

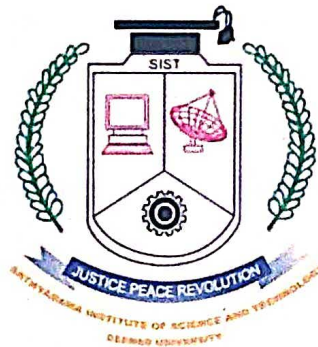
Development of Breath Analyzer for COPD and Other Pulmonary Disorders

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Technology degree in Biomedical Engineering

By

John Wesley. I (40240014)

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**DEPARTMENT OF BIOMEDICAL ENGINEERING
SCHOOL OF BIO AND CHEMICAL ENGINEERING**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade "A++" by NAAC

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APRIL 2024



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **John Wesley. I (40240014), Shyam Sundar. M (40240047)** who have done the project work as a team and carried out the project entitled "**Development of Breath Analyzer for COPD and Other Pulmonary Disorders**" under our supervision from November 2023 to April 2024.

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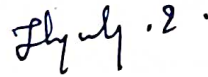
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DECLARATION

We John Wesley. I (40240014), Shyam Sundar. M (40240047) hereby declare that the Project Report entitled **Development of Breath Analyzer for COPD and Other Pulmonary Disorders** done by us under the guidance of **Dr. Grace Kanmani Prince, M.E., Ph.D** is submitted in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Biomedical Engineering.

DATE: 05/04/2024

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ABSTRACT

Chronic obstructive pulmonary disease is a chronic inflammatory lung disease that causes obstructed airflow from the lungs. There are two major conditions that contribute for this disease namely Emphysema and Chronic Bronchitis. It is the second leading cause of death in the world and affects an estimated 300 million people, while in India it is the second leading cause of death and affects an estimated 53 million people. COPD is commonly misdiagnosed. Many people who have COPD may not be diagnosed until the disease is advanced. Sometimes affected people may be treated with severe steroids without acknowledging whether the patient is suffering from exacerbated COPD or stable COPD. Long period required for the diagnosis of COPD makes it difficult for medical personnel in providing the necessary medication in a timely manner. The diagnosis methods are mostly invasive and cost inefficient. Various studies in the last twenty years demonstrate that the volatile organic compounds from the exhaled air could be used for the identification of metabolic activities undergoing inside the human body. Based on multiple studies and various research, several VOCs are found accountable for diagnosing various specific respiratory disorders. The employment of a point of care device that comprises various gas sensors that could identify the presence of the VOCs responsible for the respective respiratory disorders may help the medical personnel to respond effectively. The development of E-Nose helps in the current medical age to a large extent. But it can't be afforded by the local hospitals and primary health centers. In India, a total of nearly fifty thousand primary health centers are functioning to help this cause an initiative has been taken to develop a handheld breath analyzer for COPD and other pulmonary disorders like asthma, tuberculosis, and emphysema. The volatile organic compounds in the exhaled breath of humans are collected and analyzed with appropriate sensors for COPD and other pulmonary disorders.

Keywords: COPD, Pulmonary Disorders, Handheld Breath Analyzer, Sensors, Volatile Organic Compounds

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LIST OF ABBREVIATIONS

ABBREVIATIONS	DEFINITIONS
AGC	Automatic Gain Control
ADC	Analog to Digital Converter
COPD	Chronic Obstructive Pulmonary Disorder
CT	Computed Tomography
ECO ₂	Equivalent Carbon Dioxide
E-nose	Electronic Nose
GC	Gas Chromatography
IDE	Integrated Development Environment
MCU	Microcontroller Unit
MOX	Metal Oxide
MS	Mass Spectrometry
NTC	Negative Temperature Coefficient
PPB	Parts Per Billion
PPM	Parts Per Million
TDFN	Thin Dual Flat No-lead
TVOC	Total Volatile Organic Compounds
USB	Universal Serial Bus
VGA	Video Graphics Array
VOC	Volatile Organic Compounds

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CHAPTER 1

INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a common and treatable disease characterized by progressive airflow limitation and tissue destruction. It is associated with structural lung changes due to chronic inflammation from prolonged exposure to noxious particles or gases, most commonly cigarette smoke. Chronic inflammation causes airway narrowing and decreased lung recoil. The disease often presents with cough symptoms, dyspnea, and sputum production. Symptoms can range from being asymptomatic to respiratory failure.

COPD is primarily present in smokers and those over 40. Prevalence increases with age and is currently the third most common cause of morbidity and mortality worldwide. In 2015, the prevalence of COPD was 174 million, and there were approximately 3.2 million deaths due to COPD worldwide. However, the prevalence is likely to be underestimated due to the under diagnosis of COPD. It will typically present in adulthood and often during the winter months. Patients usually present with complaints of chronic and progressive dyspnea, cough, and sputum production. Patients may also have wheezing and chest tightness. While a smoking history is present in most cases, there are many without such a history. They should be questioned on exposure to second-hand smoke, occupational and environmental exposures, and family history. COPD is a complex interaction between Asthma, Chronic bronchitis and emphysema.

COPD is commonly misdiagnosed. Many people who have COPD may not be diagnosed until the disease is advanced. Tests may include:

Lung (pulmonary) function tests: These tests measure the amount of air you can inhale and exhale, and whether your lungs deliver enough oxygen to your blood. During the most common test, called spirometry, you blow into a large tube connected to a small machine to measure how much air your lungs can hold and how fast you can blow the air out of your lungs. Other tests include measurement of lung volumes and diffusing capacity, six-minute walk test, and pulse oximetry.

Chest X-ray: A chest X-ray can show emphysema, one of the main causes of COPD. An X-ray can also rule out other lung problems or heart failure.

CT scan: A CT scan of your lungs can help detect emphysema and help determine if you might benefit from surgery for COPD. CT scans can also be used to screen for lung cancer.

Arterial blood gas analysis: This blood test measures how well your lungs are bringing oxygen into your blood and removing carbon dioxide.

