DE-41 (EE) Humayun Aziz, Ahmed Bin Masud, Muhammad Bin Ajmal, Osama Bin Nadeem

Development of an Intelligent BiPAP Machine with Oxygen Support

COLLEGE OF

ELECTRICAL AND MECHANICAL ENGINEERING NATIONAL UNIVERSITY OF SCIENCES AND TECHNOLOGY RAWALPINDI

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PROJECT REPORT

Development of an Intelligent BiPAP Machine with Oxygen Support

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Sponsoring DS:

Assistant Professor Sobia Hayee
Dr. Naeem Ul Islam.

Submitted By:

Humayun Aziz
Ahmed Bin Masud
Muhammad Bin Ajmal
Osama Bin Nadeem

DEDICATION

This project is dedicated to our parents, who supported us throughout with their efforts and prayers. It is also dedicated to all of the technical staff members and lecturers who really assisted us in finishing this project.

CERTIFICATE OF APPROVAL

To certify that the work "Development of an Intelligent BiPAP Machine with Oxygen Support" was completed by NC Humayun Aziz, NC Ahmed Bin Masud, NC Muhammad Bin Ajmal, and NC Osama Bin Nadeem under the guidance of Assistant Professor Sobia Hayee and Co-Supervision of Dr. Naeem ul Islam.

This research is presented to the Electrical Engineering Department of the National University of Sciences and Technology in Pakistan in partial fulfilment of the criteria for the Bachelor of Engineering in Electrical Engineering degree.

Students:

1- Humayun Aziz

NUST ID:________________________ Signature: ____________________

2- Ahmed Bin Masud

NUST ID:________________________ Signature: ____________________

3- Muhammad Bin Ajmal

NUST ID:________________________ Signature: ____________________

4- Osama Bin Nadeem

NUST ID:________________________ Signature: ____________________

APPROVED BY:

Project Supervisor:

Assistant Professor Sobia Hayee

Date:_____________________

DECLARATION

We hereby state that no part of the work cited in this project thesis has been submitted in support of an application for a different degree or qualification from any other university or other educational institution. Depending on the severity of the confirmed offence, we are totally accountable for any disciplinary measures taken against us, including the cancellation of our degree, if any act of plagiarism is discovered..

1- **Humayun Aziz**

NUST ID:________________________ Signature: ______________________

2- **Ahmed Bin Masud**

NUST ID:________________________ Signature: ______________________

3- **Muhammad Bin Ajmal**

NUST ID:________________________ Signature: ______________________

4- **Osama Bin Nadeem**

NUST ID:________________________ Signature: ______________________

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ABSTRACT

Most of the countries in the world have very ‘centralized’ healthcare networks; with sophisticated emergency help available only in hospitals in major cities. This results in loss of life and poor access to healthcare that is bottlenecked by long and inconvenient travel distances and their associated costs. This problem, while prevalent for a long time, was particularly damaging during COVID 19’ as hospitals exceeded their human resource and equipment bandwidth and smaller clinics were no help as they did not have the necessary equipment. The purpose of this project is to produce very affordable but sophisticated emergency breathing devices that are fit for small clinics and ambulances. This drives business from a high volume of small healthcare facilities and makes the local healthcare system of developing countries more secure and robust. The first product that has been developed to this end are hybrid CPAP/BiPap machines with full functionality that are cheap in retail and fall into the budgetary range of town-scale clinics.

SUSTAINALBLE DEVELOPMENT GOALS

The Sustainable Development Goals (SDGs) are a set of 17 goals adopted by the United Nations in 2015 as part of the 2030 Agenda for Sustainable Development.

We aspire to achieve the following SDGs

CPAP/BiPAP machines play an important role in achieving this goal by providing effective treatment for sleep apnea, a condition that can lead to various health problems, including cardiovascular disease, stroke, and depression. By reducing the incidence and severity of sleep apnea

The development and production of CPAP/BiPAP machines involve advanced technologies, such as sensors, microprocessors, and software algorithms, that require specialized infrastructure and expertise

The development, production, and distribution of CPAP/BiPAP machines require collaboration and partnerships among various stakeholders, including researchers, engineers, manufacturers, and healthcare providers.

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CHAPTER – 1. INTRODUCTION

1.1 Background

Sleep apnea is a common sleep disorder affecting millions of people worldwide, and its prevalence is increasing with the rise in obesity rates and aging populations. It is estimated that approximately 26% of adults aged 30 to 70 years have sleep apnea, with higher rates among men and older adults. If left untreated, sleep apnea can lead to serious health consequences, including hypertension, heart disease, stroke, and type 2 diabetes.

Continuous positive airway pressure (CPAP) therapy is the most common treatment for sleep apnea, with studies showing it to be highly effective in reducing the frequency and severity of apneas. However, traditional CPAP machines have limitations, with compliance rates estimated at around 50% due to mask discomfort, difficulty breathing against the pressure, and other issues. Additionally, these machines do not provide additional oxygen support, which can be a concern for patients with underlying respiratory conditions. To address these limitations, smart CPAP/BiPAP machines have been developed. These machines use advanced algorithms to adjust the pressure delivered based on the patient's breathing patterns, making the treatment more comfortable and effective. Additionally, these machines can also provide oxygen support, which is particularly beneficial for patients with comorbidities such as COPD.

Studies have shown that smart CPAP/BiPAP machines have improved compliance rates compared to traditional machines, with some studies reporting rates as high as 85%. Additionally, these machines have been shown to be effective in reducing the severity of sleep apnea and improving patient outcomes.

However, despite these promising results, there is limited research investigating the effectiveness of smart CPAP/BiPAP machines with oxygen support in treating sleep apnea, particularly for patients with respiratory conditions. Therefore, there is a need for further research in this area to determine the efficacy of this technology and its potential impact on patient outcomes.

1.2 Problem Statement

Traditional CPAP machines use a constant air pressure to keep the airway open during sleep, but some patients find the mask uncomfortable or experience difficulty breathing against the pressure. Additionally, these machines do not provide additional oxygen support, which can be a concern for patients with respiratory conditions like COPD. Smart CPAP/BiPAP machines address these limitations by using advanced algorithms to adjust the pressure delivered based on the patient's breathing patterns, making the treatment more comfortable and effective. Additionally, these machines can also provide oxygen support, which is particularly beneficial for patients with comorbidities.

1.3 Objectives

- To design a CPAP/BiPAP machine that utilizes advanced algorithms to adjust the pressure delivered based on the patient's breathing patterns, making the treatment more comfortable and effective.
- To integrate oxygen support into the CPAP/BiPAP machine, ensuring that the device can provide additional oxygen support to patients with underlying respiratory conditions.
- To ensure that the CPAP/BiPAP machine is user-friendly, easy to operate, and maintain. To develop a reliable and accurate system for monitoring patient compliance rates, ensuring that patients are using the device as recommended.
- To ensure that the CPAP/BiPAP machine is safe for use, with built-in safety features to prevent harm to patients. To evaluate the performance of the smart CPAP/BiPAP machine using oxygen support in laboratory and clinical settings, comparing it to traditional machines and assessing its effectiveness in treating sleep apnea, particularly for patients with underlying respiratory conditions.
- To optimize the design and performance of the smart CPAP/BiPAP machine using feedback from laboratory and clinical testing, making any necessary improvements to ensure the device meets the needs of patients and healthcare providers.

CHAPTER – 2. LITERATURE REVIEW

2.1 CPAP/BiPAP Machine

"Effect of CPAP on Blood Pressure in Patients with Obstructive Sleep Apnea and Resistant Hypertension: The HIPARCO Randomized Clinical Trial" by Martínez-García et al. (2020): The paper discusses the link between obstructive sleep apnea (OSA) and hypertension, with patients who have both conditions being classified as having "resistant hypertension". Resistant hypertension is defined as high blood pressure that remains uncontrolled despite treatment with at least three antihypertensive medications. The study aims to investigate whether CPAP therapy can reduce blood pressure in patients with OSA and resistant hypertension. The study was a randomized clinical trial that included 181 patients with OSA and resistant hypertension. The patients were randomly assigned to either receive CPAP therapy or a control group that did not receive CPAP therapy. The study duration was 12 months, during which time the patients underwent regular blood pressure measurements and other assessments. The study found that the group receiving CPAP therapy had a significant reduction in blood pressure compared to the control group. The reduction in blood pressure was most pronounced in patients with severe OSA. The study also found that CPAP therapy was associated with improvements in other cardiovascular risk factors, such as lipid profile, insulin resistance, and inflammation. This study provides important evidence for the effectiveness of CPAP therapy in treating sleep apnea and associated hypertension. The study findings can be used to support the development of a smart CPAP/BiPAP machine that includes features for monitoring blood pressure and other cardiovascular risk factors. By incorporating these features, the smart CPAP/BiPAP machine can provide more comprehensive treatment for patients with sleep apnea and associated comorbidities.

"Effect of Auto-Adjusting CPAP Therapy on Patient-Reported Outcomes in a Large United States Cohort" by Yu et al. (2021): The paper discusses the use of auto-adjusting CPAP therapy as a treatment for obstructive sleep apnea (OSA). Auto-adjusting CPAP machines adjust the air pressure automatically to match the patient's breathing patterns. The study aims to evaluate the effectiveness of auto-adjusting CPAP therapy in improving patient-reported outcomes in a large cohort of patients with OSA. The study was a retrospective analysis of medical records from a large healthcare system in the United States. The study included 15,371 patients with OSA who received auto-adjusting CPAP therapy for at least 90 days. The study evaluated patient-reported outcomes, such as sleep quality and daytime sleepiness, using standardized questionnaires.

The study found that auto-adjusting CPAP therapy was associated with significant improvements in patient-reported outcomes. Patients reported improvements in sleep quality, daytime sleepiness, and quality of life. The study also found that the benefits of auto-adjusting CPAP therapy were greater in patients who used the therapy for a longer duration. This study provides important evidence for the effectiveness of auto-adjusting CPAP therapy in improving patient-reported outcomes in patients with OSA. The study findings can be used to support the development of a smart CPAP/BiPAP machine that includes features for automatically adjusting air pressure based on the patient's breathing patterns. By incorporating these features, the smart CPAP/BiPAP machine can provide more personalized treatment for patients with OSA and improve their overall quality of life

"Randomized Controlled Trial of Continuous Positive Airway Pressure on Atrial Fibrillation in Obstructive Sleep Apnea" by Kanagala et al. (2003): This study investigates the effect of continuous positive airway pressure (CPAP) on atrial fibrillation (AF) in patients with obstructive sleep apnea (OSA). OSA is a known risk factor for AF, and it is hypothesized that treatment of OSA with CPAP may reduce the risk of AF. The study was a randomized controlled trial that included 46 patients with OSA and paroxysmal AF. The patients were randomly assigned to receive either CPAP treatment or sham treatment (placebo CPAP). The study evaluated the effect of CPAP treatment on the incidence and duration of AF episodes. The study found that CPAP treatment significantly reduced the incidence and duration of AF episodes in patients with OSA. Patients who received CPAP treatment had a 42% reduction in the number of AF episodes and a 46% reduction in the duration of AF episodes compared to patients who received sham treatment. This study provides important evidence for the potential benefits of CPAP therapy in reducing the risk of AF in patients with OSA. The study findings can be used to support the development of a smart CPAP/BiPAP machine that includes features for monitoring and treating AF in patients with OSA. By incorporating these features, the smart CPAP/BiPAP machine can provide more personalized treatment for patients with OSA and reduce their risk of AF. Additionally, the study highlights the importance of adherence to CPAP therapy, which can inform the design of features to encourage patient compliance with therapy.

