Ventilators with Capnograph Smart Sensors

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Abstract

Today, the world is encountering increasing development in various fields, including industry and medicine. One of the best ways to achieve these objectives is the integration of different sciences including electronics, robotics and medicine. The ventilator set that provides respiratory function for patients gets smarter and more capable than older generations, during mechanical ventilation to prevent problems that may arise for patients and threaten the patient's life. In this article we have tried to use various sensors to create a kind of intelligent ventilator and increase the safety and efficiency of this device. In other words, by integration of medical devices we have enhanced its reliability. By using capnograph sensors and connecting it to the patient's breathing circuit, it is possible that an increase in patient exhaled carbon dioxide with the proper functioning and increased respiratory rate of the patient automatically and smart, the amount of gas in the exhaled air returns to normal. The use of pulse oximetry sensors can help us to measure oxygen saturation of arterial blood and in case of increasing the normal value, by reducing the percentage of oxygen input. Then, its value is adjusted and this prevents the occurrence of oxygen poisoning.

Keywords: Mechanical ventilation, the artificial ventilator, breathing, capnograph sensor

1-Introduction

In medicine sending air into the lungs with O2 and sending out the air with CO2 is called conditioning. This act in normal circumstances is done using the process of respiration, but when the respiratory system is unable to perform the conditioning action for any reason, using the ventilator for artificial lung ventilation is deemed essential. [3]. Ventilator or artificial respiration is a device which is used when patients suffer from respiratory problems temporarily or permanently. [1]

In a healthy person, the replacement of oxygen and carbon dioxide is carried out in lungs. Oxygen taken into the lungs is transported into the blood and co2 returns to the lungs through the circulating system and it is dispossessed.

Ventilator imitates the human respiratory system, enters the air into the patient's lungs and pauses, and then exhalation is done automatically. But it is possible that in certain cases the amount of co2 increases in expiration indicating that there might be a lack in breathing system. In this article we have tried to prevent it by the sensors that detect the problem and improve the patient's condition with a good performance and secure the secondary risks.

2- How Ventilator Works

A ventilator mixes oxygen and air up to the amount needed for the patient and delivers it to the patient by special tubes that are called. In order to insert air into the lungs, a ventilator increases the pressure in respiratory circuit and by reducing the pressure it returns the air to the lungs and then passes out of the body.

2.1- Configuration and the Components of the Ventilator

Ventilation system consists of two major parts, mechanical part and electronic part. In ventilators we can use electrical power or pneumatic power.

Pneumatic system delivers gas mixture which is considered by group therapy to the patient (psi). Room air with 100% oxygen at the mentioned pressure is given to the ventilator and it reduces the pressure and mixes it with associated gases to reach a predetermined percentage for purity. This part of the process is done by mechanical part including compressor and unidirectional valves and filters.

The electronic part of a ventilator is the meditating mind of the respiration system. This section consists of numerous electronic parts and microprocessors which control all the parameters, respiratory modes and alarms during the breathing.

In the following picture the whole overview of a controlled ventilator microprocessor is shown:

