Manhattan 2
Fan and Damper
Interconnection-Standards Development Initiative

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1.1 In the Future, Temperature Control will be Smarter

Today's HVAC (heating/ventilation/air conditioning) systems often do not accurately regulate temperature in each room, and do not move air between rooms. This is mostly due to one central fan that feeds a tree of ducts (only). Current dampers and in-line fans products, shown below, can help, yet routing their wires to a central HVAC system is labor intensive and replacement is often costly due to difficult access. Also, proprietary replacement parts are often difficult to locate as a building ages.

1.1.1 More Air Control

Distributed dampers and fans are useful when the central HVAC system is turned on, as well off. For example, when central HVAC is off, distributed fans and dampers can move air from one part of a building to other parts. If a basement is cool and a 2nd floor office is hot, and one wants the office comfortable, they might prefer to circulate air between the two, instead of powering the central AC. Homes often have basements that are thermally connected to the ground (e.g. they tend to stay cool in the summer), and making use of this can also save energy. Air might be much warmer near the ceiling of upper floors, and cooler near the floor of lower floors (hot air rises); consequently, circulating air between the two is sometimes desirable.

Rooms far from the central HVAC fan are often starved for air; subsequently, in-line booster fans are helpful at augmenting those positions.

In summary, more dampers and more fans, away from the central HVAC is often desirable, provided it is low cost, rugged, reliable, easily installed, and easily maintained over the lifetime of a building.

1.1.2 Industry Requirements

HVAC engineers have struggled for decades to gain more control over each room without significantly increasing costs. What can we do to help them? Let's begin by reviewing their requirements:

1) Service people need easy access to distributed fans and dampers, in ducts, and at vent openings, for installation and replacement.
2) Components need standardization to reduce cost via commoditization. R&D spread out over multiple companies, and competition, reduces price.
3) Components need standardization to ensure one can obtain replacement parts over a building's lifetime. Otherwise a building degrades and decreases in value when one cannot obtain proprietary replacement parts.
4) Components must connect to a reliable and fault tolerant communications system that incurs few faults over a building's lifetime.

1.2 BuildingBus Development Initiative

Manhattan 2 is developing a 2-wire communication system, called "BuildingBus", which interconnects devices in buildings. This includes physical wall windows, lights, fans, dampers, etc. The electronic PCB that attaches BuildingBus to a rolled thermal cover at a physical wall window is very similar to the PCB that connects BuildingBus to a damper or fan. Subsequently, electrical engineers (EE's) who develop BuildingBus devices can copy hardware and software produced by other researchers, and move quickly.

There are two versions. *BuildingBus 48V* caters to lower power and lower voltage whereas *BuildingBus AC* caters to higher power and higher voltage. *BuildingBus 48V* routes 48VDC power to devices with ~200W/network; whereas *BuildingBus AC* routes 110/220VAC power with ~2,000W/network to devices. Fans, industrial lighting, and motors that move heavy windows require 110/220VAC; whereas many other devices are 48V capable. 110/220VAC cable is bulky (e.g. 10 to 16awg power) and needs to conform to high voltage building codes (i.e. conduit more likely), whereas 48VDC cable is lighter (e.g. 18 to 20awg power) and satisfies low voltage building requirements.

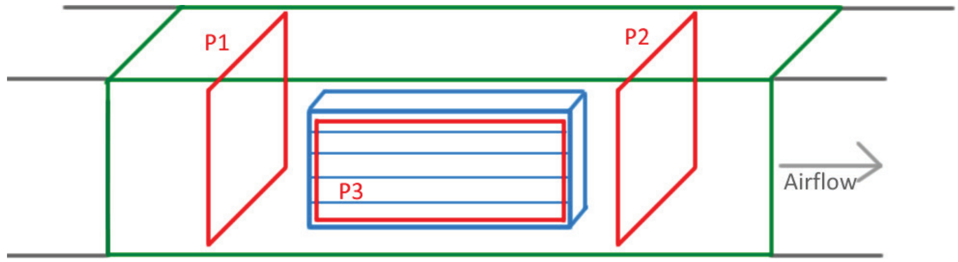
Motorized dampers and small to medium sized fans (e.g. < ~50W) are supported by BuildingBus 48V; whereas larger fans (e.g. > ~50W) require BuildingBus AC.

BuildingBus AC wires (110/220VAC hot/neutral, earth ground, ACBB Data+-), and BuildingBus 48V wires (48VDC power+-, shield/sense, LVBB Data+-), connect multiple devices in parallel, in a manner similar to that done with building power outlets. For details, search for "BuildingBus Development Initiative" in file Active Window, and search for "Team A" in Active Window Tasks.

1.3 Manhattan 2 Fan and Damper Standards Development Initiative

Manhattan 2 intends to develop mechanical interconnection standards for fan and dampers, both in-line ducts, and at vent openings. Researchers propose mechanical standards that coordinate the various manufacturers of ducts, vents, fans, dampers and supporting hardware. Mechanical engineers focus on the mechanics, cabling and electrical connectors; and electrical engineers focus on PCB's that connect BuildingBus to motors and sensors.