2.2 Oxygen Concentrator.

"Oxygen: can't live with it, can't live without it--and can't live without enough of it" by Kronenberg RS, Drage CW: The paper discusses the importance of oxygen in the human body, the implications of oxygen deprivation, and the potential risks associated with oxygen therapy. The authors highlight the importance of maintaining appropriate oxygen levels in the body and the potential negative effects of both hypo- and hyper-oxygenation The paper is a review article that synthesizes existing literature on the role of oxygen in the body and the use of oxygen therapy in clinical practice. The authors reviewed studies from a variety of fields, including pulmonology, critical care, and neurology, to provide a comprehensive overview of the topic The authors emphasize the importance of oxygen in maintaining the body's energy metabolism and the regulation of vital physiological processes. The paper discusses the potential risks associated with oxygen therapy, including oxygen toxicity, which can cause lung damage, retinopathy, and other complications. The authors also discuss the risk of suppressing the respiratory drive, which can lead to hypoventilation and carbon dioxide retention. The paper highlights the importance of monitoring oxygen levels during oxygen therapy to ensure safe and effective treatment. The authors emphasize the use of pulse oximetry as a non-invasive way to monitor oxygen saturation levels in the blood. They also discuss the importance of monitoring arterial blood gases in certain clinical contexts to ensure appropriate oxygen levels. The paper concludes that while oxygen therapy is an essential treatment in many clinical settings, it is important to use it appropriately and monitor oxygen levels to minimize the potential risks associated with oxygen therapy. The authors emphasize the importance of individualizing oxygen therapy to the patient's needs and monitoring the patient's response to treatment. This paper provides important insights into the use of oxygen therapy in the context of sleep apnea and CPAP/BiPAP treatment. The authors highlight the potential risks associated with oxygen therapy and the importance of monitoring oxygen levels during therapy to ensure safe and effective treatment. The information from this paper can be used to inform the development of a smart CPAP/BiPAP machine that incorporates oxygen monitoring and support features to ensure patients receive appropriate levels of oxygen during therapy. This can help to reduce the potential risks associated with oxygen therapy and improve the overall effectiveness of CPAP/BiPAP treatment for sleep apnea.

"A comparison of two portable oxygen concentrators on exertional desaturation and endurance exercise in COPD" by Parry et al. The paper investigates the impact of two different portable oxygen concentrators on exertional desaturation and endurance exercise in patients with chronic obstructive pulmonary disease (COPD). The authors highlight the importance of oxygen therapy in COPD and the potential benefits of using portable oxygen concentrators. The study was a randomized, double-blind, crossover trial that compared two different portable oxygen concentrators in 22 patients with COPD. The study measured oxygen saturation levels during exercise using a six-minute walk test and an endurance shuttle walk test. The study also collected data on patient-reported outcomes, including dyspnea and fatigue. The study found that both portable oxygen concentrators improved oxygen saturation levels during exercise compared to no oxygen therapy. However, one of the concentrators was more effective at maintaining oxygen saturation levels during exercise than the other. The study also found that the concentrator that was more effective at maintaining oxygen saturation levels was associated with lower levels of dyspnea and fatigue during exercise. The paper concludes that both portable oxygen concentrators were effective at improving oxygen saturation levels during exercise in patients with COPD. However, one of the concentrators was more effective at maintaining oxygen saturation levels during exercise and was associated with lower levels of dyspnea and fatigue. The authors suggest that the choice of portable oxygen concentrator may impact patient outcomes and that further research is needed to identify the most effective concentrators for patients with COPD. This paper provides important insights into the use of portable oxygen concentrators in the context of COPD and exercise. The authors highlight the potential benefits of using portable oxygen concentrators to improve oxygen saturation levels during exercise and reduce symptoms of dyspnea and fatigue. The information from this paper can be used to inform the development of a smart CPAP/BiPAP machine that incorporates oxygen monitoring and support features to improve patient outcomes. Specifically, this paper can inform the development of oxygen concentrator features and technology that can help to maintain appropriate oxygen levels during exercise and reduce the potential risks associated with oxygen therapy.

2.3 Machine Learning

"A dynamic control method for intelligent ventilator based on machine learning" by Zou and Yu (2019) presents a novel approach to controlling ventilator settings using machine learning techniques. The objective of the study is to develop an intelligent ventilator control system that can adaptively adjust ventilation parameters based on patient-specific data, thereby improving the efficacy and safety of mechanical ventilation. The authors begin by highlighting the limitations of traditional fixed-parameter ventilators, which may not optimize ventilation for individual patients' needs and can potentially cause harm or discomfort. They propose a dynamic control method that utilizes machine learning algorithms to continuously analyze patient data and adjust ventilator settings accordingly. The methodology of the study involves collecting real-time patient data, including vital signs, respiratory parameters, and clinical information. This dataset is then used to train a machine learning model, specifically a dynamic control algorithm, which can learn the optimal ventilator settings for different patient conditions and adapt to changes over time.The authors employ various machine learning techniques, such as support vector machines (SVM), artificial neural networks (ANN), and decision trees, to develop and compare different control algorithms. These algorithms are trained using a dataset comprising patient data and corresponding optimal ventilator settings, which are determined by clinical experts.The performance of the machine learning-based control algorithms is evaluated through simulations and compared against traditional fixed-parameter ventilation. The simulations involve scenarios representing different respiratory conditions and patient responses. The authors assess the algorithms' ability to achieve desired ventilation targets, minimize the occurrence of complications, and optimize patient comfort.

The paper concludes by discussing the implications and potential benefits of the proposed intelligent ventilator control system. It highlights the potential for personalized, adaptive ventilation strategies that can optimize treatment outcomes and improve patient care in clinical settings.

"Application of machine learning algorithms in detection and diagnosis of obstructive sleep apnea: A comprehensive review" by Vanitha and Sumathi (2018) provides an extensive overview of the use of machine learning algorithms in the detection and diagnosis of obstructive sleep apnea (OSA). The objective of the study is to analyze the existing literature and research on the application of machine learning techniques in OSA diagnosis, highlighting the advancements and challenges in this field.

The authors begin by providing an introduction to OSA, a common sleep disorder characterized by recurrent episodes of partial or complete blockage of the upper airway during sleep. They discuss the importance of early detection and accurate diagnosis of OSA, as it can significantly impact patients' quality of life and lead to various comorbidities if left untreated.

The methodology of the study involves conducting a comprehensive literature search and analysis of relevant articles, research papers, and conference proceedings on the application of machine learning algorithms in OSA diagnosis. The authors review and summarize the findings of these studies, categorizing them based on the specific machine learning techniques employed.

The paper covers a wide range of machine learning algorithms used in OSA detection and diagnosis, including decision trees, support vector machines, artificial neural networks, genetic algorithms, and ensemble methods. For each algorithm, the authors discuss its principles, advantages, limitations, and specific applications in OSA diagnosis.

The review also highlights the different types of data utilized in machine learning-based OSA diagnosis, such as polysomnography (PSG) data, electroencephalogram (EEG) signals, respiratory signals, and demographic and clinical features. The authors discuss the challenges associated with data collection, preprocessing, feature extraction, and model training in OSA diagnosis.

"Bi-level positive airway pressure therapy prediction in obstructive sleep apnea using machine learning techniques" by Abadi et al. (2018) presents a study on the application of machine learning techniques for predicting the effectiveness of bi-level positive airway pressure (BiPAP) therapy in patients with obstructive sleep apnea (OSA). The objective of the study is to develop a prediction model that can assist clinicians in determining the optimal BiPAP therapy settings for individual OSA patients.

The authors begin by introducing the background and importance of BiPAP therapy in managing OSA. BiPAP therapy is a form of non-invasive ventilation that provides different air pressure levels during inhalation and exhalation, aimed at improving breathing and reducing the number of respiratory events in OSA patients. However, determining the appropriate pressure settings for individual patients can be challenging, and the authors propose using machine learning techniques to develop a prediction model for this purpose.

The methodology of the study involves collecting a dataset comprising patient information, including demographic data, polysomnography (PSG) data, and clinical features. The dataset consists of OSA patients who underwent BiPAP therapy and their corresponding therapy outcomes, such as treatment success or failure.

The authors employ various machine learning algorithms, including decision trees, random forests, support vector machines, and neural networks, to develop the prediction model. The dataset is divided into training and testing sets, with the training set used to train the model and the testing set used to evaluate its performance.

To enhance the prediction model's accuracy, the authors employ feature selection techniques to identify the most relevant features from the dataset. They also utilize cross-validation techniques to assess the model's generalizability and minimize overfitting.

The performance of the prediction model is evaluated using various metrics, such as accuracy, sensitivity, specificity, and area under the receiver operating characteristic curve (AUC-ROC). The authors compare the performance of different machine learning algorithms and identify the most effective algorithm for predicting BiPAP therapy outcomes in OSA patients.

CHAPTER – 3. STM32 Blackpill

3.1 STM32

STM32 Black Pill is a small microcontroller board based on the STM32F103C8T6 microcontroller, which is a member of the STM32 family of ARM Cortex-M3 based microcontrollers. The board is called the "Black Pill" because of its small size and black color. The board is compatible with the Arduino development environment, making it easy to use for those familiar with Arduino programming. Additionally, the STM32F103C8T6 microcontroller provides a wide range of peripherals, such as timers, ADCs, SPI, I2C, UART, USB, and CAN, making it suitable for a wide range of applications.

STM32 microcontrollers are often used in ventilators and CPAP/BiPAP machines due to their high processing power, low power consumption, and a wide range of communication interfaces. Here are some reasons why STM32 is a better option for these applications:

- High processing power: STM32 microcontrollers are based on ARM Cortex-M3/M4 processors, which provide high processing power to execute complex algorithms and control systems required in ventilators and CPAP/BiPAP machines.
- Low power consumption: STM32 microcontrollers are designed to operate at low power, making them suitable for battery-powered devices such as portable ventilators and CPAP/BiPAP machines.
- Communication interfaces: STM32 microcontrollers have a wide range of communication interfaces, such as UART, I2C, SPI, CAN, USB, and Ethernet, which make it easier to connect and communicate with other devices and sensors.
- Real-time operating system (RTOS) support: STM32 microcontrollers support various RTOS such as FreeRTOS, which provides a flexible and efficient way to manage multiple tasks and processes required in ventilators and CPAP/BiPAP machines.