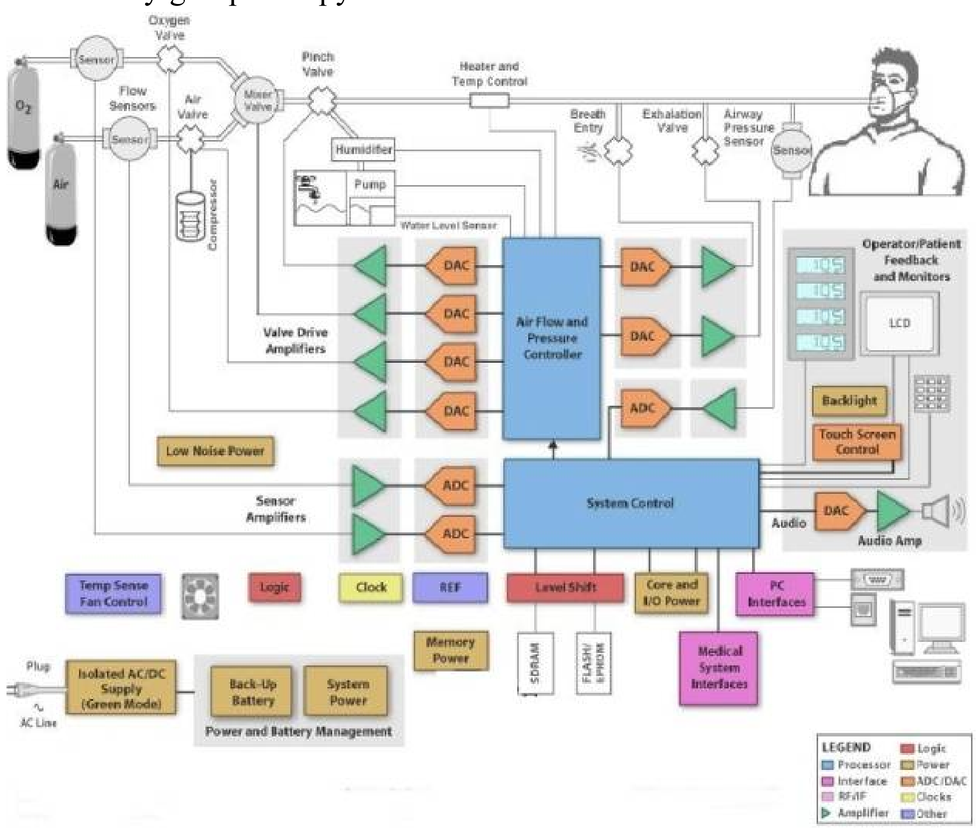

Fig.1. Configuration and components of the ventilator

2.2- How the Different Components of a Ventilator Work

Gases that are needed (air and oxygen) in order to enter the system pass from a unidirectional valve to prevent the return of the gases. In this part of gas supply there is an anti-bacterial filter to prevent the entry of bacteria and an oxygen sensor to measure and displaythe purity and percentage of oxygen.

Inside the sensor there is a material which does chemical reaction with the gas and as a result it creates electric current which is proportional to the oxygen density . Entering of air and oxygen into the device is based on the amount of FIO2 that has been set by the user. These gases are combined in the system. Output of combined air and oxygen is controlled by a galvanic sensor and if there is a difference between the preset FIO2 and exhaled air, an alarm sounds. The compressor inside the device directs air to the patient and how it works is determined by setting the flow by the user [4].

Compressor is the main part of the driving mechanism in a ventilator. Driving mechanism is a part of internal hardware of the device that uses electrical and pneumatic power and causes air to flow to the patient. After gas exchange in the lungs of the patient, expiration air enters the patient's respiratory circuit and is driven out. When we start the ventilator, the process of breathing control is done by feedback circuits. In this way the patient's situation is received by special sensors and sent to the electronic part of the device. And there, the received signals are analyzed and compared with reference parameters set by the user or the manufacturer, according to required standards and then the act of breathing is done according to the result and the program.

3-The Main Structure and Different Parts of the Intelligent Ventilator

The device is made up of two electronic and mechanical parts and programming is driven by microcontroller.

3.1- Electronic components of the ventilator

The board of this device is designed and simulated by proteus software and then it has been used by porotel DXP software. Various electronic parts are connected to create the main board of the device.

