTION BASED ON CLINICAL GUIDELINES

S. No	Indication	Target oxygen saturation	Initial therapy
1.	Type I respiratory failure	94-98%	Nasal cannulae 2-4 L/min or simple face mask 5-10 L/min
2.	Type II respiratory failure	88-92%	Venturi mask 24-28%
3.	Critical illness	94-98%	Reservoir mask 15L/min
4.	Carbon monoxide poisoning	100%	Reservoir mask 15 L/min

II. METHODOLOGY

The steps involved in implementation are discussed below.

A. *Designing the system:*

The arduino based SpO2 module named MAX 30102 is interfaced with the arduino kit to measure the oxygen saturation value. A proportional control valve is interfaced with the arduino kit to control the flow of oxygen gas delivery. In addition to this a flow sensor is also integrated to monitor the flow of oxygen gas to the patient. The LCD display interfaced with the system displays the SpO2 value and the flow value and the 4x4 kepad can be used to input the mode of disease. The block diagram of the prototype have been illustrated in fig.1

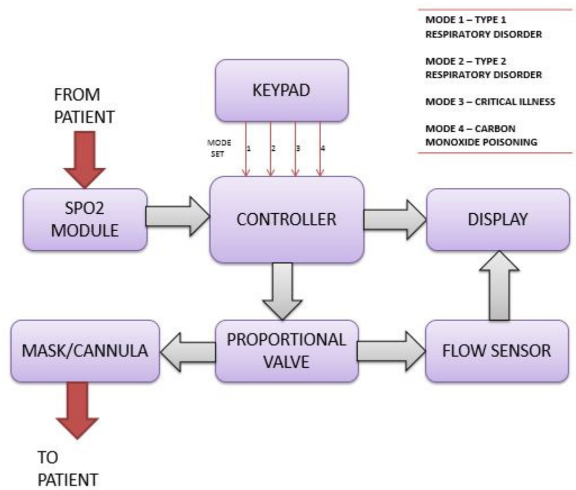


Fig. 1 Block Diagram of the Proposed System

B. *Implementing the algorithm*

The program for continuously acquiring the SpO2 value from the module is implemented first. Then the modes are classified based on the types of respiratory disorder, for each mode a specified target saturation value and flow value is set to be monitored. The program to input modes using the keypad interface is implemented. The SpO2 value of the patient serves as a feedback for controlling the oxygen delivery flow, if the saturation value is below the target value the flow is increased and if the saturation value exceeds the target the flow rate is decreased. The flow rate is controlled using the proportional valve interfaced with the controller.

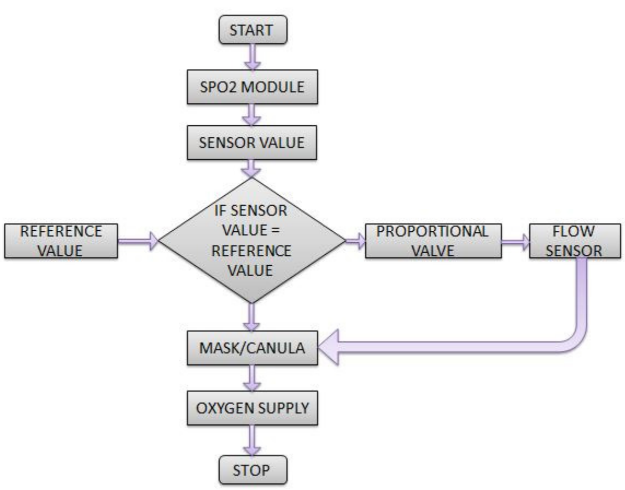
C. *Testing the prototype*

The program code was executed and the system was interfaced and tested. The MAX30102 module picked up the SpO2 value and was displayed. The modes were successfully inputted using the keypad and each mode were tested manually. For testing the saturation levels of a diseased condition the SpO2 value was changed deliberately using a potentiometer and the working of the prototype was tested.

III. WORKING

When the system is turned ON, the display asks to choose a mode of disease to be monitored and the help button shall brief the user on different modes in case of any doubts. There a four modes classified in this system for Type I and Type II respiratory disorder, one for carbon monoxide poisoning and other for critical illness. Once the mode is selected the system displays the target oxygen saturation and flow rate being monitored, it also suggests the user on the type of mask to be used. The SpO2 probe connected to the patient reads the oxygen saturation level and is displayed in real time. This saturation value is compared with the target value by the controller and based on this the flow rate is controlled. If the oxygen saturation value of thepatient falls below the target saturation level the system automatically sends a feedback to increase the flow rate of oxygen delivery by adjusting the proportional valve. If the oxygen saturation level seems to exceed the target saturation range the flow rate to the patient is decreased and once the target is achieved the flow rate is maintained. The work flow of the proposed system have been described in fig.2.

