Introduction

Similar to other professions involving hazardous environments, healthcare workers who come into contact with COVID-19 patients need equipment that provides high levels of airborne virus protection. Most healthcare institutions that treat COVID-19 patients use disposable N95 masks and plastic face shields which

(1) Do not fully protect the head and neck of the healthcare worker.

(2) Leave marks and bruises due to tight fitting straps around face and ears.

(3) Can be improperly worn without a tight seal.

(4) Can be difficult to breathe through after hours of use.

(5) Are expensive to replace every day for every healthcare worker.

A potential good solution to this problem is to provide each healthcare worker with a Powered Air-Purifying Respirator (PAPR). However, the cost of commercially available PAPRs is extremely high ($1K to $2K/unit) and the availability is insufficient to support the estimated 18 million healthcare workers in the United States alone. What is needed is a safe and effective PAPR design that can be rapidly mass produced anywhere in the world with standard manufacturing equipment and can be made for as low a cost as possible.

This document outlines the high-level goals, specific technical specifications, and measured performance of the PVPS PAPR.

High Level Goals

- **Safety**
  - Positive pressure keeps virus away from staff
  - Quality replaceable air filter (HEPA) keeps breathing air clean
  - Check for filter life with simple flow meter (Like commercial PAPR machines)
  - Battery indicator allow staff to assure continuous blower function
  - (New) Air exiting the PAPR must be filtered to prevent transmission from an infected healthcare worker using the device.

- **Visibility**
  - Large replaceable visor for full viewing visibility
  - Clear hood allows safety without isolation

- **Comfort and Mobility**
  - Unit should be easy to wear while working for many hours
  - Face shield provides easy doffing and donning
  - No long hoses to keep track of
  - Wide shroud makes it possible to operate stethoscope

- **Disinfection**
    - Throw away plastic curtain to facilitate easy cleanup
    - Simple shape plastic shroud can be cleaned easily with spray and wipes
    - Inside of shroud can be cleaned from one person to another easily

- **Financial**
    - Cost must be < $400 for a new unit
    - Operating cost must be less than the cost of using disposable respirators (N95 masks) and face shields.

Technical Specifications

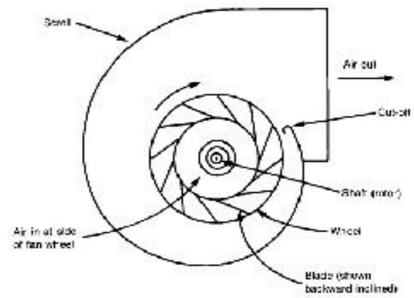
- Airflow through filter and blower must be >= 6.0 CFM (169.9 L/min)
- Weight of entire unit must be < 40 ounces (1,133.98 grams)
- Noise level inside face shield must be <= 50 dBA
- Battery life with continuous use must be >= 6 hours
- Battery status must indicate amount of battery remaining
- HEPA filter replacement time must be >= 3 months
- Assigned Protection Factor must be >= 1,000
- Unit must operate for more than 2 years in a healthcare setting

Performance

We have conducted several performance evaluation tests including quantitative tests and healthcare provider evaluations. This section will be updated soon with the results of these tests.

Revision History			
Revision	Date	Who	Description
0	3/16/2021	Rick Avila	Creation

Blower Background



All commercial PAPR systems utilize a blower as part of the design. Blowers are capable of high flow and deliver a higher-pressure differential than a conventional fan. Our goal is to deliver between 3 and 10 CFM with good output pressure. On the drawing on the right you can see that this type of blower pulls from the inlet and discharge is a 90degree discharge using a centrifugal impeller

Blower Selection

Our final selection is shown here with an attached diffuser/deflector. It is a Foxconn 90mm Blower designed for small form factor Dell computers. It has the right CFM and adequate pressure output and is lightweight. It is a PVB120G12H-P01 J50GH-A00 J50GH 0J50GH 12V 0.75 4Wire Compatible for DELL OptiPlex 790 390 990 SFF CPU Fan Cooling Fan. It is 146grams.

Initially we evaluated a 70mm blower but it did not provide the needed flow with our selected filter. The CFM for blowers are rated with no filter and it drops significantly when the filter is added to the inlet. For example: the GDStime blower is rated at 38CFM but we only saw 11 CFM at 12 volts with the Miller filter. We jumped to a GDSTIME 120mm blower to guarantee enough output. At the time we were using a Miller meter, that drastically underestimated the flow, to determine flow rate. Once we built a full prototype and experienced the impact of weight, we re-evaluated the priority on weight and moved to the smaller and lighter Foxconn 90mm blower. With a calibrated flow measurement, we were able to determine that perhaps a smaller fan could be used. The GDStime blower is 232grams.

Initial testing

Once a prototype was assembled using the 90mm Foxconn blower and Miller filter we conducted some stress tests wearing the mask. These tests were intended to see how the CO2 levels were maintained when doing a strenuous activity. These are not substitutes for a more clinical environment test but were intended to give an early indication of any issues. The CO2 levels in the front of the mask were periodically monitored using a Using a CO2 ppm meter periodically during the activity. it was determined that the airflow needed to be focused toward the front of the mask to reduce the CO2 levels during exertion. A small Diffuser/Defector attached to the output of the blower improved airflow to the front of the mask and reduced the CO2 levels.

https://www.ebay.com/itm/Carbon-Dioxide-Meter-CO2-Detector-Indoor-Air-Quality-RH-Meter-0-2000ppm-rateRange/193507135104?hash=item2d0dec8e80:g:GcgAAOSw8L9e30wF

A finger pulse/O2 meter was not used because prior test showed a long lag and not much sensitivity to the CO2 environment.

