Zephyr Ventilator and Oxygen Concentrator Prototype

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Oxygen Concentrator

Our oxygen concentrator prototype uses pressure swing adsorption technology to extract oxygen from ambient air. Compressed air feeds into our system and is cycled through two canisters full of molecular sieve that adsorb nitrogen. The valves help direct the process so that 90% pure oxygen is stored in the third canister as nitrogen gas is exhausted. To ensure the successful production of oxygen at a flow rate of 3 LPM, an inlet pressure of 6 bar and a unique timing cycle for pressurization and exhaust were required.

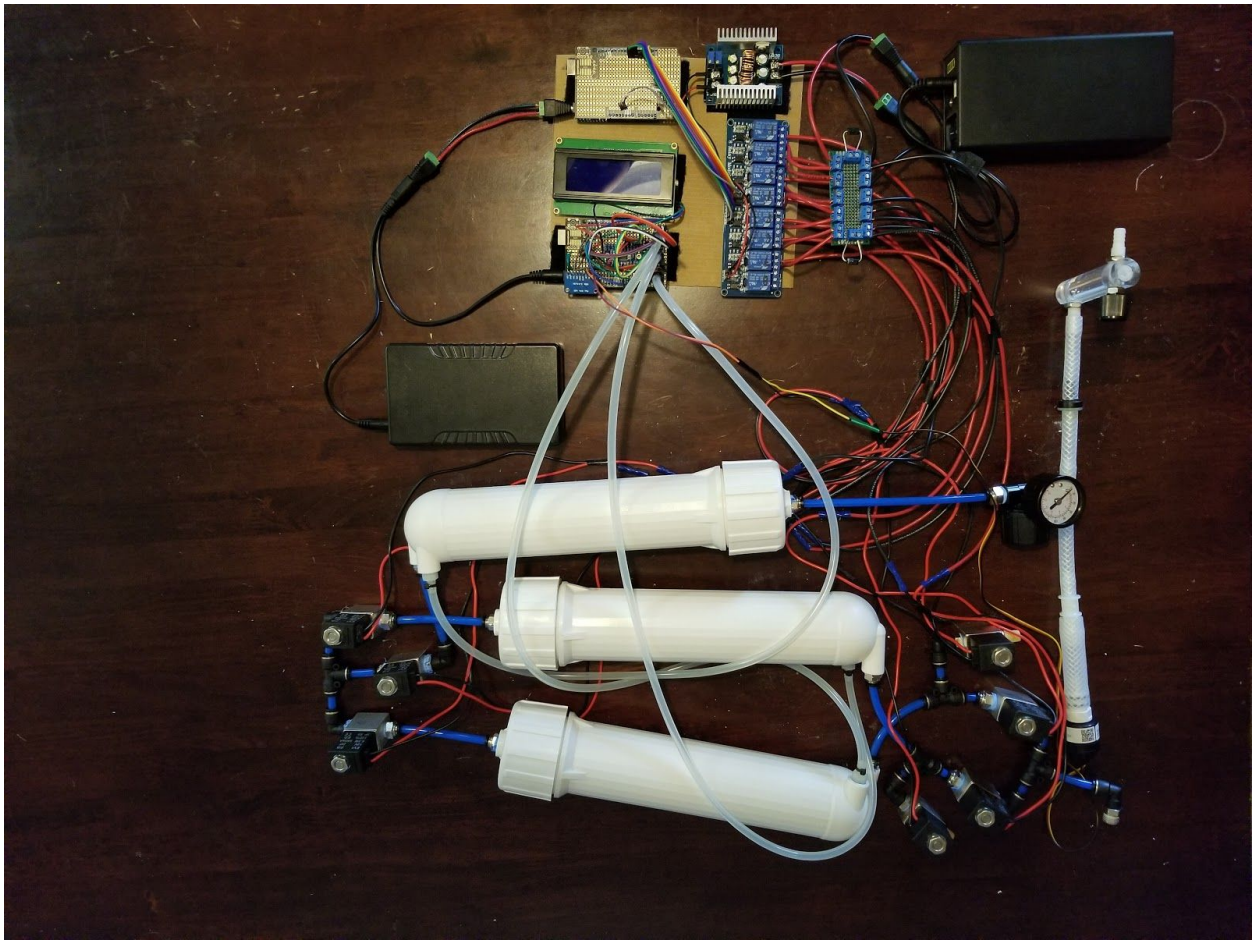


Figure 1: Full Oxygen Concentrator Setup

Timing Scheme

Cycle 1:

- Canister 1 full of molecular sieve is pressurized with air at 6 bar for 4.5 seconds while canister 2 is exhausted.

Cycle 2:

- Canister 1 full of oxygen is fed into Canister 3 (oxygen reservoir) as canister 2 continues to exhaust. This occurs for 0.4 seconds.

Cycle 3:

- Blowdown of canister 1 into canister 2 so that pressures between the two equalize. This occurs for 1.3 seconds.

Cycle 4:

- Canister 1 is exhausted as canister 2 is pressurized to 6 bar for 4.5 seconds.

The cycle repeats for each canister as nitrogen is adsorbed by the sieve and exhausted, while oxygen is fed into canister 3. This produces 90% pure oxygen at a flow rate of 3 LPM.

Oxygen Concentrator Physical System

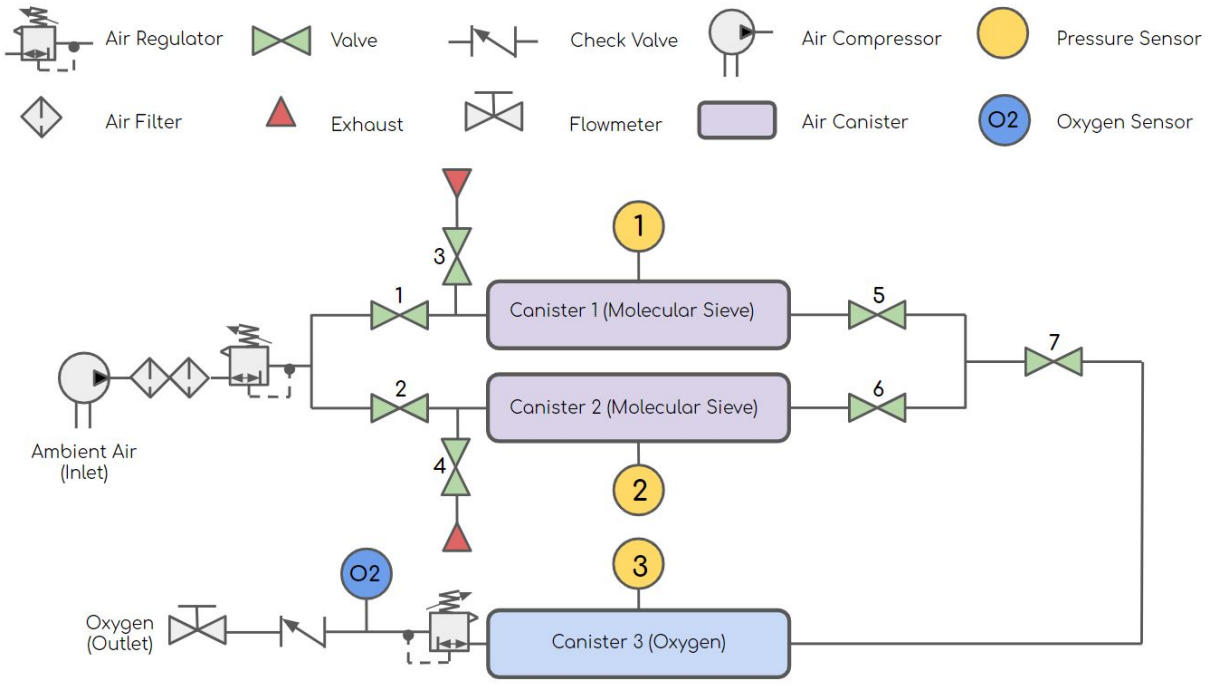


Figure 2: Oxygen Concentrator P&ID

The physical system utilizes 7 solenoid valves, 3 air canisters, and 2 air regulators to accomplish the process of pressure swing adsorption. An air compressor is used to produce the necessary pressure for nitrogen adsorption via the Zeolite molecular sieve. The compressed air is dried and filtered through a double filtration unit. The oxygen-rich air is stored in canister 3, while the nitrogen is exhausted through valves 3 and 4. Each canister's pressure is monitored with a pressure sensor and these values are displayed on the LCD screen. The oxygen produced is monitored via an oxygen sensor integrated along the outlet and is outputted to the LCD screen as well. A check valve prevents ambient air from entering the

oxygen-rich line, and the flowmeter can be adjusted to regulate the flow rate of oxygen.

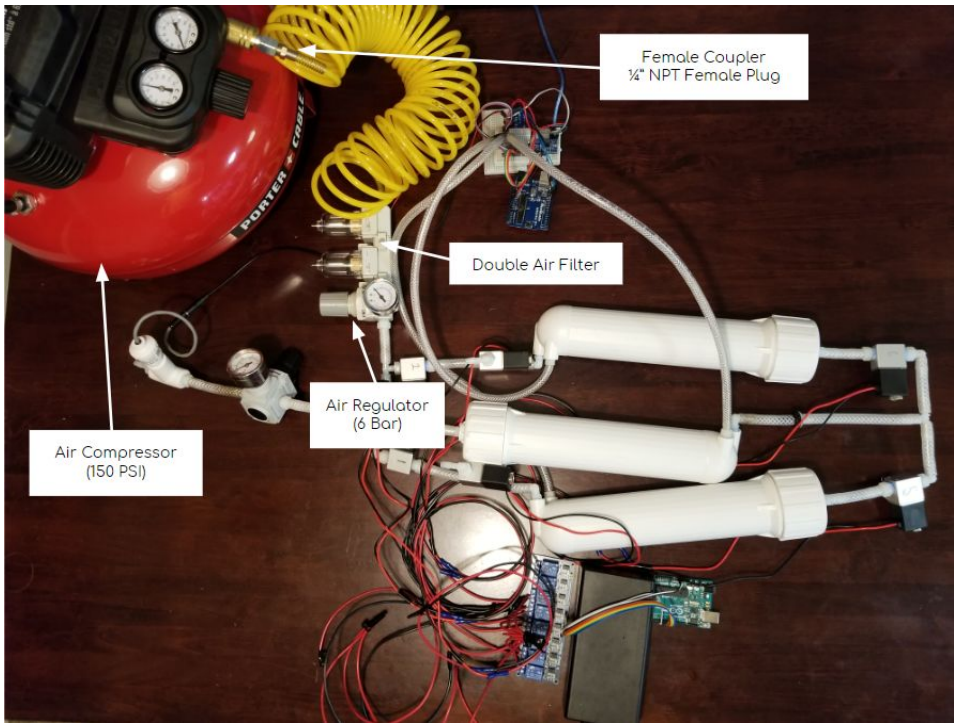


Figure 3: Compressor and Inlet
(Keep double air filter unit upright due to collection of water)

