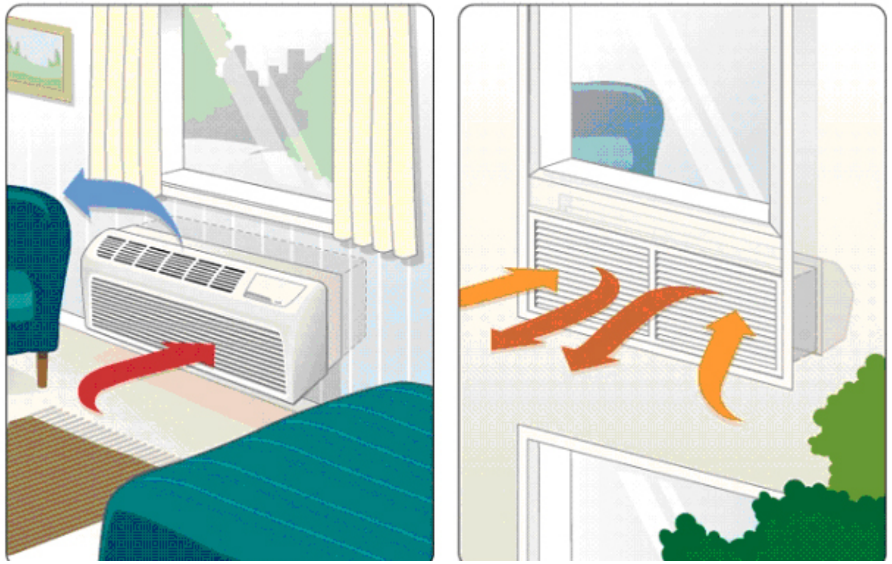
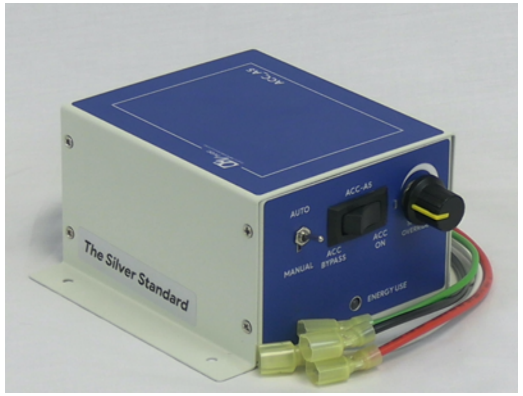


Adaptive Control: The Future of HVAC Systems

Adaptive Photonic Controller: Electronic Commutation of AC Induction Motors with adaptive control features (ACC-ECM+)



Art Durham (OGD3): (315)-858-1002 | ArtDurham@OGD3.com

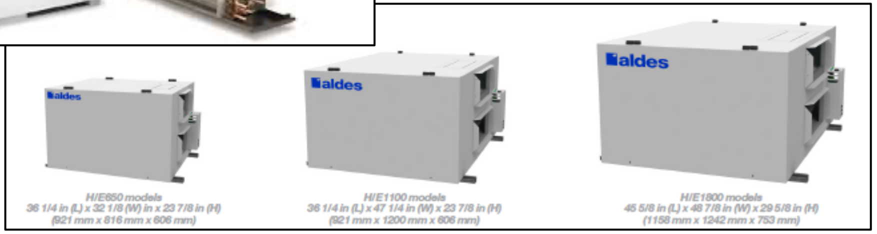
Smart Heating and Cooling: Adaptive Control

New Concepts for Smart Innovative Heating and Cooling;
Advantageous for new construction and renovation of apartments, condominiums, hotels, senior living facilities, dormitories and office buildings.

Adaptive Control: The Future of HVAC Systems

Traditional Heating/Cooling and Air Flow: Variety

Multiple Models



Multiple Manufacturers

GREENHECK
Carrier
YORK
DAIKIN
price
AMERICAN aldes VENTILATION CORPORATION
The Whalen Company

Component	Models							
	VP-A-0204	VP-A-0304	VP-A-0404	VP-A-0504	VP-A-0604	VP-A-0804	V	
Nominal Tonnage	0.50	0.75	1.00	1.25	1.50	2.00		
COOLING PERFORMANCE								
Capacity (MBTUH)	6.2	9.3	11.8	15.0	18.0	23.0		
EER (Btuh/W)	13.0	13.8	13.8	16.1	14.5	13.1		
Entering Water Temp (°F)	86	86	86	86	86	86		
Water Flow (GPM)	1.5	2.5	3.3	3.9	4.5	6.0		
Rated CFM	280	340	420	540	630	830		
Refrigerant type	R-410A	R-410A	R-410A	R-410A	R-410A	R-410A		
Refrigerant charge (oz)	23.5	26.0	25.3	33.5	35.0	38.0	46.0	46.5
HEATING PERFORMANCE								
Capacity (MBTUH)	8.0	11.5	14.5	18.2	21.6	30.0	30.0	35.9
COP	5.0	5.2	5.0	5.5	5.0	5.0	5.0	5.0
Entering Water Temp	68	68	68	68	68	68	68	68
Water Flow (GPM)	1.5	2.5	3.3	3.9	4.5	6.0	6.0	7.5
DIMENSIONS (inches)								
Width (in.)	16	16	16	18	18	18	20	20
Depth (in.)	17	17	17	20	20	20	22	22
Height (in.)	88	88	88	88	88	88	88	88
OPERATING WEIGHT (lbs.)								
Chassis	79	81	83	122	123	132	180	165
Cabinet	133	133	133	153	153	153	173	173
SHIPPING WEIGHT (lbs.)								
Chassis	85	87	89	128	129	138	186	171
Cabinet	145	145	145	165	165	165	185	185

Dimensional Data: 4 Pipe Fan Coil

Model	A	B	H	Filter Size
350	20"	20"	82"	24" x 20" x 1"
450	20"	20"	82"	24" x 20" x 1"
650	20"	20"	82"	24" x 20" x 1"
800	20"	20"	82"	24" x 20" x 1"
1000	20"	20"	82"	24" x 20" x 1"
1200	20"	20"	82"	24" x 20" x 1"

AIR VOLUME

FAN COIL: 350-1200 CFM @ 0.5 ESP

ERV: 50-120 CFM UP TO 1.0 ESP

THERMAL PERFORMANCE

FAN COIL: NORMAL ¾ TO 3-TON COOLING

NORMAL: 15 MBH TO 84 MBH HEATING

Model	Nominal Airflow Rate at 0.4 in. w.g.	Unit Type	Core Type	Defrost Mode	Motor	Recirculation kit	Unit Weight **
H650-Fi-N	735 CFM	HRV	Polypropylene	Fan Exhaust	PSC 120 VAC	683900	147 lbs (67 kg)
H650-Fi-P-N	735 CFM	HRV	Polypropylene	Fan Exhaust	PSC 120 VAC	683900	147 lbs (67 kg)
H650A-Fi-N	735 CFM	HRV	Aluminum	Fan Exhaust	PSC 120 VAC	683900	147 lbs (67 kg)
H650-Fi-EC-N	660 CFM	HRV	Polypropylene	Fan Exhaust	EC 208-230 VAC	683900	147 lbs (67 kg)
H650A-Fi--EC-N	660 CFM	HRV	Aluminum	Fan Exhaust	EC 208-230 VAC	683900	147 lbs (67 kg)
E650L-Fi-N	645 CFM	ERV	High latent transfer (HLT)	Fan Exhaust	PSC 120 VAC	683900	147 lbs (67 kg)
E650L-Fi-EC-N	575 CFM	ERV	High latent transfer (HLT)	Fan Exhaust	EC 208-230 VAC	683900	147 lbs (67 kg)
H1100-Fi-N	1245 CFM	HRV	Polypropylene	Fan Exhaust	PSC 120 VAC	683950	204 lbs (93 kg)
H1100A-Fi-N	1245 CFM	HRV	Aluminum	Fan Exhaust	PSC 120 VAC	683950	204 lbs (93 kg)
H1100-Fi-P-N	1245 CFM	HRV	Polypropylene	Fan Exhaust	PSC 120 VAC	683950	204 lbs (93 kg)
H1100-Fi-EC-N	1170 CFM	HRV	Polypropylene	Fan Exhaust	EC 208-230VAC	683950	204 lbs (93 kg)
H1100A-Fi-EC-N	1170 CFM	HRV	Aluminum	Fan Exhaust	EC 208-230 VAC	683950	204 lbs (93 kg)
E1100L-Fi-N	1100 CFM	ERV	High latent transfer (HLT)	Fan Exhaust	PSC 120 VAC	683950	204 lbs (93 kg)
E1100L-Fi-EC-N	1000 CFM	ERV	High latent transfer (HLT)	Fan Exhaust	EC 208-230 VAC	683950	204 lbs (93 kg)
H1800-Fi-N	1580 CFM	HRV	Polypropylene	Fan Exhaust	PSC 120 VAC	683960	245 lbs (111 kg)
H1800-Fi-P-N	1580 CFM	HRV	Polypropylene	Fan Exhaust	PSC 120 VAC	683960	245 lbs (111 kg)
H1800-Fi-EC-N	2075 CFM	HRV	Polypropylene	Fan Exhaust	EC 208-230VAC	683960	245 lbs (111 kg)
H1800A-Fi-N	1580 CFM	HRV	Aluminum	Fan Exhaust	PSC 120 VAC	683960	245 lbs (111 kg)
H1800A-Fi-EC-N	2100 CFM	HRV	Aluminum	Fan Exhaust	EC 208-230 VAC	683960	245 lbs (111 kg)
E1800L-Fi-N	1380 CFM	ERV	High latent transfer (HLT)	Fan Exhaust	PSC 120 VAC	683960	245 lbs (111 kg)
E1800L-Fi-EC-N	1925 CFM	ERV	High latent transfer (HLT)	Fan Exhaust	EC 208-230 VAC	683960	245 lbs (111 kg)

Multiple Models

Many varieties of types, sizes, efficiency, capacity, CFM, tonnage, refrigeration type, etc.

- Need simplification or fewer models?

Heating and Cooling: Key Objectives

Main Goals:

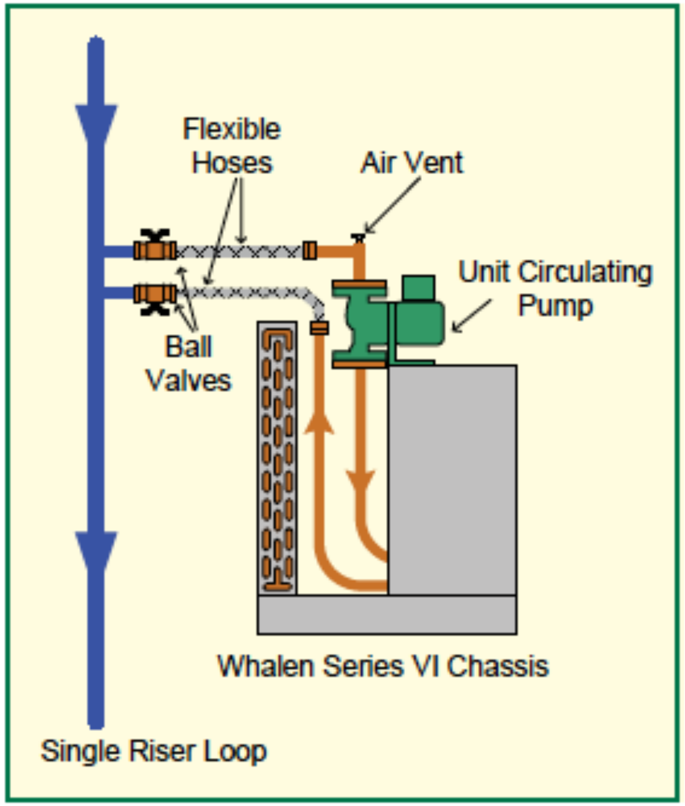
- Thermal Comfort
  - Temperature
- Maintain Good Indoor Air Quality
  - Humidity, Moisture, Filtration
- Adequate Ventilation
  - Clean, Fresh Air*
- Efficiency
  - Less Energy

Satisfy Room Occupant : Comfort Needs of End User

*Clean, Fresh Air is not always Outside Air

Heating and Cooling: Water Source Heat Pumps

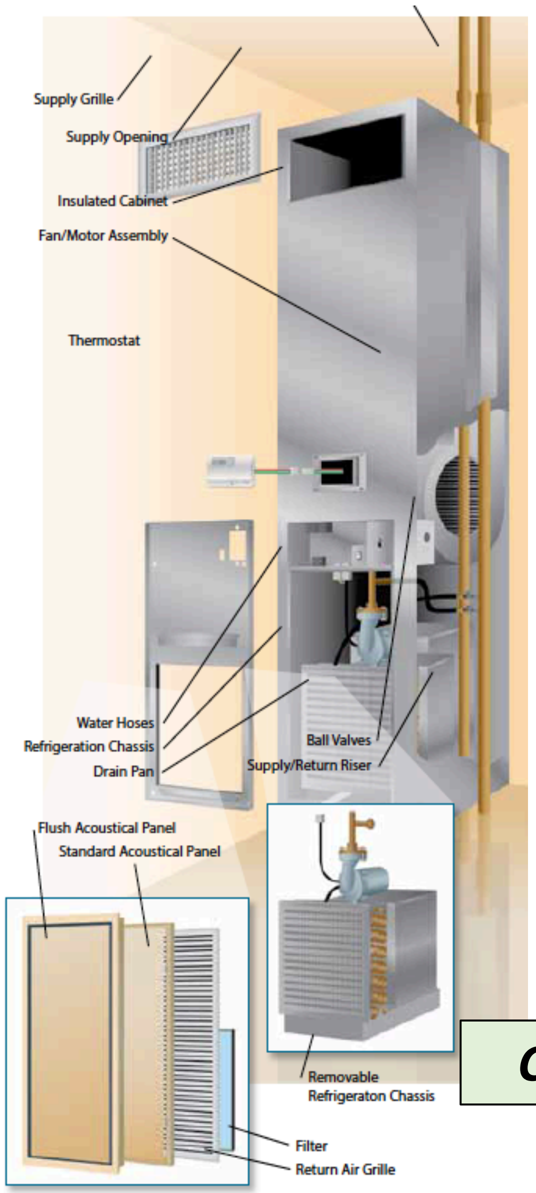
Traditional Single Riser Integral Pump Applications



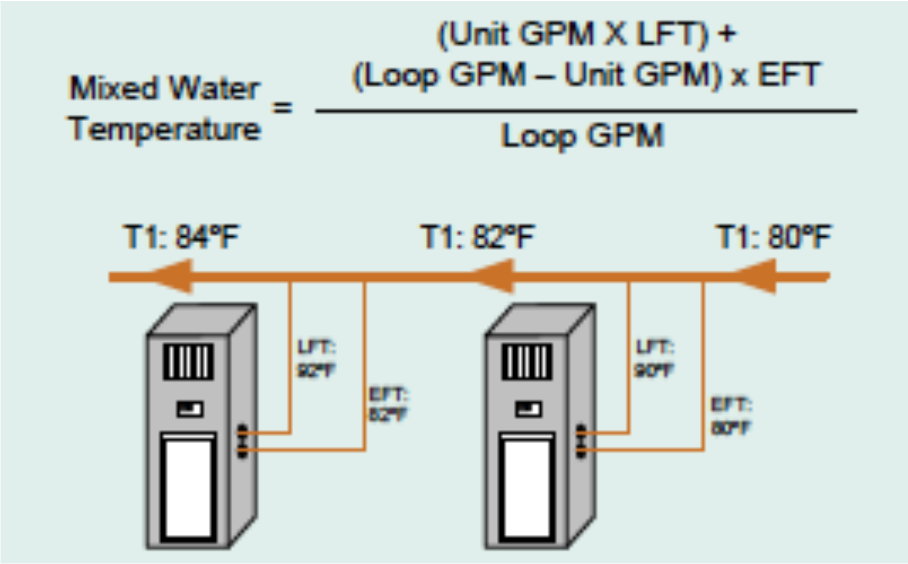
- The primary distribution system features a single main loop with a decoupled secondary distribution loop for each heat pump unit.
- Upon demand, a circulator pump provides the specified flow to each terminal unit.
- There are no limits on the number of units on a loop.
- Pipe size is determined by the total load and flow requirements of the loops.
- Loops can be split if loading becomes elevated and smaller pipe sizes are preferred. Splitting loops can reduce installation costs, save energy, and decrease pump horsepower requirements.

