October 2019

White Paper

Twinning Methods

with Commercial Rooftop HVAC Units

Twinning Overview

Twinning refers to the application where more than one rooftop unit is serving a shared supply and return duct. By operating units in unison, twinned systems can provide higher capacity and/or some system redundancy. Twinned systems are typically sized so all units must be operating to meet the worst-case demand of the building. To operate a twinned system effectively and efficiently, operating parameters (sensor values and setpoints) must be shared among all devices connected to this shared duct.

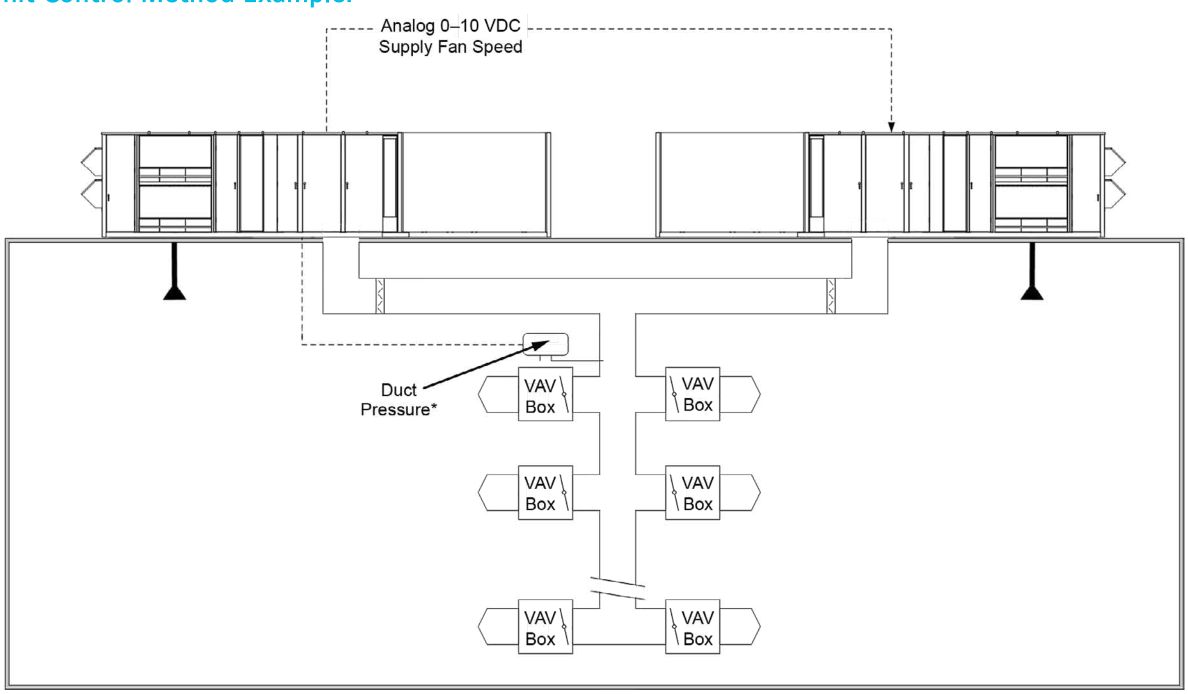
Twinning Methods – Master Driven

The basic idea of twinning is that when each unit has perfect knowledge of the system, then each unit can execute the exact same control algorithm independently. Traditional twinning methods have typically relied on a master controller to communicate operating parameters to other units in the twinned system. Typically, the system's "master" is either a unit, external controller, or building automation system (BAS).

Master Unit Control Method

Typically known as a master/satellite system, this method uses **one unit** as the "master." One duct pressure sensor is used to control the master unit's supply fan variable frequency drive (VFD), which the master then communicates its fan speed to each of the satellite units in the twinned system. Communication from the master unit is made via hardwired analog signal from the master unit controller to each satellite unit controller. When the duct static pressure reading is too low, the master unit controller speeds up all supply fans. When the duct static pressure is too high, the master unit controller slows down all supply fans. Each unit's supply fan operates at the same fan speed.

Master Unit Control Method Example:



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Twinning Methods

Master Unit Control Method Considerations:

- Requiring only a single duct pressure sensor, this may be considered the most simple/cost effective method of twinning.
- If the master unit fails, the satellite units may also fail because they rely on the master unit for a fan control signal. If the master is lost, the remaining units cannot operate correctly.
- Field provided control wiring must be run between all units.
- Essentially, this is only twinning/synchronizing the units' supply fans. There are many other unit features that operate/fluctuate (economizer, occupancy, demand control ventilation (DCV), exhaust fans, smoke control, etc.). To truly twin/synchronize units, it is ideal for these other operating parameters to also operate in unison, which is not possible with this method.

