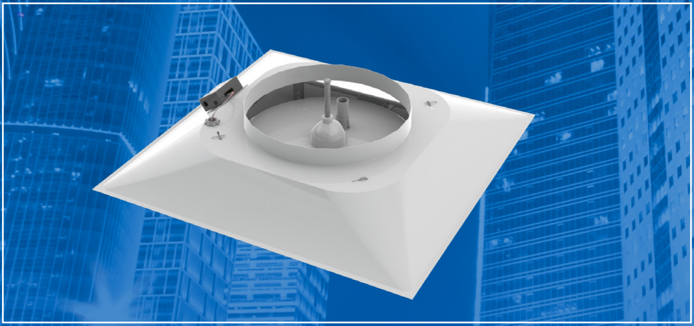
Titus

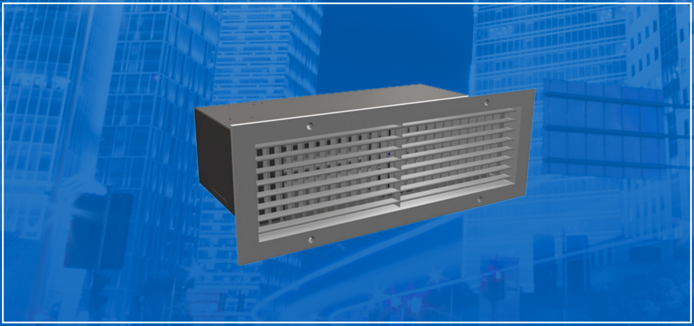
Redefine your comfort zone.™

VAV DIFFUSERS

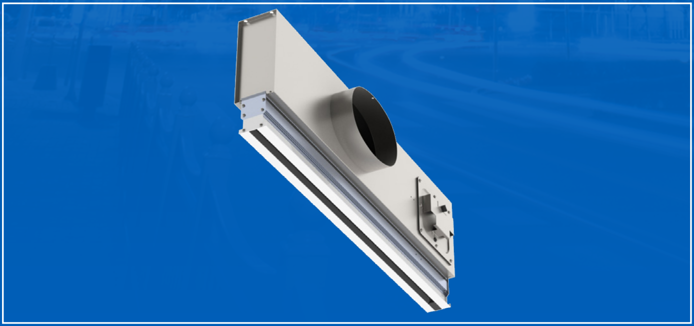
ENGINEERING GUIDE



T3SQ

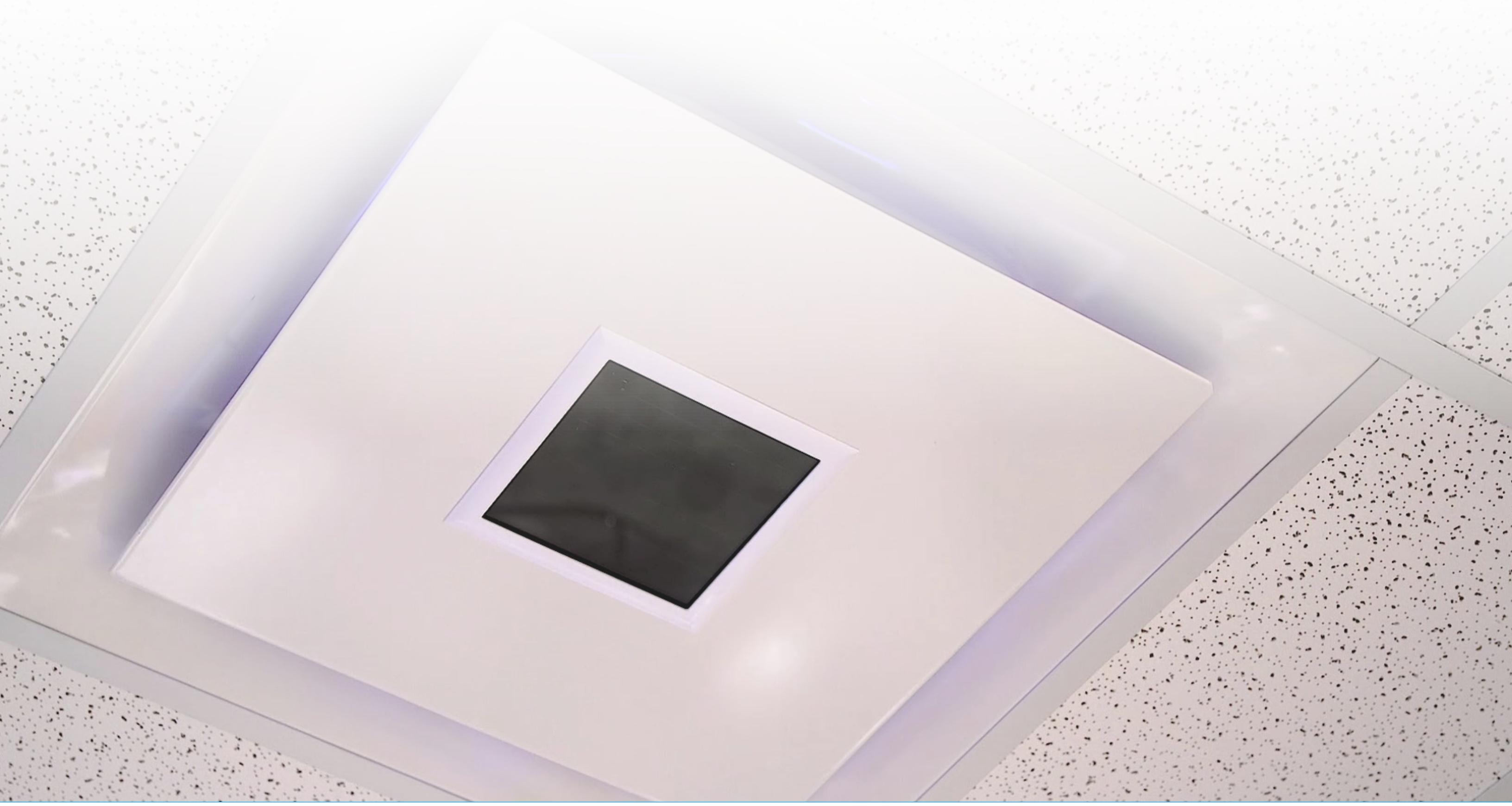


T3SW



T3LN

CONTENTS



INTRODUCTION TO VAV DIFFUSER SYSTEMS

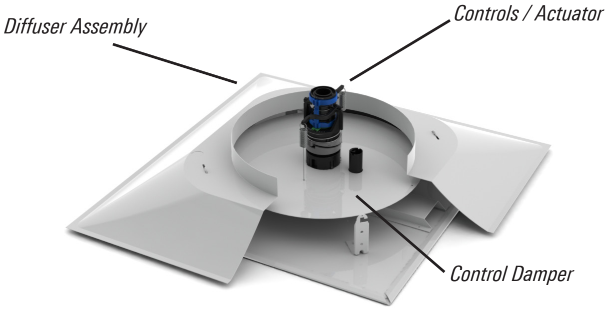
VARIABLE AIR VOLUME SYSTEMS IN NORTH AMERICA

Despite the introduction of newer "green" technologies into the North American HVAC market, Variable Air Volume (VAV) continues to be the most popular system for non-residential buildings. Most HVAC system engineers and contractors have extensive experience with the system so are more comfortable with its design and operation than other newer systems. The basic operational principles of VAV systems have barely changed since its introduction during the 1970's, although energy codes and ventilation standards have been updated to encourage more energy efficient designs and improve indoor air quality.