Establishing accurate flow

Determining the actual CFM of a given blower was a challenge initially we used a meter form the Miller welding PAPR. There are available for about $10 and initially we though that it would be a good indicator of achieving the required 6CFM flow since that is how it is used. It was eventually determined that the flow was being underestimated by that meter. This was determined using a stop watch and measuring the time it took to fill a standard 30 gallon garbage bag. It was determined that the Miller meter was not responsive enough to measure the desired flow range 3-10 CFM. Using the stop watch and bag method the flow rate was accurately determined. The volume of the bag was determined by this estimation method and using the height and width of the uninflated bag.

$$V = w^3 \left(h / (\pi w) - 0.142 \left(1 - 10^{(-h/w)} \right) \right)$$

https://en.wikipedia.org/wiki/Paper_bag_problem.

Meter refinement

Obviously, It is not convenient to use a bag for all tests. This Sensirion SFM3000 Flow meter was utilized. It was calibrated against the bag flow estimation and the Miller meter. With these measurements it is possible for a given blower and filter combination to predict airflow by input voltage and to convert the measurement of the Sensirion flow meter to CFM. This proved very helpful to understand the true airflow rates.

PAPR regulations require some type of flow QC check to understand the state of the blower and filter. This is the purpose of the Miller meter (left). As stated, we found that the meter was not calibrated for our device and we needed to adjust its sensitivity. The diameter of the ball was measured and the ball 3D printed in a series of different fill factors to find the right weight. The cap of this style meter is easy to remove and reapply so we used this to develop our version of the QC check. A 0.25gram 12.5mm ball was what was needed to measure the 6CFM from our system.

Blower performance

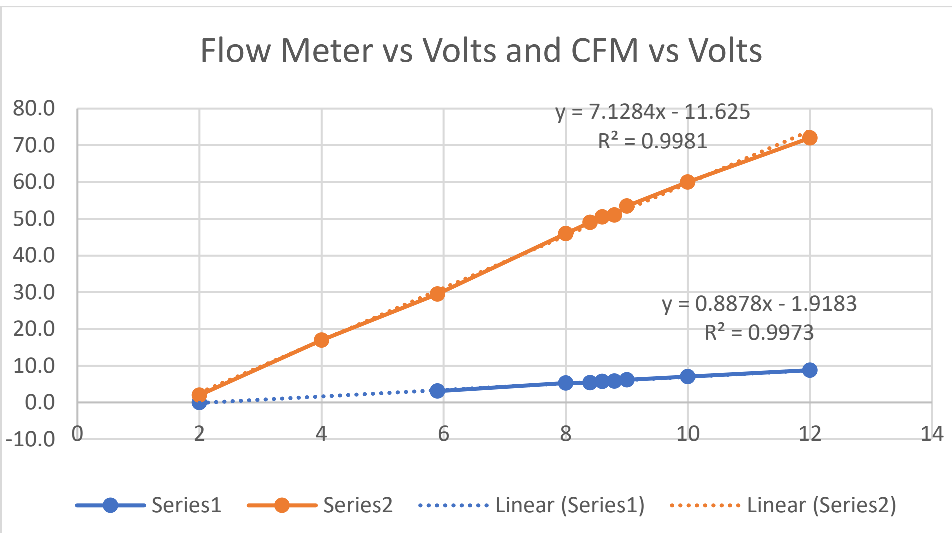
Figure 1:

time to fill (sec)	CFM*	LPM*	SFM3000	Volts	
21.35	8.78575	248.7847	72	12	8.8
26.57	7.059682	199.9079	60	10	7.1
30.58	6.133936	173.6937	53.5	9	6.1
32.17	5.830766	165.1089	51	8.8	5.8
32.96	5.691012	161.1515	50.5	8.6	5.7
34.7	5.405641	153.0707	49	8.4	5.4
35.4	5.29875	150.0439	46	8	5.3
61	3.075012	87.07465	29.5	5.9	3.1

- From bag testing

CFM estimate from equation and Sensirion measurement

Figure 2:



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With these two charts one can use volts to estimate the CFM on a system with a fresh filter or use these two equations to solve for the CFM as a function of SFM300 meter reading on any condition system.

First equation from curve fit says:

SFM3000=7.1284*Volts – 11.625 So:

Volts=(SFM3000+11.625)/7.1284

Second equation from curve fit is:

CFM=(0.8878*Volts-1.9183) – [Convert Volts to CFM for a clean filter]

Substituting. you get….

CFM=(0.8878*((SFM300+11.625)/7.1284))-1.9183 – [Convert SFM300 measurement to CFM for any condition filter and Foxconn blower]

Other considerations:

The PVP-D(Backpack) concept has to use a hose to connect to the Face Shield/Hood. There is considerable loss in the hose. While se intend to mitigate that by using a larger diameter hose it seems that the pressure drop will make the Foxconn less desirable in this configuration.

