



Title: A review of open-source ventilators for COVID-19

Authors: ESQUEDA-ELIZONDO, José Jaime, JIMÉNEZ-BERISTÁIN, Laura, MIRANDA-PASCUAL, María Elena y TRUJILLO-TOLEDO, Diego Armando

Editorial label ECORFAN: 607-8695
BCIERMMI Control Number: 2020-04
BCIERMMI Classification (2020): 211020-0004

Pages: 14
RNA: 03-2010-032610115700-14

ECORFAN-México, S.C.
143 – 50 Itzopan Street
La Florida, Ecatepec Municipality
Mexico State, 55120 Zipcode
Phone: +52 1 55 6159 2296
Skype: ecorfan-mexico.s.c.
E-mail: contacto@ecorfan.org
Facebook: ECORFAN-México S. C.
Twitter: @EcorfanC

www.ecorfan.org

Holdings		
Mexico	Colombia	Guatemala
Bolivia	Cameroon	Democratic
Spain	El Salvador	Republic
Ecuador	Taiwan	of Congo
Peru	Paraguay	Nicaragua

Mechanical Ventilators parameters

Open-source designs shared worldwide

OxyGEN project, Spain

Open Source Ventilator (OSV), Ireland

Project OpenAir, Portugal

RespiraWorks, USA, Guatemala, Kyrgyzstan

The Pandemic Ventilator Project, USA

MIT Emergency Ventilator (E-Vent) Project

Open Source Ventilator Project, University of Florida

Puritan Bennett 560 (PB 560), USA

AmboVent, Israel

Other international efforts

Conclusions

References



Mechanical Ventilators parameters

The most common commercial modes of mechanical ventilation both provide a specified number of breaths per minute (BPM) and are:

- 1) synchronized intermittent mandatory ventilation (SIMV) where patients can take additional breaths over the set rate
- 2) assist control (AC) that uses triggering so that if the patient makes an effort to breathe, it helps them, and if not, it maintains the set rate.

These modes can be used alone or in concert with

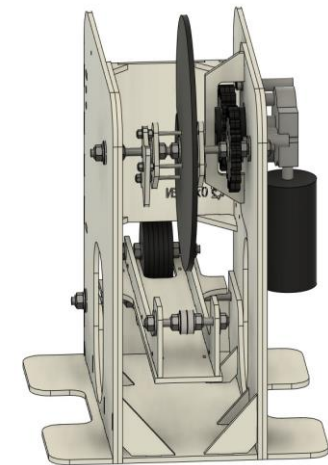
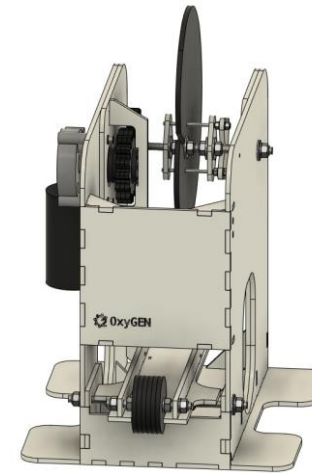
- 1) continuous positive airway pressure (CPAP), which uses a high-pressure reservoir and constant flow of gas that exceeds the patient's needs;
- 2) positive end-expiratory pressure (PEEP), which increases the residual reserve capacity and allows for many alveoli and small airways to remain open that would otherwise close off;
- 3) pressure support ventilation (PSV), which adjusts the pressure on the fly as the patient breathes to maintain a pre-set inspiratory pressure.

Open-source designs shared worldwide

Since the pandemic has affected so many countries, an increase in these types of equipment developed at low cost has been developed these days (Crowell, 2019) (OxyGen Project, 2020).

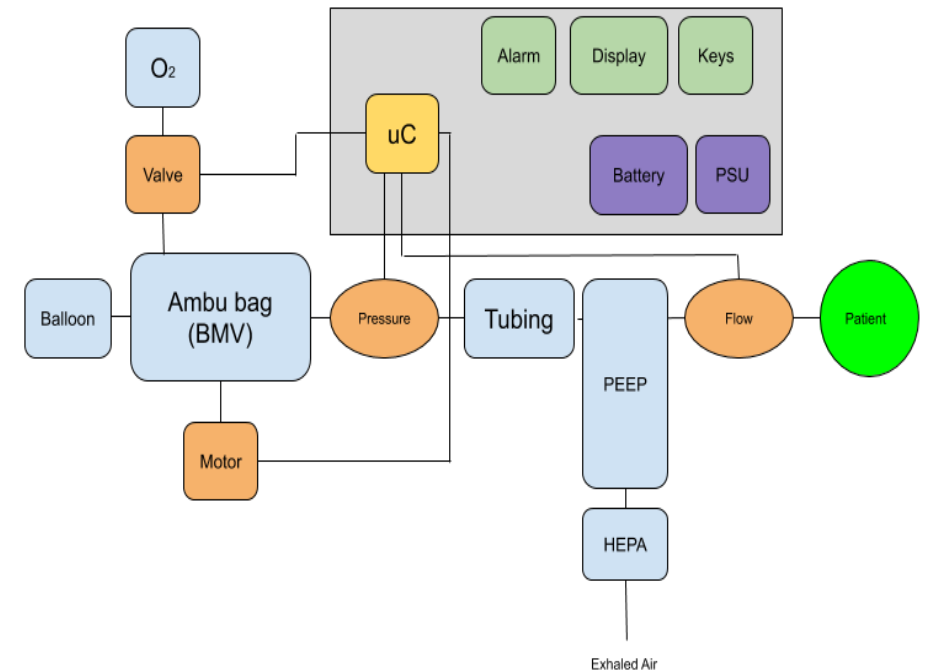
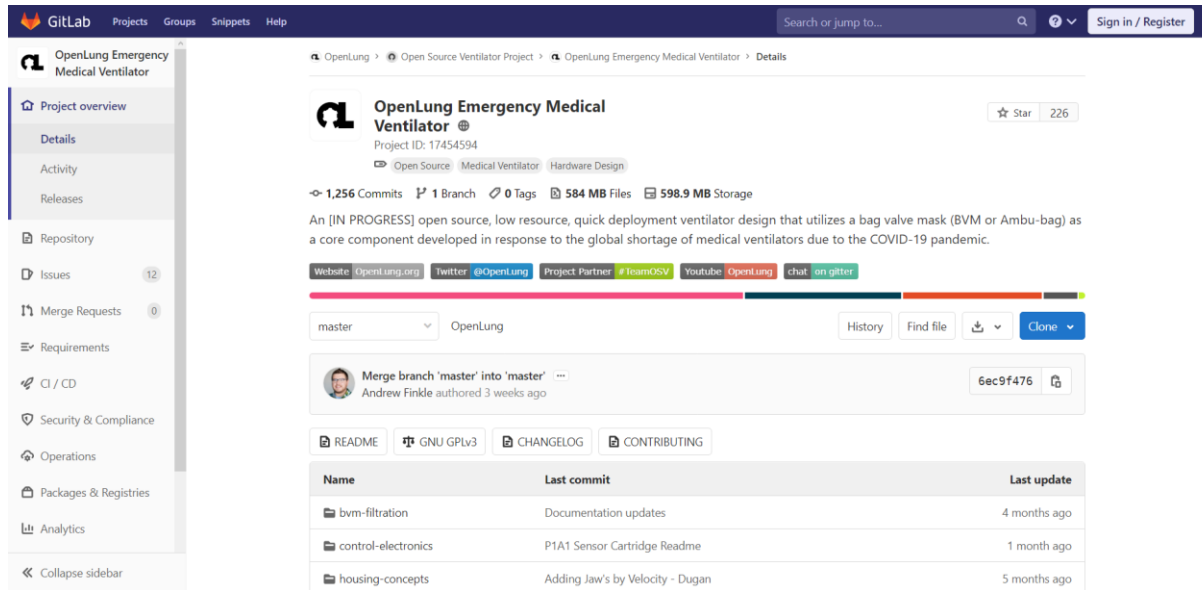
OxyGEN project, Spain