- ***Primary loops require only a standard head loss calculation by the designer.***
- ***No special sizing techniques are required for boilers, towers and terminal units.***

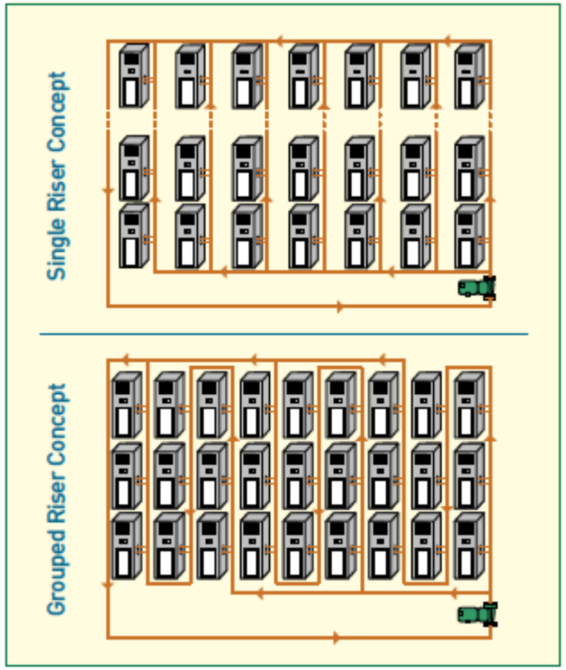
Heating and Cooling: Water Source Heat Pumps



Traditional Single Riser units work flexibly with all building types. One loop connected to each separate riser is fully sufficient for most designs. A common configuration is grouping several risers together on low rise projects.



Challenge: "Changing temperatures and conditions"



Understanding Mixed Water Temperature

- A circulating pump contained in each unit is matched to the factory-design flow rate, ensuring adequate flow **for each heat pump *independent*** of the **mixed water temperature** it encounters.

Single Unit WSHPs – Changing Temperatures, Conditions

Heating Mode
In the heating mode, hot refrigerant flows through the air coil. The heat pump supplies warm air to the conditioned space. The heat added to the room air is removed from the water flowing through the coil, plus the rejected compressor heat. (See Figure 1)

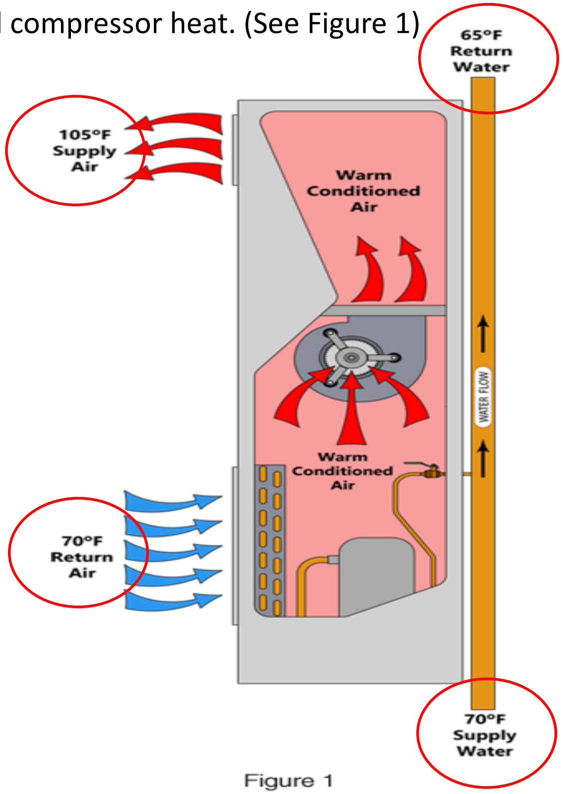


Figure 1

Cooling Mode
In the cooling mode, cold refrigerant flows through the air coil. The heat pump supplies cool air to the conditioned space. The heat removed from the room air is transferred to the water flowing through the water coil. (See Figure 2)

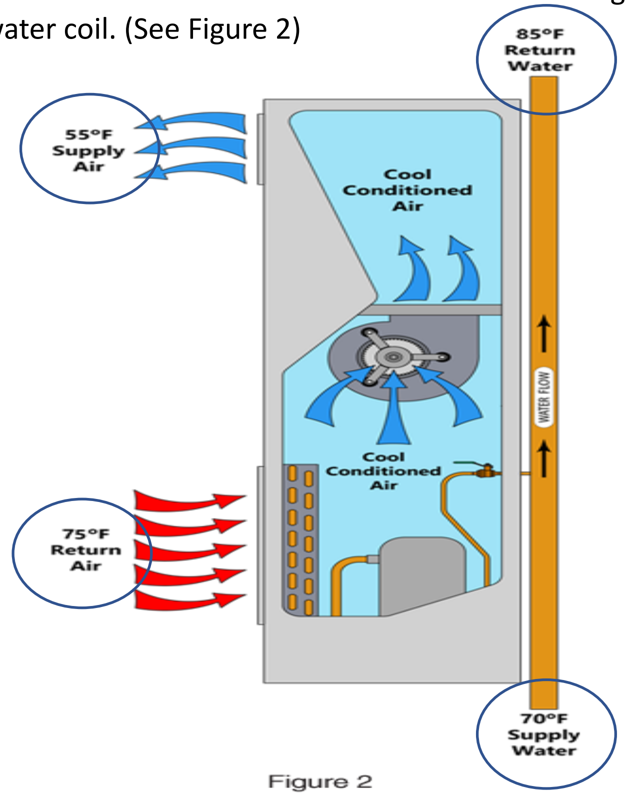


Figure 2

Riser approach has remaining issues:

- **Many complex variables**
- **Temperature change is dynamic**

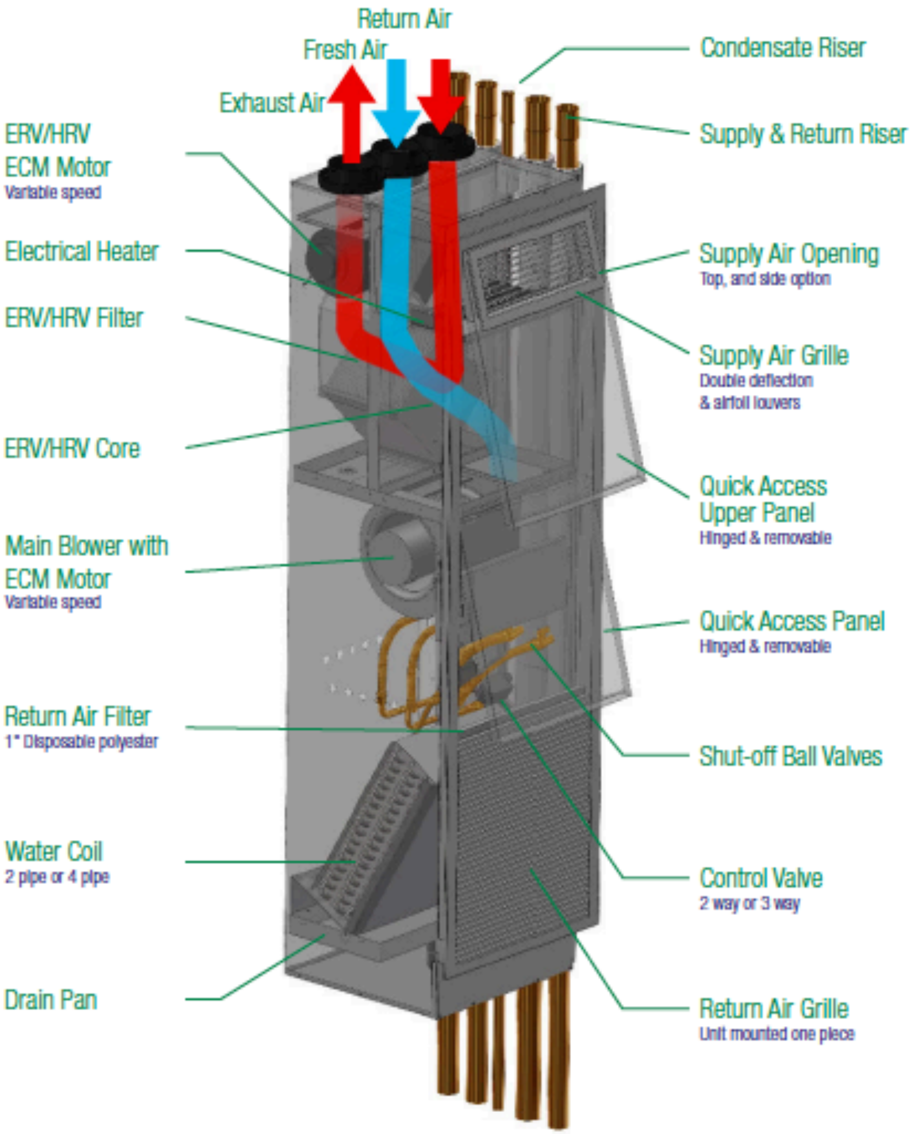
However,

- **Unit operations are fixed**
- **Fans, pumps are fixed speed**

Could benefit significantly with "smart" adaptive control

The complex variables and changing temperatures can be easily measured, tracked and used to direct the "Adaptive Controller" to optimize the Fan(s), pumps, valves, electric powered devices to change and improve performance.

Vertical Fan Coils with Energy Recovery (IQ by ALDES)



- IQ by ALDES is an intelligent ERV/HRV-integrated vertical fan coil (VFC) for high-rise apartments, condominiums, assisted living, and hotels.
- Combines two traditionally separate systems into one compact and fully integrated heating, cooling, and ventilation solution.
- Decentralized System
  - More Efficient
  - Less Complexity
  - Easier to Install and Operate
  - Less Cost

aldes

Adaptive Photonic Controller **(ACC-ECM+)**

Introduction:

- Over 40,000 units in operation*.
- Used in Retrofit and New Construction Projects.
- Used in Original Equipment Manufacturer (OEM) Products (Carrier Corp).
- Utility Incentives through Performance Measures in California, New York, Massachusetts, Vermont, Connecticut (in process).
- Multiple units integrated in:
  - Hospitality Industry (Hotels/Motels).
  - Multi Family Housing Complexes.
  - Assisted Living Facilities.
  - Schools.
  - Universities.
  - Museums

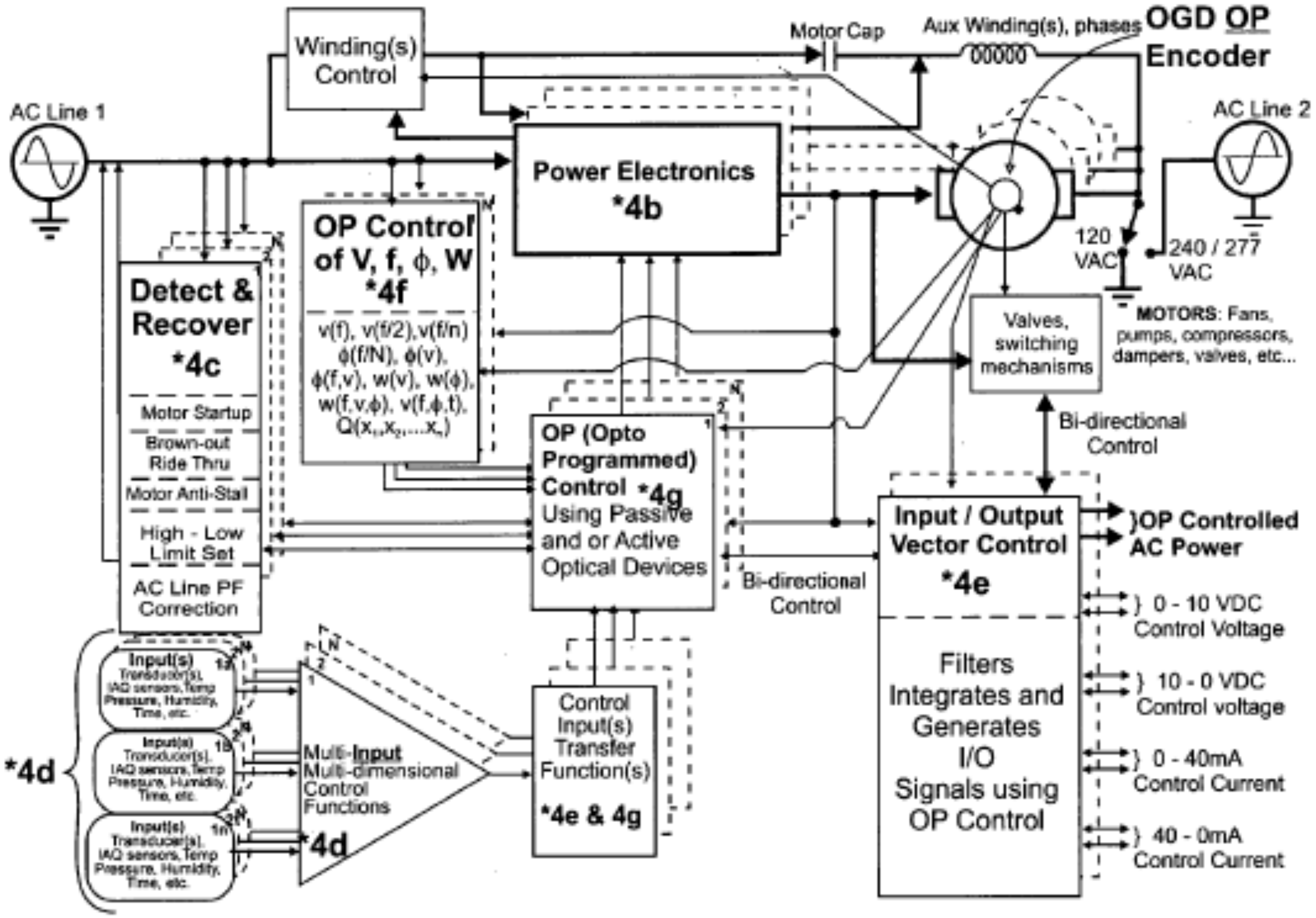
* Failures: <0.025%

The Technology:

