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Master degree in Biomedical Engineering

AUTO CPAP DEVICE FOR OBSTRUCTIVE SLEEP APNEA DISORDER PATIENTS

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Abbreviations	Description
SA	Sleep Apnea
OSA	Obstructive Sleep Apnea
CSA	Central Sleep Apnea
CPAP	Continuous Positive Airway Pressure
BiPAP	Bilevel Positive Airway Pressure
AHI	Apnea-Hypopnea Index

ABSTRACT

Sleep apnea is potentially a serious sleeping disorder, where the patients breathing repeatedly stops and starts. The most common type of sleep apnea is obstructive sleep apnea also referred as OSA. During a person sleep the soft tissue that support the throat temporarily relax causing the breathing pathway to narrow down resulting in a momentary pause in breathing, this phenomenon is called as OSA. This disorder is mainly caused due to excess weight and obesity. The basic symptoms of OSA are loud snoring, abrupt awakening during sleep accompanied by choking, headache and excessive tiredness. Without proper medical attention this OSA disorder can lead to serious medical illness such as hypertension (high blood pressure), increase risk of recurrent heart attack and stokes, atrial fibrillation (abnormal heart- beat) hence it is highly recommended to be treated with proper medical care.

A continuous- positive airway pressure machine is most commonly referred as CPAP is the most reliable treatment for OSA. Its regular use improves excessive sleepiness, cognitive performance, and quality of life. The CPAP machine sends a continuous and steady stream of air constantly to the patient through a breathing mask keeping the breathing pathway open without any blockage this method helps the patient to sleep without any obstructions.

Because the pressure necessary to maintain upper airway patency in patients with sleep apnea varies throughout the night based on body position, sleep state, and other factors, the concept of long-term CPAP treatment with a set mask pressure has been questioned. Changes in upper airway parameters, as well as difference in body weight, may cause CPAP requirements to fluctuate over the period of many weeks to months. The CPAP even after being the most reliable treatment for OSA, it has its cons such as high cost and the constant airflow can cause burns, dryness in the throat. The use of humidifier in some models reduce the risk of throat dryness to some extent but still does not give an effective result and increases the cost even more.

Alternatively, automatic computer-controlled CPAP titration (auto CPAP) may be performed over one or several nights. Auto CPAP devices adjust pressure by feedback control according to patterns of pressure, flow, or other signals recorded during treatment The pressure delivered during unsupervised auto CPAP titration could be used to estimate the therapeutic pressure for later treatment with traditional CPAP at a fixed pressure. However, in several analysis major outcomes of sleep apnea therapy, i.e., subjective sleepiness, objective vigilance, or cognitive performance, were not improved by auto CPAP compared with fixed-pressure CPAP. One report even suggests that variation in mask pressure during auto CPAP therapy might induce sleep disturbances. As an overall assessment the differences in technical characteristics of

devices from various manufacturers further complicate the potential role and use of auto CPAP therapy in the home.

The overview of this project is to completely overcome these problems providing an affordable and much advanced and integrated Auto CPAP machine using non-invasive method that reduces complication as in present models and combining the conventional CPAP technique providing an effective breathing support to the sleep apnea patient. The uniqueness of this idea is that the device remains in stand-by during normal breathing and provides support only when OSA occurs which is detected by a sensor. The implementation of this method completely removes the risk of throat infections and injuries caused by continuous airflow. Also turns out to be a very cost-efficient model by reducing the use of hardware like humidifier and less consumption of electricity as the machine only runs when apnea occurs and remain at stand-by during normal breathing unlike auto CPAP and conventional CPAP which provides constant airflow. Furthermore, the detailed description of this idea and methodology is as follows.

Key words: Sleep Apnea, Continuous Positive Airway Pressure (CPAP), Obstructive Sleep Apnea (OSA), Auto CPAP,

CHAPTER 1

1. INTRODUCTION

1.1 Background

Sleep apnea which is a prevalent illness that affects people of all ages. It is defined by episodes of airflow cessation (apnea) or reduced airflow (hypopnea) during sleep. Sleep apnea can be caused by a central lack of respiratory drive, a mechanical obstruction of the airways resulting in disrupted airflow patterns, or a combination of the two (mixed). The most prevalent type of sleep apnea is obstructive sleep apnea-hypopnea syndrome, which is also known as obstructive sleep apnea (OSA)

1.1.1 Definition and Severity of Obstructive Sleep Apnea

Sleep apnea is potentially a very serious sleep disorder in which breathing repeatedly pauses and resumes. The most common type of sleep apnea- Obstructive sleep apnea (OSA) occurs when the airway is blocked, causing pauses in breathing and loud snoring. Since sleep apnea only occurs while patient is sleeping and may only discover when they have problem with bed partner and roommates complaining about their snoring. There is two different disorders for breathing problem they are OSA and CSA and to cure these breathing disorders CPAP and BiPAP respiratory ventilation device is used. OSA is a sleep disorder characterized by the repetitive reduction of airflow while sleeping. The patient may undergo the symptoms of OSA which includes the relaxation of the muscle at their mouth and pharynx and then patient tongue drops on the soft tissue in the roof of their mouth pressing it against the back of their throat. This completely blocks the flow of air and so the patient cannot breathe normally, because their tongue blocks the upper airways through which air goes to the lungs, this will decrease the oxygen level in the body. So that the patient suddenly gets up from the bed to provide themselves with good atmosphere to increase the oxygen level in the body. Then this cycle repeats many times during night, disturbing the sleep of the patient so it is considered to be a breathing problem. Unlike obstructive sleep apnea, which is thought to be a mechanical problem, central sleep apnea is more of a signal communication problem. Obstructive sleep apnea is more common than central sleep apnea. Some estimates claim that approximately 20% of sleep apnea cases are due to CSA. But for the elderly people, it is difficult for them to move from places to get proper air supply for breathing during their sleep, causing severe breathing problem which may sometimes results in death of the person. To cure these cases, researches were done by doctors and came out with the fruitful technology which uses CPAP machine. These machines can be used by the patient's according to the doctor's suggestion.

Sleep tests that measure sleep time (and typically other sleep measures) and respiratory occurrences are used to detect sleep apnea. The presence of respiratory effort during bouts of apnea and hypopnea distinguishes OSA from central sleep apnea (in central sleep apnea, respiratory effort is lacking). Despite adequate ventilator effort, the amount of airflow is reduced in OSA. It differs from central sleep apnea, in which there is a reduced drive to breathe, reduced ventilator capacity, or abnormal ventilatory pattern.

The severity of OSA is typically quantified by the apnea-hypopnea index (AHI), the sum of the number of apneas and hypopneas per hour of sleep measured during a sleep study. AHI is often used as part of both diagnosis (and, thus, study inclusion criteria) and as an intermediate or surrogate measure for health outcomes in studies. Other commonly used sleep study measures including oxygen desaturation index (ODI), respiratory disturbance index (RDI), respiratory effort related arousals (RERA). To describe OSA, the American Academy of Sleep Medicine (AASM) produces scoring guides for AHI and other physiological events. The American Association of Sleep Medicine (AASM) is the most well recognized accrediting body for sleep laboratories in the United States. The AASM published its scoring manual (known as the "Chicago" Criteria) for the first time in 1999. Since their first set of criteria, they've changed their definitions of breathing events, sleep time, and how they are quantified several times, with substantial adjustments in 2007 and 2012 [11]. Minor revisions have been made almost annually since (the current version is v2.6, released in 2020). Notably, while the AASM has, at times, used an evidence-based approach (i.e., making recommendations based on systematically reviewed evidence) to guide their selection and revision of criteria, majority of their recommendations (i.e., scoring rules) are based on the consensus of the panel members because of insufficient evidence to support specific criteria Studies frequently utilize different criteria, and the use of specific definitions varies even within certain scoring guides, thus complicating the classification of OSA (and severity assessments For example, apnea requires a 90 percent or 100 percent cessation of airflow, and whether hypopnea requires a 3 or 4 percentage point decline in oxygen saturation and/or a 30 or 50 percent reduction in airflow is required to define hypopnea. In addition, respiratory effort related arousals (RERA) from sleep may be allowed as an alternative to desaturation to define a hypopnea. In contrast to the AHI, when RERAs are measured instead of desaturation, the "respiratory disturbance index" (RDI) is used.

The variations in definitions of OSA result in subtle variations across studies in which patients are included. Notably, unusual for medical disease diagnostic criteria, diagnosis of OSA in part depends on presence (or absence) of comorbidities. Furthermore, these criteria do not distinguish patients with OSA based on symptomatology. For example, despite clear differences in OSA characteristics among groups, people 1) with frequent respiratory disturbances who do not have symptoms of OSA, such as daytime sleepiness, 2) who have symptoms of OSA such as daytime sleepiness but have relatively less frequent respiratory disturbances, and 3) who have the comorbidities listed above but have relatively less frequent respiratory disturbances been diagnosed and treated as if they have equivalent conditions.

1.2 SLEEP APNEA

Sleep apnea is one of the common and serious sleep disorder where the patient's breathing is briefly interrupted when they are in sleep. Most of the patient's having sleep apnea are not aware of the short breathing pauses that occur hundreds of times at night and jolting of the patient which disturbs their natural sleep rhythm. During the day, the person may feel less energetic, not mentally bright, or less productive than a normal person, and many others consider snoring as a joke or something to be ashamed of. However, loud snoring, especially when combined with daytime drowsiness, could indicate sleep apnea, a common disorder in which breathing repeatedly stops and starts as patient sleep [2]. Sleep apnea can make a person tired during the day, damage their mood and relationship with their bed partner, and even put their health at risk. There are two different sleep apnea disorder are Obstructive Sleep Apnea (OSA)and Central Sleep Apnea (CSA). To cure this disorder, we can use CPAP and BiPAP machine. The benefit of this machine is that patient can sleep better at night and feel sharper and more energetic during the day. The first step to overcome sleep apnea, the patient should know and learn to recognize the symptoms of sleep apnea.

Obstructive sleep apnea (OSA) is the most prevalent type of sleep apnea, which occurs when the airway becomes blocked, resulting in pauses in breathing and loud snoring. Because sleep apnea happens while the patient is sleeping, they may not be aware of it until their bed partner or roommate complains about their snoring. Then patient may feel self-conscious about it or tempted to just make light of their snoring. It's something patient shouldn't ignore. Sleep apnea can have a significant impact on a patient's physical and mental well-being.

Sleep apnea causes chronic sleep deprivation, which can lead to daytime tiredness, slowed reflexes, impaired focus, and an increased risk of accidents. Sleep apnea can cause anger, sadness, and even diabetes, as well as major physical health issues like diabetes, heart disease, liver disease, and weight gain. With right treatment and self-help strategies, however, the patient can control their snoring and the symptoms of sleep apnea, get their sleep back on track, and feel refreshed and alert during the day.

1.3 TYPES OF APNEA

1.3.1 Obstructive sleep apnea

OSA is the most common type of sleep apnoea. This is caused by a physical block to the airflow during sleep (Figure 5). When being awake, the throat muscles help to keep the airway stiff and open which allows air to pass through to the lungs. However, when sleeping, these throat muscles relax and the throat becomes narrower. This is normal and should not affect the airflow to the lungs. But when having sleep apnea the airway gets blocked and not enough air reaches the lungs. When air squeezes past the blockage it can start a snoring.

1.3.2 Central sleep apnea (CSA)

Central sleep apnea (CSA) occurs when the brain temporarily fails to signal the muscles responsible for controlling breathing. Unlike obstructive sleep apnea, which can be thought of as a mechanical problem, central sleep apnea is more of a communication problem.

Central sleep apnea is also much less common that obstructive sleep apnea. Some estimates claim that approximately 20% of sleep apnea cases are CSA, but many others believe that number to be much lower sources.

Central sleep apnea is often caused by medical problems and conditions that affect the brainstem. These different causes often lead to varying symptoms and different types of central sleep apnea.

1.3.3 Complex sleep apnea

Some people suffering from sleep apnoea have a combination of OSA and CSA. This condition is called mixed apnoea.

1.4 SIGNS AND SYMPTOMS OF SLEEP APNEA

It can be tough to identify sleep apnea on your own, since the most prominent symptoms only occur when you're asleep. But you can get around this difficulty by asking a bed partner to observe your sleep habits, or by recording yourself during sleep. If pauses occur while you snore, and if choking or gasping follows the pauses, these are major warning signs that you have sleep apnea.

1.4.1 Major warning signs

- Loud and chronic snoring almost every night
- Choking, snorting, or gasping during sleep
- Pauses in breathing
- Waking up at night feeling short of breath
- Daytime sleepiness and fatigue, no matter how much time you spend in bed

1.4.2 Other warning signs

- Waking up with a dry mouth or sore throat
- Insomnia or night time awakenings; restless or fitful sleep
- Going to the bathroom frequently during the night
- Forgetfulness and difficulty concentrating
- Uncharacteristic moodiness, irritability, or depression
- Morning headaches

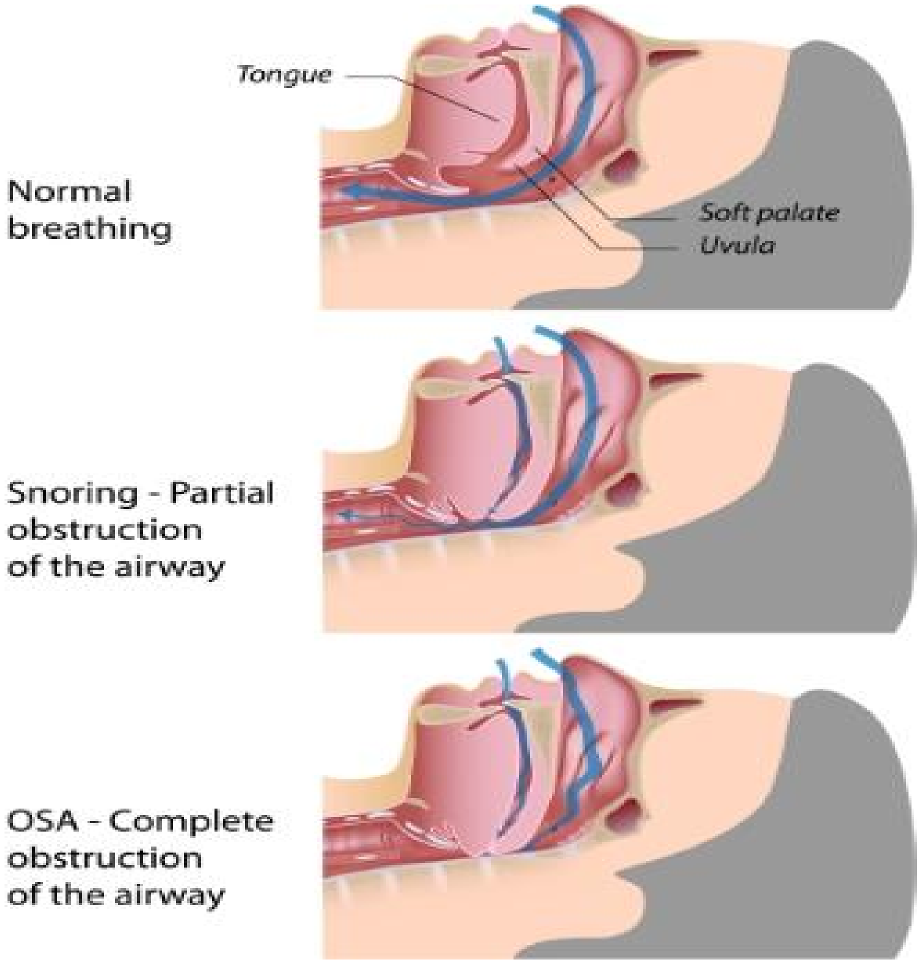

Fig.1.1 Diagrammatic representation of OSA

1.5 SLEEP APNEA CAUSES

The patient anyone have sleep apnea, they have a higher risk for obstructive sleep apnea if they are:

- Overweight, male, with a family history of sleep apnea
- Over the age of 50, a smoker, affected by high blood pressure
- Black, Hispanic, or a Pacific Islander
- Someone with a neck circumference greater than 15.75 inches (40 cm)

Other physical attributes that make patient at risk for obstructive sleep apnea include a deviated septum, receding chin, or enlarged tonsils or adenoids. Their airway may be blocked or narrowed during sleep simply because their throat muscles tend to relax more than normal. Allergies or other medical conditions that cause nasal congestion and blockage can also contribute to sleep apnea.

1.5.1 Self-help treatments

While a diagnosis of sleep apnea can be scary, it is a treatable condition. In fact, there are many things you can do on your own to help, particularly for mild to moderate sleep apnea. Lose weight, quit smoking, avoid alcohol, sleeping pills, and sedatives, Exercise regularly, avoid caffeine and heavy meals, Maintain regular sleep hours.

1.6 TREATMENT METHODS

If the patient has sleep apnea is moderate to severe, or they have tried self-help strategies and lifestyle changes without success, a sleep doctor may help you find an effective treatment. Treatment for sleep apnea has come a long way in recent times, so even if you were unhappy with sleep apnea treatment in the past, now the patient may find something that works for them.

Treatments for central and complex sleep apnea usually include treating any underlying medical condition causing the apnea, such as a heart or neuromuscular disorder, and using supplemental oxygen and breathing devices while they sleep.

Treatment options for obstructive sleep apnea:

- CPAP
- BiPAP

1.7 Breathing Disorder

- Obstructive Sleep Apnea (OSA)
- Central sleep apnea (CSA)

1.7.1 Obstructive Sleep Apnea (OSA)

Obstructive sleep apnea is the most common form of sleep apnea and is believed to affect approximately 4% of men and 2% of women. However, it is believed that only about 10% of people with OSA seek treatment leaving the majority of OSA sufferers undiagnosed.

1.7.2 Symptoms

Obstructive sleep apnea is caused by partial or complete blockage of the airways during sleep. During sleep, the patient throat muscles relax allowing the tongue and/or fatty tissues of the throat to fall back into the airways and block airflow. During an apnea event air is restricted from moving beyond the obstruction reducing blood flow to the brain. This in turn signals the brain to partially awaken from sleep to signal the body that it needs to breathe. This is often followed by a loud gasping, choking, or snorting sounds as the patient takes a deep enough breath to fight past the obstruction.

Once a breath is taken the brain returns to sleep, and the process begins once again. This process can occur just a few times a night or hundreds of times a night depending on the severity of the condition.

- **Mild OSA-** The sufferer experiences 5-14 episodes of interruptions in breathing in an hour.
- **Moderate OSA-** The sufferer experiences 15-30 episodes of interruptions in breathing in an hour.
- **Severe OSA-** The sufferer experiences 30 or more interruptions in breathing in an hour.

1.7.3 Physiological Symptoms of obstructive sleep apnea

- **Snoring**
- **Fatigue**
- **Frequent breaks in breathing** caused by an obstruction.
- **Excessive daytime sleepiness** caused by frequent interruptions of sleep.
- **Morning Headaches** stem from the loss of oxygen in your bloodstream that flows to your brain as a result of the irregular breathing at night.
- **Restless sleep**
- **Irritability**

1.7.4 Complication of OSA

- High blood pressure
- Heart diseases
- Irregular heartbeats called arrhythmias
- Stroke
- Diabetes

1.7.5 Causes of Obstructive sleep apnea

- **Weight-** People who are overweight or obese are more likely to have obstructive sleep apnea than they have to maintain a healthy weight. This can lead to restrictions in airflow as the upper respiratory system's pathway is narrowed off during sleep.
- **Age**- As people age their muscles begin to lose muscle tone. This is also true of the muscles in the throat. As throat muscles lose definition, they become weaker and more likely to collapse into the airways during sleep.
- **Enlarged tonsils or adenoids** are the leading cause of obstructive sleep apnea in children but can also affect adults who never had a tonsillectomy when they were younger.
- **Frequent alcohol use-** Alcohol relaxes the muscles in the body, and this includes the throat muscles as well which may relax to the point of blocking the airway during sleep.
- **Smoking**- Smoke is an irritant to the lungs, throat, and esophagus. It can cause inflammation and fluid retention in the upper airways that can impede airflow.

