Modular Pivoting Fan Overview

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I. Project Overview

More Control

One can reduce HVAC energy consumption with more control. One can get control with $3 microcontroller IC's in physical devices networked together with reliable communication. Devices include:

- motorized dampers inside ducts
- motorized dampers at vent openings
- fans inside ducts
- motorized valves at radiators
- pumps that moves 60°F water from ground source into radiators and heat exchangers
- pumps that move water from thermal storage tank in basement into radiators and heat exchangers (water heated or cooled via solar when sun shining)
- sensors (occupancy, indoor/outdoor temperature, sun, wind pressure)

With the above technology, one can:

- more precisely control airflow from central HVAC fan
- move air from one room to another room while HVAC is off (e.g. move cool air from basement to warm office on 2nd floor without turning on central HVAC)
- route ground source 60°F water as needed
- route thermal storage water as needed
- integrate large appliances, thermal storage water, ground source 60°F water, and central HVAC

Devices with processors exist, yet we are not doing the above due to:

- a standard way to electrically plug the above devices into a building does not exist
- a common operating system for all devices that supports plug and play and reliable integration does not exist
- standard physical plug-in modules with fans and dampers does not exist

Researchers are working on the first two obstacles (standard electrical cable and operating system). For details, see: https://www.manhattan2.org/smart-building.

In this document we focus on the last remaining obstacle, which is a proposed standard for a replaceable standardized plug-in fan.

Standardization reduces cost via commoditization. Plug and play reduces cost via less design and installation labor.

One would want a system whose additional cost is paid for with reduce energy bills within a reasonable period of time. If one can do this, then mass adoption becomes feasible.

The good news is development costs are low, and a decent amount has already been completed. Perhaps the hardest part is the operating system (i.e. BuildingBus); however, this has already been coded and is available to others free and open. This means anyone can copy and modify at no cost.

Standard Plug-In Fan

If one places a proprietary damper or fan in a duct and it fails every 15 years while the building lasts 100 years, and the manufacturer stops production after 5 years, then the building will degrade in value due to difficult to obtain replacement parts. The only way to resolve this is to make use of standardized plug-in modules at vent openings.

For example, to replace a fan or motorized damper within a duct, one would remove the vent cover, reach into the duct, remove ~4 bolts, unplug the module, remove through vent opening, and replace with new standardized module, plug-and-play.

Students at Utah State University, set up by Dixon Nielson, developed this this. All design work is free and open, which means anyone can copy and modify at no cost. For details, see: https://www.manhattan2.org/fan-and-damper.

II. Modular Pivoting Fan Overview

System Overview

The Modular Pivoting Fan is an HVAC inline fan concept that pivots in and out of the airflow. This feature allows the Modular Pivoting Fan to not obstruct airflow when not in use, saving energy while expanding the capabilities of the HVAC system. Figure 1 shows the Modular Pivoting Fan inside a section of custom duct.