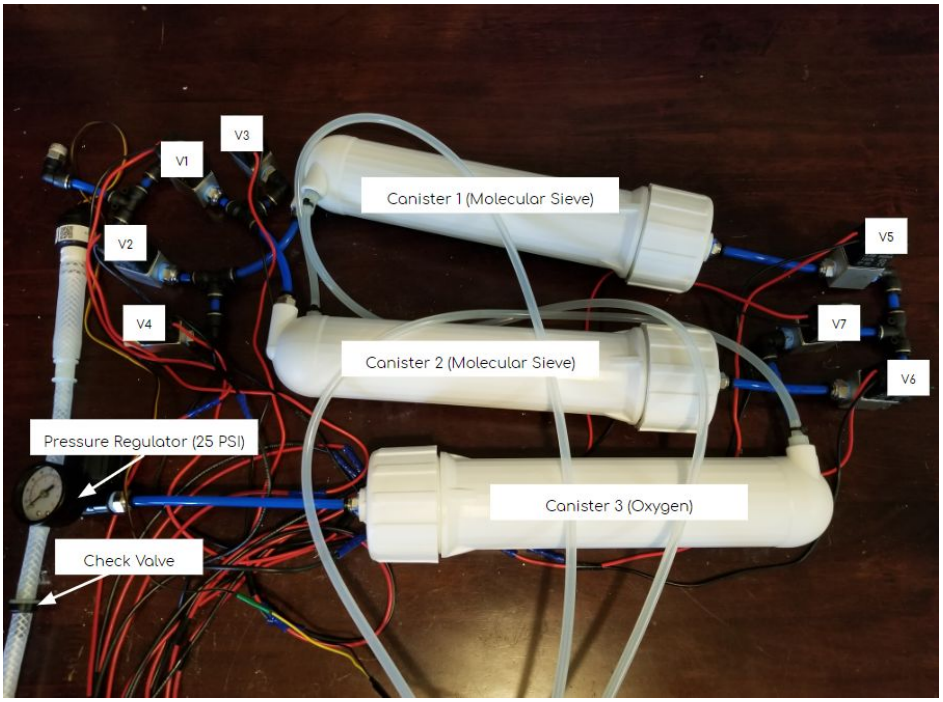


Figure 4: Valves, Canisters, and Outlet

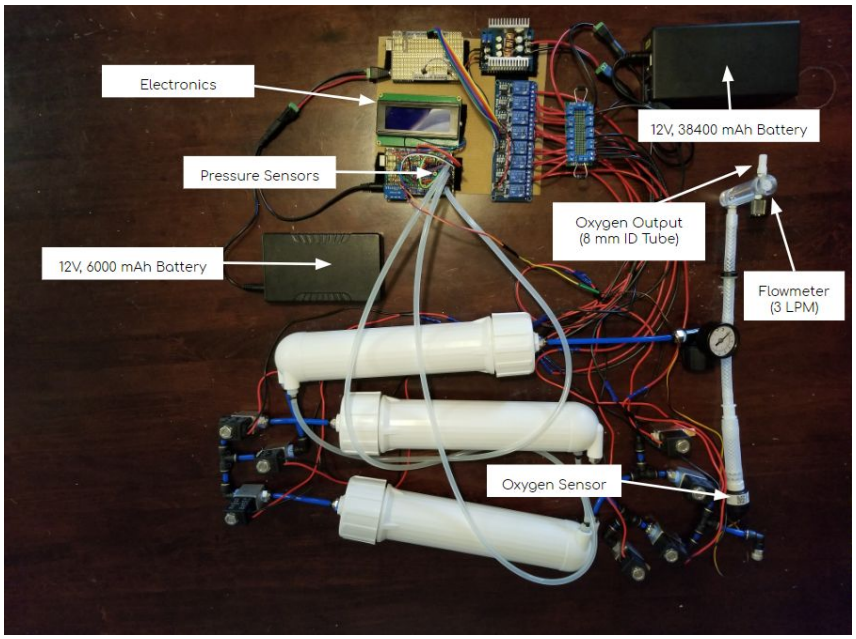


Figure 5: Flowmeter, Sensors, and Batteries

13X Molecular Sieve

The molecular sieve found in canisters 1 and 2 is Zeolite 13X. Each canister contains 500 ml of the molecular sieve which adsorbs the nitrogen from ambient air. Through testing both powder and pellets, it was found that pellets work just as well and without any fine dust introduced into the oxygen tank. The molecular sieve can be activated by baking it in the oven for 3 hours at 500 degrees Fahrenheit (260 degrees Celsius). With activation, oxygen production increases considerably.

Figure 6: Activation of Molecular Sieve (260 degrees Celsius for 3 hours)