Conclusion:

The Foxconn blower can deliver up to 8.8CFM with a clean filter and is adequate for the job. The GDStime blower may be a better design choice when weight is not as critical and a higher output is needed. The GDStime blower can deliver up to 10.9 CFM at 12.3 volts.

For the PVP-P (top of head) and PVP-B (Back of head) based design where the weight must be carried on the head, it is recommended to use the Foxconn blower. For the PVP-D (backpack) design the GDStime may be a better choice.

Revision History			
Revision	Date	Who	Description
0	9/22/2020	Bob Senzig	Creation

Tech note PVPS - F0001: – Filter selection and Design   Author: Bob Senzig : Sept 17 2020

Pandemic Virus Protection Systems

Filter Background

An N95 disposable mask is considered an adequate protection for many healthcare workers. [An N95 mask blocks 95% of incoming particles if properly fitted]. This effectiveness is lesser for particles which are smaller than 0.3 microns. This may not be adequate for prolonged exposure or for use in areas where the viral load is high. Our goal is to create a device that offer more complete protection for those situations. Human breathing has a tidal volume of 0.5 liters 10-20 times a minute. This means that the human lungs are essentially a 0.35CFM pump. A N95 Filter is around 45 IN**2. This yields an air speed of around 0.2 inches/sec. A cough or sneeze is much higher speed but we will focus on steady state breathing. We will try to show that the powered PAPR design can provide much more protection than the N95 for the wearer. A powered PAPR is not a good choice in an environment where the virus load is low because there is not filtration of the exit air. Later in the technote you will be able to see why the N95 mask material cannot be used as is in a powered unit where the airflow is increased.

HEPA filters are rated to [remove 99.97% of particles greater than 0.3 micron]. HEPA filter are available in many configuration Vacuum Cleaner, Air Freshener, Auto cabin and commercial PAPR filters. Our focus was to find a practical and economical solution that would me our performance goals.

Filter Selection

Filter selection is key to effective protection. There are two main candidates for the PVP-P device filter:

1. Miller PAPR HE particle filter designed for use in a Miller T94-R™ Miller welding system (part number 235673). It is a HEPA rated filter and is designated as NIOSH purple (High Efficiency (HE) Filter, P100 Filters).
2. Freudenberg unreleased proto PAPR filter. This a filter designed by Freudenberg Filtration Technologies a leader in automotive, industrial and environmental filters for use in a PAPR. We were able to obtain prototype units for evaluation. We deprioritized this filter due to availability beyond the evaluation units.
3. Holmes air freshener filter provide a similar size but larger True HEPA filter that can be adapted to this use. We have deprioritized this filter due to the larger size and weight concerns.

Filter evaluation criteria were simple, a size and weight compatible with our head top PVP-P and backpack style PVP-D concepts, a back pressure compatible with the blower choice, excellent filtration capability, easily handles and replaced.

1. Filtration must provide adequate filtration at the max flow rate the PAPR is capable of
2. Size: must be less than ??? x?? x ??? and less than ??? grams to be considered
3. Back pressure must provide low resistance so that lightweight blowers can deliver the required minimum 6CFM and a higher flow rate of at least 9CFM

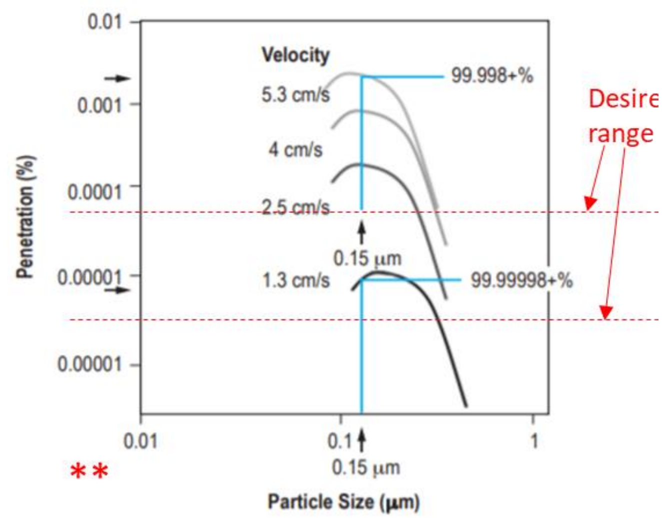
4. Easy to handle we felt that filters with a plastic carrier were easier to install and remove than the automotive style cartridge felt filters

1) Filter Design

Not being an expert in filter design we did some searching and found some useful information

a. Impact of air speed on filter efficiency

The NASA paper Submicron and Nanoparticulate Matter Removal by HEPA-Rated Media Filters and Packed Beds of Granular Materials- Perry et al shows the relationship of air speed and filtration in Figure 4. I added the red color annotation to show the range we want to operate in for the best filtration performance.



gure 4. Filter efficiency dependence on velocity; lower velocity increases efficiency. (© R. Vijayakumar. *Used with permission.*)

b. HEPA filter efficiency for COVID-19 sized particles

Filtration of airborne microorganisms: Modeling and prediction – 1999 Kowalski et al provides info on HEPA filter performance with different size particles. Here the size of the COVID particle is added for clarity. So even though the rating for a HEPA filter is a 0.3microns it does very well on COVID-19 sized particles. In Figure 9 from that publication shows the performance with Coronavirus size particles