Laboratory tests: Lab tests aren't used to diagnose COPD, but they may be used to determine the cause of your symptoms or rule out other conditions. For example, lab tests may be used to determine if you have the genetic disorder alpha-1-antitrypsin deficiency, which may be the cause of COPD in some people. This test may be done if you have a family history of COPD and develop COPD at a young age.

These diagnostic methods are not only costly but are also invasive, thereby adding to people's stress. It has been appreciated for many decades that the analysis of trace volatile organic compounds (VOCs) in exhaled breath could potentially provide cheaper, rapid, and non-invasive screening procedures to diagnose and monitor the above diseases of the lung. However, after decades of research associated with breath biomarker discovery, no breath VOC tests are clinically available. Reasons for this include the little consensus as to which breath volatiles (or pattern of volatiles) can be used to discriminate people with lung diseases, and our limited understanding of the biological origin of the identified VOCs. Lung disease diagnosis using breath VOCs is challenging. Nevertheless, the numerous studies of breath volatiles and lung disease provide guidance as to what volatiles need further investigation for use in differential diagnosis, highlight the urgent need for non-invasive clinical breath tests, illustrate the way forward for future studies, and provide significant guidance to achieve the goal of developing non-invasive diagnostic tests for lung disease.

The potential challenges of widespread use of exhaled breath analysis and barriers towards future clinical adoption include: 1) the need for biomarker replication studies including internal replication with training and test datasets and external replication; 2) standardised reporting of chemical and analytical methodologies and statistical approaches such as multivariate classification models; 3) the need for comparative studies of diagnostic accuracy of point of care

sensors such as eNose and mass spectrometry-based approaches such as GC-MS.

The employment of a point of care device which comprises various gas sensors that could identify the presence of the VOCs responsible for the respective respiratory disorders may help the medical personnel in the large amount. The development of E- Nose helps in the current medical age to a large extent. But it can't be afforded by the local hospitals and primary health centres. In India, a total of nearly fifty thousand primary health centres functioning according to a survey taken back in 2022. Here we understood the importance and try to develop a handheld breath analyser for COPD and other pulmonary disorders like Asthma, Tuberculosis, Emphysema. The volatile organic compounds in the exhaled breath of human is collected and analysed with appropriate sensors for COPD and other pulmonary disorders.

CHAPTER 2

LITERATURE SURVEY

Vasiliki Besa et.al (2015) published a work on investigating whether volatile organic compounds could be found in the breath of the COPD patients from the healthy individuals. Additionally, they investigated that VOCs could be used as biomarkers for differentiating the subjects into various subgroups of the disease. Here Ion mobility spectrometry is used for the detection of VOCs in the exhaled breath of the patients affected by COPD.

Ileana Andreea Ratiu et.al (2020) presented a systemic way for providing better ideas on using Volatile Organic Compounds as Biomarkers of asthma, COPD and other respiratory diseases. To achieve this, various analytical platforms for breath analyses were conducted. It includes proton-transfer reaction mass spectrometry (PTR-MS), Secondary electrospray ionization - mass spectrometry (SESI-MS), Ion mobility spectrometry (IMS) and Gas chromatography- mass spectrometry (GC-MS).

Valentina Vassilenko et.al (2023) devised a research that infers the ultimate potential of Volatile Organic Compounds as biomarkers for detecting the wide range of the pathological diseases. This research represents a total of sixteen diseases that are developed with a scientific base regarding the potential of Volatile Organic Compounds in the detection of diseases. The results were achieved with breath sample analysis undertaken in various independent studies with different analytical techniques and procedures. This work was performed to provide the knowledge in the relevancy of using VOCs as breath Biomarkers. For analytical procedures Gas chromatography, Mass spectrometry and Ion Mobility Spectrometry were used. Cumulatively, 16 types of pathological diseases and health conditions were found as the result of this research.

Cohen Kaminsky et.al (2013) designed a method for the collection and Gas chromatography - Mass spectrometry of halogenated Volatile Organic Compounds in the alveolar breath of humans. It is a transportable apparatus which specially sample the lung breath. Thermal desorption tube is present there to capture the VOCs named as Carbotrap 200. Each sample was thermally desorbed from the trap

in automated GC-MS apparatus. The halogenated alkanes have inhibitory effects that will fight against oxidative stress deleterious reactions. Repeated and Re-injection of effluent from one chromatographic column to second column of orthogonal phase paves way for the occurrence of two-dimensional gas chromatography. Resonators based on Nano Electro Mechanical Systems are a particular type of gravimetric gas sensors coated with a sensitive layer of polymer and this eventually generates an additional load.

Alex pizzino et.al (2018) created a technique to identify whether Volatile Organic Compounds from the exhaled alveolar breath could be used for the discrimination of stable COPD from the exacerbated COPD. Three kinds of patient groups were included for this study. Samples were collected by optimising a sampling strategy. Then samples collected by optimizing the sampling strategy. Additionally analysed using A thermal desorption-gas chromatography-time of flight-mass spectrometer (TD-GC-ToF-MS). As a result, 105 Volatile Organic Compounds were identified in the breath samples. The results indicated that breath analysis done using TD-GC-ToF-MS can be reliable. It Is accurate and easy to perform the diagnosis between AECOPD and COPD. Ketones are mostly observed at the highest levels in exhaled breath of AECOPD and some of which are related to bacterial pathogens.

Albert C. Roldaan et.al (2009) hypothesized that breathprints by electronic nose could discriminate patients affected by COPD and Asthma. Totally ninety subjects were selected for the cross-sectional study, out of that 30 patients were affected by COPD and 20 patients were affected by Asthma, 20 nonsmoking control subjects and 20 smoking control subjects. The expiratory vital capacity was collected in a Tedlar bag and sampled by electronic nose. Molecular profiling of air from the exhaled breath has the ability to differentiate patients affected by COPD and Asthma and the control subjects.