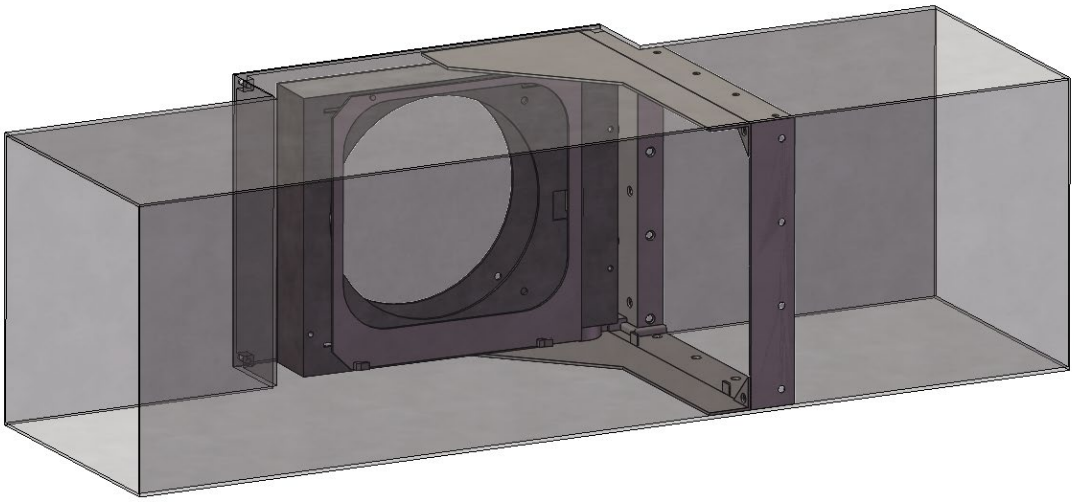
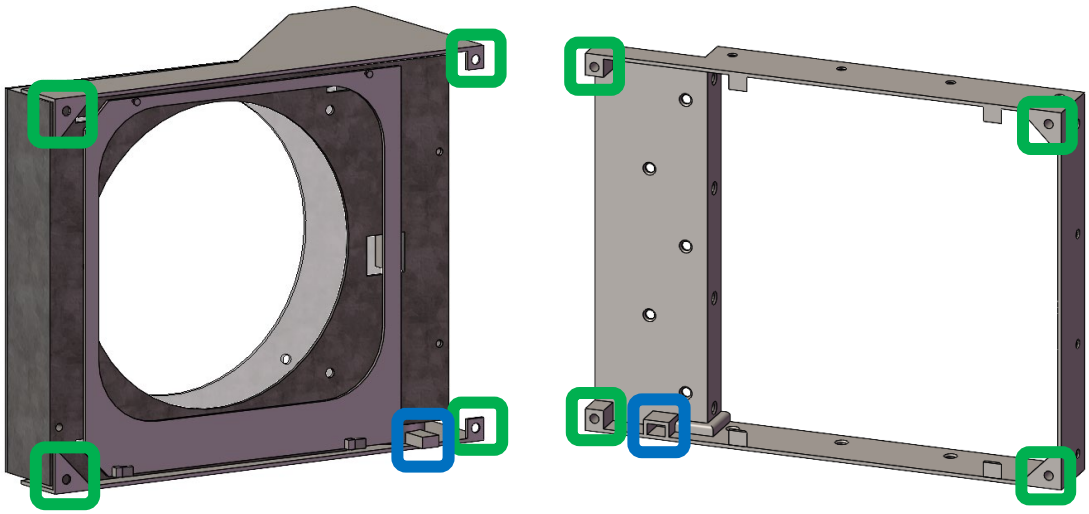


Figure 1. Modular Pivoting Fan assembled inside a custom duct.

The Modular Pivoting Fan consists of two separate assemblies. A mounting bracket with standardized bolt locations and a modular fan assembly. The mounting bracket and modular fan assembly are mechanically connected at four bolt locations and electrically connected by a single power and data connection. Figure 2 shows the bolt and electrical connection locations.



a) b)

Figure 2. Bolt (green) and electrical connection (blue) locations on the a) modular fan assembly and b) mounting bracket.

Installing the Modular Pivoting Fan is a simple process. The mounting bracket is permanently installed in the custom duct section by spot welds or duct screws. This duct and mounting bracket assembly is then installed in the HVAC system. Additional support can be added by bolting or screwing through the mounting bracket and duct into a stud as shown in Figure 3.

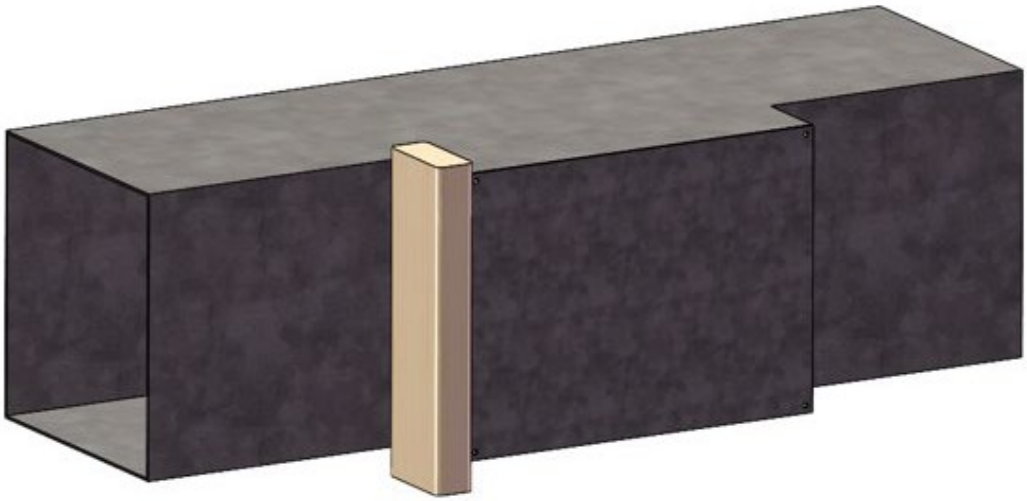


Figure 3. Additional support is provided by attaching the duct to a stud at the location shown.

The modular fan assembly is then installed in the following steps:

1. Remove vent cover to access the fan location.
2. Insert the modular fan assembly into the duct such that the electrical connector and bolt hole locations are lined up.
3. Install bolts into the four bolt locations.
4. Replace vent cover.