- **Adaptive Climate Controller (ACC) or Adaptive Photonic Controller** is a proven "smart control" technology with key features being cost effective, high efficiency, quiet and clean control of air-flow and other load bearing applications.
- Managing these features creates high value products.
- ***Electronic Commutation of AC Induction Motors with adaptive control features (ACC-ECM+)***

Control System: Photonic/Analog System Programming

(ACC-ECM+): AC ECMs with adaptive control



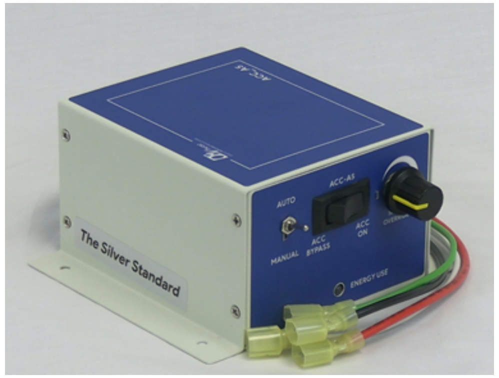
Uses Analog Control Method

No conversion from Analog to Digital -> Digital to Analog

Direct Sensor(s) Input*:

- **Temperature**
- **Humidity**
- **O_2, CO_2**
- **VDC, IDC, VAC**
- **AC Power**
- **Status etc.**
- **BMS Ready**

*Implemented

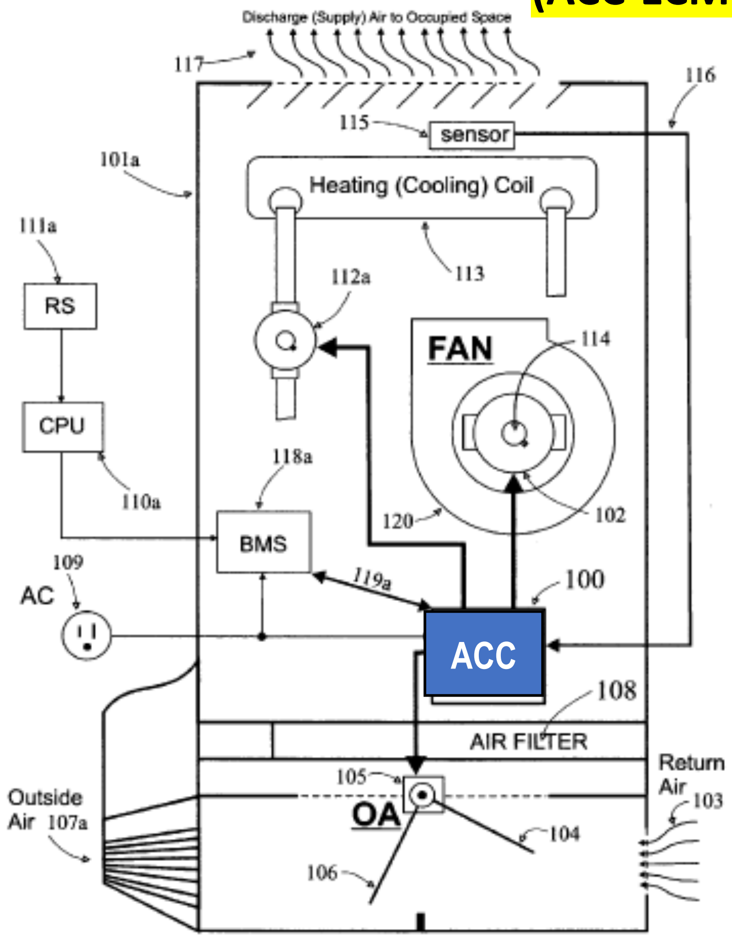


Adaptive Control: The Future of HVAC Systems

Adaptive Control of HVAC-R Unit: Fan Coil Unit

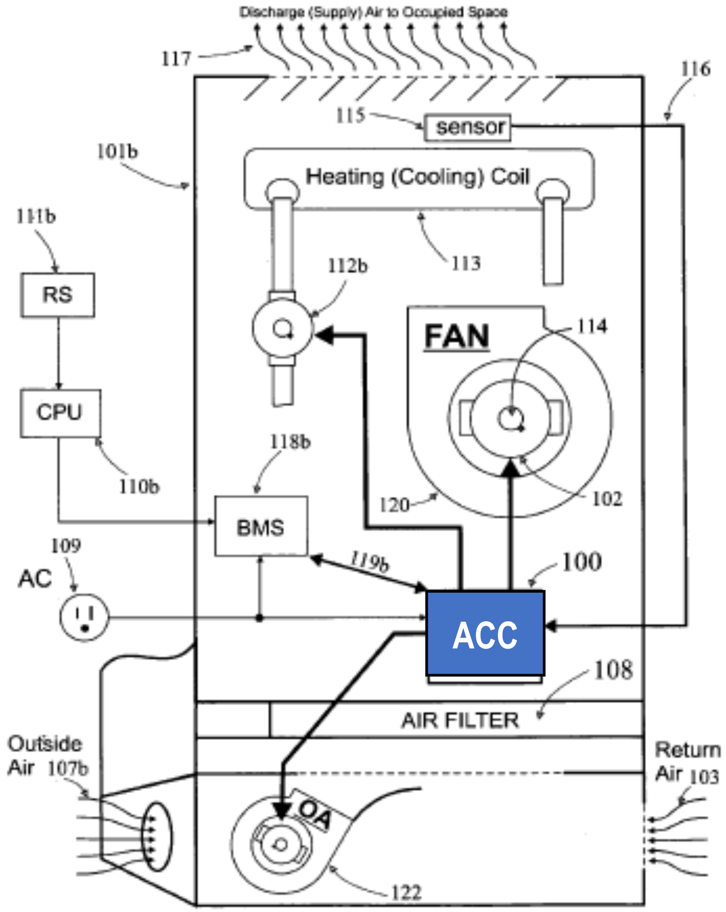
(ACC-ECM+): AC ECMs with adaptive control

"Patent Drawings"



Retrofit Application

Change



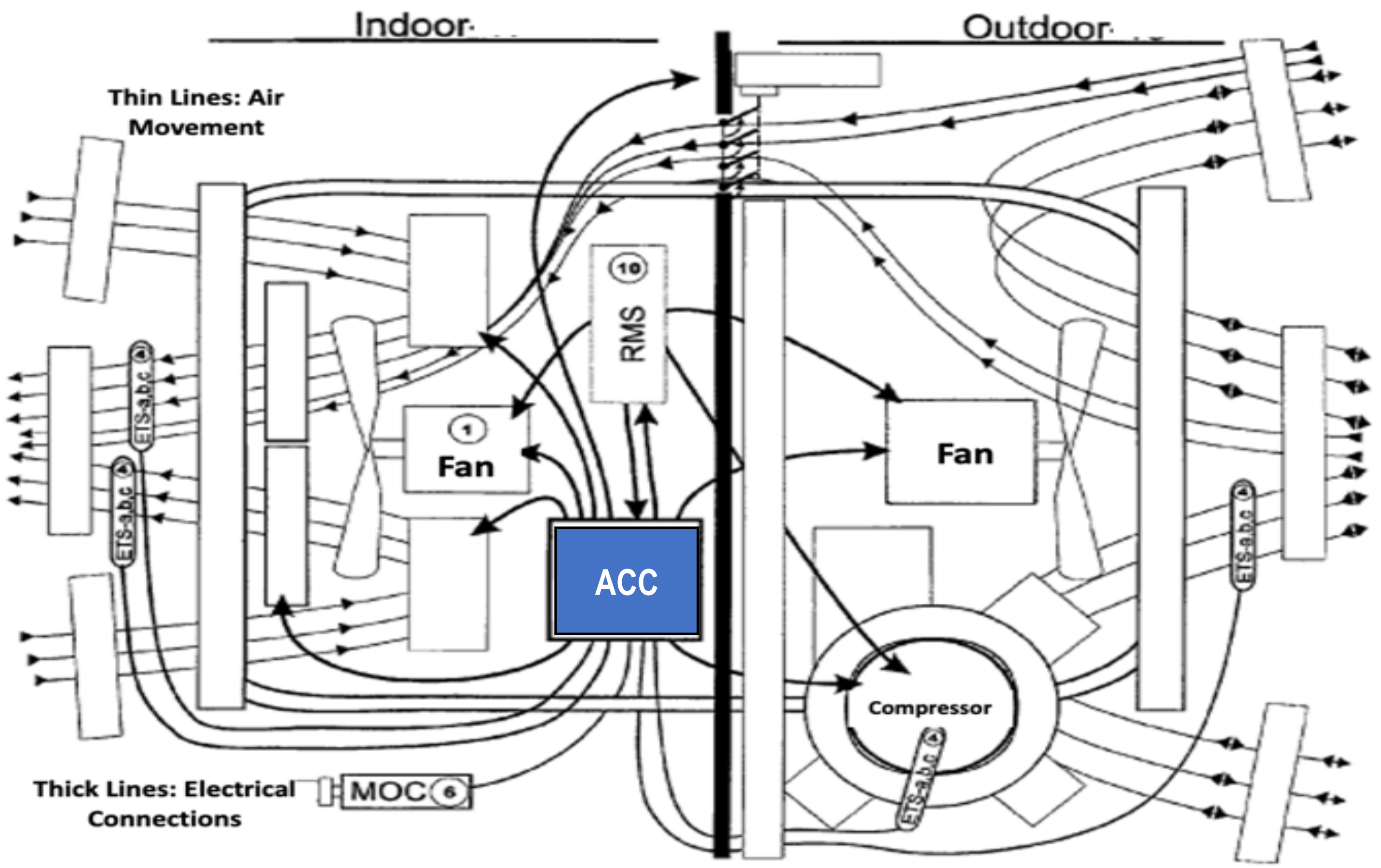
Updated Configuration

One Size System: Program to vary CFM over wide range (ex. 200– 2000 CFM)

Fan Coil Unit: Measure and track changing conditions to control, operate, optimize and "adapt"

Adaptive Control of HVAC-R System: PTAC Unit

(ACC-ECM+): AC ECMs with adaptive control



The adaptive controller **runs** the internal fan(s) in **continuous but "Adaptive Control" mode that intelligently adapts air flow to match mixed temps** of the discharge air with the room, return air.

Improvement of both **indoor and outdoor fan motors, compressor and heating element occurs** utilizing this **continuously dynamic, adaptive smart controller.**

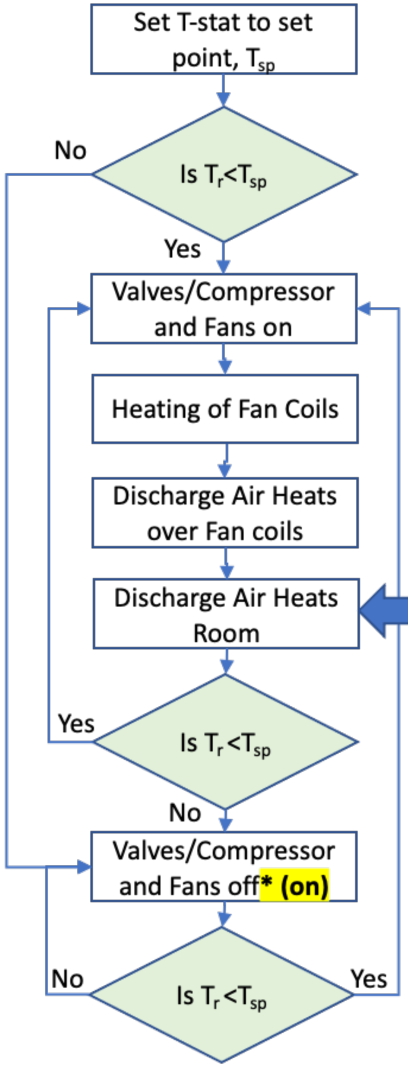
HVAC-R - PTAC Unit: Measure and track changing conditions to control, operate, optimize and "adapt"

Sequence of Operation: Traditional vs. Adaptive Control

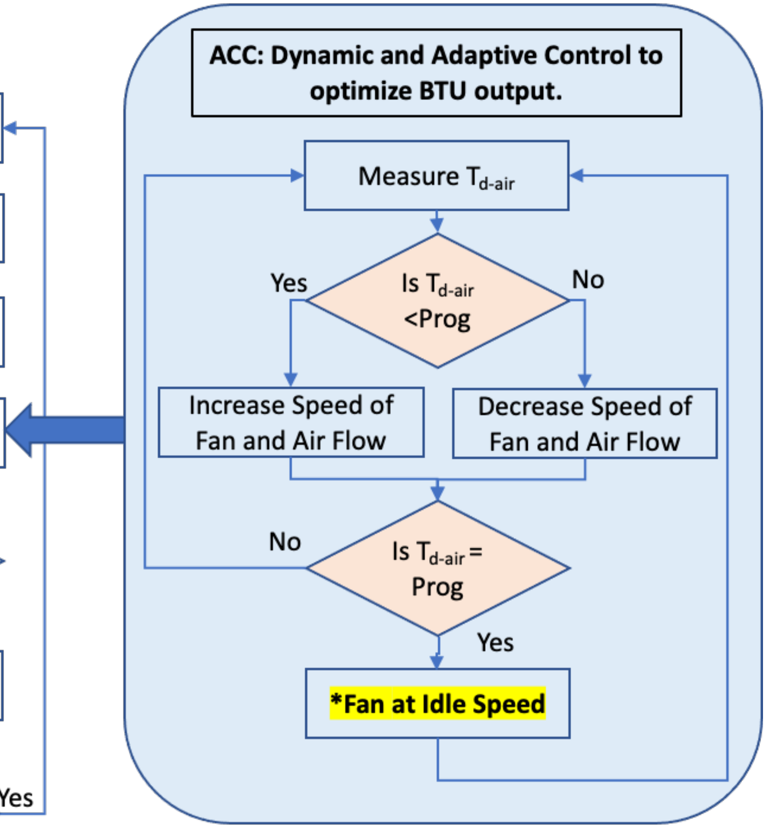
HEATING MODE: Traditional

(ACC-ECM+): AC ECMs with adaptive control

T_{sp}: Thermostat Set Point Temperature
T_r: Room Temperature
$T_{d\text{-}air}$: Discharge Air Temperature (ACC only)