- It is a collaborative hardware project initiated and directed by Protofy.xyz, a Spanish company based in Barcelona, in charge of providing innovative hardware and software solutions.
- The project's mission is to provide a chance for survival to those who do not have access to a medical artificial ventilator for any reason.
- It is a low-cost hardware system with simple and easily available components, based on the automation of a manual resuscitator (Ambu-bag), with the idea of contributing to saving lives (OxyGen Project, 2020).
- It has received the approval of the AEMPS (Spanish Agency for Medicines and Health Products) to start its use on patients at all hospitals that adhere to the clinical study.



Open Source Ventilator (OSV), Ireland

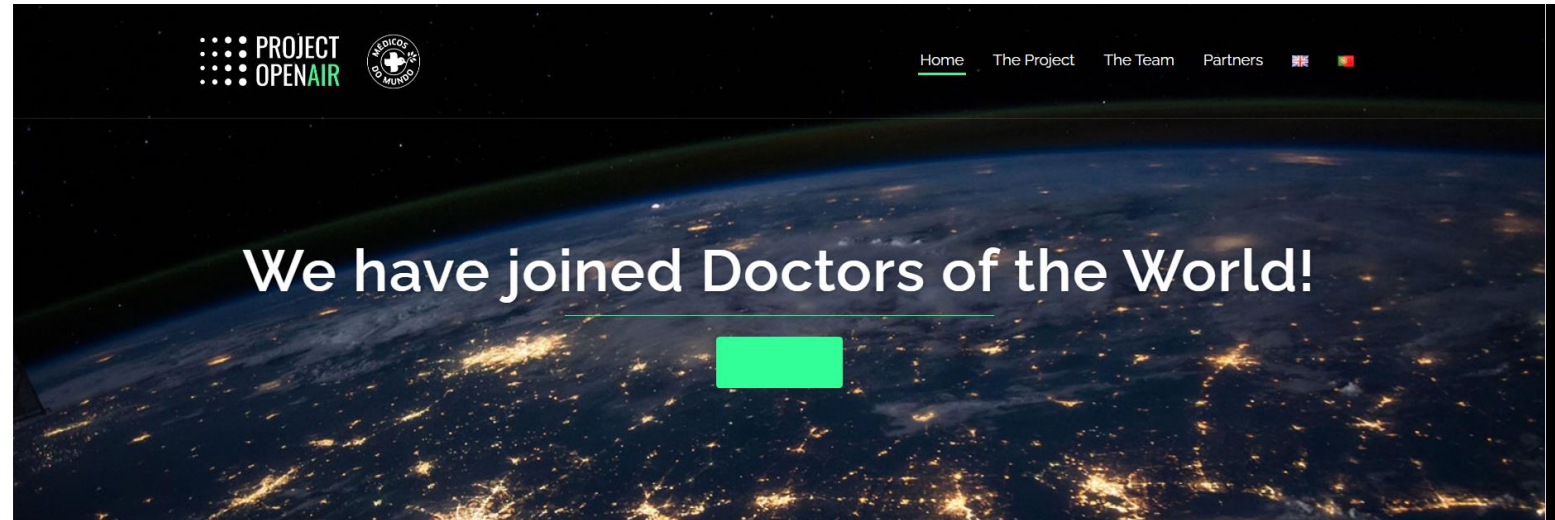
- The Irish OSV company developed a collaborative Field Emergency Ventilator (FEV) with the Irish Health Service ((OSCMS), 2020).
- They have formed a team of engineers, designers, and medical professionals to develop new low-resource interventions, all working collaboratively online.
- Traditionally manufactured and bagged valve masks (BVMs), 3D printed components are being considered to maximize potential manufacturing capabilities.
- It is a fast-deploying, low-resource, open-source (in progress) fan design that uses a valve bag-mask (BVM or Ambu-bag) as the core component.