Figure 7: 13X Pellets Stored in Sleeve in Canisters 1 and 2

Oxygen Concentrator Electrical System

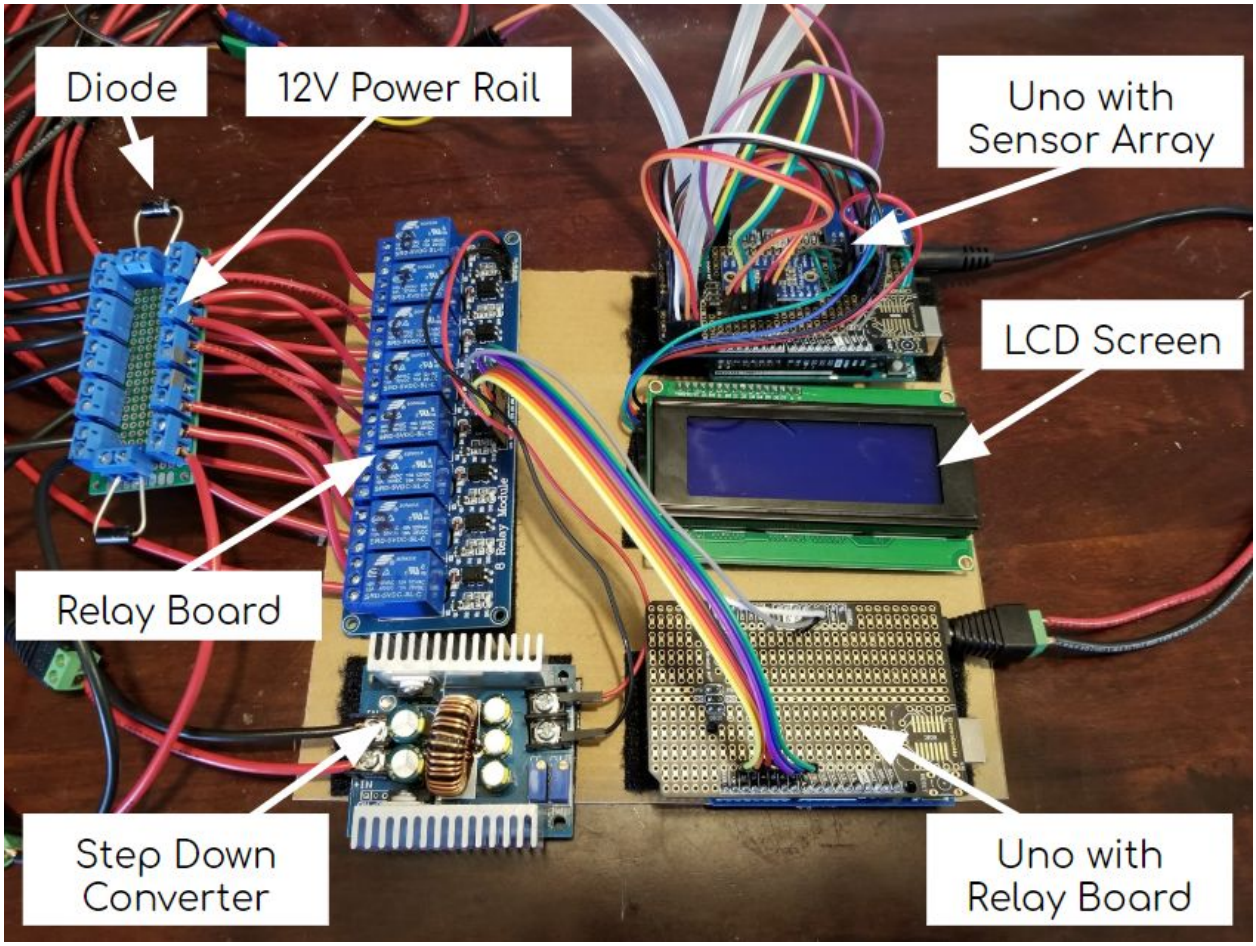


Figure 8: Oxygen Concentrator Electronics

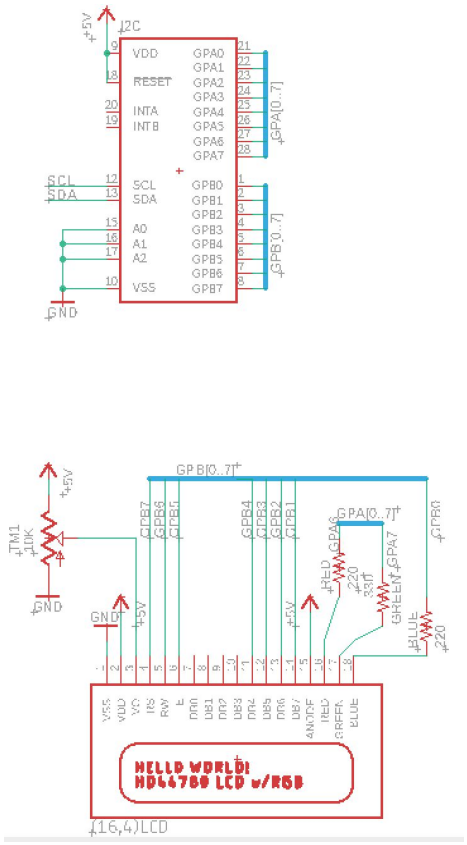


Figure 9: LCD Screen with I2C

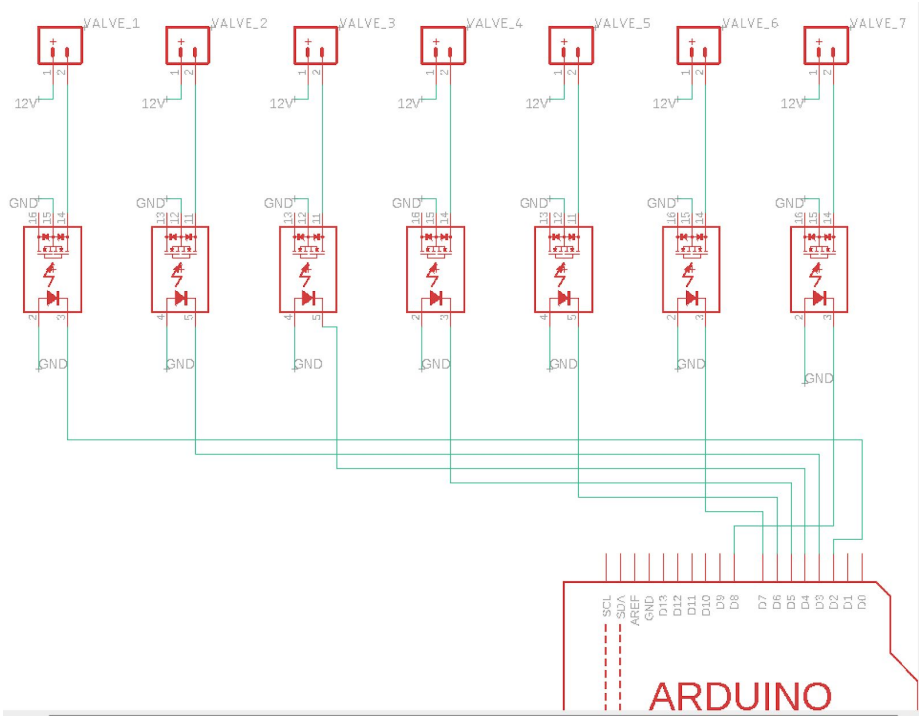


Figure 10: Arduino Uno with Relay Board

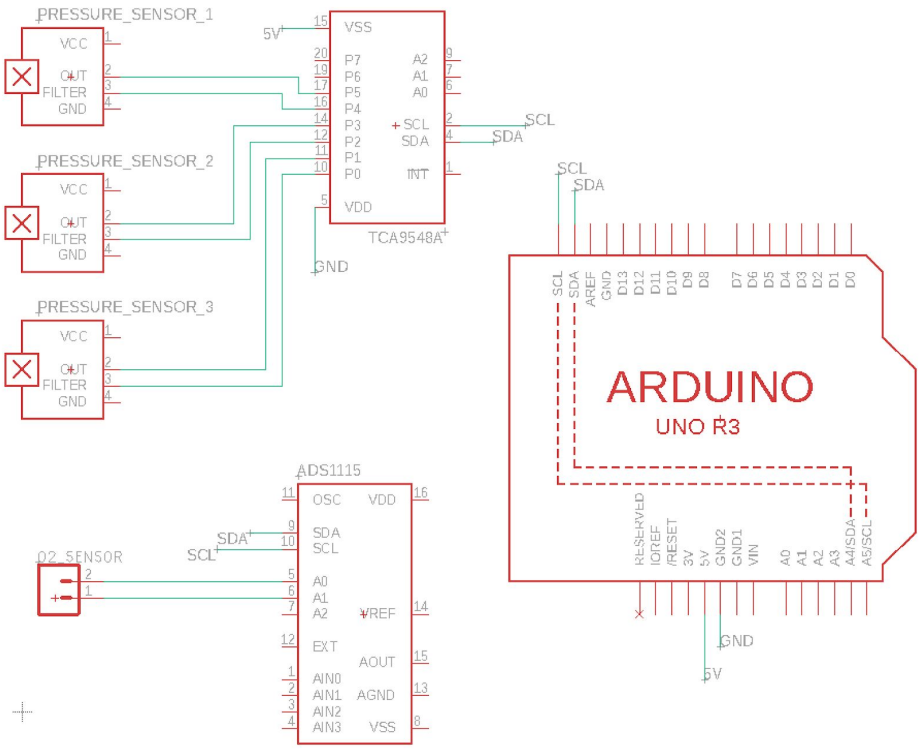


Figure 11: Arduino Uno with Sensor Array
(Multiplexer, ADC, & Pressure Sensors)

Bill of Materials for Oxygen Concentrator

Oxygen Concentrator Physical System						
Item	Unit Quantity	Description	Supplier	Link	Item Cost	Total Cost
Reverse Osmosis Membrane Housing	3	Holds pressurized air and oxygen. (500 PSI Max)	Amazon	LINK	$15.99	$47.97
Electric Solenoid Air Valve	7	Directs air within the PSA system. (¼" NPT 2-Way NC Valve, 12V, 0.54 A)	Amazon	LINK	$12.98	$90.86
Air Compressor	1	Generates compressed air for PSA system. (150 PSI, 2.6 CFM, 6-Gallon)	Amazon	LINK	$99.00	$99.00
Air Pressure Regulator	1	Regulates outlet pressure of oxygen. (¼" NPT, 0-2 Bar)	Amazon	LINK	$29.99	$29.99
Oxygen Flowmeter	1	Regulates outlet flow of oxygen. (0-10 LPM, 8 mm ID Tubing)	Amazon	LINK	$13.93	$13.93
Double Air Filter and Regulator Unit	1	Dries and filters compressed air. (¼" NPT, 0-145 PSI)	Amazon	LINK	$27.99	$27.99
Air 3-Way Manifold	1	Connects air compressor to O2 concentrator. (¼" Industrial Coupler)	Home Depot	LINK	$15.98	$15.98
Air Tool Accessory Kit	1	Interfacing for air compressor. -(2) ¼" NPT Male Plugs, (1) ¼" NPT Female Plug, (1) ¼" NPT Female Coupler	Home Depot	LINK	$11.98	$11.98
Push to Connect Air Fittings (10 Pack)	6	Fittings used for valves and air regulators. (¼" Tube OD, ¼" NPT Male)	Amazon	LINK	$13.99	$8.39

Push to Connect Air Fittings (10 Pack)	6	Fittings used for air tanks. (¼" Tube Od, ⅛" NPT Male)	Amazon	LINK	$13.99	$8.39
Push to Connect Air Fittings - 90 Degree (10 Pack)	6	Fittings used for valves and air regulators. (¼" Tube OD, ¼" NPT Male)	Amazon	LINK	$15.99	$9.59
Pneumatic Air Tubing	10 m	Tubing used for PSA system. (¼" OD)	Amazon	LINK	$12.99	$12.99
Barbed Tube Fitting Tee Adapter (10 Pack)	1	Connector used for air regulator and oxygen outlet. (¼" Tube ID, ¼" NPT Male)	McMaster-Carr	LINK	$8.29	$0.83
Barbed Tube Fitting Reducer (10 Pack	1	Connector used for oxygen sensor. (½" to ¼" Tube ID)	McMaster-Carr	LINK	$6.60	$0.66
Barbed Check Valve	1	Prevents atmospheric backflow. (¼" Tube ID, 0.5 PSI min. pressure)	McMaster-Carr	LINK	$4.05	$4.05
High Pressure Tubing	25 ft	Tubing for barbed pressure sensors. (⅛" ID, 21/64" OD)	McMaster-Carr	LINK	$17.50	$17.50
High Pressure Tubing	10 ft	Tubing for outlet of oxygen. (¼" ID, 7/16" OD)	McMaster-Carr	LINK	$6.90	$6.90
High Pressure Tubing	10 ft	Tubing for oxygen sensor. (½" ID, ¾" OD)	McMaster-Carr	LINK	$11.20	$11.20
Pantyhose (2 Pack)	1 Pair	Sleeve used to contain Zeolite in canisters.	Walmart	N/A	$0.94	$0.47
Zip Ties (150 Pack)	2	Used for tying Zeolite sleeves.	Amazon	LINK	$8.98	$0.12
13X Molecular Sieve	6.5 lb	Zeolite pellets used to adsorb nitrogen.	Amazon	LINK	$35.00	$35.00
Total Cost						$453.79

Oxygen Concentrator Electrical System						
Item	Unit Quantity	Description	Supplier	Link	Item Cost	Total Cost
Arduino Uno	2	Microcontroller for oxygen concentrator. (7-20V)	Amazon	LINK	$12.99	$25.98
Arduino Uno Shield Board (3 Pack)	2	Expansion protoboard for microcontroller.	Amazon	LINK	$14.99	$9.99
LCD Module Shield	1	LCD screen that monitors pressures and oxygen production. (5V, I2C)	Amazon	LINK	$12.99	$12.99
8 Channel Relay Module	1	Relay module that toggles solenoid valves for PSA system. (5V)	Amazon	LINK	$8.99	$8.99
Step Down Buck Converter	1	Steps down 12V from power supply to 5V. (6V-40V to 1.2V-35V Converter, 20A)	Amazon	LINK	$14.44	$14.44
Analog to Digital Converter	1	ADC for amplifying signal from oxygen sensor. (16 Bit, 5V, I2C)	Amazon	LINK	$9.99	$9.99
I2C Multiplexer	1	Multiplexer used for pressure sensors with the same I2C address. (5V, I2C)	Amazon	LINK	$11.84	$11.84
Pressure Sensor	3	Barbed pressure sensor for air canisters. (0-100 PSI, 5V, I2C)	Digikey Electronics	LINK	$32.32	$96.96
Oxygen Sensor	1	Sensor for measuring oxygen production. (Output Signal: 9-13 mV in ambient air, 29 psi max)	Mouser Electronics	LINK	$58.88	$58.88
Screw Terminal Blocks (60 Pack)	12	Streamlines mounting for thicker gauge wire. (2 Pin, 5 mm Pitch)	Amazon	LINK	$8.69	$1.74
PCB Board (30 Pack)	1	Streamlines mounting and 12V power rail.	Amazon	LINK	$10.99	$0.36

		(30 x 70 mm)				
Power Connector Jacks (10 Male & 10 Female Pack)	4 Male	Connectors for power supply to electronics. (5.5 mm x 2.1 mm M&F)	Amazon	LINK	$7.49	$1.50
Barrel Plug Splitter	1	Male Plug to 2 Female Jack (5.5 mm x 2.1 mm)	Amazon	LINK	$9.96	$9.96
Barrel Plug Splitter (2 Pack)	1	Female Plug to 2 Male Jack (5.5 mm x 2.1 mm)	Amazon	LINK	$5.59	$2.80
Dupont Cables (120 Pack)	N/A	M to F, M to M, F to F jumper wires for connecting sensors.	Amazon	LINK	$5.79	$5.79
Jumper Wires (560 Pack)	N/A	Assorted jumper wires for wiring protoboards	Amazon	LINK	$10.99	$10.99
Red 18 AWG Wire (25 Feet)	N/A	Wire used for high current loads of solenoid valves.	McMaster-Carr	LINK	$5.56	$5.56
Black 18 AWG Wire (25 Feet)	N/A	Wire used for high current loads of solenoid valves.	McMaster-Carr	LINK	$5.56	$5.56
Diode Assortment Kit (240 Pack)	2	Used to counter back EMF from the solenoid valves. (Schottky Diode 40V, 3A)	Amazon	LINK	$9.99	$0.08
12V, 38400 mAh Battery	1	Battery used for powering solenoid valves.	Amazon	LINK	$89.99	$89.99
12V, 6000 mAh Battery	1	Battery used for powering electronics.	Amazon	LINK	$35.99	$35.99
12V, 10A Power Supply	1	Power supply used for powering solenoid valves.	Amazon	LINK	$23.99	$23.99
12V, 5A Power Supply	1	Power supply used for powering electronics.	Amazon	LINK	$11.99	$11.99
Type C Power Plug Adapter	2	Plug adapter from Type B to Type C.	Amazon	LINK	$12.99	$25.98
Total Cost						$482.34

Ventilator

Our ventilator prototype is made from commercial off the shelf components coupled with custom 3D printed parts. Taking into account both patient comfort and healthcare worker safety, we have included filtration, humidification, and sterilization units. Our integrated sensors accurately measure pressure, humidity and oxygen levels, and tidal volume which allows for reliable and safe ventilation. This coupled with our LCD screen and user friendly GUI allows medical professionals to easily and effectively operate our ventilator unit.