Conventional single duct VAV systems are designed around a VAV terminal reheat box, Direct Digital Controls (DDC)/ Thermostat and separate grilles or diffusers that introduce the conditioned air into the occupied space. These three distinct system components are often supplied by multiple manufacturers and installed in separate operations by more than one contractor. This group of components control the space temperature and ventilation requirements of a single thermal zone. Due to the relatively high cost of the VAV control components, project budget constraints often force design engineers to group several separate rooms (with similar thermal loads) into a single thermal zone to reduce the quantity of VAV terminals and controls. This design approach results in a comfort compromise for the occupants, as only one of the rooms is fitted with an adjustable thermostat. Also, as the thermal loads and occupancy will vary across the rooms served by the VAV box, energy is wasted as some of the rooms may be overcooled or heated and over ventilated during unoccupied periods. The latest ASHRAE Standard 62-2016 - Ventilation for Acceptable Indoor Air Quality, allows the ventilation air to be reduced to zero during unoccupied hours but only if the system is fitted with demand control ventilation controls. This energy saving enhancement can only be fully realized if every room is fitted with unique controls resulting in high system costs.

CONVENIENT INSTALLATION

VAV diffusers combine three major VAV zone control components into a single unit which is usually installed by one contractor. There are two types of VAV diffuser available on the market, self powered (requiring no external wiring) and electronic. All types incorporate a diffuser assembly, housing an air control damper, onboard sensors and controls that operate the integral control damper.



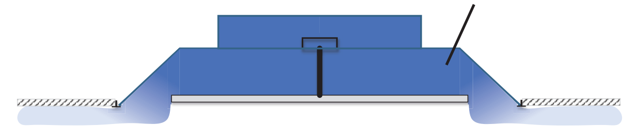
The VAV diffuser control damper regulates the airflow to the space to maintain the room setpoint temperature which is sensed through an onboard or remote mounted room thermostat.

HVAC systems designed around VAV diffusers allow every room within the building to be fitted with thermal controls and therefore eliminates the control compromises inherent with traditional single duct VAV.

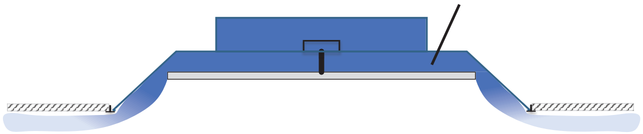
VAV DIFFUSER SYSTEM BENEFITS

VARIABLE GEOMETRY IMPROVES COMFORT

The airflow control disc or damper that modulates the airflow also reduces the supply air discharge area of the diffuser at low airflow conditions, so maintains a high air exit velocity which keeps the supply air attached to the ceiling preventing dumping. A high room air to supply air mixing rate is achieved irrespective of the room load, offering improved comfort over conventional VAV systems installed with fixed geometry diffusers.



VAV diffuser with damper fully open, max. airflow



VAV diffuser with damper 25% open, min. airflow

MAINTAINED ADPI

Air Diffusion Performance Index (ADPI) is a statistical rating of space temperature and air speed relative to occupant comfort levels. Higher ADPI values indicate that the space will be more comfortable for most occupants. With traditional fixed geometry diffusers, the ADPI will vary depending on the volume flow rate through the diffusers. A reduced airflow rate results in a reduced ADPI rating and lower comfort levels, while variable geometry VAV diffusers maintain a consistent ADPI irrespective of the volume flow rate.

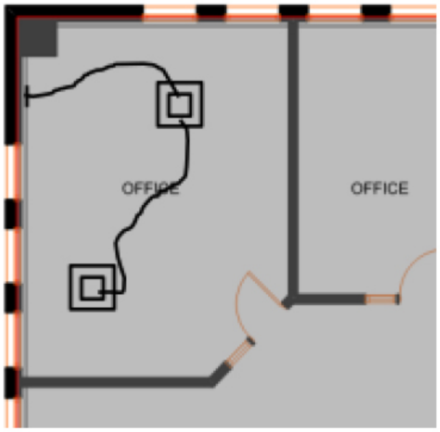
REDUCED ENERGY COSTS

As every room in the building can be fitted with user adjustable temperature controls, overcooling/heating occurs less frequently reducing energy costs.

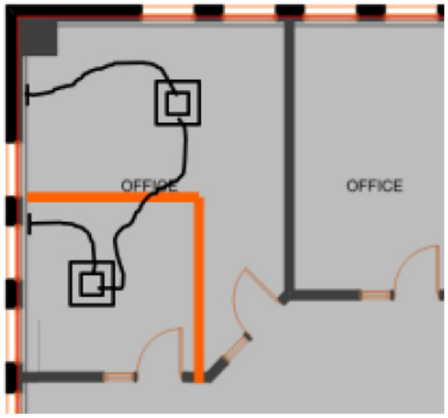
The ductwork system serving VAV diffusers is usually designed to operate at a lower pressure than a conventional VAV terminal unit system, so the main air handling unit fans can operate at around 0.5 in. w.c. lower than a conventional vav system.

EASE OF SPACE RECONFIGURATION

One of the key features of a VAV diffuser system is flexibility. As every diffuser is fitted with onboard controls, changes to the control zoning can be accomplished without any major alteration work. For example, a single office with two diffusers can be reconfigured into two smaller offices and still maintain temperature control in both by simply fitting a thermostat to the second diffuser.



Single office fitted with VAV diffusers



Office space separated into two each fitted with a VAV diffuser and thermostat

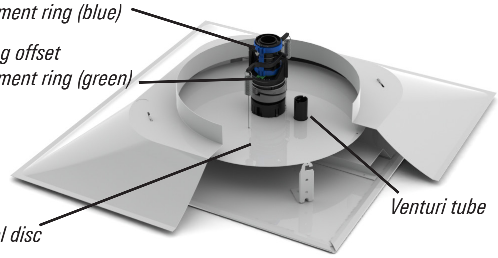
REDUCED SYSTEM COSTS

A VAV diffuser system can be installed at a lower cost than a conventional VAV system for many applications as a VAV diffuser and thermostat cost significantly less than a separate VAV terminal, DDC controls and diffuser. Buildings with a high density of smaller separate spaces such as buildings with numerous small private offices are one example of where the overall installed costs are expected to be lower.

