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DESIGN AND DEVELOPMENT OF MOBILE OPERATED PORTABLE VENTILATOR

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ABSTRACT

This paper describes the concept of full function portable ventilator, which have low cost, minimum weight, compact, small-sized. It can easily operate by mobile application and that application able to measure PEEP pressure, tidal volume and flow rate. The essential components used are stepper motor, rack and pinion, motor driver, Nod MCU, Acrylic sheet, Battery etc. There are some open sources Hardware ventilator (OSM-MVs) have been used during COVID-19 Pandemic. The ventilator device breaths by compressing a convention bag-valve mask (BVM) with a help of Rack and Pinion, that eliminate the need of human operator for the BVM. Initially the prototype is built out by Acrylic Sheets, it is work as thermal insulator and it's approximately 20% better than glass. The measurement of portable ventilator is 9.8*4.7*7 inches (250*120*180) mm and weighting 2.20lbs (1.5kg). It is driven by the motor driver powered by a VDC battery. The sensors are used to operate it by a mobile operation for measurement of tidal volume, PEEP pressure etc. The design is made up of CAD software and also makes Ansys for this device. The experimental results taking after testing on artificial lung that where the Positive Inspiratory Pressure (PIP), respiratory rate (RR), tidal volume, Positive end- expiratory pressure (PEEP) and its accuracy exceeding human capabilities in BVM.

KEYWORDS: Portable Ventilator, Medical used, Cad software, Mobile operated.

1. INTRODUCTION

The purpose of ventilator is to maintain homeostatic between two gas concentration which is Carbon dioxide (CO_2) and Oxygen (O_2). Oxygen is input into the patient and carbon dioxide is coming out. There are of two types Medical ventilation: a) invasive mechanical ventilation and b) non-invasive ventilation. An endotracheal tube used in the invasive mechanical ventilation that is inserted into the trachea for the flow of oxygen towards the lungs of the patient. Internal tube does not employ the non-invasive.

The non-invasive ventilation devices such as continuous positive airway pressure (CPAP) device and oxygen hoods are also used in the management less severe COVID-19 patients, so as avoid the need of mechanical ventilator which is invasive in nature. COVID-19 pandemic needs Ventilators for severely affected patients, building of ventilator in the role of 3-D printing technology. In hospital, the patient who are on ventilator for years, months or week. The only reasons they do not sent them back home is because they need to be sent on a ventilator.

Now, a low-cost portable ventilator makes it possible for patient to go home. At before time and even today, there is no cost-effective ventilator available in India.

The cheapest portable ventilator cost 4-5 lacks and most of them are bulky require technical expertise and not at all user-friendly. Compare to normal ventilator this device is extremely portable, very small, less weight and it runs off an Android phone. Traditional ventilator is big and portable ventilator is small in size and it exactly same

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as traditional ventilator, while being fraction in size & fraction in cost as well. Traditional ventilator lots of shortcomings and portable ventilator actually supersedes. Traditional ventilator needs oxygen supply, it needs medical air. So can't take it home for long – term ventilation. Whereas portable ventilator just can simply plug it in and it works just fine.

The partially open-source bag valve mask-based Rep Rap ventilator in the resuscitation system is based on Arduino controller with a real-time operating system. It is installed on a largely RepRap 3d printable parametric component-based structure. (Aliaksei Petsiuk et. al. July 2020). Ventilator used as respirator and it is uses as hospital and intensive care. The mobile respirator is usage in ambulance or military vehicles, mostly first aid. (Jur, 2018) There are many emergency and portable ventilators in the market, then the lacking is found in adequate low-cost ventilators. (Huseinni, 18 march 2020). The hospital equipment aimed to design and prototype that can be assembled readily-available mechanical ventilator.

- Cost of ventilator machine in India
  - Single mode: 20,000 to 2,00,000
  - Portable Transportation Ventilator: 3,00,000- 10,00,000
  - ICU Ventilator: 7,00,000 to 65,00,000

  {Prices are approximate}

The methodological process making this mobile operated portable ventilator can be divided into the main following steps:

- Conceptual design preparation
- Cad model design
- Laser cutting technology and 3d printing
- Fabrication and Assembly
- Software development
- Testing
- Ansys analysis

2. PROCEDURE FOR PORTABLE VENTILATOR

2.1 Review Stage

The ventilation unit is complex devices and contains many sensors and analyze respiration to actuators and some parameter to assist and control of the ventilation (H. Jur, 2018). In a poor- resources development country their greater number of respiratory diseases are rises (Krishnamoorthy, 2014). The low-cost ventilator is the automated by electrical device and that manually compressed by bag valve mask (H. Jur, 2018). The open-source medical devices prevent lock-in mechanisms and that enable seamless data sharing and necessary to creates the large datasets for Machine learning (ML) and Artificial Intelligence (AI) (Simone More, 2020).