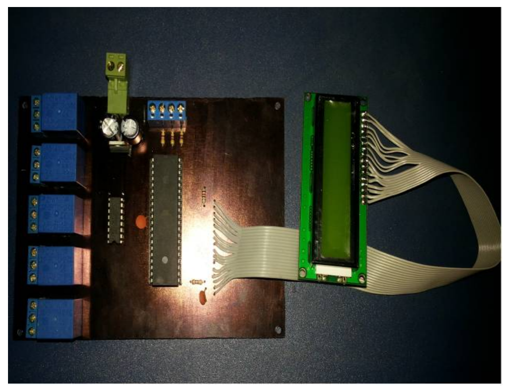

Fig.2. Main board

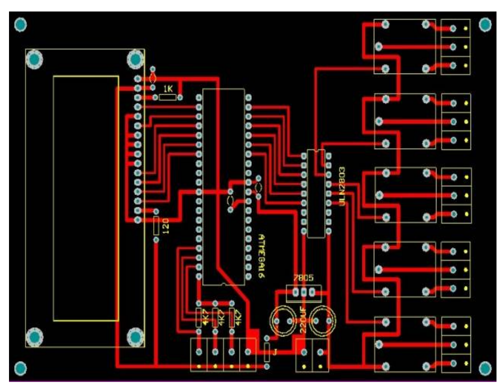

Fig.3. Printed circuit devices

All electronic circuits are on the main board as a printed in circuit. In figure (3) the main design of the printed circuit is shown. In this picture we can see the orbits and how the different parts of the device are connected.

Electronic components of the device are: a variety of electronic resistances, diodes, transistors, high voltage buffer 8 bit ULN 2803, relays, voltage regulators, types of capacitors which are used according to the need.

3.2- Other Components of the Device

To control the amount of flow, we use an electric tap in this device.

Electric tap is located in the respiration direction, after out flowing of combined gases and adjusting the flow rate of gases entering the air bag. Also this tap is used for adjusting inflowing gases from the end of air bag.

Oxygen and air regulator, which reduce high pressure of the cylinder, is used in medical devices, and delivers gas directly to the patient.

Oxygen sensor used in this device, controls the percentage of inflowing oxygen to the patient. The amount is given in numeric items to the device. This amount of oxygen is: mixed with the air and delivered to the patient through the respiration circuit.

Fig.4. Oxygen Sensor Device

3.3. Microcontroller of the Device

Microcontrollers have input – output, and power of processing. A microcontroller is a single - chip computer.

It can save or run a program. It consists of CPU (central processing unit), RAM (random access memory), ROM (ready only memory), serial and parallel ports, timers and lines I/O (input-output).

There are different types of microcontrollers: such as 8051, 89C51, Atmega16L, Atmega16 and so on. In this device we have used Atmega16.

3.4- Device Motor

The engine of the device that causes bellow movement is 12 volts. When this engine works is makes the bellow open or close and so controls the patient's breathing rate.

Fig.5. Motor

3.5- Air bag of the device (bellow)

Regulated air enters a bag which is called bellow. The air inside the bag is pressed by motor, enters the breathing circuit and then is delivered to the patient.

The number of breaths set by the patient, the motor has the same number airbag compresses so the air is delivered to the patient and respiration takes place.