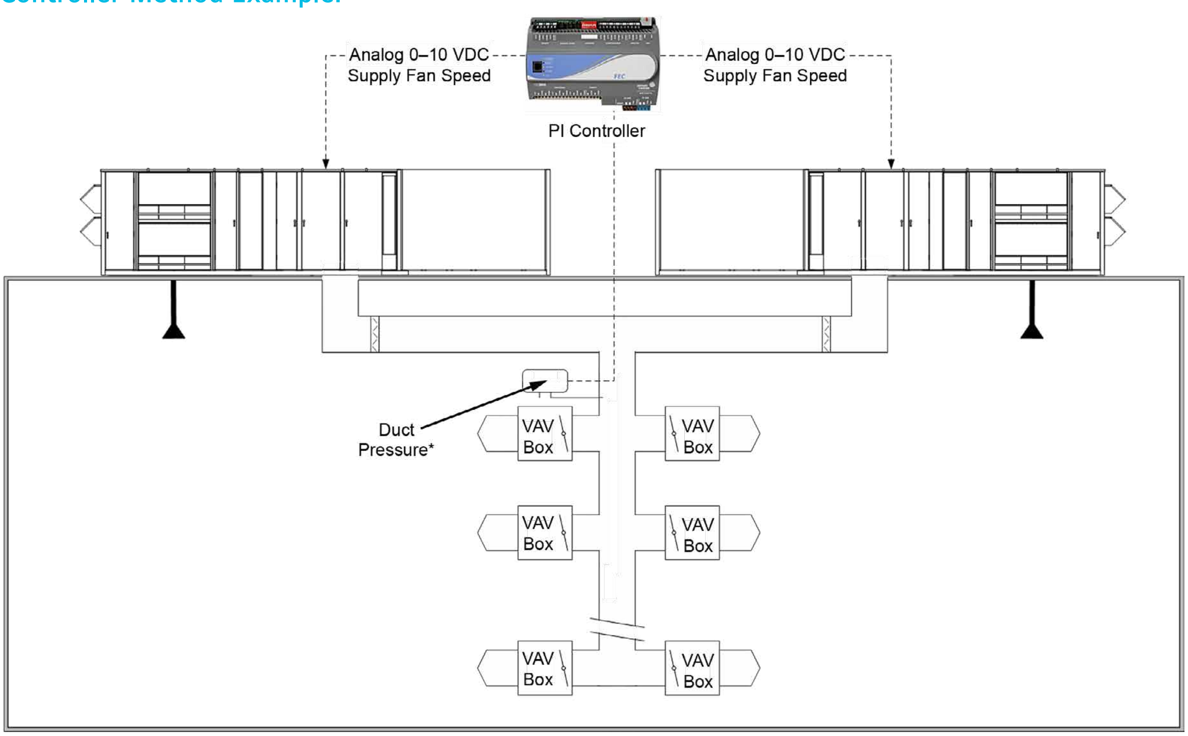
External Controller Method

In this method, an **external controller** acts as the master for all the units within the twinned system. The external controller receives input from the duct pressure sensor and determines the fan speed required. The external controller communicates the required fan speed via hardwired analog signal to each of the twinned units. When the duct static pressure reading is too low, the external controller speeds up all supply fans. When the duct static pressure is too high, the external controller slows down all supply fans.

External Controller Method Considerations:

- This method has an advantage over the master unit control method because even if there is a problem with one unit, the rest of the units can continue to operate.
- Like the master unit control method, this system uses only one duct pressure sensor to control the twinned system.
- If a problem occurs with the external controller, control of all units is lost.
- Only supply fan speed is synced.
- Wiring/programming/installation of this application typically costs more than the master unit control method. A building owner may like the idea of not losing all units when a unit goes down, however other building owners may not want to rely on an additional controller.
- You must hard wire the external controller to each unit.

External Controller Method Example:



Building Automation System (BAS) Control Method

Similar to other master driven systems, one unit receives input from a duct pressure sensor. This unit communicates its supply fan speed to the BAS, and the **BAS communicates** the fan speed to the other units.