1.7.6 Treatment for OSA

- Continuous positive airway pressure **(CPAP)**

One of the initial treatment choices for treating OSA is to employ CPAP therapy. Sleep apnea patients wear a breathing mask while sleeping with a CPAP device. Just enough continuous air pressure is provided to the patient's airways via the mask to prevent tissue from collapsing (and causing breathing pauses and snoring) during sleep. Although CPAP machines are successful in treating sleep apnea, they do not cure the condition. Your sleep apnea may return if you stop using your CPAP machine. Conceptually, the effectiveness of CPAP use may vary depending on a host of factors, including differences in diagnostic criteria (which will affect which patients are treated), differences in scoring AHI and other sleep study measures (which will affect which patients are treated, how the severity of disease is assessed, and the degree to which treatment is deemed to be working), comorbidities (which may affect both who is treated and the likelihood that treatment will benefit the patient), and other factors.

Non-CPAP treatments that are prescribed in clinical practice for OSA include dental and mandibular devices to improve oral airway obstruction, along with a range of surgical treatments, including implanted structural supports to reduce obstruction. Other nonsurgical interventions used to treat OSA include devices to alter sleep position (positional therapy), physical therapy to improve oropharyngeal muscle tone, complementary and alternative medicine techniques, pharmacological agents (including ventilatory stimulants or rapid eye movement sleep suppressants), and nerve stimulation.

For specific groups of patients, other interventions that are used in clinical practice for treatment include atrial overdrive pacing for patients with nocturnal bradycardia, weight loss interventions (including bariatric surgery), and various surgical interventions that aim to alter the anatomy of the air passages to alleviate postulated obstructive mechanisms. These specialized interventions are not first-line treatments, do not provide as a direct comparator to CPAP for the vast majority of incident patients, and hence are not the subject of this analysis.

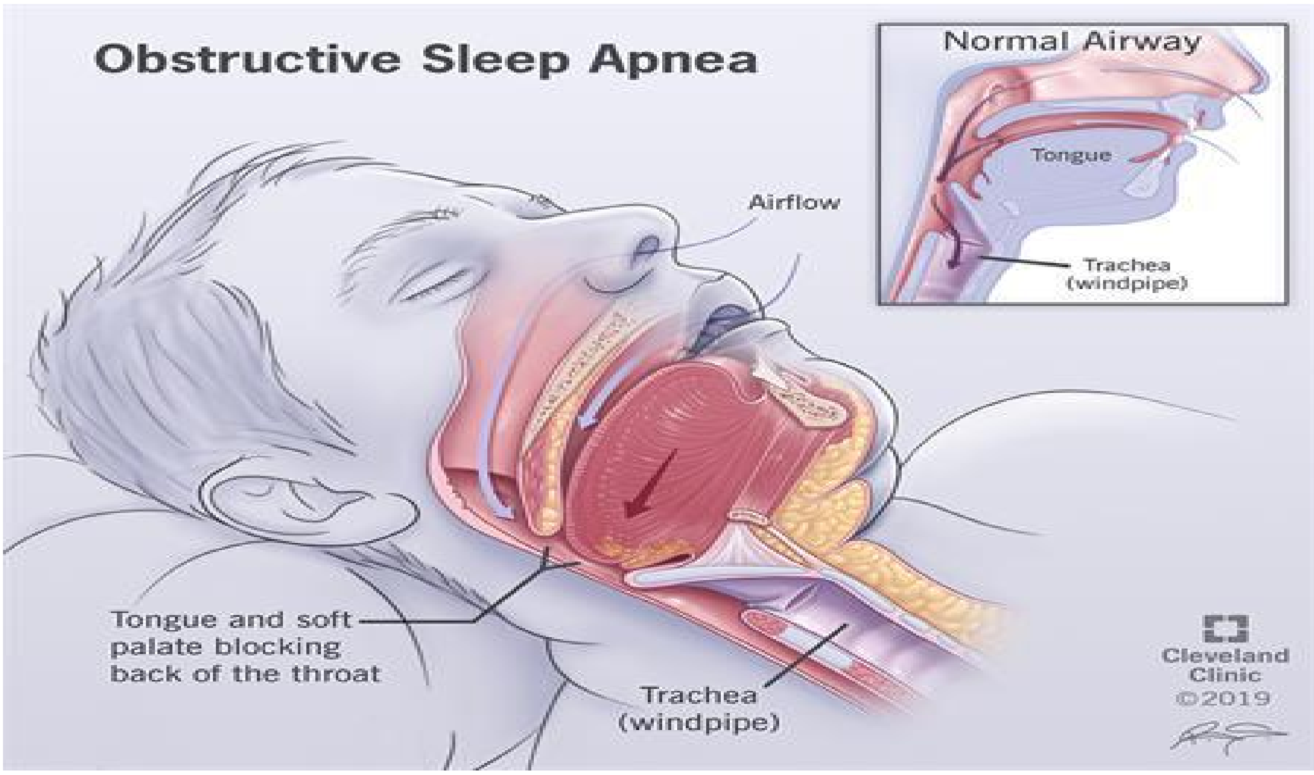

Fig 1.2 Physiological part of Normal and Obstruction representation.

1.7.7 Central sleep apnea (CSA)

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Central sleep apnea is also much less common that obstructive sleep apnea. Some estimates claim that approximately 20% of sleep apnea cases are CSA, but many others believe that number to be much lower sources.

Central sleep apnea is often caused by medical problems and conditions that affect the brainstem. These different causes often lead to varying symptoms and different types of central sleep apnea.

1.7.8 Symptoms

- Irregular breathing during sleep
- Shortness of breath leading to awakenings
- Daytime drowsiness
- Chronic fatigue
- Morning headaches
- Restless Sleep
- Difficulty concentrating
- Mood changes
- Snoring

1.7.9 Causes of Central sleep apnea

- Parkinson's disease
- Medical conditions that affect the brain stem including brain infection and stroke
- Obesity
- Certain medications like narcotic painkillers
- Heart failure

1.7.10 Treatment for central sleep apnea

- **Bilevel positive airway pressure (BiPAP)**

  Bilevel positive airway pressure is similar to CPAP except that BiPAP adjusts the level of air being delivered depending on whether the patient is inhaling or exhaling. During inhalation, an electronic sensor tells the BiPAP to send more air through the mask to clear the apnea-causing obstruction. When the user exhales, the air pressure is reduced. This decrease is helpful for sleep apnea sufferers who have a rough time breathing out against the constant pressure of a CPAP machine.

1.8 SLEEP STUDY

Sleep studies are tests that record the body activity during sleep. This study is helpful to identification of sleep disorder. In this study polysomnography a type of sleep study is a gold standard to rule out OSA. If a home study does not find OSA, but the patient still complains of unrefreshing sleep and daytime sleepiness. In a polysomnography is necessary to find other possible disorder. If the doctor suggests patient to undergo for sleep study or PSG it will be wondering for the patient with this study can know about sleep apnea, periodic limb movement disorder, restless leg syndrome night time behaviour like sleep walking and REM sleep behaviour disorder. This can be analysis by while patient in sleeping state. A sleep study is a non-invasive overnight exam that allows doctor to monitor you while patient sleep to see what`s happening in patient’s brain and body. For this test the patient wants to go to the sleep lab. A sleep study will also measure things such as eye movements, oxygen level in patient blood through sensor, heart and breathing rate, snoring and body movements. Before go to bed in the exam room, a technologist will place sensor, or electrodes on patient head and body and can move from one place to another in comfortable way. This study should be continued for 2 weeks.

1.8.1 Home sleep test (HST)

To diagnose sleep apnea and sleep disorder, a patient undergoes a PSG sleep study. This is typically done in a sleep lab, requiring the patient to spend the night in-lab, while PSG equipment records physiological data. Now technologies are improved a PSG can be performed at home and is called a home sleep study or home sleep test.

1.8.2 Benefits of HST

The patient can self-administer the home sleep test and able to spend the night in his own bed in familiar surroundings. Home sleep testing can be especially advantageous to the home-bound, elderly or those with chronic illness and nurses or family members are spending the night and take care of the patient. Then it also reduces the transportation costs. The typical cost of a home sleep test or home sleep study is only a fraction of the cost of an in-lab sleep study. It helps to diagnosis of obstructive sleep apnea.

1.8.3 Diagnostics of sleep tests

An overnight sleep study, also known as **a polysomnogram (PSG), can test for and diagnose a whole range of sleep disorders** including: breathing disorders, periodic limb movement disorders (PLMD), circadian rhythm disorders, hypersomnia, insomnia, and many more. A HST however, is only capable of testing for breathing disorders such as **Obstructive sleep apnea.**

1.8.4 Equipment used in sleep tests

A PSG is used as monitoring devices to accurately diagnose a variety of sleep disorders.

- Electrodes on the head to measure brain activity
- Electrodes on the face to measure eye and jaw muscle activity
- Elastic belts to measure breathing effort
- Electrodes on the legs to record muscle movement
- ECG monitors to measure heart rate and rhythm
- Other devices to measure oxygen levels, breathing activity, and snoring

The HST is used strictly for diagnosing breathing disorders, it requires far less equipment. A HST comes in a small package that includes devices that are easy for patients to apply themselves.

- A small nasal cannula to measure airflow
- A belt around the upper chest to measure respiratory effort

- A finger clip to measure the oxygen saturation in the blood

1.9 DEVICE DESCRIPTION

1.9.1 Continuous positive airway pressure (CPAP)

Colin Sullivan, (National Sleep Foundation, 2015) an Australian physician, devised CPAP in 1980, and it was first used in Sweden in 1986 (Swedevox, 2014). It was in the 1990's that CPAP really had a breakthrough in the Swedish healthcare system and since then the technology and number of users of CPAP has increased dramatically (Gillström & al., 2014).

The most popular therapy option for persons with breathing issues, the most common of which is obstructive sleep apnea, is CPAP equipment (OSA). Breathing cessations are common in OSA patients, and they occur when airway blockages cause them to cease breathing for a few seconds at a time throughout the night. People who suffer with sleep apnea may encounter anywhere from 5 to 100 breathing disruptions each hour, depending on the severity of their condition. These disturbances can result in a variety of health issues, such as chronic daytime sleepiness and restless sleep, as well as heart disease and stroke. A CPAP device keeps the airway pressure constant during inhalation and exhalation. This is generally achieved by an air compressor that works to maintain the desired airway pressure despite the inhalation and exhalation of the patient [3].

Continuous positive airway pressure machines keep the throat from collapsing by gently blowing pressured air through it at a constant pressure. CPAP machines are made up of three key pieces and are very simple to use. A CPAP machine is just a little compressor. It draws in ambient air and gently pressurizes it to provide exactly the appropriate amount of air pressure to clear the obstruction. A changeable filter in the machine's air intake section filters out particles and contaminants. Most newer CPAP devices also include a small water tank that heats up when the machine is turned on, providing moisture to the air when the patient breathes in. People who live in dry or arid areas or who frequently wake up with dry mouth, throat, or nasal cavities would benefit from these built-in humidifiers. The motors of CPAP machines are incredibly silent [4].

The hose is essentially a delivery system for pressurised air from the motor to the mask wearer. While most hoses are 6 feet long, the diameter of the hoses varies depending on the machine being used. The majorities of hoses are now heated to prevent humidifier water condensation.

Fig.1.3 CPAP Hoses

Not everyone is comfortable using the same masks as others because CPAP masks come in a variety of shapes and sizes. While sizes and shapes may vary to accommodate different face shapes, there are usually three types of masks to choose from: nasal pillows, nasal masks, and full-face masks. The most crucial aspect of CPAP compliance is finding the correct mask for your unique level of comfort [5].

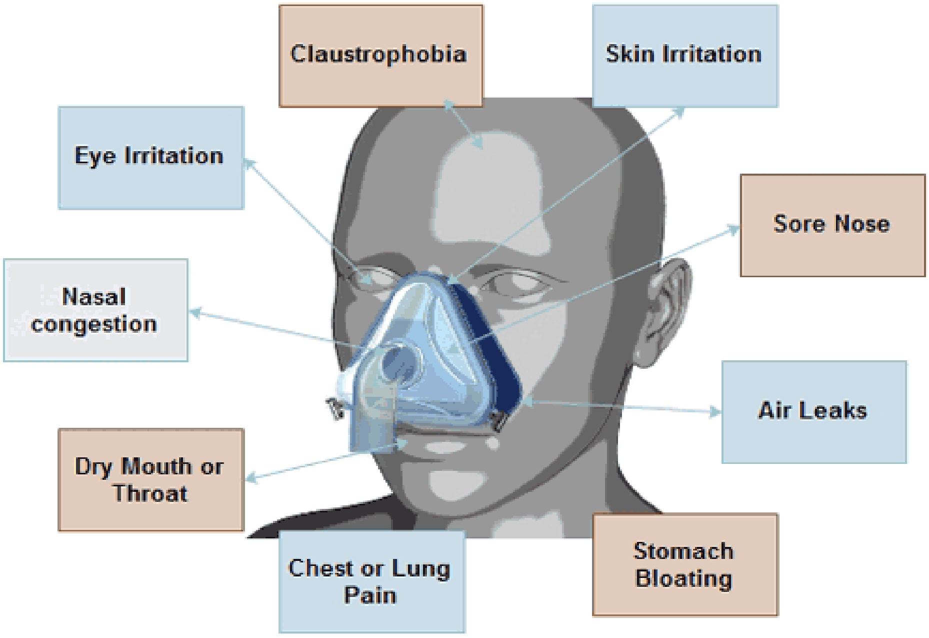


Fig.1.4 CPAP Mask setup

1.9.2 CPAP RESULT

Those who begin using their CPAP devices, often begin to experience immediate positive results including.

- Elimination of snoring and breathing obstructions.
- Improvement in quality of nightly sleep.
- Lower blood pressure both during the day and at night.
- Decrease daytime drowsiness.

Fig.1.5 CPAP Manual machine

Fig. 1.6 CPAP device connect with patient during sleep

1.9.3 MAXIMUM PRESSURE RATE FOR CPAP AND BiPAP

CPAP

- The maximum pressure rate for the patient have certain settings they are,
- The lowest setting on CPAP machine may be 4 to 5 centimetres of water pressure.
- The vast majority of people require more pressure than this lowest setting.
- The maximum setting varies with the type of machine, but I could be as high as 25 to 30 Cold Working Pressure (CWP).

BiPAP

- If you prefer standard pressure settings for the machine.
- The auto BiPAP allows for fixed IPAP and EPAP and a function which transitions the machine to automatic during the night.
- It also has a wide pressure range (4 – 25cm).

Table.1.1 Pressure Range of CAPA and BiPAP

Parameter	**Control Range**	**Control Instruments**
IPAP	4 to 40 cm H2O	1 cm H2O
EPAP	4 to 20 cm H2O	1 cm H2O
CPAP	4 to 20 cm H2O	1 cm H2O
Rate	4 to 40 BPM	1BPM
Time Inspiration	0.5 to 0.3 sec	0.1 sec
IPAP Rise Time	0.05 to 0.4	4 set points 0.05,0.1,0.2,0.4 sec
Oxygen Concentration (% O2)	21 to 100%	4% from 21% to 25% 5% from 25% to 100%

1.9.4 COMPARISON BETWEEN NORMAL AND DISORDER PERSON

- There are some pressure settings for the patient and how the normal patient will take their breath in comfortable manner.

Table.1.2 Comparison between Normal and Disorder person breathing pressure rate

Breathing Rate	**Normal Person**	**Sleep apnea disorder person**
Respiration Rate	8 – 12	16 – 38
Tidal volume	500 ml	950 ml
Minute Volume	4 – 6 L	13L (Awake - CSA) 14L (Awake - OHS) 15L (Awake - OSA) 20 – 22L (Asleep)
Inspiration flow rate	280 ml/sec	620 ml/sec
Co2	40 – 45 mm Hg	Hypocapnia, Hypercapnia, Normocarbia

1.10 Global CPAP Devices Market is Expected in 2028

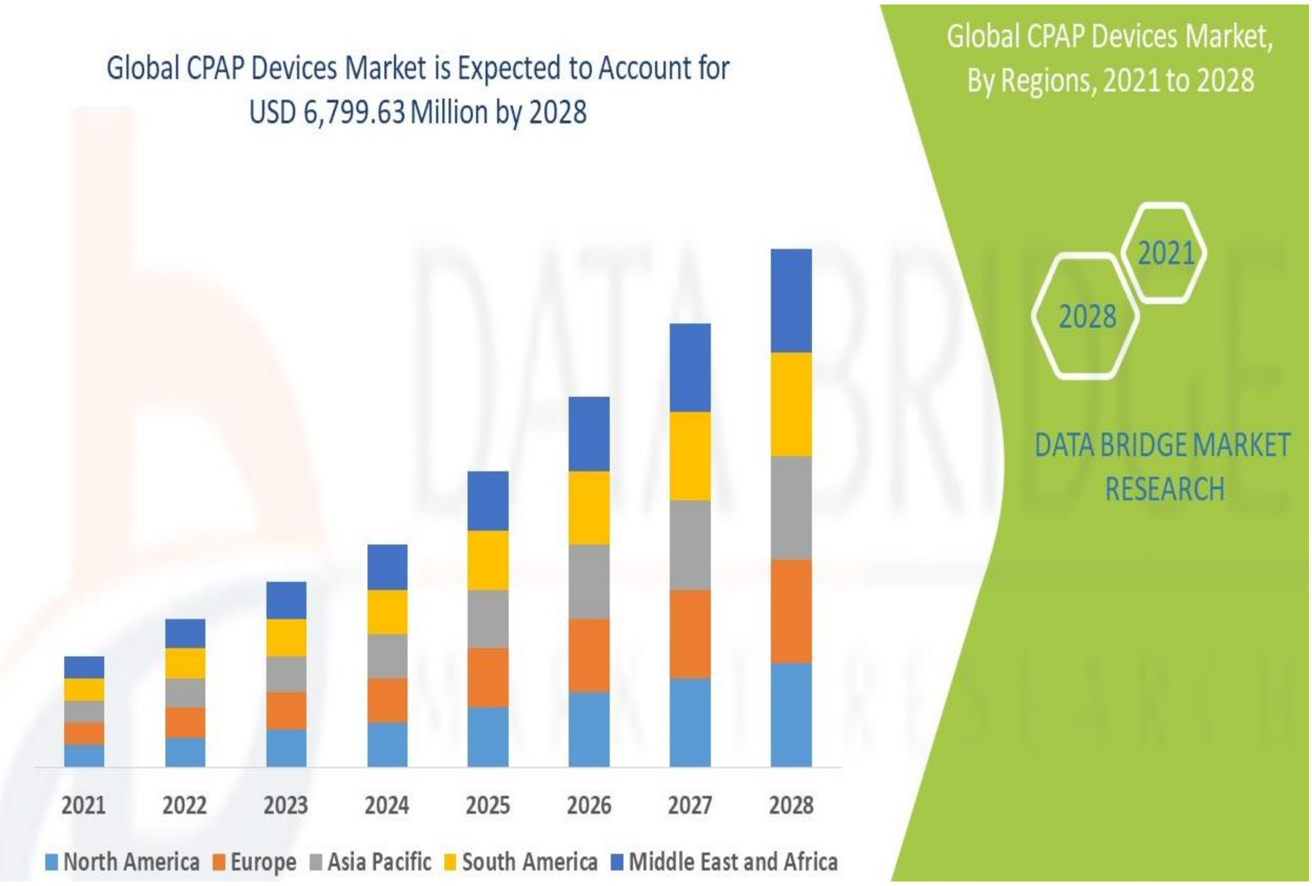


Fig. 1.7 Global CPAP device market expected in 2028

Description

Global CPAP Devices Market, By Product Type (Fixed Pressure CPAP Device, Auto Adjusting CPAP Device, CPAP Motors, CPAP Hoses, CPAP Mask and Others), Features (Humidifier, Portability and Heated Tubing), Automation (Manual and Automatic), End User (Hospitals, Private Clinics, Home Care and Others), Country (U.S., Canada, Mexico, Germany, Italy, U.K., France, Spain, Netherland, Belgium, Switzerland, Turkey, Russia, Rest of Europe, Japan, China, India, South Korea, Australia, Singapore, Malaysia, Thailand, Indonesia, Philippines, Rest of Asia- Pacific, Brazil, Argentina, Rest of South America, South Africa, Saudi Arabia, UAE, Egypt, Israel, Rest of Middle East & Africa) Industry Trends and Forecast to 2028.