In theory, one can add fan/damper hardware in three positions: in-line duct upstream (P1), in-line duct downstream (P2), and at vent opening (P3).



At each of these three positions, one could potentially install an insert that is one of: fan only, motorized damper only, or fan plus damper combination. This enables the following capabilities.

- Temperature zone each room via motorized dampers and temperature sensors at all vent openings (i.e. independently regulate temperature of each room).
- Move air from one room to any other room via a combination of fans and motorized dampers at various locations, while central HVAC system is OFF (e.g. cool 2nd floor office with cold basement air).
- Boost the central HVAC system's delivery of air to various parts of the building via a combination of dampers and "booster" fans. Sometimes central HVAC systems are deficient at delivering air to rooms far from the central fan, and a booster fan is one remedy.

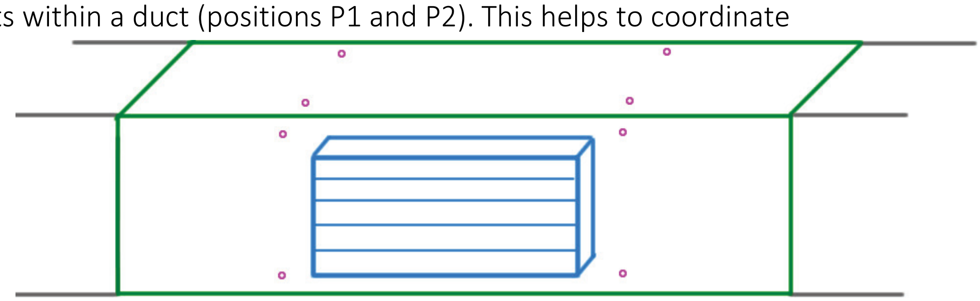
Also, there are disadvantages of adding fans/dampers:

- Initial costs, which we aim to reduce via standardization.
- Maintenance costs, which we aim to reduce via rugged and fault tolerant electronics.
- Reduced airflow when central HVAC is ON and distributed damper/fan is not being used (e.g. in-line fan mechanism might be bulky and obstruct airflow). Engineers look at ways to minimize this.

1.4 Researchers Propose Fan and Damper Mounting System

1.4.1 Researchers Propose Standards that Define Mounting of Fan/Damper Inserts In-Line Ducts, for New Construction

Let's begin with something simple: Mounting. Researchers propose mechanical standards that determine how a fan/damper mounts within a duct (positions P1 and P2). This helps to coordinate manufacturers of inserts with manufacturers of duct components.



Pictured here is a duct at a vent position, with nuts (violet) welded to the duct internal wall. In theory, a proposed standard would consist of a drawing and a table that defines placement of these nuts, and thread size, for different standard duct sizes. Each duct size could be represented on one row within the table (e.g. 6x9" duct has m8 nuts 2cm from corners; and 12x18" duct has m10 nut 3cm from corners). Researchers create drawing and table for both rectangular ducts and circular ducts.

Instead of welded nuts, one might utilize welded threaded posts, welded stamped sheet metal brackets, or glued plastic brackets. Or, provide welded nuts which mate with stamped metal or plastic brackets.

Vibration and load forces for fans might be ~10 times greater than that for dampers (or more). Subsequently, one might pre-position 8 welded nuts in a duct wall, where a fan uses 8, and a damper uses 4.

What mates with hardware (e.g. welded nuts)? One could have fan/damper inserts mate directly with hardware; or brackets mate with hardware and fan/damper inserts mate with brackets. Researchers explore both options.

1.4.2 Researchers Propose Standards that Define Mounting of Fan/Damper Inserts, At Vent Open Openings, for New Construction

This is similar to in-line ducts, discussed previously, yet pertains to vent openings (position P3). One might spot weld nuts at standard positions, on internal surface, along opening perimeter, for fan, damper, and fan + damper inserts. Alternatively, one might consider replacing grill, discussed next, yet features on internal duct wall can withstand significantly greater load forces than typical grille mounting hardware.

1.4.3 Researchers Propose Standards that Support Replacing Grille with Motorized Damper

In theory, one can replace a grille with a motorized fan and/or damper, and make use of existing mounting hardware (e.g. two screws at side of grill, shown to the right). However, this mounting is not designed to support fan vibration/loading; therefore, it might work with motorized dampers, yet not heavier fans.

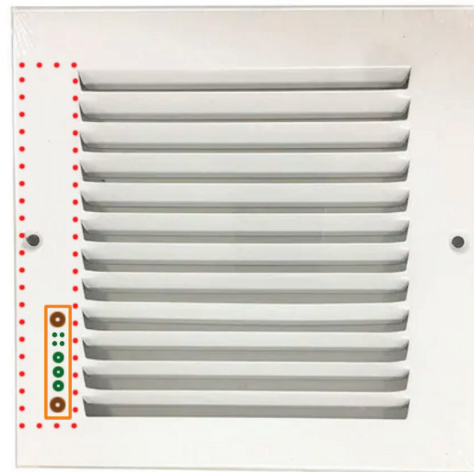
Researchers explore this concept and consider what is needed to make it viable. Researchers provide comments for fan/damper manufacturers that include: review of common grille sizes and hardware placement, typical load capabilities, and maximum available depth.

