2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #32558

Student Senior Project and COVID-19

Dr. Alireza Kavianpour, DeVry University, Pomona

Dr. Alireza Kavianpour received his PH.D. Degree from University of Southern California (USC). He is currently Senior Professor at DeVry University, Pomona, CA. Dr. Kavianpour is the author and co-author of over fifty technical papers all published in IEEE Journals or referred conferences. Before joining DeVry University he was a researcher at the University of California, Irvine and consultant at Qualcom Inc. His main interests are in the areas of embedded systems and computer architecture.

John Castellanos, DeVry University, Pomona
Adam Doty, DeVry University, Pomona
Michael Sweeting, DeVry University, Pomona
Isasio Velez, DeVry University, Pomona
Nathan Watson , DeVry University, Pomona

Student Senior Project and Covid-19

Abstract

In this paper, the design of a negative pressure room in tandem with a standard residential **H**eating, **V**entilation, and **A**ir **C**onditioning (HVAC) system will be discussed. The need for such a room is urgent because of the recent pandemic that has disrupted both the economy and the health and welfare of not only in the US but the entire world. This project is geared towards providing a means to quarantine family members safely and securely in a room within a home. This isolation room can be controlled and monitored and has an alarm to alert family members of system warnings and malfunctions. The idea is to make the system simple enough that users could install it with a little modification in the room.

Because of the outbreak of **Co**rona**vi**rus **D**isease 20**19**, abbreviated as COVID-19 and its viable potential to overwhelm health care facilities as observed in the most of countries, the authors hope to provide a cost-effective solution that could ease the demand of the isolation room in the hospitals.

1- Introduction:

Negative pressure rooms, also called isolation rooms, are a type of hospital room that keeps patients with infectious illnesses, or patients who are susceptible to infections from others, away from other patients, visitors, and healthcare staff. Negative pressure rooms are in high demand with the current outbreak and in the foreseeable future. This technology and various applications can be observed throughout the healthcare industry and are commonly used for patients suffering from such respiratory ailments as tuberculosis. Because of the ease at which COVID-19 is spread along with numerous other respiratory illnesses, converting a room in a residence to a negative pressure application could prove beneficial on several platforms. Current guidelines of the **A**merican **S**ociety of **H**eating, **R**efrigeration and **A**ir-Conditioning **E**ngineers' (ASHRAE) Standard 170 suggest "Ventilation of Health Care Facilities, which is integrated into the Facility Guidelines Institute's *Guidelines for Design and Construction of Health Care Facilities,* requires each isolation room to have a permanently installed visual device or mechanism to constantly monitor the air pressure differential of the room when occupied by a patient who requires isolation." Utilizing a similar device to interface with a user to monitor and control negative pressure inside a typical room in a residence will allow us to reach the goal of our project, as well as providing an audible and visual alarm that can warn other residents of potential system malfunctions and needs for repairing the system.

Health care facilities have stringent standards and regulations pertaining to such matters geared towards protecting health care professionals and other patients. It is our goal to create a safe environment for a family that may fall subject to quarantine and relieve some of the stress healthcare facilities may face. It is not our intent to completely replicate the medical standards a healthcare facility is required to uphold. Family members who have been diagnosed with airborne infectious diseases will drastically reduce spreading infection through the adaption of this project's goal.

Low pressures are often measured in inches of water column or "WC. Like most units of measure, it has a very simple origin, in a water manometer 1″ of water column is literally the amount of force it takes to raise the column of water by 1". While some water manometers (water tube) are still in use the vast majority are either dial or digital gauges that still use the same scale. One psi is equal to 27.71 inches of water column; therefore water column is most often used to measure pressures under one psi. These low pressures are most often read using a manometer gauge.

Negative pressure rooms require a minimum of 12 air exchanges per hour and maintain a minimum -0.010 inches of WC. By utilizing standard ASHRAE calculations for residential applications we can achieve the goal of negative pressure for prolonged amounts of time using continuous duty motor applications[3,4,5,6]. Health Facilities Management states "Exhaust from negative-pressure isolation rooms, associated anterooms and associated toilet rooms must be discharged directly to the outdoors without mixing with exhaust from any non-AII rooms." This means we must inform the user that any return ducts will have to be sealed off, so the contaminated air does not make its way back to the air-handler potentially spreading the infection. This can be achieved through a step by step set of instructions provided to the homeowner upon installation.