1.10.1 Market analysis

This CPAP devices market report details recent developments, trade regulations, import export analysis, production analysis, value chain optimization, market share, impact of domestic and localized market players, analyses opportunities in terms of emerging revenue pockets, changes in market regulations, strategic market growth analysis, market size, category market growths, application niches and dominance, product approvals, product launches, geographic distribution, and product approvals.

1.10.2 Market scope

The market for CPAP equipment is divided into four categories: product type, features, automation, and end user. These sectors' growth will help you analyze inadequate growth categories in the industries, as well as provide users with a thorough market overview and industry insights to help them make strategic decisions for core market application discovery.

- The CPAP devices market is divided into fixed pressure CPAP devices, auto adjusting CPAP devices, CPAP motors, CPAP hoses, CPAP mask, and others based on product type.
- The CPAP equipment market is divided into three categories based on features: humidifier, portability, and heated tubing.
- The CPAP equipment market is divided into two categories based on automation: manual and automatic.
- The CPAP equipment market is divided into hospitals, private clinics, home care, and others, depending on the end user.

The high costs of CPAP machines, on the other hand, will limit the market's potential. Getting acclimated to wearing CPAP equipment can be a difficult process that causes sleeping pain. The market's growth will be hampered as a result of this. In developing economies, a lack of awareness of CPAP machines would further stymie market expansion. According to Data Bridge Market Research, the CPAP devices market would grow at an annual rate of roughly 8.33 percent from 2021 to 2028. This means that by 2028, the market value will have increased from USD 3,586.37 million in 2020 to USD 6,799.63 million. The two primary drivers driving the growth of the CPAP devices market are the rising global prevalence of cancer and the growth and expansion of the life sciences industry.

1.11 Sleep apnea device manufactures

Fig.1.8 CPAP device manufactures

1.11.1 Existing models

DreamStation 2Auto CPAP Advanced

Fig.1.9. DreamStation 2Auto CPAP Advanced

- The Ramp Plus feature allows patients to set a comfortable starting pressure. Once set, Ramp Plus will be automatically activated for future therapy sessions.
- Pressure will increase automatically if an event is detected.

AirSense 10 Series

Fig.1.10. AirSense 10 Series

- User-friendly controls and an intuitive interface make it simple to navigate settings and the nightly sleep report.
- AutoRamp feature delivers a low airflow pressure to help you fall asleep, then steadily increases to your prescribed level.

CHAPTER 2

LITERATURE REVIEW

Obstructive Sleep Apnea (OSA) is becoming a global health problem, owing to the obesity epidemic. However, thorough prevalence data are still lacking, and global OSA research has yet to be structured. A worldwide picture evaluating the risk/burden of OSA was generated using the most recent comprehensive age/gender-specific BMI and obesity data. The findings were given in light of an in-depth examination of OSA research as well as the socioeconomic and scientific backgrounds of the countries. While the United States, Canada, and Japan have the biggest number of OSA publications, Iceland, Greece, and Israel came out on top when it came to connecting scientific production to socioeconomic factors. China, India, and Russia, on the other hand, performed poorly in these relations. According to an analysis of the estimated population at risk (EPR) of OSA, the leading countries are the United States, China, India, and Brazil. Despite the fact that the EPR and OSA research were highly connected, large geographical disparities between anticipated demand and actual research performance were discovered, particularly in developing countries but not exclusively. [2]

OSA is noticeably widespread amoung the population. It is associated with age and obesity. Only part of people with OSA amoung the population have signs and symptoms in the form of daylight sleepiness. The occurrence of OSA and OSA syndrome has accelerated in epidemiological research over time. Differences and the growth in occurrence of sleep apnea are in all likelihood because of special diagnostic equipment, definitions, examine layout and traits of covered topics. Cardiovascular disease, especially stroke is associated with OSA and topics below the age of 70 run an accelerated danger of early loss of life in the event that they be afflicted by OSA.[3]

In the United States, obstructive sleep apnea (OSA) affects 17% of women and 34% of men, with a comparable prevalence in other nations. This article provides an update on how to diagnose and treat OSA. Excessive drowsiness is the most prevalent presenting symptom of OSA; however, it is only reported by 15 percent to 50 percent of patients with OSA in the general population. OSA is linked to a two- to three-fold increase in the risk of cardiovascular and metabolic disorders. Home sleep apnea testing, which has a sensitivity of about 80%, can be used to identify OSA in many patients. Weight loss and exercise, as well as positive airway pressure, are effective treatments. OSA is prevalent, and its incidence is rising in tandem with the rise in obesity rates. [1]

In eleven published epidemiological studies published between 1993 and 2013, the prevalence of obstructive sleep apnea (OSA) characterized by an apnea-hypopnea index (AHI) of 5 was 22 percent (range, 9-37 percent) in men and 17 percent (range, 4-50 percent) in women. Excessive daytime drowsiness was found in 6% (range, 3-18%) of men and 4% (range, 1-17%) of women with OSA. OSA was reported in 37 percent of men and 50 percent of women in studies from 2008 and 2013, respectively. OSA is more common in males than in women, and it gets worse as you get older and gain weight. Smoking and drinking alcohol have also been suggested as risk factors, however the evidence is mixed. Excessive daytime sleepiness is thought to be the most critical symptom of OSA, however only a small percentage of people with an AHI of 5 report it, and one study found no link between daily sleepiness and sleep apnea in women. Sleep apnea is linked to stroke, hypertension, and coronary artery disease. There is a link between OSA and diabetes mellitus, according to cross-sectional research. Patients under the age of 70 who have OSA are at a higher risk of dying young.[3]

A tissue biopsy cannot be used to diagnose obstructive sleep apnea, unlike other disorders such as cancer. As a result, calibrating any test for OSA diagnosis is problematic due to the lack of a gold standard by which to assess the genuine illness condition. Polysomnography (PSG) in a monitored setting (sleep laboratory) has traditionally considered the gold standard for diagnosing OSA. This necessitates keeping an eye on patients while they are sleeping. A patient is admitted to the sleep laboratory for the night and is closely observed by a technician.[4]

Electroencephalography, electrooculography, submental electromyography, electrocardiography, respiratory movement or effort, nasal or oral airflow, pulse oximetry, and limb movement electromyography are all examples of polysomnography. PSG tracks sleep stages, respiratory effort, oxygen saturation, heart rate, body position, and limb movements, among other things. The apnea-hypopnea index (AHI) or respiratory disturbance index is calculated using these data (RDI The AHI is calculated as the sum of apneas and hypopneas per hour of sleep, with apnea defined as a pause in breathing for more than 10 seconds and hypopnea defined as a drop in respiratory effort with less than 4% oxygen desaturation. The RDI is calculated as the total number of apneas, hypopneas, and other abnormal respiratory episodes per hour of sleep. The names are frequently used interchangeably. Polysomnography is a time-consuming and costly procedure performed in a sleep lab. Portable devices have evolved as a result of technological advancements that evaluate the same sleep characteristics whether in sleep laboratories or at home.[4]

The AHI has been commonly used to diagnose OSA, but with a variety of cut-off levels, the foundation for which is frequently unclear or arbitrary. AHI of more than five events per hour of sleep is generally regarded abnormal, and the patient is diagnosed with a sleep disturbance. The diagnosis of OSA is based on an abnormal AHI combined with severe daytime drowsiness. Continuous positive airway pressure therapy (CPAP) is the treatment of choice for people with OSA. Polysomnography can also be used to adjust CPAP to a person's specific needs.[4]

An article published in the early 21st century states that, for moderate to severe obstructive sleep apnea, nasal continuous positive airway pressure (CPAP) is the treatment of choice (OSA). This technique prevents upper airway collapse during sleep by using a pneumatic splint. Auto CPAP (APAP) can help with some of the most common issues. Flow (apnea or hypopnea), snoring (airway vibration), airflow profile flattening (airflow limitation), or airway impedance are all monitored by the devices (forced oscillation technique).[5]

Continuous positive airway pressure (CPAP) therapy for obstructive sleep apnea has evolved into increasingly sophisticated techniques of treatment for various forms of sleep-disordered breathing during the last few decades. While the basics of this therapy are based on the principles of splinting the airway and providing aided ventilation, the advent of modern technology and downsizing is altering the field's previous traditions. The goal of this study is to expand our awareness of various forms of PAP therapy by explaining why they are used, obtaining a basic understanding of device technology, and critically evaluating clinical research findings while highlighting challenges to implementation. It is critical to disseminate such information in order to avoid knowledge gaps among healthcare providers and systems.[9]

Continuous positive airway pressure (CPAP) has become the most common treatment for OSA since its introduction in the early 1980s, and it has been found to reduce drowsiness, hypertension, and a variety of cardiovascular markers. Despite its successes, treatment adherence remains a significant restriction. The evidence for the use of positive airway pressure (PAP) therapy, its many forms, and the approaches used to enhance adherence will be discussed in this article. We'll also talk about the future of PAP therapy in OSA and how to personalize care.[8]

The patented algorithms in each APAP device gradually boost pressure in response to identified breathing episodes. After all events have been deleted, the pressure is gradually lowered until events are detected again. As a result, the lowest effective pressure is achieved (auto-adjusting). The average night-time pressure in some patients may be up to 6 cm H_2O lower than the maximum pressure allowed. Auto CPAP devices have been shown to be effective for auto-titration and long-term treatment. In majority of cases, they can be utilized in the auto-titrating mode to set a fixed level of CPAP for conventional treatment. More research is needed into the use of unattended titration techniques. For success, proper patient selection and education are almost certainly required. There is conflicting data for and against the concept that APAP will promote positive pressure treatment acceptance and adherence as a chronic treatment. However, certain subsets of the OSA population may find APAP treatment to be far more acceptable.[5]

As an attempt to look into the best qualitative treatment for OSA an article states that, obstructive sleep apnea syndrome affects a large percentage of adults and is linked to an increased risk of cardiovascular morbidity and mortality. For obstructive sleep apnea, nasal continuous positive airway pressure (CPAP) is the therapy of choice (OSA). Not only can automatic CPAP (APAP) be used for therapy, but it can also be used to recommend the best CPAP setting. Ninety-five newly diagnosed patients with moderate and severe obstructive sleep apnea syndrome (mean age 51.96 years) were included in the study. The patients were assigned to one of the two devices under investigation: APAP or fixed pressure CPAP. AUTO patients had a lower mean effective pressure (7.67 cm H_2O vs. CPAP 8.51 cm H_2O, $p=0.03$), while CPAP patients had a statistically significant reduced residual AHI (mean difference 1.6, CI 95 percent 0.7 – 2.5, $p=0.001$). To summarize, the AUTO technique appears to be equally successful as CPAP and provides a mechanism for determining a single constant pressure that is acceptable for long-term use with a traditional CPAP device.[6]

After going through a couple of articles and published papers, the best treatment currently available for OSA turns out to be AUTO CPAP. When reading a research paper to gain more knowledge about this device it was given as, automatic continuous positive airway pressure (APAP) devices adjust the delivered pressure based on the patient's breathing patterns and, as a result, may be better suited to patients who have a variety of pressure demands during sleep due to factors such as body posture, sleep stage, or nightly variability. Various manufacturers' devices use different algorithms; thus, they may react differently when exposed to the same disrupted breathing pattern. In a bench test, we wanted to see how well a variety of currently available APAP devices performed.

For two-hour experiments, a computer-controlled model simulating the breathing pattern of a patient with obstructive sleep apnea (OSA) was attached to various APAP devices and flow and pressure values were taken. AirSense 10 (ResMed), Dreamstar (Sefam), Icon (Fisher & Paykel), Resmart (BMC), SOMNObalance (Weinmann), System One (Respironics), and XT-Auto were among the devices tested (Apex). Each device was put through its paces twice.

Each device's response was remarkably diverse. While some devices were able to restore regular breathing, exceeding the required pressure in some circumstances, others were unable to eradicate disturbed breathing occurrences (mainly prolonged flow limitation). The mean and maximum pressures were 7.3–14.6 cmH2O and 10.4–17.9 cmH2O, respectively, while the time it took to achieve maximum pressure was 4.4–96.0 minutes.

Because each APAP device has its own algorithm, the reaction to an OSA bench simulation differed dramatically. This must be considered while treating OSA patients with nasal pressure and comparing clinical trial findings.[7]

An automated method for detecting the existence of sleep apnea using the acoustic signal of respiration is described in a research study. The Voice Activity Detection (VAD) technique was used to characterize breathing sound, which measures the energy of the acoustic respiratory signal during breath and breath hold. The performance of our classification method is evaluated using real respiratory signals, and the findings reveal that the VAD is a valuable tool for segmenting breath into sound and silent segments. Furthermore, the method we created can be used as a foundation for future development of an OSA screening tool.[10].

After going through many articles and research papers to gain knowledge about OSA and treatments for it I have concluded that OSA is a globally widespread sleeping disorder which still has not reached a complete awareness of the serious medical problems it can cause. The simple and quality treatment for OSA started with a conventional CPAP, with a few disadvantages like giving continuous and constant pressure was causing throat injuries and disturbance during sleep so it was upgraded and evolved into an Auto CPAP. The Auto CPAP device does not give continuous and constant pressure all night instead it does pressure titration based on each individuals' physical factors such as body mass, breathing rate and age to give variations in pressure preventing disturbance in sleep. But still giving air all night to the patient caused throat injuries, to overcome this issue an humidifier was introduced which humidifies the air given to the patient providing moisturized air. The CPAP device when brought in the market was a costly device and with each addition of hardware and each upgrade of the device increased the cost even more making it unavailable for all people. After serious study on the specifications of the CPAP device in the market and its disadvantages, I founded that there is a need for a new treatment for OSA which overcomes all the issues on current market device in a reduced price making it cost efficient and available to all people. I have come up with the idea of an Auto CPAP device which senses the breathing of the patient and provides support only when apnea occurs and remain at standby during normal breathing this sensing runs at regular time intervals providing effective support during apnea, and by remaining in standby when apnea does not occur the device reduces power consumption increasing the life span of the device, since it is in standby during normal breathing there is no continuous airflow all night it prevents throat injuries and dryness therefore the need of humidifier is not necessary thus reducing the cost also. This new and integrated Auto CPAP device will prove to be the effective and quality treatment for OSA.

CHAPTER 3

3. Methodology

After going through many articles and research papers and few blogs of researchers, it is found that OSA is a globally widespread sleeping disorder which still has not reached a complete awareness of the serious medical problems it can cause. The simple and quality treatment for OSA started with a conventional CPAP.

The CPAP has a few disadvantages like giving continuous and constant pressure was causing throat injuries, stomach discomfort and bloating and disturbance during sleep are the most common side effects. So it was upgraded and evolved into an Auto CPAP. Congestion or inflammation of the nasal passages is one of the most prevalent side effects of Auto CPAP therapy and still giving air all night to the patient caused throat injuries, to overcome this issue an humidifier was introduced which humidifies the air given to the patient providing moisturized air. When the CPAP device was first introduced to the market, it was a costly equipment, and each addition of hardware and upgrade increased the cost even more, making it unaffordable for most individuals.

After conducting extensive research into the features and disadvantages of the current CPAP device on the market, I discovered that there is a need for a new treatment for OSA that addresses all of the issues with the current market device at a lower cost, making it cost effective and accessible to all people.

Inorder to do so I developed the concept of an Auto CPAP device that senses the patient's breathing and provides support only when apnea occurs, while remaining in standby mode during normal breathing. This sensing runs at regular time intervals, providing effective support during apnea, and by remaining in standby mode when apnea does not occur, the device reduces power consumption, increasing the device's life span. Because it is in standby mode during normal breathing, there is no continuous airflow all night, which prevents throat injuries and dryness and eliminates the need for a humidifier, lowering the cost. This new, integrated Auto CPAP device will be an effective and high-quality treatment for OSA.

Brainstorming

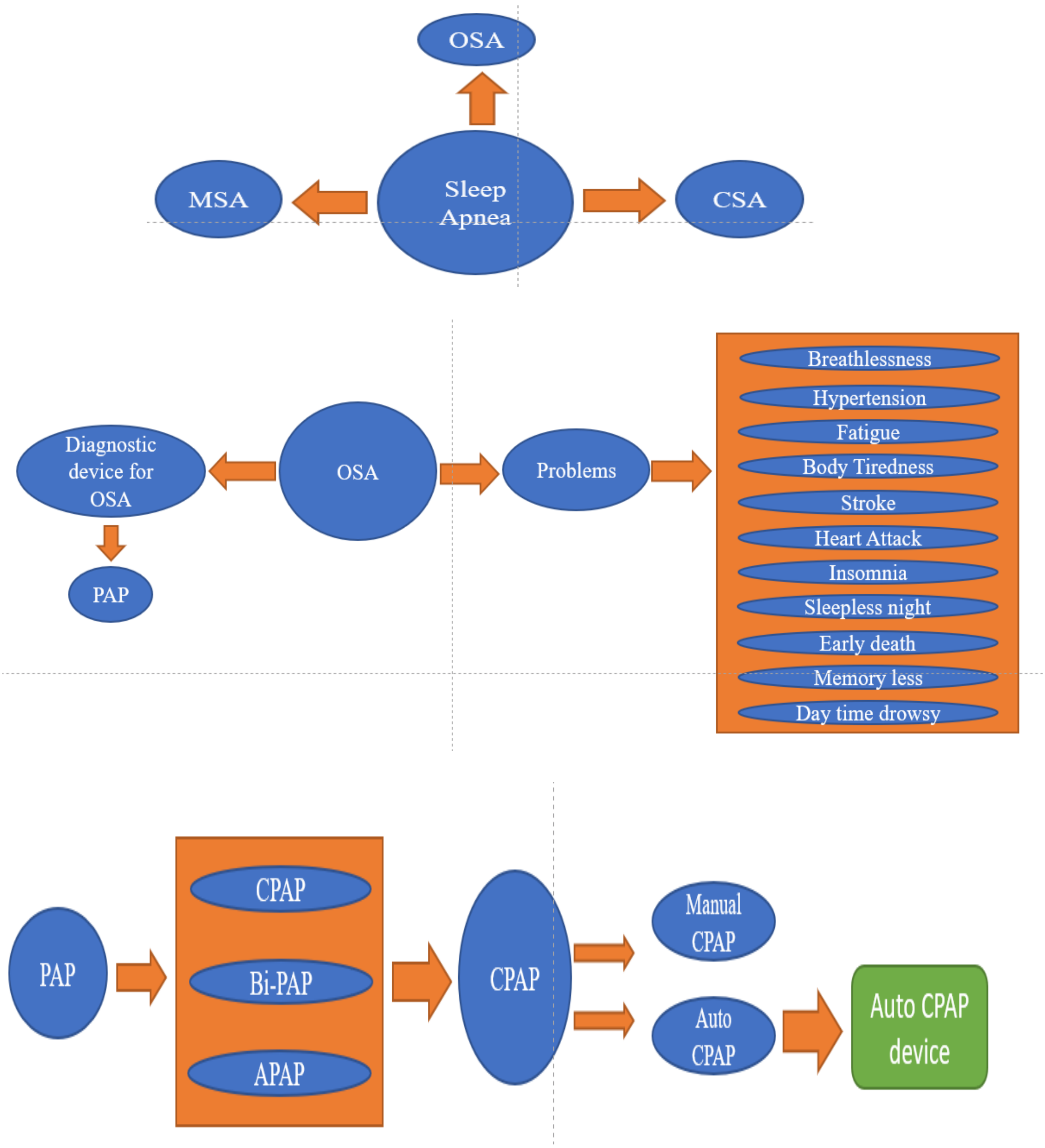


Fig 3.1 Brainstorming idea mentioned the problem and exact diagnostic device for Auto CPAP.