Aisling Forder et.al (2023) devised a study to review the evidence and the studies that helps in exploring the underlying mechanisms in the COPD affected people who are prone to the risk of Lung cancer. Genetic and epigenetic changes, along with the aberrant expression of non-coding RNAs, alters the expression of cancer and immune-related genes by predisposing the lung epithelium to

carcinogenesis. A situation named as chronic inflammatory environment generated by oxidative stress plays a specific role in decreasing genomic integrity and promoting epithelial-mesenchymal-transition. Abnormal regulation of the lung microenvironment and microbiome results in chronic inflammation, which is found in COPD and this can facilitate cancer initiation in various tumour types.

Helmut Teschler et.al (2015) investigated whether Volatile Organic Compounds (VOCs) could be detected in the air exhaled breath of the patients with Chronic Obstructive Pulmonary Disease and whether the detected VOCs could differentiate the healthy objects from the COPD affected subjects. VOCs could be also used as biomarkers for classifying patients into different subgroups of the disease. To detect the exhaled breath of COPD patients Ion mobility spectrometry was used. A total one hundred and thirty-seven peaks were found to have a significant difference between the COPD group and the combined healthy smokers and nonsmoker group. Among that six Volatile Organic Compounds were contributed mostly for distinguishing COPD patients from healthy subjects with 70% accuracy.

Zimmermann et.al (2016) designed a novel breath sampling device for finding the Volatile Organic Compounds that are related to the Chronic Obstructive Pulmonary Disease. A large number of subjects were included for the study. Two hundred and twenty-two subjects were recruited in Hannover and Marburg, this includes subjects with mild to moderate COPD and healthy subjects. All these controls were conditioned to inhale the cleaned room air. The exhalation process takes place in a steel reservoir under exhalation flow control. As a result, one hundred and thirty-four breath Volatile Organic compounds were extensively characterized and it provides the evidence for fourteen COPD related VOCs of which 10 have not been reported before.

Raffaele Antonelli Incalzi et.al (2018) constructed a monocentric prospective study which is followed by 1 year of follow-up. All the patients undergone Pulmonary function tests, arterial gas analysis, bioimpedance analysis, six minutes walking test and Volatile Organic Compounds collection. The exhaled breath from the patients were collected with Pneumopipe. After the exhaled breath underwent analyzation by BIONOTE electronic nose. K-fold cross-validated partial least

discriminant analysis: accuracy, sensitivity, and specificity along with the Cohen's kappa for agreement were calculated. A total of sixty-three control subjects were recruited for the study.

Giovanna Elisiana Carpagnano et.al (2023) in the year, collected and compared the progress made in Volatile organic compounds analysis by using the two methods along with their instrumental characteristics. Gas chromatography-Mass spectrometry and E-nose have a great potential in a multitude of relevant aspects of the disease in the young as well as the adults. These provide high values in the differential diagnosis between asthma and the other medical conditions like wheezing, cystic fibrosis, allergic rhinitis and Chronic Obstructive Pulmonary disease. Lung function, FeNO and eosinophil contributes in the accuracy of this method. Gas chromatography - mass chromatography and E - nose appears to be the more promising for the non-invasive diagnosis, assessment and the monitoring of the primary disease along with the subgroups of the primary lung disorders.

Linda van der sande et.al (2012) in the year, systematically reviewed the exhaled Volatile organic compounds with respect to their potential clinical usage in the Pulmonary disorders such as lung cancer, asthma, cystic fibrosis (CF), chronic obstructive Pulmonary disorder, infections in the respiratory tract of the affected patients and so on. Totally seventy-three studies were conducted and a huge number control subjects were recruited for helping in the conduction of this study. Three thousand, nine hundred and fifty-two patients and two thousand, nine hundred and seventy-three healthy controls underwent the tests. The collection and analysis of the exhaled Volatile organic compounds is non-invasive and can be easily applied for a huge range of patients including severely affected adults as well as the children. Inter- laboratory comparability was challenged by the heterogeneity of this studies.

Cesar Ilizatliturri-Hernandez et.al (2019) conducted a prospective study which was performed with the help of twenty-three chronic obstructive Pulmonary Obstructive disease patients and thirty-three healthy control subjects. The exhaled breath air from the affected patients were performed with Tedlar bags. The samples were analyzed by FCG E nose and the identification of Volatile organic compounds was based on the kovats index. Canonical discriminant analysis [canonical analysis

of principal coordinates (CAP) and principal component analysis (PCA) contributes for the reduction in the raw data. Seventeen Volatile Organic Compounds was identified by the FCG E-nose technology that helps in distinguishing the chronic Obstructive Pulmonary disorder patients from the healthy individuals. This pilot study vividly demonstrates the useful application of FGC e-Nose for detecting the biomarkers from the exhaled breath of the patients affected by chronic Obstructive pulmonary disorder.

Hossam Haick et.al (2019) discussed a new frontier for fast, risk-free and potentially cost-effective diagnostics of respiratory diseases by actively detecting Volatile organic Compounds (VOCs) that are available in the exhaled breath of the patient. Didactic presentation of the overlaying concept and the chemistry of the exhaled breath is discussed as one part of this review. The other part explains the various sensors that have been developed and utilised in the detection of the respiratory diseases such as chronic Obstructive pulmonary disorder, asthma, lung cancer, tuberculosis, pneumoconiosis, Obstructive sleep apnoea syndrome, cystic fibrosis and Pulmonary arterial hypertension by analysing the Volatile organic compounds in exhaled breath. The sensor arrays, sensing devices and the improvement of the sensing devices was also discussed.

Adithya Cattamanchi et.al (2022) devised a study that focused on the low biomarker concentrations which is determined to be clinically relevant according to the preliminary Gas chromatography- Mass spectrometry studies about the levels that are detected in the patient breath. The cyclic voltammogram and the square wave voltammogram of copper (II) was found changing distinctly when a little amount of MN (0.1 mM) is added to the respective solution, with less than two minutes of analyses time. 3 separate peaks were exhibited by copper (II) during square wave voltammetry. When the known interaction of biomarkers is established, 'fingerprint' method could be used to find the specific biomarkers.

