engineering proceedings

MDPI

Proceeding Paper

Development and Prototyping of Oxygen Analyzer †

Bidheyak Pokharel,Thiyam Deepa Beeta *, Sachin Devkota and Devanand Kumar Sah

Department of Biomedical Engineering, Vel Tech Rangarajan Dr. Sagunthala R & D Institute of Science and Technology, Chennai 600062, India; bidheyakpokharel@gmail.com (B.P.); shahsdevanand949@gmail.com (S.D.); devkotasachin7674@gmail.com (D.K.S.)

* Correspondence: thiyamdeepabeeta@veltech.edu.in

† Presented at The 11th International Electronic Conference on Sensors and Applications (ECSA-11), 26–28 November 2024; Available online: https://sciforum.net/event/ecsa-11.

Abstract: In the context of developing countries, medical instruments are imported from foreign countries. To overcome this challenge, the design of an oxygen analyzer using ultrasonic flow sensor technology and a microcontroller while promoting local innovation and reducing dependency on imported equipment is presented here. Moreover, it aims to enhance patient care by ensuring accurate oxygen concentration and flow rate measurements on ventilators and oxygen concentrators. The measure data using the proposed system has been validated by comparing it with the data obtained using the standard oxygen analyzer equipment like VT-900 Gas Analyzer Fluke Biomedical and Ultra Max oxygen analyzer. Measurements were conducted on hospital ventilators with oxygen concentration (FiO_2) settings from 21% to 100% in 5% increments, and flow rate settings from 1 L/m to 10 L/m. Results show an error value of 2.1% for oxygen concentration and 0.6 L/m for flow rate measurements. Based on the analysis, it can be concluded that the proposed system works well. Additionally, it offers portability, affordability, and user-friendliness, overcoming the limitations of existing options. This project seeks to contribute to the healthcare infrastructure in developing countries like Nepal, India, Bangladesh, etc by providing a domestically produced solution for oxygen analysis.

Keywords: oxygen analyzer; ultrasonic flow sensor; microcontroller; ventilator

Citation: Pokharel, B.; Devkota, S.; Sah, D.K. Development and Prototyping Of Oxygen Analyzer. *Eng. Proc.* **2024**, *6*, x. https://doi.org/10.3390/xxxxx

Academic Editor(s): Name

Published: 26 November 2024

1. Introduction

The introduction should briefly place the study in a broad context and define the purpose of the work and its significance. An oxygen Analyzer is a device that measures Oxygen concentration in the ambient Air, of Oxygen Cylinders, Oxygen Concentrators, Medical Ventilators, Incubators, etc. [1,2]. It reads Oxygen Concentration in percentage. Also, this vital device is used in various fields, including medical, industrial, and environmental applications, to measure oxygen concentration in gasses accurately. This instrument ensures safety, quality control, and process optimization in diverse industries [2]. In medical settings, oxygen analyzers are indispensable for monitoring and controlling the oxygen levels in respiratory gasses delivered to patients during anesthesia, mechanical ventilation, and respiratory therapy. They help healthcare professionals ensure that patients receive the appropriate amount of oxygen, critical for maintaining physiological function and preventing hypoxia-related complications [4,5]. In industrial processes, oxygen analyzers are employed to monitor and control oxygen concentrations in manufacturing environments, such as pharmaceutical production, food and beverage processing, and chemical synthesis. These analyzers aid in maintaining optimal conditions for chemical reactions, enhancing product quality, and ensuring workplace safety. Furthermore, oxygen analyzers are crucial in environmental monitoring applications, including air quality assessment, combustion control, and environmental research. By accurately measuring oxygen levels in ambient air and emissions, these instruments facilitate compliance with environmental regulations, identification of pollution sources, and mitigation of environmental impact [6]. Traditionally, oxygen analyzers have relied on electrochemical, paramagnetic, or zirconia-based sensors for oxygen detection. However, advancements in sensor technology, microcontrollers, and display systems have enabled the development of more compact, cost-effective, and user-friendly oxygen analyzers. This project aims to design and develop an oxygen analyzer utilizing innovative components, including NL-PD10NF40 Oxygen Concentration Sensor, arduino nano microcontrollers, and OLED displays. By leveraging these technologies, the project seeks to create a portable, low-cost, and user-friendly oxygen analyzer tailored to healthcare facilities, research laboratories, and industrial operations in the developing country. The introduction of a domestically produced oxygen analyzer holds significant potential for improving healthcare infrastructure, promoting local innovation, and reducing dependency on imported equipment. Through rigorous testing, calibration, and optimization processes, this project endeavors to deliver a reliable and efficient oxygen analysis solution that addresses the specific challenges and requirements.