Fig. 2 Work Flow of the System



IV. RESULT AND DISCUSSION:

The SpO2 value obtained from the module where compared with the values obtained using a wireless pulse oximeter to check accuracy. It was found that both values seemed to match when used in different people. Next to test the working of the system, the input SpO2 module was interchanged with a potentiometer to induce a difference in the saturation value to manipulate a diseased condition. It was recorded that when the saturation value was dropped below the saturation value the flow rate increased and for a value exceeding the target the flow rate started decreasing. When the oxygen saturation was maintained in the target range the flow rate was maintained and left unchanged and hence these results show the proof of concept. The completed prototype module of the proposed system is shown in fig.3.The individual test results for each mode have been tabulated below(Table.II-V).

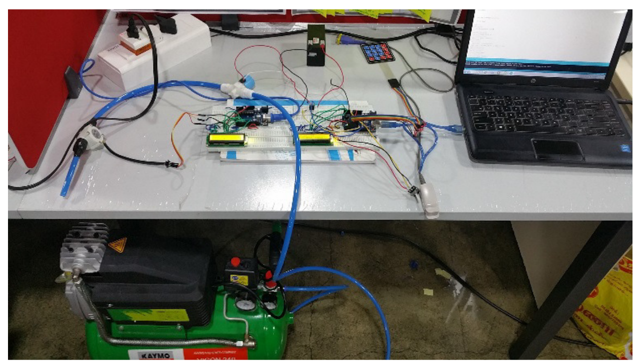


Fig. 3 Prototype of the Proposed System

Table. II illustrates the test result for mode 1 with standard saturation level from 94-98%.

TABLE II
TEST RESULT FOR MODE 1

Trial	MODE 1(Type 1 Respiratory Disorder)		
	Acquired & Manipulated value	**Comparison with Standard value**	**Flow status**
1.	89 92 91	Less	Flow rate increases.
2.	94 96 97	Equal	Flow rate Maintained .
3.	99 99.8 100	Greater	Flow rate decreases

Table. III illustrates the test result for mode 2 with standard saturation level from 88-92%.

TABLE III
TEST RESULT FOR MODE 2

Trial	MODE 2(Type 2 Respiratory Disorder)		
	Acquired & Manipulated value	**Comparison with standard value**	**Flow status**
1.	87 83 85	Less	Flow rate increases.
2.	91 88 90	Equal	Flow rate Maintained.
3.	94 96 98	Greater	Flow rate decreases

Table. IV illustrates the test result for mode 3 with standard saturation level from 94-98%.

TABLE IV
TEST RESULT FOR MODE 3

Trial	MODE 3(Critical illness)		
	Acquired & Manipulated value	**Comparison with Standard value**	**Flow status**
1.	93 88 90	Less	Flow rate increases.
2.	95 97 98	Equal	Flow rate Maintained.
3.	99 99.8 100	Greater	Flow rate decreases

Table. V illustrates the test result for mode 4 with standard saturation level of 100%.

TABLE V
TEST RESULT FOR MODE 4

Trial	MODE 4(carbon monoxide poisoning)		
	Acquired & Manipulated value	**Comparison with Standard value**	**Flow status**
1.	94 87 92	Less	Flow rate increases.
2.	100	Equal	Flow rate Maintained.

V. CONCLUSION & FUTURE WORK

Improper and unregulated oxygen supply in oxygen therapy are a serious cause for many tragedies. The inadequate supply of oxygen can lead to hypoxemia and excess supply of oxygen can cause hyperoxia which can be life threatening. The system developed shall perform as an assistive device for the personal care patients without much knowledge on oxygen therapy. It ensures a continuous and uninterrupted oxygen delivery to the patient and make sure that the patient only receives the prescribed or needed dose of oxygen saving them from risks of hyperoxia and hypoxemia, this also help conserve oxygen gas by limiting the unwanted supply to the patient.

In future, the system can be integrated with an IoT module to send real time patient data over a cloud which can be accessed anywhere. So that in hospital care the concerned authorities can view the data in their main desk. In personal care, the by stander can monitor the patient while roaming away from home. This ensures a constant monitoring of the patient and hence improving the safety and quality of the therapy.

An object detection algorithm or a sensor module can be implemented with the system to make sure that the patients does not remove the mask unknowingly which can prove dangerous especially when the treatment is automated.

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