Anke Maitland-van der Zee et.al (2021) in the year, discussed whether E-nose could provide better discrimination rate between smokers and non-smokers. A cross sectional analysis is performed in the patients who are affected with chronic Obstructive Pulmonary disorder and the patients affected with asthma and with the healthy subjects. The measurements of e-Nose were performed with help

of SpiroNose. E- Nose signals were described by Principal component (PC) and the linear discriminant analysis were determined. The accuracy of the models was assessed by the receiver-operator curve (AUC). A total of three hundred and three never smokers and five hundred and ninety-three regular smokers were recruited for the study.

Ohann-Christoph Licht et.al (2020) decided to detect the Volatile organic compounds in the exhaled air of the human breath. It is performed with the help of e- Nose technology which has huge potential in improving or offering alternative solutions to the diagnostic tests that are now employed for the Pulmonary and respiratory disorders. It provides more accuracy and increased discriminative power for helping in differentiating between the healthy and affected individuals along with the subgroups of the disease. It is also helpful in detecting infections that occur in patients with respiratory disorders including asthma, cystic fibrosis and lung malignancies.

Pierluigi Carat et.al (2017) in the year reviewed the e-nose technology application in the respiratory diseases according to the principal literature. Mild and severe asthma affected people were discriminated According to their age with the help of E-nose based on the sensor arrays of conducting polymers named as Cyranose 320. FeNO or spirometry techniques provided low performance when compared with the performance of Quartz microbalance sensor system (QMB). The performance of E-Nose is also better than the performance of the FeNO regarding the steroid responsiveness. E-Nose developed based on the metal oxide semiconductors (MOS) combined and integrated with spirometry and named as Spironose. The mycobacterium tuberculosis could be detected by e-nose based on fourteen gas sensors array in combination with neural network system (Bloodhound).

Martina Meszaros et.al (2020) in the year reviewed the literature that were published on the topics of E-noses and Chronic obstructive Pulmonary disease and provided ideas for identifying the methodological, physiological and disease-realer factors which could potentially disturb the results. The performance of the E-Nose mainly depends on the number of subject groups tested. Small sample size is not much effective. The patients with chronic Obstructive Pulmonary disorder from the

non-COPD regular smokers were discriminated with a cross validation of 0.66 by using Cyranose 320 and LDA.

Christopher Brightling et.al (2021) conducted a systematic review which evaluates the diagnostic accuracy of the Volatile organic Compounds (VOCs) in detecting the respiratory diseases. The relationship between the mentioned Volatile organic compounds and the biomarkers mentioned for the type-2 inflammation is explained vividly. PRISMA method were employed for the study. It is a systemic search program conducted in a span of twenty-three years. (from January 1997 - December 2020).

CHAPTER 3

AIM AND SCOPE

3.1 AIM

To fabricate and translate the prototype of voc based COPD device to a handheld device.

To establish the difference VOC in the exhaled breath of healthy patients vs patients with COPD.

To differentiate between stable and acute exacerbation of COPD.

To provide results in 60 seconds, so that clinicians could make to a decision on treatment - Need for antibiotics alone or antibiotics with steroids.

To train the dataset using Artificial Intelligence to classify the collected data to differentiate between health and diseased state using respiratory breathing patterns using a microphone.

3.2 SCOPE

Till date, to our knowledge there are no handheld portable device available for the diagnosis of COPD through exhaled breath air.

Diagnosis of COPD through Volatile Organic Compounds is now done by Gas chromatography and ion spectrometry techniques which requires a lot of time and highly expensive.

We are going to develop a portable Handheld device for diagnosing COPD with exhaled air.

This is a Non-invasive technique to Diagnose COPD by VOCs released in the exhaled air because of the catabolic activity of the body with Co₂ and TVOC sensors with an LED Display to provide the analysis of the acquired data.

This may provide the assistance for the doctors to make a decision earlier according to the rate of the disease in the patient in an effective manner at a low cost.

CHAPTER 4

MATERIALS AND METHODS

Chronic obstructive pulmonary disease (COPD) is a prevalent lung condition causing airflow obstruction, comprising chronic bronchitis etc,. Often it is misdiagnosed. Traditional diagnosis is invasive and time-consuming, hindering timely treatment. To address this, a breath analyzer is being developed, utilizing volatile organic compounds for rapid and non-invasive detection of COPD and other pulmonary disorders, aiding prompt medical intervention.

4.1 METHODOLOGY

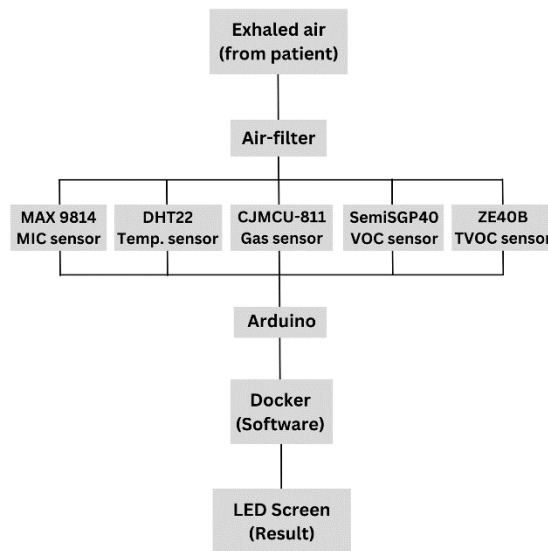


Fig:4.1 Methodology

Figure 4.1 is the basic block diagram and methodology of the project and each block is explained below

- Exhaled air observation through air filter: The exhaled air from the COPD patient is directed through an air filter located at the mouth of a vent. This filter likely helps to capture any particulate matter or contaminants in the air for analysis.
- Using air filters at the mouth of ventilation devices
- enables non-invasive monitoring of exhaled air, which is particularly beneficial for COPD patients who may already experience respiratory discomfort or have compromised lung function.
- Integration of sensors with Arduino Uno: The collected air passes through multiple sensors integrated with an Arduino Uno microcontroller board. These

sensors include the MAX9814 microphone sensor, DHT22 temperature sensor, and CJMCU811 gas sensor.