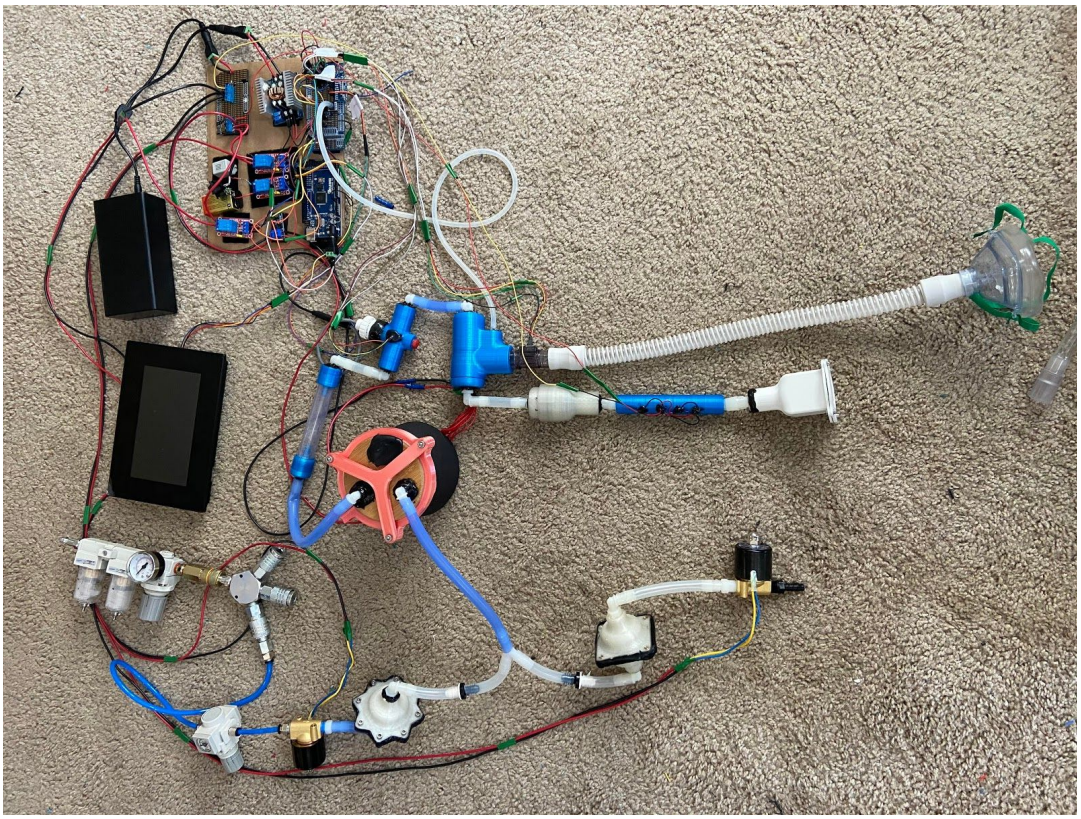


Figure 12: Full Ventilator Setup

Ventilator Physical System

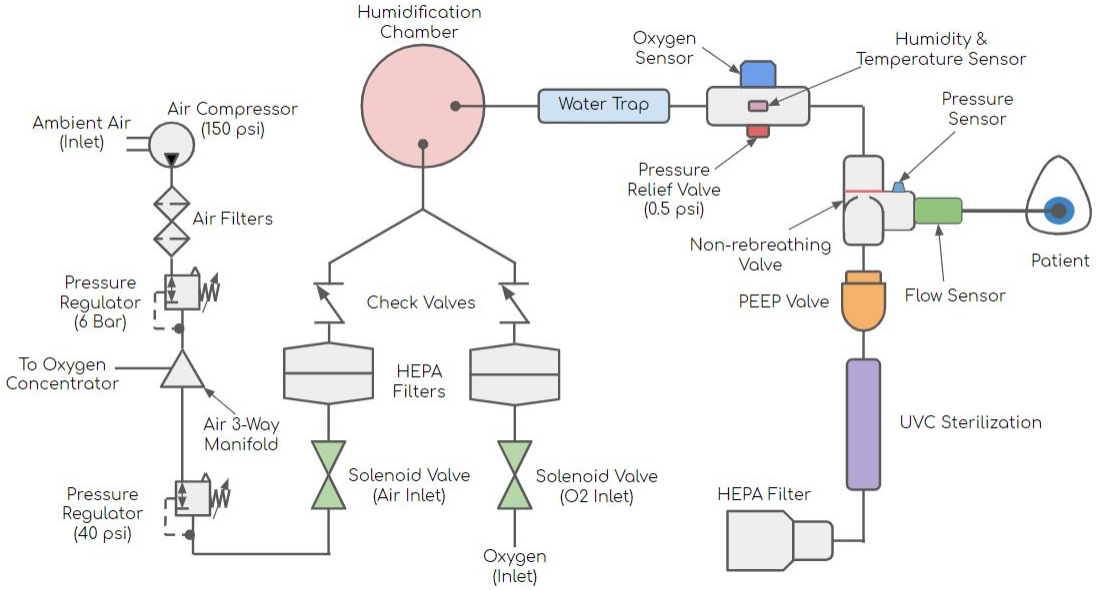


Figure 13: Ventilator P&ID

Our ventilator prototype uses pressure-regulated compressed air to provide consistent and reliable ventilation. HEPA filters are incorporated for both inlets of ambient air and oxygen. These feed into a temperature controlled humidity chamber in which the dry air becomes humidified to maximize patient comfort. The inline water trap collects excess condensation and moisture. A non-rebreathing valve is utilized to redirect air going in and out of the patient's lungs. Our ventilator flow circuit, including our custom adjustable PEEP valve, were created with the help of additive manufacturing techniques. Healthcare worker safety is also taken into account in our design which can be seen in our unique sterilization components. An exhaust HEPA filter and UVC LED array is built into the outlet of the ventilator circuit to capture and sterilize any particles coming from the patient's lungs.

In addition to that, our system of integrated sensors is able to detect static pressure in the flow circuit, humidity and temperature, oxygen concentration, as well as tidal volume upon inspiration, even at very small flow rates. This allows for accurate monitoring of ventilation.

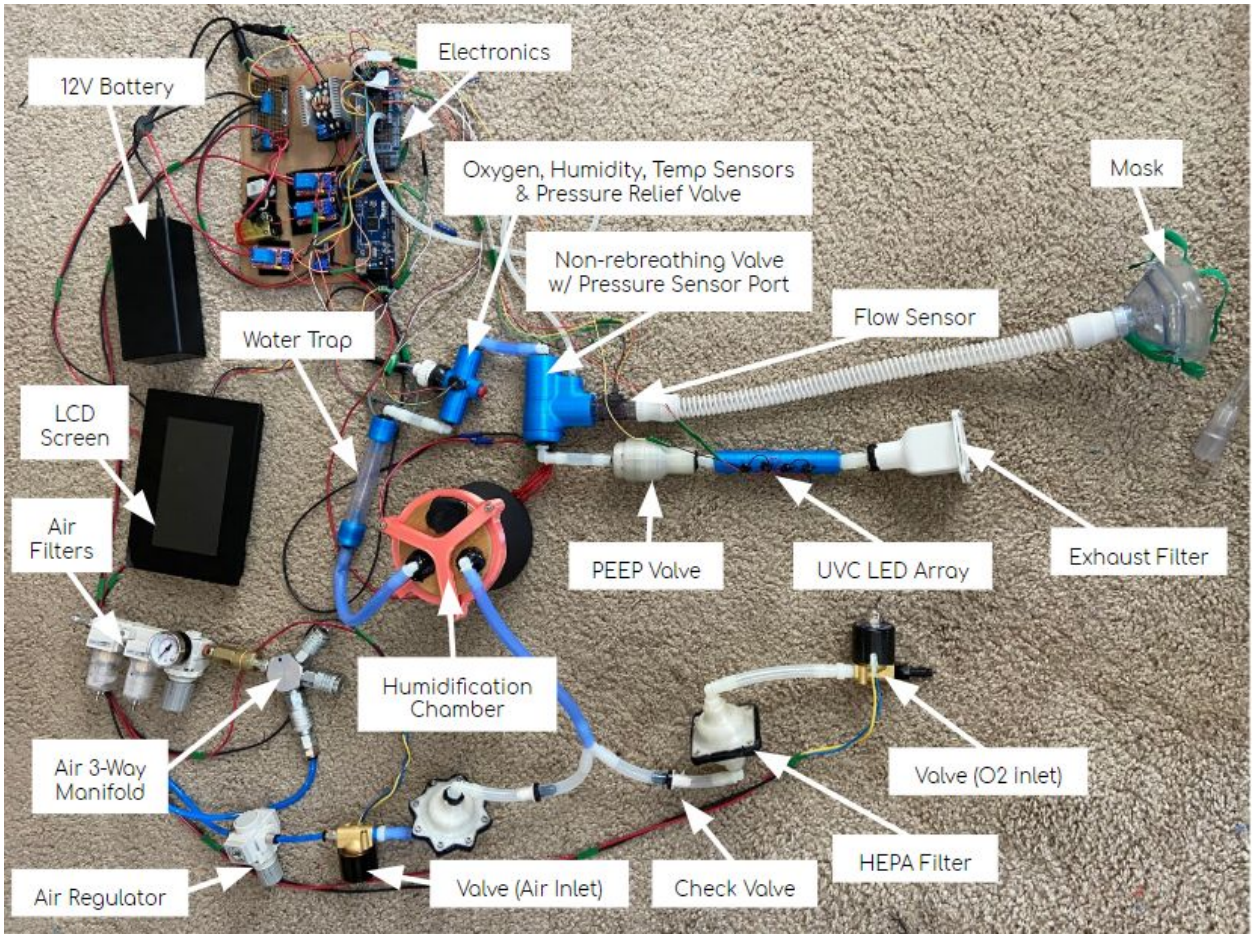
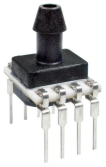
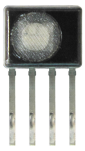
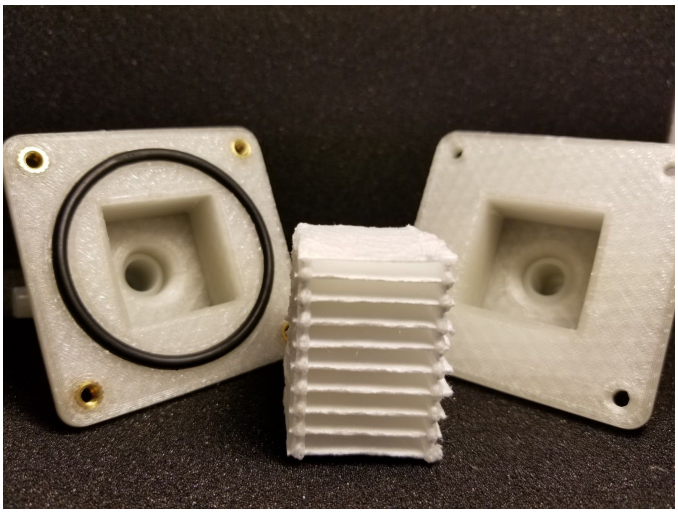