HEATING MODE: With Adaptive Controller



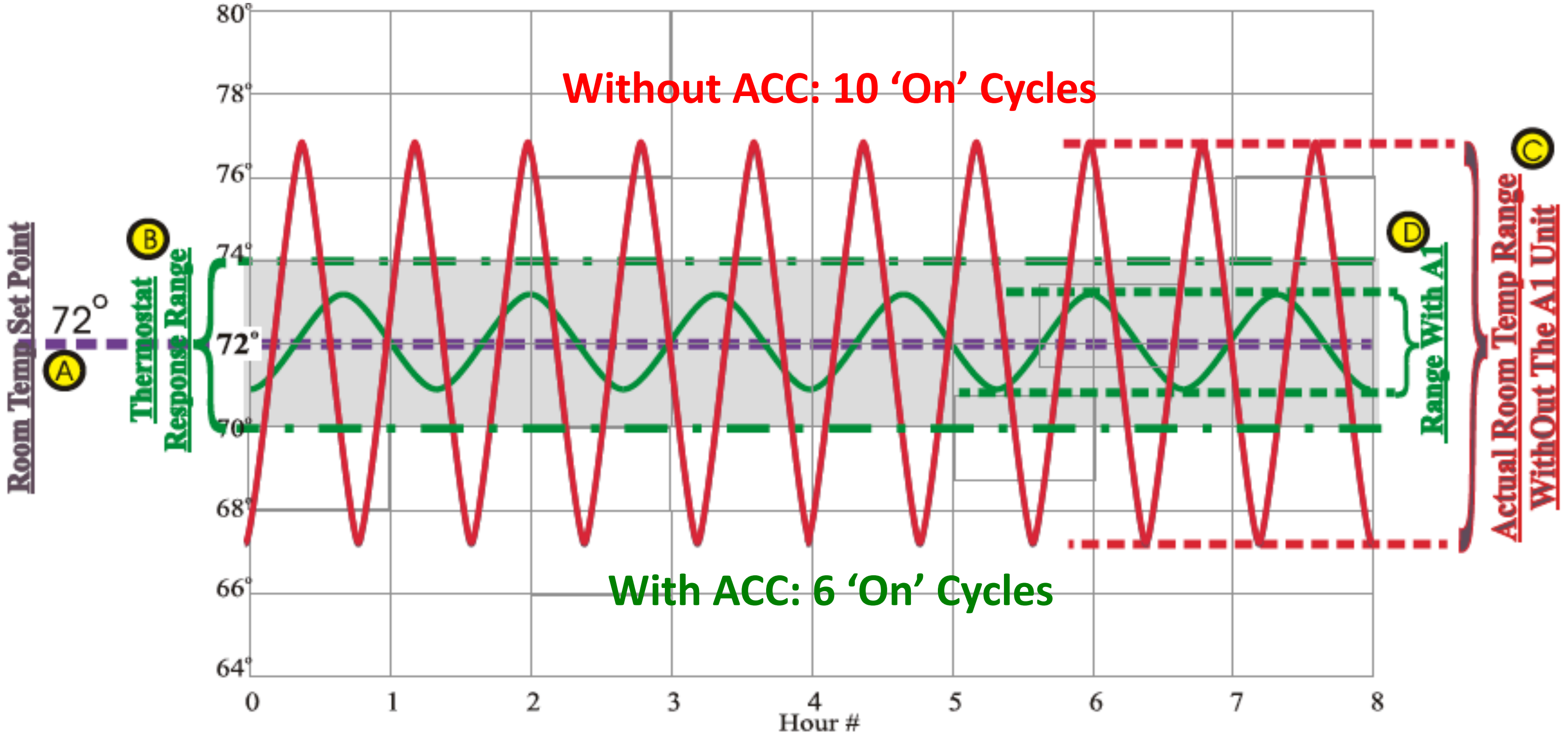
Adaptive Controller provides true "smarts" to match Air Flow to BTU output.

Measures and tracks therms dynamically to power fans and optimize in real time.

Adaptive Control: The Future of HVAC Systems

Tighter Set-Point Control for Better Occupant Comfort

Satisfy Room Occupant : Comfort Needs of End User



Since tighter control of room temperature is maintained and stratification **effects are reduced, compressor and heating element demand of the packaged heat pump are significantly reduced.**

Improved Indoor User Climate Comfort – key end goal!

Adaptive Control: The Future of HVAC Systems

Reduced Energy Usage Through Smarter HVAC Operation

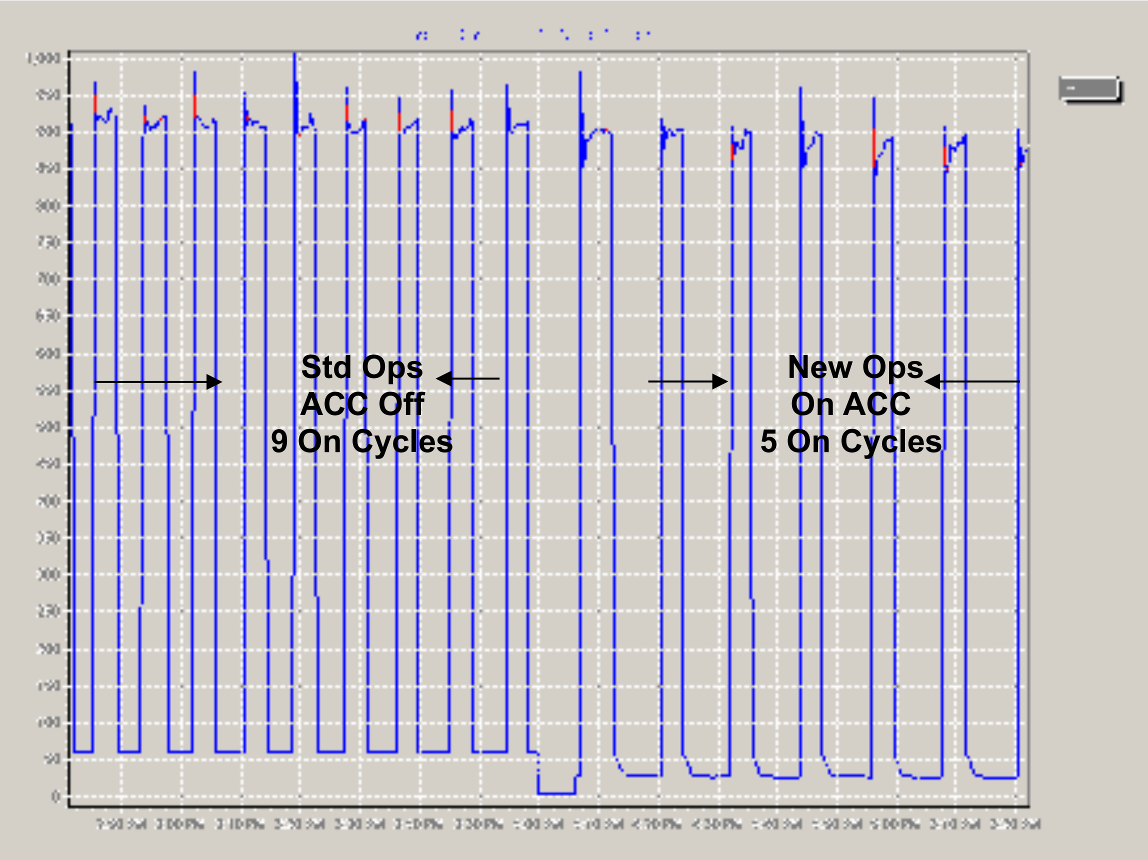
Reduced Energy

Reduces Total HVAC Energy use of Watts:

- **Always reduces total HVAC run time at same temperature!**
- Increases the HVAC Off Cycle time!
- **Usually reduces the number of HVAC on/off cycles**!
- The **demand power and energy used is less** with the ACC.
- When climate data is factored in the results get even better!
- Adaptive, ramps-up, ramps-down, sensing, tracking, optimizing cycle run times for most HVAC-R systems.

***30 - 42% Energy Savings** with the ACC control*
***2.2 - 5.4% Demand Power** improvement*

Cycle Plot at 72* Set Point:



Potential Air Flow Applications with Adaptive Control

ERVs

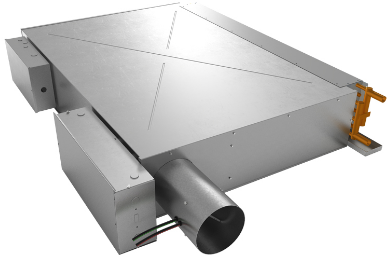
Fan Coils

Ventilation Fans

PTACs

Water Source Heat Pumps

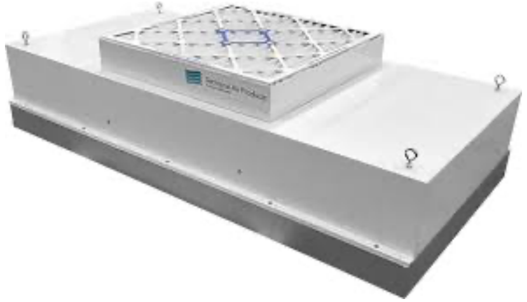
Vertical Fan Coils



Fan Powered DOAS

Lab Exhaust Fans

VAVs



Fan Filter Units

Adaptive Control: The Future of HVAC Systems

Energy Saving Calculations

Method for Calculating Annual Energy and Peak Coincident Demand Savings

Annual Electric Energy Savings:

$$\Delta kWh = \Delta kWh_{Heating} + \Delta kWh_{Cooling}$$

$$\Delta \mathrm{kWh}_{Cooling} = units \times \frac{(W_{Baseline} \times ESF_{Cooling})}{1{,}000} \times LF \times EFLHc \times (1 + HVAC_c)$$

$$\Delta \mathrm{kWh}_{Heating} = units \times \frac{(W_{Baseline} \times ESF_{Heating})}{1{,}000} \times LF \times EFLHh \times (1 - HVAC_c)$$

Summer Peak Coincident Demand Savings:

$$\Delta \mathrm{kW} = units \times \frac{(W_{Baseline} \times ESF_{Cooling})}{1{,}000} \times LF \times (1 + HVAC_d) \times CF$$

Where:

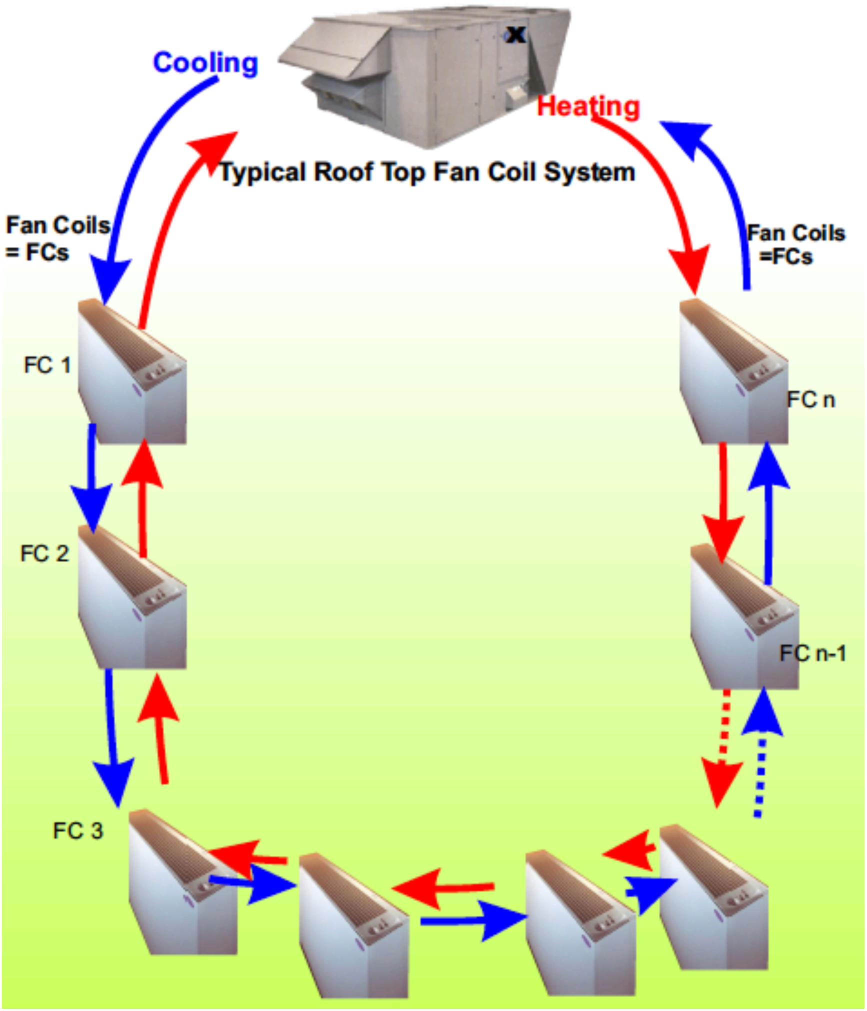
ΔkWh	= Annual electric energy savings
ΔkW	= Peak coincident demand electric savings
$\Delta therms$	= Annual gas energy savings
units	= Number of measures installed under the program
$\Delta kWh_{Cooling}$	= Annual electric energy savings during the cooling season
$\Delta kWh_{Heating}$	= Annual electric energy savings during the heating season
$W_{Baseline}$	= Baseline HVAC System Wattage; Measured "OR" Calculated Below
$W_{Baseline}$	$= W_{Evaporator} + W_{Condenser} + W_{Compressor}$
$W_{Evaporator}$	$= V_{Nameplate} \times A_{Nameplate} \times PF$
$W_{Condenser}$	$= V_{Nameplate} \times A_{Nameplate} \times PF$
$W_{Compressor}$	$= V_{Nameplate} \times A_{Nameplate} \times PF$
ESF	= Energy Savings Factor
PF	= Motor Power Factor
LF	= Motor load factor
hrs	= Operating hours
EFLHc	= Equivalent Full Load Hours for Cooling from TRM
EFLHf	= Equivalent Full Load Hours for Heating from TRM
HVACc	= HVAC interaction factor for annual electric energy consumption
HVAC*d*	= HVAC interaction factor at utility summer peak hour
HVAC*g*	= HVAC interaction factor for annual natural gas consumption
CF	= Coincidence factor

Benefits: Energy Savings - Multiple Applications

Applications with Motor Driven Equipment and Savings Results:

- **Fan Coils** - steam, hot **water, chilled, both.**
  - 20% to > 50% Savings Electricity and Fuel Source.
- **Hot Air Furnaces** – oil, gas, electric.
  - 17% to >35% savings *Fuel & Electricity.
- **Pumps** - well, pool, sump, others.
  - 15% to > 30% Electricity Savings.
- **Compressors** – rotary, reciprocating, scroll.
  - 12% to 50% Electricity Savings.
- **Electric** - stoves, fans, lights, coils.
  - 12% to > 60% Electricity Savings.
- **A/C's** - central, window, split, PTACs.
  - 14% to >44% System Electric Savings, fans, compressor, heater.

Roof Top Unit with Fan Coils and Adaptive Control



- Typical RTU HVAC system with fan coils using 1/15 to 1/3 hp motors
- **Improvements made by upgrading performance of individual Fan Coil Units (FCU)**
- Provides **net reduction** in power consumption **for each FCU fan use** and valve **open/run time**.
- Reduction in run time **ripples directly** to a dramatic **reduction** of refrigeration loading the **chiller or heater** components.
- Other connecting FCU system losses are reduced
- Achieves **system wide improvement** in performance for **better thermal comfort**, indoor **air quality, quiet, energy savings and lowered construction costs: could reduce boiler capacity!**

Validation References

Adaptive Climate Control Selected Experts and Customers with Documented Savings:

Labs, Experts, Universities, Customers who did independent tests:

- U.S. DOE, NYSERDA, ETL, NYPA, NYS OGS.
- S.U., Clarkson, Texas A&M, MIT, SUNY.
- Carrier, JCI, Air Products, Air Therm, McQuay, Enalysis.