- Observation through Docker software: The data collected by the sensors is transmitted to a computer system running Docker software. Docker likely facilitates the management of software applications and their dependencies in a virtualized environment.
- MAX9814 sensor for sound observation: The MAX9814 microphone sensor is utilized to monitor the sound of the breath. Changes in the sound pattern could potentially indicate respiratory issues or abnormalities.
- DHT22 temperature sensor: This sensor measures the temperature of the exhaled air. Variations in temperature may provide insights into the patient's respiratory health or the presence of inflammation.
- CJMCU811 gas sensor: This sensor is employed to detect the levels of carbon dioxide (CO₂) and total volatile organic compounds (VOCs) in the exhaled air. Elevated levels of these gases may indicate respiratory distress or other health concerns.
- Data analysis and processing: The values obtained from the sensors are analyzed and processed using software. This software likely performs calculations, comparisons, and possibly data visualization to extract meaningful insights from the sensor readings.
- Screening in LED screen: The processed data is then displayed on an LED screen integrated into the prototype. This screen provides a visual representation of the analyzed parameters, allowing for real-time monitoring and observation of the patient's respiratory condition.

4.2 HARDWARE REQUIREMENTS

4.2.1 MAX9814 MIC

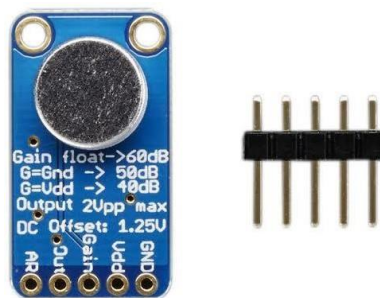


Fig:4.2 MAX9814 MIC Sensor

In figure 4.2, MAX9814 is a low-cost, high-quality microphone amplifier with automatic gain control (AGC) and low-noise microphone bias. The device features a low-noise preamplifier, variable gain amplifier (VGA), output amplifier, microphone-bias-voltage generator, and AGC control circuitry.

The low-noise preamplifier has a fixed 12dB gain, while the VGA gain automatically adjusts from 20dB to 0dB, depending on the output voltage and the AGC threshold. The output amplifier offers selectable gains of 8dB, 18dB, and 28dB. With no compression, the cascade of the amplifiers results in an overall gain of 40dB, 50dB, or 60dB. A trilevel digital input programs the output amplifier gain. An external resistive divider controls the AGC threshold and a single capacitor programs the attack/release times. A trilevel digital input programs the ratio of attack-to-release time. The hold time of the AGC is fixed at 30ms. The lownoise microphone-bias-voltage generator can bias most electret microphones. The MAX9814 is available in the space-saving, 14-pin TDFN package. This device is specified over the -40°C to +85°C extended temperature range.

4.2.2 DHT11 Sensor



Fig:4.3 DHT11 Temperature Sensor

In Figure 4.3, The DHT11 is a commonly used Temperature and humidity sensor that comes with a dedicated NTC to measure temperature and an 8-bit microcontroller to output the values of temperature and humidity as serial data.

The DHT11 is a commonly used Temperature and humidity sensor. The sensor comes with a dedicated NTC to measure temperature and an 8-bit microcontroller to output the values of temperature and humidity as serial data. The

sensor is also factory calibrated and hence easy to interface with other microcontrollers.

The sensor can measure temperature from 0°C to 50°C and humidity from 20% to 90% with an accuracy of $\pm 1^\circ\text{C}$ and $\pm 1\%$. So if you are looking to measure in this range then this sensor might be the right choice for you.

4.2.3 CJMCU 811

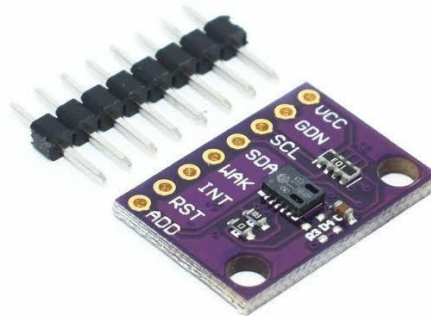


Fig:4.4 CJMCU811 Sensor

In Figure 4.4, The CCS811 Air Quality Breakout Board is a digital gas sensor capable of sensing a wide range of Total Volatile Organic Compounds (TVOC) & equivalent carbon dioxide (eCO₂) with metal oxide (MOX) levels. This sensor can identify the air quality whether the air is pure to breathe or not. The CCS811 is very tiny and ultra-low power consumption device that can be used in wearables and handheld device for monitoring Indoor Air Quality.

The CCS811 Air Quality Sensor Breakout Board is a digital gas sensor that senses a wide range of Total Volatile Organic Compounds (TVOCs) along with equivalent carbon dioxide (eCO₂) and metal oxide (MOX) levels. The sensor can be used for monitoring Indoor Air Quality. The system can be used with a microcontroller unit (MCU), which includes an Analog-to-Digital converter (ADC) & an I²C interface.

This sensor measure eCO₂ concentration within a range of 400 to 8192 parts per million (ppm), and TVOC concentration within a range of 0 to 1187 parts per billion (ppb).

4.2.4 1 x 7Semi SGP40 VOC Air Quality Sensor

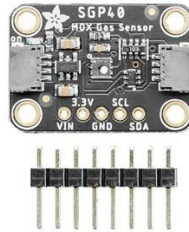


Fig:4.5 7Semi SGP40 VOC Air Quality Sensor

In Figure 4.5, SGP40 is a digital VOC (volatile organic compounds) sensor designed for easy integration into air treatment devices and air quality monitors. Based on our patented CMOSens Technology, the SGP40 offers a complete sensor system on a single chip and features a digital I²C interface, a temperature-controlled micro-hotplate and a humidity-compensated indoor air quality signal. In combination with our powerful VOC Algorithm (part of the gas index algorithm software), the sensor signal can be directly used to evaluate indoor air quality, e.g., for triggering the gradual fan control of an air treatment device. Both the SGP40 chip and VOC algorithm feature unrivaled robustness in the final application over their lifetimes. Pushing the multipixel and multi-hotplate approach to the next level of individual control of each sensing element, the SGP40 enables a drastic reduction in power consumption, making it suitable for battery-driven applications as well.