Researchers also consider standards that define placement of electronics and cabling. Electrician who wires building will want to route cable to a specific position (e.g. lower left corner). Perhaps connector or short ~6" cable with standardize connector is placed at this position that mates with grille assembly. Perhaps markings in duct at standard positions suggest where to punch hole for port that mates with

~6" cable + standard connector. Perhaps suggested port location is in two positions (e.g. left wall, and lower wall) at lower-left corner to help avoid obstacles. Manufacturers of fan/damper hardware would provide mating connector at same positions. Researchers propose standard that defines connector and placement.

Researchers consider location of electronics PCB. Does this need to be in a standard position, or can researchers suggest an envelope in which fan/damper manufactures place all structure?

In the case of a motorized damper, one might look at placing PCB/mechanism (red) under the left external surface, as shown to the right. A standardized molded plastic frame (blue) is affixed to drywall (brown) and seals to duct wall (violet) via duct tape. BuildingBus cable (yellow) attaches to socket (orange) embedded in frame. Grille with damper (green) contains PCB/mechanism (red) and BuildingBus plug (purple) is soldered to this PCB.



Alternatively, one might look at replacing the previously discussed frame/plug/socket (blue/purple/orange) with a dangling BuildingBus cable that has a Memory IC + cover clamshell attachment (described later). This might mate with screw terminals soldered to PCB (red).

If one wanted to support a fan, they might look at a heavy frame (blue) mounted on wood studs (not drywall, not duct wall), and provide plenty of bolts between fan-augmented grille and frame. Also, one might look at placing wood stud a standard distance from duct wall, and positioning motor between wood stud and wall, to reduce airflow restriction when fan is off.

Researchers explore advantages and disadvantages of the various options. Also, after reviewing different grille types, researchers will have a better sense of what is needed to coordinator the various participants.

In both cases (duct in-line and vent opening), servicing is done at vent position. This is necessary, since a building might last 3 to 10 times longer than fans and motorized dampers, and require occasional replacement with standardized components available from multiple suppliers.

1.4.4 Researchers Make Suggestions and Let others Proceed as They Desire

Researchers can make multiple suggestions, and standards bodies will pick and choose as desired. One can expect interest to vary with each suggestion over time. For example, on one year one body might take interest in one proposal, and in the following year, another body might take interest in others.

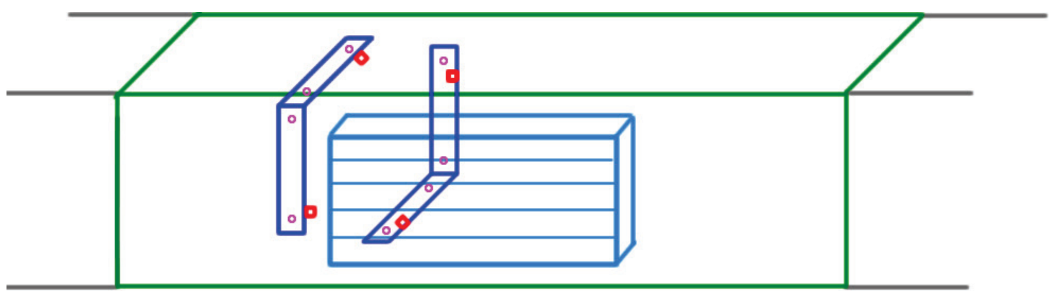
Researchers make all drawings, spreadsheets, simulations, software, and schematics available to the world free and open. This means anyone can copy, and modify, as desired. Subsequently, researchers do not need to be too concerned with details, since they are likely to be reworked by industry engineers.

Standards bodies often cannot get started unless they are handed a first draft, which is the job of researchers.

In summary, researchers have no authority, they make suggestions, and they let others proceed as desired.

1.4.5 Researchers Propose Standard that Defines Fan and Damper Mounting for Existing Construction

The above approach supports new construction duct components. However, what might one do with existing construction, or a vent opening that is cut into the side of a duct in the field?



Researchers propose a standard that defines an internal bracket system, illustrated here in blue, which affixes to internal duct wall, post construction. Mounting brackets affix to duct wall, possibly via sheet metal screws (violet), and fan/damper inserts attach to mounting bracket, possibly via small angle brackets (red). Researchers explore jigs/templates that might help position brackets.

Researchers propose a mechanical standard with a mechanical drawing of a rectangular duct, and a mechanical drawing of a circular duct, and a table for each to cover different sizes, for existing construction. Researchers do this for vent openings as well as in-line inserts (i.e. under a traditional grille).

We want brackets to mate with fan/damper inserts, therefore the placement of the features that interface these two need to be in agreed upon positions (i.e. each row of table might show positions and thread sizes of the red tabs). What else needs to be specified in order to coordinate the various participants?