<https://gitlab.com/open-source-ventilator/ventilator/OpenLung>

Project OpenAir, Portugal

- This prototype implements the pressure-controlled continuous mandatory ventilation mode (PC-CMV) with settable breathing rates, inspiration/expiration time ratios, and FiO₂ modulation.
- Pure oxygen at the standard pressure of 4 bar (400 kPa) is fed from the hospital supply to an adjustable pressure regulator with an output range of 20 to 40 mbar, allowing the PIP pressure to be set by just turning a knob.
- The regulator output is fed to the inspiration electro valve that should have enough aperture for the air to pass through easily at normal breathing flows (Pereira et al., 2020a).



**Together
we can**

It's in moments like these that we can show what we're made of.

#ProjectOpenAir was created to limit the lack of medical equipment on the fight against Covid-19.

<https://projectopenair.org/en/home-2/>

RespiraWorks, USA, Guatemala, Kyrgyzstan

- They are a team with backgrounds in medical devices, quality assurance, nuclear power, submarine life, and project management.
- They are located in Berkeley, Denver, Guatemala, Kyrgyzstan, and places around the world.
- The design of this emergency ventilator is based on a blower



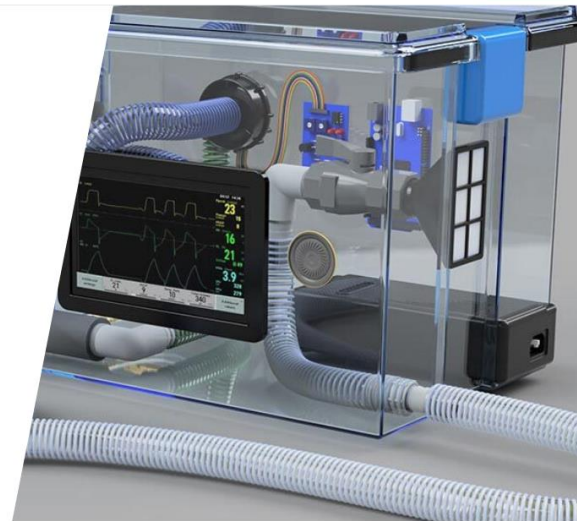
ABOUT EN ESPAÑOL UPDATES TEAM JOIN US RESOURCES SUPPORTERS DONATE



Designing and distributing a low-cost ventilator for the developing world.

Our mission is to build an open-source, high-quality ventilator for people in distress, wherever they are.

[View updates](#) [Donate](#) [Join us](#)



Our Focus

We partnered with [Hospitalito Atitlán](#), a small non-profit hospital in Guatemala, as a pilot location for our ventilator. There are currently fewer than 500 ventilators in the whole country — far too

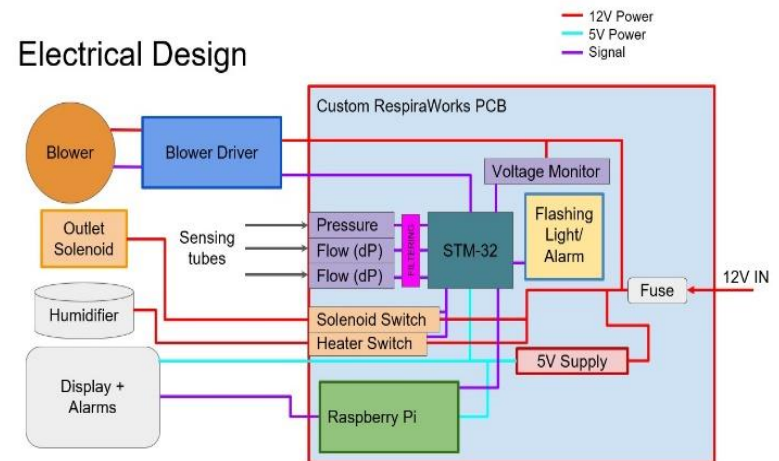
Esta web utiliza cookies para mejorar la experiencia y proporcionar funcionalidades adicionales. [Detalles](#)