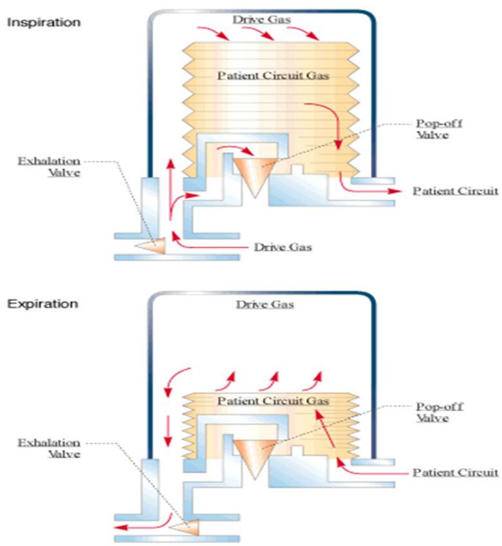

Fig.6. How Bellow the Ventilator

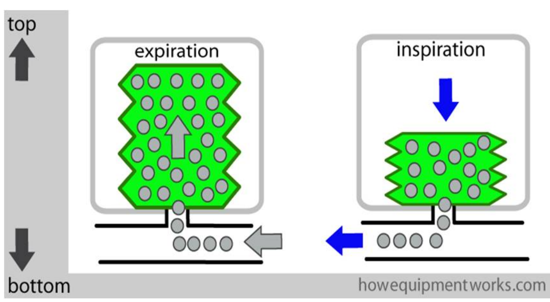

Fig.7. Schematic Moving Bellow the Ventilator

3.6- Programming Environment of Device

There are various types of AVR compilers. Among them BASCOM, ODEVISION, FASTAVR and AVR STUDIO have more reliability and are more important.

One of the most powerful of them is BASCOM AVR. BASCOM support all AVR micros and user BASIC language for programming AVR.

3.7- Mechanical parts of the device

In the project we have used CATIA software to design and make mechanical parts. This software is professional software to design types of robots and it is also used in industry.

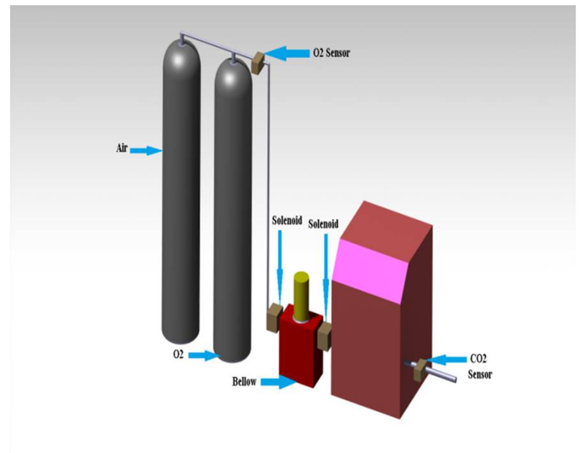

Fig.8. Mechanical Schematic

4. Making the Device Intelligent

This device intelligently controls the function of gases in exhaled air by carbon dioxide sensor.

4.1- Carbon Dioxide Sensor (capnograph)

This sensor is designed to detect CO2 gas in the breathing circuit. It measures the amount of carbon dioxide which is exhaled, and lets corresponding output. If the amount of carbon dioxide is more than normal rate it increases breathing for compensation.

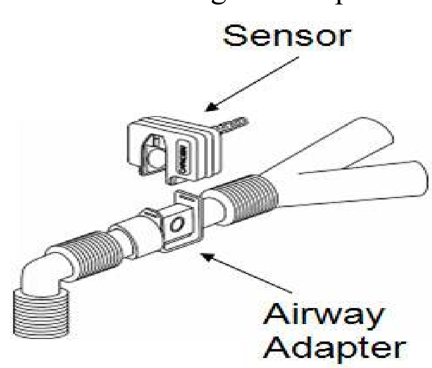

Fig.9. Schematic of the CO2 Sensor on Breathing Circuit

In normal circumstances when blood rate for ventilation (V/Q) is normal, PetCO2 has a value of about (35-45 mmHg) and if (V/Q) declines PetCO2 increases and this sensor can detect PetCO2 increase.

Fig.10. The Internal Circuitry Capnograph Sensor (sensor CO2)

4.2- Intelligent Adjusting of Carbon Dioxide

Processing carbon dioxide (capnometering) is used for evaluating the ventilation conditions. Hypercapnia or increase of carbon dioxide occurs in lack of ventilation or mismatch of blood perfusion.

In this case capnograph sensor which is placed on the patient' breathing circuit detects the increase in exhaled carbon dioxide and if it increases more than normal rate, the sensor increases the number of respiration and adjusts output of this gas. PetCO2 indicates the amount of carbon dioxide in the blood and normal range of it is (35-45 mmHg).

Increasing more than (35mmHg) is called respiratory acidosis and reduction of it lower than (35mmHg) respiratory alkalosis. In order to make intelligent and increase the security of the ventilator carbon dioxide sensor is placed at the end of circuit, near the patient's mouth, to measure the amount of this gas in exhaled air, and in case of conflict with the normal range, it adjusts it with function control, because the increase of this gas in exhalation indicates that there is a disorder in gas exchanging.