Obviously, brackets that mate with pre-positioned welded-nuts (new construction, discussed previously) would support the same fan/damper inserts as brackets that attach to vent wall via sheet metals screws (post-construction, described here). For example, the red tabs shown above would be in the same position for both cases.

Fan/Damper manufacturers would prefer their products be used in as many different positions as possible. Researchers explore having fan/damper inserts support both in-line duct and vent opening positions.

If a fan/damper insert is large relative to the size of a vent opening, then one might need to break the insert into multiple pieces, and reassemble inside the duct. Researchers explore how this might work.

1.5 Electrical Cables

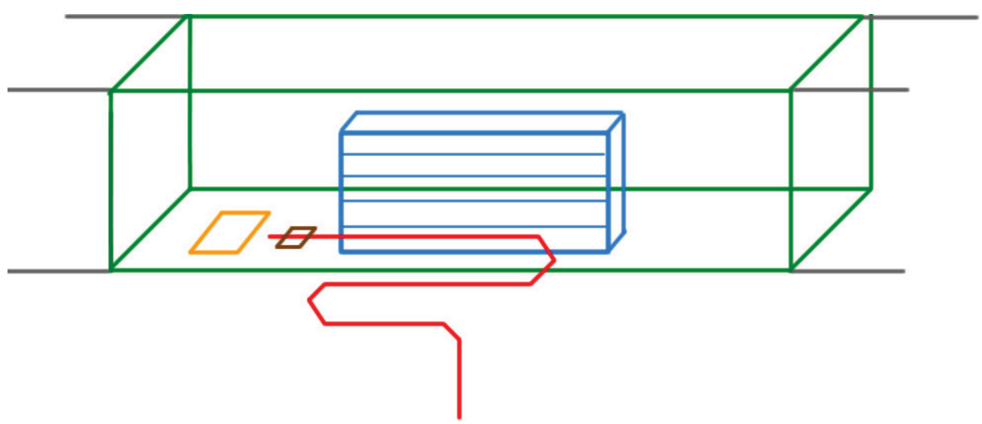
1.5.1 Electrical Cable Provides Power and Control

Let's make the following assumptions regarding electrical cabling:

- A 5-wire BuildingBus AC or BuildingBus 48V cable routes to all fan/damper devices, in parallel, using tree topology wiring (not daisy-chain, not star point-to-point). For details, see previous Chapter "BuildingBus Development Initiative".
- Cable routes to sockets that mate with fan/dampers.
- Tiny memory IC embedded in each socket is programmed with physical location information, probably by electrician who wires building, and 2 wires connect this IC to fan/damper device.

Shown to the right is a typical 5-wire cable that contains heavy wires for power and lighter wires for data (e.g. Southwire #NM-B-PCS DUO). BuildingBus AC cable might contain 110/220VAC power wires (e.g. 10 to 16awg, 1.3 to 2.6mm diameter), whereas BuildingBus 48V might contain lighter power wires (e.g. 18 to 20awg, 0.8 to 1.0mm diameter). For details, see Wire Sizes.

1.5.2 Researchers Propose Standard that Defines how Pre-positioned Cable enters duct



Researchers propose standards that facilitate pre-positioning cable during construction, with the intent of entering the duct at any time post-construction. What might this look like? Perhaps cable (red) with built in slack is taped (brown) to external wall of duct, and standardized decal (orange) is affixed to internal wall of duct at time of construction (i.e. electrician pre-positions cable). Then, later, one cuts duct at decal position, fishes for cable, and installs air-tight port.

If one installs fans/dampers at time of construction, then the port might be installed at that time without the pre-position tape and decal.

If cable can slide in and out of port and has enough slack, then electrician might pull ~0.5m of cable through port, through vent, and into room, for purposes of securing end of cable to damper/fan via screw terminals. Alternatively, if cable does not move easily at port, then electrician requires comfortable access to the cable/device junction via vent opening. Researchers consider the various options.

1.5.3 Prepositioned Cable Facilitates Full Zone Capable

Let's assume "Full Zone" refers to full temperature control over all rooms, "Full Zone Installed" refers to a system that is Full Zone and it is fully functional, and "Full Zone Capable" refers to new construction that has the ability to later be upgraded to "Installed". We would like for Capable to be so cheap all builders do it and defer later decisions/costs to others; or they provide a fully zoned finished product. Also, it is possible that future building codes will require new construction to be automation capable, which might entail pre-positioning cable at each vent. Alternatively, an electrician might look at routing a cable via attic or basement, post construction, with varying degrees of feasibility.

1.5.4 Researchers Propose Standard that Defines Mechanical Ports for Cable that Enters Duct

The 5-wire cable outside the duct enters the duct through a hole and then connect to a fan or damper insert ("device"). Since devices are wired in parallel, one 5-wire cable could in theory connect to multiple devices. For example, one might connect an inline fan, vent fan, inline damper, and vent damper all to the same cable.