Using Sensirion's CMOSens technology, the SGP40 offers a complete sensor system on a single chip, including a temperature-controlled micro-hotplate and a humidity-compensated indoor air quality signal. In combination with Sensirion's powerful VOC algorithm, the sensor can directly evaluate indoor air quality. It has low power consumption (2.6mA), a fast response time (2s), and a small size. The sensor can be used to evaluate air quality without the need for calibration.

Features

- Ultra-low power consumption(2.6mA)
- Built-in temperature and humidity compensation, no need to calibrate
- VOC index for direct air quality indication

4.2.5 Winsen Electrochemical TVOC Detection Module ZE40B-TVOC



Fig:4.6 Winsen Electrochemical TVOC Detection Module ZE40B-TVOC

In Figure 4.6, The ZE40B-TVOC electrochemical alcohol module is a general-purpose, miniaturized module. The electrochemical principle is used to detect the presence of TVOC in the air, which has good selectivity and stability. Built-in temperature sensor for temperature compensation; digital output and analog voltage output for easy use. ZE40A-TVOC is a universal gas module designed and manufactured by combining proven electrochemical detection technology with sophisticated circuit design.

4.3 SOFTWARE REQUIREMENTS

4.3.1 Arduino UNO



Fig:4.7 Arduino UNO

In Figure 4.7, It is a low-cost, flexible, and easy-to-use programmable open-source microcontroller board that can be integrated into a variety of electronic projects. This board can be interfaced with other Arduino boards, Arduino shields, Raspberry Pi boards and can control relays, LEDs, servos, and motors as an output. Arduino UNO features AVR microcontroller Atmega328, 6 analogue input pins, and 14 digital I/O pins out of which 6 are used as PWM output.

This board contains a USB interface i.e. USB cable is used to connect the board with the computer and Arduino IDE (Integrated Development Environment) software is used to program the board.

The unit comes with 32KB flash memory that is used to store the number of instructions while the SRAM is 2KB and EEPROM is 1KB.

The operating voltage of the unit is 5V which projects the microcontroller on the board and its associated circuitry operates at 5V while the input voltage ranges between 6V to 20V and the recommended input voltage ranges from 7V to 12V.

4.3.2 Libraries Used

- ADAFRUIT - MAX9814 Sensor
- DHT22 ARDUINO – Temperature sensor
- ADAFRUIT CCS811- Gas Sensor
- LIQUID CRYSTAL LIBRARY – Arduino LCD Display
- ESPLORA – Arduino Library

4.3.2.1 ADAFRUIT Max9814 Sensor

This fancy microphone amplifier module is a step above the rest, with built in automatic gain control. The AGC in the amplifier means that nearby 'loud' sounds will be quieted so they don't overwhelm & 'clip' the amplifier, and even quiet, far-away sounds will be amplified. This amplifier is great for when you want to record or detect audio in a setting where levels change and you don't want to have to tweak the amplifier gain all the time.

The chip at the heart of this amp is the MAX9814, and has a few options you can configure with the breakout. The default 'max gain' is 60dB, but can be set to 40dB or 50dB by jumpering the Gain pin to VCC or ground.

4.3.2.2 LIQUID CRYSTAL LIBRARY Arduino LCD Display

This library allows an Arduino/Genuino board to control LiquidCrystal displays (LCDs) based on the Hitachi HD44780 (or a compatible) chipset, which is found on most text-based LCDs. The library works with in either 4 or 8 bit mode (i.e. using 4 or 8 data lines in addition to the rs, enable, and, optionally, the rw control lines).

4.3.2.3 ESPLORA Arduino Library

The Arduino Esplora is a microcontroller board derived from the Arduino Leonardo. The Esplora differs from all preceding Arduino boards in that it provides a number of built-in, ready-to-use set of onboard sensors for interaction.

4.4 ARDUINO CONNECTION

- The MAX9814 typically has pins for power (VCC and GND), audio output (OUT), and gain control (GAIN).
- Connect the VCC pin of the MAX9814 to a 3.3V or 5V pin on the Arduino (check the datasheet for the operating voltage range of the sensor). Connect the GND pin of the MAX9814 to a ground pin on the Arduino.
- Connect the OUT pin of the MAX9814 to an analog input pin on the Arduino to read the audio levels.
- By connecting the data pin of the DHT22 sensor to one of the digital pins on the Arduino board, establish the communication and retrieve temperature and humidity data from the sensor.
- Connect the power (VCC) and ground (GND) pins of the sensor to the appropriate pins on the Arduino to provide power to the sensor.
- The CJMCU-811 sensor will have pins labeled VCC, GND, SDA (Data), and SCL (Clock).
- Connect the SDA pin of the CJMCU-811 sensor to the Arduino's SDA pin (A4 on most Arduino boards).
- Connect the SCL pin of the CJMCU-811 sensor to the Arduino's SCL pin (A5 on most Arduino boards).
- Connect the 1 x 7Semi SGP40 VOC Air Quality Sensor with an Arduino board by using the I2C (Inter-Integrated Circuit) protocol. The Arduino board

communicates with the sensor using the I2C interface, enabling data transfer between the sensor and the microcontroller.

- connect the Winsen Electrochemical TVOC Detection Module ZE40B-TVOC with an Arduino board, using the analog output of the detection module to interface with one of the analog input pins on the Arduino. This allows the Arduino to read the analog signal from the detection module and process the data accordingly.
- Connect the LCD (Liquid Crystal Display) with an Arduino board allows for real-time data visualization and user interaction.