The first VAV diffuser products appeared on the market in the late 1970's. These early designs used a thermally expanding petroleum wax element to move a control disc or damper to modulate the airflow. These mechanical units were simple in design and did not require external power or wiring to operate, so installation costs were low. Thermally powered diffusers have some inherent limitations, such as slow temperature change response times and variable accuracy. VAV diffuser development has come a long way since, with modern systems designed around digital platforms and computer controlled interfaces. There are now three different technologies powering the VAV diffusers available from Titus.

THERMAL DIFFUSERS (MODEL T3SQ-4)

The T3SQ-4 thermal diffuser features a forced induction temperature sensing element that draws room air into the sensor to ensure high sensing accuracy.

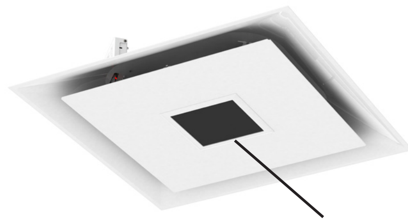


Temperature set point adjustment is accomplished by rotating the blue colored ring. Heating offset temperature is adjusted by rotating the green ring.

AMBIENT LIGHT POWERED DIFFUSERS (MODEL HELIOS)

The Helios is the latest development in VAV diffuser technology available from Titus. This diffuser combines the accuracy of digital controls and the convenience of wireless installation. It is essentially a modern version of a thermally powered diffuser. The unit is powered by light captured from the room which is stored in a capacitor located on the control board. The diffuser requires a lighting level of only 120 LUX to function which can be artificial or natural sunlight, so will work well in normally lit interior spaces.

The storage capacitor can store power for up to 3-4 weeks without a light source and will power down into a sleep mode when the room is unoccupied.



The temperature set points can be adjusted in one of two ways. Every Helios diffuser is fitted with onboard potentiometers for temperature and minimum damper position adjustment. Alternatively, the Helios can be adjusted with the optional wireless remote thermostat also powered by ambient light.

ON BOARD SENSING

REMOTE SENSING

Up to 10 diffusers can be controlled with one wall thermostat. The Postmaster routes the communications between the 'stat and diffusers, powered by plugging into a 120v wall outlet.

WIRED DIGITAL DIFFUSERS (MODELS T3SQ-2, T3SW, T3LN)

The Titus wired digital diffuser product family operate on an IP based communication platform, Multi Loop Modular (MLM) controls. The MLM based VAV diffuser system offers the most advanced features of the Titus product offering including BMS integration, a remote monitoring/control software interface and electric top up heating.

An MLM system is scalable and easily configurable. Systems can consist of a stand alone system comprising a single diffuser and power supply to 1000's of diffusers integrated into BACnet Building Automation System. The MLM software (downloadable from the Titus website) can be used to manage the system centrally and perform the following operations:

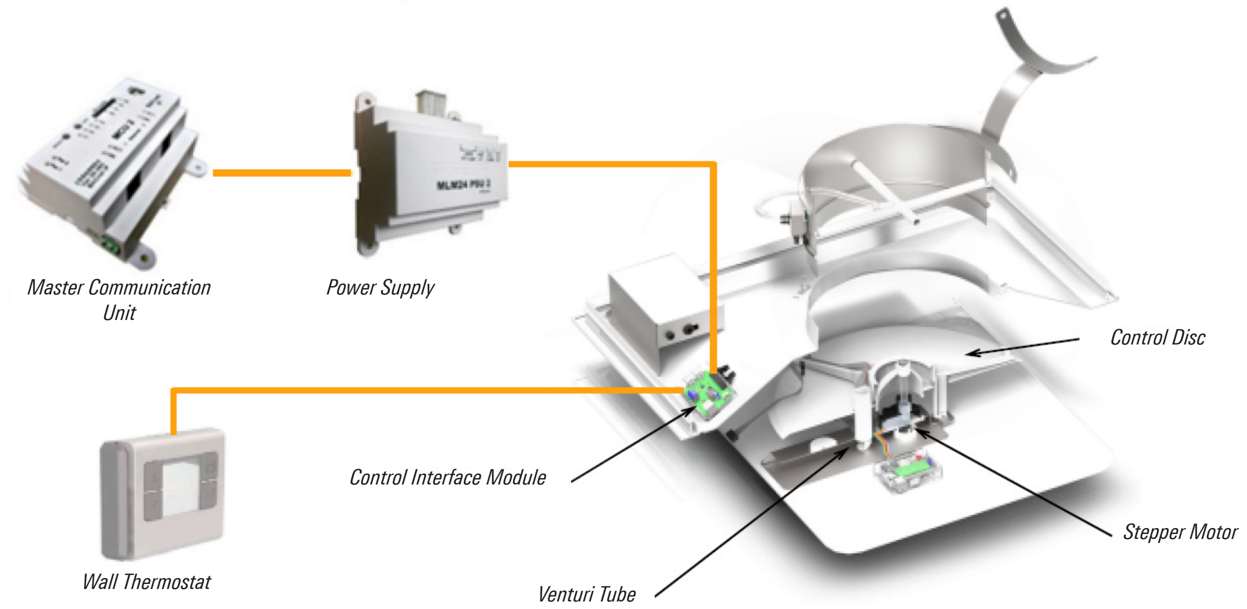
- Monitoring of room conditions
- Room condition data logging
- Temperature set point adjustments
- Fault monitoring