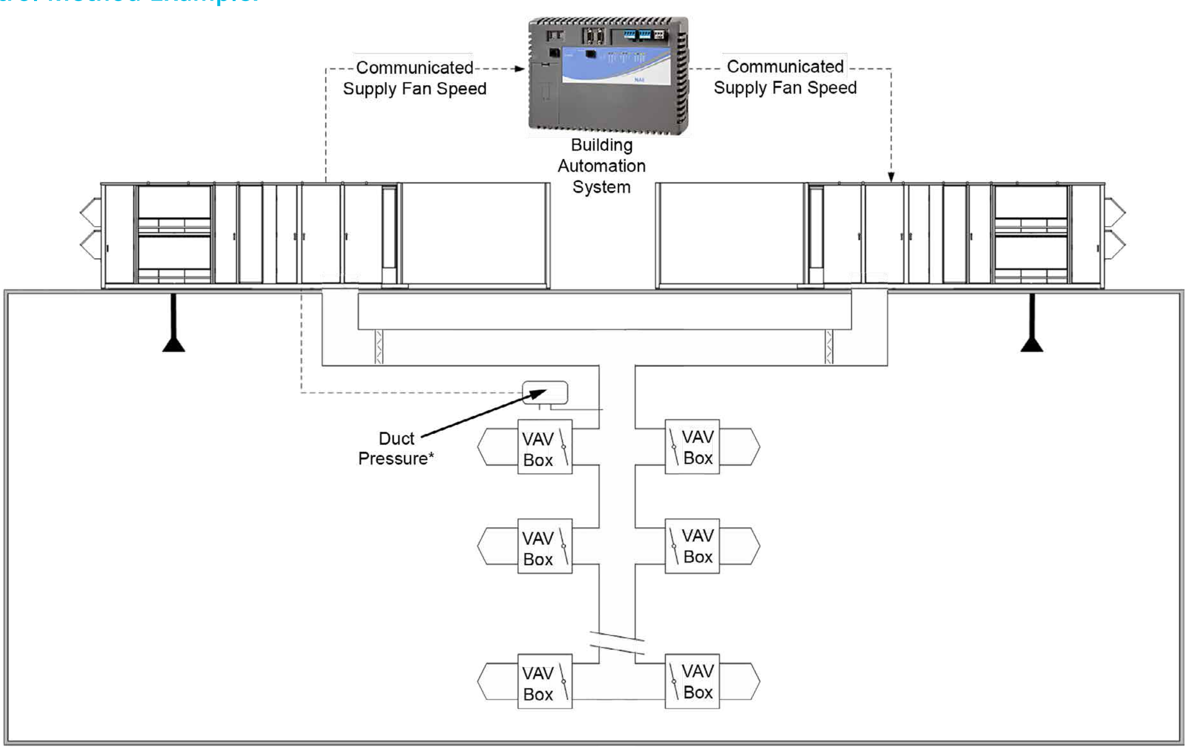
BAS Control Method Considerations:

- Similarly to the previously discussed methods, this method uses only one set of sensors for the entire system.
- Using a BAS system may be the preferred method for projects that already have a BAS included or for which programmers are very familiar with how to manipulate it and consider it the easier means of execution. This is not always the case for standalone rooftop HVAC projects, and including a BAS could be a costly addition when there are not other pieces of equipment being controlled or other benefits from having it.
- The twinned system still relies on a master (BAS) to communicate operating points to the satellite units. If BAS communication is lost, the satellite units fail. If the system is operating with one set of sensors and the communicating/lead unit fails to communicate to the BAS, the satellite units fail.
- Network communication speed may not be fast enough to properly read and communicate, control duct pressure and fan speed. This can lead to units "fighting" each other, where the supply fan speeds are in constant oscillation opposite from each other.

Twinning Methods – Masterless Twinning

One disadvantage all of the previously mentioned systems share is the dependence on a "master" and a single point of failure for the system. This means that if there are problems with the master, this could lead to failure of the entire system. One way around that is through masterless twinning, also referred to as independent twinning. In a masterless twinned system, several operating parameters are synchronized while others operate independently. To synchronize parameters, each twinned unit in the group broadcasts its key parameter values so it can be used by the other rooftop units in the group.

BAS Control Method Example:



Twinning Methods

Because each unit receives the same operating parameters, then each rooftop unit can execute the exact same control algorithm independently. This has the advantage of being more robust to individual communication errors or sensor failures and less complex than with master driven methods in general. If one unit fails or is manually shut down, the remaining units continue to run without interruption. In the master/satellite unit arrangement, when the master unit is disabled, the failover logic to a different master is more complicated and may result in disrupting the system. Independent twinning prevents such disruptions or failures in the system.

Also, additional unit operating parameters are able to be adjusted to provide better control and comfort, rather than just fan speed as previously mentioned with master driven systems. Various settings are automatically synchronized by the masterless system. The synchronized features include supply fan control, economizer suitability, occupancy, DCV, exhaust fan control, and smoke control. The points below outline each shared operating parameter and why it is important to synchronize their values in a twinned system.