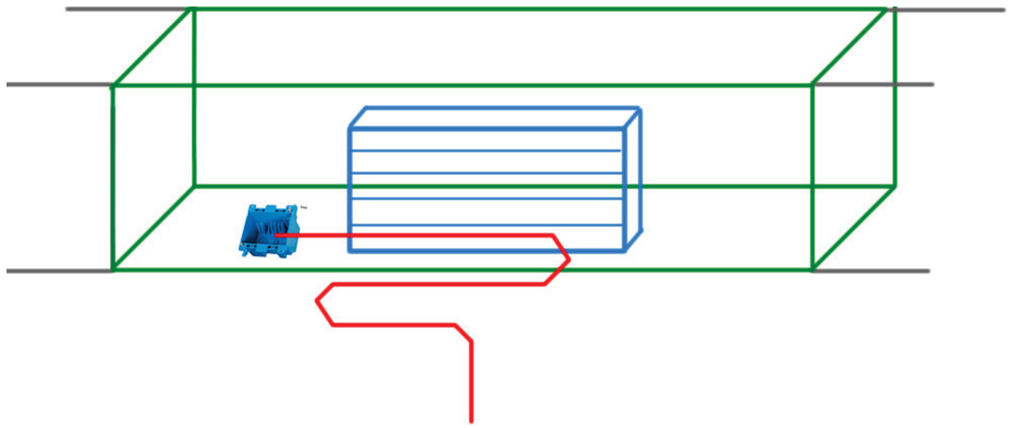
One needs to seal air at the location where the cable enters the duct for several reasons:

- Pressure from outside wind will push air into internal wall cavity (next to 2x4 or 2x6 wood framing), which will push air through hole in duct, which will push air into room. This airflow often entails energy loss (e.g. cold air leaks into room during winter).
- Mold and building materials in a wall sometimes adversely affect health (e.g. mold allergy). A hole in the duct metal wall (e.g. where BuildingBus cable enters duct) provides a path for potential pathogens to enter the room due to pressure from outside wind (discussed previously) or convection currents (hot air rises).

In summary, we do not want to introduce holes in ducts.

Rubber grommets, plastic grommets, and silicone might help seal a cable as it passes through a duct wall. The cable might not be circular, therefore a custom mechanical port component might be needed. What might this look like? Perhaps one cuts 2" diameter hole in duct and then 3" diameter plate with special hole for cable is affixed to duct wall via sheet metal screws and adhesive or gasket. Or one mounts grommet directly into duct wall.

1.5.5 Researchers Consider Standards that Determine how Electrical Box Secures to Duct Wall



In many traditional systems, 110/220VAC power wires terminate at an electrical box. In theory, one might secured one to the outside wall of a duct, and then access the contents via a hole and plate in the duct, pictured here.

This involves several challenges:

- Installation personnel might not be able to see inside the electrical box, unless it is positioned close to vent opening. A mirror and light might help.
- Duct might be pressed against drywall or plywood, with little space for electrical box.

The good news is that a PVC electrical box is molded and therefore could be formed into a custom shape with helpful features. For example, one might mold a groove for a rubber gasket that seals airtight between electrical box opening and duct wall. Cut-out in duct wall might provide access to box internal cavity. Since duct might be pressed against drywall or plywood, researchers look at minimizing box depth. Researchers explore how fan and/or damper insert might mate w/ electrical box.

Alternatively, one might have a plastic bracket affix to internal duct wall that mates with electrical box in some way.

1.5.6 Researchers Explore Routing Cables inside Ducts

Researchers explore routing 5-wire cable within ducts (e.g. 20ft long duct with 2 vents might route 5-wire cable inside the duct over the entire 20ft length). What fire/electrical codes are involved (e.g. 300.22)? What electrical insulation is required (e.g. heat resistant, no outgassing)? What voltage level is acceptable (e.g. low voltage)? What grounding is required for the duct (e.g. connect earth ground to metal duct to reduce shock hazard in case electrical insulation fails in duct)? How might one secure cable to duct wall (vibration can lead to chafed insulation and cause it to fail)? Is metal conduit required? Allow duct internal wiring for both new construction and existing construction (one has access to duct external surfaces with new construction and therefore external routing might be preferred with new construction; however, reducing energy loss in existing construction might outweigh concerns over internal wires)?

Running cables in ducts for fans is trickier than running cables for motorized dampers since fans use 10 to 30-fold more power, and fan vibration is more likely to damage cable. There is a movement to reduce building energy consumption, therefore wiring in ducts might become more acceptable provided various concerns are addresses.

Alternatively, one can look at having cables drop in from attic, or rise up from basement, which is more feasible in some cases than others.

Researchers possibly suggest changes to fire/electrical codes.