After brainstorming many ideas and analysing the features in the current market models I have come up with a few ideas,

- Idea 1: The current market model consists of a IOT module which collects data recorded, but since it is just an advancement but is not an essential requirement and hence it can be neglected, providing a cost-efficient device.

- Idea 2: In addition to the removal of IOT the embedded micro controller can also be simplified with a normal Arduino microcontroller reducing the cost.

- Idea 3: The use of humidifier in the advanced models to prevent throat injuries increase the cost of the device by nearly 20%, so providing a suitable alteration and removing the humidifier will reduce the cost very much.

Combining all these the final ideology is to provide an affordable and much advanced and integrated Auto CPAP machine using non-invasive method that reduces complication as in present models and combining the conventional CPAP technique providing an effective breathing support to the sleep apnea patient. The uniqueness of this idea is that the device remains in stand-by during normal breathing and provides support only when OSA occurs which is detected by a sensor. The implementation of this method completely removes the risk of throat infections and injuries caused by continuous airflow. Also turns out to be a very cost-efficient model by reducing the use of hardware like humidifier and less consumption of electricity as the machine only runs when apnea occurs and remain at stand-by during normal breathing unlike auto CPAP and conventional CPAP which provides constant airflow. This new, integrated Auto CPAP device will provide an effective and high-quality treatment for sleep apnea.

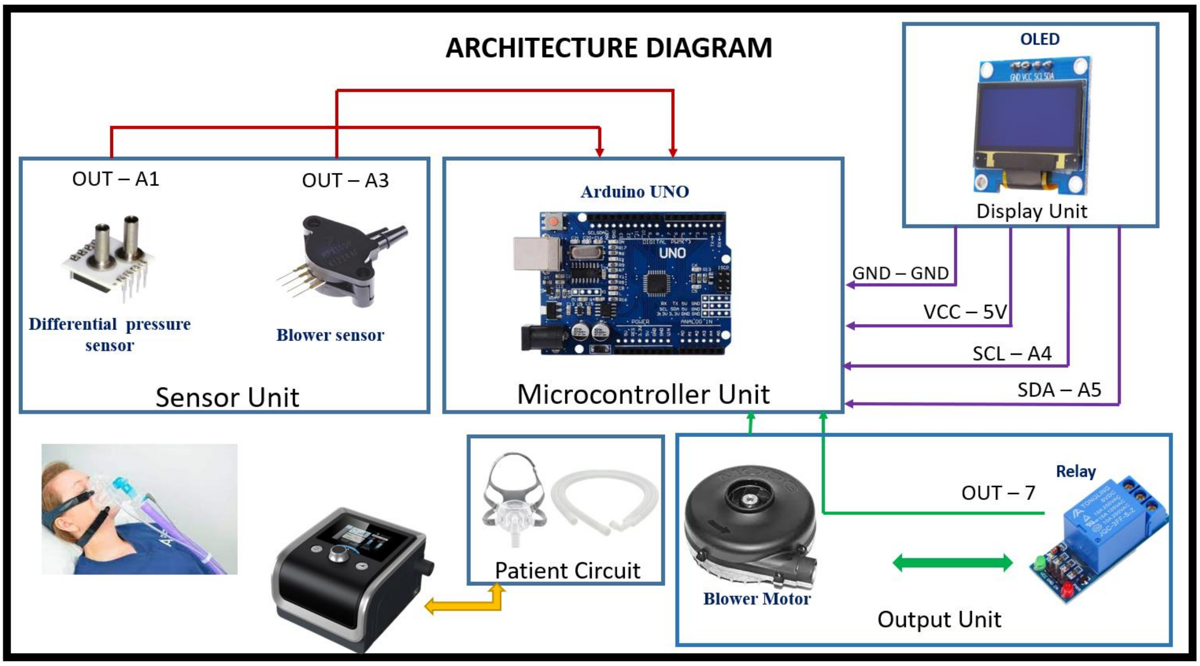


Fig.3.2. Hardware block diagram

Description:

In this architecture diagram it represents each component and their pin connection with Microcontroller unit.

Microcontroller unit:

In my research work, I came across with different controller board and I have finalized with Arduino Atmega328P. It's very easy accessible component and it can support to the device exactly same as the high-end microcontroller. The price wise is affordable the specification are

Operating Voltage	5V
Recommended Input Voltage	7-12V
Input Voltage Limits	6-20V
DC Current on I/O Pins	40 mA
DC Current on 3.3V Pin	50 mA
Flash Memory	32 KB (0.5 KB is used for Bootloader)
Frequency (Clock Speed)	16 MHz

Blower Motor:

Blower is most important part for the Auto CPAP device with help of pressured air helps to clear the obstructions. Technical specification chosen is 12v DC motor with high quality of voltage output with low noise, which will not disturb during their sleep.

BLDC board:

The BLDC board is a three-phase brushless DC motor driver board based on MOSFET. Technical specification of the BLDC board has good operating voltage is DC 12V - 36 V. Important factor is need for the blower is speed control 0.1V-5V.

Relay Module:

A relay module is an electrical switch that operated by an electromagnet. It has low power signal from the micro controller. When activated, the electromagnet pulls to either open or close an electrical circuit by using the module used to turn ON/OFF the blower motor.

Patient sensor:

Specification of pressure sensor (SPD102DAHYB). The sensor has a range of 102 mm H_2O FS and the output is radiometric to the power supply voltage. In the pressure sensor has supply voltage is up to 5.25 V and it take only 2 mA supply for continuous sensing. It has good response time 25Ms its most important factor for Sleep Apnea product. In addition, it can overload pressure until the maximum of 50 cmH_2O

Blower sensor:

The MPX10 series silicon piezo resistive pressure sensors give a very precise and linear voltage output for applied pressure. Blower sensor has the differential pressure range is up to 10kPa their take supply voltage is 6 VDC. It has good Sensitivity for sensing the pressure 3.5mV/kPa. It's very suitable sensor for reading the pressure, which comes from blower.

OLED display:

Technical Specification of OLED display is and has good resolution and for the cost effective manner it is a best one for choosing for my product. It use only 5V Power supply is use and has 128x64 Dot Resolution. It will directly connect to the Microcontroller3.3V. Total current taken is 8 mA.

Table 3.1 Market Price of Auto CPAP device

Market Device	Device Components and Materials	Cost	Idea- 1	Idea-2	Idea-3
DreamStation 2Auto CPAP Advanced	Blower fan	200€	✔	✔	✔
	Blower Sensor	40€	✔	✔	✔
	Patient Sensor	59€	✔	✔	✔
	Embedded Microcontroller	150€	✔	✖	✖
	Humidifier	99€	✔	✔	✖
	IOT	200€	✖	✖	✖
	Face mask	50€	✔	✔	✔
	Patient circuit	25€	✔	✔	✔
	Body material	60€	✔	✔	✔
	Cost	883€	683€	533€	434€

3.1 ARDUINO MICROCONTROLLER

- The **Arduino Uno** is an open-source microcontroller based on the microchip ATMEGA 328P microcontroller and developed by Arduino.cc.
- The board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits.

- The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable.
- It can be powered by the USB cable or by an external 9 Volt power supply, though it accepts voltages between 7 and 20 volts.

3.1.1 ARDUINO UNO

- **Arduino Uno** is a microcontroller board based on 8-bit ATmega328P microcontroller. Along with ATmega328P, it consists other components such as crystal oscillator, serial communication, voltage regulator, etc. to support the microcontroller. Arduino Uno has 14 digital input/output pins (out of which 6 can be used as PWM outputs), 6 analog input pins, a USB connection, A Power barrel jack, an ICSP header and a reset button.
- The 14 digital input/output pins can be used as input or output pins by using pinMode(), digitalRead() and digitalWrite() functions in arduino programming. Each pin operates at 5V and can provide or receive a maximum of 40mA current, and has an internal pull-up resistor of 20-50 KOhms which are disconnected by default. Out of these 14 pins, some pins have specific functions as listed below:
- **Serial Pins 0 (Rx) and 1 (Tx):** Rx and Tx pins are used to receive and transmit TTL serial data. They are connected with the corresponding ATmega328P USB to TTL serial chip.

- **External Interrupt Pins 2 and 3:** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.
- **PWM Pins 3, 5, 6, 9 and 11:** These pins provide an 8-bit PWM output by using analog Write() function.
- **SPI Pins 10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK):** These pins are used for SPI communication.
- **In-built LED Pin 13:** This pin is connected with an built-in LED, when pin 13 is HIGH – LED is on and when pin 13 is LOW, its off
- Along with 14 Digital pins, there are 6 analog input pins, each of which provide 10 bits of resolution, i.e., 1024 different values. They measure from 0 to 5 volts but this limit can be increased by using AREF pin with analog Reference () function.
- Analog pin 4 (SDA) and pin 5 (SCA) also used for TWI communication using Wire library.

- **AREF:** Used to provide reference voltage for analog inputs with analog Reference () function.
- **Reset Pin:** Making this pin LOW, resets the microcontroller.

Fig.3.3 Arduino UNO Microcontroller

Table.3.2. PIN DESCRIPTION

Pin Category	**Pin Name**	**Details**
Power	Vin, 3.3V, 5V, GND	Vin: Input voltage to Arduino when using an external power source. 5V: Regulated power supply used to power microcontroller and other components on the board. 3.3V: 3.3V supply generated by on-board voltage regulator. Maximum current draw is 50mA. GND: ground pins.
Reset	Reset	Resets the microcontroller.
Analog Pins	A0 – A5	Used to provide analog input in the range of 0-5V
Input/Output Pins	Digital Pins 0 - 13	Can be used as input or output pins.
Serial	0(Rx), 1(Tx)	Used to receive and transmit TTL serial data.
External Interrupts	2, 3	To trigger an interrupt.
PWM	3, 5, 6, 9, 11	Provides 8-bit PWM output.
SPI	10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK)	Used for SPI communication.
Inbuilt LED	13	To turn on the inbuilt LED.
TWI	A4 (SDA), A5 (SCA)	Used for TWI communication.
AREF	AREF	To provide reference voltage for input voltage.

Table.3.3. ARDUINO TECHNICAL SPECIFICATION

Microcontroller	ATmega328P – 8 bit AVR family microcontroller
Operating Voltage	5V
Recommended Input Voltage	7-12V
Input Voltage Limits	6-20V
Analog Input Pins	6 (A0 – A5)
Digital I/O Pins	14 (Out of which 6 provide PWM output)
DC Current on I/O Pins	40 mA
DC Current on 3.3V Pin	50 mA
Flash Memory	32 KB (0.5 KB is used for Bootloader)
SRAM	2 KB
EEPROM	1 KB
Frequency (Clock Speed)	16 MHz

3.1.2 Communication

Arduino can be used to communicate with a computer, another Arduino board or other microcontrollers. The ATmega328P microcontroller provides UART TTL (5V) serial communication which can be done using digital pin 0 (Rx) and digital pin 1 (Tx). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The ATmega16U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, a .inf file is required. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. There are two RX and TX LEDs on the arduino board which will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (not for serial communication on pins 0 and 1). A SoftwareSerial library allows for serial communication on any of the Uno's digital pins. The ATmega328P also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus.

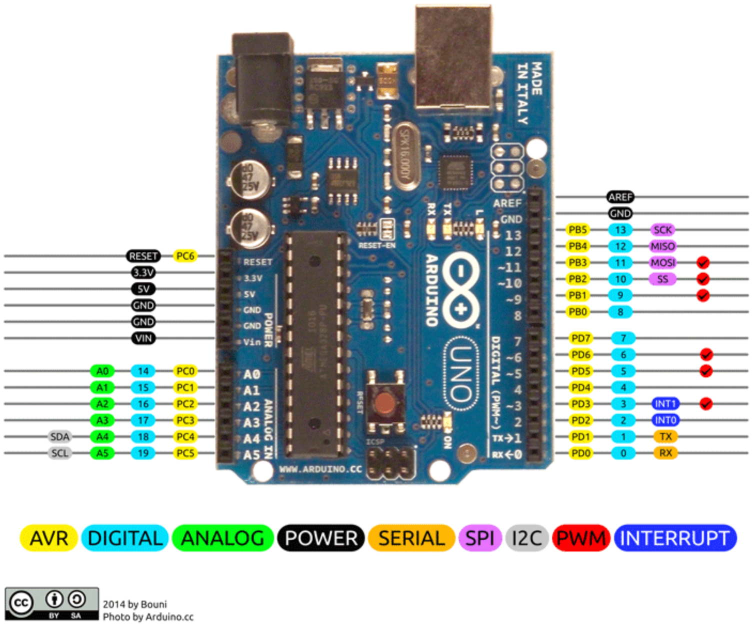


Fig.3.4 ARDUINO UNO PIN DIAGRAM

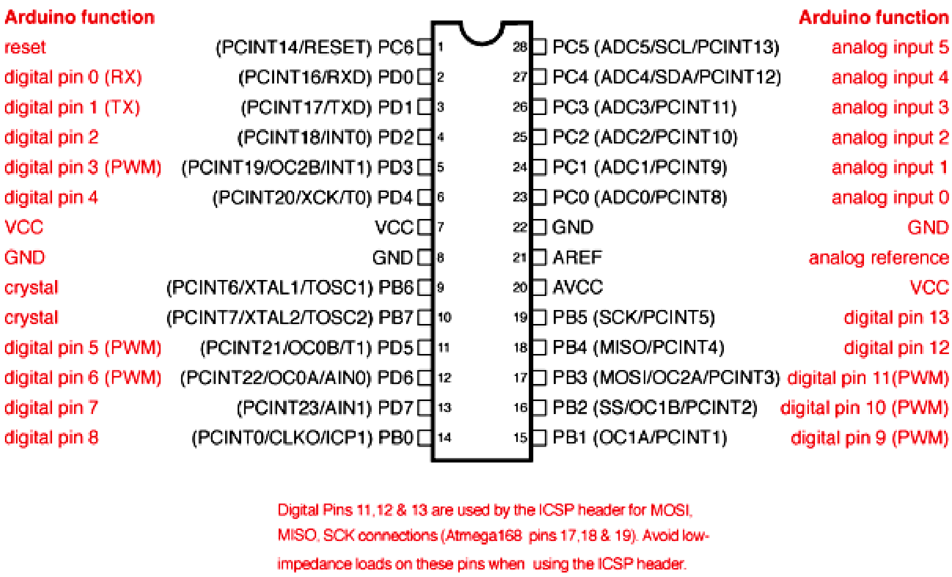


Fig.3.5 ATMEGA 328 PIN DIAGRAM

3.1.3 SOFTWARE

Arduino IDE (Integrated Development Environment) is required to program the Arduino Uno board.

3.1.4 APPLICATION

- Prototyping of Electronics Products and Systems
- Multiple DIY Projects.
- Easy to use for beginner level DIYers and makers.
- Projects requiring Multiple I/O interfaces and communications

3.2 OLED

- OLED (Organic Light Emitting Diodes) is a flat light emitting technology, made by placing a series of organic thin films between two conductors.
- When electrical current is applied, a bright light is emitted. OLEDs are emissive displays that do not require a backlight and so are thinner and more efficient than LCD displays (which do require a white backlight)

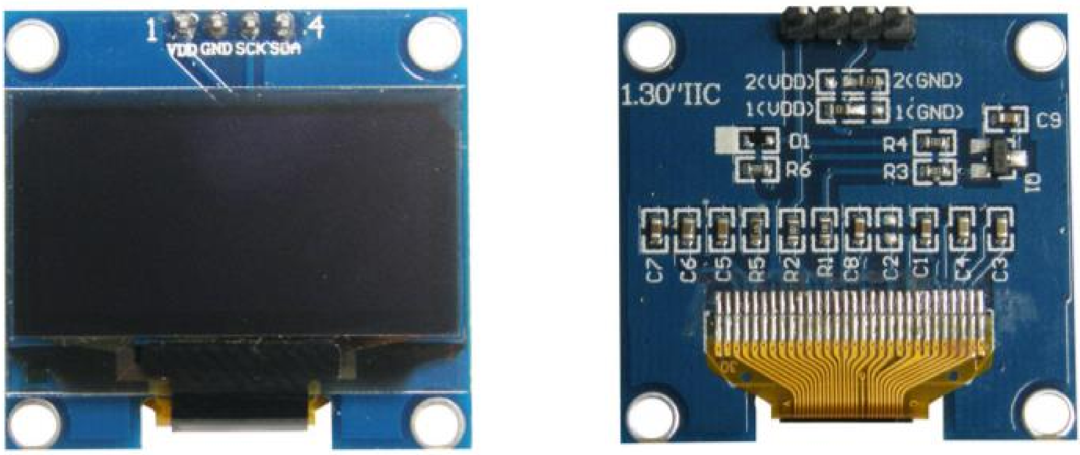


Fig.3.6 OLED Display

3.2.1 SPECIFICATION

- Use CHIP No.SH1106
- Use 3.3V-5V POWER SUPPLY
- Graphic LCD 1.3” in width with 128x64 Dot Resolution
- White Display is used for the model OLED 1.3 I2C WHITE and blue Display is used for the model OLED 1.3 I2C BLUE - Use I2C Interface
- Directly connect signal to Microcontroller 3.3V and 5V without connecting through Voltage Regulator Circuit
- Total Current when running together is 8 mA - PCB Size: 33.7 mm x 35.5 mm

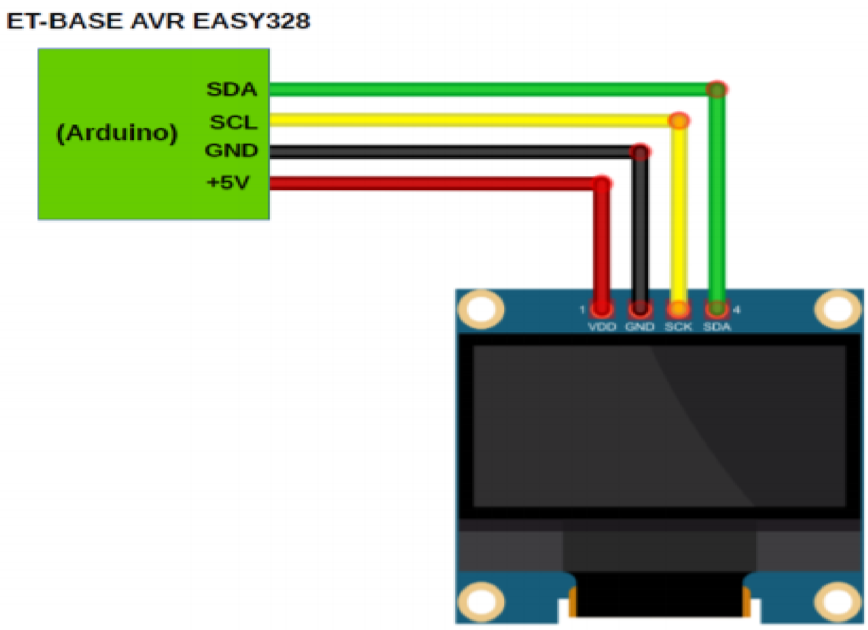


Fig.3.7 OLED pin Diagram

Table.3.4. OLED Pin Description

PIN NO	PIN NAME	DESCRIPTION
1	VDD	Pin Power Supply For LCD Using 3.3 V- 5 V
2	GND	Pin Ground
3	SCK	Pin SCL of I2C Interface
4	SDA	Pin SDA of I2C Interface

3.3 BLOWER

Blowers combine compact, high-energy 3-phase brushless DC motors and an efficient airfoil design to give outstanding output power per unit volume. The motor uses high-energy rare-earth magnets to deliver the necessary torque to the blower, allowing for optimum airflow in the smallest amount of system space.

High-reliability, long-life ball bearings with specially formulated lubrication are used in these high-efficiency small air movers to extend the life without the need to re-lubricate.

- The 12V dc blower motor is used to pump the air way pressure to the patient circuit.
- The blower produces enough air pressure to clear the sleep apnea when it occurs to the patient
- 7530 12V DC Blower made of special and premium materials. It is high temperature resistant and extremely durable.
- This blower fan has projector blower centrifugal fan for powerful air throw. It is made of high quality PBT+30% glass line +VO and Bearing with high precision make it provide long life and low noise.
- It can be taken in use to handle the temperature cooling 75°C. Its Working temperature 40°C with the continuous working of 24 hours capacity.