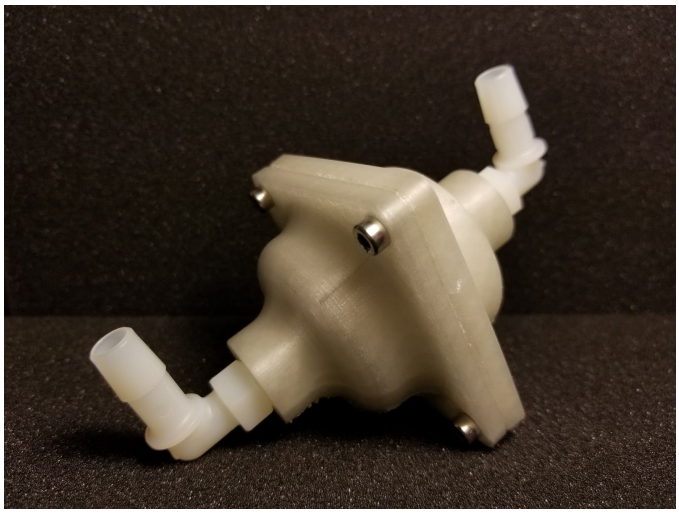
Figure 14: Ventilator Flow Circuit

Integrated Sensors

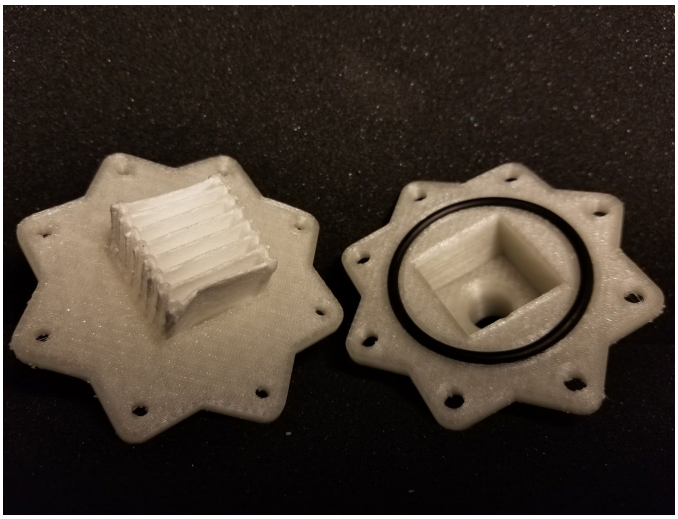
Pressure Sensor - Honeywell SSCDANN100PG5A5		- 0-100 PSI - 5V - I2C
Oxygen Sensor - Maxtec MAX-13C		- 0-100% O2 - 13.0-17.0 mV (Ambient Air) - 25 psi (Max pressure) - Interfaces w/ Analog to Digital Converter
Flow Sensor - Sensiron SFM3200-250		- -100-250 LPM - 5V - I2C
Humidity & Temperature Sensor - Honeywell HIH8121-021-001		- 0-100% RH - -40-125 °C - Hydrophobic Filter - 5V - I2C
UVC LED Array - American Opto Plus L944-UV265-2-20 x4		- 265 nm - 6.5 V, 30 mA - Sterilization of patient expiratory line

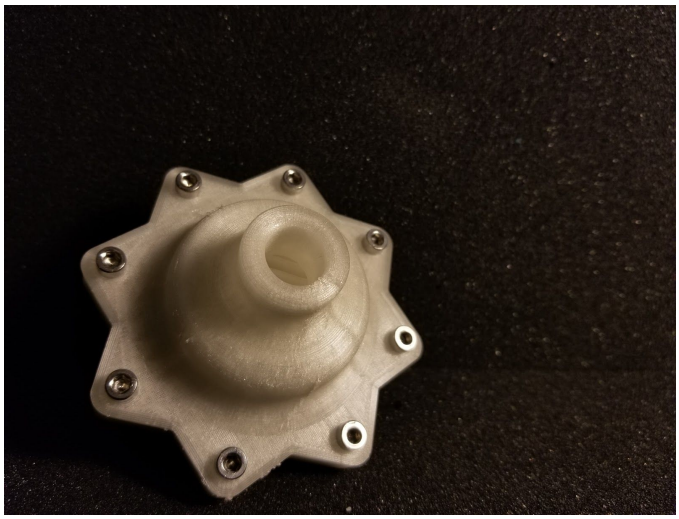
Custom 3D Printed Parts



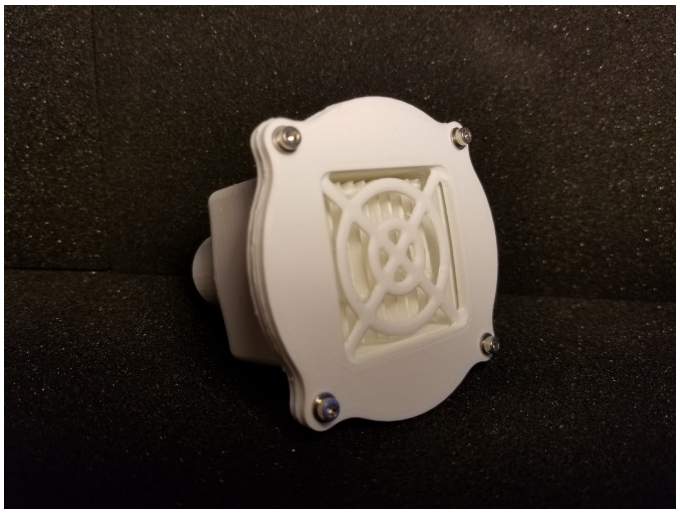


Figures 15 & 16: HEPA Filter from Oxygen Concentrator

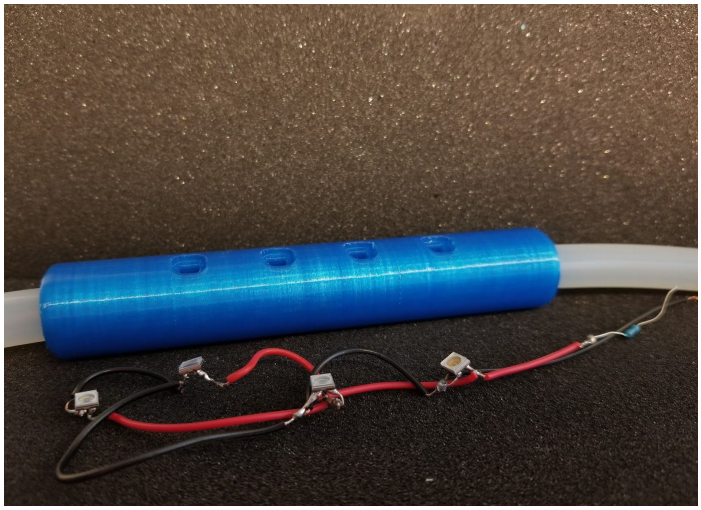


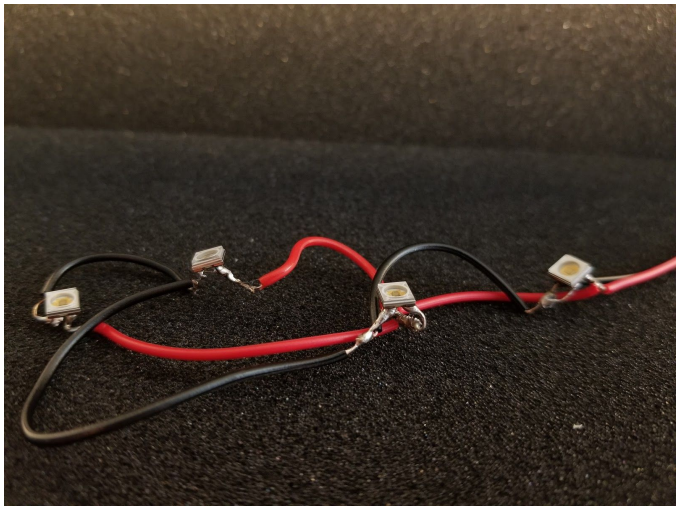


Figures 17 & 18: HEPA Filter from Air Compressor



Figures 19 & 20: Exhaust Filter (HEPA)





Figures 21 & 22: UVC LEDs Array for Sterilizing Expired Air

Figure 23: PEEP Valve

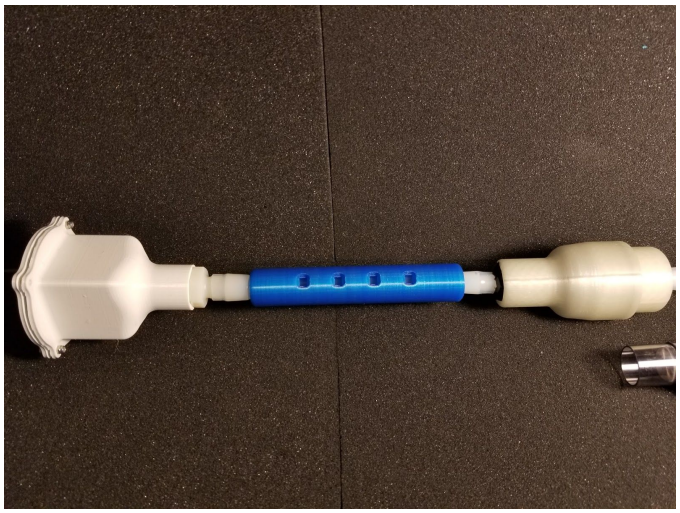
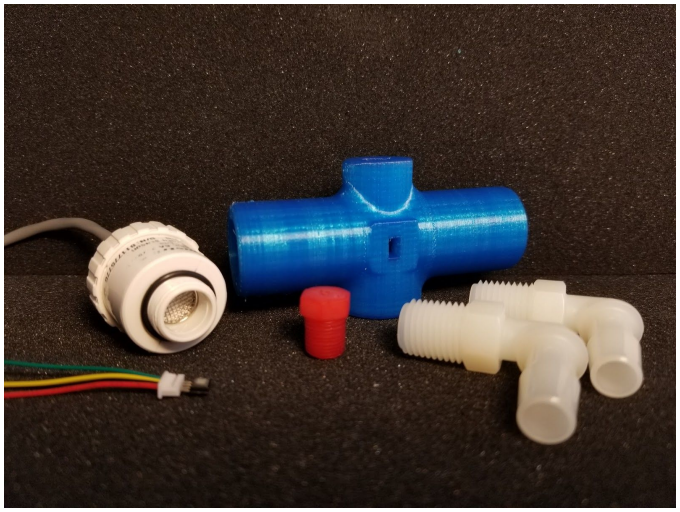
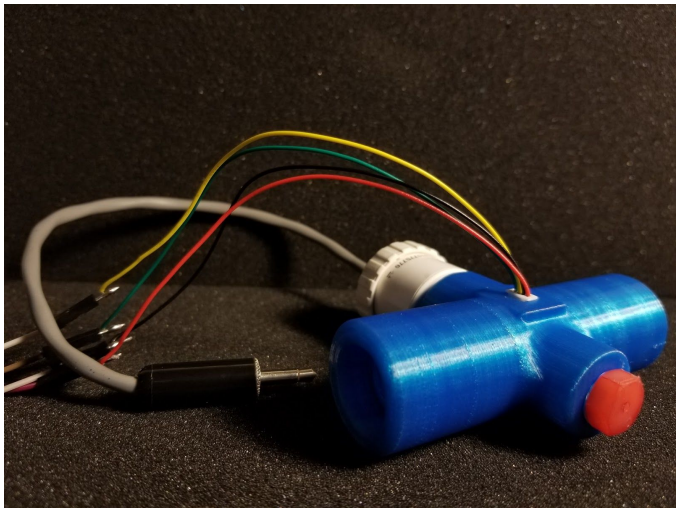