Supply air from the HVAC system will have to be considered while performing our calculations as static pressure from the house will affect potential pressure differentials. Sealing of the room will also be an important aspect pertaining to this application and step by step instruction manual will further assist in achieving and maintaining negative pressure. With the current outbreak scientists and healthcare professionals around the world are teaming up to battle this epidemic. With persons being sent home from over impacted healthcare facilities, negative pressure technologies may be the answer to combating such infections.

2- Requirements

1-Negative pressure rooms require a minimum of 12 air exchanges per hour.

2-Depending on the factors such as room size, orientation, and the number of windows present, more than 12 air changes per hour may be necessary.

3-Maintaining a minimum -0.010 inches of WC (water column). One psi is equal to 28 inches WC.

4-Supply CFM (Cubic Feet/Minute) into the room is at least 294CFM.

5-Exhaust from negative-pressure isolation and associated toilet room must be discharged directly to the outdoors without mixing with exhaust from the rest of the house.

6-Any return ducts in that room will have to be sealed off.

7-Sealing of the room is an important aspect pertaining to this application.

8-Entrance door has a half-inch gap under the door.

9-Windows, light fixtures and outlets are sealed so that air only exits the room through a new filtered exhaust system. That means the room is actually a big vacuum.

10-Room sucks in air through the gap under the door/AC. Then, an exhaust will eject the diseased air in the room to the outside.

11-The windows can't be opened. The doors close automatically.

12-The ceiling is trickier to handle, because the average drop ceiling isn't going to be airtight, and the gaps above the drop ceiling can be shared between rooms, since they run all sorts of electrical and plumbing equipment.

13-Replace recessed light fixtures with surface-mounted fixtures.

3- Block Diagram:

Figures 1 and 2 display the negative pressure room controller and its components.