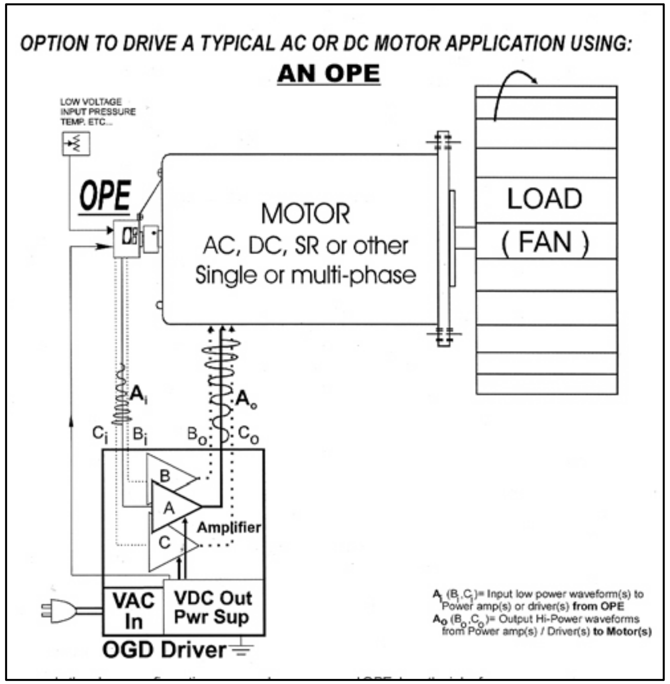
Locations and Building Types with Savings Results:

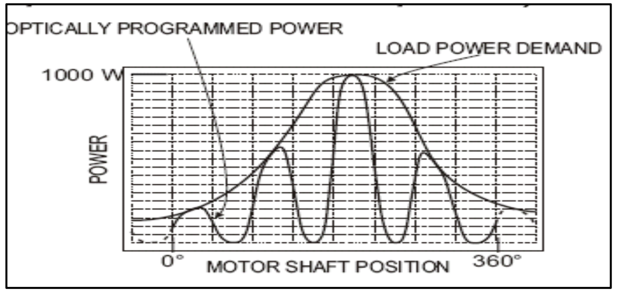
- Hotels, Hospitals, Motels, Restaurants.
- Pre- to High schools, Universities, College Dorms.
- Museums, Libraries, Court Rooms, U.S. Congress.
- Residences - Homes, Condos, Multi-Family Housing, Mobile Courts.
- Factories, Office Buildings, Garages, Stores, Bowling Alleys.

Core Technology Overview

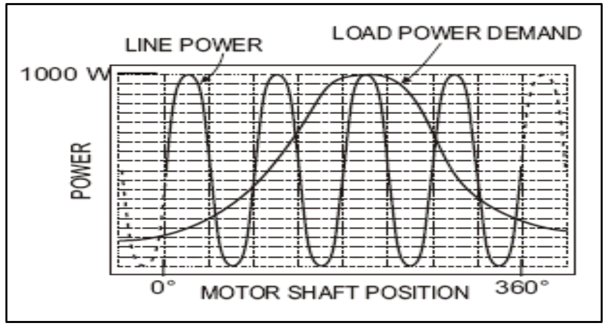
(ACC-ECM+): AC ECMs with adaptive control

- Patented* Photonic Programmer Encoder (PPE) Technology to run at adaptive speeds determined by sensors.
- Uses Photonic Transducers and Graphical Apertures Integrated into Intelligent, Signal and Vector Processors used as Analog Power Controllers.
- Improved Speed Control of AC motors - continuously adapts to end-user requirements compared to fixed speed systems.
- Simple, low cost solution that offers adaptive airflow that tracks/follows air temperature.

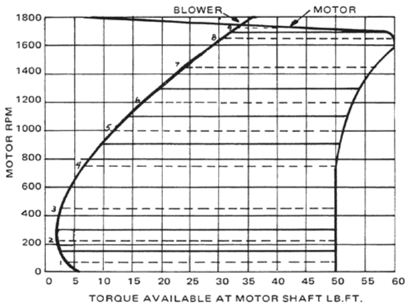




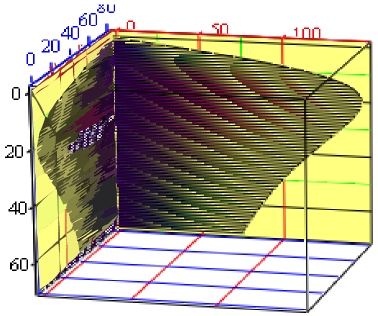
ADATIVE SPEED



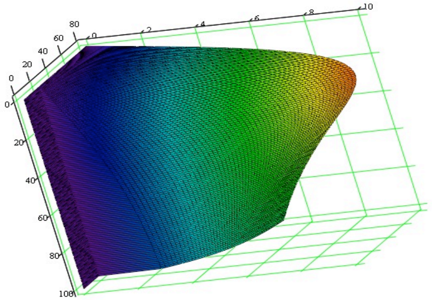
FIXED SPEED



Standard Fan & Motor
2D Torque Plot 60 Hz



Dual 2D Fan / Motor
Dual Torque slip / Hz



PPP FULL 3D Fan / Motor
Speed Torque Control Plot

- 18+ Patents
- 300+ Claims
- 30,000 units deployed

By OGD Inc.

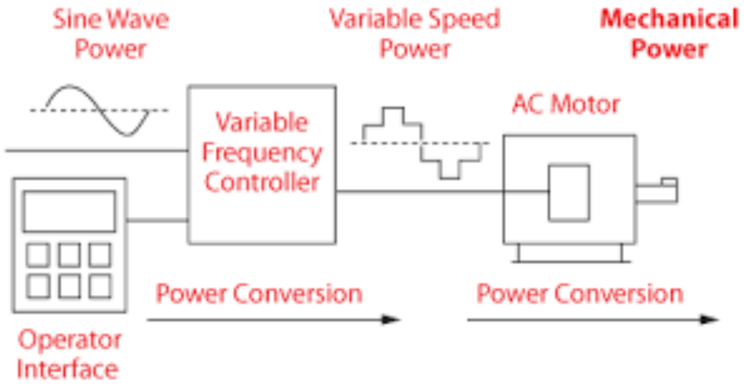
Adaptive Control: The Future of HVAC Systems

Comparison with VSD and ECM

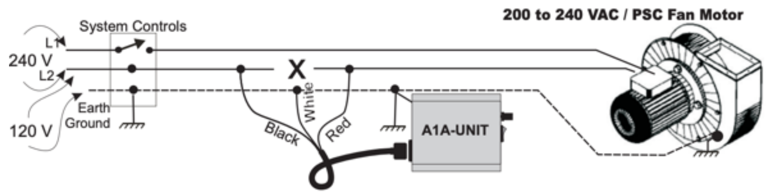
Adaptive Photonic Controller	Variable Speed Drives	EC Motors (permanent magnet)
Uses photonic wave programming	Uses digital software programming	Uses digital software programming
Analog vector output power	Inverter high frequency, digital switching output power	Digital conversion using opposite magnetic field for switching
Reduced control and power conversion steps - external	Multiple analog/digital, digital/analog control and power conversion - external	Rectifier coverts AC/DC - internal
Lower losses, heat, waste	Losses generate heat, waste (requires heat sinks)	Lower losses, heat
Reduced harmonics	Creates harmonics	Creates harmonics
No special materials	Specialty semiconductors	Rare earth materials and semiconductors
Less complex, compact	High complexity, bulky	High complexity, bulky
Lower cost, low maintenance	High cost, high maintenance	High cost, high maintenance

Adaptive Photonic Controller: Electronic Commutation of AC Induction Motors with adaptive control features (ACC-ECM+)

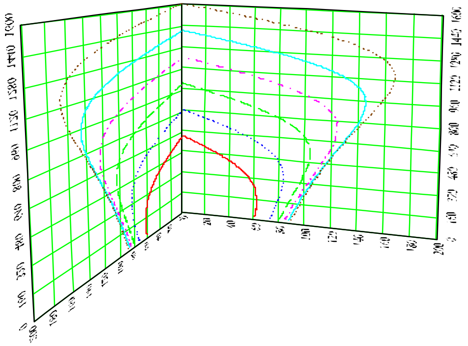
Variable Speed



ACC Technology: 3 Wire Install (+ Ground)

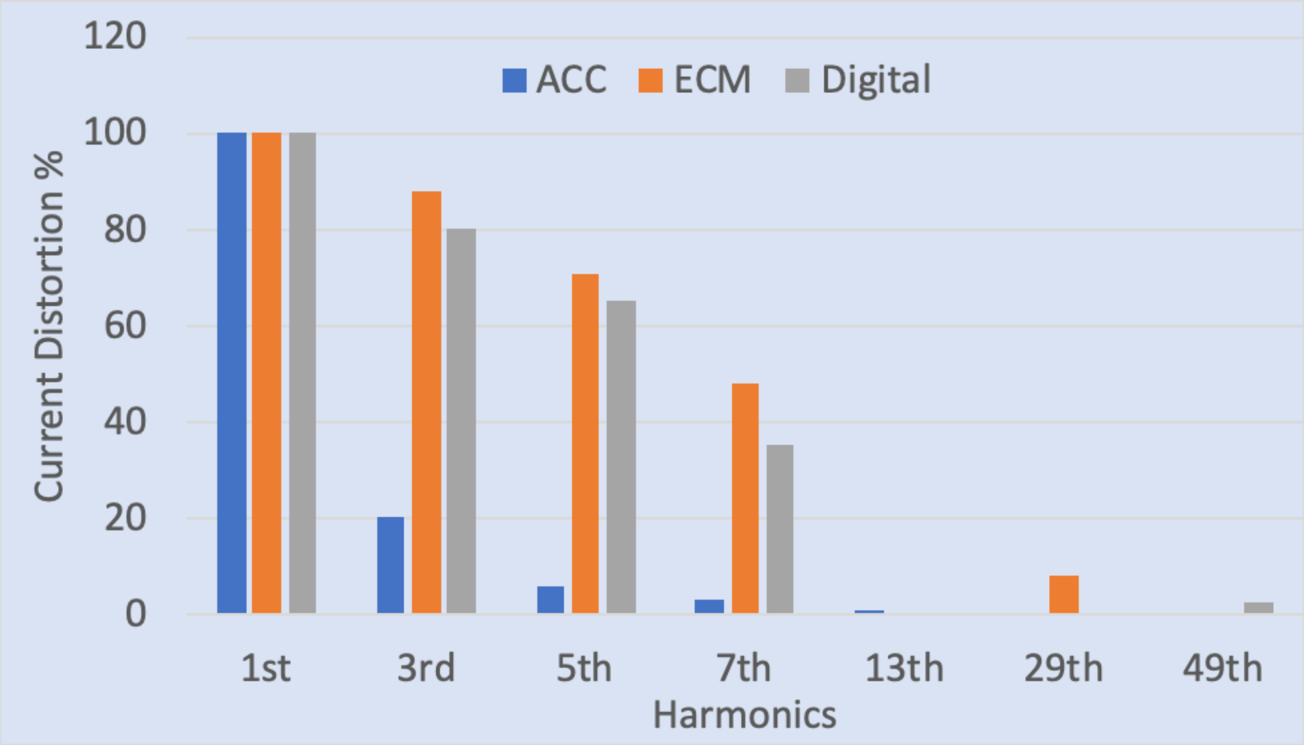


Dual Multi 2D Fan / Motor Variable Torque Multi Hz.



Adaptive Control: The Future of HVAC Systems

Features: Reduced Harmonics



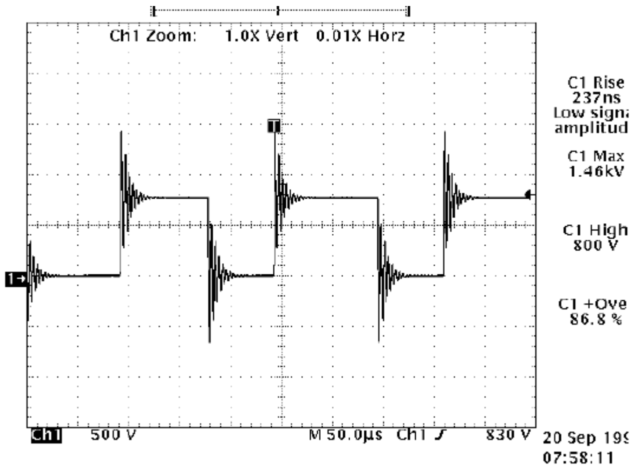
Current Harmonics for powering a FAN VAV with different variable speed drives: Adaptive Climate Control (ACC), Electronically Commuted Motor (ECM) and Variable Digital Drive (Digital)

Adaptive Climate Control (ACC-ECM+) Reduces Harmonics from Current and Voltage Distortion:

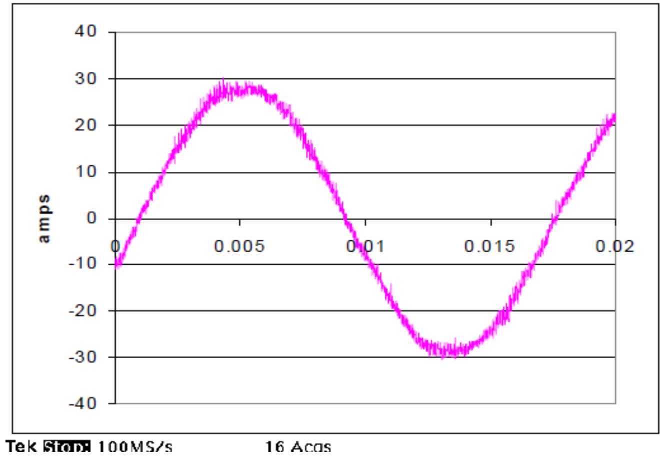
- ACC Keeps AC Grid and AC Motor Cleaner than ECM and VSDs.
- Variable speed drives and ECMs are well known for reducing power consumption of an electric motor, but….
- ECM and other Digital PWM (Pulse Width Module) products create Noise and Interference Harmonics in current and voltage in motor that can reflect power issues back into the AC Grid and can cause additional challenges.