Features:

• All voltages are available in addition to 24 VDC.

• There is an AC input accessible.

• Open collector tach output, weak pull-up on board

• Input speed control from 0 to 5 V or PWM (0 - 10 V on AC version)

• Electronics for internal or external drives

• Brushless 3-phase DC motor with high efficiency

• External drive with direct access to Halls and phase leads as an option

• UL-certified component

3.3.1 SPECIFICATION

- 12V 2-point Pin DC 0.13A.
- Made of high-quality PBT 30% glass line VO
- Bearing is a high precision, long life and low noise.
- Excellent for cooling heat sinks on hot ends, prints, or other cooling needs

Table 3.5. Specification of Blower

Model	7530 blowers
Color	Black
Cable length (cm)	10
Material	High quality plastic
Mounting Screw Hole	4mm
Air inlet size	49mm
Outlet size	35*25 mm
Shipment weight	0.06 kg

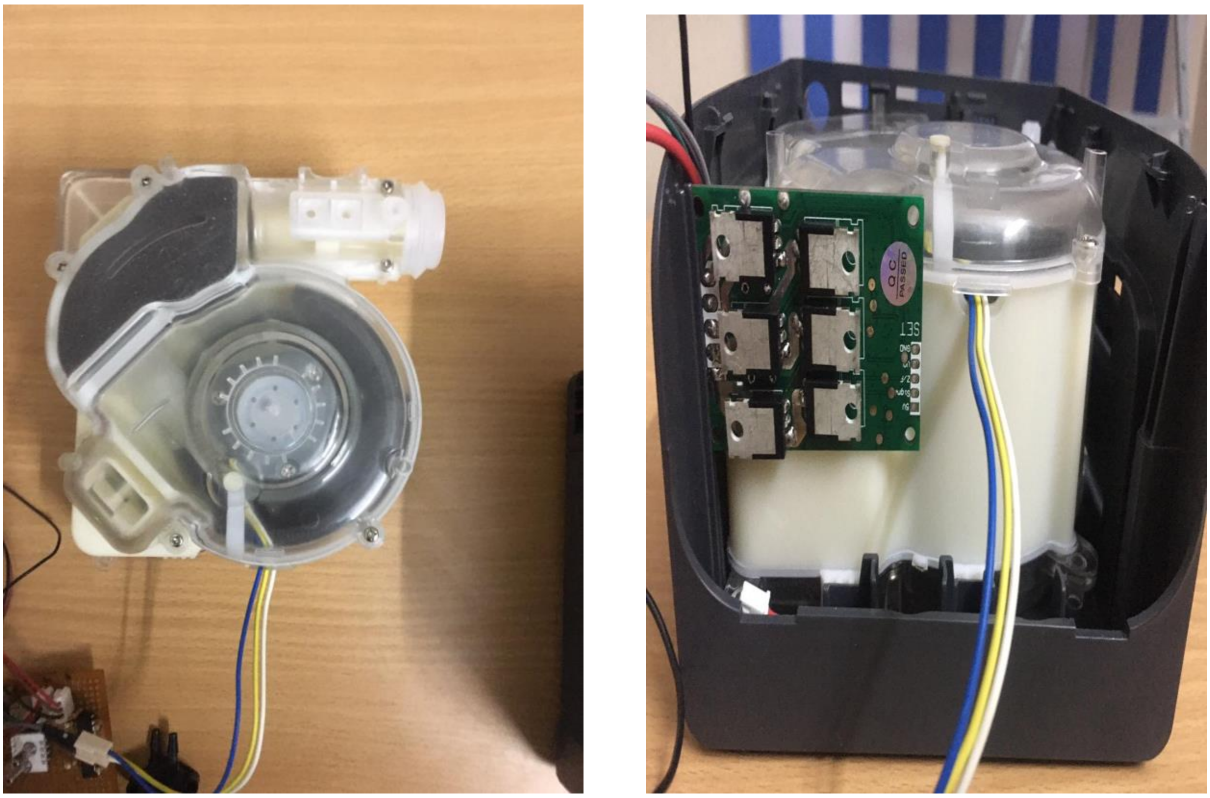


Fig.3.8. Blower setup with BLDC board

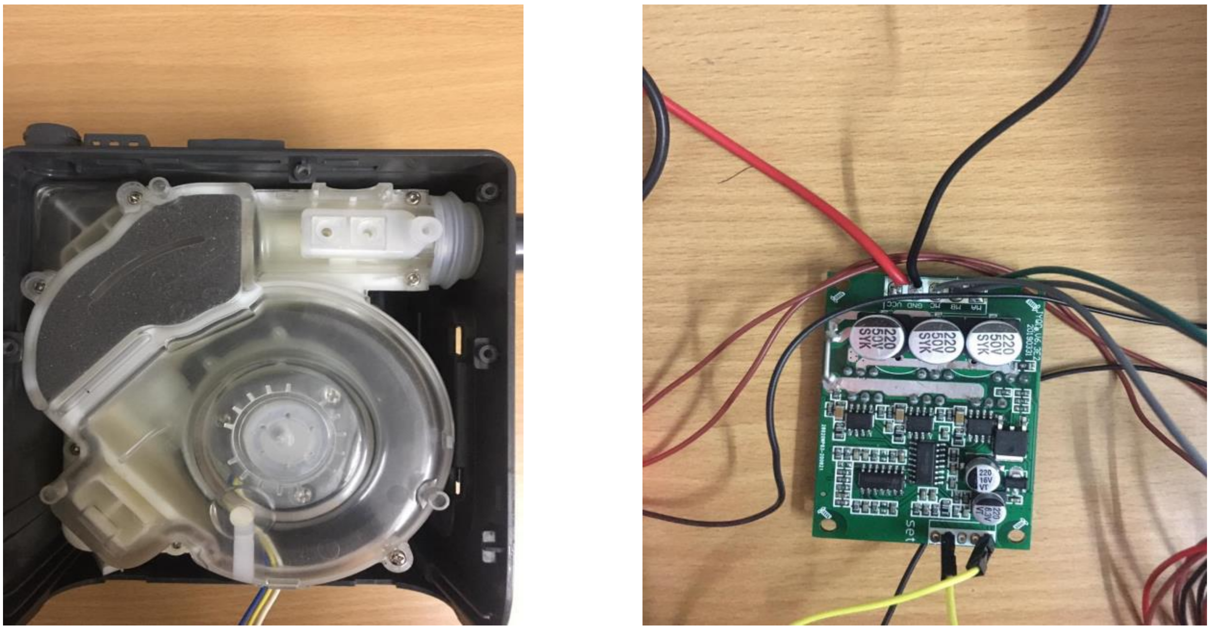


Fig.3.9 Picture of Blower and BLDC board

3.4 BLDC BOARD

The BLDC board is a three-phase brushless DC motor driver board based on MOSFET. The device is a cost-effective and simple-to-use solution for low-voltage motor driving applications such as fans, drones, and power tools. The board is designed for sensor or sensor-less vector control FOC algorithms with three shunt sensing.

3.4.1 SPECIFICATION

Table 3.6. BLDC specification

Operating Voltage	DC 12V-36V
Operating current	≤15A
Output power	≤500W
Speed control	0.1V-5V or PWM input
Operating temperature	-40-85°C
Operating humidity	≤90%
Protection	Overload protection, locked-rotor protection, over-current protection
Functions	Speed pulse signal output, soft reversing (485,CAN port optional)
Overall dimension	63X42.5X17mm (L*W*H)
Net weight	30g
Optional component	Speed regulating potentiometer external 5 digit tachometer

3.5 DIFFERENTIAL PRESSURE SENSOR (SPD102DAHYB)

The **Smartec** differential pressure sensor has an amplified analogue output. The sensor is compensated for offset, sensitivity, temperature drift and nonlinearity. The sensor has a range of 102 mm H2O FS and the output is radiometric to the power supply voltage. Other pressure ranges on request (0.3 – 100 PSI).

Table 3.7. Specification of pressure sensor (SPD102DAHYB)

PARAMETER	MIN	TYP	MAX	UNITS
Supply voltage	4.75	5.00	5.25	V
Supply current			2.0	mA
Pressure range		+/- 102		MmH2O
Zero output	2.45	2.5	2.55	Vdc@Ommh2O
Span output		2.00		Vdc
Response time		25		Ms
linearity	-2.5		+2.5	%FS
Thermal hysteresis	-0.1		+0.1	%FS
Temp coeff offset	-2.5		+2.5	%FS
Temp coeff span	-2		+2	%FS
Pressure overload			10x	Rating
Temp compensation	0		50	*C

Table 3.8. Pin Description of patient sensor

PIN	**DESCRIPTION**
1	**NC**
2	**GND**
3	**OUT**
4	**VCC**
5-8	**NC**

Fig.3.10 Picture of SPD102DAHYB Pressure Sensor

3.6 BLOWER SENSOR

The MPX10 series silicon piezoresistive pressure sensors give a very precise and linear voltage output that is proportional to the applied pressure. Manufacturers can design and add their own external temperature compensation and signal conditioning networks to these common, low-cost, uncompensated sensors. Because of the predictability of Freescale's single element strain gauge design, compensation approaches are simplified.

Features

• Low Cost

• Silicon Shear Stress Strain Gauge with a Patented Design

• Supply Voltage Ratiometric

• Options for Differential and Gauge

• Surface Mount Package with Epoxy Unibody Element or Thermoplastic (PPS)

Fig.3.11 MPX100P Pressor sensor

Table 3.9. Specification of Blower sensor

Characteristic	Symbol	Min	Typ	Max	Units
Differential Pressure Range[1]	P_{OP}	0	—	10	kPa
Supply Voltage[2]	V_S	—	3.0	6.0	V_{DC}
Supply Current	I_O	—	6.0	—	mAdc
Full Scale Span[3]	V_{FSS}	20	35	50	mV
Offset[4]	V_{OFF}	0	20	35	mV
Sensitivity	ΔV/ΔP	—	3.5	—	mV/kPa
Linearity	—	–1.0	—	1.0	$\%V_{FSS}$
Pressure Hysteresis (0 to 10 kPa)	—	—	±0.1	—	$\%V_{FSS}$
Temperature Hysteresis	—	—	±0.5	—	$\%V_{FSS}$
Temperature Coefficient of Full Scale Span	TCV_{FSS}	–0.22	—	–0.16	$\%V_{FSS}/°C$
Temperature Coefficient of Offset	TCV_{OFF}	—	±15	—	μV/°C
Temperature Coefficient of Resistance	TCR	0.21	—	0.27	$\%Z_{IN}/°C$
Input Impedance	Z_{IN}	400	—	550	Ω
Output Impedance	Z_{OUT}	750	—	1250	Ω
Response Time[5] (10% to 90%)	t_R	—	1.0	—	ms
Warm-Up Time[6]	—	—	20	—	ms
Offset Stability[7]	—	—	±0.5	—	$\%V_{FSS}$

3.7 CAPACITOR

Energy is stored in the form of an electrostatic field in a capacitor, which is a passive electrical component. A capacitor is made up of two conducting plates separated by an insulating material known as the dielectric. The capacitance is related to the plate surface areas and inversely proportional to the gap between the plates. The dielectric constant of the material separating the plates also affects capacitance. The farad, shortened, is the standard unit of capacitance. This is a large unit; more common units are the microfarad μF.

The nominal capacitance is probably the most important capacitor specifications. The basic unit of capacitance is the Farad, although most capacitors have values as well below a Farad – the submultiples are microfarad, a millionth of a Farad, 10^-6.

Fig.3.12 Capacitors (100 nf)

3.8 RESISTOR

A resistor passive two terminal electronic component that implements electrical resistance as a circuit element. In electronic circuits, resistors are used to reduce current flow, adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses. High-power resistors, which can waste hundreds of watts of electrical power as heat, can be utilized in motor controllers, power distribution systems, and transmission test loads. The resistance of fixed resistors varies only significantly with temperature, time, or operating voltage.

Fig.3.13 Resistor

RELAY MODULE

A relay module is an electrical switch that is operated by an electromagnet. The electromagnet is activated by a separate low power signal from the micro controller. When activated, the electromagnet pulls to either open or close an electrical circuit by using this module it is used to turn ON/OFF the blower motor.

Fig.3.14 Relay Module

Schematic diagram of Auto CPAP device

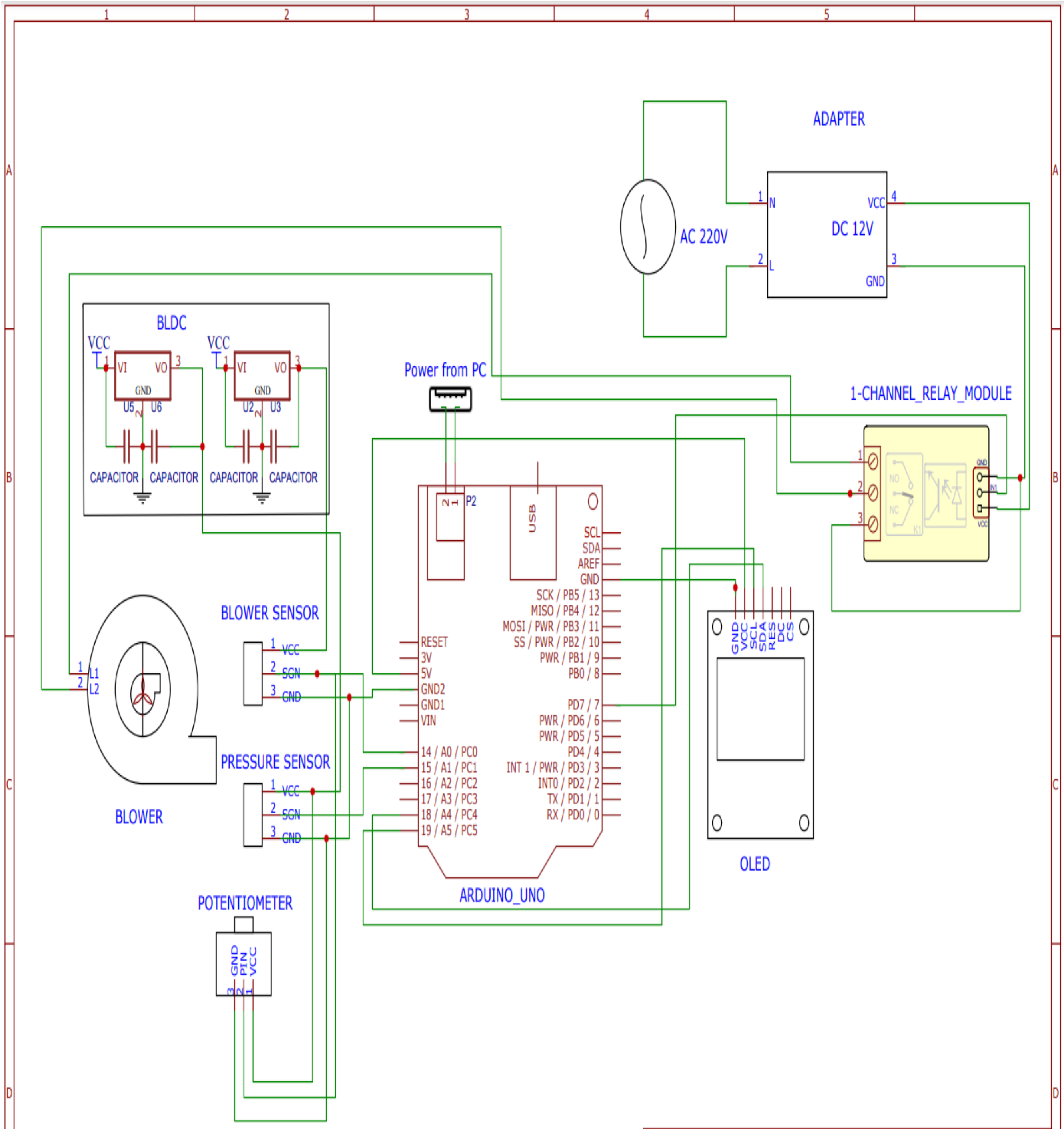


Fig.3.15. Circuit diagram

Description:

In this schematic diagram represents the circuit diagram represents the connection with precise manner with help of EasyEDA software. Its complete internal components are used for the simulation without any short circuit before getting into the hardware setup.

3.9 SOFTWARE DESCRIPTION

3.9.1 ARDUINO SOFTWARE

The Arduino IDE is a piece of software that runs on your computer and allows you to create sketches (the Arduino equivalent of a program) for various Arduino boards. Processing, a relatively simple hardware programming language similar to C, is the foundation of the Arduino programming language. After writing the code in the Arduino IDE, it should be uploaded to the Arduino board for execution.

3.9.2 ARDUINO LIBRARY

There is a necessity to install the Arduino libraries for all of the numerous types of small OLED monochrome displays. The code we offer is for any Arduino; if you want to use another microcontroller, you can easily alter it, the interface we use is basic bit-twiddling SPI or I2CUsing these OLEDs with Arduino sketches requires that two libraries be installed: Adafruit_SSD1306, which handles the low-level communication with the hardware, and Adafruit_GFX, which builds atop this to add graphics functions like lines, circles and text. In recent versions of the Arduino IDE software (1.6.2 and later), this is most easily done through the Arduino Library Manager.

3.9.3 EMBEDDED C

The C standard committee created Embedded C as a set of language extensions for the C programming language to address commonality issues that emerge with C extensions for different embedded devices. To handle exotic features like fixed point arithmetic, many different memory banks, and fundamental I/O operations, embedded C programming has traditionally required nonstandard modifications to the C language. In 2008, the C Standards Committee changed the language to address these issues by defining a uniform standard that all implementations must adhere to. Fixed-point arithmetic, named address spaces, and basic I/O hardware addressing are among the features not accessible in standard C. The majority of the syntax and semantics of conventional C are used in embedded C, e.g., structures and union, main () function, variable definition, loops (while, for), datatype declaration, bit operations, conditional statements (if, switch, case), functions, arrays and strings, macros, etc.

3.9.4 ADVANTAGES:

- It is small and simpler to learn, understand, program and debug.

- Compared to assembly language, C code written is more reliable and scalable, more portable between different platforms.
- C compilers are available for almost all embedded devices in use today, and there is a large pool of experienced C programmers.
- As C combines functionality of assembly language and features of high-level languages, C is treated as a ‘middle-level computer language’ or ‘high level assembly language’.
- It is fairly efficient.
- It supports access to I/O and provides ease of management of large embedded projects.
- Other High-level programming language like Pascal, FORTRAN also provide some of the advantages.