Figure 24: Expiration Line





Figures 25 & 26: Connector for Oxygen Sensor, Temperature/Humidity Sensor, and Pressure Relief Valve

Figures 27 & 28: Non-rebreathing Valve

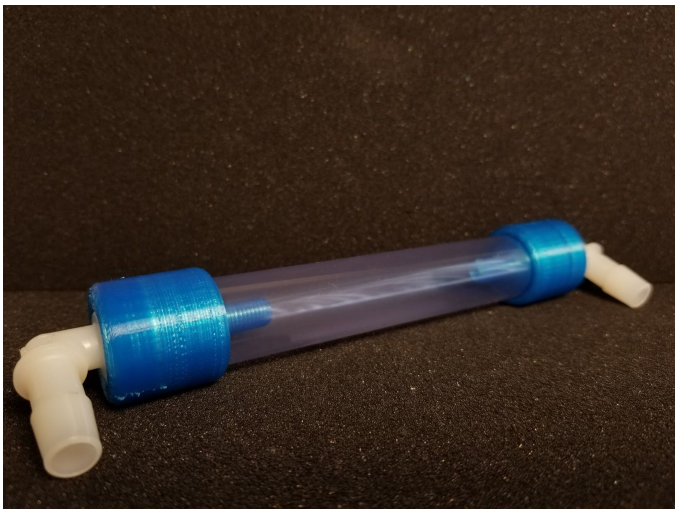


Figure 29 & 30: Water Trap

Figures 31 & 32: Humidification Chamber w/ Heater Elements
(Water should be filled to top edge of heater element)

- 100% RH @ 34 °C, adds moisture and warmth to inspiratory air, and improves patient comfort and compliance

Ventilator Electrical System

All of the following circuits should be wired to the Arduino Mega 2560 with a 5V, 9V, and 12V power supply as directed.