4.3- Carbon Dioxide Control Mechanism

Ventilator set can intelligently control carbon dioxide in exhaled air by combining capnograph sensor. This function control is done with a control system.

Every control system has three parts: input, processing and output. Input operator controls inputs to determine the status process.

In this part of the ventilator carbon dioxide sensors is located. Processing part according to entries makes responses and necessary outputs. This is done by microcontroller and output part gives produced commands to the process.

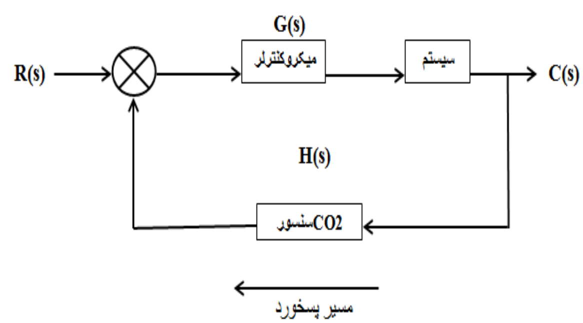

Fig.11. Control Mechanisms

Generally control system of this device is a closed loop system which measures the amount of carbon dioxide output in feedback by capnograph sensor and compares it with normal values.

If it is consistent with the normal range, it continues the process and if it is different it increases the number of respiration and continues it until CO2 gas reaches the normal range.

5- Discussion and Conclusion

5.1- Results of the Control System of the Device

Some parameters on the basis of sex, age and weight of the patient, should be given to the device as input and the device does artificial respiration according to the parameters.

During the artificial respiration if carbon dioxide increases in exhaled air, device sensor immediately distinguishes it, measures it with a normal value and increases the number of respiration and so reduces CO2, and continues it until it reaches normal range, then the device returns to a predetermined amount.

I dare to say that using capnograph sensor causes the devise to be intelligent and in case of negligence or disregard of medical staff, this sensor can save patients' lives and prevent risks for the patient by early diagnosis and proper functioning. As a result, significantly the sensor increases the patient safety.

In the following image, output device performance in terms of the amount of carbon dioxide and respiratory rate are shown.

6- Results and Future Development

Ventilator can be equipped with different sensors to increase the efficiency and security of the device.

In addition to the carbon dioxide sensor that measures the amount of exhaled co2 gas, we can use pulseoxymetry sensors to measure oxygen saturation of arterial blood and if it becomes more than usual range the device reduces the percentage of oxygen saturation because it can cause poisoning especially in children and cause death.

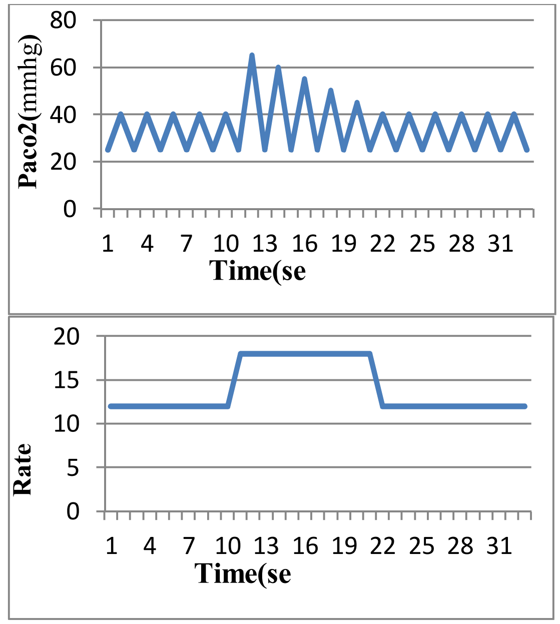

Fig.12. Paco2 Charts in Terms of Output and Respiratory Rate

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