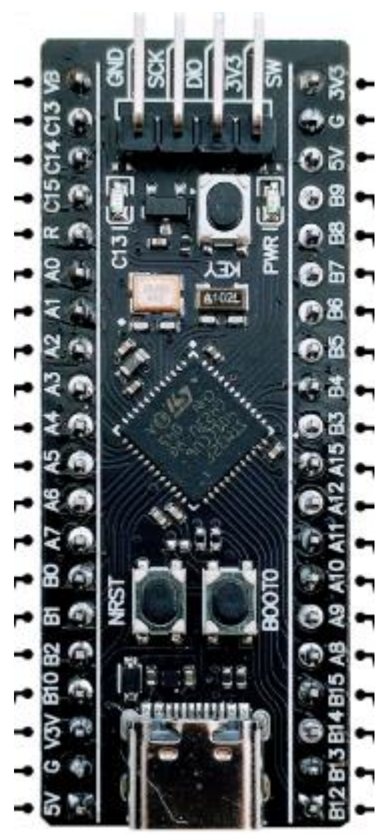

Figure 1 STM32 Black Pill

- Safety and reliability: STM32 microcontrollers are designed to meet various safety and reliability standards, such as IEC 60601-1, which is a standard for medical electrical

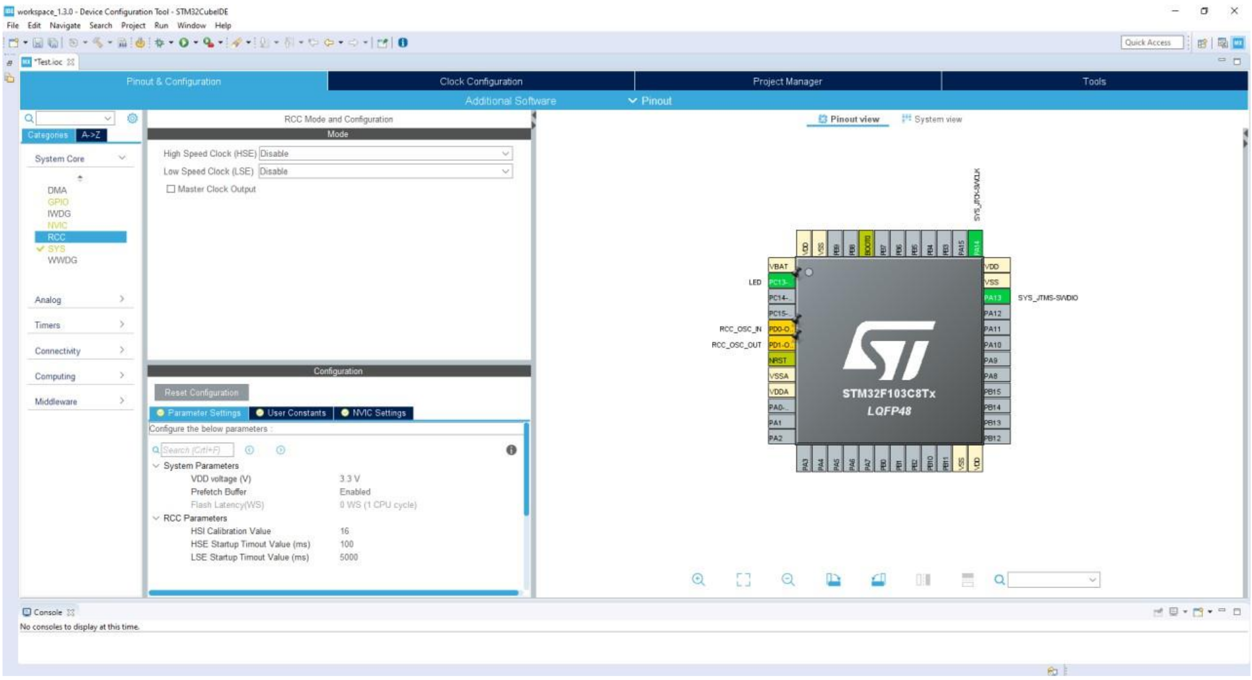

Figure 2 STM Cube IDE Interface

equipment, ensuring that they are safe and reliable for use in medical devices.

3.1 STM Cube IDE Interface.

STM Cube Ide will be used to program STM32 Black pill.

3.1.1 Prescaler

Prescalers are used in STM32 microcontrollers to divide the frequency of an input clock signal before it is used as a clock source for a peripheral, such as a timer or an external interrupt. The prescaler value determines how much the input clock frequency is divided before it is used by the peripheral. For example, a prescaler value of 10 would divide the input clock frequency by 10 before it is used as a clock source. Prescalers can be used to adjust the frequency of a peripheral to meet specific timing requirements. For example, in a timer peripheral, the prescaler can be used to adjust the timer frequency to match the desired output waveform frequency. This is important in applications such as motor control or PWM (Pulse Width Modulation) signal generation.

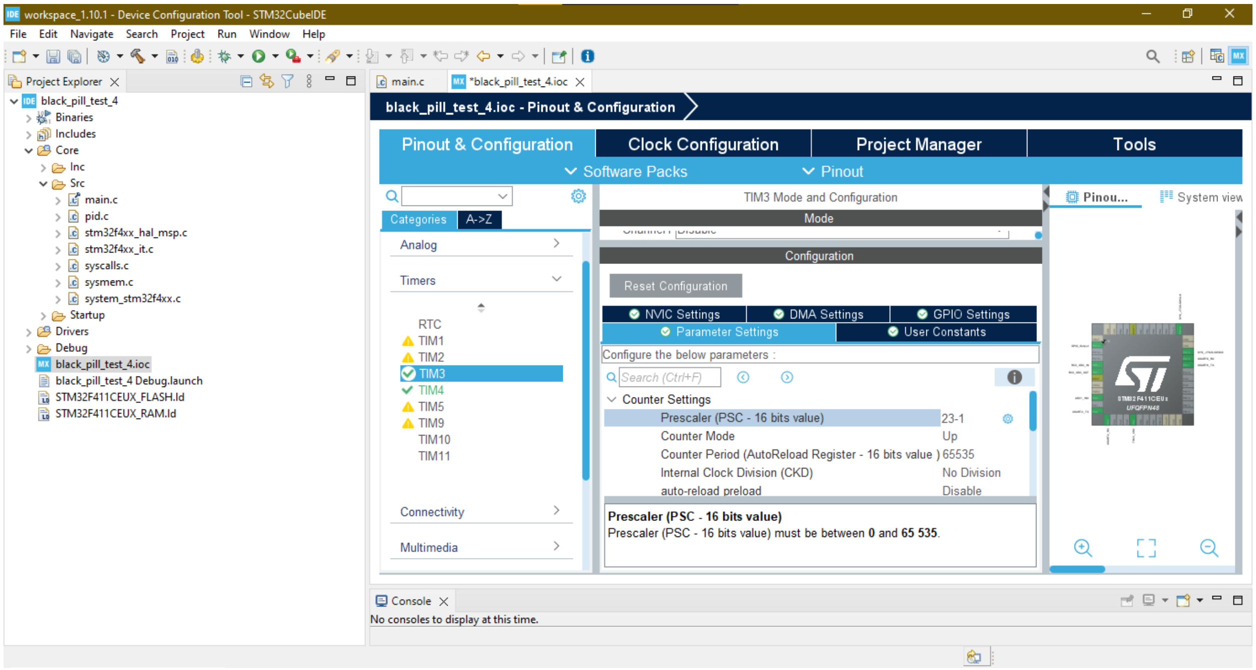

Figure 3 Prescalar

$$Prescalar = \frac{Maximum\ Frequency\ of\ the\ system}{(AutoReload\ Register\ Maximum\ Value) \times (Frequency)}$$

$$= \frac{72 \times 10^6}{65535 \times 50}$$

$$= 21.9 \sim 22$$

In STM32 microcontrollers, the prescaler register value is written with "-1" because the prescaler value itself is always one less than the value stored in the prescaler register.

The reason for this is that the prescaler register is typically an n-bit register, where n is the number of bits used to represent the register value. Since the prescaler value is always one less than the value stored in the prescaler register, this ensures that the prescaler value fits within the n-bit register. Overall, writing the prescaler value with "-1" is a convention used in STM32 microcontrollers to ensure that the prescaler value fits within the n-bit prescaler register and to simplify the formula for calculating the prescaler value.

Hence we write 22 as 23-1

3.1.2 Timer Configuration

Here's an overview of the timer peripherals on this board and their usage:

1. General Purpose Timer (TIM1, TIM2, TIM3, TIM4) These timers are designed for general-purpose timing and counting applications. They are 16-bit timers and can operate in a variety of modes, including:

- Input capture mode: Measures the duration of an external event and stores the result in the timer register.
- Output compare mode: Generates an output signal when the timer value matches a predefined compare value.
- PWM mode: Generates a pulse-width modulated (PWM) output signal for controlling the duty cycle of a signal.

2. Advanced Control Timer (TIM1) This timer is designed for advanced control applications, such as motor control or power conversion. It is a 16-bit timer and can operate in a variety of modes, including:

- Center-aligned PWM mode: Generates a PWM output signal with a center-aligned waveform.
- Complementary PWM mode: Generates two complementary PWM signals with opposite polarities.

3. Basic Timer (TIM6, TIM7)

- These timers are designed for basic timing applications and are 16-bit timers. They do not support input capture or output compare modes

NOTE: We will Only use Timer 3 and Timer 4.

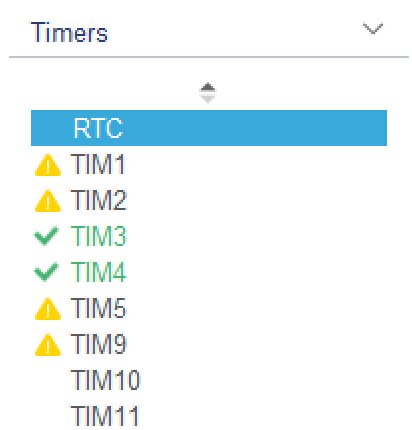

Figure 4: Timers

3.2 STM Code.

This code sets up the basic includes for a C program for an STM32 microcontroller, including important header files for working with strings and standard input/output, as well as a custom header file for implementing a PID controller.(Figure 4)

main.c   *black_pill_test_4.ioc

```
/* USER CODE BEGIN Header */
/**
  ******************************************************************************
  * @file           : main.c
  * @brief          : Main program body
  ******************************************************************************
  * @attention
  *
  * Copyright (c) 2022 STMicroelectronics.
  * All rights reserved.
  *
  * This software is licensed under terms that can be found in the LICENSE file
  * in the root directory of this software component.
  * If no LICENSE file comes with this software, it is provided AS-IS.
  *
  ******************************************************************************
  */
/* USER CODE END Header */
/* Includes ------------------------------------------------------------------*/
#include "main.h"

/* Private includes ----------------------------------------------------------*/
/* USER CODE BEGIN Includes */
#include "string.h"
#include "stdio.h"
#include "pid.h"
/* USER CODE END Includes */

/* Private typedef -----------------------------------------------------------*/
/* USER CODE BEGIN PTD */

/* USER CODE END PTD */

/* Private define ------------------------------------------------------------*/
```

Figure 5: Included Libraries

The code declares handles for two timers, **htim3** and **htim4**. These handles will be used to control the timers, which are used for timing and triggering events on the microcontroller. Next, the code declares handles for two UARTs, huart2 and huart6. UARTs are used for serial communication and these handles will be used to configure and send/receive data over these communication channels. Finally, the code declares several function prototypes for initializing the microcontroller's peripherals, including the system clock, GPIO pins, ADC, timers, UARTs, and DMA channels.(Figure 5)

```c
/* USER CODE END PM */

/* Private variables ---------------------------------------------------------*/
ADC_HandleTypeDef hadc1;

TIM_HandleTypeDef htim3;
TIM_HandleTypeDef htim4;

UART_HandleTypeDef huart2;
UART_HandleTypeDef huart6;
DMA_HandleTypeDef hdma_usart2_rx;

/* USER CODE BEGIN PV */

/* USER CODE END PV */

/* Private function prototypes -----------------------------------------------*/
void SystemClock_Config(void);
static void MX_GPIO_Init(void);
static void MX_DMA_Init(void);
static void MX_ADC1_Init(void);
static void MX_TIM3_Init(void);
static void MX_USART2_UART_Init(void);
static void MX_USART6_UART_Init(void);
static void MX_TIM4_Init(void);
/* USER CODE BEGIN PFP */

/* USER CODE END PFP */

/* Private user code ---------------------------------------------------------*/
/* USER CODE BEGIN 0 */

//user parameters:
```