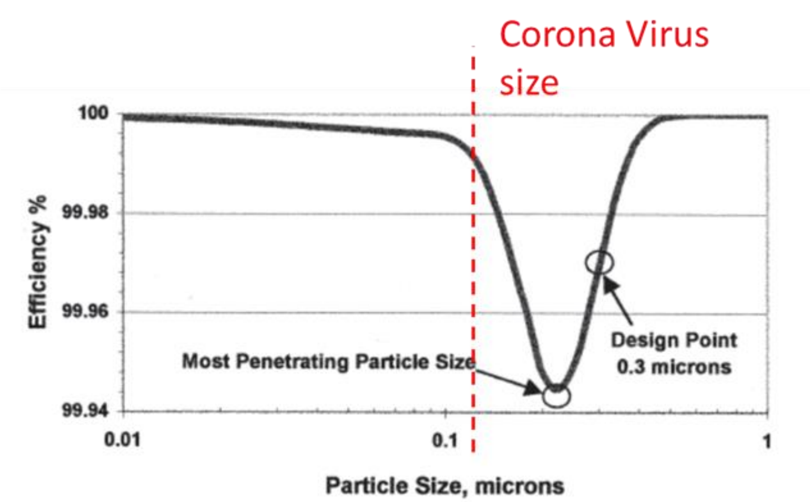


Figure 2 *Typical performance of a HEPA 99.9% filter.*

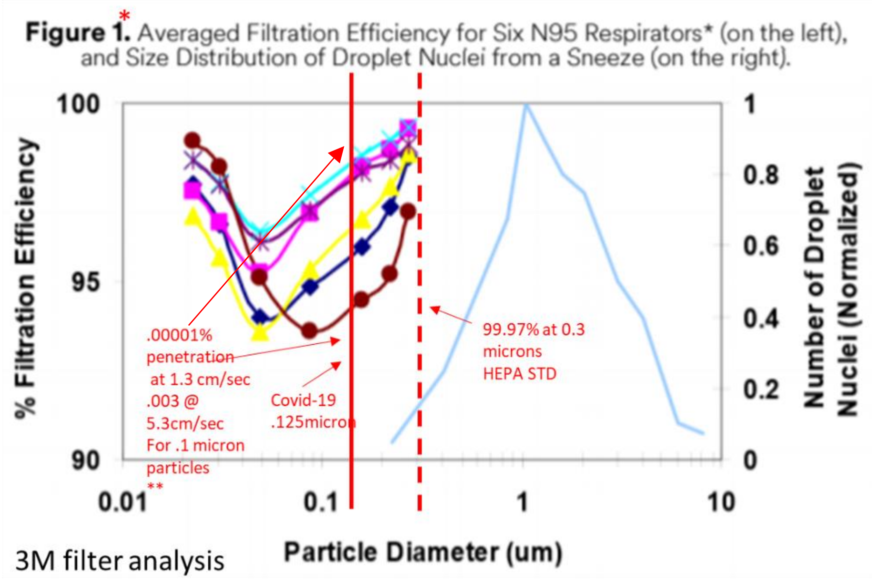


Figure 1.* Averaged Filtration Efficiency for Six N95 Respirators* (on the left), and Size Distribution of Droplet Nuclei from a Sneeze (on the right).

3M filter analysis

This figure from a 3M analysis of how N95 masks performs against a water droplet (cough) and Covid-19 sized particles shows that even having an airspeed higher than 5.3 cm/sec the HEPA filter yields superior performancehttps://fastlifehacks.com/n95-vs-ffp/

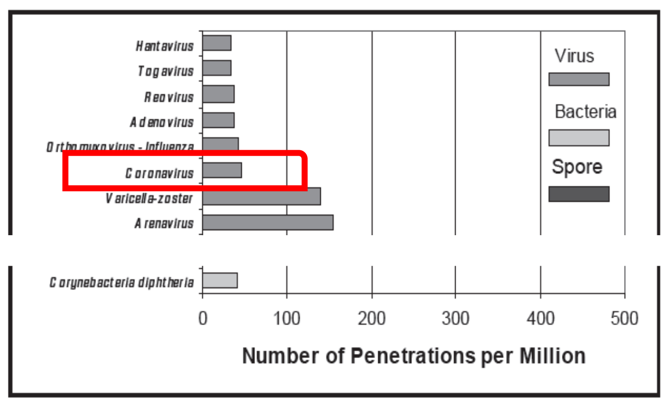
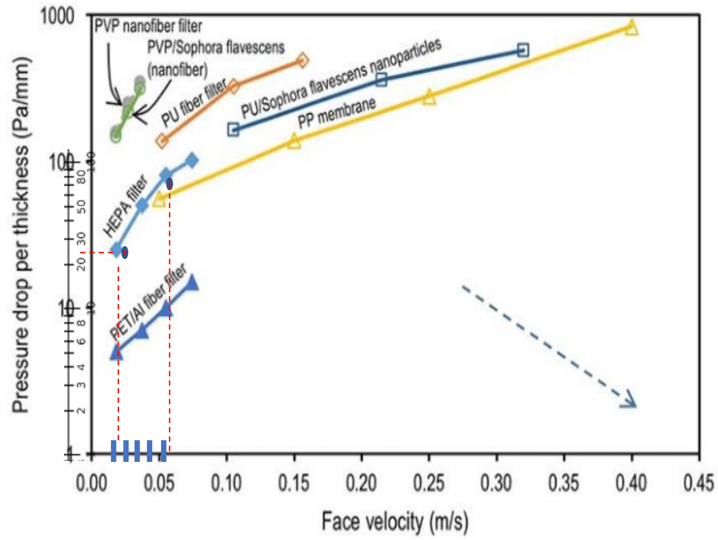