COST EFFECTIVE NETWORKING

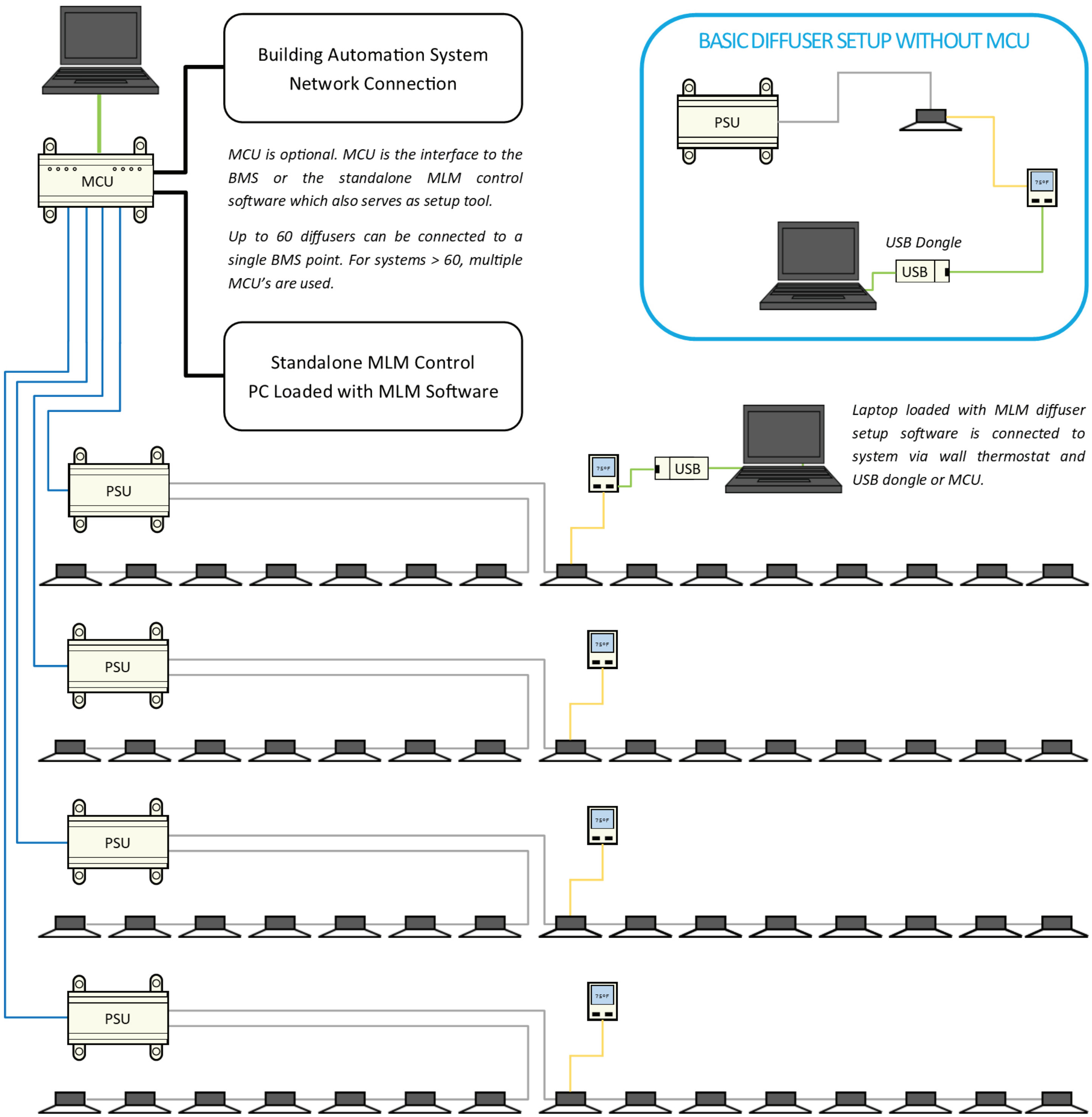
The master communications unit (MCU) is the gateway to the BMS. Up to 60 diffusers can be connected to one MCU, reducing BMS connection costs considerably compared to other systems. Multiple MCU's can be connected together to serve larger buildings.

MCU's have 4 sockets for connection to the power supplies (PSU) which provide power and route communications to the diffusers. Up to 15 diffusers can be fitted to one PSU with any combination of Master and Drone diffusers as long as at least one diffuser is a Master (fitted with thermostat). Diffusers are daisy chained using the supplied 4-pin minifit cables and connectors .

T3SQ-2 DIGITAL DIFFUSER SYSTEM COMPONENTS



Cabling Color Key
- *USB*
- *RJ-12*
- *4-pin mini fit (25' long)*
- *RJ-9 (25' long)*
- *CAT 5*



APPLICATIONS

VAV diffuser systems can be used in most applications where VAV systems are typically used including:

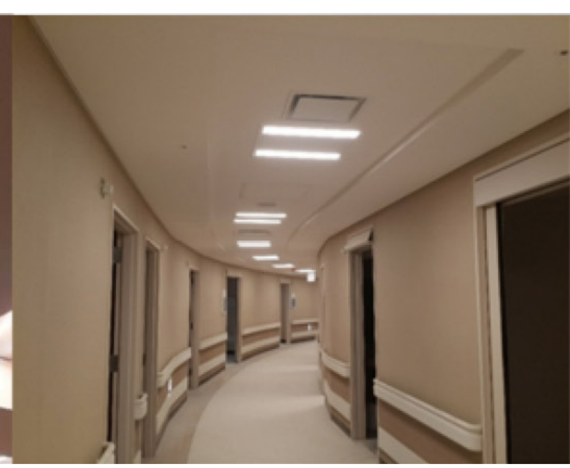
- Commercial offices, medical offices
- Government buildings
- Educational buildings
- Banks
- Warehouse/Office combos
- Retail outlets
- Cafeterias

Correctly designed VAV diffuser systems are generally as quiet as traditional single duct systems, although unlike conventional VAV terminals, secondary silencers cannot be installed downstream of the VAV diffuser air dampers. For this reason the system is not suitable for applications with stringent noise criteria (< NC25) such as recording studios.

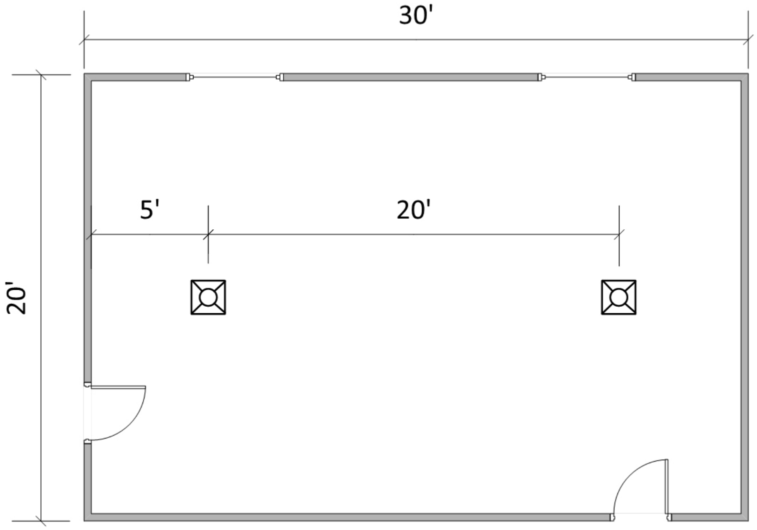
In the past, VAV diffuser systems have gained a reputation for being low budget, limited functionality systems. The introduction of digital products with full BMS integration and other advanced features is changing this perception.

The three VAV diffuser technologies available from Titus are suitable for a wide range of applications and budgets. The table below compares the available features/options and relative system costs of each platform.