Figure 6 : Declaring Timers and input/output Pins

The variables are declared which will be used in CPAP / BiPAP Modes. (Figure 6)

```c
/* USER CODE END PFP */

/* Private user code ---------------------------------------------------------*/
/* USER CODE BEGIN 0 */

//user parameters:
    char mode[5] = "CPap";
    int IPap = 0;
    int EPap = 0;
    unsigned long inspt = 0;
    int BPM = 0;
    int trigp = 0;
//control parameters:
    char modecopy[5] = "CPap";
    int expt = 3000;
    char *breath = "inhaling";
    char IPap_d[100] = "0";
    char EPap_d[100] = "0";
    char inspt_d[100] = "0";
    char BPM_d[100] = "0";
    char trigp_d[100] = "0";
    char *ststp = "Stop";
//Pressure sensor
    uint16_t raw;
    char msg[10];
    int Volts; double dVolts;
    double Pressure;    double corr_Pressure;
    //used for averaging:
    double Pressurediff;
    double Pressuresent;
//PID
    PID_TypeDef TPID;
    double PIDOut, Setpoint;
```

Figure 7: Initializing CPAP/BiPAP Variables

Nextion Screen will be used for our display. Human Machine Interface (HMI) displays that are designed to be easy to use and integrate One of the key features of Nextion displays is that they are programmable and customizable using the Nextion Editor software, which allows users to design their own custom user interfaces and upload them to the display via a simple serial interface. Functions are used to effectively communicate between the screen and microprocessor. The given code defines three functions, **NEXTION_SendString**, **NEXTION_Sendnum**, and **NEXTION_Sendpic**, which are used to send commands to a Nextion display via a UART interface. (Figure 7)

main.c   *black_pill_test_4.ioc

```c
//Nextion:
    uint8_t Cmd_End[3] = {0xFF,0xFF,0xFF};  // command end sequence
    void NEXTION_SendString (char *ID, char *string)
        {
            char buf[50];
            int len = sprintf (buf, "%s.txt=\"%s\"", ID, string);
            HAL_UART_Transmit(&huart2, (uint8_t *)buf, len, 1000);
            HAL_UART_Transmit(&huart2, Cmd_End, 3, 100);
        }
    void NEXTION_Sendnum (char *ID, char *string)
    {
        char buf[50];
        int len = sprintf (buf, "%s.val=%s", ID, string);       //difference b/w this and the one used for txt is that the text's sprintf puts "" around the stri
        HAL_UART_Transmit(&huart2, (uint8_t *)buf, len, 1000);
        HAL_UART_Transmit(&huart2, Cmd_End, 3, 100);
    }
    void NEXTION_Sendpic (char *ID, char *string)
    {
        char buf[50];
        int len = sprintf (buf, "%s.pic=%s", ID, string);       //difference b/w this and the one used for txt is that the text's sprintf puts "" around the stri
        HAL_UART_Transmit(&huart2, (uint8_t *)buf, len, 1000);
        HAL_UART_Transmit(&huart2, Cmd_End, 3, 100);
    }
//serials:
        char Rx_data[16]    = ",TT,00000000000,";
        char Rx_data2[16]   = ",TT,00000000000,";
//opening serials:
        //char *array[5];
        //int i=0;
        char *resetter = "0";
//DMA Callback functions:
    void HAL_UART_RxHalfCpltCallback(UART_HandleTypeDef *huart)
        {
            //HAL_UART_Transmit(&huart2, "aaa", strlen("aaa"), 0xFFFF);
```

Figure 8 : Nextion Display Functions.

The PID controller is initialized with a setpoint of zero and three tuning parameters: 2.5 for the proportional gain, 2.0 for the integral gain, and 0 for the derivative gain.

The ADC measurement is converted to volts by :

$$dVolts = Volts \times \frac{5}{4096}$$

The variable 'corr_Pressure' is then computed using:

$$corr_{Pressure} = \frac{1000 \times ((\frac{dVolts}{5}) - 0.04)}{0.09}$$

main.c   *black_pill_test_4.ioc

```c
/* Initialize all configured peripherals */
MX_GPIO_Init();
MX_DMA_Init();
MX_ADC1_Init();
MX_TIM3_Init();
MX_USART2_UART_Init();
MX_USART6_UART_Init();
MX_TIM4_Init();
/* USER CODE BEGIN 2 */
// PID set-up
            Setpoint = 0;
            PID(&TPID, &Pressure, &PIDOut, &Setpoint, 2.5, 2.0, 0, _PID_P_ON_E, _PID_CD_DIRECT);
            PID_SetMode(&TPID, _PID_MODE_AUTOMATIC);
            PID_SetSampleTime(&TPID, 5);
            PID_SetOutputLimits(&TPID, 4800, 6500);
  //Correction Pressure
            HAL_ADC_Start(&hadc1);
            HAL_ADC_PollForConversion(&hadc1, HAL_MAX_DELAY);
            raw = HAL_ADC_GetValue(&hadc1);
            raw = raw - '0';
            Volts = raw;
            dVolts = (double) Volts*5/4096;
            corr_Pressure = 1000.00*((dVolts/(5.00))-0.04)/0.09;
```

Figure 9 : PID Set Up

The PID controller is also set to operate in automatic mode and with a sample time of 5 milliseconds. The output of the controller is limited to a range of 4800 to 6500.

```c
  // Fan set-up
            TIM3 -> CCR2=4900;
            HAL_TIM_PWM_Start(&htim3, TIM_CHANNEL_2);
            HAL_Delay(1000);          //5000. set to 5000 if not done
            int i = 0;
            while (i<5999)
              {
                  TIM3 -> CCR2=i;
                  i = i+1;
                  if (i>6000) { i=4800;}
                  HAL_Delay(0);       //delay 1. set to 1
              }
            TIM3 -> CCR2=5000;    //shut down the fan after running it on loop once
      // DMA Uart Receive
          HAL_UART_Receive_DMA (&huart2, Rx_data, 16);
/* USER CODE END 2 */
```

Figure 10 : Fan Setup

There are two modes in the machine

- Continuous Positive Airway Pressure Mode.
- Bilevel Positive Airway Pressure Mode.

The CPAP Mode requires only one measurement “Inhale Positive Airway Pressure” or IPAP, Whereas BiPAP Mode requires

- “Inhale Positive Airway Pressure” or IPAP.
- “Exhale Positive Airway Pressure “ or EPAP.
- “Beats Per Minute” or BPM
- Triggering Point.

```c
        //CPap mode:
            if (strcmp(array[0], "C") == 0)
                {
                  HAL_GPIO_WritePin(GPIOC, GPIO_PIN_13, 0);   HAL_Delay(30);
                  HAL_GPIO_WritePin(GPIOC, GPIO_PIN_13, 1);   HAL_Delay(30);
                  HAL_GPIO_WritePin(GPIOC, GPIO_PIN_13, 0);   HAL_Delay(30);
                  HAL_GPIO_WritePin(GPIOC, GPIO_PIN_13, 1);   HAL_Delay(30);
                  HAL_GPIO_WritePin(GPIOC, GPIO_PIN_13, 0);   HAL_Delay(30);
                  sprintf(mode, "CPap");
                  sprintf(modecopy, "CPap");
                  IPap =      atoi(array[1]);
                  pagestatus = "next";
                  HAL_UART_Transmit(&huart6, "CPap", strlen("CPap"), 0xFFFF); HAL_UART_Transmit(&huart6, "\n", strlen("\n"), 0xFFFF);
                }
        //BiPap mode:
            if (strcmp(array[0], "B") == 0)
              {
                  HAL_GPIO_WritePin(GPIOC, GPIO_PIN_13, 0);   HAL_Delay(20);
                  HAL_GPIO_WritePin(GPIOC, GPIO_PIN_13, 1);   HAL_Delay(20);
                  HAL_GPIO_WritePin(GPIOC, GPIO_PIN_13, 0);   HAL_Delay(20);
                  HAL_GPIO_WritePin(GPIOC, GPIO_PIN_13, 1);   HAL_Delay(20);
                  HAL_GPIO_WritePin(GPIOC, GPIO_PIN_13, 0);   HAL_Delay(20);
                  sprintf(mode, "BiPap");
                  sprintf(modecopy, "BiPap");
                  IPap =      atoi(array[1]);
                  EPap =      atoi(array[2]);
                  inspt =     atoi(array[3]);     inspt = inspt*1000;
                  BPM =       atoi(array[4]);     expt = (inspt)-(1000.00*60.00/BPM);     if (expt < 0)   {   expt = -1*expt;     }
                  trigp =     atoi(array[5]);
                  pagestatus = "next";
                  HAL_UART_Transmit(&huart6, "BiPap", strlen("BiPap"), 0xFFFF);   HAL_UART_Transmit(&huart6, "\n", strlen("\n"), 0xFFFF);
                }
```

Figure 11 : Taking CPAP/BiPAP Values from Nextion Display

CHAPTER – 4. GRAPHICAL USER INTERFACE

4.1 Nextion Display

Nextion is a brand of intelligent displays that are designed to simplify the process of building user interfaces for electronic projects. Nextion displays are equipped with a microcontroller and a touch-sensitive display, and they allow you to create user interfaces that can interact with other electronic components such as sensors, motors, and other devices. Overall, the ease of use, touchscreen functionality, flexibility, and integration capabilities of Nextion displays make them an attractive option for medical device designers looking to create intuitive, user-friendly interfaces for their devices.

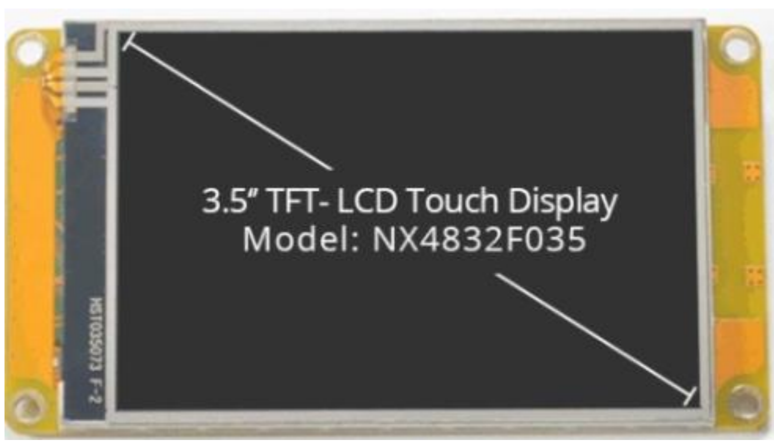

Figure 12 Nextion 3.5 Inch Display (Front)

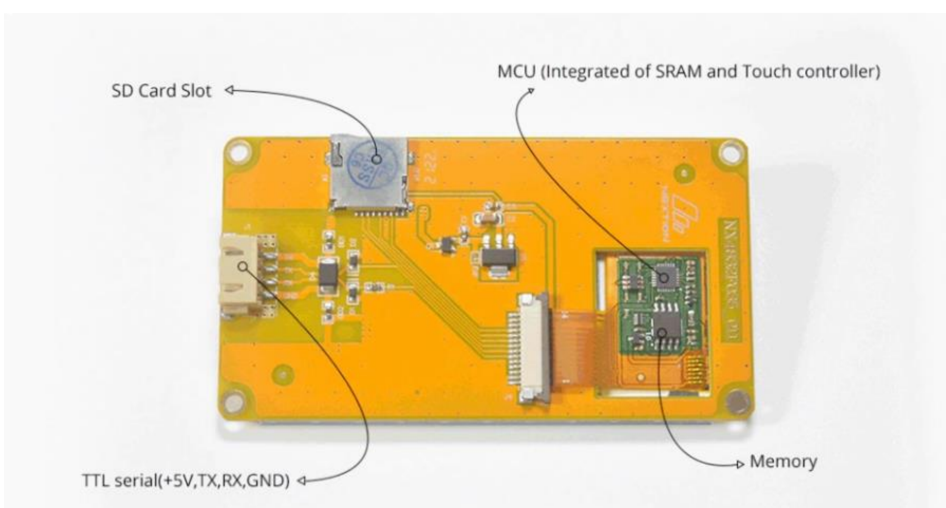

Figure 13 Nextion 3.5 Inch Display (Back)

At the start of the GUI , there will be three options given to the user:

- CPAP
- BiPAP

4.1.1 CPAP

Continuous positive airway pressure (CPAP) is a medical therapy used to treat sleep apnea, a condition where a person's breathing is interrupted during sleep. A CPAP machine delivers a steady stream of air pressure through a mask worn over the nose and/or mouth, which keeps the airway open and prevents interruptions in breathing.