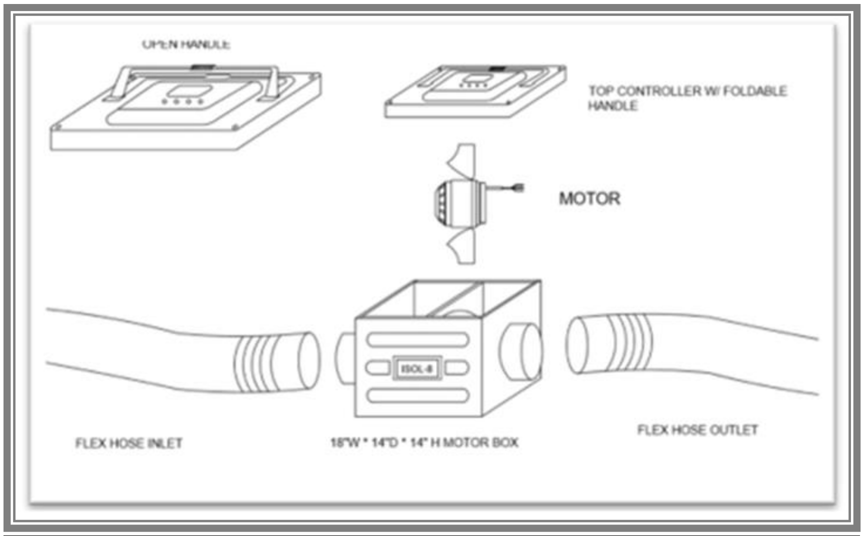

Figure 1 Block diagram of a negative pressure room

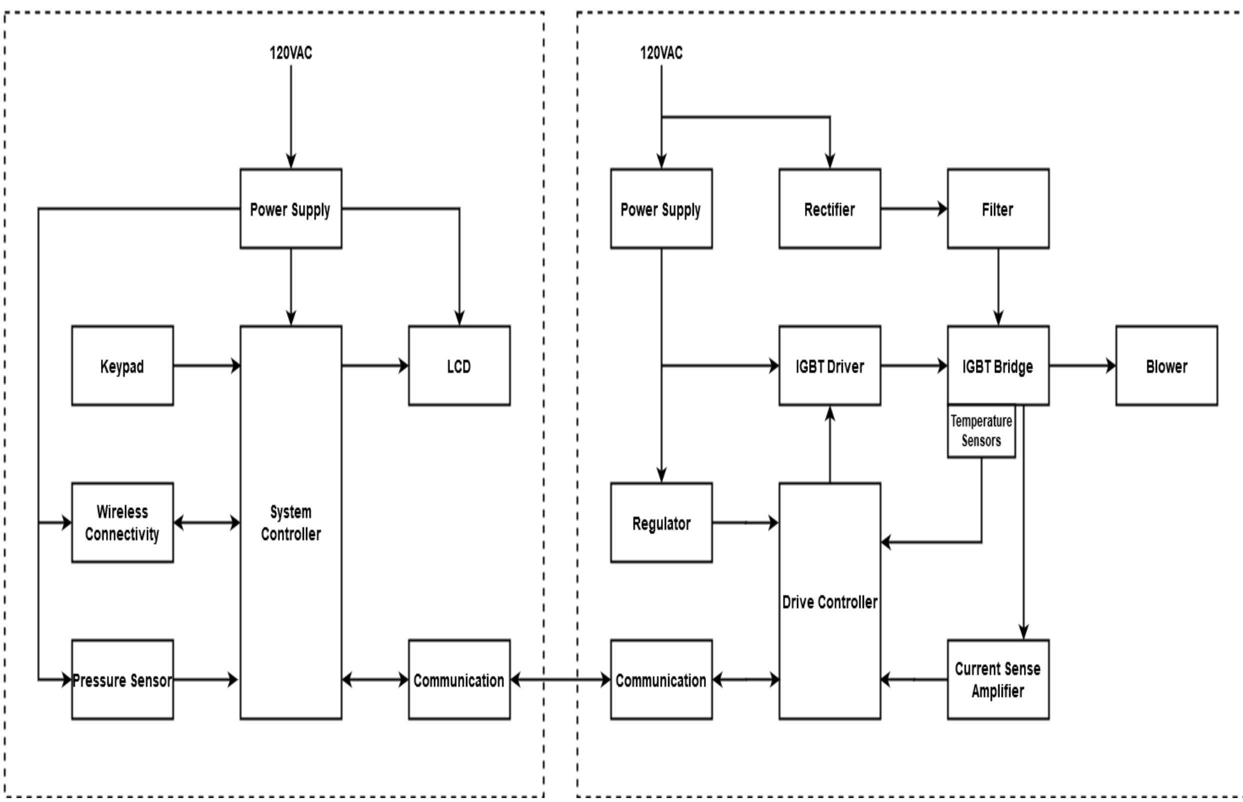

Figure 2 Block diagram negative pressure room controller and its components

4- Room Layout Example

Figure 3 displays a typical room layout for negative pressure controller and its components.

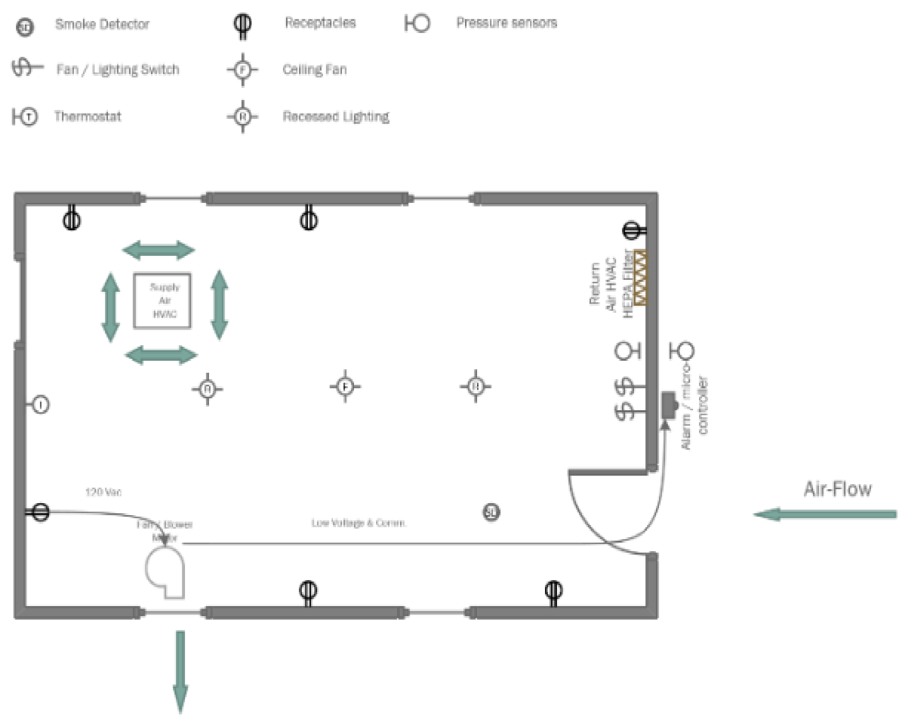

Figure 3 Typical room layout for negative pressure controller and its components

5- Project Operation:

This system is centered around a blower that pulls air from other parts of the building, through the room being used for isolation, and exhausts it outside. To do this the isolation room must be sealed as good as is practical in a home isolation situation. This means the user must cover windows, unused doors, HVAC return vents, and other potential points of unwanted air ingress/egress using materials provided in the kit. Smoke detectors, CO_2 detectors, and other safety devices must not be covered. The primary points of air ingress into the room are intended to be around and under the active door, and via the room's HVAC feed vent.