- The supply fan control must be synchronized to maintain discharge air (DA) static pressure between all units serving the same duct. This requires all reliable DA static pressure values from the rooftop units to be averaged before passing to the proportional-integral-derivative (PID). The static pressure setpoint must also be synchronized, and any change to one setpoint must be shared with the other rooftop units. This allows the PID in each rooftop unit to calculate the same output value and run all the supply fans at the same speed.

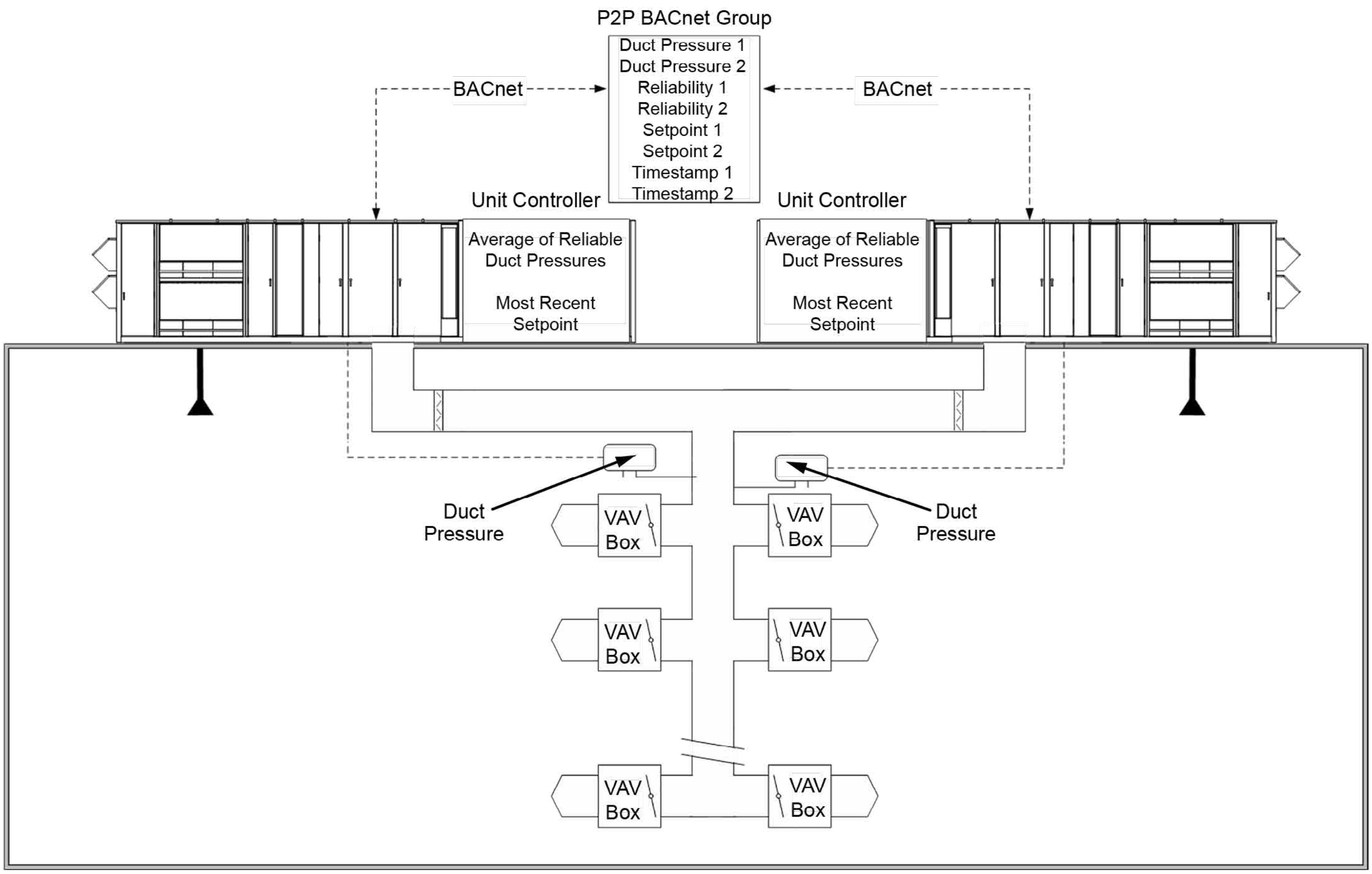
  During start-up of a previously shutdown rooftop unit, the supply fan speed slowly ramps up until it matches the fan speeds of the rooftop units currently in operation. When the additional rooftop unit begins ramping, the static pressure increases, causing the other rooftop unit fan speeds to slow down to reach the setpoint. Once the rooftop unit fan speed matches the existing rooftop units, it releases into control.
- The economizer suitability should also be synchronized to allow all the units to use the outside air (OA) damper for free cooling when available. This also avoids a situation where one unit is operating in economizer mode while another unit operates in mechanical cooling mode.
- The occupancy for the twinned units must also be synchronized to allow all units to switch between occupied and unoccupied modes simultaneously. This includes the occupancy schedule and warm-up/cool down if enabled.
- The DCV is synchronized to allow the OA damper minimum position to be reset equally between the units. This requires the indoor CO_2 values from the units to be shared and the maximum to be passed to the reset logic to ensure sufficient outside air is brought in for proper ventilation. The indoor CO_2 setpoint also synchronizes so the reset calculation is the same across all units.
- The exhaust fan system must be synchronized to allow for proper building pressurization. This requires the building static pressure values from each unit to be averaged before passing to the PID. The building static pressure setpoint also synchronizes, and any change to one setpoint must be shared with the other rooftop units.
- The smoke control feature is synchronized to ensure all units properly switch between the purge, pressurization, or depressurization modes. This requires the three smoke control binary inputs and their priorities on each unit to be shared so that when any binary input is ON, all twinned units respond the same way.
- The temperature control, return fan systems, and safety shutdowns can operate individually on each unit. The temperature setpoints synchronize to allow for similar operation between the units. The temperature loops are not required to be as tightly coupled as the supply and exhaust fan systems.
- The diagram on the next page shows the basic configuration with two units sharing a common supply duct. Each unit has its own duct static pressure sensor to allow the rooftop units to run independently when one or more units are shut down for maintenance or BAS communication is lost. The units share duct static pressure present value, reliability, and setpoint. The units use the averaged values of duct static pressure when the shared values are reliable. When a local sensor is unreliable on a given unit, that unit can use the shared value and continue to operate, which is not possible without twinning. The other advantage is a change in duct static setpoint at one unit is propagated to the other units. The user does not need to make setpoint changes at all units.