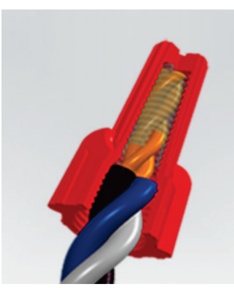
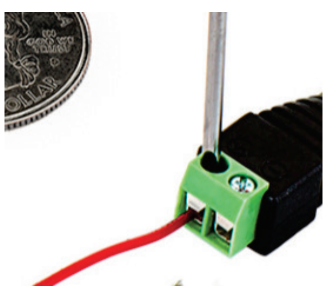
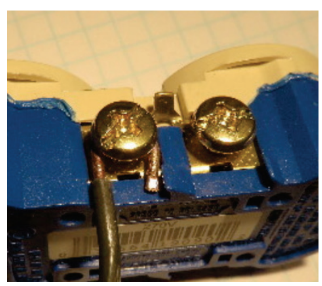
If one wants their suggestions to be taken seriously they must: insure safety (e.g. no electrical shock if something breaks), avoid fire (e.g. no fire if something breaks), avoid adversely effecting health (no outgassing of harmful materials), and avoid materials that degrade prematurely (e.g. some plastics, rubbers and adhesives do not tolerate HVAC level heat).

Building and fire codes are often updated annually and are open to suggestions. They look at benefits and costs, and try to be reasonable.

1.6 Researchers Explore Cable/Device Plug/Socket Interface

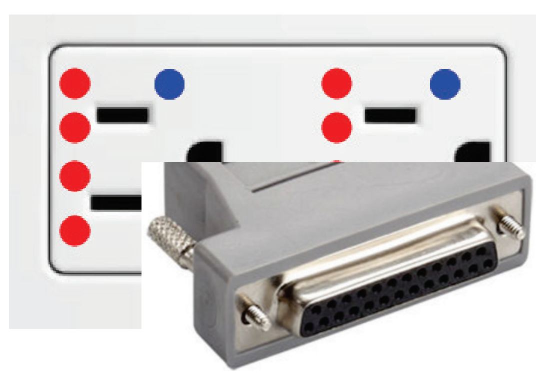
1.6.1 Researchers Propose Standard that Defines how Cable Connects to Fan/Damper

Researchers propose standards that define how a cable might connect to a fan or damper. Wire nuts, screw terminals, wire under screw head, and crimped connectors are traditional methods; all pictured below. Screw terminals are currently popular with automation. 110/220VAC power is often not routed in a small connector due to high voltages and currents.


In some cases, more than one device is attached to one cable. Subsequently, a method to attach multiple devices in parallel is needed. One remedy is to place 2 wires into one screw terminal or two wires under one screw head, and implement a daisy-chain configuration.

1.6.2 Researchers Consider Electrical Socket Accessible from Inside Duct



Researchers consider adding a 7-pin electrical socket that is mounted on duct internal wall and accessible from vent opening. This socket is possibly mounted inside an electrical box, described above. Shown here are two sockets in parallel. Two pins are power+-, one pin is earth ground, two pins are Data+/-, and two pins are memory IC Memory+/-. As mentioned previously, a memory IC is embedded in the socket and contains location information (e.g. "living room, front wall, 3rd vent from left").

Fan and wind vibration might cause the traditional plug/socket to be physically unstable; therefore researchers consider securing plug to socket via one or more decent-sized bolts (e.g. threads shown above in **blue**). It is not unusual for bolts to help secure connectors, an example of which is shown at the right. Another option is a circular threaded connector that uses many threads to insure a solid mechanical connection.

Screw force (wire under screw head or wire in screw terminal) is considered to be a more reliable connection than plug/socket; however, bulky plug/sockets with securing bolts (**blue** above) might be acceptable.

To reduce effect of airflow on electrical contacts, one might recess plug/socket within electrical box. Note that European 110/220VAC power plugs tend to be more rugged than American.

Within the duct, researchers consider routing cable in conduit, raceway, channel, or other protected structure to reduce vibration from airflow and/or fan.

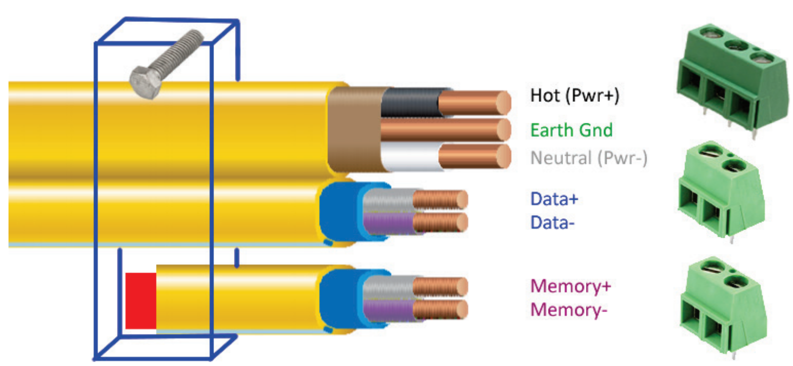
Industry might favor screw terminals, pictured to the right, over plug/socket, since one still needs to strip wires and terminate cable at socket. Yet attaching to a socket is done once by the electrician at the time of construction, and he/she might have special tools and skills to reduce labor time. If one does use screw terminals, they might also want to mechanically connect the cable to the device (e.g. via strain relief), to reduce vibration at the electrical point of contact.