Aceptar cookies

<https://respira.works/>

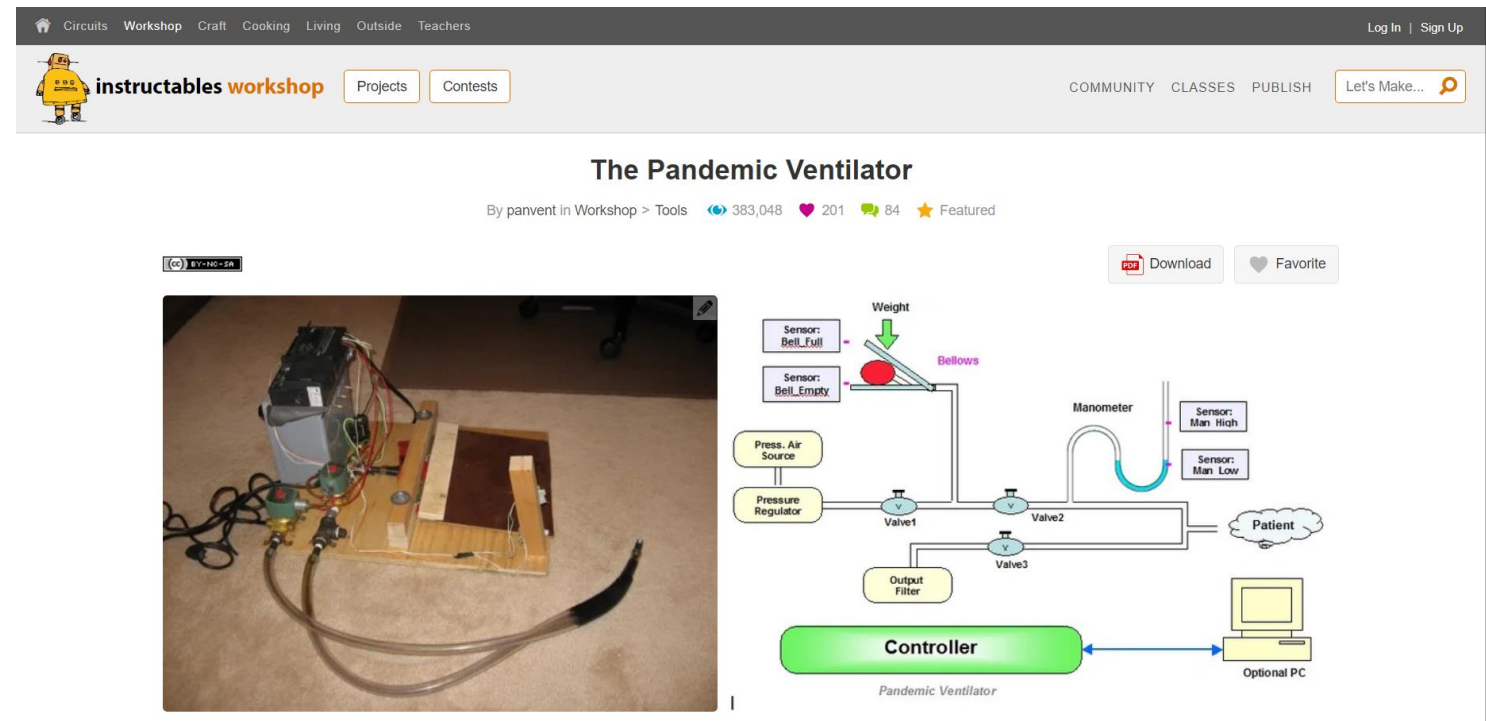


Electrical Design



The Pandemic Ventilator Project, USA

- The Pandemic Ventilator Project is an open-source hardware project and the information presented of this project is only for development and investigative purposes.
- The prototypes presented are not fully functional devices and have had no safety testing done.
- This project consists of the bellows unit, which is made of wood, valves and piping, a PLC controller, some wires and switches, and a power supply unit.
- The whole unit is mounted on a piece of 1/2 inch thick plywood that is 18 inches by 21 inches. a device agrees to waive any liability.



The screenshot shows the Instructables Workshop interface for the project "The Pandemic Ventilator" by parvent. The page includes navigation tabs for Circuits, Workshop, Craft, Cooking, Living, Outside, and Teachers. The project title is prominently displayed, along with statistics: 383,048 views, 201 likes, and 84 comments. It is marked as a "Featured" project. Below the title, there are options to "Download" the PDF and mark it as a "Favorite". The main content area features a schematic diagram of the ventilator system, a photograph of the physical prototype, and a smaller version of the schematic diagram. The schematic diagram illustrates the flow of air from a "Press. Air Source" through a "Pressure Regulator" and "Valve1" to a "Bellows" unit. The bellows unit is equipped with a "Weight" and two sensors: "Sensor: Bell_Full" and "Sensor: Bell_Empty". Air from the bellows passes through "Valve2" and a "Manometer" (with "Sensor: Man_High" and "Sensor: Man_Low") to a "Patient". A "Controller" (labeled "Pandemic Ventilator") is connected to an "Optional PC" and manages the system via "Valve3" and an "Output Filter".

<https://www.instructables.com/id/The-Pandemic-Ventilator/>

MIT Emergency Ventilator (E-Vent) Project

- This project is based on automating a manual resuscitator, as a potential means for longer-term ventilation.
- This is a completely off-label use, but they recognize the global interest when a hospital has used up all ventilators and the only option is manual bagging a patient.
- This may allow less severe patients to be cared for by less specialized clinicians, while resources are focused on those most in need. It has a 12V DC @ 5A power supply and is based on the open hardware platform Arduino UNO.

MIT Emergency Ventilator

Design Toolbox

Home Clinical Mechanical Controls & Electrical Experiments & Results Resources Team Other Teams News