3.10 Block Diagram

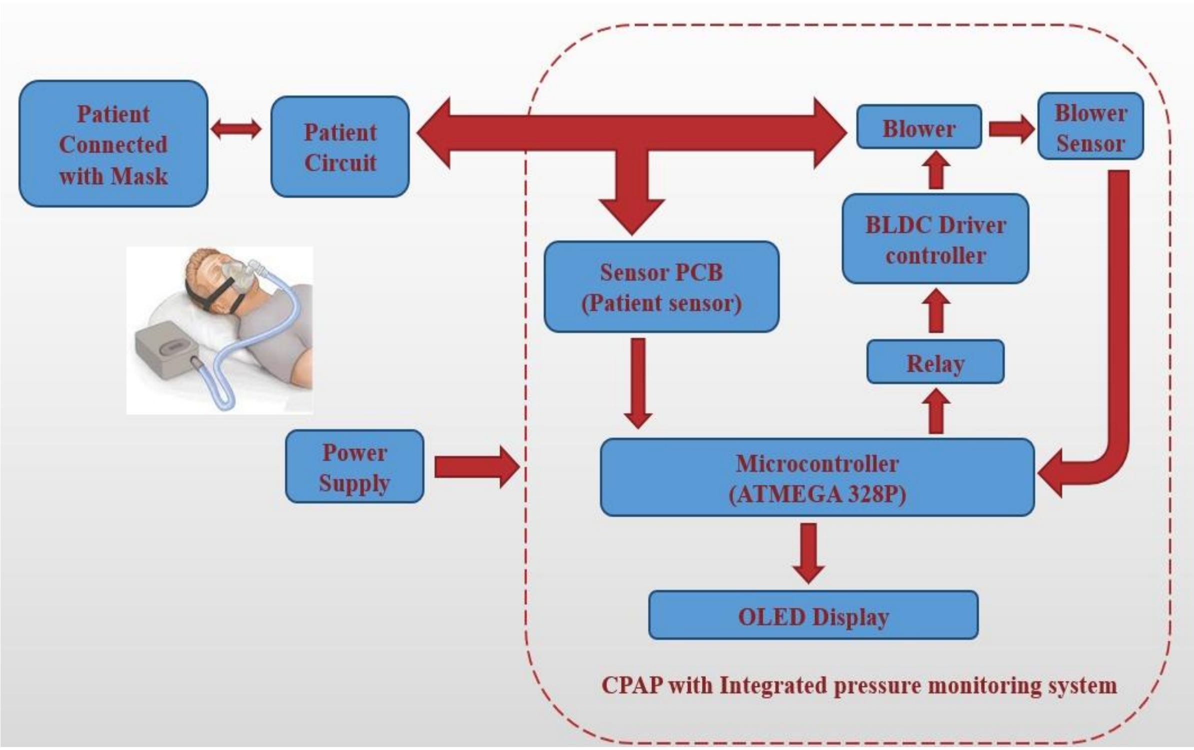


Fig.3.16 Block Diagram of Auto CPAP machine.

Description:

In the initial condition when the patient is connected with a face mask and hose pipe which is connected to the device circuit.

- The device when given power supply starts to detect and sense the breathing of the patient whether the patient is breathing normally or there is apnea occurring.

- If the patient is breathing normally the device will remain in standby and does not give any support.

- This is sensed by the patient sensor and the signal is transmitted to the microcontroller (atmega328p), it processes the signal and displays in the OLED display that apnea is not detected the condition is “standby”.

- If the condition changes and apnea is detected the patient sensor immediately sends signal to the microcontroller (atmega328p), it processes the signal and send to the relay module which switch on the blower circuit and provide support to the patient.

- This blower circuit is controlled by the BLDC board which receives the signal from the microcontroller and sends the information to the blower sensor which takes care of the operation of the blower. The blower sensor is the main component of this circuit which monitors the pressure given to the patient.

- When this condition is active the OLED displays “CPAP ON”, “Apnea detected”, and “PSV and BSV”.

3.10.1 Power supply

Power supply an AC adapter, AC/DC converter is a type of external power supply, often enclosed in a case similar to an AC plug. The other common name includes plug-in-adapter, line power adapter, power adapter. Adapters for battery powered equipment may be described as chargers are discharges. AC adapters are used with electrical devices that require power but do not contain internal components to derive the required voltage and power from mains power. The internal circuitry of an external power supply is very similar to the design that would be used for a built-in or internal supply. Then use of an external power supply allows portability of equipment powered by mains and it is used only with specified power source. This adapter helps to convert the 230V to 12V for electrical component which is used for CPAP and BiPAP machine. Then with help of voltage regulator the power has been separated to each component are like PIC microcontroller, Mini pump, LCD, pressure sensor, pressure releasing valve.

3.10.2 Switch control

The switching controllers are important part in the CPAP machine. The function of switching control is only to ON/OFF the machine. And it helps to change the mode of operation in the machine like according to patient needful they can change to CPAP or BiPAP mode.

3.10.3 Display

Display process is helps to see the CPAP condition whether it is ON/OFF and to see apnea is occurred or NOT.

3.10.4 Processing unit of machine

The input is given to the control unit that is an ARDUINO UNO it is use to control the whole system of CPAP machine. The controller unit act as an important role in the device to maintain and analysing the pressure signals.

3.11 Working principle of CPAP device

The electronic components which is used in the device is well studied and the data sheet of the respective components are studied.

• So that, its specifications are studied and according to that the circuit diagram is designed for the hardware.

• For each component like for pressure sensor other electronic component is used like extra resistor, capacitor, and amplifiers which is known because of the data sheet of the respective components.

• So according to the data sheet the circuit diagram for the pressure sensor SPD102DAHY which is used to measure the breathing pressure.

• For SPD102DAHYB sensor an 100nf capacitor is connected to the sensor for better output of the signal.

• After the circuit diagram is designed for the pressure sensor, the output pin of the pressure sensor is connected to the ARDUINO UNO microcontroller which is used to control the blower according to the signal from the pressure sensor and to display the whether the CPAP is ON/OFF in the OLED display.

- A relay module is used to control the blower, which act as a switching element for the blower to turn ON/OFF according the breathing of the patient

- This 5V relay module is connected to the digital pin in the ARDUINO UNO microcontroller.

- When the microcontroller receives minimum signal from the pressure sensor for some period of time, it is programmed to send signal to the relay module, so that the relay turns ON the blower.

- The microcontroller is programmed using the Arduino IDE Embedded C program to monitor the breathing signal of the patient.

- After the software part is completed the pressure sensor module, relay module, blower and OLED display is connected to the microcontroller.

- After the connection of the hardware, it is simulated in the LABVIEW software to check whether the designed circuit and system is correct or not.

- So, in the simulation, we got promising output of the system and the threshold value of the breathing signal is acquired in order to program the threshold value in the microcontroller,

- So that when the breathing signal of the patient reaches the threshold value for up to 10 seconds continuously then it is programmed to turn ON the blower.

- After the apnea is found and turned ON the blower, it is programmed to run standby for up to 10 or 20 minutes, after the standby time the blower is turned OFF automatically.

- And it starts to monitor the breathing of the patient, after the simulation the hardware is used for real time testing.

- Where the blower is connected to the patient circuit which is connected to the patient mask.

• Where the sensor module relay and blower are assembled and real time testing is done.

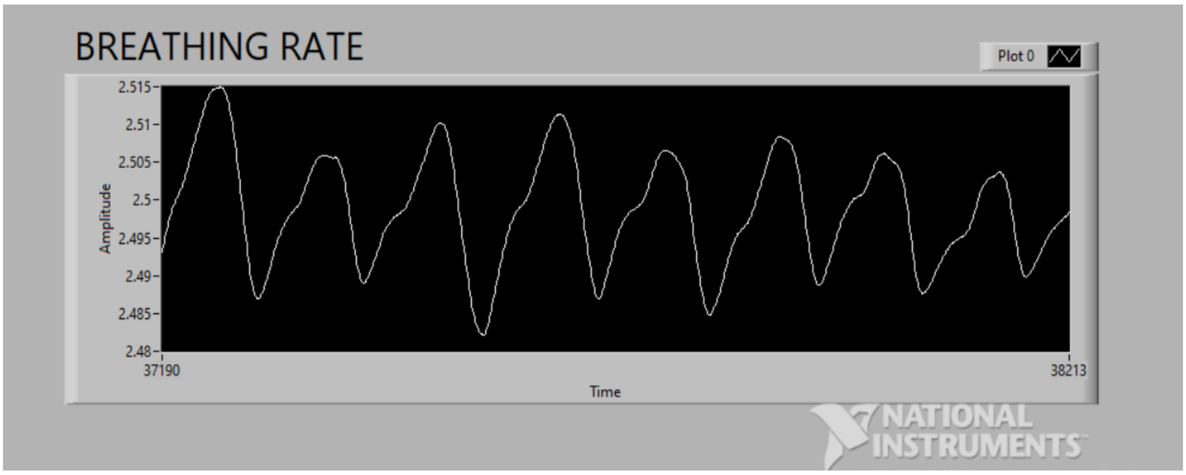


Fig 3.17. Normal Breathing signal

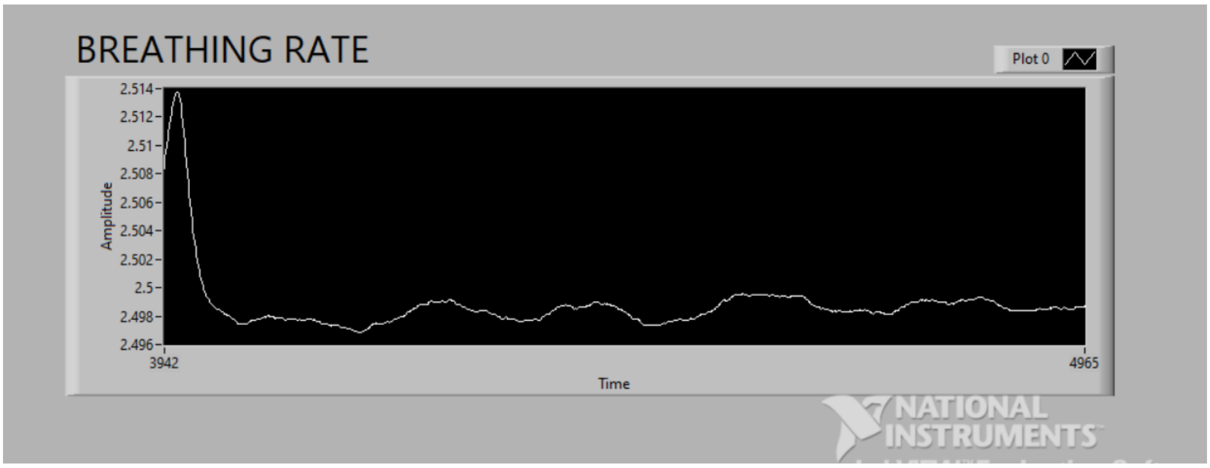


Fig 3.18. Breathing signal when Apnea occurs

3.12 Software for CPAP

- Software part is developed to monitor the patient's breathing rate in order to identify the apnea
- For microcontroller, it is used to execute the operation to turn ON/OFF the blower when the apnea is occurred at a given period of time.
- And the Arduino programming library is used to display the pressure exerted by the blower and the breathing rate of the patient and standby running time of the blower motor in the OLED display.
- We'll be using embedded C programming for the Arduino UNO; a slope formula is used to get a linear output signal from the sensor
- And a threshold value is set in the program, in order to control the blower.

3.13 Flow chart coding description for Auto CPAP device

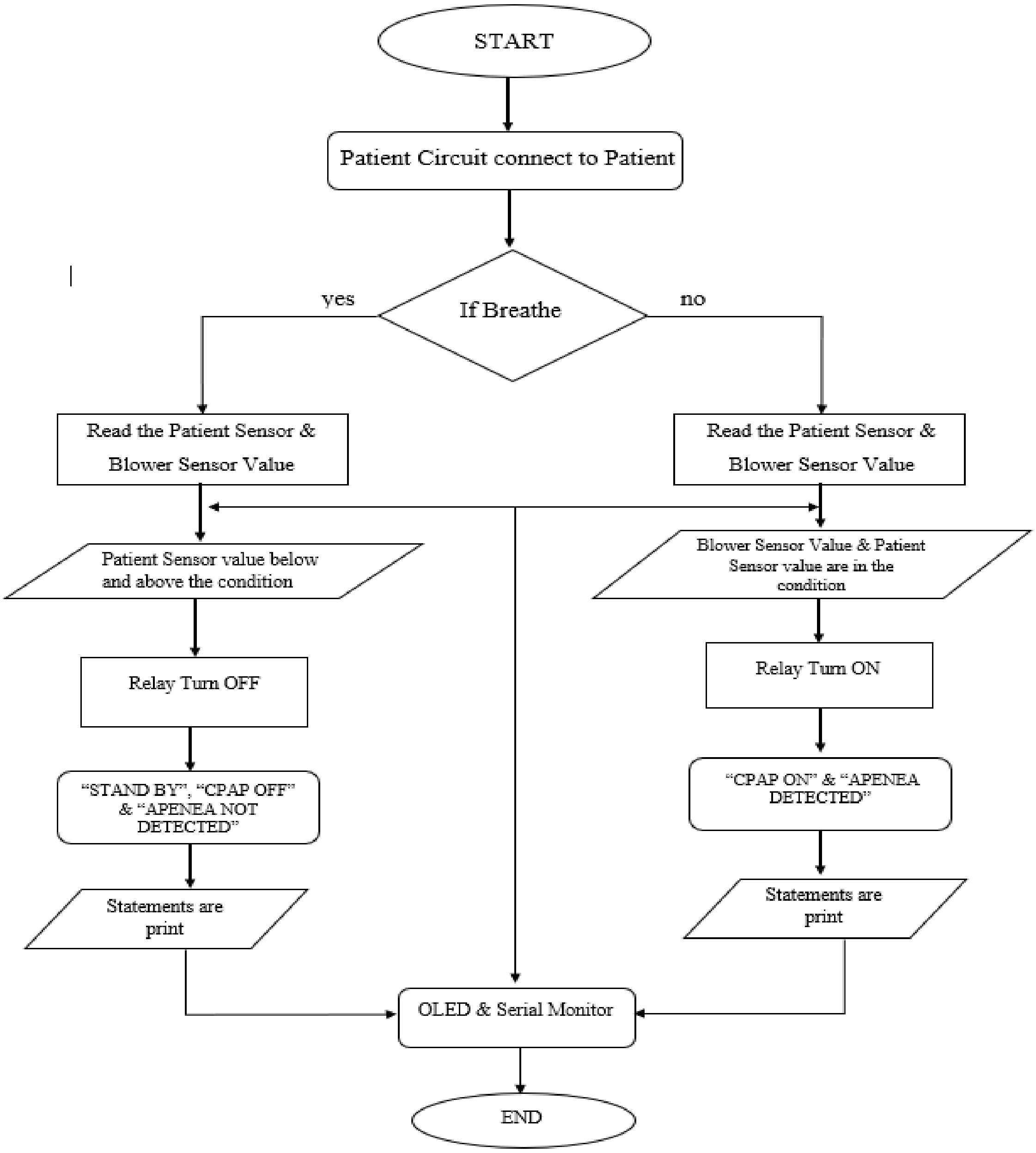


Fig 3.19 Breathing signal when Apnea occurs

Description:

The above flow chart is the representation of the Auto CPAP coding in which the description of whole process is given. It is a closed loop program structure that start with detecting the patients breathing, if there is normal breathing it displays "STANDBY" and if apnea occurs it gives signal to the microcontroller to provide support to the patient and displays "APNEA DETECTED". This information is displayed through an OLED display as well as a serial monitor.

3.14 HARDWARE SETUP

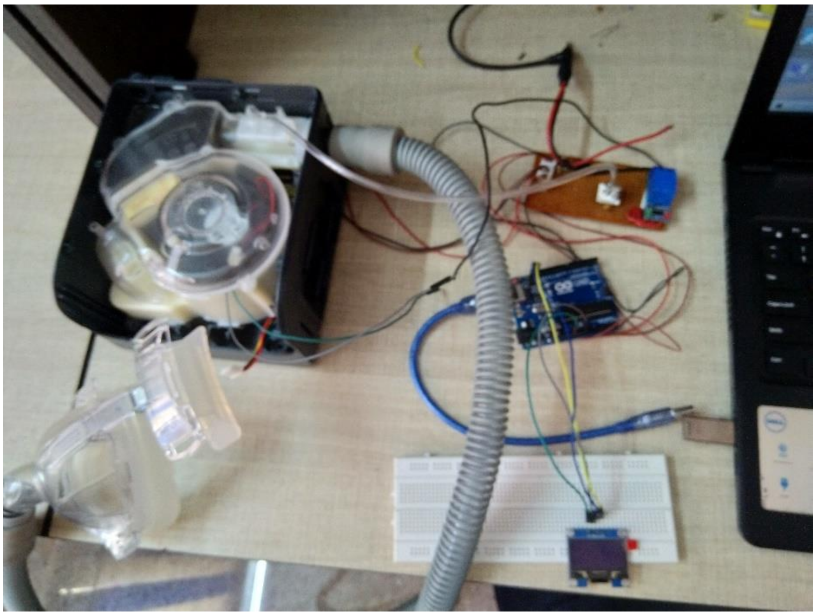


Fig 3.20. Picture of the Hardware Setup

Description:

The above figure 5.4 display the hardware setup which includes the blower circuit consisting of the blower, blower sensor and BLDC board that is connected to the hose pipe which is further connected to the patient mask. There is also the OLED display.

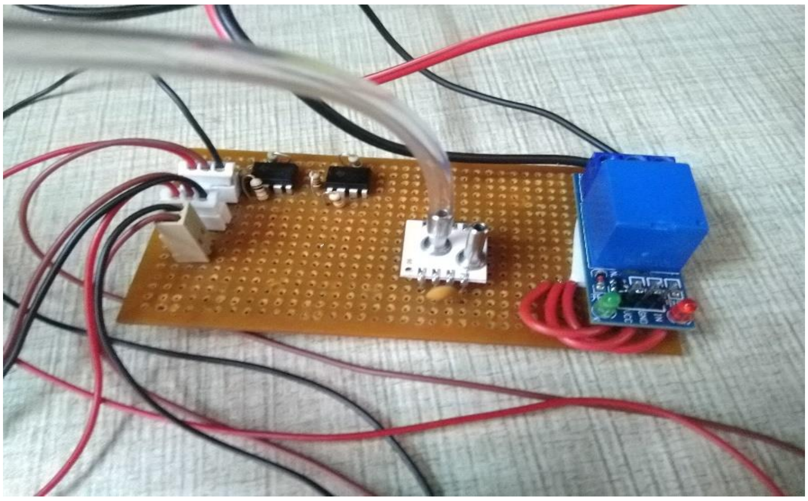


Fig 3.21. Picture of the Sensor and Relay Module

Description:

This figure 5.5 is the hardware connection of the patient sensor and relay module, this circuit responsible for the loop conditions at regular time intervals, also initiating the device to provide breathing support or to remain standby based on the signals received from the microcontroller.

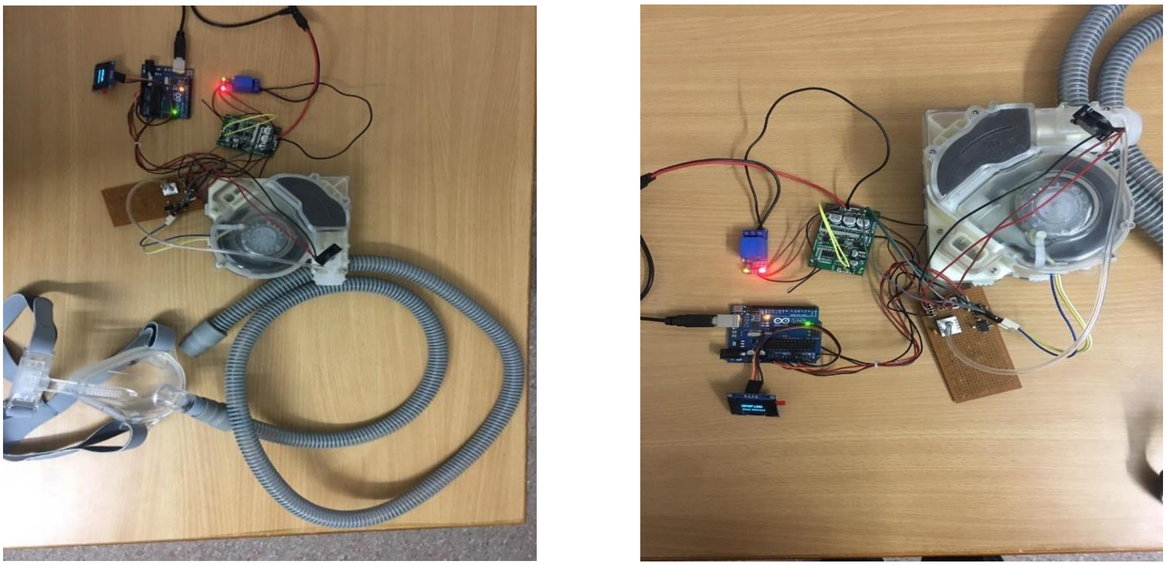


Fig.3.22. Complete setup of Auto CPAP device

Description:

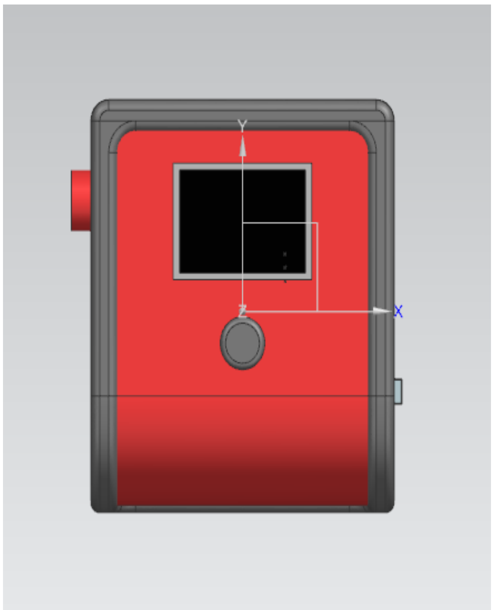
The above figure 5.6 the complete hardware setup of the Auto CPAP device.