The Artificial Manual Breathing Unit (AMBU) operating device use in prototype that is affordable as a substitute to the ventilator in Postgraduate Institute of Medical Education and Research, Chandigarh. Eight patients used one ventilator through a ventilator splitter. Role of 3-D Printer technology in ventilator production.

The parts of ventilator quickly and cheaply seem promising that used of 3D printing in manufacturing. The main parts of the ventilator are the need of the hour in Additive Medicine (AM) technology for the designing and developing process.

2.2 Electrical connection

The block diagram of electrical connection for portable ventilator is depicted in Fig. 1:

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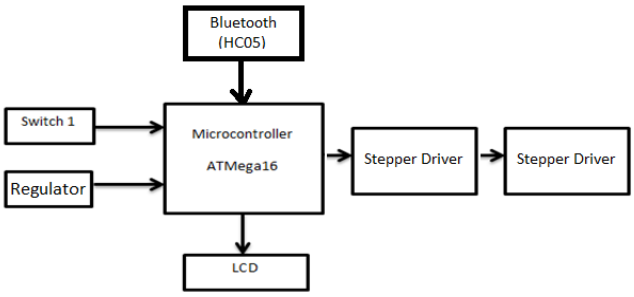

Fig. 1

The all-output signals generated from flex sensors are n analogue used in Micro-controller ATMEGA 16 and these signals need to be digitized before they can be transmitted to encoder. The main controller in this project is used as microcontroller ATMEGA 16. It has inbuilt ADC module, the sensors and inbuilt multiplexer for sensor signal selection which digitizes all analogue signals. It supports both serial and parallel communication facilities.

Atmel's Mega AVR family with low power consumption has an 8-bit high performance microcontroller of the ATmega16. 131 powerful instructions that enhanced RISC (Reduced Instruction Set Computing) for Atmega16. One machine cycle that use as instructions execute. A maximum frequency of 16MHz worked on Atmega16. ATMEGA 16 devices are available in 40-pin with the following characteristics.

- It is 8-bit Microcontroller
- System is RISC Architecture
- It has Small set of Instruction set
- It has 131 powerful Instructions
- Compatibility avail 28/40 Pin Ics
- Speed operate Max 16 MHz, Voltage 2-5.5 v
- Memory: Flash Program-16KB, RAM-1 KB and EEPROM Data Mem- 512 Bytes
- Low power, High speed Flash/EEPROM Technology
- It has on chip Timers. 2 Timers are avail
- Analog to Digital Converter that is built on USART, Analog Comparator, SPI JTAG etc.
- In built Multiplexer availability for signal Selection
- It has serial and Parallel Communication facilities
- Here the Capture, Compare and Pulse width modulation
- The four 8bit Ports designated as PORT A, PORT B, PORT C, PORT D for their Internal and External usage

PCB DESIGN

To finish creating a component a schematic symbol must be linked to a PCB symbol so that the software can relate the pins between the two as depicted in Fig. 2.

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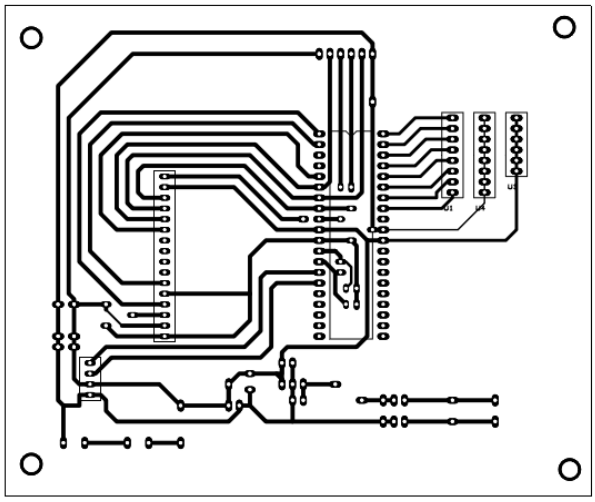

Fig. 2 PCB Design

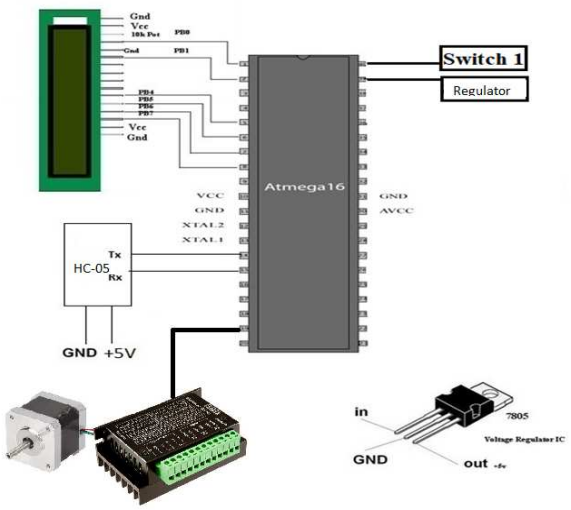

Fig. 3 Circuit Digram

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Impact Factor: 5.164
CODEN: IJESS7