Masterless Twinning Considerations

- This method has the ability to share sensor values across all units. The benefit eliminates multiple points of failure from the system (no interruptions in control when a sensor becomes unreliable) and reduces system cost and wiring by sharing optional features among multiple units.
- Masterless twinning has the ability to share setpoints across twinned units. When a user changes a setpoint at one unit, it is transmitted to multiple units.
- There is no loss of control when communication errors occur (i.e. if a controller fails, the system continues to operate).
- Simple configuration and commissioning.
- Quicker response time. There is no need to wait for a message from the master to adjust control of the system.
- It is recommended that each unit have its own set of sensors. This is not required for operation, but when only a single set is used, the value of redundancy is lost.

In summary, twinning is a great application that is used to provide higher capacity and system redundancy. The right method for you may depend on the project size and complexity, building control system, installation requirements, cost, and other factors.

Masterless Twinning Example:



Johnson Controls Premier Rooftop Units Masterless Twinning

Unit Requirements

- A BAS should be selected for all Premier units in a twinned application
- An optional building system interface board. This is only needed for the isolation dampers, not for BAS communication
- Variable air volume (VAV) system types only
- All units must be the same size
- Fan systems have tuning disabled
- External control not supported

System Requirements

BAS/Communication Details

Each unit communicates via BACnet® MS/TP, which is native on the main control board.

Duct Static Transducers

Each rooftop unit in a twinning application requires its own duct static pressure sensor. This is not required for the system to work, but it is recommended for redundancy. This allows the rooftop units to run independently when one or more units are shut down for maintenance or BAS communication is lost. The same static pressure probe can be connected to all discharge pressure transducers.

Building Static Transducers

For units equipped with an exhaust fan, each rooftop unit requires its own building static pressure sensor. This is not required for the system to work, but it is recommended for redundancy. This allows the rooftop units to run independently when one or more units are shut down for maintenance or BAS communication is lost. The same static pressure probe can be connected to all building pressure transducers.

Manual Reset High Duct Pressure Switch

Each unit has a manual reset high duct pressure switch installed to prevent over pressurization of the supply duct, which is standard on all units.

Isolation Dampers (Field Supplied)

Isolation dampers are recommended to be installed in the supply and return ductwork. Masterless twinning can operate without isolation dampers installed, but system performance is affected. Without isolating units in the group that are off, there would be a system pressure drop and the fans on those units would "freewheel." Each damper must include an end switch to ensure the dampers are fully open before the supply fan can start. The Premier unit can provide control of these isolation dampers via the building system interface board. When the unit is started, the unit controller commands the dampers open. When the unit is stopped, the unit controller commands the dampers closed.

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