MIT Emergency Ventilator Project

DONATE NOW

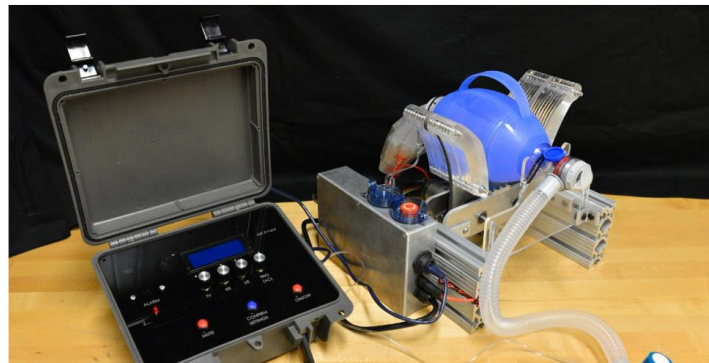
REGISTER
ACCESSIBILITY
LOGIN

Search

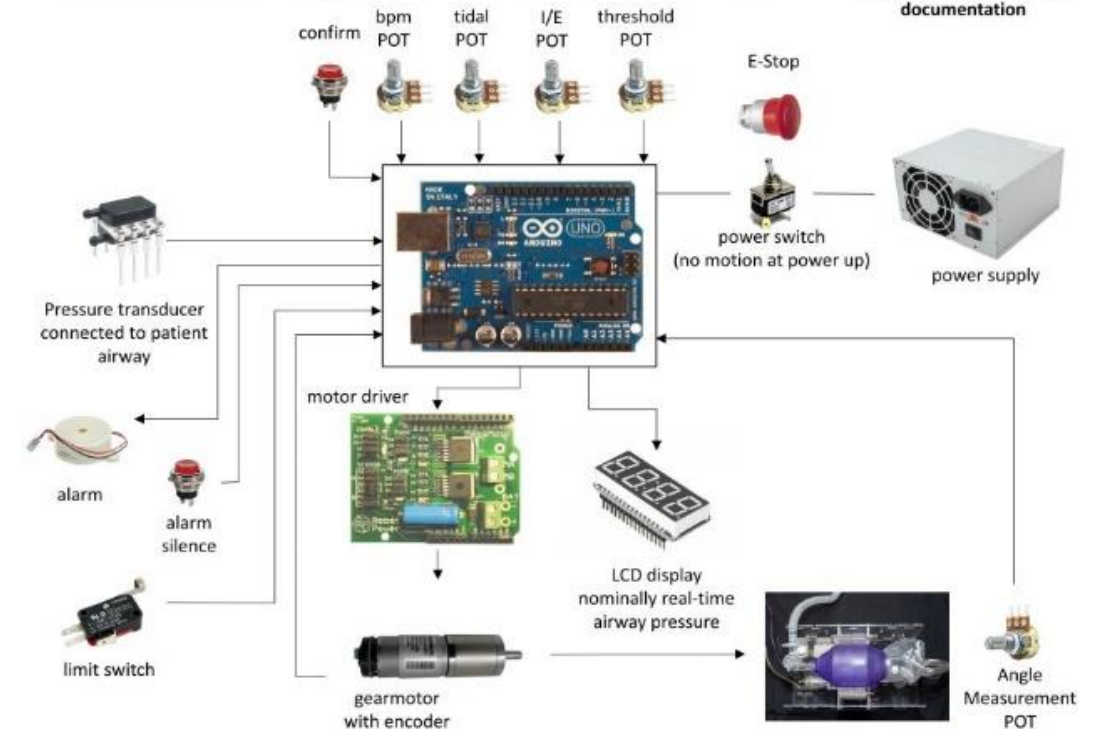
NEWS

COVID-19 Research Summary

Waveform Analysis



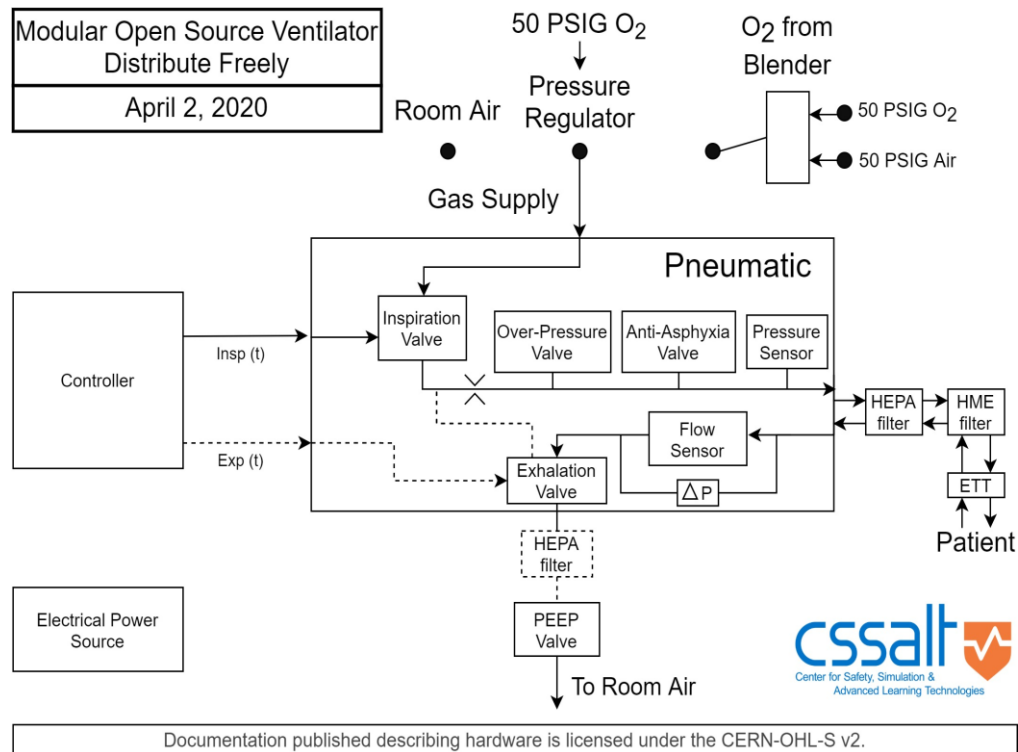
Electrical System Architecture



<https://e-vent.mit.edu/>

Open Source Ventilator Project, University of Florida

- It is a ventilator system for adults (older adults at higher risk) based on positive pressure-volume control for intubated patients who do not breathe spontaneously.
- The designs are modular, allowing different modules to be combined according to local availability.
- It has an out of box design: all parts are commercially accessible.



UFHealth
Healing Learning Discovery Community visit University of Florida

The Center for Safety, Simulation and Advanced Learning Technologies
University of Florida Health

Search Our Site

Sign up for MOCA

Home Technology Development Open-Source Ventilator Project

Open-Source Ventilator Project

Open-Source, Open-Architecture Ventilator Design

This webpage created March 17, 2020

This open-source project has been created to address predicted ventilator shortage worldwide due to the COVID-19 pandemic and host open-source contributions – **Distribute freely**