- Adjust pressure settings: The Nextion display allows the user to adjust the pressure settings of the CPAP machine. This includes adjusting the pressure level or setting up ramp features to gradually increase the pressure over a period of time.
- Display current pressure: The Nextion display shows the current pressure being delivered by the CPAP machine. This allows the user to monitor the therapy and ensure that the pressure is at the appropriate level.

Figure14 CPAP Set Pressure

Figure 15 CPAP Display Pressure

4.1.2 BiPAP

BiPAP (bilevel positive airway pressure) is a medical therapy similar to CPAP, but with two different pressure levels: a higher level of pressure during inhalation and a lower level of pressure during exhalation. BiPAP is often used to treat conditions such as chronic obstructive pulmonary disease (COPD) or congestive heart failure (CHF).

- Inhale Pressure: Adjust the IPAP according to the user's needs.
- Exhale Pressure: Adjust the EPAP according to the user's needs.
- BPM: BPM stands for beats per minute and is a common measurement of heart rate. It refers to the number of times the heart beats in a minute.
- Trigger point: Trigger points in BiPAP settings refer to the pressure level at which the machine switches from the inhalation phase to the exhalation phase. The trigger point is the point at which the BiPAP machine detects that the user has completed an inhalation and should begin to lower the pressure to the exhalation phase.

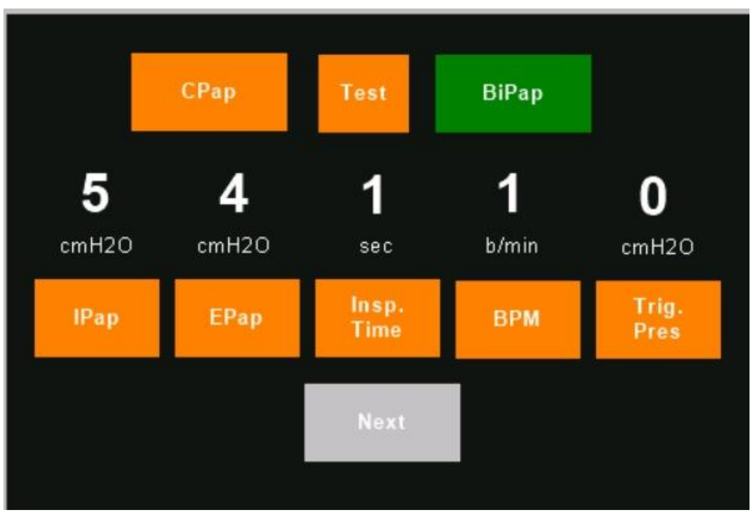

Figure 16 BiPAP Set up

CHAPTER – 5. HARDWARE

The hardware components used in the project are as follows:

- **STM32 Blackpill** - a microcontroller board based on the STM32F103C8T6 ARM Cortex-M3 CPU
- **MPX5010 Differential Pressure Sensor** - a high-accuracy sensor capable of measuring pressure differences
- **KE-25 Oxygen Sensor** - a sensor that can measure oxygen concentration in gas
- **BLDC Blower Fans** - brushless DC motors that can provide high-efficiency air flow and pressure control
- **Nextion HMI Display** - a touchscreen display for user interaction and feedback
- **BLHeli-32** - an open-source firmware for controlling brushless DC motors
- **12V Power Supply** - a power source for the hardware components
- **2-Way Solenoid Valve** - a valve for controlling the flow of gas, which can be used for oxygen support
- **Oxygen Concentrator** - a device that extracts oxygen from the air and delivers it to the user via a cannula or mask
- **CPAP/BiPAP Mask** - a mask that delivers positive airway pressure to the user to treat sleep apnea or other breathing disorders
- **Pinching Valve** - valve that controls the flow of fluid through a tube by squeezing or pinching it shut
- **Oximeter** - a non-invasive device that measures the oxygen saturation in a person's blood

5.1 Differential Pressure Sensor

Figure 17 Pressure Sensor

The MPX5010 has a wide pressure range of 0-10 kPa and a high sensitivity of 45 mV/kPa, making it suitable for a variety of applications such as medical equipment, the MPX5010 is a versatile and reliable differential pressure sensor that can be used in a wide range of applications that require accurate pressure measurements. In a CPAP/BiPAP machine with oxygen support, it could be used to measure the differential pressure between the user's lungs and the surrounding air to adjust the airflow and ensure proper oxygenation.

5.2 KE 25 Oxygen Sensor

The KE-25 oxygen sensor is a type of electrochemical sensor that is commonly used to measure the concentration of oxygen in a gas mixture. It is composed of a sensing electrode, a reference electrode, and an electrolyte solution that allows for the transfer of oxygen molecules The output signal from the KE-25 oxygen sensor is linearly proportional to the concentration of oxygen in the gas mixture being measured. CPAP/BiPAP machine with oxygen support, the KE-25 sensor could be used to monitor the concentration of oxygen in the air being delivered to the user's lungs and adjust the oxygen supply as needed to ensure proper oxygenation.

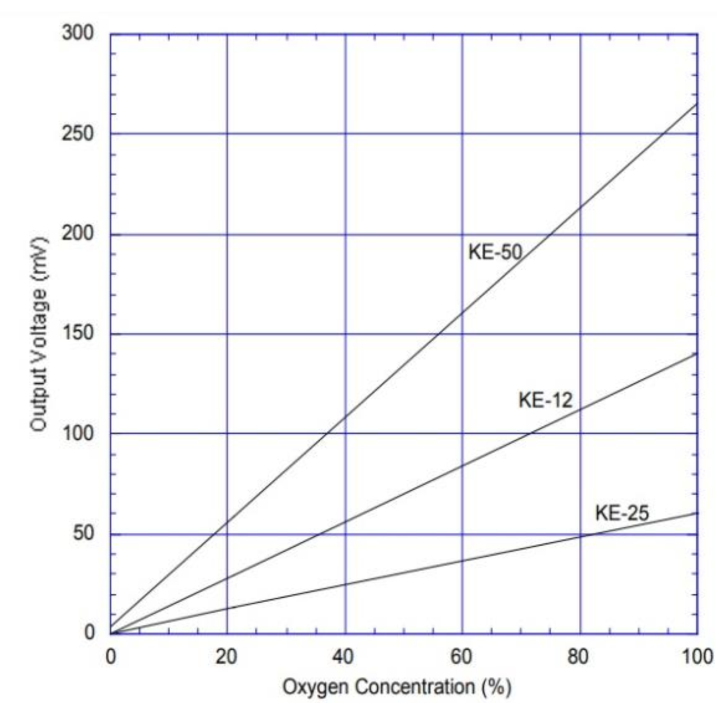

Figure 18 KE 25 Graph (Datasheet)

$$\text{Oxygen Concentration} = (\text{mV}) \times 1.9265 + 0.5345$$

5.3 BLDC Fans

BLDC (Brushless DC) blower fans are a type of electric motor-driven fan that uses electronic commutation instead of brushes to achieve more precise and efficient control of the fan's speed and power consumption. In the context of a CPAP/BiPAP machine with oxygen support, BLDC blower fans could be used to control the flow of air and oxygen to the user's lungs, allowing for precise control of the air pressure and oxygen concentration. This could help improve the effectiveness and comfort of the therapy, while also reducing the overall power consumption and noise levels of the device.

5.4 BLHeli – 32

BLHeli32 is a firmware developed for electronic speed controllers (ESCs) used in brushless DC motors (BLDC). It is an open-source firmware that can be flashed onto ESCs to improve their performance, especially in applications where precise motor control is required. In a CPAP/BiPAP machine, BLHeli32 can be used to control the speed of the BLDC blower fans used to deliver air to the patient. With precise motor control, the machine can maintain a consistent air pressure and flow rate, improving the effectiveness of the therapy.

In BLHeli32, the current limit can be set using the "Current Limit" parameter. The user can choose a maximum current value that the ESC will allow the motor to draw. If the motor tries to draw more current than the limit, the ESC will reduce the motor's power to prevent damage.

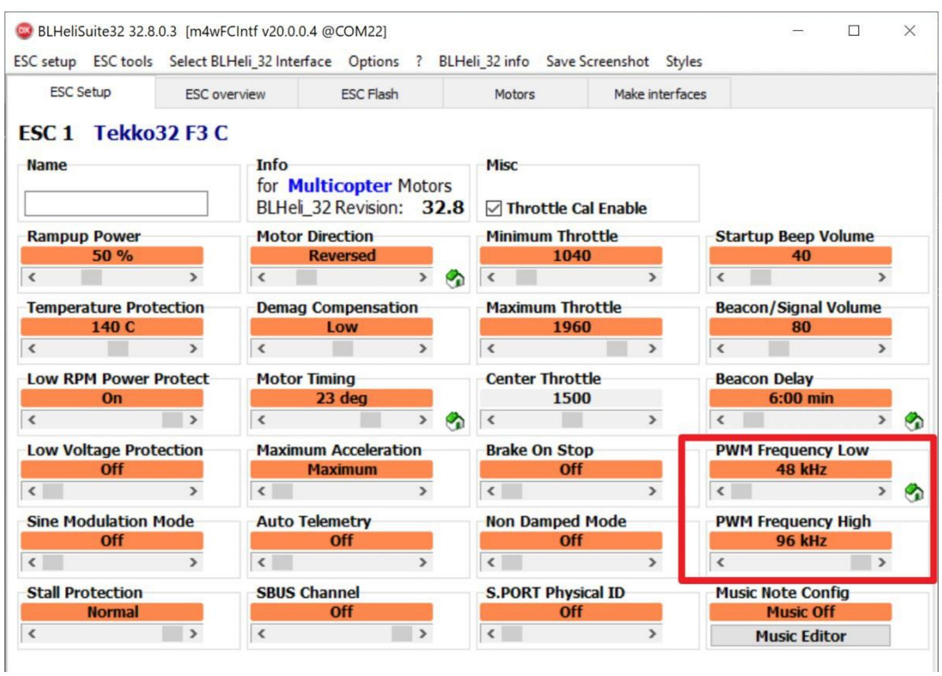

Figure 20 BLHeli32 Configuration

5.5 Two Way Solenoid Valve

When an electrical current is applied to

Figure 19 KE 25 in action

the solenoid coil, a magnetic field is generated which moves the valve stem, allowing fluid or gas to flow through the valve from the inlet port to the outlet port. When the electrical current is removed, the magnetic field dissipates, and a spring returns the valve to its original position, blocking the flow of fluid or gas.

In CPAP/BiPAP machines, a two-way solenoid valve can be used to control the flow of oxygen or air to the patient. The valve can be programmed to open or close based on certain conditions, such as the patient's breathing patterns or the oxygen level in the room. This helps to ensure that the patient receives the correct amount of oxygen or air to maintain optimal breathing and prevent complications.