Arduino UNO Pin Mapping

+5V ----- [MAX9814 MIC] VCC

GND ----- [MAX9814 MIC] GND

A0 ----- [MAX9814 MIC] OUT

+5V ----- [DHT11] VCC

GND ----- [DHT11] GND

D2 ----- [DHT11] DATA

+5V ----- [CJMCU 811] VCC

GND ----- [CJMCU 811] GND

A1 ----- [CJMCU 811] SDA

A2 ----- [CJMCU 811] SCL

+5V ----- [7Semi SGP40] VCC

GND ----- [7Semi SGP40] GND

A3 ----- [7Semi SGP40] SDA

A4 ----- [7Semi SGP40] SCL

+5V ----- [Winsen ZE40B-TVOC] VCC

GND ----- [Winsen ZE40B-TVOC] GND

D3 ----- [Winsen ZE40B-TVOC] RX

D4 ----- [Winsen ZE40B-TVOC] TX

CHAPTER 5

RESULTS AND DISCUSSIONS

The development of a handheld breath analyzer for COPD and other pulmonary disorders like asthma, tuberculosis, and emphysema could indeed revolutionize the way these conditions are diagnosed and managed, particularly in resource-limited settings such as many parts of India. Here's a hypothetical scenario illustrating the positive impact of employing such a prototype in real-time:

Consider a rural primary health center in a remote area of India where access to advanced diagnostic tools and specialists is limited. A 50-year-old farmer named Raj has been experiencing chronic cough, wheezing, and shortness of breath for several months. He visits the primary health center, where the healthcare provider suspects COPD due to Raj's smoking history and exposure to biomass fuels during farming activities.

Traditionally, diagnosing COPD in such a setting would be challenging. The healthcare provider might rely on symptoms and basic spirometry tests, but definitive diagnosis and differentiation from other pulmonary conditions like asthma or tuberculosis would require referral to a specialist facility, which could take weeks or even months.

However, with the introduction of the handheld breath analyzer prototype, the healthcare provider can now collect a sample of Raj's exhaled breath and analyze it on-site using the device's sensors. Within minutes, the device provides a comprehensive analysis indicating elevated levels of volatile organic compounds associated with COPD.

Armed with this real-time information, the healthcare provider can confidently diagnose Raj with COPD and initiate appropriate treatment and counseling immediately. This timely intervention not only relieves Raj's symptoms but also prevents disease progression and complications, improving his quality of life and productivity as a farmer.

Furthermore, the versatility of the handheld breath analyzer allows the healthcare provider to screen other patients presenting with respiratory symptoms

quickly and accurately, facilitating early detection and management of various pulmonary disorders in the community.

Overall, the successful implementation of the prototype in real-time at the primary health center demonstrates its potential to bridge the gap in COPD diagnosis and management, particularly in underserved regions, ultimately saving lives and reducing the burden of respiratory diseases in India and beyond.

5.1 HARDWARE OUTCOME

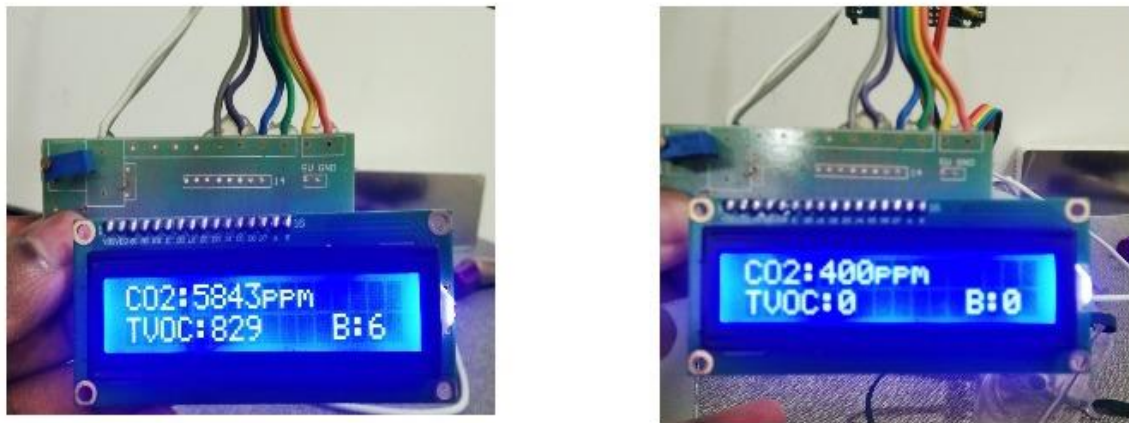


Fig:5.1 Prototype Outcome

In figure 5.1, CO₂ level and TVOC is displayed on LCD display.

TVOC (Total Volatile Organic Compounds): This measurement indicates the concentration of various organic compounds present in the exhaled air. TVOC levels can be influenced by environmental factors such as pollution or indoor air quality, as well as by the individual's respiratory health and metabolism.

B (Breath Sound): This likely represents the analysis of breath sounds captured by the microphone sensor. Variations in breath sounds can provide insights into respiratory function and any abnormalities such as wheezing or diminished breath sounds.

CO₂ Level: This measurement reflects the concentration of carbon dioxide in the exhaled breath.

5.1.1 CO₂ level Interpretations

Low CO₂ Level: A low CO₂ level, known as hypocapnia, can occur due to hyperventilation or over-breathing. It may also result from conditions such as

pulmonary embolism, metabolic alkalosis, or certain medications. Symptoms of hypocapnia can include dizziness, confusion, shortness of breath, and tingling sensations. In severe cases, it can lead to respiratory alkalosis and potentially cause seizures or loss of consciousness.

High CO2 Level: Elevated CO2 levels, known as hypercapnia, often indicate inadequate ventilation or impaired gas exchange. In COPD patients, high CO2 levels (hypercapnic respiratory failure) can result from chronic respiratory acidosis due to the inability to effectively expel carbon dioxide. Symptoms may include confusion, lethargy, headaches, shortness of breath, and in severe cases, respiratory failure. Hypercapnia requires prompt medical attention and may necessitate interventions such as supplemental oxygen therapy or mechanical ventilation.

Monitoring CO2 levels is crucial for managing respiratory conditions like COPD, as it helps assess ventilation adequacy and guide treatment decisions. Regular monitoring allows for early detection of abnormalities, enabling timely intervention to prevent complications and optimize respiratory function.