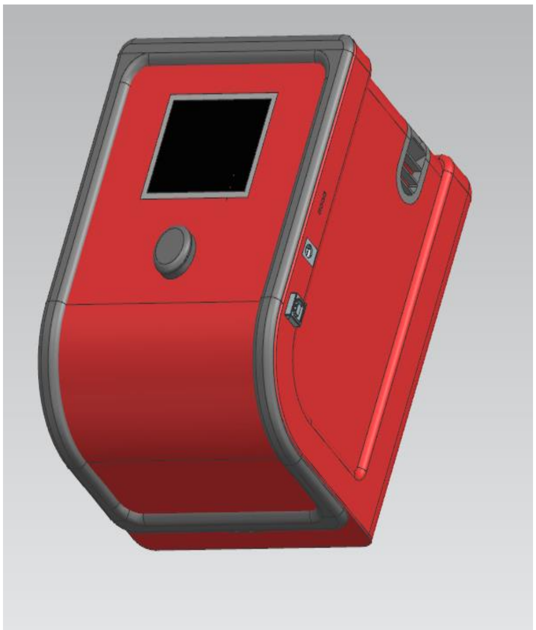
3.14.1 Pin Connections

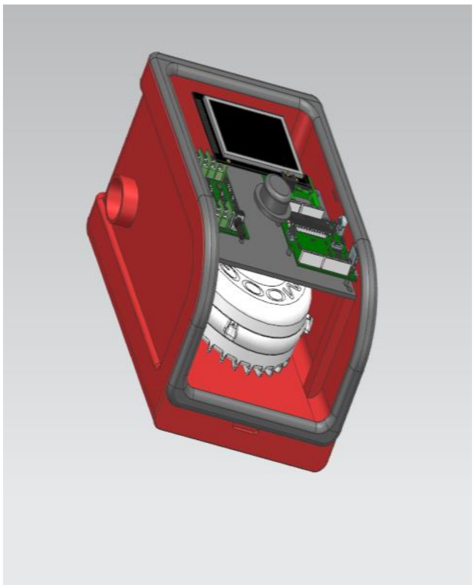
- Power supply is given to the ARDUINO UNO Microcontroller (ATMEGA 128) Through the power cord in the Arduino.
- From the pressure sensor (SPD102DHYAB) the output pin 3 is connected to the input pin of the Arduino A1.
- The VCC and GND connections required for the sensor is connected from the Arduino pins
- And a 100nf capacitor is connected to the pressure sensor (SPD102DHYAB) in between the VCC and GND
- For the relay module, VCC and GND connections are given from the Arduino pins.
- And the input pin of the relay module is connected to the Arduino digital pin 8.

- For the switching control pin1 is connected to the VCC pin of the blower and pin 2 is connected to the VCC of the 12V adaptor.
- And the GND connection of the adaptor is connected to the GND connection of the blower.
- For the OLED display connection, the pins SCL and SDA from the display to communicate to the microcontroller is connected to the SDA and SCL pins of the microcontroller
- And the VCC is connected to the 5V pin of the microcontroller and following GND connection is connected to the microcontroller.

3D view of External body structure of Auto CPAP device







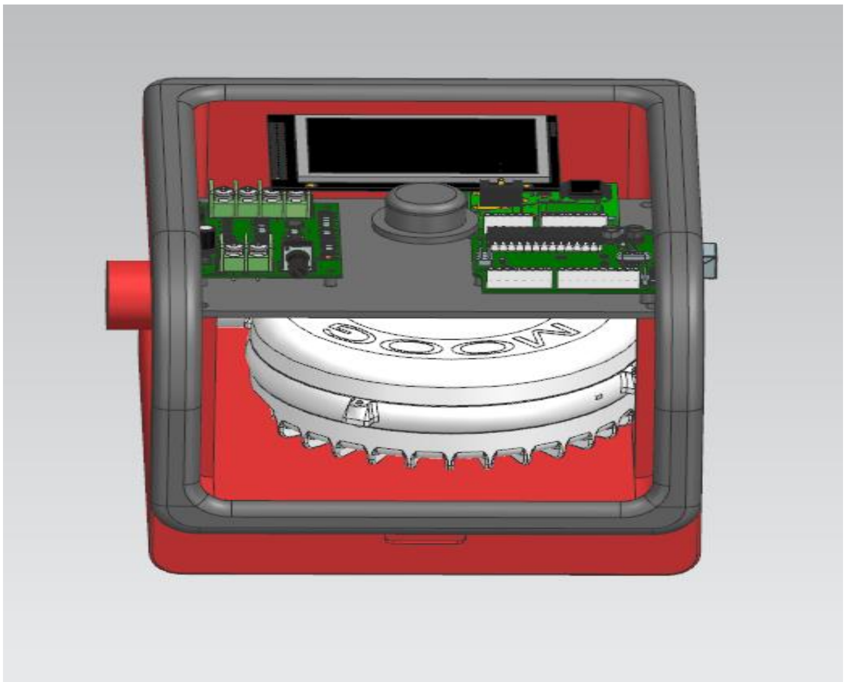


Fig. 3.23 3-D design view of Auto CPAP device

Description:

- This is a 3D model of the auto CPAP device, which developed in the NX software. This the expected outcome design for the device, which includes all the hardware inside it.
- This 3D mainly focused on the structural view of the Auto CPAP device and the internal placement of the components.
- It is a compact and portable design.
- In this 3D view, I have shown the all direction of the device. In this outlet given for connecting the patient circuit externally the slot for air outlet, the knob is helps to adjust the pressure. Furthermore external slot for the electronic USB connections and power supply to the device.

CHAPTER 4

RESULT

The ideology to provide an affordable and much advanced and integrated Auto CPAP machine using non-invasive method that reduces complication as in present models and combining the conventional CPAP technique providing an effective breathing support to the sleep apnea patient has been developed successfully. According to the initial idea an Auto CPAP device which continuously monitor the breathing rate of the patient, and the device gives the positive pressure to the patient only when the apnea occurs, and after a period of time it is turned OFF automatically, reducing the excessive usage of the device, where the energy conservation is done.

Fig.4.1. CPAP OFF apnea not detected condition

Description:

The above figure 6.2 represents the display output of the device when there is no apnea detected and the patient is breathing normally.

"STAND BY"- this indicates the device is in standby mode since the condition is that the patient is normally.

"Time Duration : 5 Sec"- This indicates the time duration for which the device will remain in the same condition until the next loop is run for sensing the patients further condition.

"CPAP OFF"- This indicates that there is no breathing support provided by the CPAP device and the device is temporarily off until the next condition.

"APNEA NOT DETECED"- This indicates that the patient sensor has detected no occurrence of apnea and the patient is breathing normally.

Fig 4.2. Mask away from patient consider apnea detected

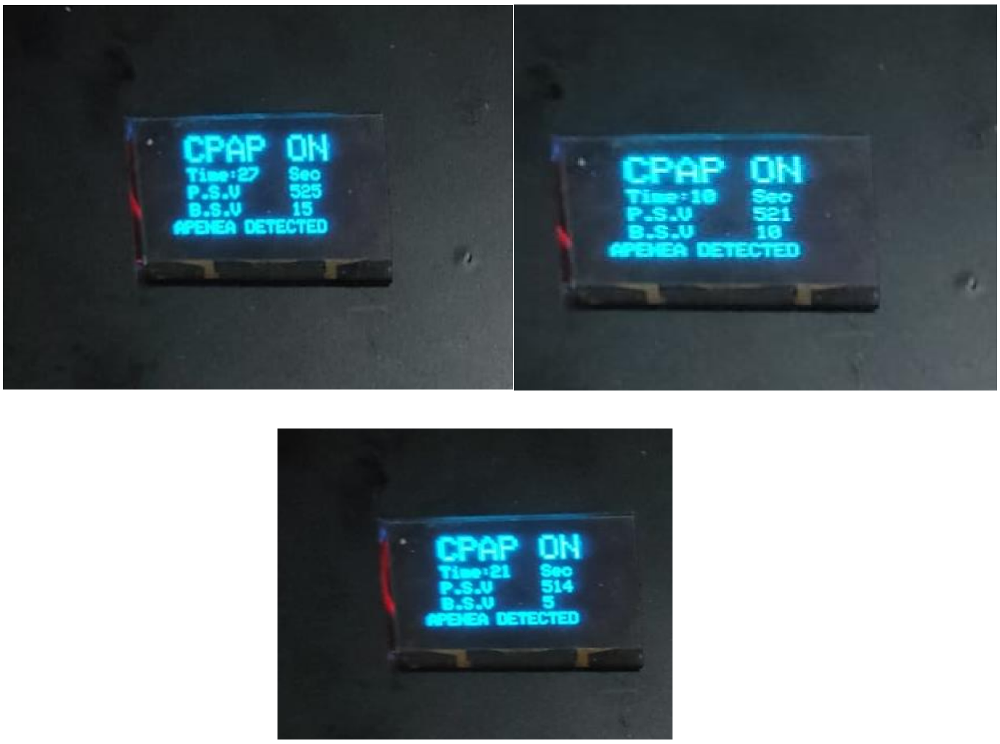


Fig.4.3. CPAP ON apnea detected condition

Description:

The above figure 6.3 represents the display output when there is apnea detected in the patient.

“CPAP ON”- when the patient sensor does not detect normal breathing from the patient it sends signal to the microcontroller, the signal is processed and displayed as “CPAP ON” and also sends the signal to the relay module to start supporting the patients breathing.

“Time:27 Sec”- This is the time duration for which the device will continuously provide breathing support until the next loop runs to again check the patients breathing condition.

“P.S.V 525”- This is the patient sensor value upon which the whole loop condition runs. When the patient is not having normal breathing and there apnea occurring the P.S.V will be around 525, 514, 521 and not more than 530. So when the P.S.V is less then the given condition the device will sense that apnea has occurred and will start to support the patient to breathe.

“B.S.V 15”- This is the blower sensor value obtained from the blower sensor which monitors the airflow given to the patient. The pressure value given to the patient is measured in

CmH$_2$O unit. The standard pressure given to the patient is 5, 10, 15, 20 CmH$_2$O. this value can be changed manually according to the patients need prescribed by the doctor.

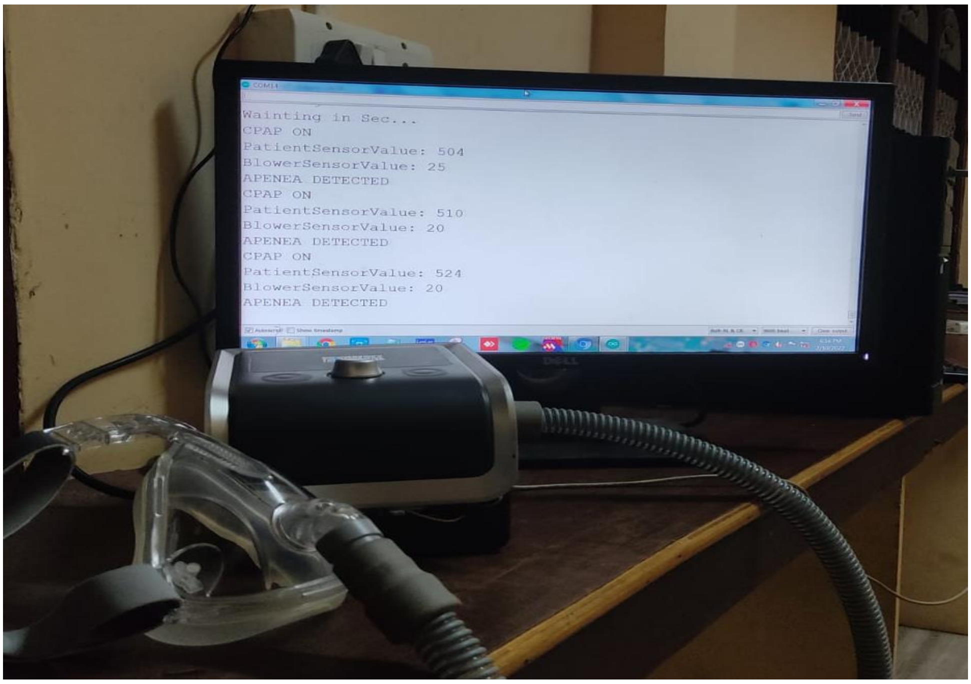


Fig 4.4. Complete set up checking serial monitor

Description:

The figure 6.4 represents the serial monitoring of the result obtained by the patient sensor and the blower sensor. This result can also be viewed in the OLED display and also simultaneously in a serial monitor which can also be stored if wanted for future references.

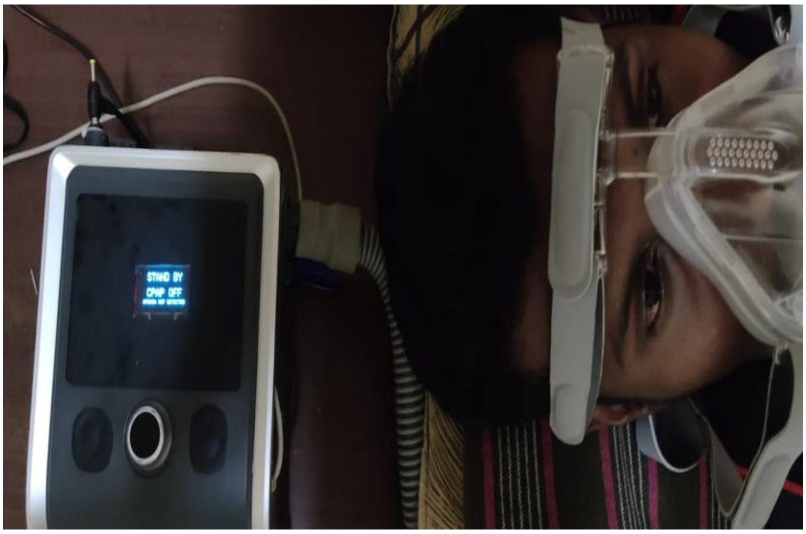


Fig 4.5. Picture of the OLED Display Output

Description:

This figure 6.5 shows how the device is connected to a patient through the patient mask. Since the device is connected to a patient who has a normal breathing the output in the display indicates the first condition as given in figure 4.1.

5. DISCUSSION

Sleep apnea , a serious sleeping disorder in which the patient has breathing in irregular intervals such as random start and stop of inhaling and exhaling. Majority of the people don't consider the seriousness and impact caused by this disorder, but if not treated with proper medical care it may lead to serious illness. The most common type of sleep apnea is OSA (obstructive sleep apnea) where the soft tissues and throat muscles supporting breathing fail to perform their function causing sudden pauses during breathing resulting in sleep obstructions. The patients mental and physical health is affected because of this.

The major treatment provided for OSA is the CPAP (continuous positive airway pressure) device which induces air into the patient by means of a breathing mask, opening the airway for normal breathing in order to avoid obstructions in breathing and sleep. Though the CPAP being the conventional treatment, the continuous airflow under constant pressure into patient caused throat injuries, dryness and due to the constant artificial flow of air there was obstructions in sleep. To provide a more effective treatment compared to the conventional CPAP an integrated device called Auto CPAP was introduced which provides air which a pressure control where the pressure given varies according to the need of the patient, also varies with respect to the body weight breathing rate of the patient. This turned out to be a customized device for each patient and an effective replacement for the conventional treatment. Still the treatment provided by the Auto CPAP was causing throat injuries and dryness due to the constant flow of air. To overcome this a humidifier was used which humidifies the air given to the patient avoiding throat dryness and making it comfortable to breathe. But the use of humidifier increased the power consumption reducing the life span of the device and there was also an increase in the cost of the device making it unavailable and unaffordable to all people.

The significance of this research project is providing an efficient model compared to the conventional CPAP and Auto CPAP. The idea of this new automated CPAP for OSA patient is to make a CPAP device with a blower sensor and a relay module. The blower sensor helps is sensing the breathing of the patient and the relay module to run a loop for the given condition. The uniqueness of this device is that when the mask is connected to the patient the device senses whether the patient is breathing normally without any apnea, if so then the device will remain in standby and does not induce air or support breathing. If not, the device senses there is a pause in breathing and apnea has occurred the device starts to induce air to the patient supporting to breathe. These two conditions are looped and repeatedly checked at regular time intervals by the relay module providing an advanced Auto CPAP device which only gives breathing support when apnea occurs and remains at standby rest of the time. This method does not require the use of hardware like humidifier thus reducing the cost of the device and making it affordable to all people, by providing support only during apnea removes the risk of throat dryness and injuries because there is no constant airflow, by remaining in standby during normal breathing the power consumption is very less compared to the other models thus increasing the life span of the device.

To implement this idea into a working device, at the initial stage an Arduino program was made with an if else condition. The condition was to determine whether the patient is breathing normally or not. If yes, then the device should remain in standby. Else the device should induce air into the patient and provide breathing support. These are the two main conditions of the program followed by the display instructions as of how to give display for both the conditions. After framing the program and compiling it without any errors the program was uploaded in the Arduino uno microcontroller and the circuit setup began by connecting the sensors, relay module, blower, filter, hose pipe, patient mask, power supply, led display, connection boards and wires.

The LabVIEW platform was used to test run the designed circuit and find the proper schematic setup. LabVIEW stands for laboratory virtual instrumentation engineering workbench. It is a system's engineering software for applications that demand rapid access to hardware and data insights for test, measurement, and control. It is a graphical programming environment which is used by engineers to develop research based on automated system devices and production test systems. It is being used by many researchers to perform sophisticated test, measurements and control applications. In completion with the circuit and schematic setup multiple stimulations were done obtaining different outputs and the correct circuit setup with a schematic workflow was determined and a successful stimulation was done resulting in the expected output. The hardware was designed in a 3D model and prepared with the circuit and schematic flow obtained from the stimulations. Once the hardware setup was completed the device was tested on a single patient as a result of this trail the desired output was obtained.

Thus a new and advanced Auto CPAP device is made with the implantation of the initial idea along with getting the desired output has been proved to be a significant replacement for the conventional CPAP and Auto CPAP.

CHAPTER 6

CONCLUSION

The research project of "Automated CPAP for Obstructive Sleep Apnea", started with the idea of completely overcoming the difficulties and disadvantages such as,

- Throat injuries and dryness caused by constant flow of air all night in conventional CPAP causing disruptions in sleep.
- Even though being effective than conventional CPAP problems like, not enough pressure to open clear pathway for breathing due to variations in pressure in Auto CPAP and providing air in varying pressure still cause throat dryness as there is constant flow al night.
- Use of humidifiers in order to overcome the throat dryness and injuries by providing moisturized air to the patient increase the cost of the device making it unavailable and not affordable to all people.
- Using a humidifier also increases the power consumption reducing the life span of the device.

These are the major common problems in current market models. As intended by the implementation of a unique idea to design a Automated CPAP device which can sense the breathing of the patient to remain in standby and provide support by sensing apnea occurrence and repeatedly running these process at regular time intervals is obtained as shown in the result above. After several stimulations and patient trails a desired Automated CPAP device is created successfully.