		Features/Options Available									
							Variants				
VAV Diffuser Platform	Titus Product References	Remote Wireless Thermostats	Electric Heaters	BMS Integration	Control Software	Pressure Relief Rings	Square	Linear Slot	Sidewall	Power Source	Relative System Installed Cost
Thermally Powered	T3SQ-4	×	×	×	×	✓	✓	×	×	Expanding Wax	Very Low
Wireless Digital	HELIOS	✓	×	×	×	×	✓	×	×	Ambient Light	Low
Wired Digital	T3SQ-2,T3SW,T3LN	×	✓	✓	✓	✓	✓	✓	✓	120-277VAC	Medium



SELECTION EXAMPLE



Design Parameters & Airflow Calculations
Room Design Temperature.................... 75°F
Cooling Supply Air Temperature............ 55°F
Room Noise Criteria............................... NC 35
Room Dimensions.................................. 30′ x 20′ x 10′
Cooling Load.. 25 BTU/H per sq. ft.
= 30 x 20 x 25....................................... 15,000 BTU/H
Required Airflow = Qsens/ (1.08 x Δt)
= 15,000/ (1.08 x 20)............................. 694 CFM

DIFFUSER SELECTION

Inlet Size	Neck Velocity Velocity Pressure	400 0.010	500 0.016	600 0.022	700 0.031	800 0.040	900 0.050	1000 0.062
6"	Static pressure	0.022	0.034	0.049	0.066	0.086	0.11	0.134
	Total Pressure	0.032	0.50	0.071	0.097	0.126	0.16	0.196
	cfm	79	98	118	137	157	177	196
	NC	-	-	13	18	22	26	29
	Throw, ft	1-1-4	1-2-5	1-3-7	2-4-7	2-4-8	3-5-8	3-5-9
8"	Static pressure	0.024	0.038	0.054	0.074	0.097	0.122	0.151
	Total Pressure	0.034	0.054	0.076	0.105	0.137	0.172	0.213
	cfm	140	175	209	244	279	314	349
	NC	-	15	20	24	28	31	34
	Throw, ft	1-3-6	2-4-8	3-5-9	4-5-11	4-6-11	5-7-12	5-8-13
10"	Static pressure	0.038	0.059	0.085	0.116	0.152	0.192	0.237
	Total Pressure	0.048	0.075	0.107	0.147	0.192	0.242	0.299
	cfm	218	273	327	382	436	491	545
	NC	17	23	28	32	36	39	42
	Throw, ft	4-6-11	5-7-13	6-9-14	7-10-15	8-11-16	9-12-17	10-13-18
12"	Static pressure	0.062	0.097	0.14	0.191	0.249	0.315	0.389
	Total Pressure	0.072	0.113	0.162	0.222	0.289	0.365	0.451
	cfm	314	393	471	550	628	707	785
	NC	18	25	31	36	40	43	47
	Throw, ft	5-7-13	6-9-14	7-11-16	9-12-17	10-13-18	11-14-19	12-14-20

Solution:
The performance data indicates that two diffusers of either size 10 or 12 will comply with the requirements. Each of these, when supplied with 350 CFM has a throw to 50 FPM of approximately 14 feet. Using a throw mapping procedure* with a vertical distance of four feet from the top of the occupied zone and the ceiling, the remaining 10 feet of throw should define the distance between the diffusers and their discharge collision point. The diffuser spacing twice that, or 20 feet in this case, would be required to assure that no velocity in the occupied zone exceeds 50 FPM.

**Reference Titus 2018 Product Catalog, Engineering Guide section, page B11.*

SYSTEM DESIGN–PRIMARY AIR

VAV OR CONSTANT VOLUME PRIMARY AIR?

VAV diffuser systems are designed in a similar way to conventional VAV systems with just a few minor differences. VAV diffusers are pressure dependent so the ductwork serving the diffusers should be designed with this in mind to prevent excessive noise and temperature control issues. Generally, there are three common design approaches taken with VAV diffusers systems, depending on the building type/budget and if the primary air system air handling units are constant or variable volume.

CONSTANT VOLUME PRIMARY AIR SYSTEM

This type of system is usually designed around rooftop constant volume AHU's fitted with refrigerant based (DX) cooling coils. VAV diffusers are installed in most of the spaces with conventional diffusers being installed in the less critical zones (such as the corridors) where the thermal loads exhibit less variation. As the VAV diffuser air dampers start to close in response to reduced loads, the excess duct pressure must be released via pressure relief dampers. The excess air is usually spilled into the ceiling cavity or directly into the return duct system, the latter being preferable as the bypass air will collect less heat from the ceiling cavity if it is ducted directly back to the AHU. Releasing the bypass air directly into the ceiling cavity may also result in room temperature control issues if the bypass air short circuits back into the room via ceiling transfer grilles. Top up heating is usually performed by electric heaters fitted into the neck of the diffusers.

A constant volume DX based system offers the lowest cost and is typically used on smaller projects.

VARIABLE VOLUME PRIMARY AIR SYSTEM

A variable volume primary air system consists of AHU's fitted with variable speed fans and on larger buildings, chilled water heat exchange coils. Conventional return ductwork is used instead of an air bypass system. Pressure control dampers are fitted to the duct runouts to the VAV diffusers. Hydronic or electric heaters can be fitted into the ductwork serving the perimeter zones enabling simultaneous heating and cooling as required for the perimeter exposures.