Power to the system is standard residential power consisting of 100-240VAC 50/60Hz on a 15- or 20-amp circuit breaker. This voltage is stepped down to supply power for the controller and blower via an off-the-shelf switching power supply. All wiring and loads are protected according to **N**ational **E**lectric **C**ode (NEC) standards.

Core functions are controlled by a Silicon Labs C8051F38x microcontroller running a user program atop a concurrent operating system. A small keypad and **L**iquid **C**rystal **D**isplay (LCD) allow the system to interface with users, including providing visual cues to the user via the LCD's **R**ed, **G**reen, and **B**lue (RGB) backlight. A piezoelectric buzzer is also included for audible feedback.

The system receives pressure differential data, in the form of analog voltages, from one or more pressure sensors. In the case of a single sensor, one input of the sensor is placed outside the room, and the other input is placed inside the room to produce a voltage proportional to the differential pressure. With two sensors, one is placed outside the room and the other inside the room, and the pressure differential is calculated in firmware.

The keypad interface allows navigation through the program settings enabling the user to adjust operational parameters such as upper and lower pressure limits, blower speed limits, calibrations, and alarm enables and silencing. Prior to operating the system, the user must zeroize the system's pressure readings by opening the door to the room the system is installed in and initializing a system calibration.

For safety and compliance, any connections to wall power will be inside of junction box or control panel and connected to equipment ground with neutral bonded as part of the residential electrical system. Any exhaust system exiting the room as part of the HVAC system will be covered and sealed for proper operation or filtered with **Hi**gh-**E**fficiency **P**articulate **A**bsorbing (HEPA) filtration[1,2].

6-Project main components

(a)-Motor

The motor is a one stage, 120VAC, 6 inches inlet/outlet turbine-style motor that can provide an air exhaust of up to 980 CFM. It has the capability of being stepped down to 90VAC to provide a slower exhaust output. According to the calculations of supply CFM into the room (294CFM), this motor will be more than enough to make the isolation room negative. We will also be adding single phase **V**ariable **F**requency **D**rive (VFD) to further slow the CFM exhaust to reduce the quantity of air controlled, cool air, from escaping, therefore allowing more comfort for the isolated person.

(b)-Sensor

Diff Press Click is an accurate pressure sensor (Figure 4). This sensor can measure a differential pressure and utilizes a very precise differential pressure sensor from NXP, labeled as MPXV7007DP. This piezo-resistive transducer is an advanced monolithic pressure sensor, combining advanced **M**icro-**E**lectro **M**echanical **S**ystems (MEMS) manufacturing technologies with on-chip signal processing, providing accurate measurement with very low drift over temperature. The sensor outputs an analog voltage, linearly dependent on the applied pressure.

This voltage is digitized by an accurate **A**nalog to **D**igital (A/D) converter and delivered to the **I**nter-**I**ntegrated **C**ircuit (I2C) interface.

(c)- Microcontroller

An 8-bit microcontroller Silicon Labs 8051 Microcontroller. This controller has long history of use in automotive and industrial applications.

Notes	Pin	mikroBUS				Pin	Notes
	NC	1	AN	PWM	16	NC	
	NC	2	RST	INT	15	NC	
	NC	3	CS	RX	14	NC	
	NC	4	SCK	TX	13	NC	
	NC	5	MISO	SCL	12	SCL	I2C Clock

Figure 4: Pressure sensor

7- Future Use and Expansion

Taking this system further and adding more features may prove beneficial on a multitude of platforms. Some examples of additional features include:

(a)- WIFI & Bluetooth connectivity

Having the capability to send alarms and or remote monitor such rooms could increase awareness of system operations and perform adjustments without having to physically be at the location otherwise compromising isolation. Because WIFI and Bluetooth functions aren't safety-critical, inexpensive off-the-shelf adapters can be used to provide such connectivity.

(b)- Creating Software Application and Development

Developing software such as a monitoring system that can be adapted to existing network configurations that can allow a user to monitor multiple systems at once. Also, giving the user certain functions like changing velocity and monitoring pressure will allow for ease of maintaining the system. This could be as simple as browser-based application or an integration into a BAS (**B**uilding **A**utomation **S**ystem). By pushing **G**raphic **U**ser **I**nterface (GUI) functions to devices users already have, system cost and complexity can be kept to a minimum, simultaneously enhancing core system stability while providing a better user experience.