When the modular fan assembly requires maintenance or replacement, the steps above can be reversed to remove the fan from the duct.

System Performance

The purpose of a pivoting inline fan is to maximize air flow through the duct when the fan is not in use. This can be measured by comparing the cross section of the duct without the Modular Pivoting Fan to a duct with the fan installed. The highlighted area in Figure 4 shows the obstructions to the duct because of the Modular Pivoting Fan.

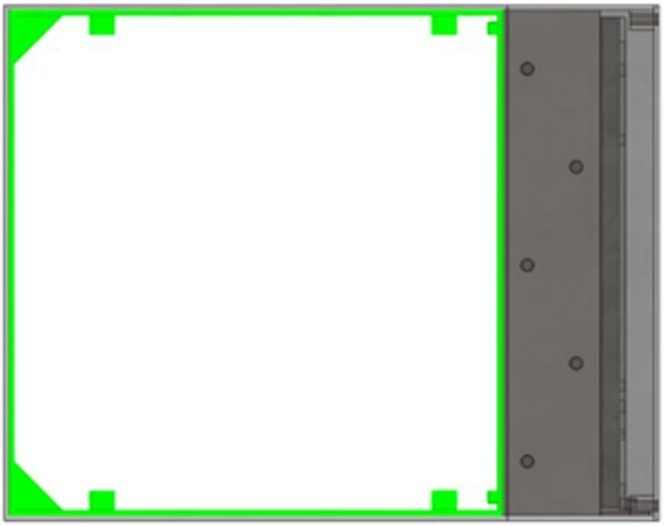


Figure 4. The duct cross section obstructed by a retracted modular pivoting fan is shown in green.

The cross section of a 10 in. square duct is approximately 104.03 in^2 and the area taken up by the Modular Pivoting Fan when retracted is 6.01 in^2. This results in a total cross section reduction of 5.77 %.

The modular fan assembly design is intended to vary from different manufactures while the mounting bracket and associated mating features on the modular fan assembly will be standardized across the industry. This allows for a plug-and-play system such that modular fan assemblies from multiple manufactures will be interchangeable.

The Modular Pivoting Fan can be scaled to fit any standardized duct size. Required bolt locations and duct bump out sizes for several duct sizes are listed in the document Modular Pivoting Fan Standard found at https://www.manhattan2.org/fan-and-damper.

III. Major Subsystem Overview

Mounting Bracket

The mounting bracket provides strength and rigidity for the modular fan assembly and transfers loads and vibrations to the building. The mounting bracket is shown in figure 5.

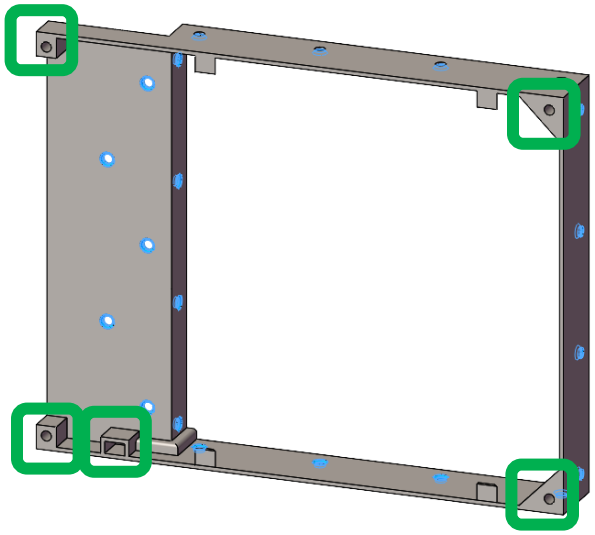


Figure 5. Mounting bracket showing attachment point locations. Mounting bracket to duct are in blue and mounting bracket to modular fan assembly in green.

Located on the mounting bracket are bolt threads for attaching the duct to the bracket and the bracket to the modular fan assembly. The holes highlighted in blue in Figure 5 are for attaching the mounting bracket to the duct and attaching the mounting bracket through the duct to a stud as shown previously in Figure 3.

The location of bolts and an electrical connector are highlighted in green in Figure 5. The bolt threads are used for physically connecting the modular fan assembly to the mounting bracket. The electrical connection provides power and data to the modular fan assembly. All the location in green in Figure 5 are standardized to allow for plug-and-play modules.

The power and data cable must be shielded from vibrations or heat to avoid damaging the wires and causing a short circuit. The cables can enter the duct directly underneath the connection

point on the mounting bracket or can be installed further down the duct and run to the electrical connection point through a conduit.