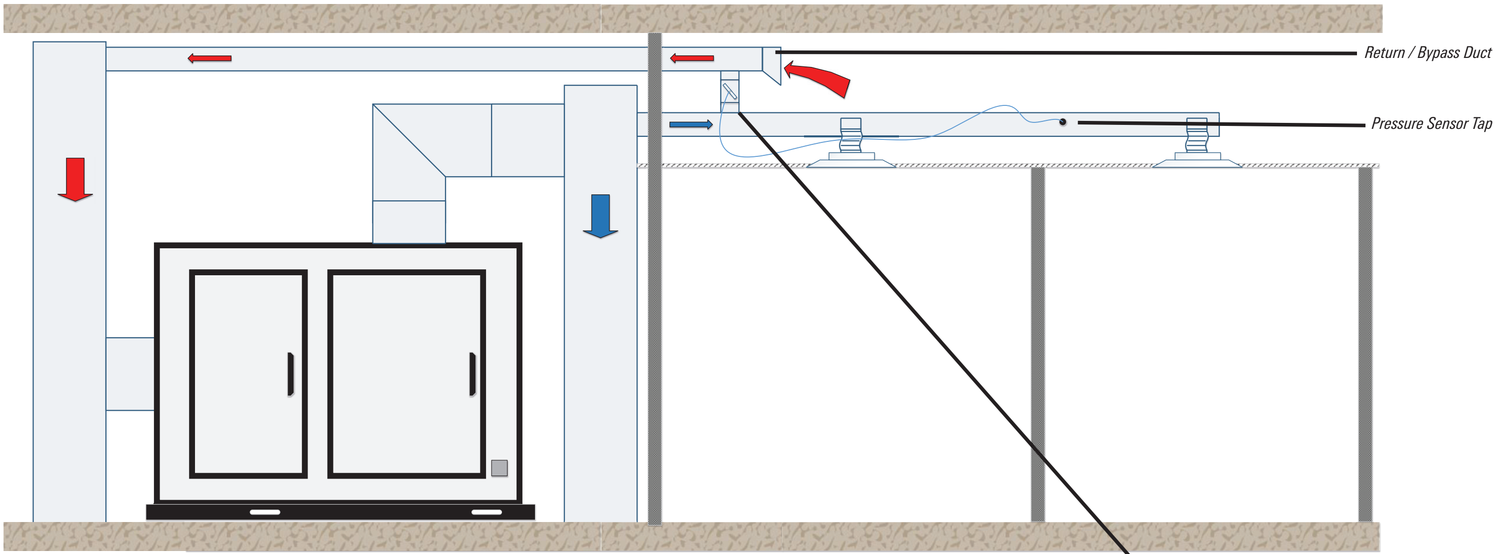
A variable volume based primary air system offers improved energy performance with tighter/improved temperature control but at a higher cost than constant volume systems.

RETROFIT SYSTEMS

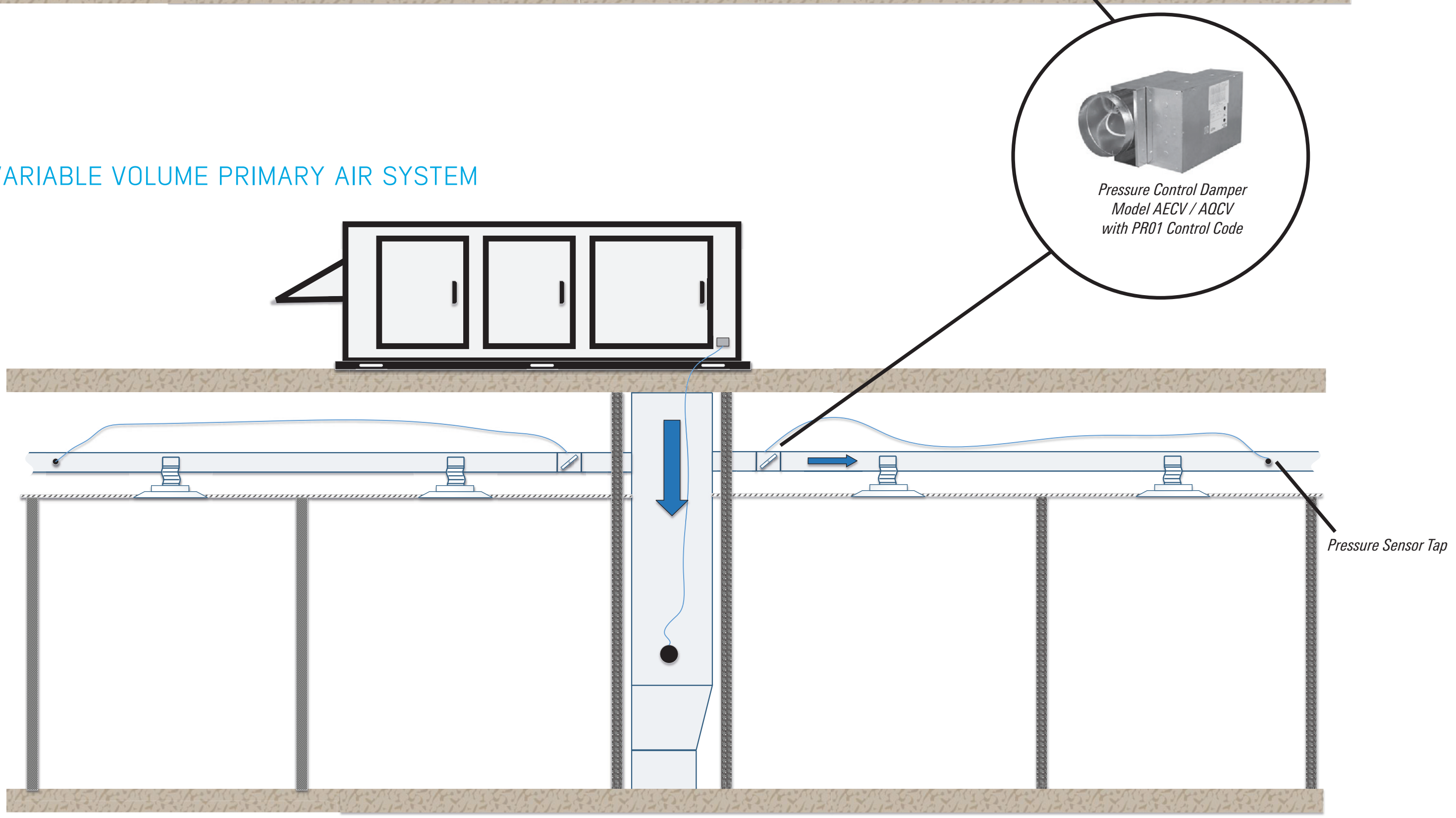
VAV diffusers are often used to solve temperature control issues in buildings with existing HVAC systems. The design approach will depend on the type of system that the VAV diffusers are being installed into. A common error is to fit VAV diffusers into a system without any consideration to pressure relief, which often leads to noise complaints. Bypass dampers or pressure relief rings should be used in most retrofit installations.

SYSTEM DESIGN-PRIMARY AIR

CONSTANT VOLUME / BYPASS PRIMARY AIR SYSTEM



VARIABLE VOLUME PRIMARY AIR SYSTEM



DUCTWORK SIZING METHODS

A VAV diffuser HVAC system requires a little more care and attention to the ductwork design and sizing compared to other systems. Poor duct sizing, excessively complex duct routes and lack of pressure control can lead to high room noise levels and compromised space temperature control. The duct system should be designed to avoid large differences in static pressure at the start and end of the duct runouts serving the VAV diffusers.

There are generally two design techniques used for sizing the ductwork for VAV diffuser systems, Equal Friction and Static Regain.

EQUAL FRICTION METHOD

Equal friction is the easiest duct sizing technique and is the most widely used in HVAC system design. As the name implies, the ductwork is sized so it has an equal airflow resistance along the entire length and is usually performed using a nomograph selection tool. One notable outcome of this design method is that the static pressure will reduce in the direction of airflow along the duct runouts which may result in high static pressures at the start of the duct runouts resulting in excessive noise generation at the VAV diffusers located at the start of the run.