5.2 SOFTWARE OUTCOME



Fig:5.2 Software Results

Figure 5.2 presents a comprehensive overview of the various parameters measured by the handheld breath analyzer for COPD. Each parameter provides valuable insights into the respiratory health and condition of the patient. Here's a summary of the information presented in Figure 5.2

- *Temperature*: Reflects the temperature of exhaled air, offering insights into potential inflammatory or infectious conditions within the respiratory system.
- *Pressure*: Indicates the pressure of exhaled breath or ambient air pressure, which can influence breathing patterns and may serve as an indicator of respiratory issues.
- *Humidity*: Provides information about the moisture content of exhaled air, with abnormal levels potentially indicating respiratory conditions like asthma or COPD exacerbations.
- *Dewpoint*: Monitors the temperature at which air becomes saturated with water vapor, aiding in assessing the moisture content of exhaled air, crucial for respiratory health.
- *Altitude*: Measures altitude, aiding in understanding how environmental factors impact respiratory function, especially relevant for COPD patients experiencing difficulty breathing at higher elevations.
- *Gas (Oxygen)*: Indicates the concentration of oxygen in exhaled air, crucial for assessing respiratory function and ensuring adequate tissue oxygenation.
- *Temperature CCS*: Likely a specific temperature measurement related to a particular sensor or calibration, providing more detailed temperature data.
- *CO2 (Carbon Dioxide)*: Monitors CO2 levels, with elevated levels indicating inadequate ventilation or respiratory distress, particularly relevant for COPD patients with impaired gas exchange.
- *TVOC (Total Volatile Organic Compounds)*: Provides an indication of the overall level of volatile organic compounds in exhaled air, suggesting exposure to pollutants or respiratory irritants.

- *Microphone (Sound)*: Monitors breath sounds, offering insights into respiratory function and potential abnormalities such as airway obstruction.

By analyzing these parameters collectively, healthcare providers can gain a holistic understanding of the patient's respiratory health, enabling early detection of exacerbations or complications and facilitating timely intervention to optimize patient outcomes. Figure 5.2 serves as a visual representation of the breadth of information captured by the breath analyzer, aiding in comprehensive respiratory assessment for COPD patients.

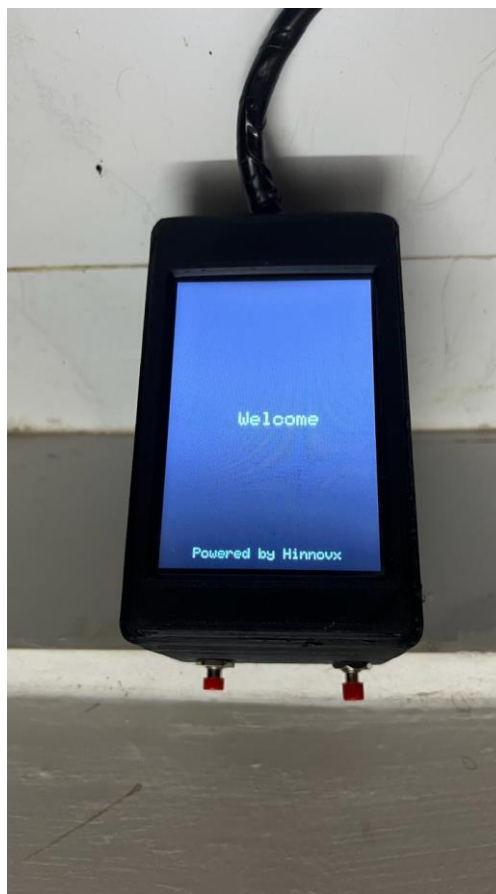


Fig:5.3 Complete Prototype

CHAPTER 6

SUMMARY AND CONCLUSION

In conclusion, the development of a handheld breath analyzer for COPD and other pulmonary disorders presents a promising solution to several challenges faced in the timely diagnosis and management of these conditions. By harnessing the power of volatile organic compounds (VOCs) present in exhaled breath, this innovative device offers a non-invasive and efficient method for identifying respiratory disorders such as COPD, asthma, tuberculosis, and emphysema.

The application of this prototype in real-time settings holds immense potential for revolutionizing healthcare delivery, particularly in resource-constrained environments like India where COPD and other pulmonary disorders pose significant burdens on the healthcare system. By providing medical personnel at primary health centers and local hospitals with a simple yet effective tool for early detection and monitoring of respiratory conditions, the handheld breath analyzer can facilitate timely intervention and personalized treatment strategies.

Moreover, the affordability and accessibility of this device make it particularly well-suited for deployment across a wide range of healthcare settings, including remote and underserved areas where access to advanced diagnostic technologies may be limited. By empowering healthcare providers with the means to promptly identify and manage respiratory disorders, the handheld breath analyzer has the potential to improve patient outcomes, reduce healthcare costs, and alleviate the burden of chronic lung diseases on individuals and communities alike.

The employment of this prototype in real-time clinical practice represents a significant step forward in the fight against COPD and other pulmonary disorders. By leveraging cutting-edge technology to harness the diagnostic power of exhaled VOCs, this device has the potential to transform respiratory healthcare delivery, ultimately improving the quality of life for millions of individuals worldwide.

Consider a patient presenting with symptoms suggestive of COPD at a primary health center in a remote village in India. Using the handheld breath analyzer, the healthcare provider conducts a rapid assessment by analyzing the patient's exhaled breath for specific VOCs associated with COPD. Within minutes,

the device confirms the presence of COPD, allowing the provider to initiate appropriate treatment promptly. Subsequent monitoring with the device enables ongoing evaluation of the patient's response to therapy, ensuring timely adjustments as needed.

In summary, the deployment of a handheld breath analyzer for COPD and other pulmonary disorders offers a practical and effective solution for early diagnosis, point-of-care testing, and real-time monitoring, thereby improving patient outcomes and healthcare delivery in resource-limited settings.

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