Donate to Our COVID-19 Ventilators Project

Subpages

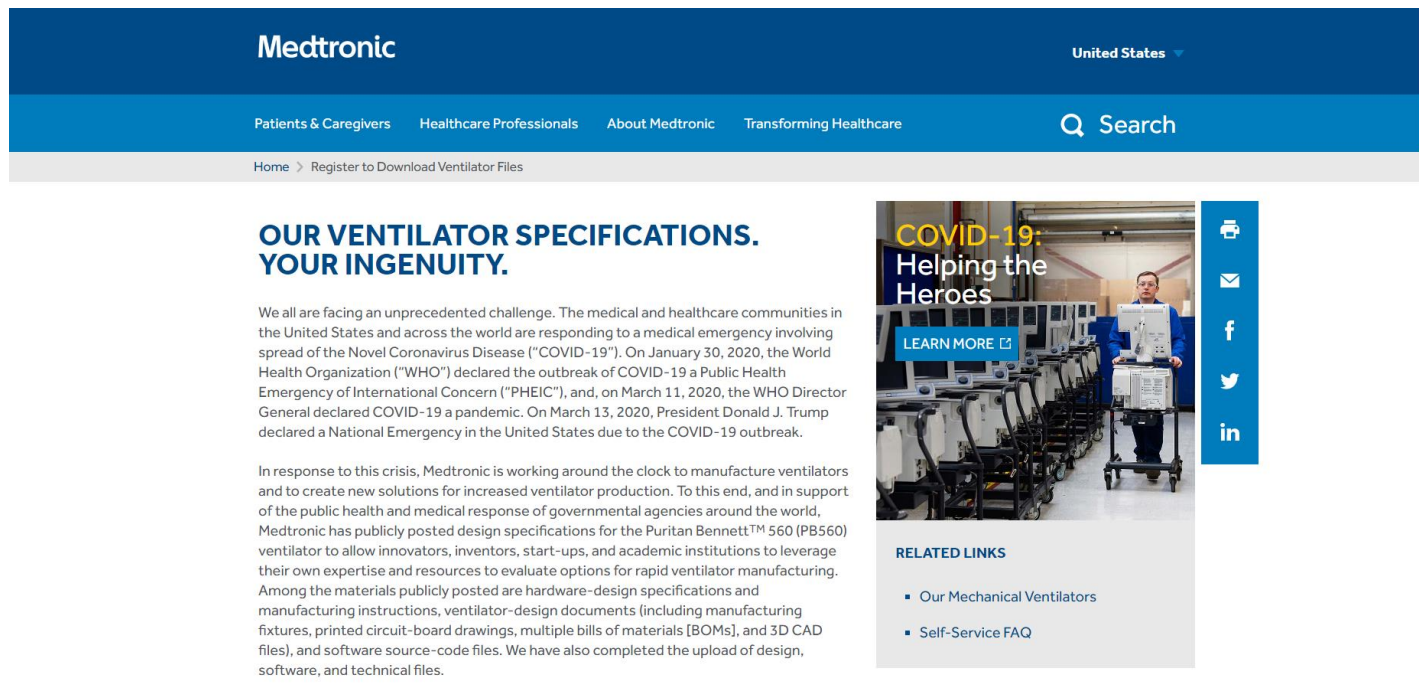
Fixed-Design Ventilator
Engineering Specifications
Bill of Materials

Contact Us
Design Localization
In the Media

<https://simulation.health.ufl.edu/technology-development/open-source-ventilator-project/>

Puritan Bennett 560 (PB 560), USA

- This device plans were released by Medtronic to help people in the COVID 19 pandemic.
- It is pump-based and it was designed in 2010, so it has been a long time in use (Medtronic, 2020).
- This device is more complicated to build and also more expensive, but probably offers more features, and has already been approved by numerous governments.
- Another fact is that some of the elements are discontinued now and it is not easy to find them.
- Also, some industrial facilities are needed to build them.



The screenshot shows the Medtronic website interface. At the top, there is a navigation bar with the Medtronic logo, a dropdown menu for "United States", and a search bar. Below the navigation bar, there are links for "Patients & Caregivers", "Healthcare Professionals", "About Medtronic", and "Transforming Healthcare". The main content area features a section titled "OUR VENTILATOR SPECIFICATIONS. YOUR INGENUITY." with a sub-section "COVID-19: Helping the Heroes" and a "LEARN MORE" button. To the right of this section is a vertical sidebar with social media icons for print, email, Facebook, Twitter, and LinkedIn. Below the main content, there is a "RELATED LINKS" section with two items: "Our Mechanical Ventilators" and "Self-Service FAQ".

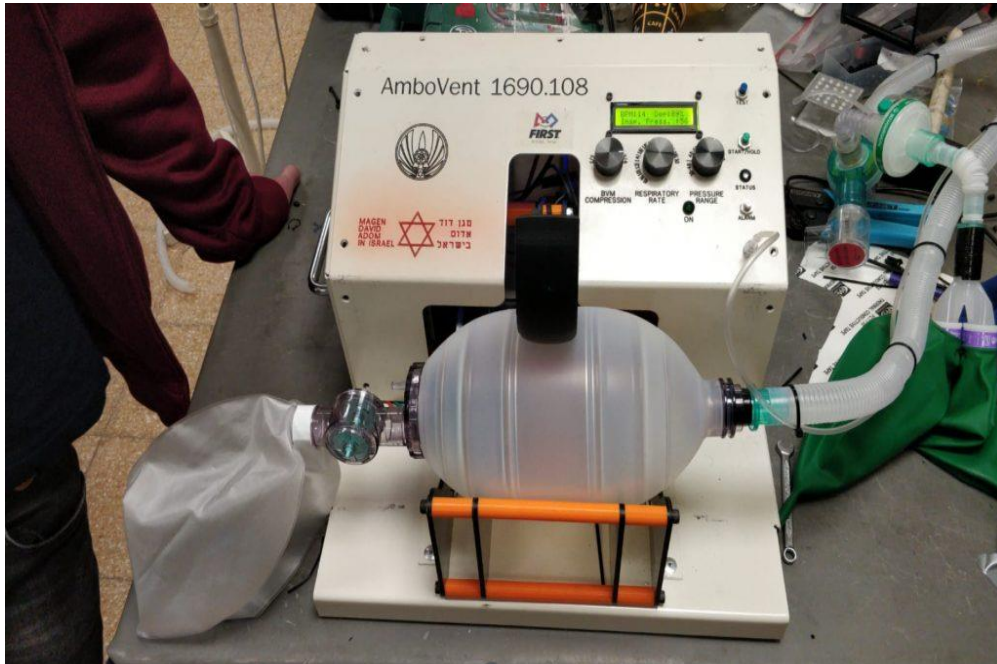
Puritan Bennett™
Respirador 560



https://www.medtronic.com/us-en/e/open-files.html?cmpid=vanity_url_medtronic_com_openventilator_Corp_US_Covid19_FY20

AmboVent, Israel

- “AmboVent” is a device inspired by the bag-valve-mask ventilators that paramedics use when they’re manually ventilating patients in an ambulance, which also offers controls for respiration rate, volume, and maximum peak pressure.
- The device is being developed as a global partnership for the greater good, in open-source code mentality, on a non-profit basis to enable free and simple mass production by anyone, anywhere in the world.
- It is designed as an alternative automatic, controlled, ventilation system for adults, to be used only in emergencies when no other approved ventilation machines are available (Israel Air Force, 2020).