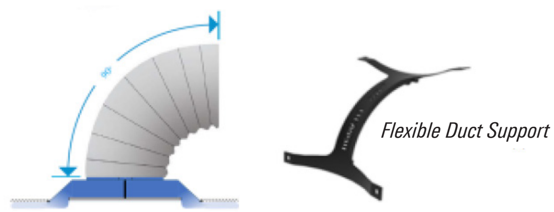
STATIC REGAIN METHOD

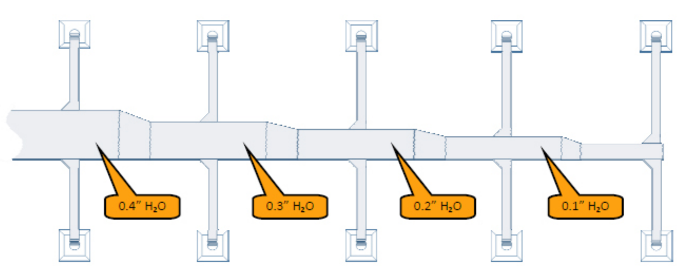
Static regain is the most difficult and time consuming duct sizing technique, but generally produces the most ideal conditions for use with VAV diffusers while also producing the most energy efficient design. Ducts are sized so that the pressure loss of the duct section/fittings is equal to regain of pressure caused by the reduction of velocity from the upstream to the downstream section. This produces duct runouts with equal static pressure along the entire length. When used with pressure control dampers (PCD's), the static pressure can be set at the start of the duct runout at a value that will produce satisfactory noise and throw performance at the VAV diffusers, typically around 0.1-0.2" H_2O.

While static regain is technically the best approach, it is not essential to use for all VAV diffuser systems. The static regain method is best suited for larger buildings with long duct runouts and complex duct routes. For smaller buildings, the equal friction method can produce satisfactory results if care is taken to minimize fitting losses.

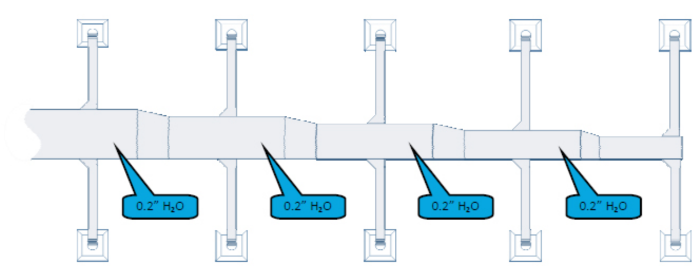
DUCTWORK SYSTEM DESIGN TIPS

- Limit the flexible duct length to diffuser connections to 5' or less
- Use low loss fittings wherever possible: bends with turning vanes, smooth wye duct branches etc
- Use duct support elbows on diffuser flexible ducts
- Use pressure control dampers on diffuser duct runouts





Equal Friction Duct Sizing

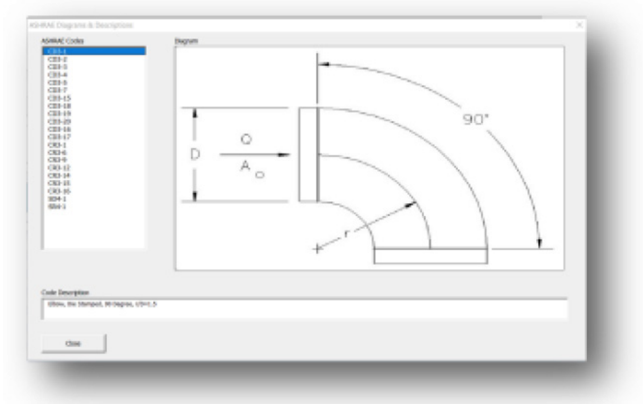


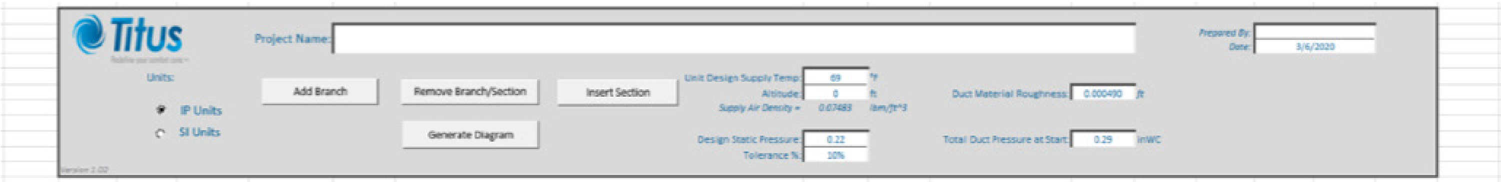
Static Regain Duct Sizing

STATIC REGAIN DUCT SIZING SOFTWARE

Titus offers a basic Excel based duct sizing tool to help engineers design duct systems using the static regain method. The tool works by analyzing each section of the duct system calculating velocities, velocity pressures and static pressures. The software features a database of commonly used duct fittings with ASHRAE Loss Coefficients and is specifically designed to quickly size the runouts for a VAV diffuser system.

The software can be obtained through your local Titus representative.





Branch 1

Static Pressure Calculation

Section Number	Duct Length	Vol. Flow Rate	Duct Width/Diameter	Duct Height	Duct Fitting	Duct Fitting instruction	Equiv. Diameter	ASHRAE Loss Coefficient	Duct Area	Total Volumetric Flow	Duct Velocity	Fitting Loss	Friction Loss	Total Pressure	Velocity Pressure	Static Pressure
	Duct Parameter Inputs (Select From Dropdowns)						Calculations							Results		
	ft	CFM	in	in			ft		ft^2	CFM	ft/s	inWC	inWC	inWC	inWC	inWC
	27	1070			-	-			6.61					0.29		
1.01	6.0	0	14				14.00		1.07	1070	1001	0.000	0.006	0.28	0.06	0.22
1.02	1.0	0	14		CD3-1	Elbow, Die Stamped, 90 Degree, r/D = 1.5	14.00	0.11	1.07	1070	1001	0.007	0.001	0.28	0.06	0.21
1.03	2.0	500	14			Branch	14.00	0.15	1.07	1070	1001	0.009	0.002	0.26	0.06	0.20
1.04	3.0	120	12				12.00		0.79	570	726	0.000	0.002	0.26	0.03	0.23
1.04.1	0.5	0	12		SD4-1-30	Transition, Round to Round, Supply Air Systems - 30 Degree Angle	12.00	0.07	0.79	450	573	0.001	0.000	0.26	0.02	0.24
1.05	7.0	200	10				10.00		0.55	450	825	0.000	0.008	0.25	0.04	0.21
1.06	1.0	150	8				8.00		0.35	250	716	0.000	0.001	0.25	0.03	0.22
1.06.1	0.5	0	8		SD4-1-30	Transition, Round to Round, Supply Air Systems - 30 Degree Angle	8.00	0.14	0.35	100	286	0.001	0.000	0.25	0.01	0.25
1.07	1.0	0	6				6.00		0.20	100	509	0.000	0.001	0.25	0.02	0.23
1.08	1.0	0	6		CD3-1	Elbow, Die Stamped, 90 Degree, r/D = 1.5	6.00	0.14	0.20	100	509	0.002	0.001	0.25	0.02	0.23
1.09	4.0	100	6				6.00		0.20	100	509	0.000	0.003	0.24	0.02	0.23
1.10																