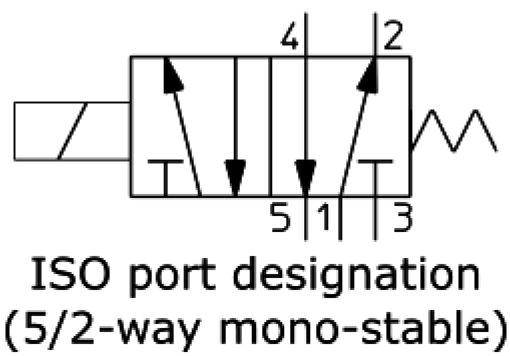

Figure 21 Solenoid Valve

5.6 Pinch Valve WK01-417-6/8 12VDC

A pinch valve can be used in the oxygen concentrator to control the flow of oxygen from the sieve bed to the flow meter. When the valve is open, oxygen can flow freely into the flow meter and tubing, allowing the patient to receive the required amount of oxygen. When the valve is closed, the flow of oxygen is stopped, preventing oxygen from escaping from the concentrator and ensuring that the patient does not receive too much or too little oxygen.

The advantage of using a pinch valve in an oxygen concentrator is that it provides precise control over the flow of oxygen. Additionally, pinch valves are easy to clean and maintain, making them a reliable and cost-effective option for use in oxygen concentrators.

5.7 Oximeter MAX30100

A pulse oximeter, which is a small device that attaches to the fingertip or earlobe. The pulse oximeter emits two different wavelengths of light that pass through the finger or earlobe and are detected by a photodetector on the other side. An oximeter can be incorporated into an oxygen concentrator to provide a way to monitor the oxygen saturation levels of the patient receiving oxygen therapy. The oximeter can be connected to the oxygen tubing, and the readings can be displayed on the concentrator's control panel or a separate monitor. Overall, incorporating an oximeter into an oxygen concentrator can provide a valuable tool for monitoring the patient's oxygen saturation levels and ensuring that they are receiving the correct amount of oxygen therapy.

5.8 Oxygen Concentrator

An oxygen concentrator is a medical device that is designed to provide oxygen therapy to patients with respiratory problems or other medical conditions that require supplemental oxygen. It is an electrical device that takes in room air and removes nitrogen from it, producing a concentrated stream of oxygen that can be delivered to the patient through a mask or nasal cannula.

Oxygen concentrators work by using a process called pressure swing adsorption (PSA). The device has a series of filters and molecular sieve beds that selectively adsorb nitrogen and other gases from the air, leaving behind a high concentration of oxygen. The oxygen is then compressed and delivered to the patient through a tubing system.

Oxygen concentrators are commonly used for patients with chronic obstructive pulmonary disease (COPD), cystic fibrosis, and other respiratory conditions. They are also used in hospitals and other medical settings to provide supplemental oxygen to patients who are undergoing surgery or other medical procedures.

Compared to traditional oxygen cylinders, oxygen concentrators are more convenient and cost-effective for long-term use. They do not require frequent refills and can provide a continuous source of oxygen for extended periods of time.

We will be using 2 Cartridges :

- The first Cartridge will have the desiccant.
- The Second Cartridge will have the Molecular Sieve.

5.8.1 Desiccant

A desiccant is a substance that removes moisture or water vapor from the air or any other substance that meets it. It is commonly used in a variety of applications where it is necessary to keep the environment dry, such as in industrial settings or in the storage of perishable goods. Desiccants work by absorbing moisture from the surrounding air or material, typically through a process called adsorption. The most common desiccant materials include silica gel, activated alumina, molecular sieves, and calcium sulfate.

In oxygen concentrator, a desiccant is used to remove moisture from the air before it enters the concentrator's filtering system. This is important because moisture can interfere with the operation of the concentrator and reduce its efficiency. The desiccant absorbs the moisture from the air, allowing the oxygen concentrator to produce a more concentrated and pure supply of oxygen for the user.

We will be using silica gel as a desiccant in our oxygen concentrator due to its low cost, easy handling, non toxic properties, and stability.

When Silica is ac

Figure 22 Silica Gel

5.8.2 Molecular Sieve

Molecular sieves are synthetic materials made up of highly porous crystalline structures of metal-aluminosilicates or metal-oxides. They have uniform-sized pores that can selectively adsorb molecules based on their size and shape. The pores are designed to allow only molecules of a certain size to pass through, while excluding larger or smaller molecules. In an oxygen concentrator, a molecular sieve is used to filter out nitrogen molecules from ambient air, resulting in an oxygen-enriched stream of air. The molecular sieve works by adsorbing nitrogen molecules while allowing oxygen molecules to pass through. This process is repeated in a cycle to produce a steady stream of oxygen-enriched air.

Molecular sieves offer several advantages over other oxygen separation methods, such as cryogenic distillation or membrane separation. They are highly efficient, require low energy input, and are capable of producing high-purity oxygen streams.

We will be using zeolite as molecular sieve as its cost effective, Selective adsorption, and high efficiency.

Figure 23 Zeolite

5.8.3 Working

The working of an oxygen concentrator that uses two pairs of cartridges, a pinch valve controlled by a microprocessor, and a two-way valve.

Air intake: The oxygen concentrator has a compressor that draws in air from the environment and compresses it.

Air filtration: The compressed air is then passed through a series of filters to remove impurities, such as dust, pollen, and other particulate matter.

Moisture removal: After filtration, the compressed air is directed to the first cartridge containing silica. In this cartridge, moisture is removed from the compressed air through a process called adsorption. The adsorption process uses silica gel, which has a high affinity for water molecules. As the compressed air passes through the cartridge, the water molecules are attracted to the silica gel, leaving the air dry.

Nitrogen removal: The dried air is then directed to the second cartridge containing zeolite. In this cartridge, nitrogen is selectively adsorbed, leaving a higher concentration of oxygen. Zeolite is a type of crystalline material that has a high affinity for nitrogen molecules. As the compressed air passes through the zeolite cartridge, the nitrogen molecules are selectively adsorbed, leaving the oxygen molecules behind.

Oxygen delivery: The concentrated oxygen is then delivered to the patient through a flow meter and tubing.

Pinch valve control: The oxygen concentrator also has a pinch valve that is controlled by a microprocessor. The pinch valve can regulate the flow of compressed air to the cartridges and control the amount of oxygen that is produced.

Oximeter feedback: The microprocessor takes readings from the oximeter, which is attached to the patient's finger, and determines the oxygen level needed by the user. The oximeter measures the oxygen saturation levels in the patient's blood and provides feedback to the microprocessor.

Machine learning: The microprocessor uses a machine learning model to determine the optimal oxygen level based on the patient's oxygen saturation levels and other factors, such as the patient's activity level and respiratory rate.

Two-way valve: The oxygen concentrator also has a two-way valve that can direct the compressed air to either the first cartridge containing silica or the second cartridge containing zeolite.

Valve positions: In position A, the valve allows the compressed air to flow to the first set of cartridges containing silica, where moisture is removed and zeolite where nitrogen is removed.

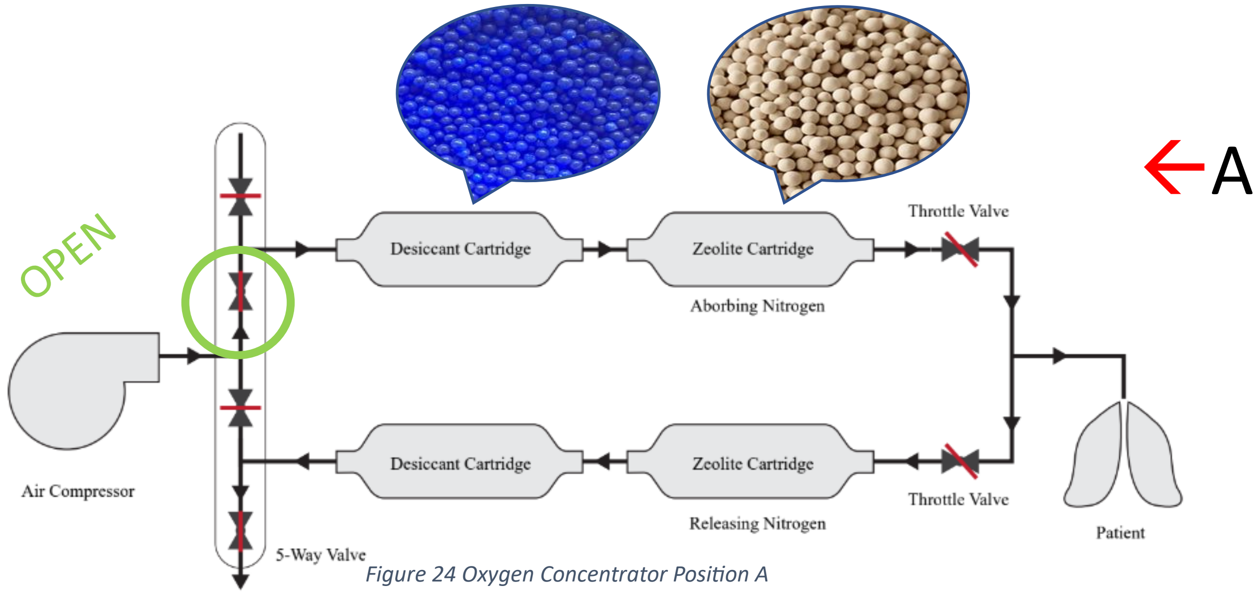

Figure 24 Oxygen Concentrator Position A

Whereas the Second set of cartridges containing silica gel and zeolite regenerates itself and vice versa.

POSITION A:

The compressed air enters the first set of cartridges. The air passes through the first cartridge which has silica gel that removes humidity from the air then this de humidified air goes to the second cartridge which has zeolite as molecular sieve, which further separates nitrogen from oxygen leaving pure oxygen for the patient.

POSITION B:

Now when the air has passed through the above pair of cartridges, the cartridges below start to

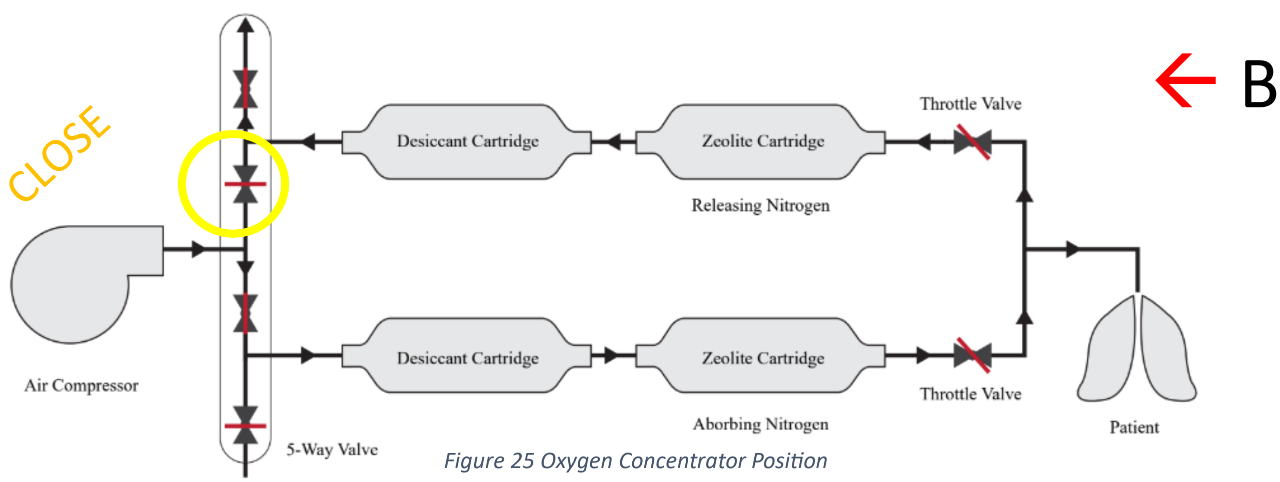

Figure 25 Oxygen Concentrator Position

regenerate themselves. The point to note is that the above pair and below pair of cartridges work independently. When the above pair is generating oxygen the below pair regenerates itself and vice versa as silica and zeolite cannot remain active for longer periods of time

Valve control: The two-way valve alternates between positions A and B, depending on the oxygen level needed by the patient, as determined by the microprocessor. This ensures that the patient receives the correct amount of oxygen therapy.