2. Methodology

2.1. Data Acquisition

The parameters such as concentration, flow rate, temperature, pressure, and volume were taken from the Ventilator and the oxygen concentrator. Measurements were made 16 times. After that, measurements were made using a comparison device, namely Ultramax O_2 Oxygen Analyzer and Fluke Biomedical Gas Flow Analyzer VT-900A [7].

2.2. Components and Tools

The tools used are the NL-PD10NF40 sensor using one sensor that can read the output oxygen concentration, oxygen flow rate, and temperature. After that, Arduino Nano is used as a Microcontroller and connected to NLPD10NF40 as a sensor to read output from the Oxygen Concentrator and then display it on the 0.98-inch OLED Display.

2.3. Block and Flow Diagram

2.3.1. Working Principle

When the "ON" button is pressed, the voltage from the battery is then sent to Arduino Nano VCC where the positive terminal is connected and the negative terminal is connected to the GND pin after that the sensor detects concentration, flow rate, and temperature from the ventilator and concentrator output, the output of the sensor is divided into namely concentration, flow rate, and temperature. The sensor Rx pin is connected to the Arduino TX pin and the sensor TX pin is connected to the Arduino Nano Rx pin for serial communication and the sensor follows USART protocol for communication.

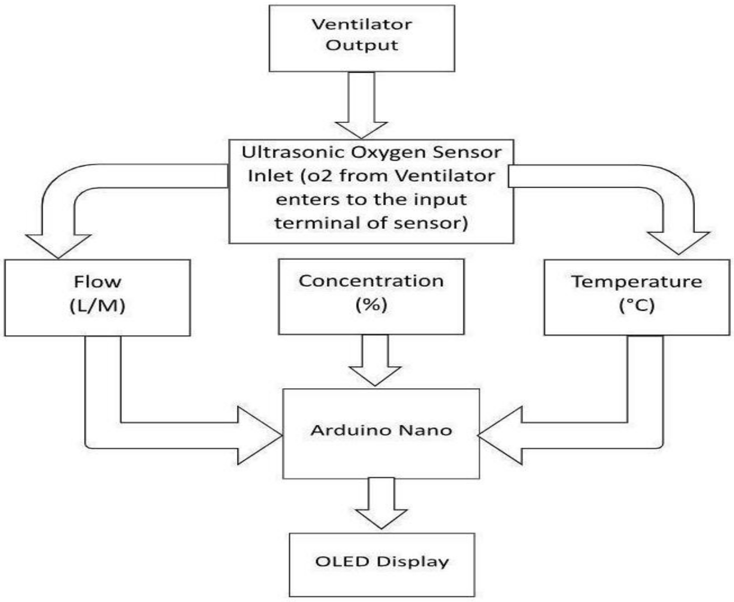

Figure 1. Flow Diagram of Oxygen Analyzer.

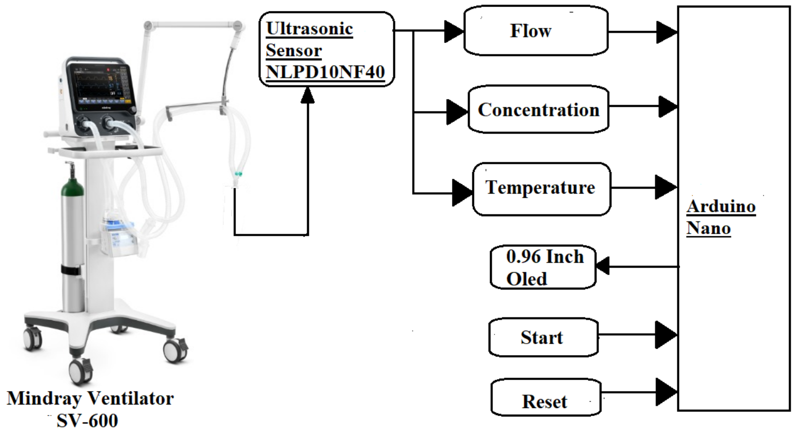

Figure 2. Block Diagram of Oxygen Analyzer.