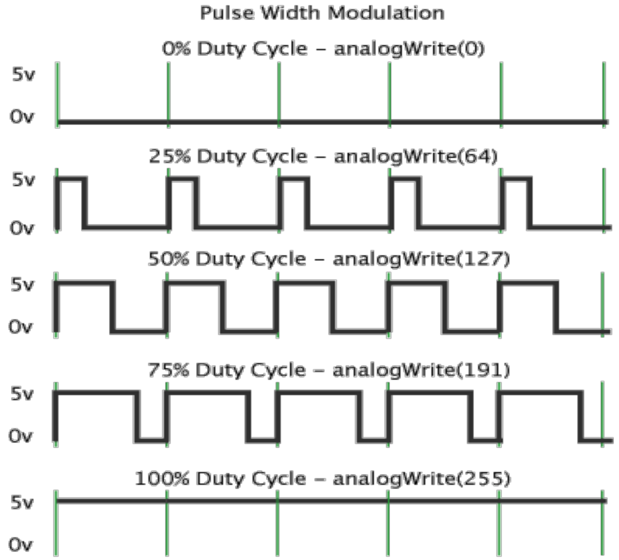
Issues with Pulsed Width Modulation

Typical PWM Voltage overshoot (Both High & Low “Ringing”)
(Note @ VI=460; Vhi=800v; Vlo=237v)

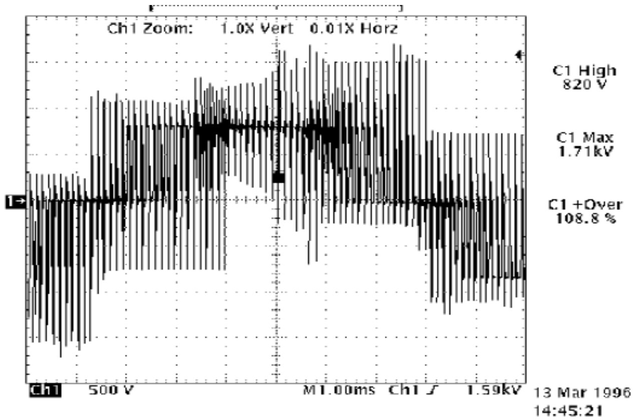


Typical PWM High Speed Switched Current
(When motor windings can manage overshoot Voltages)

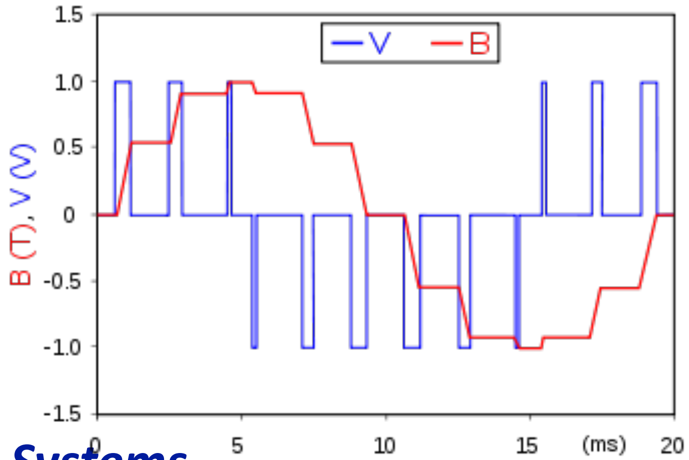




PWM Voltage overshoot “Ringing” & “Harmonics”
(Note @ VI=820v; Vhi=1.71kv -> 109% overshoot)



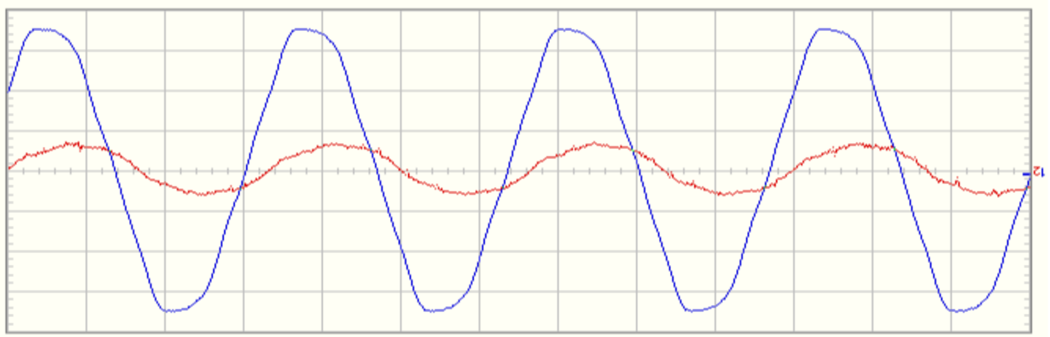
Example of PWM in an AC motor drive



AC line Power vs. ACC Smart Vector Control Power

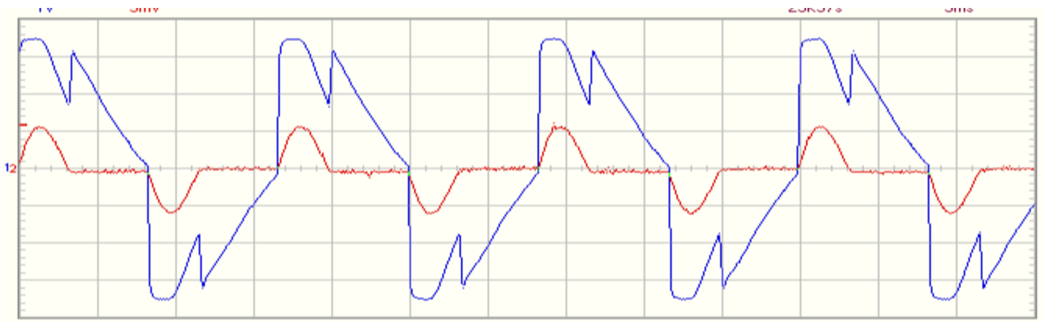
Voltage and Current Overlay for AC Induction Fan Motor

1] AC fan Motor Voltage / Current plot = Full AC Line Power



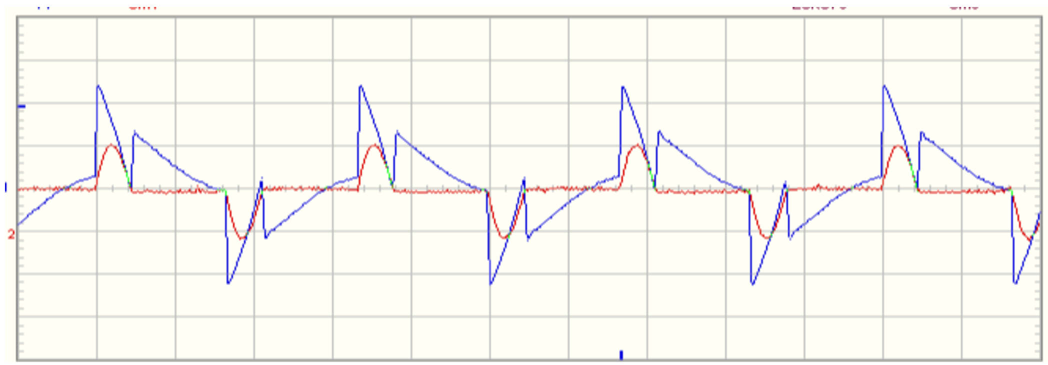
AC Line Power (Note Significant MOTOR current Lag)
Poor Power Factor (PF), Power, Efficiency, etc.

2] AC fan Motor Voltage / Current plot = Full ACC High Power



Full ACC Control Power (NO MOTOR Current Lag)
Less PF distortion, Less Power Wasted, Braking effect, etc.

3] AC fan Motor Voltage / Current plot = ACC Low Power

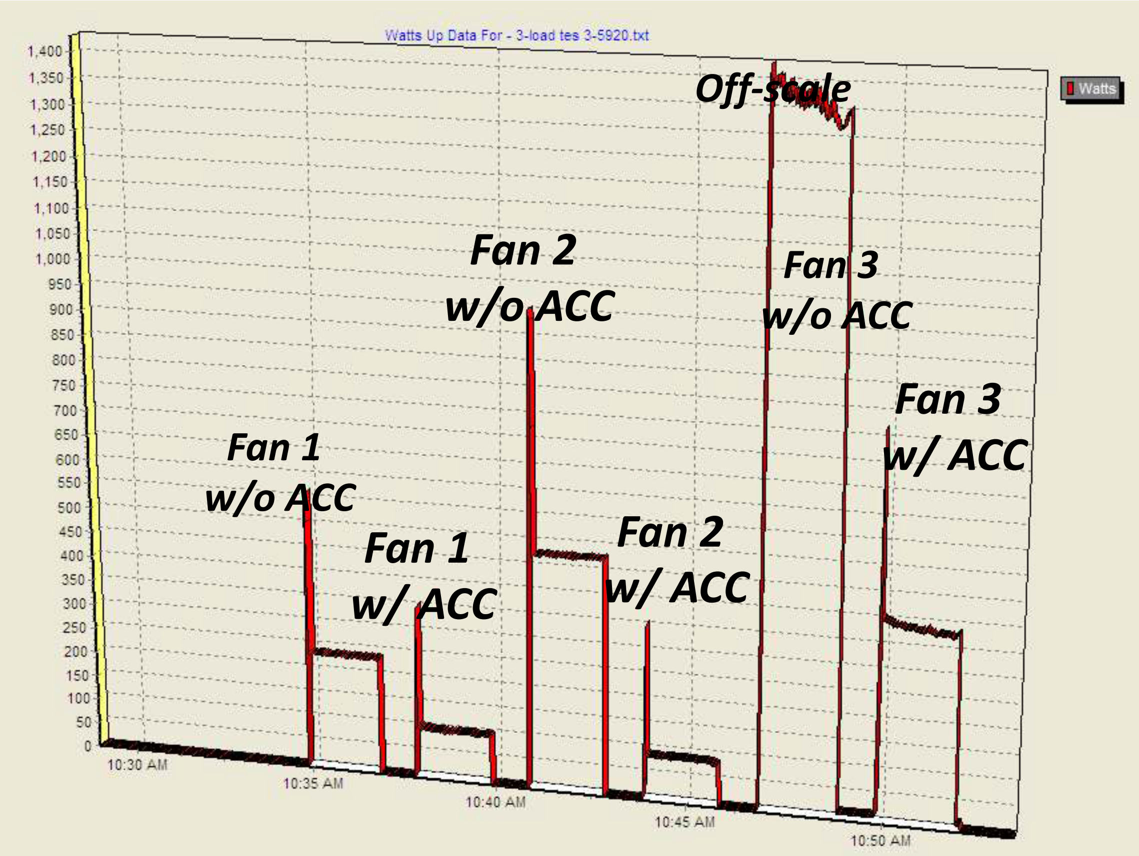


ACC High to Low Power Control (MOTOR Volts /Current always In sync)
Reduced Harmonics, Noise, Heat, Power Waste at all outputs

Features: Improved Soft Start

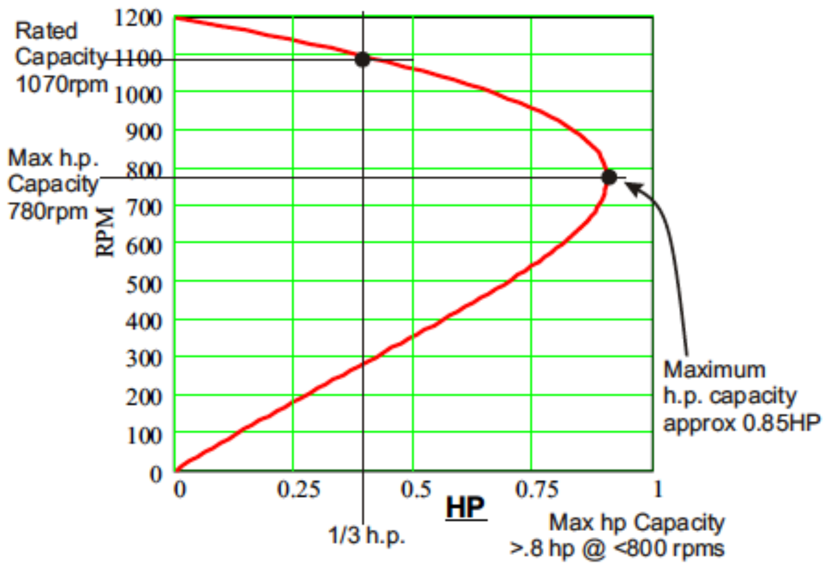
Soft Start achieved by Adaptive Climate Control (ACC-ECM+)

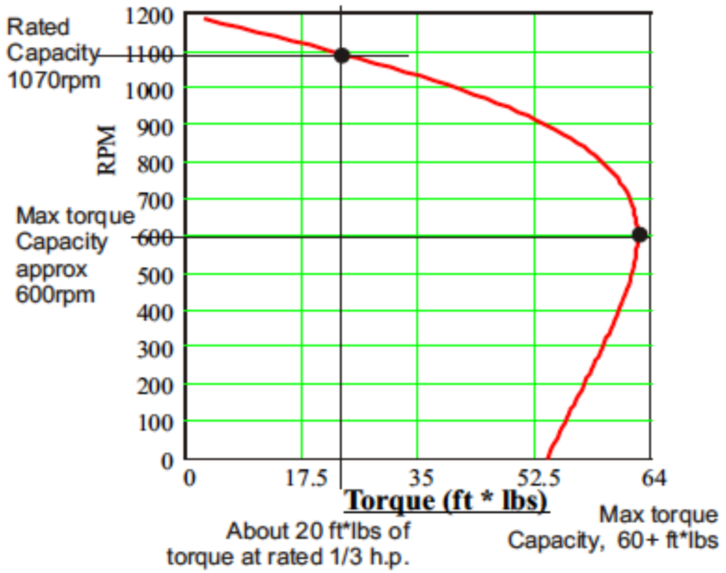
- Innovative method that controls motor current and acceleration.
- Allows the user to select between early, constant or late acceleration/deceleration depending upon the application requirements.
- Adaptive control monitors motor performance by analyzing each start and adjusting accordingly to maintain optimum control.
- ACC lowers overall power usage.



Three examples of fan motor power loads with and without ACC showing in-rush start-up energy (kWD) as well as run energy use (kWh)

Horse Power, RPM and Torque





Horse Power vs. RPM:

- Maximum HP capacity for this 0.3HP motor is 0.85HP
  - 2X rated capacity
- Motor's maximum HP capacity is not at higher motor speeds or rated speed (1070 RPM).
- Point of maximum HP is motors most efficient operating point.
- What if an intelligent motor controller could operate and hold a motor at its optimum operating point across its entire operating range? = maximum efficiency system!
- Setting and maintaining this maximum torque point would produce constant maximum efficiency.

**** This hp profile is w/o a start winding**

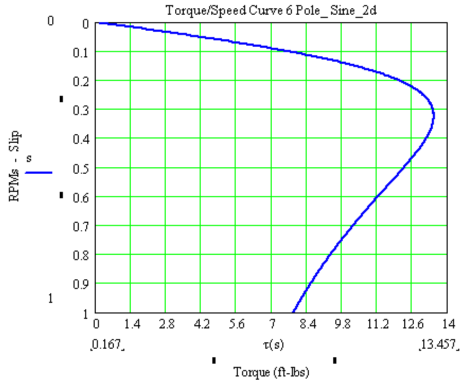
Torque vs. RPM:

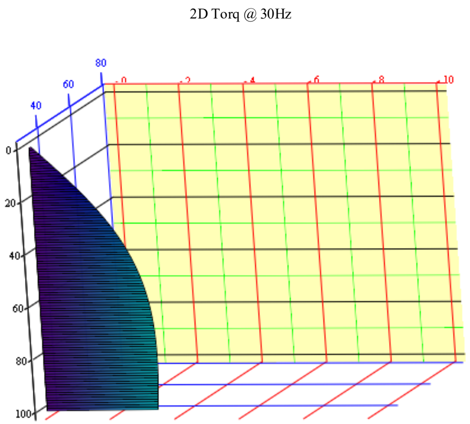
- The 1/3HP motor, at its rated 1070RPM, produces a torque of ~20 ft*lb: <u>only 1/3 of its actual torque capacity!</u>
- Point of maximum torque is the motors point of highest conversion from electrical to mechanical force.
- Maximum torque and maximum horse power is in range of 600 to 780 RPM.
- Provides maximum efficiency and/or maximum power delivery capacity.
- The same can be applied to 1/4 up to 1/2 HP motor applications.