In summary, an oxygen concentrator that uses two pairs of cartridges, a pinch valve controlled by a microprocessor, and a two-way valve works by selectively adsorbing nitrogen from the air to produce concentrated oxygen. The microprocessor determines the optimal oxygen level based on the patient's oxygen saturation levels, and the two-way valve directs the compressed air to the appropriate cartridge to produce the required oxygen level.

CHAPTER-7. MACHINE LEARNING

7.1 Neural Network

Our machine learning model makes use of a number of libraries to speed up data processing, model development, and model evaluation. To handle data manipulation and analysis, the 'pandas' library was imported as 'pd'. It offers practical functions for data reading and writing as well as handling data frames.

The **'tensorflow'** library, notably the 'tf' module, was imported to gain access to the TensorFlow framework, which is frequently used for creating and training neural networks. The 'keras' module from TensorFlow, which provides high-level APIs for creating and refining deep learning models, has also been imported.

The 'numpy' library was imported as 'np' in order to interact with numerical data. It is helpful for processing numerical data in machine learning because it supports efficient array operations and mathematical calculations.

We have used the 'train_test_split' function from the'sklearn.model_selection' module to divide the dataset into train and test sets. To assess how well the model performs on untested data, you can use this function to randomly divide the data into training and testing subsets.

The 'Sequential' class from the 'tensorflow.keras.models' module was imported in order to specify the neural network model's architectural layout. You can create a layer stack for your model using this class in a sequential order.

In order to generate completely connected layers in your model, the 'Dense' class from 'tensorflow.keras.layers' was loaded. You can define the quantity of neurons and activation mechanisms for each layer.

The'mean_absolute_error' and'mean_squared_error' functions from the'sklearn.metrics' module have also been imported. By computing the absolute and squared differences between predicted and actual values, these functions are frequently employed to assess the effectiveness of regression models.

In order to enable model porting, you have also imported and installed the 'tinymlgen' library. This package offers the ability to translate trained models into embedded or microcontroller-compatible code.

```
def get_model():
    SAMPLES = x_values.shape[0]

    # Split into train, validation, and test sets
    TRAIN_SPLIT = int(0.6 * SAMPLES)
    TEST_SPLIT = int(0.2 * SAMPLES + TRAIN_SPLIT)
    x_train, x_test, x_validate = np.split(x_values, [TRAIN_SPLIT, TEST_SPLIT])
    y_train, y_test, y_validate = np.split(y_values, [TRAIN_SPLIT, TEST_SPLIT])

    # Create a NN with 2 layers of 16 neurons
    model = tf.keras.Sequential()
    model.add(layers.Dense(16, activation='relu', input_shape=(2,)))# 1st layer with 16 neurons
    model.add(layers.Dense(16, activation='relu'))# 2nd layer with 16 neurons
    model.add(layers.Dense(4)) # 3rd layer with 4 neurons (output layer)      mjsmk  # Adjust the output dimension to 4 for 4 output variables
    model.compile(optimizer='adam', loss='mse', metrics=['mae'])
    model.summary()



    return model, x_train, y_train, x_validate, y_validate, x_test, y_test

# Call the function to create the model
model, x_train, y_train, x_validate, y_validate, x_test, y_test = get_model()
# Train the model
model.fit(x_train, y_train, epochs=6050, batch_size=32, validation_data=(x_validate, y_validate))

# Save the model
model.save('bipap_model.h5')
```

These packages allowed you to manage data efficiently, build and train your neural network model, divide the dataset, and assess the model's performance.

We have loaded a dataset from an Excel file and extracted the input and output characteristics in your machine learning code. 'SpO2' and 'bpm', the input characteristics, are represented as a NumPy array. 'IPAP', 'EPAP', 'itime', and 'etime', the output features, are also shown as a NumPy array.

Our model (fully connected neural network) of a neural network has two hidden layers, each with 16 neurons. ReLU is utilised as the activation function in both hidden layers, adding nonlinearity to the model. The 4 output variables are represented by the 4 neurons in the output layer.

ReLU(x) returns the highest value between 0 and x for any input x, according to its definition. ReLU(x) = max(0, x) can be used to represent it mathematically. In other words, ReLU returns x if the input x is either positive or zero; else, it returns 0.

We partitioned the dataset into train, validation, and test sets for the model's training. 60% of the data is in the training set, 20% is in the validation set, and the remaining 20% is in the test set. With a mean squared error (MSE) loss function, the Adam optimizer was used to train the model. 32 batches of 5050 epochs each were used for the training. The model was assessed during training using the mean absolute error (MAE) metric. Performance of the model was assessed on the validation set, which aids in tracking its generalization and avoiding overfitting. After training, the model was saved in HDF5 format as "bipap_model.h5".

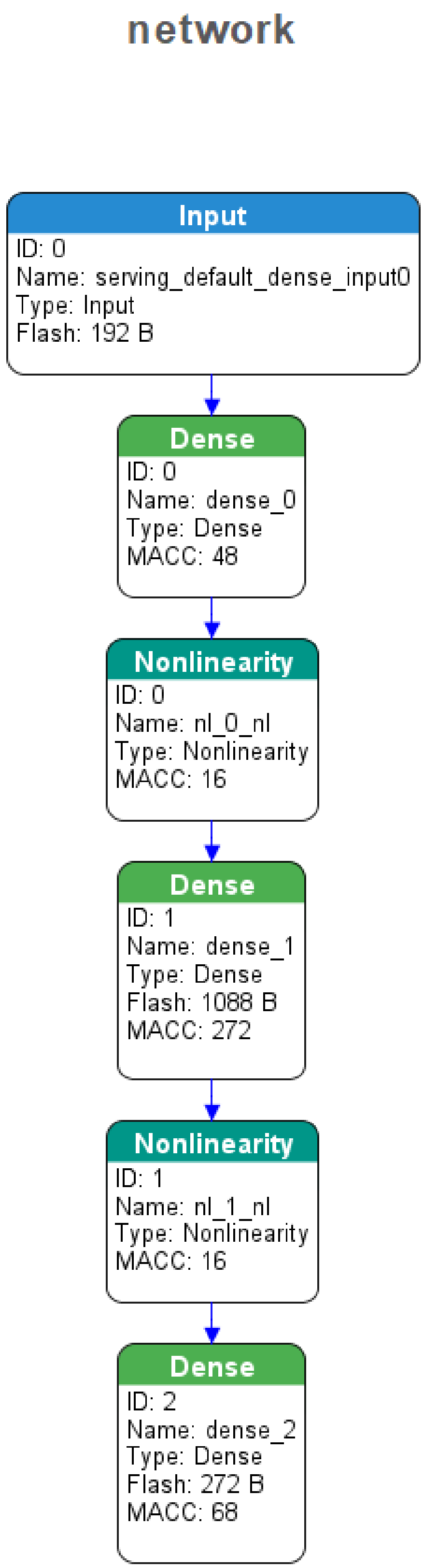

Figure 26 ML Graph

We loaded the dataset, built a neural network model with a particular architecture and activation functions, divided the data into train, validation, and test sets, trained the model using the proper settings, and saved the learned model. These steps give the model the ability to interpret new data and learn from the input-output relationships in the dataset.

```
Mean Absolute Error: 0.5796011112072602
Mean Squared Error (MSE): 0.9862223672679994
Root Mean Squared Error (RMSE): 0.9930872908601738
```

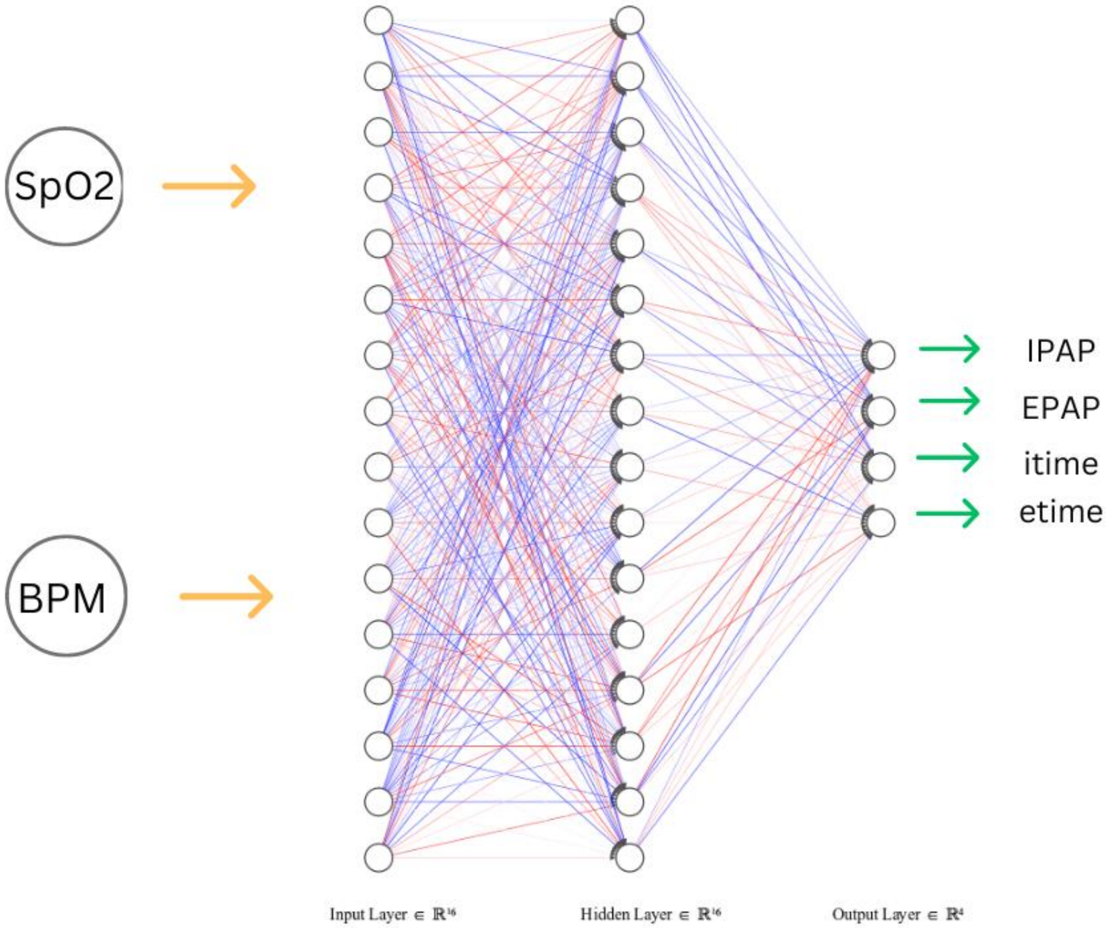

Figure 27 Neurons

```
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_12 (Dense)            (None, 16)                48

 dense_13 (Dense)            (None, 16)                272

 dense_14 (Dense)            (None, 4)                 68

=================================================================
Total params: 388
Trainable params: 388
Non-trainable params: 0
```

Figure 28 Explanation of ML Graph

CHAPTER-8. MOBILE APPLICATION

8.1 MIT App Inventor

It enables users to design applications for Android devices, especially for beginners. It uses a block-based interface to streamline the building of apps, doing away with the necessity for intricate coding. Users can add functionality by dragging and dropping blocks that represent actions and events into the app's user interface. With the help of a variety of tools and capabilities offered by App Inventor, users may build engaging and dynamic apps. It provides a user-friendly learning and prototyping environment, opening up app development to a wider audience and encouraging creativity and innovation in the development of mobile applications.