CoronaTech Innovation Headquarters - Israel


AmboVent

**Help us move faster
than the virus can kill.**

we have launched the crowdfunding phase

Automatic, Controlled Resuscitator Device

**AmboVent
1690.108**



Emergency ventilation alternative system

Other international efforts

At (Read, 2020) is published a classified Analysis of Open Source COVID-19 Pandemic Ventilator Projects

Browser tabs: Mechanical Ventilator Milano, Disposiciones para la adquisi..., Evaluation of Open Source V..., GitHub - PubInV/covid19-ve..., Engineering_Specifications_C..., translate - Buscar con Googl...

URL: docs.google.com/spreadsheets/u/1/d/e/2PACX-1vTYAf1dxoliO46VAWH1NlhwrFBn9mguqS2bh1spnEu4AVVN1cj1vaEm6vOp5Z6UnaAbUwd8dsICXdm/pubhtml

Evaluation of Open Source Ventilators

Projects Drives Monitors Flow Sensors Standards User Display/Control Oxygen Blender Sanitizer Valves Patient Inflating Valves Mentionable

Analysis of Open Source COVID-19 Pandemic Ventilator Projects

Look Down! We've added tabs for modules to encourage modularity!

Rank by Average

April 15, 2020 Public Invention <https://www.pubinv.org> Home Repo: <https://github.com/PubInV/covid19-vent-list>

Link to definition of evaluation criteria: https://docs.google.com/document/d/e/2PACX-1vRI9yZ27Kvsf1tcNwvHqH1A81pO8qHL62TWpY_VY-UeLWdK9x-4-3hNw3DbkemCizExpSg8RfnxIP/pub

Project Name	Project Link	Openness	Buildability (1 unit)	Community Support	Functional Testing	Reliability Testing	COVID-19 Suitability	Clinician Friendly	Average	Manufacturability (1000s)	Date Last Evaluated	Point of Contact	Team Needs	Drive	Spontaneous Breathing	Modes
Ambovent	https://1nn0v8ter.rocks/Ambovent	5	5	5	4	3	4	4	4.29	3	2020-05-15	dreliram@gmail.com		AmbuBag		
Medtronic Puritan Bennett (PB) 5	http://newsroom.medtronic.com	4	2.5	4	5	5	4	5	4.21	4	2020-04-19			Pump		
MUR (Minimal Universal Respira	https://www.mur-project.org/	4	4	4	3.5	4	3.5	3.5	3.79	2.5	2020-04-19	https://www.mur-project.org/		Pressure Regulation		
Open Source Ventilator Project	https://simulation.health.ufl.edu	4	3.5	5	3.5	2.5	4	3.5	3.71	4	2020-04-19	https://simulation.health.ufl.edu		Bellows		
Rice OEDK Design: ApolloBVM	http://oedk.rice.edu/apollobvm	5	4	4	2.5	2.5	3	2.5	3.36	2.5	2020-04-19	amy.k@rice.edu		AmbuBag		
A.R.M.E.E. Ventilator	www.ameevent.com	5	5	4	2	3	2	2.5	3.36	5	2020-04-19	warrenkoch@gm		Pneumatic	Y	
COVID-19 Rapid Manufacture Ve	https://www.instructables.com	5	4	4	3	0	3.5	3.5	3.29	2.5	2020-04-19	https://www.instr		AmbuBag		
OpenVentilator (PopSolutions)	https://www.popsolutions.co/e	5	3.5	4	3.5	3	2	2	3.29	3	2020-04-08	contact@openve		Bellows		
Low-Cost Open Source	https://github.com/jcl5m1/vent	5	4	4	3	1	3	3	3.29	3	2020-04-19	https://github.com		Pump		
DIY-Beatmungsgerät [Respirator	https://devpost.com/software/c	5	4	3	2.5	2	3	3	3.21	0	2020-04-19	https://docs.goo		AmbuBag		
MakAir	https://github.com/makers-for	4.5	2.5	5	3	2	2	3	3.14			quentin.adam@				
OperationAIR	https://www.operationair.org/	4	4	4	3	2	3	2	3.14		2020-05-05	info@operationa		Mass Flow Controller		
PREVAIL NY	https://jmawireless.com/prevail	4.5	4	3	2.5	0	4	3.5	3.07	3.5	2020-04-19	customerservice		AmbuBag		
VentilAid	https://www.ventilaid.org/	5	4	4	3	0	2.5	2.5	3.00	2.5	2020-04-08	media@urbicum		Bellows		
CoroVent	https://www.corovent.cz/	3.5	2.5	4	4	0	3.5	3.5	3.00		2020-04-10	simon.rakosnik@		Bellows		
Flow-i Bridge Project	https://grabcad.com/library/flow-i	4	2.5	3	2	2	3.5	4	3.00		2020-04-25		clinical validation	Servo Gas Module		
Protofy Team OxyGEN	https://oxygen.protofy.xyz/	5	4	4	3	1	2	1	2.86	3	2020-04-19	https://www.oxy		AmbuBag		
Jeff Ebin's Prototype	https://www.ebcore.io/?fbclid=	5	4	3	1	0	4	3	2.86	1	2020-04-08	jeffrey@ebcore.i		AmbuBag		
Open Breath Italy	https://www.openbreath.it/	3.5	2.5	3.5	3	1	3.5	2.5	2.79		2020-04-19	info@openbreath		Pressure regulat Y		
CoRescue	https://corescue.org	4	1	4	3.5	0	3	3.5	2.71		2020-04-19	aaupandemic-v				
MARK-19 Ventilator	https://www.mark-19.com	3	2	3	4	3	2	2	2.71		2020-04-19					
vent4us	https://www.vent4us.com/	3	2	3	2.5	2.5	4	2	2.71		2020-04-25	utahstanford@				

Published by Google Sheets - Report Abuse - Updated automatically every 5 minutes

The ventilation projects are qualified from 0 or 1 to 5, in seven categories:

- Openness,
- Community Support,
- Buildability,
- Functionally Tested,
- Reliability Tested,
- COVID-19 Suitability,
- Clinician Friendly.