SYSTEM DESIGN—ZONE HEATING

Larger buildings that frequently demand simultaneous heating and cooling across different zones can utilize hydronic or electric duct mounted heater coils. These are typically controlled by the BMS using the VAV diffuser wall thermostats if the VAV diffuser system is integrated into the BMS. Separate thermostats will be required if VAV diffusers without BMS integration capability are used. The heater coils are energized based on a space temperature voting system programed into the BMS.

Most VAV diffusers feature auto changeover so will detect when the supply air is in heating or cooling mode.

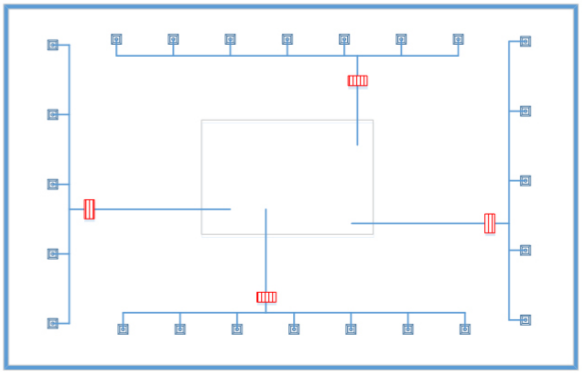
For smaller buildings fitted with a single rooftop AHU and without zone heating coils, the VAV diffusers thermostats can be used in a programmed voting system to supply either heated or cooled air to satisfy the majority of the individual spaces demands.

ELECTRIC HEATING COILS

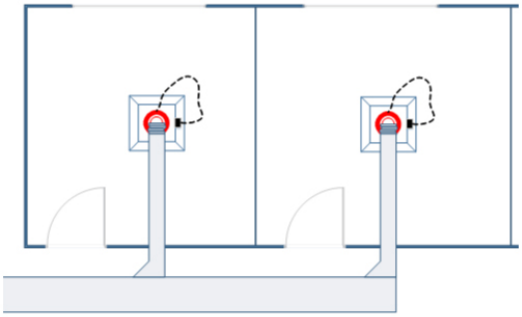
Electric heater coils up to 2Kw capacity are available as an option for some VAV diffuser models. The VAV diffuser onboard controls energize the heaters, so no additional thermostats or programming will be required.

PERIMETER HEATING

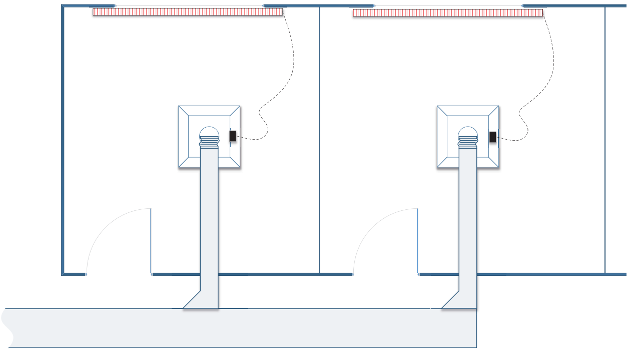
Low level perimeter heating systems can be used with VAV diffusers. When the AHU is supplying cool air to the building, the VAV diffuser dampers will close to the minimum setting (providing minimum ventilation air to the space) and the perimeter heating system will be energized to satisfy the heating demand.



Zone Hydronic Heating Coils Controlled by the BMS



Electric Heater Coils Fitted to the VAV Diffusers



Perimeter Heating System

VAV diffuser systems should be designed with pressure control dampers installed into the ductwork or incorporated into the diffusers, in one of two configurations, inline for VAV supply primary air or bypass for constant volume systems.

Pressure control dampers are available in electronic and mechanical versions:

MECHANICAL PRESSURE CONTROL DAMPERS

PRESSURE RELIEF RINGS

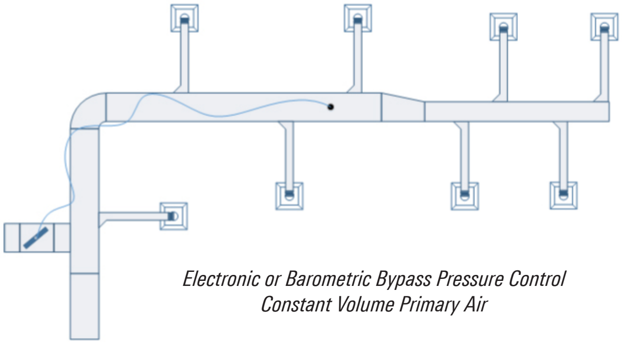
Pressure relief rings are designed for installation into the inlet of the VAV diffuser. As the diffuser damper moves towards a closed position, the spring operated damper blades open, releasing the excess air pressure into the ceiling space.

BAROMETRIC DAMPERS

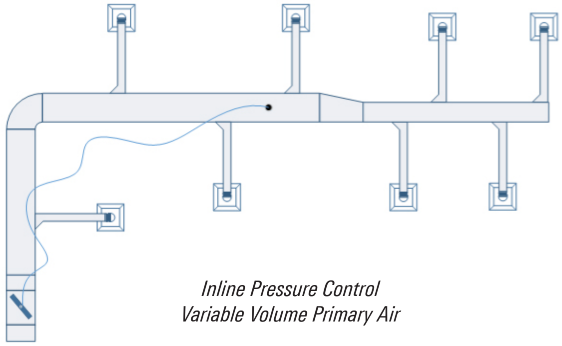
Barometric dampers consists of a damper blade mounted on a shaft fitted with a counterweight. Duct air pressure forces the damper blade open. The position of the counterweight can be adjusted along the length of the shaft.

ELECTRONIC PRESSURE CONTROL DAMPERS

Electronic pressure control dampers are available in circular or rectangular configurations and can be installed inline or duct bypass. These dampers are provided with a pressure tap which should be inserted 2/3rds downstream of the duct runout.



Electronic or Barometric Bypass Pressure Control
Constant Volume Primary Air



Inline Pressure Control
Variable Volume Primary Air

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