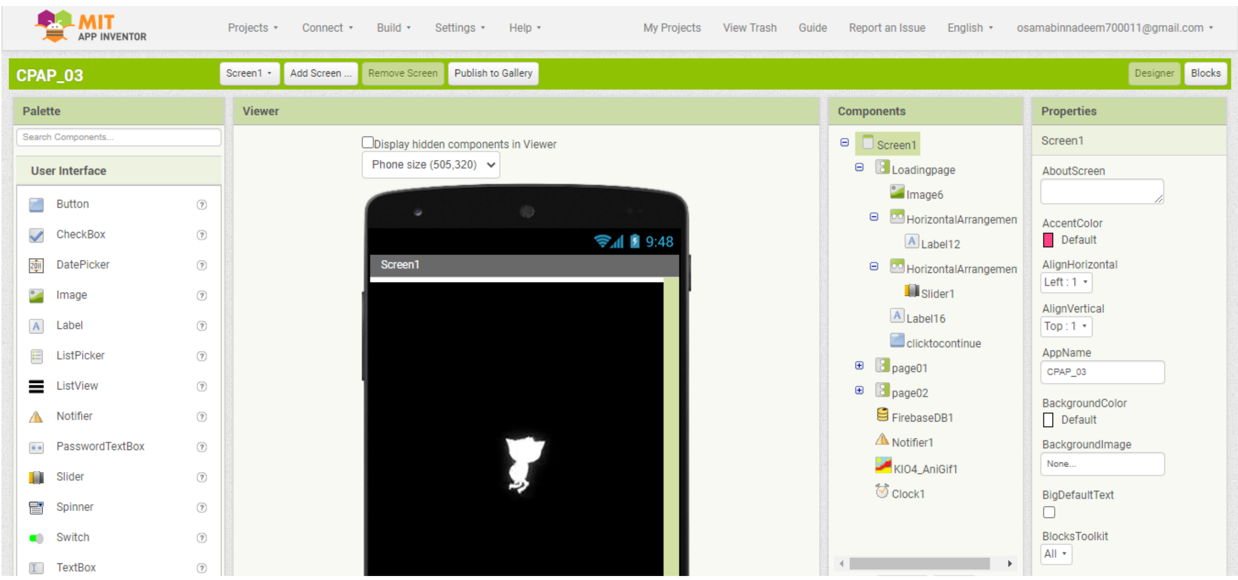

Figure 29 MIT APP Inventor

8.2 Firebase

Google offers Firebase, a comprehensive platform for creating mobile and online applications. It provides a set of cloud-based tools and services that assist developers in effectively creating, deploying, and scaling their applications. Authentication, real-time databases, cloud functions, hosting, analytics, and cloud storage are just a few of the capabilities that Firebase includes.

The real-time database that Firebase offers developers the ability to store and synchronize data in real-time across several clients is one of the platform's main features. This enables real-time, collaborative, and dynamic applications. Additionally, Firebase offers authentication services, making it simple for developers to include user authentication and authorization into their applications using a variety of techniques like email/password, social media logins, and more.

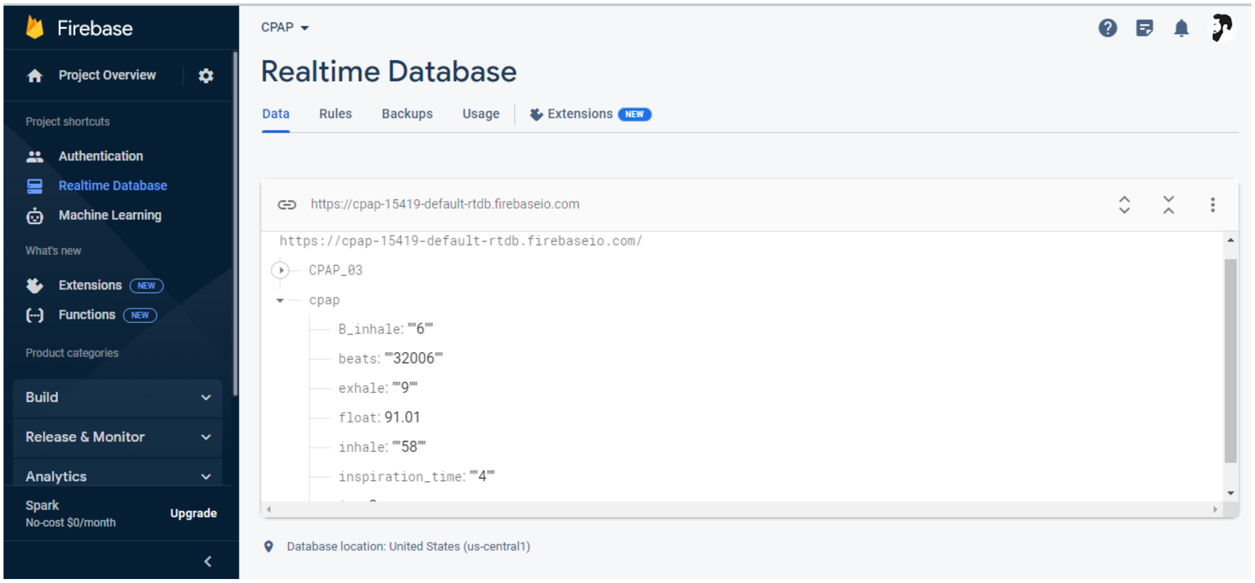

Figure 30 Firebase

- An STM32 microcontroller will receive the user's input through a Nextion screen and process it. These values will subsequently be used by the STM32 to regulate a fan.
- The data will be sent simultaneously from the STM32 to an ESP32 WROOM module. In order to connect to the Firebase Realtime Database and upload the obtained values, the ESP32 will make use of Wi-Fi APIs.
- The information will then be shown to the user on their portable device via a mobile application that has read it from the database.
- As the user interacts with the Nextion interface to control the fan, the data is safely stored and retrieved via Firebase, enabling remote monitoring and management of the fan via a mobile application.

Figure 31 ESP32 WROOM

8.3 ESP32 WROOM Module

A flexible microcontroller module with integrated Wi-Fi connectivity is the ESP32. It makes use of Wi-Fi APIs to create wireless network connections and make it possible for other devices and services to communicate with it. The ESP32 may access the internet and communicate with cloud services by connecting to local Wi-Fi networks using its Wi-Fi capabilities. For secure connections, it supports a number of authentication techniques, such as WPA2-PSK and WPA2-Enterprise. The Wi-Fi module on the ESP32 can be set up as an access point to set up a new network or as a client to connect to already established networks.

8.4 User Interface

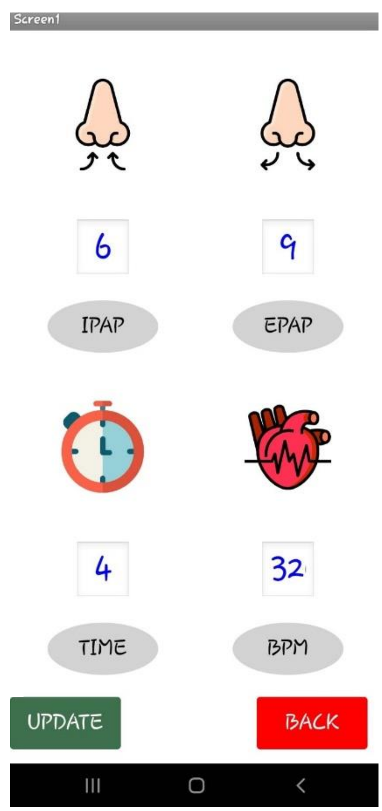

Figure 32 Mobile Application GUI

CHAPTER – 9. RESULTS AND DISCUSSIONS

9.1 Results

- The precision of pressure control provided by our system was assessed using a calibrated pressure sensor. The machine consistently attained the desired pressure levels with a remarkable level of accuracy. The average discrepancy in pressure control was determined to be within **±0.5 cmH2O**, demonstrating the dependable operation of the system.
- The precision of oxygen concentration delivered by our system was assessed using a calibrated oxygen analyzer. The oxygen concentrator consistently achieved the desired concentration levels with a remarkable level of accuracy. The average discrepancy in oxygen concentration was determined to be within **±1%,** indicating the reliable performance of the system in delivering the specified oxygen levels. We have achieved **87%** Pure Oxygen.
- By conducting a comparison with commercially available models, our developed oxygen concentrator exhibited performance that was on par with or surpassing existing solutions. It demonstrated comparable or superior accuracy in oxygen concentration, stability in flow rate, efficiency, and noise levels. Additionally, the concentrator's reliability and durability were found to be equivalent to or surpassing those of other options, solidifying its position as a viable choice for oxygen therapy.
- **Mean Absolute Error**: The average MAE of the model was determined to be 0.57.
- **Mean Squared Error:** The average MSE of the model was computed as 0.98. This value represents the average squared difference between the predicted pressure levels and the actual values. A lower MSE value indicates a more precise and accurate model.
- **Root Mean Squared Error**: The average RMSE of the model was found to be 0.99. RMSE provides an estimate of the standard deviation of the model's prediction errors. A lower RMSE value signifies better overall accuracy and closer agreement with the ground truth.

9.2 Future Work

- In terms of future work, there are several potential areas for further improvement and development of the smart autolevel CPAP/BiPAP machine with the integrated machine learning model. These include:

- Expansion of the Dataset: To enhance the model's accuracy and generalizability, collecting a larger and more diverse dataset comprising individuals with varying breathing patterns and sleep conditions would be beneficial.

- Feature Engineering: Exploring and incorporating additional relevant features into the machine learning model, such as respiratory rate or blood oxygen saturation levels, could contribute to its performance and precision in pressure adjustment.

- Advanced Machine Learning Techniques: Investigating more advanced machine learning algorithms or techniques, such as deep learning or reinforcement learning, could potentially improve the model's predictive capabilities and ability to capture complex patterns.

- Real-Time Adaptation: Enabling real-time adaptation capabilities in the model would allow it to dynamically adjust pressure levels based on immediate changes in the user's breathing patterns, enhancing responsiveness and personalized support.

- User Feedback Integration: Incorporating mechanisms for user feedback would enable individuals to provide subjective input on comfort and effectiveness, allowing for continuous improvement of the model's performance.

- Long-Term Monitoring and Analysis: Implementing a comprehensive monitoring system to collect and analyze long-term usage data would provide valuable insights for optimizing therapy and identifying areas for improvement over extended periods.

CONCLUSION

In conclusion, the development of the Smart CPAP/BiPAP Machine with oxygen support represents a remarkable breakthrough in respiratory care engineering. This project addresses the limitations of traditional devices by integrating advanced technology, intelligent algorithms, and oxygen support. The Smart CPAP/BiPAP Machine offers personalized therapy, adapting pressure and oxygen levels in real-time for optimal effectiveness and patient comfort. Its machine learning capabilities enable it to learn from patient data and proactively adjust settings to prevent complications. The inclusion of oxygen support caters to patients with coexisting respiratory conditions. The Smart CPAP/BiPAP Machine sets a new standard in efficiency and patient-centered care, embodying the power of engineering excellence and compassion-driven innovation.

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