Figure 9 *The most penetrating microorganisms: HEPA 99.9% filter, single pass.*

In this figure the impact of speed on pressure drop is shown. To get a reasonable pressure drop so the blower does not have to work as hard a low air speed is desired. I added the scale to make interpretation easier. This is from [Recent advances in antimicrobial air filter – Komaladewi et al]



2) Filter Physical Size

The Face Shield/Hood structure in the PVP-P concept and the mini backpack desired in the PVP-D design limit the practical filter size to 5 x 10" inches. For PVP-P a smaller 7x4" is more desirable. Filter size to achieve the desired air speed you can calculate the needed filter square area from the CFM flow rate and the desired speed. It is not possible to meet the size constraints with a single layer filter. A pleated filer design is required. This equation was described in a design notes created by [Arron Sun on the OPEN PAPR Facebook site]. The following table shows 3 different available filters that we down selected and the anticipated filter performance,

Filter Efficiency

The pressure drop generated by the filter is dependent on the linear flow rate through the filter, thus the filter linear flow rate is inversely correlated with the total area of the filter. As most filters are pleated, this area is larger than the area of the individual filter.

$$A = w\sqrt{h^2 + (pd)^2}, f_l = f_v/A$$

- A = total filter media area
- w: width of filter package
- h: height of filter package
- d: depth of filter package
- p: the total number of heightwise pleats over the entire package
- f_l: linear flow for the filter media
- f_v: target volumetric flow

Filter	Height	Width	thickness	#Folds	Sq In filter area	Pressure drop @6CFM	Operating CFM	Air Speed in/sec	Penetration %
Freudenberg	6.3	4.8	.86	51	458	Med	6	.376	0.000006
Holmes	9.5	4.1	1.13	53	418	Low	6	.414	0.00001
Miller	6.5	3.75	.5	65	224	High	6	1.026	0.00016
N95	7	7	N/A	N/A	49	N/A	0.35	.201	5%

From this analysis, the packaging and the availability criteria, the Miller filter was chosen as the primary filter. We also considered that this particular filter would not be in high demand for healthcare use because of the weight and design of the commercial Miller welding PAPR, the unit is not practical in a healthcare environment. We thought that this would likely mean filters would stay readily available.

Revision History			
Revision	Date	Who	Description
0	9/22/2020	Bob Senzig	Creation

3) Ease of filter change/Packaging

This 3M publication presents performance of a N95 mask vs particle size. Technical Data Bulletin #174 Respiratory Protection for Airborne Exposures to Biohazards

Comparison between Prototype and proposed Control specifications
2020-05-05

Electronic Control specifications (preliminary)

1. Will use an off-shelf M18 battery (Milwaukee Electric Tool or other brands compatible with MET chargers)
2. Will provide a single pushbutton which will cycle from OFF to a number of fan speeds yet to be determined.
3. Will monitor Battery voltage and Fan amperage to determine the following conditions:
    a. Low Battery (verified by using the battery indicator build into the battery pack
    b. Possible Filter sealing issues or blockage.
4. Will begin modulating the fan between the selected speed and the maximum speed to indicate any of the fault conditions listed above.
5. Will remove power to the Fan connector within 5 seconds after the Fan is disconnected.
6. Will remove power to the Fan connector when the battery voltage drops below 14.5 volts.
7. Will be sealed to allow outer-surface cleaning

Five Prototype Manual Control boxes - 2020-05-04

- The only user control is a potentiometer which allows adjustment of the output voltage between two internal trim pot values. The initial minimum is set at 7.85v which has been determined by filter testing with a GDStime GDB1232Q2005 Blower.
- They provide crude battery discharge protection at >13.5 volts, where the minimum specified limit is 12.7 volts before battery damage starts to occur.
- The battery protection will cut power to the fan. However, the estimated run time from even the smallest available MET pack is close to 10 hours.
- These prototypes provide no user feedback for low battery or filter problems.
- These prototypes are NOT sealed and should only be wiped down with alcohol to remove contaminants.