Core Technology Overview

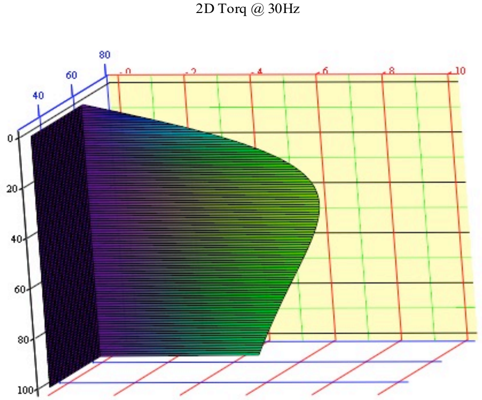
Graphics showing AC torque control approach is more than simple 2D plots.
Note plot migration to determine Vector structure.

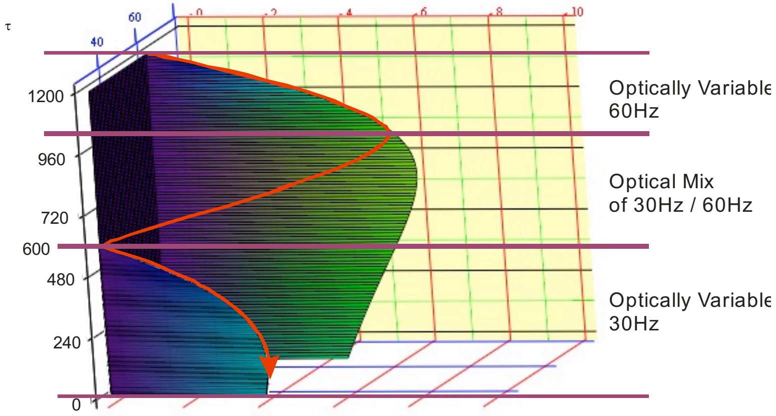
Standard 2D Torque Plot



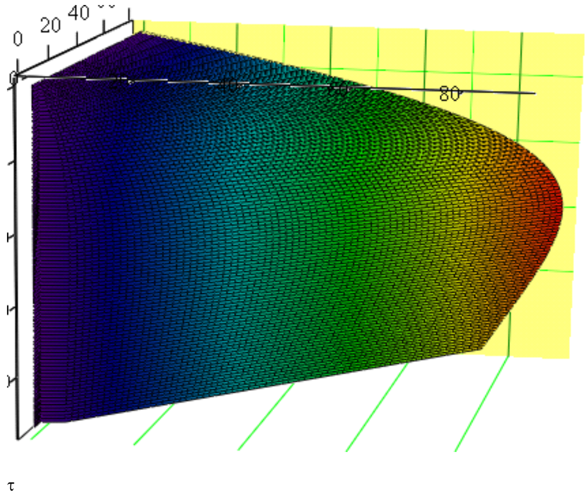


ACC Map of 2D Torque Plot



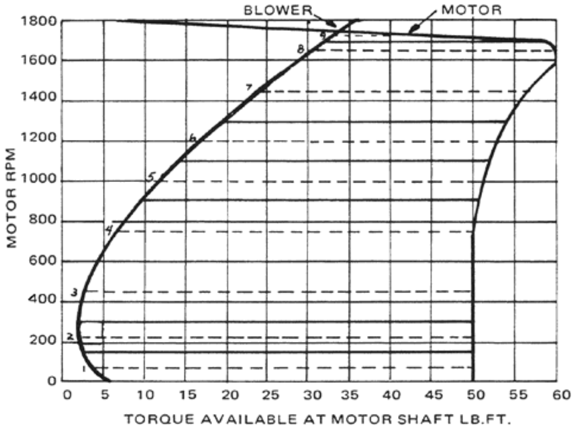


Full 3D surface Map of multi-vector options for this motor

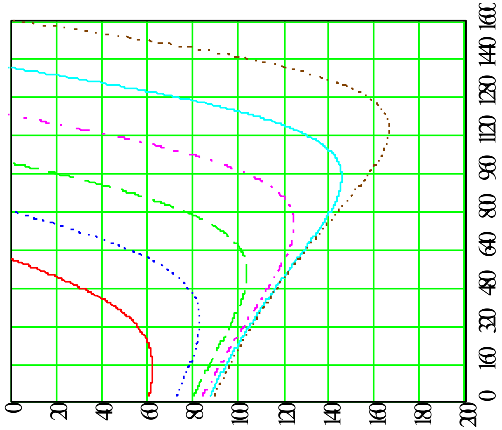


Adaptive Controller:

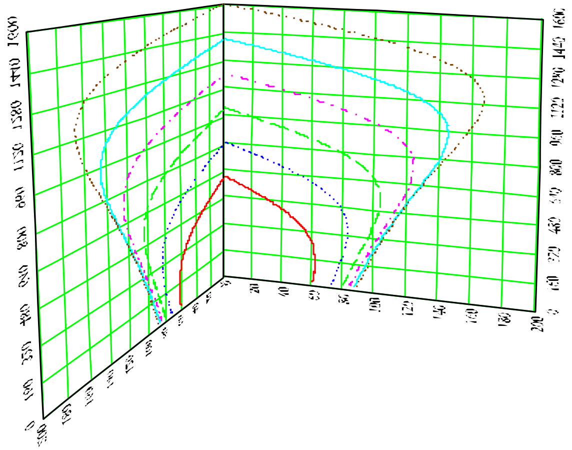
Standard Fan & Motor
2D Torque Plot 60 hz



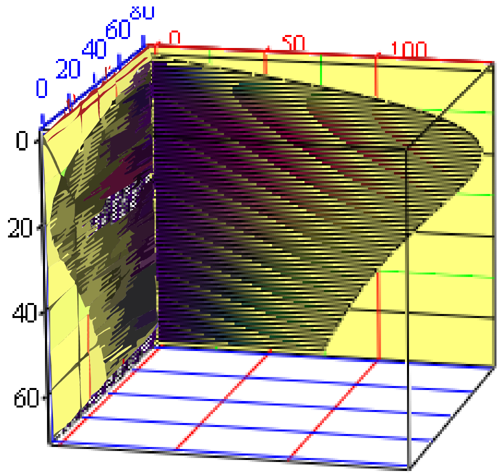
Multi 2D Fan / Motor
Torque Plot Multi Hz



Dual Multi 2D Fan / Motor
Variable Torque Multi Hz



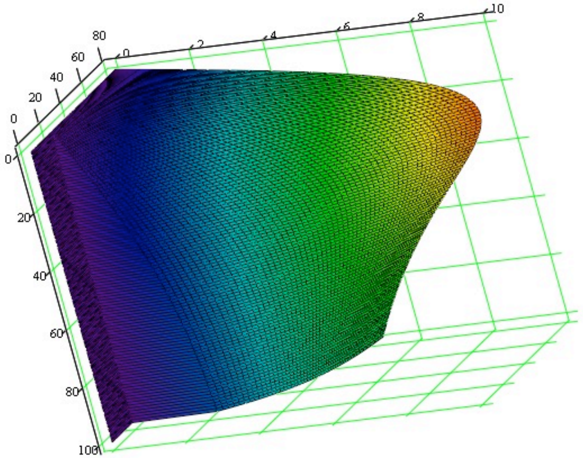
Dual 2D Fan / Motor
Dual Torque slip vs Hz



OPP AC Motor Equation for
Variable Continuous Torque

$$\tau_{s,f} := \frac{R_R \cdot \frac{f}{60}}{\left(\frac{s}{100}\right)\cdot 4\cdot\pi\cdot\frac{f}{p}} \cdot \frac{\left(V_1\cdot\frac{f}{60}\right)^2}{\frac{R_R^{\,2}}{\left(\frac{s}{100}\right)^2} + \left(\frac{f}{60}\cdot X_E\right)^2}$$

OPP FULL 3D Fan / Motor
Torque Control Plot

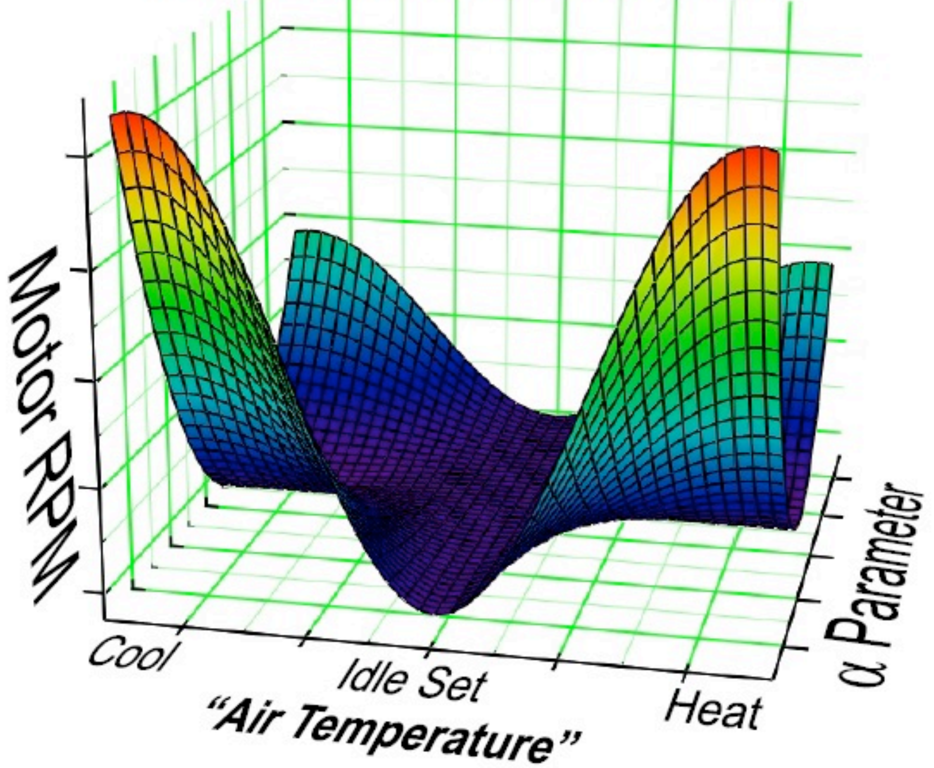


- **2D Torque Options for Fan & Motor Power Control w/ OPP**
- **Map to 3D Torque Control: Commutation & Optimization**

Adaptive Control: The Future of HVAC Systems

Adaptive Controller: Programming Options 3D

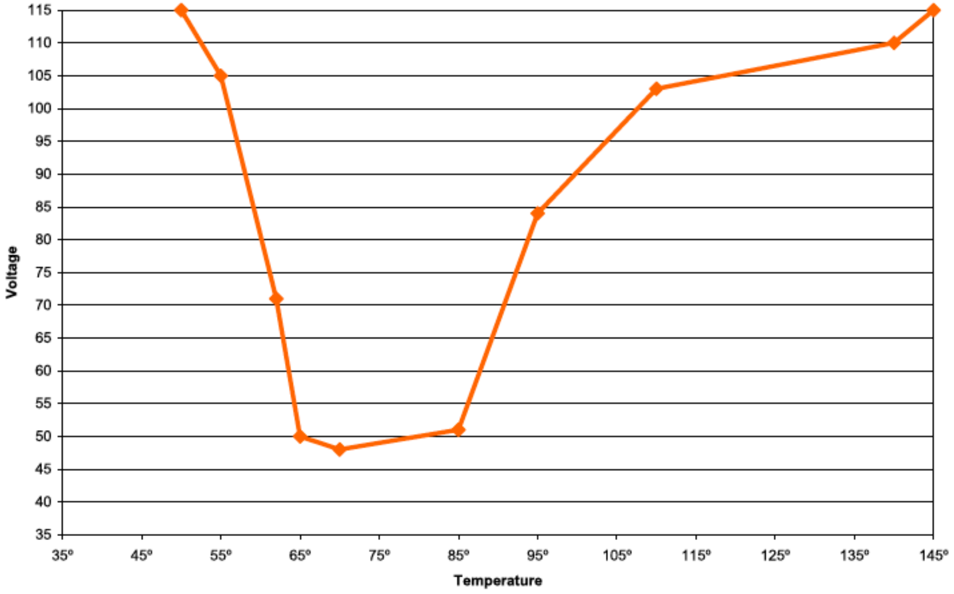
Dual-Temperature Input Example



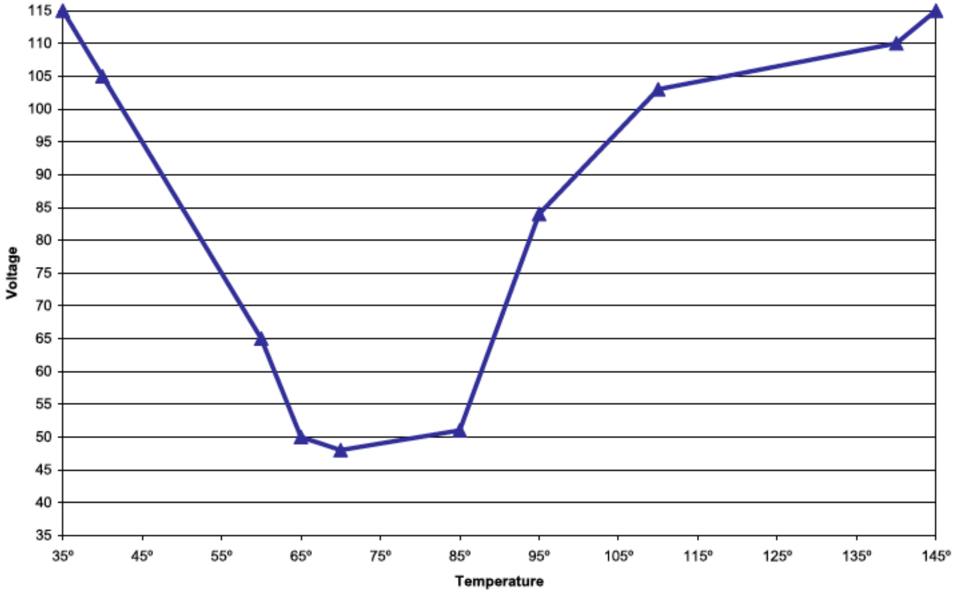
This complex surface represents an example of the 3 dimensional (3d) Optically Programmable (OP) capability of OGD's A1Unit-CU's... As illustrated the Power / RPM output response is /can be a result of multiple concurrent inputs.

In this specific example RPM is shown as a function of Air Temperature (x) along with say Ambient / Outdoor or any "α" Parameter (z).
Any number of 3d surfaces / curves can be mapped / profiled in the above domain for the A1Unit if properly Op'd...