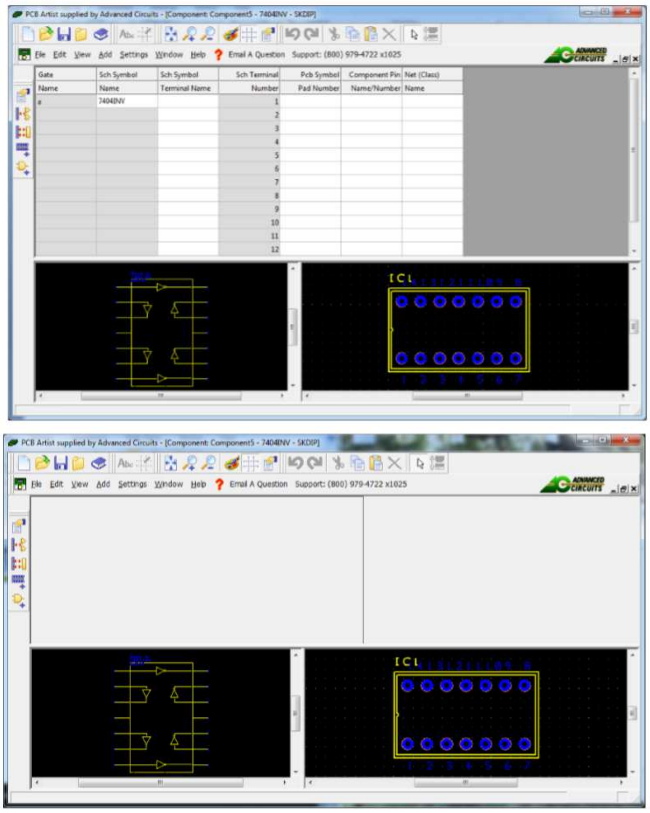

Fig. 4. PCB Artist Design

In today market there is PCBs are the backbone of any production level electronic device, and the knowledge of PCB layout tools be a vital skill. PCBs depending on the application that are used for both analog and digital circuits. Design considerations taken by the designer for different types of circuits.

AVR Studio:
The framework for compiling programs provides Atmel's free IDE (Integrated Development Environment), AVR Studio and downloading them to the microcontroller, AVR microcontrollers that comes with the ability to simulate programs. The ability of the simulator has not only executed AVR instructions but also it simulates limited digital I/O (input/output). AVR Studio is relatively similar to other IDEs that used for introduction to programming classes, like Microsoft Studio Express C, Eclipse, or NetBeans.

2.3 Electrical components
The component is used for the making the portable ventilator are as follows:

- Stepper motor
- Rack and pinion
- Motor driver
- Nod MCU
- Acrylic sheet
- Battery

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Stepper Motor
Mostly a stepper motor widely used NEMA-17 and NEMA-23. The stepper motor is a brushless DC electric motor that divides a full rotation into a member of equal steps.

Rack and Pinion
A rack and pinion are a type of linear actuator that comprises a circular gear (the pinion) engaging a linear gear (the rack), that operated to translation of rotational motion into linear motion. The rack to be driven linearly by cause of driving the pinion into rotation. The pinion that can be drive rotationally with the help of driving the rack linearly. The straight and helical gears that can be use a rack and pinion drive. Quieter operation and higher load bearing capacity was preferred by Helical gears. The maximum force that can be transmitted in a rack and pinion mechanism is determined by the tooth pitch and the size of the pinion.

Fig. 5. Schematic diagram of Rack and Pinion

Motor driver
A motor driver is an essential device that provides the required voltage and current, so that to get a smooth operation. It is DC type of motor turn into steps. Selection of proper power supply, microcontroller, and the motor driver is very important to design a stepper motor driver. A single motor driver board can handle the currents a voltage for a motor. The pulse signals with the help of a driver that controller by synchronizing for a stepper motor. This motor driver takes the pulse signals from microcontroller and then changes them into the motion of the stepper motor.