Propellerhead PAPR Hood - Electronics Design Diary

2020-05-05 - Preliminary Electronic Control specifications

1. Will use an off-shelf M18 battery (Milwaukee Electric Tool or other brands compatible with MET chargers)
2. Will provide a single pushbutton which will cycle from OFF to a number of fan speeds yet to be determined.
3. Will monitor Battery voltage and Fan amperage to determine the following conditions:
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7. Will be sealed to allow outer-surface cleaning

2020-05-04 - Qty 5 Proto Battery Boxes have been assembled

- The only user control is a potentiometer which allows adjustment of the output voltage between two internal trim pots. The initial minimum is set at 7.85v which has been determined by filter testing with a GDStime GDB1232Q2005 Blower.
- They do provide crude battery discharge protection below 13.5 volts, where the minimum specified limit is 12.7 volts before battery damage stats to occur.
- The battery protection will cut power to the fan. However, the run time from even the smallest available MET pack is close to 10 hours.
- These prototypes provide no user feedback for low battery or filter problems.
- These prototypes are NOT sealed and should only be wiped down with alcohol to remove contaminants.
- Each box took 13 Hours to print. Each cover took 1 Hour to print.

2020-04-22 - First Proto Battery Box given to Bob for testing

2020-04-14 - First printing of MET adapter version 13

Due to the time-consuming measurements required to provide a usable interface, it took a lot longer than I thought to model the battery adapter in SCAD. This box will be used to make the first prototype control with a potentiometer.

2020-04-08 - Design Constraints

At this point there are more PCB mechanical concerns than there are electrical concerns. Since a circuit design is highly dependent on resolving these issues, I will try to list the issues to see if we can keep this project on track.

Propellerhead PAPR Hood - Electronics Design Diary

1. **Location of the PCB** - The major issue with electronics is disinfection. Even if the PCB is conformal-coated, physical stresses during wipe down could cause component damage, ESD could cause electrical damage and chemicals could damage connectors.
    a. If the PCB is in the Hood then it will be subjected to the user-generated pathogens and will need to be cleaned occasionally.
    b. If the PCB is in the Blower Backpack, the user controls would have to the remotely located.
    c. If the PCB is in the Battery Assembly it would not require any cleaning. Even with both designs mechanical buttons through small holes in the case would be accessible. An Overlay would be inexpensive and provide a durable seal. With the proper material selection, overlay chemical cleaning would not be an issue. The number of connections is reduced because the battery wires would tie into the PCB

2. **Wiring between components**. With normal use, wires will break over time, connectors will get dirty, break or may disconnect unless secured.
    a. Connector to Battery Pack. Details are available. Durability may be an issue. One person suggested using epoxy to secure the pins and wires to the 3D printed assembly. This is time consuming in production. An injection-molded part with inserted pins exceeds the project time budget.
    b. Cable between Battery connector and Battery Assembly Output connector. This should include a 1/2 Amp replaceable fuse.
    c. Cable between Battery Assembly and Hood or Backpack Assembly. This should have connectors on both ends to allow replacement if damage occurs. There should also be a means to firmly secure it to the Battery Assembly.
        i. Molex 2451350420 (US supply 1100) 2.0m makes 2 cables $9.00 will plug into board-mounted connector. No connector at Hood.
        ii. Molex 2451350410 (US supply 1100) 1.0m makes 1 cable $8.00 will plug into board-mount connector and in-line connector at blower

        iii. TE T4070014041-001 Socket (US Stock 1600) $7.00
        TE 1-2273003-1 Cable (US Stock 883) $8.00
        Although this is a sealed connector, it adds an extra assembly step, the socket cable must be soldered to the PCB.
    d. Cable between the Fan and PCB. We should be able to get the Fan with a connector. This would plug into a socket on the PCB.
    e. Cable between the PCB and Buttons. Unless the buttons can be mounted on the PCB (preferred) a cable will be required.

i. Although Capacitive touch would eliminate a number of cleaning issues, research indicates that reliability and noise immunity may not make this approach practical. The time development and testing time would exceed the project time budget.

ii. Medical Graphic Overlay with 2 buttons requires some tooling, but would be able to be placed on the top of the hood. The hole in the hood would be covered by the label and the adhesive would provide a durable seal. Include in the assembly is an integral flex cable with connector that plugs into the PCB. The length of this cable is limited.

iii. Mechanical buttons on PCB that would protrude through holes in the top of the mask. An Overlay would be inexpensive and provide a durable seal. With the proper material selection, cleaning would not be an issue.

iv. If the PCB is located in a blower backpack, a cable and button assembly would be required. Depending on where this would be mounted, durability and disinfection will be issues.

f. **System Feedback** - Devices include LEDs, Vibrators and Beepers.

i. LEDs require a remotely-located circuit board within range of the user's vision, cable and connectors. It will be subjected to cleaning. Or have to be in a housing. Lots of design compromises.

ii. A Vibrator in the Battery Assembly might not be felt through all of the clothing that the user wears.

iii. A Beeper requires a physical opening to produce a high sound level

1. If it is located in the Battery Assembly it will be exposed to room pathogens and possibly allow disease transmission.
2. For the PropellerHead, it could be located in the exit of the Blower. A third wire would be needed in the cable to the PCB in the Battery Assembly.
3. For the Blower Backpack, it could be located behind the Filter. The sound should be able to exit through the filter.

3. **MTBF -** is directly related to how many parts are involved in a system. Keeping the number of parts to a minimum ensures better reliability over time.
4. **Time to Production** - With each component in the system there is time to research availability, engineer the component, design the tooling, produce the tooling, procure materials and setup production lines. Our time is very limited. We must concentrate on the best way to build this product with the least number of manufacturing steps.