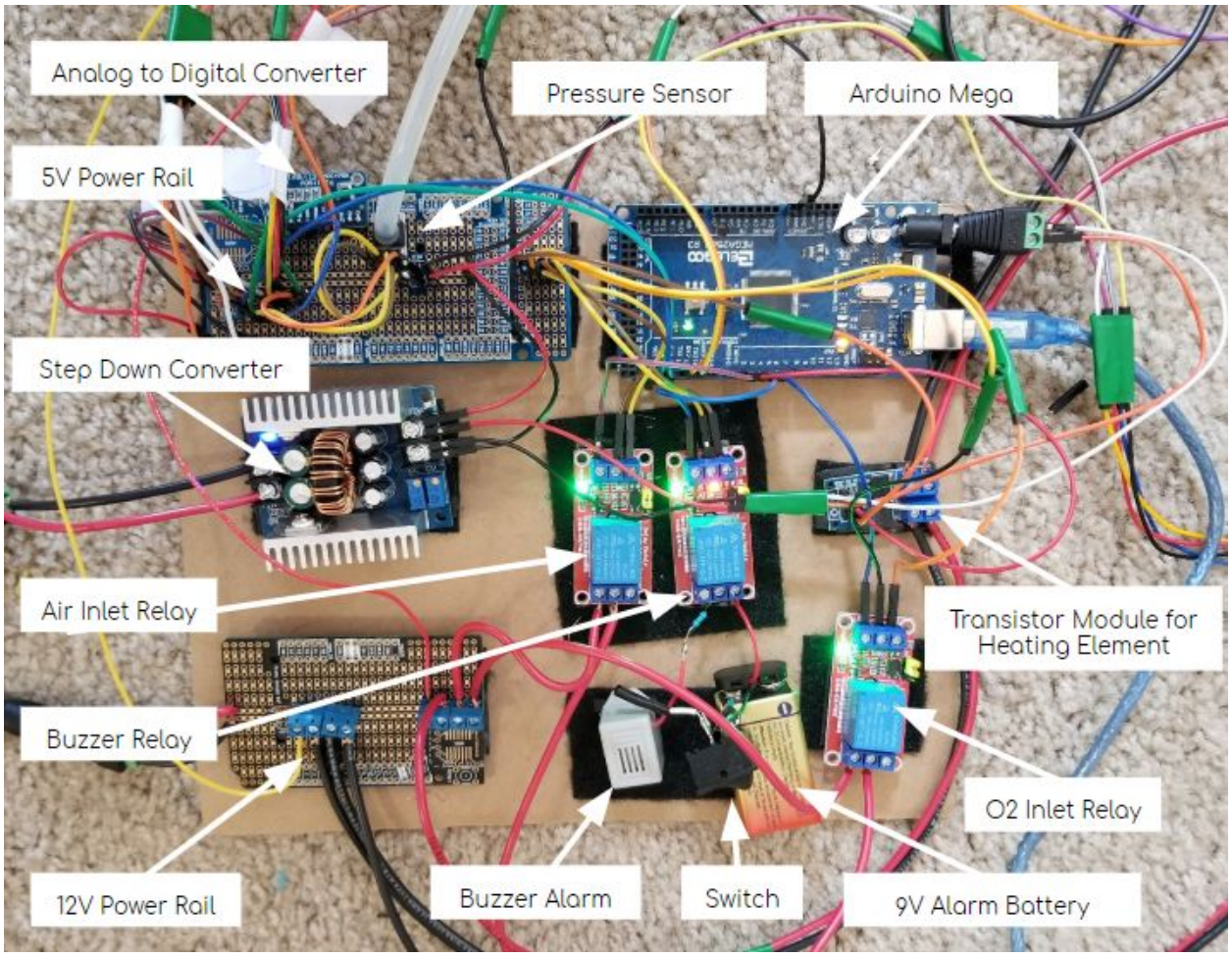


Figure 33: Ventilator Electronics

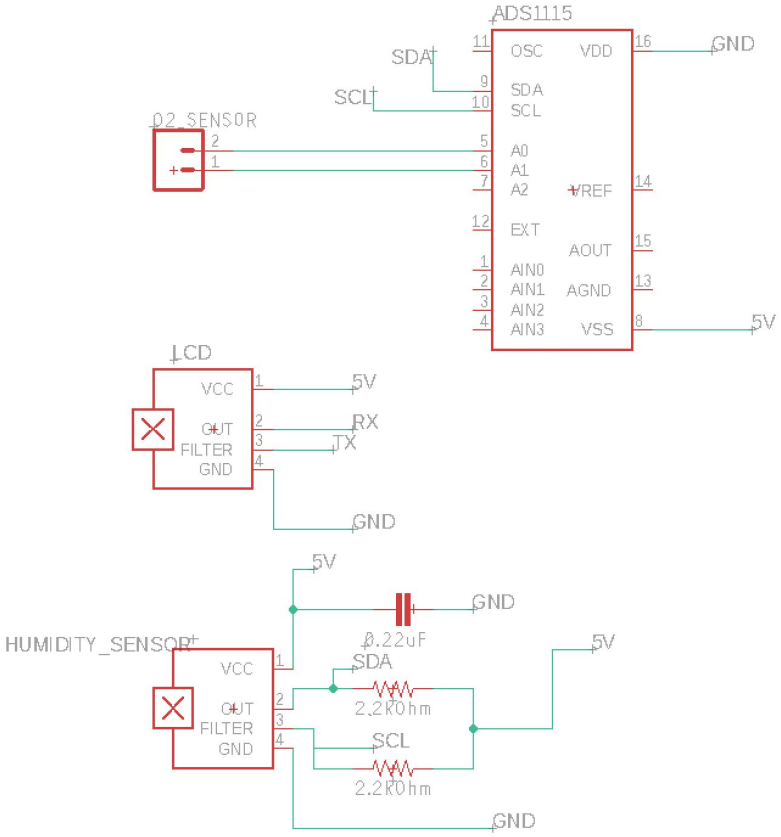


Figure 34: LCD and Sensors

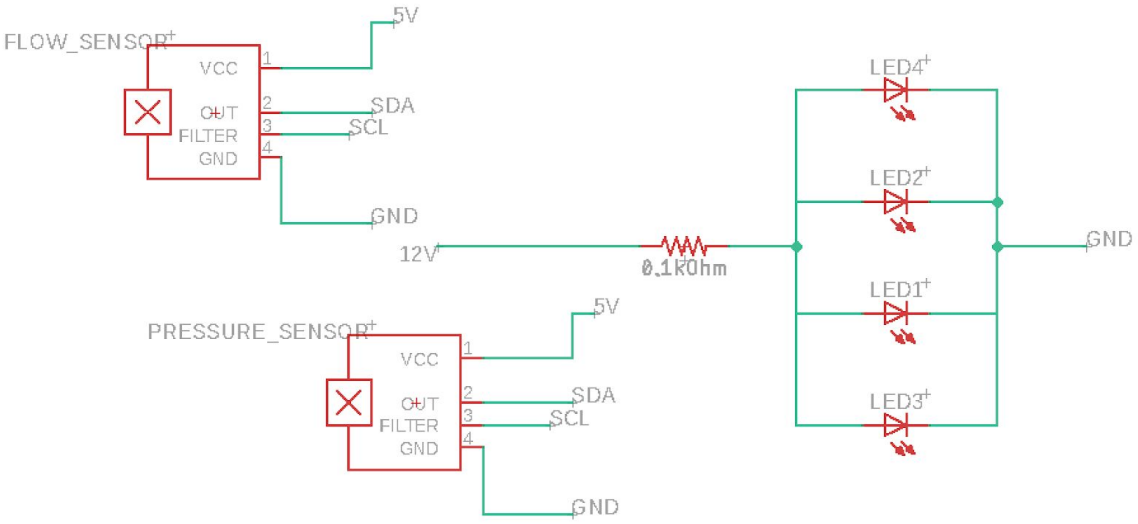


Figure 35: UVC LED Array and Sensors

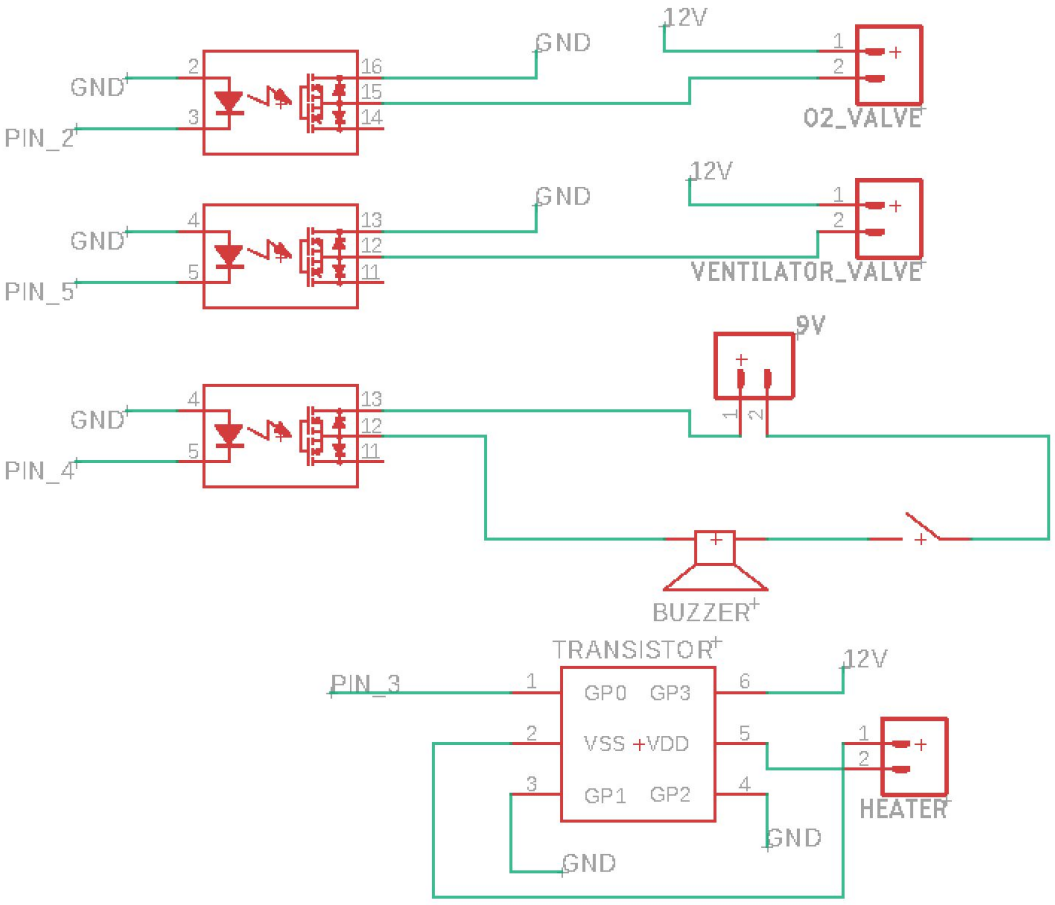


Figure 36: Relays and Transistor Module

Bill of Materials for Ventilator

Ventilator Physical System						
Item	Unit Quantity	Description	Supplier	Link	Item Cost	Total Cost
CPAP Tubing	1	Tubing going to patient. (Length 18 in, 22 mm ID)	Amazon	LINK	$11.75	$11.75
Resuscitation Mask (CPR Mask Kit)	1	Mask for the patient. (Adult)	Amazon	LINK	$9.95	$9.95
Electric Solenoid Air Valve	2	Valve for inlet oxygen and compressed air. (¼" NPT, NC, 12V, 3.5A)	Amazon	LINK	$10.99	$21.98
Air Regulator	1	Air regulator for inlet compressed air. (¼" NPT Female, 145 psi max pressure)	McMaster-Carr	LINK	$30.96	$30.96
HEPA Filter	1	HEPA filter used for filtering fine particles. (Captures particles as small as 0.3 microns)	Amazon	LINK	$19.95	$19.95
Food Storage Jar w/ Airtight Seal	1	Vessel used for humidification chamber. (18.6 fluid ounces)	Amazon	LINK	$13.77	$13.77
Water Trap Tube (2 Pack)	1	Tube used for water trap collector.	Amazon	LINK	$6.99	$3.50
Check Valve (2 Pack)	2	Check valves for O2 and air lines. (⅜" OD, 5 cm H2O min pressure)	Amazon	LINK	$9.98	$9.98
Silicone Rubber Sheet	1	Rubber flap for non-rebreathing valve. (0.020" Thick, 6" x 6", 35A Hardness)	McMaster-Carr	LINK	$14.20	$14.20
Metric O-Ring Assortment (419 Pack)	4	O-Rings used for airtight seals. -(2) R-32, (2) R-22	Amazon	LINK	$15.08	$0.14

Skewer Springs (10 Pack)	1	Spring used for PEEP valve.	Amazon	LINK	$7.99	$0.80
Barbed Tube Fitting (10 Pack)	4	Connector pieces for 3D printed components. (⅜" ID Tube, ¼" NPT Male)	McMaster-Carr	LINK	$6.84	$2.74
Barbed Tube Fitting Elbow (10 Pack) x2	11	Connector pieces for 3D printed components. (⅜" ID Tube, ¼" NPT Male)	McMaster-Carr	LINK	$11.05	$12.16
Barbed Tube Fitting Wye Connector (10 Pack)	1	Connector piece for inlet O2 and compressed air to humidification chamber. (⅜" Tube ID)	McMaster-Carr	LINK	$16.40	$1.64
Barbed Tube Fitting	1	Connector for oxygen tubing. (8 mm ID Tube, ¼" NPT Male)	McMaster-Carr	LINK	$2.47	$2.47
Barbed Tube Fitting (10 Pack)	1	Fitting for barbed pressure sensor. (⅛" ID Tube, ¼" NPT)	McMaster-Carr	LINK	$8.68	$0.87
Pressure Relief Valve	1	Pressure relief valve for ventilator circuit. (⅛" NPT, 0.5 psi max pressure)	McMaster-Carr	LINK	$19.89	$19.89
Silicone Rubber Tubing (5 feet)	1	Tubing for ventilator circuit. (⅜" ID, ½" OD, Semi-Clear White)	McMaster-Carr	LINK	$8.05	$8.05
Silicone Rubber Tubing (5 feet)	1	Tubing for ventilator circuit. (⅜" ID, ½" OD, Semi-Clear Blue)	McMaster-Carr	LINK	$8.05	$8.05
Plastic Tubing (50 feet)	1	Tubing for barbed pressure sensor. (2 mm ID, 4 mm OD)	McMaster-Carr	LINK	$13.50	$13.50
O-Ring (50 Pack)	2	O-rings used for airtight seal for humidification chamber. (3 3/16" OD, 3" ID)	McMaster-Carr	LINK	$11.65	$0.47
Rubber Foam Insulation Sheet	1	Foam insulation used for heater elements of humidification chamber. (36" x 48", 220	McMaster-Carr	LINK	$20.61	$20.61

		degrees C max temperature)				
PLA 3D Printer Filament Spool	1	Filament used for 3D printed components. (1.75 mm, 1 kg spool)	Amazon	LINK	$28.99	$28.99
M5 Socket Head Screw (100 Pack)	4	Used for fastening humidification chamber. (M5, 16 mm long)	McMaster-Carr	LINK	$11.29	$0.45
M5 Heat-Set Inserts (50 Pack)	4	Used for fastening humidification chamber. (M5, 6.7 mm long)	McMaster-Carr	LINK	$12.42	$0.99
M2.5 Socket Head Screw (100 Pack)	16	Used for fastening HEPA filters. (M2.5, 8 mm long)	McMaster-Carr	LINK	$5.42	$0.87
M2.5 Heat-Set Inserts (100 Pack)	16	Used for fastening HEPA filters. (M2.5, 3.4 mm long)	McMaster-Carr	LINK	$11.19	$1.79
Total Cost						$260.52

Ventilator Electrical System						
Item	Unit Quantity	Description	Supplier	Link	Item Cost	Total Cost
Arduino Mega	1	Microcontroller for ventilator. (7-20V)	Amazon	LINK	$15.99	$15.99
Arduino Mega Shield Board (2 Pack)	1	Expansion protoboard for microcontroller.	Amazon	LINK	$14.99	$7.50
Arduino Uno Shield Board (3 Pack)	1	Expansion protoboard for microcontroller.	Amazon	LINK	$14.99	$4.99
7" LCD Display Panel	1	Capacitive touch LCD display for the ventilator.	Amazon	LINK	$129.85	$129.85
32 GB Micro SD Card (5 Pack)	1	Micro SD card used for uploading GUI to LCD display. (32 GB)	Amazon	LINK	$25.98	$5.20
Step Down Buck Converter	1	Steps down 12V from power supply to 5V. (6V-40V to 1.2V-35V Converter, 20A)	Amazon	LINK	$14.44	$14.44
1 Channel Relay Board (10 Pack)	3	Relay module that toggles solenoid valves for ventilator. (5V)	Amazon	LINK	$12.99	$3.90
High-Power Transistor (10 Pack)	1	Transistor module that pulse width modulate voltage to heater blanket. (5V-36V, 30A)	Amazon	LINK	$22.99	$2.30
Analog to Digital Converter	1	ADC for amplifying signal from oxygen sensor. (16 Bit, 5V, I2C)	Amazon	LINK	$9.99	$9.99
Pressure Sensor	1	Barbed pressure sensor for ventilator. (0-100 PSI, 5V, I2C)	Digikey Electronics	LINK	$32.32	$32.32
Oxygen Sensor (Maxtec Max-13C)	1	Oxygen sensor for ventilator. (13.0-16.5 mV in ambient air, 18 psi max pressure)	Cables and Sensors	LINK	$92.00	$92.00
3.5 mm Female Barrel Jack	1	Used for connecting oxygen sensor.	Amazon	LINK	$7.99	$3.99

(2 Pack)						
Flow Sensor	1	Used for determining tidal volume. (5V, I2C, Flow Range: 250 LPM, 15.5 psi max pressure)	Digikey Electronics	LINK	$144.00	$144.00
Humidity Sensor	1	Used for measuring humidity and temperature. (5V, I2C, w/ Filter)	Mouser Electronics	LINK	$11.25	$11.25
0.22 uF Capacitor	1	Used for humidity circuit.	Digikey Electronics	LINK	$0.35	$0.35
UVC LED	4	LEDs for UVC sterilization line. (6.5V, 30 mA, 120 degree viewing angle, 272 nm wavelength)	Digikey Electronics	LINK	$7.04	$28.16
Resistors (1050 Pack)	3	Used for UVC and humidity circuits. - (1) 0.1 kOhm, (2) 2.2 kOhm	Amazon	LINK	$11.99	$0.03
Heater Element (4 Pack) x2	5	Heating element with adhesive for humidity chamber. (25 mm x 50 mm, 12V, 7W)	Amazon	LINK	$15.99	$19.99
Buzzer (5 Pack)	1	Buzzer serves as the alarm. (3-24V)	Amazon	LINK	$7.99	$1.60
On/Off Rocker Switch (16 Pack)	1	Switch for the buzzer circuit. (125V, 10A)	Amazon	LINK	$4.99	$0.31
Screw Terminal Blocks (60 Pack)	4	Streamlines mounting for thicker gauge wire. (2 Pin, 5 mm Pitch)	Amazon	LINK	$8.69	$0.58
Power Connector Jacks (10 Male & 10 Female Pack)	3 Male	Connectors for power supply to electronics. (5.5 mm x 2.1 mm M&F)	Amazon	LINK	$7.49	$1.12
Barrel Plug Splitter	1	Male Plug to 2 Female Jack (5.5 mm x 2.1 mm)	Amazon	LINK	$9.96	$9.96
Dupont Cables (120 Pack)	N/A	M to F, M to M, F to F jumper wires for	Amazon	LINK	$5.79	$5.79

		connecting sensors.				
Jumper Wires (560 Pack)	N/A	Assorted jumper wires for wiring protoboards.	Amazon	LINK	$10.99	$10.99
Red 18 AWG Wire (25 Feet)	N/A	Wire used for high current loads.	McMaster-Carr	LINK	$5.56	$5.56
Black 18 AWG Wire (25 Feet)	N/A	Wire used for high current loads.	McMaster-Carr	LINK	$5.56	$5.56
12V, 38400 mAh Battery	1	Battery used for powering ventilator.	Amazon	LINK	$89.99	$89.99
9V Battery (8 Pack)	1	Failsafe battery used for powering the alarm.	Amazon	LINK	$10.99	$1.37
12V, 10A Power Supply	1	Power supply used for powering the ventilator.	Amazon	LINK	$23.99	$23.99
Type C Power Plug Adapter	1	Plug adapter from Type B to Type C.	Amazon	LINK	$12.99	$12.99
Total Cost						$666.06

Zephyr Ventilator and Oxygen Concentrator User Manual

Set-up (once assembled):

1. Make sure ALL power supplies are turned **off**.

2. Make sure ALL air pressure regulators/flow meters are **closed.** Air pressure regulators can be closed by pulling out the knob, turning it in the direction of the "-" until it stops, and pressing it in to lock it in place. Flow meters can be closed by turning it in the direction of the "-" until it stops.