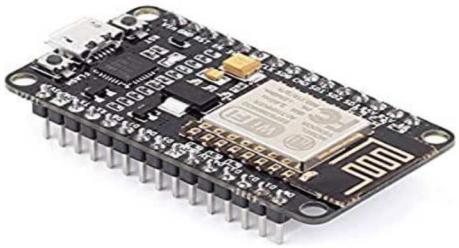

Fig. 6. Schematic diagram of Motor driver

NodeMCU
NodeMCU is a low-cost open source IoT platform. It initially included firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which was based on the ESP-12 module. For a support the ESP32 32-bit MCU was added.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Acrylic Sheets

Acrylic Sheets. ...Acrylic plastic weight is less than half of glass for that has many times greater impact resistance. As a thermal insulator, it is approximately 20% better than glass. It is tasteless and odorless

Fig. 5. Schematic diagram of Acrylic Sheets

Battery

The electrode materials are change during discharge for that batteries are use once to discharged; for the common example the flashlights and a multitude of portable electronic devices the alkaline battery used. An applied electric current that can used as discharged and recharged multiple times for secondary (rechargeable) battery; the original composition of the electrodes can be restored by reverse current. Examples the portable electronics such as laptops and mobile phones contain the lead-acid batteries used in vehicles and lithium-ion batteries.

3. METHODOLOGIES

In this project the portable ventilator system is using acrylic material for making structure of the project which is cut by CO_2 laser cutting machine and for the AMBU bag compression were use stepper motor. Stepper motor is more forward and reverse with the help of stepper controller. For all this operation it connects to this system with 12V, 10Kh battery and speed of the system is controlled by mobile application which make it more user friendly and portable.

Prototype ventilator have electrical component including an electric motor connected to centrifuentrifugal impeller. The test-lung's 'leak' feature for varying degrees of circuit leak accessed during the performance. (A. Darwood, 2019)

To create a modular ventilator for rapid prototyping technologies (3D printing and 2D cutting). A flow meter was used as air reservoir for wall oxygen source in the artificial manual breathing unit (AMBU) bag. The artificial manual breathing unit (AMBU) bag.

A commercially available stepper motor (Nema 23with 3Nm of holding torque) motor driver (Toshiba TB6560) was powered by a 12 V 5A power supply. (Jayesh Dhanani et. al. 2020)

To avoid exhaled air to be recycle used for bag and mask are connected via a valve. Ambu Bags are designed to be hand-squeezed, a tiresome operation usually performed by first responders as emergency breathing aid, often during ambulance transport. (Simone Mora et. al. 2020)

Improvement:

- Enable change the sensor which used for flow and pressure measurement.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

- If mask is not fitted properly there is leakages occurred. This can happen as a mistake by the medical staff, but also in case the patients have major face injuries or simply because of facial hair.
- Find out to stop the leakages of airway occlusion or leakage during testing.

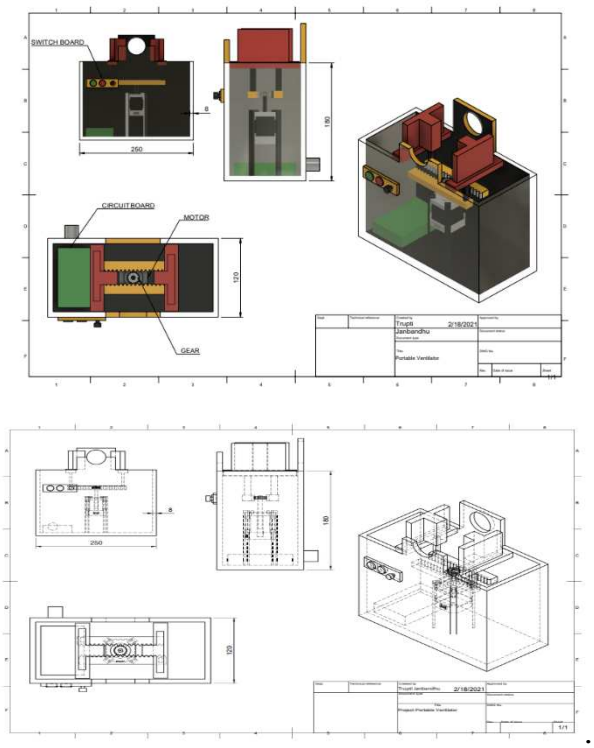

Fig. 6.

Advantages

It is compact in size, light in weight, wireless in operation portable, battery operated, easy to operate and 4–6-hour battery backup.

4. LIMITATION AND FUTURE SCOPE

- In this portable ventilator system if the used of Artificial Intelligence (AI) so it can separate or control air flow according to the need of a person, this can help to save life of many people.
- Spring washers that are recommended to be used in the motor mounting system that prevent possible bolt loosening due to motor vibrations. (Petsiuk, 2020)
- It can use compact and long-life battery for increase the time of working of portable ventilator.
- During compression, the bag support that shift and rotate by self- inflating bag, that lead to deviation of the set ventilation parameters. A fixing component that uses an elastic band, for future, the make of bag movement physically impossible then it's necessary to redesign the system. (Petsiuk, 2020)

5. CONCLUSION

The portable ventilator is very usable in urban and rural areas for providing immediate oxygen to a person and protecting their life in critical condition due to its portable and wireless operation which make it easy to operate.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

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