2020-04-07 - Switch to MET 4.0Ah and 5.0Ah batteries

I spent the morning dissecting my Milwaukee Electric Tool M18 components, a Drill, a charger and two battery packs that are still in production.

I also went to Home Depot and looked at other brands. None of the others appeared to be any better. Since my packs used Samsung cells, I researched their available cells and discovered a good correlation between the different MET packs and the cells.

Analysis: PAPR_Battery_comparison.doc

Propellerhead PAPR Hood - Electronics Design Diary

2020-04-06 - Blowers Arrived

They seem to draw 1/2 the current that was specified on Alibaba. Not sure they will have the capacity we require. If they do, we will require only 4 watts.

2020-04-03 - Placed Digikey order $209.22

2020-04-07 Update - This order is useless because we changed Batteries. Will attempt to return the 2 - ADM00865 MCP1665 Switcher Demo Kits $86.00

2020-04-02 -

2020-04-01 - Possible Conflicts

After our evening discussion,

2020-03-31 - Possible Conflicts

I wish we had a year to develop all of the features that you proposed. There are so many unknowns and conflicts in this project that some features might not be possible in the time we have..

My initial concept is to use Fan Motor Amperage for battery and filter status.

- Depending on the resolution of this monitor circuit, we might be able to get an idea of the filter status, but it may not be possible with the three fan speeds, unknown sealing and variations in filter density.
    - The difference between the absence or presence of a filter will make a big difference in the fan amperage. However, the change between a clean filter and a clogged filter may be so miniscule that it may not be detectable except at the highest fan speed and a known throat sealing situation. The throat seal will probably introduce far more variation in amperage than a clogged filter.
    - The least expensive CO_2 module appears to be around $40. But, the effectiveness of such a monitor is highly dependent on where it is placed in the hood, will be subject to deterioration due to the high moisture content in the hood..
- We made the decision to go to Off-Shelf Phone Charger battery packs to allow for better availability. However, no two packs will have similar capacities. This is in direct conflict with the battery Life monitoring because we will not know the total battery capacity. We can ASSUME, but will not have control of what happens in the field. Field adjustment of battery life would not be possible unless the facility always used the exact same packs for every mask. Most hospitals have a person that verifies equipment and performs minor maintenance. Therefore, we might have to grossly under-estimate the capacity.

USB Support

- I have to talk with Darryl to see if he has ever done an integrated USB, but at this time, rolling USB support into the single Micro of this project does not appear to provide any benefit that justifies the time (which would include a PC Driver and programming user interface). This is why many development boards have a separate Micro dedicated to the USB programming port.

- Many of the projects that I have worked on over the past 20 years are setup with the ability to initially program the Micro using a connector-less connection to the manufacturer's standard programmers as well as re-programming and monitoring of run-time parameters with an inexpensive serial interface.
- The alternative is to do what has been done on development boards. Add a USB interface chip which could be removed from the production board. The cost of these devices includes the Driver support and allows serial re-programming and monitoring of run-time parameters.

LED and buttons with the dinosaur approach

- Once the Fan moves out of the helmet onto a backpack, buttons and LEDs become very difficult.
- There are a few possible solutions
  - Use a 10 conductor cable that travels up the inside (or outside) of the airway between the circuit board by the motor/battery to the LED/button board.
  - Use a 4 conductor cable to travels up the inside (or outside) of the airway between the circuit board by the motor to a separate micro on the LED/button board.
  - Eliminate the LED/button board and use the audible alarm to indicate battery and filter status by a series of short tones with pauses that decrease as battery life decreases. Someone else would have to control the fan.
  - (Bob) If we have a necklace to hold the bottom to a shape could the buttons and indicator be added to that? What do you recommend?
- Wireless would require a separate battery on the LED/button which would require additional maintenance.

Propellerhead PAPR Hood - Electronics Design Diary

2020-03-27 - Control Board initial refinements

Controls and indicators

Two Switches, On/Off (Left) and Fan Speed (Right)