(c)-Capability of reversing the motor creating positive air pressure.

This could undoubtedly benefit many who are not infected by keeping potential viruses and other contaminates out of a given area. This could apply to persons with compromised immune systems who live in a residence with other people. This would benefit such infrastructures as Nursing Homes, Hospitals and Residential applications.

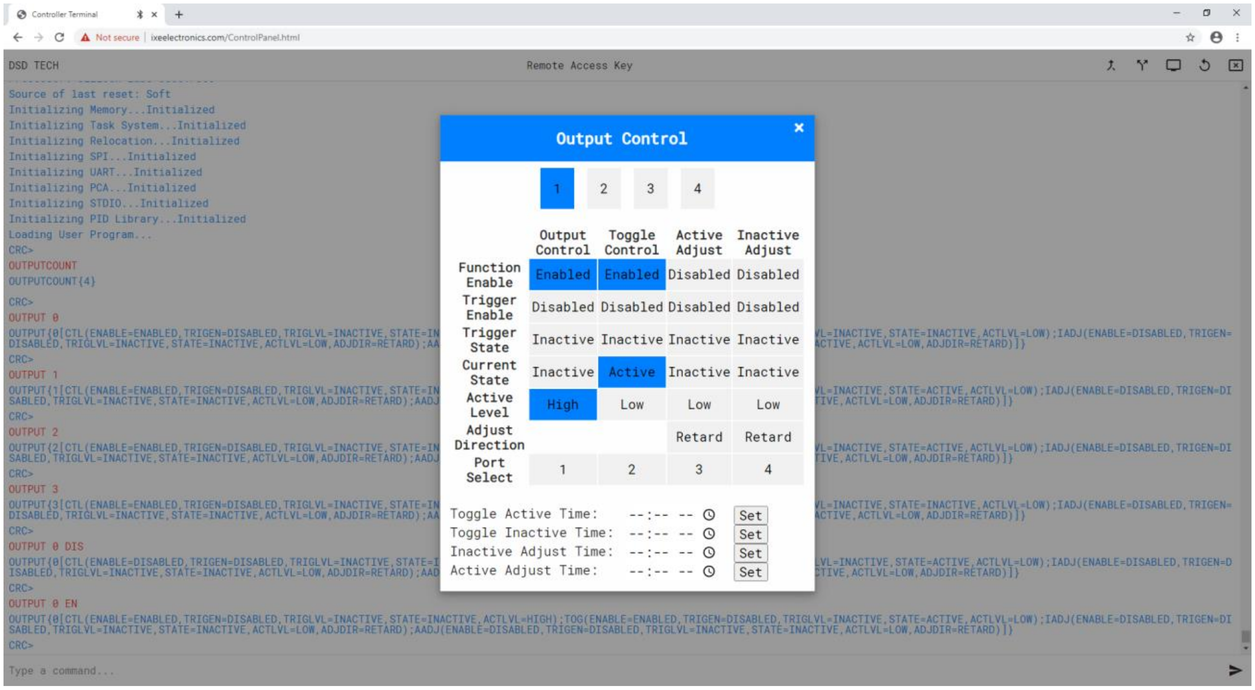

Figure 5 Example browser-based GUI with command terminal

7- Conclusion

Currently, at many health care facilities worldwide, staff is trying to make areas of operation more negative or positive in respect to existing infrastructure. This is a huge challenge throughout the healthcare industry as such facilities are being overrun and potentially working under less than safe practices. Having the capability to quickly tie into existing infrastructure and potentially make areas of operation safer for both employees and patients has proven critical during the pandemic.

Given current events and the potential of this project, it is easy to observe many applications for this adaptable technology.

8- References

1- Buchla, D. M., & Floyd, T. L. DC/AC Fundamentals. Up Saddle River, NJ: Pearson, 2013.

2- Mazidi, J. G., Mazidi, M. A., & McKinlay, R. D. The 8051 microcontroller and embedded systems: Using Assembly and C (2nd ed., Vol. 1). Prentice Hall, 2006.

3- Herrick, M. Planning and maintaining hospital air isolation rooms, hfmmagazine.com, 2017.

4- Falke, Rob. 'Doc'., Use the Air Changes Calculation to Determine Room CFM https://www.contractingbusiness.com/service/article/20868246/, 2016

5-"Airborne Infection Isolation Rooms." Centers for Disease Control and Prevention, CDC, 2020.

6-Airborne infection isolation rooms, www.mintie.com/assets/pdf/education/AIIR%20for%20TB.pdf, Mintie.com, 2008,