The disadvantage of plug/socket over screw force between cable and device is that plug/socket is one more connection that might fail.

See also: Cable Management and National Electrical Code.

1.6.3 Researchers Consider Standard that Affixes Memory Chip to end of Cable

If we don't have a physical socket, we still need a Memory IC at cable end and we need this to not travel when one replaces device. Researchers consider a small module that clamps to cable end, perhaps with a clamshell design (e.g. hinge at one end and bolt at the other). This is illustrated to the right, with the memory IC shown in red.

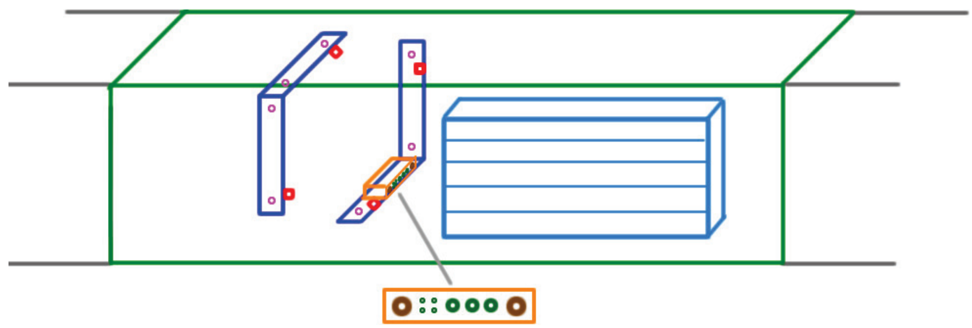


The power wires and data wires cannot touch duct metal; therefore, they need to be covered with a hood while not in use (i.e. we do not want live 220VAC at end of dangling cable touching duct metal).

Perhaps the previously discussed clamshell module would also have a Cover that shields cable end when not used?

If multiple devices (e.g. fans, dampers) are connected to one cable, then one would need to add stubs to the cable, and then attach one memory IC clamp-on module to each stub.

1.6.4 Researchers Consider Custom Mounting Bracket with Built-in Electrical Socket



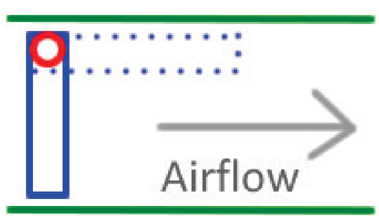
Researchers consider metal or plastic bracket with built-in 7-pin electrical sockets that provide mounting support and electrical connection to fan/damper inserts.

The 7-pin BuildingBus 48V connector would be different from the BuildingBus AC connector, since the latter involves higher voltages and more power (i.e. 220VAC sinewave spans from -380V to +380V).

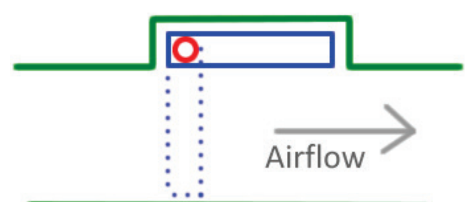
To resist fan vibration, one would probably place decent-sized bolts at left and right of electrical contacts, as shown above in brown.

1.7 Fan Considerations

1.7.1 Pivot-Capable Fan Assembly



Researchers consider pivot-able fan, illustrated to the left, which moves out of the way (e.g. pivot 90 degrees) when central HVAC fan is ON and in-line duct fan is OFF, to reduce air blocked by fan.



Researchers also consider a protruding bay within duct, for pivot-able fan, as illustrated to the right.

There are different types of fans, some of which consume more space than others. Researchers review the various options along with their advantages and disadvantages.

1.7.2 Vibration and Noise

Vibration and noise are two important considerations when working with fans. Researchers explore ways to minimize both.

1.7.3 Multiple fans

If aspect ratio of a rectangular duct is high, then one might consider installing two fans, or one motor with two propellers.

1.8 Sensors

1.8.1 Temperature

One can easily add a temperature sensor accurate to ±0.1°C for approximately $0.15 (e.g. #NTCG103JX103). This sensor will produce an error if it is thermally connected to a warm fan, or makes contact with central hot or cold air. If one places a temperature sensor on vent grille external surface, and measures temperature when airflow is off, then one can measure room temperature. If vent is high and ceiling to floor differential is several degrees, then one will not be measuring temperature of occupant 3 ft above floor.

It would be helpful if electrician specifies floor to socket physical distance (e.g. meters) when they program memory IC's with location information. This would enable system to better understand thermal gradient as one moves vertically, which is very important since this is often a non-trivial quantity.

1.8.2 Airflow

In theory, one can measure airflow yet it is not clear how helpful this is. If one has an air velocity sensor near a spinning fan, then air current around the fan will affect the measurement.

1.8.3 Humidity

It is probably helpful to measure humidity in at least one location within a room, yet measuring it everywhere is probably not needed.