FUTURE SCOPE

During the early stages, when sleep apnea disorder was found to be serious sleeping disorder a CPAP device was introduced by Dr. Colin Sullivan in June 1980. The first version of CPAP machine in which Sullivan carried out his experiments was a vacuum cleaner set which sent out air. Later when was approached by a patient he refined his research and the first CPAP used on patient was merely a paint compressor whose air flow was being reversed, tubing was attached to the compressor which was connected to a mask. The sound from this compressor during air flow was way too loud. This CPAP machine is far from the modern device in present.

Then evolved the conventional CPAP which is used as a base model for our modern devices. Initially this conventional CPAP performed the basic function of sending air into the patient and create a clear pathway for breathing. Later there were some upgrades with software and display, adjustable mask in various sizes according to the patient comfort. This model suffered from a serious disadvantage of giving constant flow of air all night with same pressure causing throat injuries and dryness which made it difficult to use regularly.

In order to overcome this issue an Auto CPAP device was introduced which had a pressure titration process added by which the pressure of air flow varies in accordance with the patient breathing. But at sometimes the pressure was not able to adjust enough to create a free air pathway to breathe. Later an upgrade was provided in which a humidifier was used to moisturize the air given to the patient to prevent throat injuries ad dryness. The use of humidifier increased the cost of device and the life of the device was also reduced.

To overcome this issue our research to make an upgraded version Auto CPAP device is introduced in which the device can sense the breathing of the patient to remain in standby and provide support by sensing apnea occurrence and repeatedly running these processes at regular time intervals. Once this design is in the market it will be the most cost efficient, ease of use and reliable model for sleep apnea treatment. As we can see the evolution of this device over the course of time has been very significant and with our current technological advancement even more integrated and advanced models can also be used in the future. Some of the predictable upgrades that can be introduced are,

- The current models have manual pressure setting this can be upgraded by automatic pressure setting feature by sensing the breathing of the patient.

- The pressure giving to the patient are given based on the physical characteristics like body mass and breathing rate, this can be upgraded by giving pressure from low to high increasing at regular time interval which makes the patient mentally induce the sense of breathing and try to breathe without support and by few seconds the pressure will increase and the device will start to support breathing. This continuous induce of natural breathing feel will help in fast curing.

- Currently the data of the patient can only be viewed for that moment in the display of the device, with the use of a Wi-Fi module the data collected from the device will be able to get stored in a cloud by using IOT. This will be a verry useful advancement as it makes it possible to view the patient data for a course of time and get analysis on the condition, severeness and recovery of the patient.

- An integrated device with both the mechanism of a CPAP and BiPAP device can be a future advancement in treating sleep apnea in order to get a fast recovery.

And several more advancements and upgrades which we might never know are yet to come in this digital century.

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8. Appendix

#include "U8glib.h"

// setup u8g object, please remove comment from one of the following constructor calls

// IMPORTANT NOTE: The following list is incomplete. The complete list of supported

// devices with all constructor calls is here: http://code.google.com/p/u8glib/wiki/device

//U8GLIB_NHD27OLED_BW u8g(13, 11, 10, 9); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_NHD27OLED_2X_BW u8g(13, 11, 10, 9); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_NHD27OLED_GR u8g(13, 11, 10, 9); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_NHD27OLED_2X_GR u8g(13, 11, 10, 9); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_NHD31OLED_BW u8g(13, 11, 10, 9); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_NHD31OLED_2X_BW u8g(13, 11, 10, 9); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_NHD31OLED_GR u8g(13, 11, 10, 9); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_NHD31OLED_2X_GR u8g(13, 11, 10, 9); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_DOGS102 u8g(13, 11, 10, 9, 8); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_DOGM132 u8g(13, 11, 10, 9); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_DOGM128 u8g(13, 11, 10, 9);   // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_DOGM128_2X u8g(13, 11, 10, 9);   // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_ST7920_128X64_1X u8g(8, 9, 10, 11, 4, 5, 6, 7, 18, 17, 16);   // 8Bit Com: D0..D7: 8,9,10,11,4,5,6,7 en=18, di=17,rw=16

//U8GLIB_ST7920_128X64_4X u8g(8, 9, 10, 11, 4, 5, 6, 7, 18, 17, 16);   // 8Bit Com: D0..D7: 8,9,10,11,4,5,6,7 en=18, di=17,rw=16

//U8GLIB_ST7920_128X64_1X u8g(18, 16, 17); // SPI Com: SCK = en = 18, MOSI = rw = 16, CS = di = 17

//U8GLIB_ST7920_128X64_4X u8g(18, 16, 17); // SPI Com: SCK = en = 18, MOSI = rw = 16, CS = di = 17

//U8GLIB_ST7920_192X32_1X u8g(8, 9, 10, 11, 4, 5, 6, 7, 18, 17, 16);   // 8Bit Com: D0..D7: 8,9,10,11,4,5,6,7 en=18, di=17,rw=16

//U8GLIB_ST7920_192X32_4X u8g(8, 9, 10, 11, 4, 5, 6, 7, 18, 17, 16);   // 8Bit Com: D0..D7: 8,9,10,11,4,5,6,7 en=18, di=17,rw=16

//U8GLIB_ST7920_192X32_1X u8g(18, 16, 17); // SPI Com: SCK = en = 18, MOSI = rw = 16, CS = di = 17

//U8GLIB_ST7920_192X32_4X u8g(18, 16, 17); // SPI Com: SCK = en = 18, MOSI = rw = 16, CS = di = 17

//U8GLIB_ST7920_192X32_1X u8g(13, 11, 10); // SPI Com: SCK = en = 13, MOSI = rw = 11, CS = di = 10

//U8GLIB_ST7920_192X32_4X u8g(10);   // SPI Com: SCK = en = 13, MOSI = rw = 11, CS = di = 10, HW SPI

//U8GLIB_ST7920_202X32_1X u8g(8, 9, 10, 11, 4, 5, 6, 7, 18, 17, 16);   // 8Bit Com: D0..D7: 8,9,10,11,4,5,6,7 en=18, di=17,rw=16

//U8GLIB_ST7920_202X32_4X u8g(8, 9, 10, 11, 4, 5, 6, 7, 18, 17, 16);   // 8Bit Com: D0..D7: 8,9,10,11,4,5,6,7 en=18, di=17,rw=16

//U8GLIB_ST7920_202X32_1X u8g(18, 16, 17); // SPI Com: SCK = en = 18, MOSI = rw = 16, CS = di = 17

//U8GLIB_ST7920_202X32_4X u8g(18, 16, 17); // SPI Com: SCK = en = 18, MOSI = rw = 16, CS = di = 17

//U8GLIB_LM6059 u8g(13, 11, 10, 9); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_LM6063 u8g(13, 11, 10, 9); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_DOGXL160_BW u8g(10, 9); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_DOGXL160_GR u8g(13, 11, 10, 9); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_DOGXL160_2X_BW u8g(13, 11, 10, 9); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_DOGXL160_2X_GR u8g(13, 11, 10, 9); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_PCD8544 u8g(13, 11, 10, 9, 8); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9, Reset = 8

//U8GLIB_PCF8812 u8g(13, 11, 10, 9, 8); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9, Reset = 8

//U8GLIB_KS0108_128 u8g(8, 9, 10, 11, 4, 5, 6, 7, 18, 14, 15, 17, 16); // 8Bit Com: D0..D7: 8,9,10,11,4,5,6,7 en=18, cs1=14, cs2=15,di=17,rw=16

//U8GLIB_LC7981_160X80 u8g(8, 9, 10, 11, 4, 5, 6, 7, 18, 14, 15, 17, 16); // 8Bit Com: D0..D7: 8,9,10,11,4,5,6,7 en=18, cs=14 ,di=15,rw=17, reset = 16

//U8GLIB_LC7981_240X64 u8g(8, 9, 10, 11, 4, 5, 6, 7, 18, 14, 15, 17, 16); // 8Bit Com: D0..D7: 8,9,10,11,4,5,6,7 en=18, cs=14 ,di=15,rw=17, reset = 16

//U8GLIB_LC7981_240X128 u8g(8, 9, 10, 11, 4, 5, 6, 7, 18, 14, 15, 17, 16); // 8Bit Com: D0..D7: 8,9,10,11,4,5,6,7 en=18, cs=14 ,di=15,rw=17, reset = 16

//U8GLIB_ILI9325D_320x240 u8g(18,17,19,U8G_PIN_NONE,16); // 8Bit Com: D0..D7: 0,1,2,3,4,5,6,7 en=wr=18, cs=17, rs=19, rd=U8G_PIN_NONE, reset = 16

//U8GLIB_SBN1661_122X32 u8g(8,9,10,11,4,5,6,7,14,15, 17, U8G_PIN_NONE, 16); // 8Bit Com: D0..D7: 8,9,10,11,4,5,6,7 cs1=14, cs2=15,di=17,rw=16,reset = 16

//U8GLIB_SSD1306_128X64 u8g(13, 11, 10, 9); // SW SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_SSD1306_128X64 u8g(4, 5, 6, 7); // SW SPI Com: SCK = 4, MOSI = 5, CS = 6, A0 = 7 (new white HalTec OLED)

//U8GLIB_SSD1306_128X64 u8g(10, 9); // HW SPI Com: CS = 10, A0 = 9 (Hardware Pins are SCK = 13 and MOSI = 11)

//U8GLIB_SSD1306_128X64 u8g(U8G_I2C_OPT_NONE|U8G_I2C_OPT_DEV_0); // I2C / TWI

//U8GLIB_SSD1306_128X64 u8g(U8G_I2C_OPT_DEV_0|U8G_I2C_OPT_NO_ACK|U8G_I2C_OPT_FAST); // Fast I2C / TWI

//U8GLIB_SSD1306_128X64 u8g(U8G_I2C_OPT_NO_ACK); // Display which does not send AC

//U8GLIB_SSD1306_ADAFRUIT_128X64 u8g(13, 11, 10, 9); // SW SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_SSD1306_ADAFRUIT_128X64 u8g(10, 9); // HW SPI Com: CS = 10, A0 = 9 (Hardware Pins are SCK = 13 and MOSI = 11)

//U8GLIB_SSD1306_128X32 u8g(13, 11, 10, 9); // SW SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_SSD1306_128X32 u8g(10, 9); // HW SPI Com: CS = 10, A0 = 9 (Hardware Pins are SCK = 13 and MOSI = 11)

//U8GLIB_SSD1306_128X32 u8g(U8G_I2C_OPT_NONE); // I2C / TWI

//U8GLIB_SH1106_128X64 u8g(13, 11, 10, 9); // SW SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_SH1106_128X64 u8g(4, 5, 6, 7); // SW SPI Com: SCK = 4, MOSI = 5, CS = 6, A0 = 7 (new blue HalTec OLED)

U8GLIB_SH1106_128X64 u8g(U8G_I2C_OPT_NONE); // I2C / TWI

//U8GLIB_SH1106_128X64 u8g(U8G_I2C_OPT_DEV_0|U8G_I2C_OPT_FAST); // Dev 0, Fast I2C / TWI

//U8GLIB_SH1106_128X64 u8g(U8G_I2C_OPT_NO_ACK); // Display which does not send ACK

//U8GLIB_SSD1309_128X64 u8g(13, 11, 10, 9); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_SSD1327_96X96_GR u8g(U8G_I2C_OPT_NONE); // I2C

//U8GLIB_SSD1327_96X96_2X_GR u8g(U8G_I2C_OPT_NONE); // I2C

//U8GLIB_UC1611_DOGM240 u8g(U8G_I2C_OPT_NONE); // I2C

//U8GLIB_UC1611_DOGM240 u8g(13, 11, 10, 9); // SW SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_UC1611_DOGM240 u8g(10, 9);   // HW SPI Com: CS = 10, A0 = 9 (Hardware Pins are SCK = 13 and MOSI = 11)

//U8GLIB_UC1611_DOGXL240 u8g(U8G_I2C_OPT_NONE); // I2C

//U8GLIB_UC1611_DOGXL240 u8g(13, 11, 10, 9); // SW SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9

//U8GLIB_UC1611_DOGXL240 u8g(10, 9);   // HW SPI Com: CS = 10, A0 = 9 (Hardware Pins are SCK = 13 and MOSI = 11)

//U8GLIB_NHD_C12864 u8g(13, 11, 10, 9, 8); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9, RST = 8

//U8GLIB_NHD_C12832 u8g(13, 11, 10, 9, 8); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9, RST = 8

//U8GLIB_LD7032_60x32 u8g(13, 11, 10, 9, 8); // SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9, RST = 8

//U8GLIB_LD7032_60x32 u8g(11, 12, 9, 10, 8); // SPI Com: SCK = 11, MOSI = 12, CS = 9, A0 = 10, RST = 8 (SW SPI Nano Board)

//U8GLIB_UC1608_240X64 u8g(13, 11, 10, 9, 8); // SW SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9, RST = 8

//U8GLIB_UC1608_240X64_2X u8g(13, 11, 10, 9, 8); // SW SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9, RST = 8

//U8GLIB_UC1608_240X64 u8g(10, 9, 8); // HW SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9, RST = 8

//U8GLIB_UC1608_240X64_2X u8g(10, 9, 8); // HW SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9, RST = 8

//U8GLIB_UC1608_240X u8g(13, 11, 10, 9, 8); // SW SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9, RST = 8

//U8GLIB_UC1608_240X64_2X u8g(13, 11, 10, 9, 8); // SW SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9, RST = 8

//U8GLIB_UC1608_240X64 u8g(10, 9, 8); // HW SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9, RST = 8

//U8GLIB_UC1608_240X64_2X u8g(10, 9, 8); // HW SPI Com: SCK = 13, MOSI = 11, CS = 10, A0 = 9, RST = 8

//U8GLIB_T6963_240X128 u8g(8, 9, 10, 11, 4, 5, 6, 7, 14, 15, 17, 18, 16); // 8Bit Com: D0..D7: 8,9,10,11,4,5,6,7, cs=14, a0=15, wr=17, rd=18, reset=16

//U8GLIB_T6963_128X128 u8g(8, 9, 10, 11, 4, 5, 6, 7, 14, 15, 17, 18, 16); // 8Bit Com: D0..D7: 8,9,10,11,4,5,6,7, cs=14, a0=15, wr=17, rd=18, reset=16

//U8GLIB_T6963_240X64 u8g(8, 9, 10, 11, 4, 5, 6, 7, 14, 15, 17, 18, 16); // 8Bit Com: D0..D7: 8,9,10,11,4,5,6,7, cs=14, a0=15, wr=17, rd=18, reset=16

//U8GLIB_T6963_128X64 u8g(8, 9, 10, 11, 4, 5, 6, 7, 14, 15, 17, 18, 16); // 8Bit Com: D0..D7: 8,9,10,11,4,5,6,7, cs=14, a0=15, wr=17, rd=18, reset=16

//U8GLIB_HT1632_24X16 u8g(3, 2, 4); // WR = 3, DATA = 2, CS = 4

```
//U8GLIB_SSD1351_128X128_332 u8g(13, 11, 8, 9, 7); // Arduino UNO: SW SPI Com: SCK = 13, MOSI = 11, CS = 8, A0 = 9, RESET = 7 (http://electronics.ilsoft.co.uk/ArduinoShield.aspx)

//U8GLIB_SSD1351_128X128_332 u8g(76, 75, 8, 9, 7); // Arduino DUE: SW SPI Com: SCK = 13, MOSI = 11, CS = 8, A0 = 9, RESET = 7 (http://electronics.ilsoft.co.uk/ArduinoShield.aspx)

//U8GLIB_SSD1351_128X128_332 u8g(8, 9, 7); // Arduino: HW SPI Com: SCK = 13, MOSI = 11, CS = 8, A0 = 9, RESET = 7 (http://electronics.ilsoft.co.uk/ArduinoShield.aspx)

//U8GLIB_SSD1351_128X128_HICOLOR u8g(76, 75, 8, 9, 7); // Arduino DUE, SW SPI Com: SCK = 76, MOSI = 75, CS = 8, A0 = 9, RESET = 7 (http://electronics.ilsoft.co.uk/ArduinoShield.aspx)

//U8GLIB_SSD1351_128X128_HICOLOR u8g(8, 9, 7); // Arduino, HW SPI Com: SCK = 76, MOSI = 75, CS = 8, A0 = 9, RESET = 7 (http://electronics.ilsoft.co.uk/ArduinoShield.aspx)

//U8GLIB_SSD1351_128X128GH_332 u8g(8, 9, 7); // Arduino, HW SPI Com: SCK = 76, MOSI = 75, CS = 8, A0 = 9, RESET = 7 (Freetronics OLED)

//U8GLIB_SSD1351_128X128GH_HICOLOR u8g(8, 9, 7); // Arduino, HW SPI Com: SCK = 76, MOSI = 75, CS = 8, A0 = 9, RESET = 7 (Freetronics OLED)


#include <Wire.h>

#include <Adafruit_SH1106.h>

#define OLED_RESET 4

Adafruit_SH1106 display(OLED_RESET);

int PSV,BSV;

void setup()

{

  Serial.begin(9600);
```

```
  pinMode(A1, INPUT);
  pinMode(A3, INPUT);
  pinMode(7, OUTPUT);
  display.begin(SH1106_SWITCHCAPVCC, 0x3C);
  display.display(); delay(500);
}
void notbreathe()
{
  intro();
  for (int i = 30; i >= 0; i--)
  {
    int PSV = analogRead(A1);
  int BSV = analogRead(A3);
   BSV =  5 * (BSV/ 200);
    digitalWrite(7, LOW);
    display.setTextSize(2);
    display.setTextColor(WHITE);
    display.setCursor(20, 2 ); display.println("CPAP ON");
    display.setTextSize(1);
    display.setCursor(0, 20); display.print("Time:");
    display.setCursor(50, 20); display.print(i);
    display.setCursor(80, 20); display.print("Sec");
    display.setTextSize(1.5);
    Serial.print("P.S.V");
    display.setCursor(20, 30); display.println("P.S.V"); Serial.print(PSV);
```

```
    display.setCursor(80, 30); display.println(PSV); Serial.print("B.S.V");
    display.setCursor(20, 40); display.println("B.S.V");  Serial.println(BSV);
    display.setCursor(80, 40); display.println(BSV);
    display.setTextSize(1.0);
    display.setCursor(10, 50);
    display.println("APENEA DETECTED");
    display.display(); delay(1000);
    display.clearDisplay();
  }
  }
void breathe()
{
  digitalWrite(7, HIGH);
    display.setTextSize(2);
    display.setTextColor(WHITE);
    display.setCursor(20, 2 ); display.println("STAND BY");
    display.setTextSize(2);
    display.setCursor(20, 30);
    display.println("CPAP OFF");
    display.setTextSize(1.5);
    display.setCursor(10, 50);
    display.println("APENEA NOT DETECTED");
    display.display(); delay(1000);
    display.clearDisplay();
  }
```

```
void intro()
{
  for (int i = 5; i >= 0; i--)
  {
    digitalWrite(7, HIGH);
    display.setTextSize(2);
    display.setTextColor(WHITE);
    display.setCursor(20, 2 ); display.println("STAND BY");
    display.setTextSize(1);
    display.setCursor(20, 20); display.print("Time:");
    display.setCursor(90, 20); display.print(i);
    display.setCursor(100, 20); display.print("Sec");
    display.setTextSize(2);
    display.setCursor(20, 30);
    display.println("CPAP OFF");
    display.setTextSize(1.0);
    display.setCursor(10, 50);
    display.println("APENEA NOT DETECTED");
    display.display(); delay(1000);
    display.clearDisplay();
  }
}
void loop()
{
  int PSV = analogRead(A1);
```

```
  int BSV = analogRead(A3);

  BSV =  5 * (BSV/ 200);

  Serial.println("PSV:");Serial.println(PSV);

   Serial.println("BSV:");Serial.println(BSV);delay(1000);

 if(PSV<560 &&PSV>530 ||PSV==512
||PSV==513||PSV==514||PSV==515||PSV==516||PSV==517||PSV==518||PSV==508||PSV==
509||PSV==510||PSV==512)

 {

  notbreathe();

  }

  else

  {

    breathe();

    }

}
```