2.4. Design

The material selected for our 3D printing endeavor was Polylactic acid (PLA), a biodegradable polyester known for its environmental sustainability and versatility. PLA is derived from renewable resources like cornstarch or sugarcane, making it an eco-friendly choice. Furthermore, PLA is compatible with a wide range of 3D printers, facilitating smooth printing processes and ensuring high-quality results.

3. Result and Analysis

Three oxygen analyzers were used to gather data: the VT 900 Gas Analyzer from Fluke Biomedical, the Ultramax Oxygen Analyzer, and our project's oxygen analyzer. The results are shown below in Table 1.

The ventilator was set to concentrations of 21% to 100% with an increment of 5%. After each concentration was set, the three devices were used to measure the actual percentage at each setting, and the readings were recorded in an Excel sheet. The VT 900 Gas Analyzer was used first, followed by our project's analyzer, and finally, the Ultramax Oxygen Analyzer. After recording the data, absolute errors between the standard ventilator values and the VT 900 Gas Analyzer, project analyzer, and Ultramax Oxygen Analyzer readings were calculated. The mean absolute errors for each dataset were then computed.

To analyze the accuracy of each analyzer, the data collected from each concentration setting was compared to the standard value and plotted. The slope of the line between the measured and standard values was calculated to assess the accuracy. These data show the largest error value of approximately 0.9 L/M at the setting points of 1 L/M and the smallest error value of 0.2 L/M at the setting point of 8 L/M.

Table 1. Measurement of Oxygen Concentration.

Set FiO_2 at the Ventilator	Achieved FiO_2 at VT 900	Error (VT900)	Achieved FiO_2 at Oxygen Analyzer	Error (Oxygen analyzer)	Achieved FiO_2 at Ultra Max O_2 Analyzer	Error(Ultra Max O_2 Analyzer)
21	21.29	0.29	21	0	20.1	0.9
25	25.04	0.04	23	2	23.8	1.2
30	30.075	0.075	30.5	0.5	28.4	1.6
35	35.06	0.06	37.3	2.3	33.3	1.7
40	40.23	0.23	43.3	3.3	37.81	2.19
45	45.075	0.075	49.4	4.4	42.5	2.5
50	50.35	0.35	53.4	3.4	47	3
55	55.375	0.375	57.5	2.5	51.6	3.4
60	60.77	0.77	61.9	1.9	56.1	3.9
65	66.025	1.025	66.2	1.2	60.9	4.1
70	70.69	0.69	70.3	0.3	65.42	4.58
75	75.67	0.67	75.5	0.5	69.9	5.1
80	80.8	0.8	78.8	1.2	74.2	5.8
85	85.9	0.9	82.5	2.5	78.61	6.39
90	90.14	0.14	87.3	2.7	82.8	7.2
95	94.14	0.86	92.32	2.68	87.3	7.7
100	99.45	0.55	95.6	4.4	91.45	8.55
Error		0.46470588		2.10470588		4.10647058

From these data, the largest error value is approximately 5 percent at the setting points of 40 and 100 percent and the smallest error value is 0.3 percent at the setting point of 70 percent. Similarly, for the flow rate measurement, the oxygen concentrator was set from 0 L/m up to 10 L/m. In each set point all three devices were used to measure the flow rate from the concentrator one after another in each set point. All the data that was obtained was recorded. The VT 900 Gas Analyzer was used first, followed by our project's analyzer, and finally, the Ultramax Oxygen Analyzer.

4. Discussion

Our testing protocol involved assessing oxygen levels ranging from 21% to 100%, with increments of 5% and flow rate settings from 1 L/m to 10 L/m. These error values provide insights into the consistency and variability of our measurements across different settings. Throughout our testing, we observed variations in the error values across different oxygen concentration and flow rate settings. These variations highlight the inherent challenges and complexities associated with accurately measuring oxygen levels and flow rates in a clinical setting. One notable finding from our analysis is the standard deviation values obtained for oxygen concentration and flow rate measurements. Despite the variability observed in our measurements, the standard deviation values suggest a reasonable degree of consistency in our data. This includes ensuring that our measurement system is capable of accurately capturing oxygen levels up to 95.6% and optimizing the flow rate measurement capabilities to minimize errors.