Modular Fan Assembly

The modular fan assembly consists of four sub-assemblies. The modular fan assembly bracket, fan housing, pivoting mechanism, and locking mechanism. The complete modular fan assembly is shown in Figure 6.

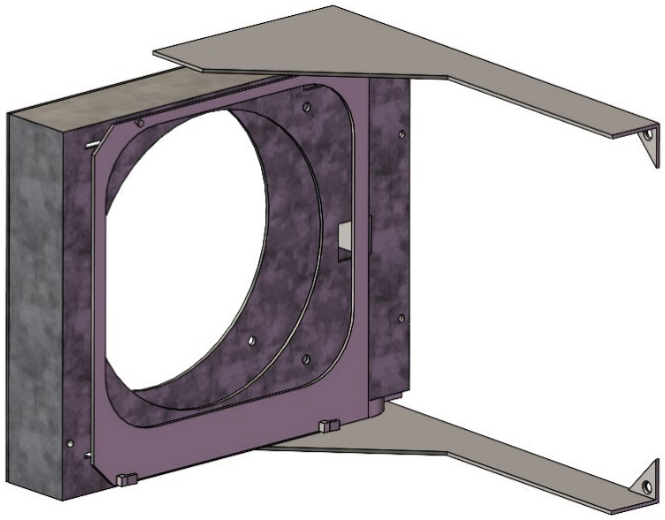
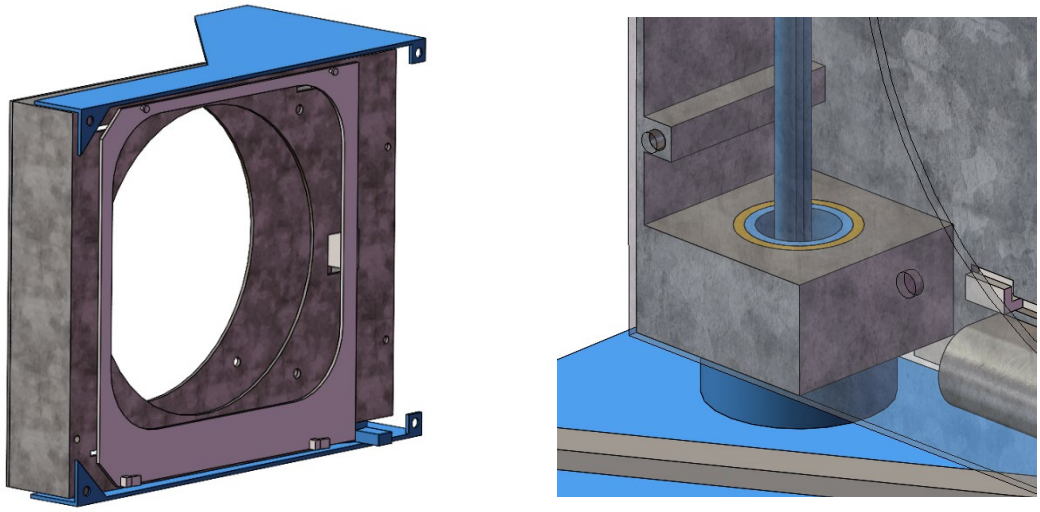


Figure 6. Modular fan assembly in the retracted position.

Modular Fan Assembly Bracket

The modular fan assembly bracket contains the mating surface between the modular fan assembly and the mounting bracket, pivoting posts for the fan housing, and the electrical connection route between the electrical connection and the fan housing. Figure 7a shows the modular fan assembly bracket and Figure 7b shoes the route of the power and data cable through the bracket.



a) b)

Figure 7. a) Modular fan assembly bracket. b) Power and data cables are routed from the electrical connection point to the fan housing through the lower pivoting point.

Fan Housing

The fan housing encloses major components such as the fan, pivoting mechanism, internal wiring, and provides support for the locking mechanism. The fan housing is shown in Figure 9.

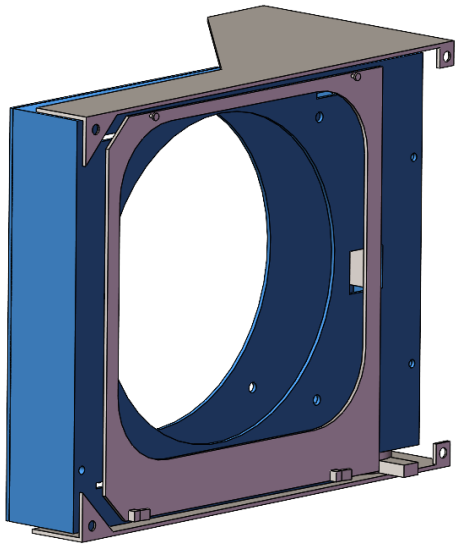


Figure 9. Fan housing.