3. Plug in the air compressor and turn it **on** by pressing the power button located at the top of the compressor. (For best use, allow the tank pressure to reach its maximum of 150 psi before continuing).

4. Using the knob at the front of the compressor, set the regulated (outlet) pressure to 100 psi.

Oxygen Concentrator:

1. Make sure both the air pressure regulator and flow meter **connected to the end of the system** are **closed**.

2. Make sure the **outlet** of the flow meter is disconnected from the ventilator to allow air to exhaust from the system and oxygen to build up.

3. Turn **on** both 12V power supplies. At this point, you should be able to hear clicking from the relay board AND the valves, and the LCD screen should display the current oxygen percentage (~21%) as well as the current

pressure values within each tank (~0 psi). (Tank 1 & Tank 2 store the molecular sieve. Tank 3 stores the oxygen-rich air).

4. Open the air pressure regulator/air filter **connected to the compressor** by pulling out the knob, turning it in the direction of the "+" until you reach 6 bar, and pressing it in to lock it in place. The system is now operating and you should see the pressure values changing on the LCD screen.

5. Once Tank 3 reaches ~75 psi, open both the air pressure regulator and flow meter **connected to Tank 3** by setting them to 25 psi and 3 LPM respectively. This will allow the air to slowly vent out from the system, building up more oxygen-rich air in Tank 3.

NOTE: If the pressure in Tank 3 drops below 1 bar (~14.7 psi), close the flow meter to allow the pressure to rebuild and store the oxygen-rich air. Reopen the flow meter to 3 LPM once the pressure in Tank 3 reaches ~75 psi again.

6. Once the LCD screen reads ~90% Oxygen, **close** the flow meter and attach the ventilator to the **outlet** of the flow meter.

Ventilator:

1. Make sure the air pressure regulator **connected to the ventilator** is **closed**.

2. Open the air pressure regulator/air filter **connected to the compressor** by pulling out the knob, turning it in the direction of the "+" until you reach 6 bar, and pressing it in to lock it in place.

3. Open the air pressure regulator **connected to the ventilator** by pulling out the knob, turning it in the direction of the "+" until you reach 40 psi, and pressing it in to lock it in place.

4. Test the alarm system by attaching a 9V battery to the alarm (if not already attached) and turning on the switch **to the 9V and NOT the 12V power supply**. This is the switch that is used to control the alarm when the

entire ventilator loses power from the main power supply. If the alarm does not turn on, then replace the 9V battery and retest.

5. Turn **on** the 12V power supply. At this point, the alarm should turn off and the LCD display should turn on.

NOTE: Make sure the LCD display does not contain a micro SD card before powering on since it will assume it is receiving an update. In this case, simply turn off the 12V power supply, remove the micro SD card, and turn on the 12V power supply once more.

6. Press the "Reset" button on the Arduino to ensure proper use.

7. You should now see a "Welcome" screen. Touch anywhere to begin.

Figure 37: Welcome Screen

8. You should now see the main page that shows the status of the ventilation system. Initially, the ventilation system will be "OFF." This is what is known as "Standby Mode."

Figure 38: Main Page w/ Ventilation System OFF

9. From here, the system will contain default settings - this includes target values and alarm limits. These can be adjusted both before and/or after the ventilation system is turned on. To adjust the target values, click the "SETTINGS" button from the main page to go to the page with the default settings. From here, you can use the sliders/buttons to increase and decrease the current target values; however, to actually change the pressure (insp & exp), volume, or FiO2, you have to adjust the air pressure regulators and flow meters on the physical system accordingly.

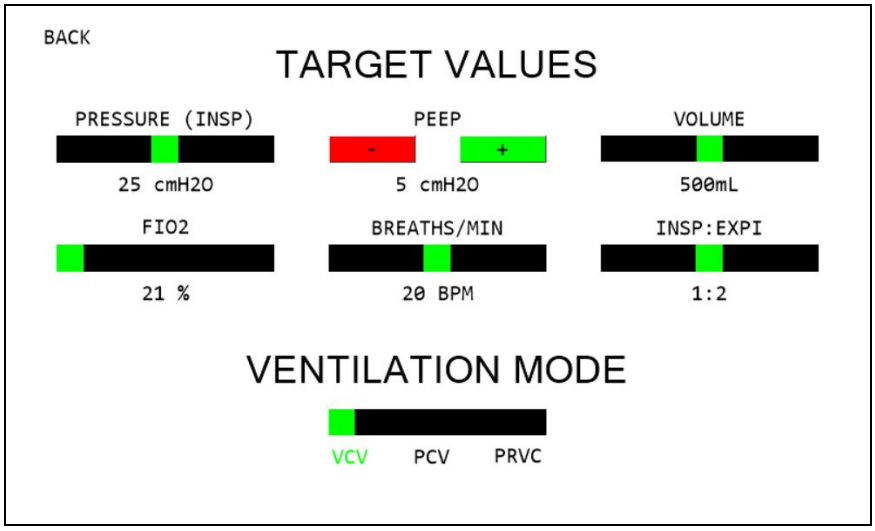


Figure 39: Settings Page

NOTE: To adjust the pressure or volume, adjust the air pressure regulator **connected to the ventilator**. To adjust the PEEP value, adjust the PEEP valve **connected to the expiratory line**. To adjust the FiO2, adjust the flow meter **connected to the oxygen concentrator**.

NOTE: On this same page, there is a slider to change the ventilation mode; unfortunately, our current setup does not support this feature. We needed a flow meter with higher flow rate values to be able to implement this feature. This can be easily implemented with this kind of flow meter.

To adjust the alarm limits, click the "Alarm Limits" button from the main page to go to the page with the default alarm limits settings. From here you can use the sliders to increase and decrease the maximum and minimum values for pressure, volume, and FiO2.

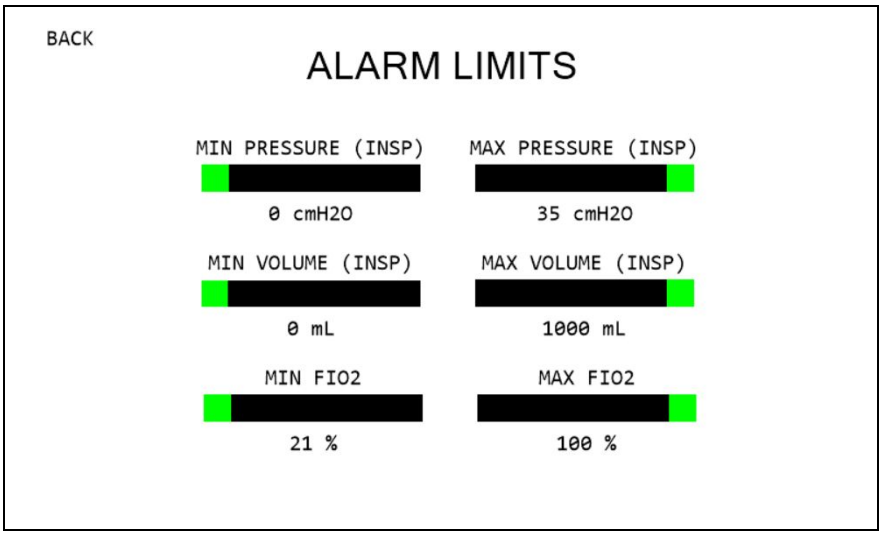


Figure 40: Alarm Limits Page

NOTE: Unlike the target values, adjusting the alarm limits from the LCD display will automatically adjust when the alarm will sound.

10. To turn on the ventilator, simply press the red "OFF" button; it will change to a green button that says "ON" when the ventilation system is on.

Figure 41: Main Page w/ Ventilation System ON

11. To monitor the current values of the ventilation system, go to the "INFO" page. Here you will be able to see what values are being read by the different sensors.

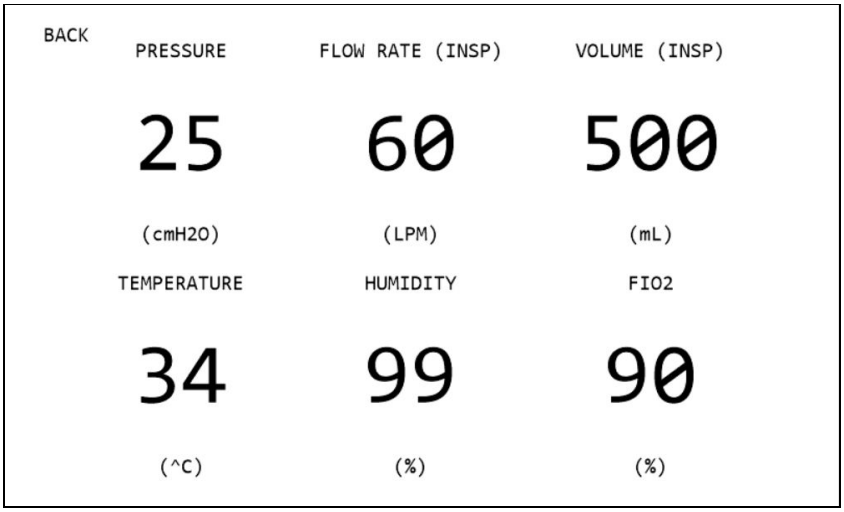


Figure 42: Info Page

12. If any of the pressure/volume values go out of bounds, then the alarm will sound and the ventilation system will power off. If the FiO2 value goes out of bounds, then the alarm will sound but the ventilation system will not power off since this can be adjusted without the potential of harming the patient. To turn off the alarm when it is automatically activated, go back to the main page and there will be a "snooze" button you can press to silence it.

Figure 43: Main Page w/ Snooze Button Activated

13. To turn off the ventilation system without shutting off the battery, simply press the green "ON" button; it will change to the red button that says "OFF" when the ventilation system is off. The system will now be in "Standby Mode" again.