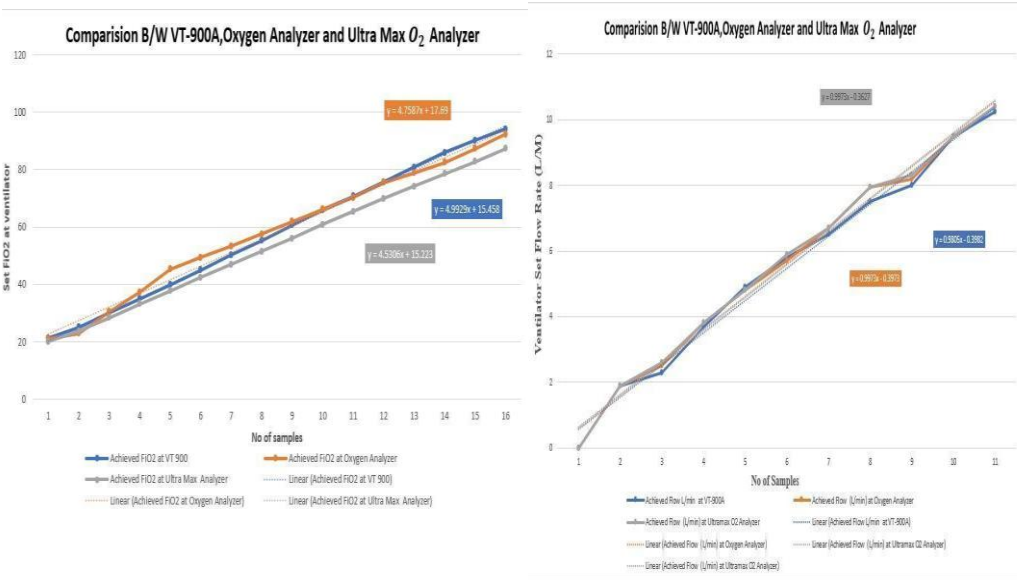

Figure 3. (**Left**) FiO_2 and (**Right**) Oxygen Flow Rate comparison between VT-900, Oxygen Analyzer, UltraMax and developed Oxygen Analyzer.

Table 2. Oxygen flow rate measurement.

Set Flow from Concentrator (L/min)	Achieved Flow L/min at VT-900A	Error at VT-900A	Achieved Flow (L/min) at Oxygen Analyzer	Error at Oxygen Analyzer	Achieved Flow (L/min) at Ultramax O_2 Analyzer	Error at Ultra Max O_2 Analyzer
0	0	0	0	0	0	0
1	1.9	0.9	1.9	0.9	1.9	0.9
2	2.3	0.3	2.5	0.5	2.6	0.6
3	3.7	0.7	3.8	0.8	3.8	0.8
4	4.9	0.9	4.8	0.8	4.8	0.8
5	5.8	0.8	5.7	0.7	5.88	0.88
6	6.5	0.5	6.7	0.7	6.7	0.7
7	7.5	0.5	7.95	0.95	7.95	0.95
8	8	0	8.2	0.2	8.3	0.3
9	9.5	0.5	9.5	0.5	9.5	0.5
10	10.23	0.23	10.4	0.4	10.4	0.4
Error		0.4845454		0.586363		0.62090909

5. Conclusions

By creating a convenient, cost-effective gadget for measuring oxygen concentration, the extend points to improve the openness, reasonableness, and unwavering quality of oxygen examination innovation within the nation. Through a precise approach enveloping plan, prototyping, testing, and approval, the extend has effectively illustrated the achievability and adequacy of locally sourced and made arrangements in the assembly of the particular needs of developing country`s healthcare and inquire about divisions. After testing and recovering information on the estimation information employing a ventilator as a comparison, our testing convention included surveying oxygen levels extending from 21 percent to 100 percent, with increases of 5 percent, and stream rate settings from 1 L/m to 10 L/m.

Author Contributions:.

Funding:

Institutional Review Board Statement:

Informed Consent Statement:

Data Availability Statement:

Conflicts of Interest:

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