Conclusions

- There are a lot of different projects for designing and replicating ventilators for people in this COVID 19 pandemic.
- We can conclude that most of the projects developed worldwide are not approved yet for medical use, except for the OxyGen Project and the Medtronic's Puritan Bennett 560, but the buildability parameter is very important.
- The information collected and classified in the Analysis of Open Source COVID-19 Pandemic Ventilator Projects is very useful to know the international experiences obtained in the design and construction of these ventilators.
- Also, there are different kinds of ventilators, so anyone can choose the one who fits the needs of their local community.

Project	Country	Drive	Build	Average	
OxyGEN	Spain	Ambu bag	4	2.95	4
OSV	Ireland	Ambu bag	2	0.90	
Open Air	Portugal	Pressure Control	1	0.70	
Respira Works	USA-Guatemala	Fan	4	3.25	2
Pandemic Ventilator	USA	Bellow	1	1.30	
E-Vent	USA	Ambu bag	3	2.80	
Open Source Ventilator	USA	Positive Pressure Control	3.5	3.15	3
Puritan Bennett 560	USA	Pump	2.5	4.45	
AmboVent	Israel	Ambu bag	5	4.45	1

References



- (OSCMS), O. S. C.-19 M. S. (2020). Open Source Ventilator. Retrieved May 13, 2020, from <https://opensourceventilator.ie/>
- Andreoli, T., Benjamin, I. J., Griggs, R. C., & Wing, E. J. (2015). Cecil Essentials of MEDICINE. In Saunders, Elsevier (Vol. 6). <https://doi.org/10.1017/CBO9781107415324.004>
- Crowell, R. (2019). Conoce el respirador manual automatizado que estamos creando en la UFG - Revista Disruptiva. Retrieved April 20, 2020, from Investigación y Ciencia website: <https://www.disruptiva.media/conoce-el-respirador-manual-automatizado-que-estamos-creando-en-la-ufg/>
- Florida, U. (2020). Open Source Ventilator Project » The Center for Safety, Simulation and Advanced Learning Technologies » UF Academic Health Center » University of Florida. Retrieved May 21, 2020, from <https://simulation.health.ufl.edu/technology-development/open-source-ventilator-project/>
- Force, I. A. (2020). Welcome to AmboVent 1690.108. Retrieved May 22, 2020, from <https://members.smoove.io/view.ashx?message=h44741568O122392748O219654O122323322&r=1009>
- Gobierno de México. (2020). Instituto de Salud para el Bienestar | Instituto de Salud para el Bienestar | Gobierno | gob.mx. In Blog Instituto de Salud para el Bienestar. Retrieved from <https://www.gob.mx/insabi/articulos/instituto-de-salud-para-el-bienestar-230778>
- Instructables. (2020). The Pandemic Ventilator : 6 Steps (with Pictures) - Instructables. Retrieved May 18, 2020, from <https://www.instructables.com/id/The-Pandemic-Ventilator/>
- Medtronic. (2020). Register to Download Ventilator Files | Medtronic. Retrieved May 22, 2020, from https://www.medtronic.com/us-en/e/open-files.html?cmpid=vanity_url_medtronic_com_openventilator_Corp_US_Covid19_FY20
- MIT, T. (2020). MIT E-VENT | Emergency ventilator design toolbox. Retrieved May 18, 2020, from <https://e-vent.mit.edu/>
- OxyGen PProject. (2020). OxyGEN Project. Retrieved April 20, 2020, from <https://www.oxygen.protofy.xyz/>
- Pearce, J. M. (2020a). A review of open source ventilators for COVID-19 and future pandemics. F1000Research, 9, 218. <https://doi.org/10.12688/f1000research.22942.1>
- Pearce, J. M. (2020b). A review of open source ventilators for COVID-19 and future pandemics. F1000Research, 9, 218. <https://doi.org/10.12688/f1000research.22942.1>
- Pereira, A., Lopes, L., Fonte, P., Póvoa, P., Santos, T. G., Martinho, A., ... Pimenta, M. (2020). Prototype of an affordable pressure-controlled emergency mechanical ventilator for COVID-19.
- Read, R. L. (2020). Analysis of Open Source COVID-19 Pandemic Ventilator Projects. Retrieved May 23, 2020, from <https://medium.com/@RobertLeeRead/analysis-of-open-source-covid-19-pandemic-ventilator-projects-27acf9075f7e>
- RespiraWorks, T. (2020). Home | RespiraWorks. Retrieved May 14, 2020, from <https://respira.works/>
- Secretaría de Salud, G. de M. (2020). COVID-19 - gob.mx. Retrieved April 20, 2020, from <https://coronavirus.gob.mx/covid-19/>
- Sloan, M. (2020). MDA and other Israeli organizations partner on making low-cost ventilator for coronavirus | AFMDA | Saving Lives in Israel. Retrieved May 22, 2020, from <https://afmda.org/low-cost-ventilator-for-coronavirus/>
- Williams, M. (Rice U. (2019). Student invention gives patients the breath of life. Retrieved April 20, 2020, from Rice News website: <http://news.rice.edu/2019/05/01/student-invention-gives-patients-the-breath-of-life-2/>
- Worldometer. (2020). Coronavirus Cases. <https://doi.org/10.1101/2020.01.23.20018549V2>



ECORFAN®

© ECORFAN-Mexico, S.C.

No part of this document covered by the Federal Copyright Law may be reproduced, transmitted or used in any form or medium, whether graphic, electronic or mechanical, including but not limited to the following: Citations in articles and comments Bibliographical, compilation of radio or electronic journalistic data. For the effects of articles 13, 162,163 fraction I, 164 fraction I, 168, 169,209 fraction III and other relative of the Federal Law of Copyright. Violations: Be forced to prosecute under Mexican copyright law. The use of general descriptive names, registered names, trademarks, in this publication do not imply, uniformly in the absence of a specific statement, that such names are exempt from the relevant protector in laws and regulations of Mexico and therefore free for General use of the international scientific community. BCIERMMI is part of the media of ECORFAN-Mexico, S.C., E: 94-443.F: 008- (www.ecorfan.org/ booklets)