1.8.4 Occupancy Sensing

Typically, occupancy sensors are high and have visibility to a large part of a room. In some cases, vent grilles satisfy this requirement. Consequently, researchers explore how an occupancy sensor might connect to vent inserts. Perhaps some products have PCB's that include occupancy sensing? Or perhaps their PCB's have a connector which mates with an occupancy sensing module?

1.8.5 Security Camera

Security cameras could potentially be added to motorized vent grille inserts; however, BuildingBus is slow and not designed to handle images. BuildingBus might be helpful a providing power and mounting support to cameras which transfer images via Wi-Fi. Wi-Fi reliability is one to two 9's (90% to 99%), which might be acceptable in some applications.

1.9 Electrical Considerations

1.9.1 Controlling 48VDC Power

One can easily turn on and off 48VDC power via a solid state relay (e.g. #CPC1002, $0.60, 60V, 600mA, 30W).

1.9.2 Variable Speed Fans

To control temperature precisely and comfortable, we need Variable speed fans (e.g. example circuits #1 and #2). Implementing variable speed requires more sophisticated electronics than on/off, yet is doable with a low cost microcontroller. EE Researchers develop electronics that support both On/Off and variable speed motors, via both BuildingBus 48V and BuildingBus AC. In the latter case, BuildingBus AC puts 110VAC or 220VAC into PCB, PCB converts to VDC, and then PCB converts to AC yet at a different frequency, and this is fed into an AC motor. With BuildingBus 48V, 48VDC is fed into a PCB which converts it to a different voltage, which is then fed into a DC motor.

1.9.3 Fan Electricity

We are working with three types of fans: 48VDC, 110VAC, and 220VAC; and one must make sure the fan matches the power supply, else damage may occur.

1.10 Ma2 Smart Building Interconnection-Standards Development Initiative

Manhattan 2 (Ma2) intends to develop electrical, mechanical, and communications standards that define how devices interconnect within the building of the future. Devices include motors that control thermal covers over physical wall windows, motors that control curtains and blinds, fans in ducts, dampers in ducts, lights, occupancy sensors, washing machines, ovens, refrigerators, dish washers, HVAC systems, pumps that control 58°F ground source water, thermal storage water, valves on room water-filled radiators, etc.

This initiative involves developing a 2-wire communication standards between multiple devices that provides the following features: supports CANbus communication between ~$1 microprocessors, no damage upon accidental short to power wires, devices use little power when not in use (sleep), wiring supports tree topology (daisy chain not required), hot socket compatible (no damage when attach wires with power on), ≥ 99.999% reliable (not wireless), and transceivers consume ≤ ~10mW of power when signaling (as opposed to ~10x more utilized by RS-485 or 120Ω CANbus).

We are calling this new network "BuildingBus™", for lack of a better term, and there are two versions. *BuildingBus 48V* caters to lower power and lower voltage whereas *BuildingBus AC* caters to higher power and higher voltage. *BuildingBus 48V* routes 48VDC power to devices with ~200W/network; whereas *BuildingBus AC* routes 110/220VAC power with ~2,000W/network to devices. Fans, industrial lighting, and motors that move heavy windows require 110/220VAC; whereas many other devices are 48V capable. 110/220VAC cable is bulky and needs to conform to high voltage building codes (i.e. conduit more likely), whereas 48VDC cable is lighter and satisfies low voltage building requirements. For details, search for "BuildingBus Development Initiative" in file Active Window.

We make use of existing standards whenever possible, and propose new standards as needed.

Researchers do *not* necessarily design products to be manufactured and sold. Instead, they propose interconnection standards, and prototypes that demonstrate those standards. These are then provided to standards bodies (e.g. IEEE), which modify as desired, and establish plug-and-play standardization.

All materials produced by researchers are given away for free, to encourage utilization by standards bodies, to reduce CO_2 emissions. This includes mechanical drawings, electrical schematics and software source code.

Ma2 is also developing standards that define how solar material attaches directly to building surfaces, such as plywood. The proposed solar material is ~1.5cm thick and contains embedded electronics that perform power conversion. This material can be applied to both roof and wall surfaces, edge-to-edge.

Prototypes develop by researchers use the same processor, and utilize common code. This helps researchers move quickly. Cost reduction is a later step, done by industry, after standards are finalized. The Xmc4200 processor, for example, supports almost all devices. A prototype that moves a window thermal cover, and a prototype of the DC-DC converter embedded in solar material, can both be implemented with this one processor, for example. It provides: 16x 12bit a/d channels, 2x 12bit d/a channels, analog comparators, 2 CANbus channels, counter/timers, 256KBFlash, and 40 KB Ram. All within one tiny package.

See Also:

- Ma2 Smart Building Interconnection-Standards Development Initiative (Plan)
- Ma2 Active Window Development Initiative (Plan, Research Teams Yr1)
- Ma2 BiPV/LiPV Rollable Photovoltaic Research Initiative (Plan, Research Teams Yr1)
- Ma2 Fan and Damper Interconnection-Standards Development Initiative (Plan)