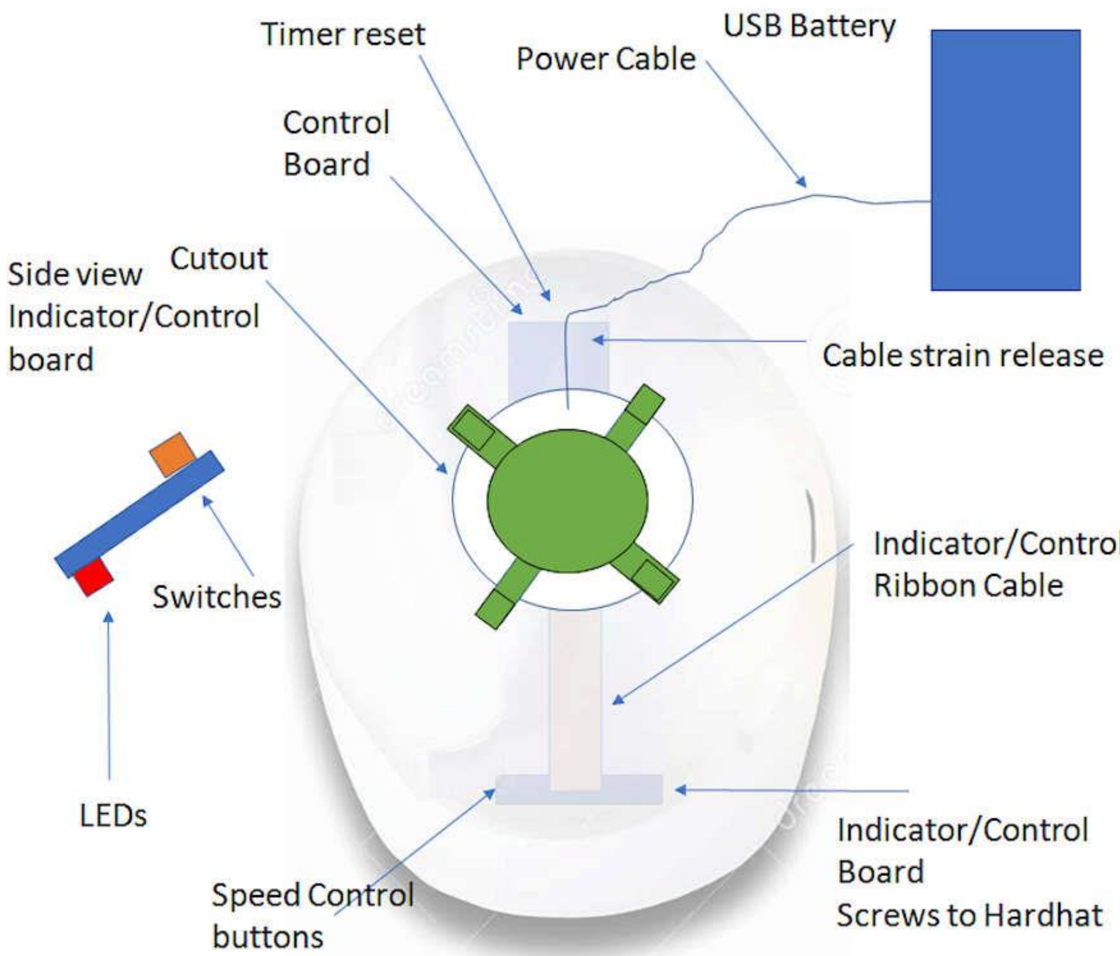
- Pressing On/Off will toggle On-Off
- Pressing Fan Speed will loop through available speeds
- Pressing both buttons for 2 seconds will reset Battery Life Timer

LEDs

- 4 total, 2 Green, 2 Red-Green
- 2 Green and 1 Red-Green will make up a Battery Life bar
  - 3 Green - 100% Battery
  - 2 Green - 75% Battery
  - 1 Green - 50% Battery
  - 1 Yellow - (Red+Grn) 25% Battery
  - 1 Red Flashing - 10% Battery
- 1 for possible Filter Status, Green-OK, Yellow-Clog, Red-No Filter??

Propellerhead PAPR Hood - Electronics Design Diary

2020-03-26 - Preliminary Control Board Requirements



1. Fan Speed – External access
    - Goal: Maintain positive pressure at all speeds. User can set required speed
    - Solution :
        - 4 Speeds –
            - Minimum Speed still needs to pressurize bag,
            - Medium speed – Set for conversation level,
            - Max speed based on Max tolerated noise
            - Momentary Ludicrous speed – Fan Max for bag flushing and seal test at bag installation
        - Momentary off – For stethoscope listening, and inaudible conversation
        - Standby Off – two quick presses of momentary off will sound an audible and visual indicator that the system will shut off in 10 seconds. If the button is pressed once again the standby off is abandoned. The timer shall be suspended if the 10seconds are complete and standby Off is activated

2. Battery life
    - Goal: Provide the wearer and support staff an indicator of battery life of standard USB batteries
    - Solution: To utilize standard USB batteries with no feedback the battery life is tracked via amperage over time
    - A means shall be proved to reset the timer when a fresh battery is installed
        - An internal button provided so that when a fresh battery is installed and the fan starts the timer starts
        - The timer reset button can be activated with a heavy magnet placed on the timer activation sensor. With this a user can reset the timer if they install a fresh battery
    - When the battery timer reaches 75% of the expected life a yellow LED is activated
    - 3 Green LED will track the progress of the Battery timer
    - When the Timer reaches 90% of the expected life a RED blinking LED is activated and an audible alarm sounds
    - Audible Alarms need to be audible inside the helmet
    - Visual alarms need to be visible to the wearer and the person servicing the battery
    - Battery status can blink slowly to conserve battery power
    - Selected Fan speed will be considered when tracking battery time on
    - Expected battery life should be 13 hours
3. Filter indicators
    - Goal: Provide feedback on properly installed filter and clogged filter
    - Solution: Use motor speed amperage as an indication of back pressure
    - If too little resistance in detected a Filter installation error alarm and indicator are activated
    - If too much resistance is detected the filter clogged error alarm and indicator are activated
    - Since these levels are unknown the design limits shall be settable via the USB cable.

2020-03-25 - Blowers Ordered - $37.05

An order was placed through Alibaba with Susan from xinyujie.com.

2020-03-22 - And so it begins