Adaptive Controller: Profiles

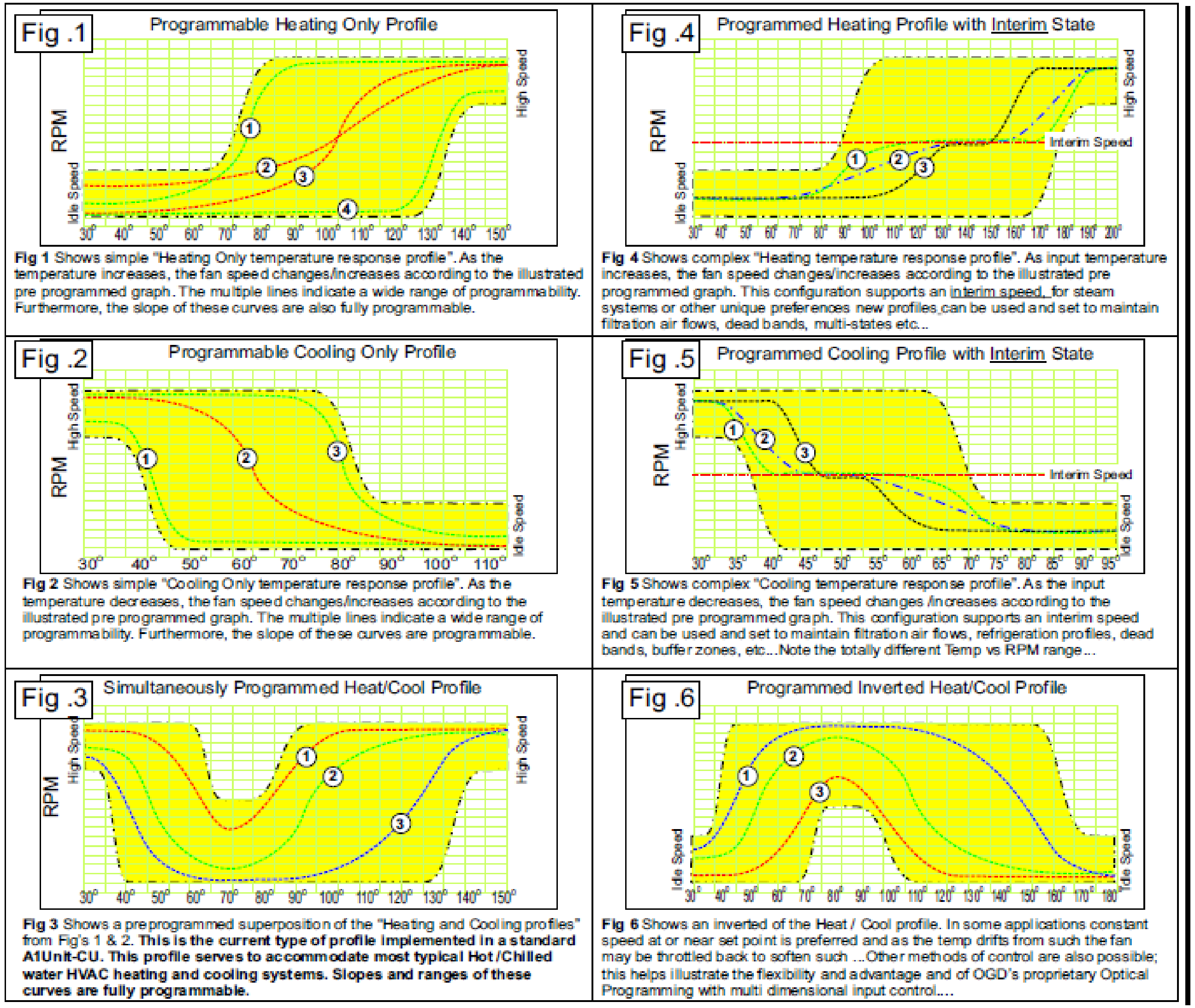


Standard Coil Profile



Cool Profile

Adaptive Controller: Temp Profile Programming Options 2D



Adaptive Controller

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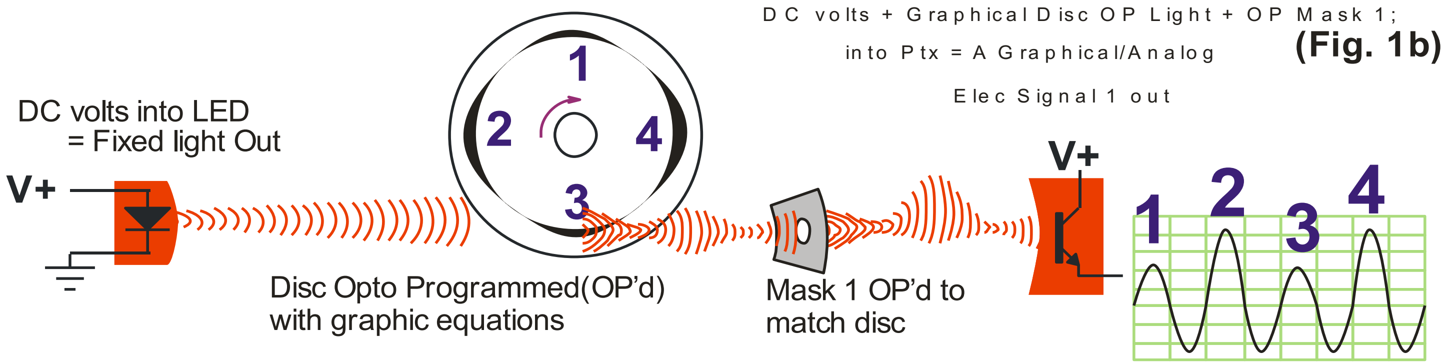
Adaptive Controller: Temp Profile Programming Options 2D

% of "Line" RPM/CFM	PTAC Cooling Temperature	PTAC Heating Temperature	Hot Air Furnace Temperature	Refrigeration Temperature	Freezer Temperature	Hot Water/ Steam	*Other items/ Programmable Parameters*
105%	35°	120°	140°	20°	0°	200°	*HUMIDITY*
95%	40°	?	?	?	?	?	*PRESSURE*
90%	45°						*SPEED*
85%	50°						*CO2*
75%	55°						*O2*
40%	60°						*0-10v*
25%	65°	?	?	?	?	?	*4-20mA*
0-20%	*"Ambient"* 72°	72°	72°	38°	10°	72°	

Current Programming Options

Adaptive Control: The Future of HVAC Systems

Basic Photonic (OPP) Programming



Not just Hz; 1, 2, 3, 4 = OP's

Three Basic Encoder Components:

1. Emitter – Input: Converts DC volts to light waves
2. Detector – Output: Converts light to electricity
3. Shutter – I/O*: Rotating disk *alters fixed light into "Wave Data"*

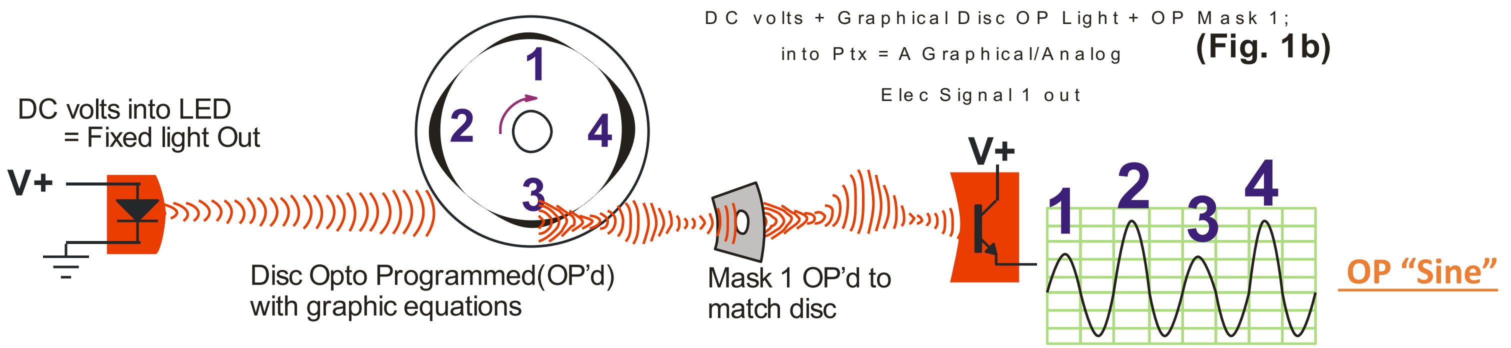
The three elements become a Opto (Photonic) Program:

- Disk Now becomes a Light Wave (LW) Opto Program (OP1)
- Mask also becomes complementary (LW) Opto Program (OP2)

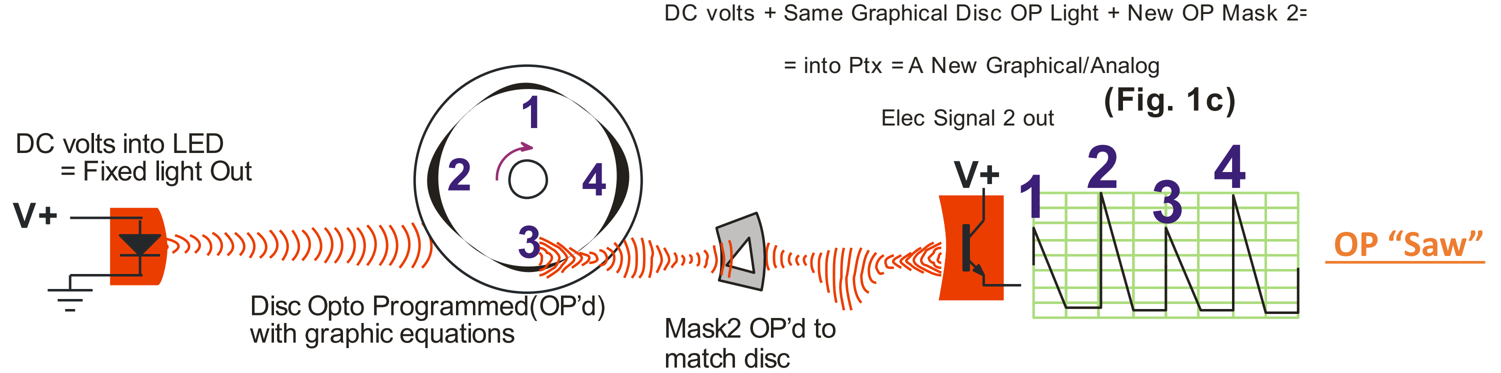
In addition to Feed Back of "What Happened" now can: Create, Instruct, Control …. "Opto Program"
***"Feed forward* ----> What should happen"**

Basic Photonic Programming

Basic way to change the output electric signal is to change the "Fixed OP2-Mask" vector / graphic Program:



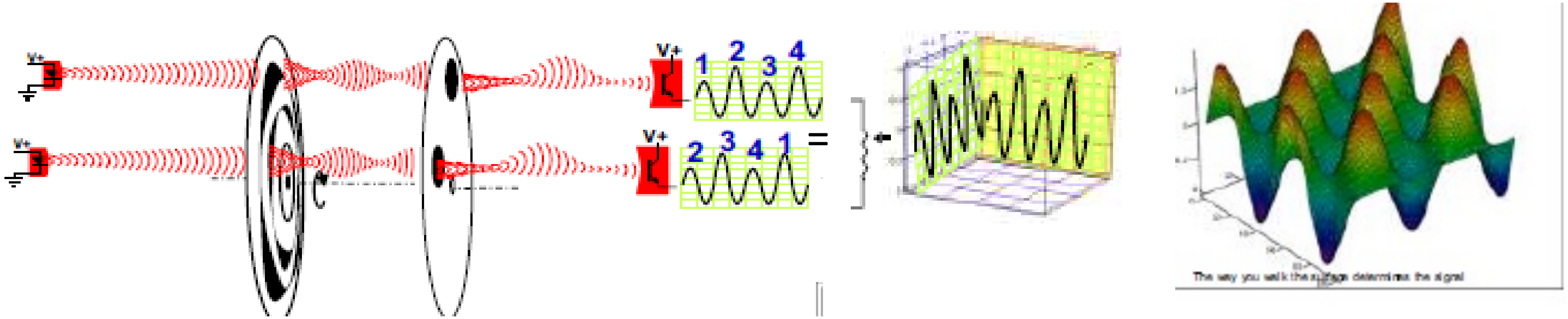
All other OPP elements are kept the same but just changing the "Mask" changes the light wave which completely changes the computed output!



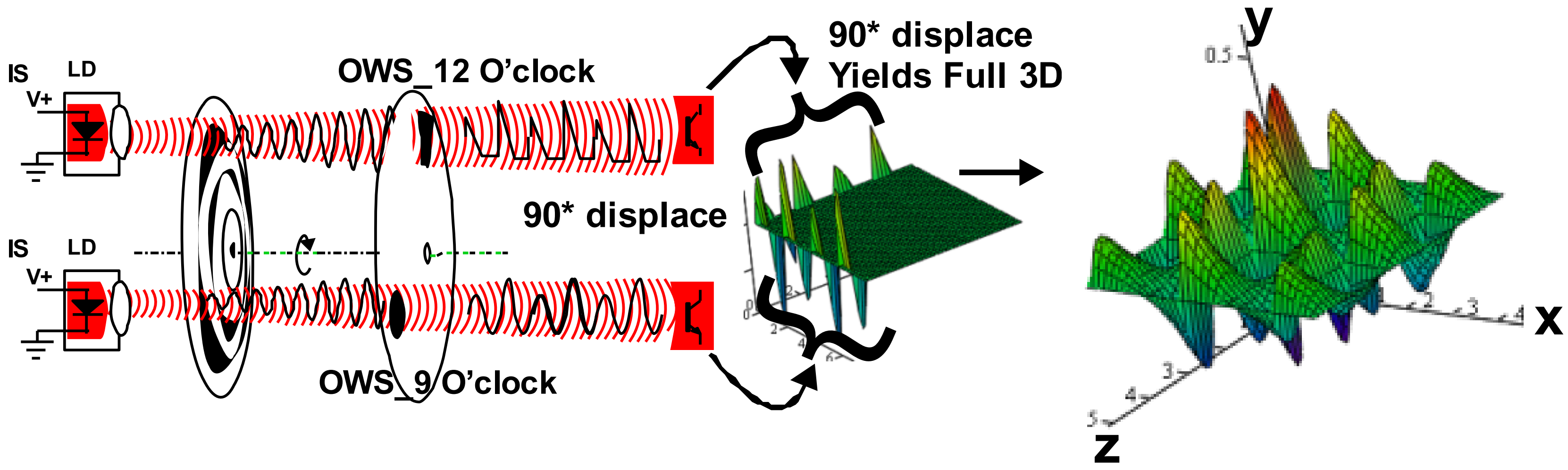
Same Input and Disk but new Analog Computing Path

Basic Photonic Programming

Two identical OPP paths at 90* create Sine and Cosine 2D vectors that map a 3D Function:



Two OPP paths at a physical angular displacement using the same disk are signal and vector phased linked such that they form a linked coordinate space = 3D Surface



Parallel 2D Vectors create 3D Photonic Computing and Control

Summary

<u>Patented Photonic Operation provides:</u>

Electronic Commutation: of AC Induction Motors (AC-ECM+)

Power Performance: Smart "Adaptive Approach"

Uses: Analog *Control Methods*

Enables: Direct Analog Power-Commutation!

Optimized and Enhanced Machines, Units, Systems with Power Operations

No: AC to DC to AC Power Switching

No: Harmonics, EMI, Poor Power Factor, Filters, Chokes, Heat Sinks, etc.

Adaptive Control: Animation and Test Results

https://www.youtube.com/watch?v=HrPloLC_0L4

Video: Introduction to ACC (Animation).

Test Results when Integrated with:

- Unit Ventilators.
- Fan Coils.
- Variable Air Volume Units.

Adaptive Control: Intro to Comfort Pulse (CA Model)

https://youtu.be/7cAHa__2Rog

Adaptive Control: The Future of HVAC Systems

<u>Contacts</u>

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