The fan housing is made of sheet metal and comprises of the fan housing and fan housing cover. On the fan housing are several features used to pivot, lock in place, mount motors, and mount a fan. The position of the fan housing is measured using pressure sensors. This way the system knows when to stop the pivoting mechanism and engage the locking mechanism.

Pivoting Mechanism

The pivoting mechanism moves the fan housing from the retracted position to the extended position. This motion is created with a screw and connection linkage. The motor turns a screw that is attached securely to the bottom of the fan housing. The screw then moves a translating nut up or down the screw. This translating nut is attached to a connecting linkage that pushes or pulls the fun housing in or out of the bump out section. This design prevents unwanted movement when the fan is retracted or extended. The pivoting mechanism is shown in Figure 10.

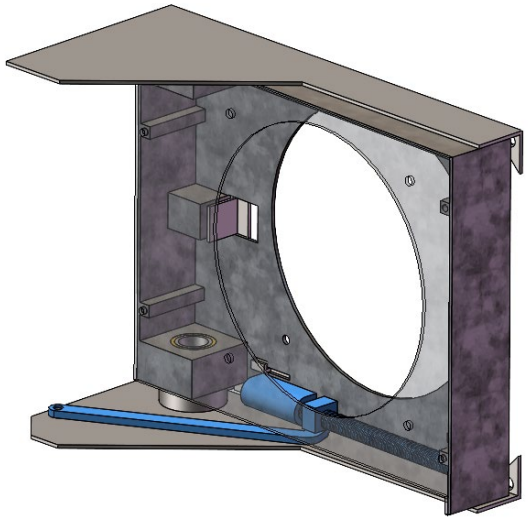
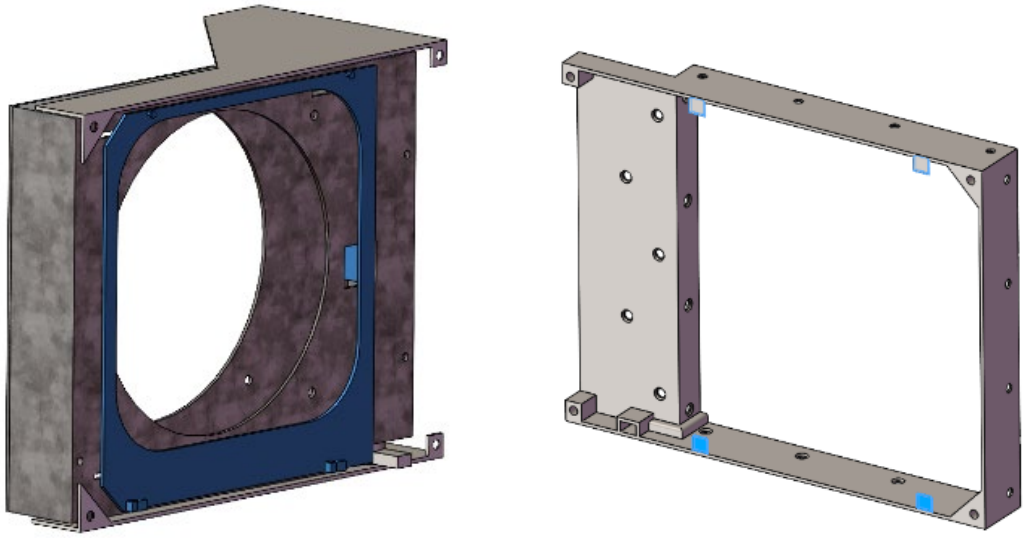


Figure 10. Pivoting Mechanism.

Locking Mechanism

The purpose of the locking mechanism is to mechanically connect the fan housing to the mounting bracket when the fan housing is fully extended. Large vibrational forces may be created when the fan is operating, and the locking mechanism transfers these forces from the fan to the structure of the building without causing unwanted motion.

Figure 11 shows the locking mechanism. The locking mechanism consists of a locking plate, receiving tabs, and a liner motor to create motion. The locking plate is held in place by the fan housing and can translate side to side. When the fan housing is fully extended, the locking plate moves due to the linear motor and engages locking tabs on the locking plate with receiving tabs on the mounting bracket. This mechanically connects the fan housing with the mounting bracket.



a) b)

Figure 11. Locking Mechanism showing the a) locking plate and b) receiving tabs on the mounting bracket.