



Trane TR1 Series VFD

# Competitive Comparison White Paper

*Trane's Best Opportunity to Dominate VFD  
Sales for the HVAC Industry*



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# Competitive Comparisons

## ABB ACH 400 vs. Trane TR1 Series VFD

### ABB Company Background

ABB is a Swiss Finnish conglomerate concentrating in power and automation. They have design and manufacturing facilities in many countries. Total employment is about 146,000. AC drives are designed and manufactured in both Finland and New Berlin, Wisconsin. ABB has the largest market share of AC drives for HVAC applications in North America. Low pricing and broad market coverage are among their strengths.

Company Web Site: <http://www.abb.com/>

### Product



The ACH 400 Series is the variable torque/HVAC version of their ACS 400 Series industrial drive. In ratings through 400 HP @ 460 V (100 HP @ 208 V), ABB offers a unique “electronic bypass” that replaces the control transformer with a regulated DC power supply to control the contactors with DC rather than AC power. Traditional bypasses can also be supplied, but they are normally built by a non-factory panel shop. Electronic bypass only allows two-contactor bypass. To meet three-contactor bypass specifications, ABB must supply a manually operated drive disconnect switch in conjunction with the two-contactor electronic bypass. Two-contactor bypass drives of 50 HP @ 460 V and below (40 HP @ 208 V) are supplied in a very tall and narrow configuration. Two-contactor plus drive disconnect VFDs are supplied in a side-by-side configuration that is still relatively tall. Larger drives are supplied in a box-in-a box configuration. A smaller enclosure that mounts below the drive to house a disconnect switch is also available. Drive only configurations of 50 HP @ 460 V and 40 HP @ 208 and below require an add-on box, supplied, to meet NEMA 1.

### ABB Drive Features

The ACH 400 Series is fairly easy to program and operate. An HVAC macro sets up most parameters for HVAC use. A DC link reactor is standard. Space is required on both sides of the drive for ventilation. The only standard serial communication is Modbus.

### ABB Bypass Features

The electronic bypass has some good features including the ability to operate reliably down to 65% of rated voltage. Common run/stop is standard. Selectable auto/manual bypass is standard. A power flow schematic with LEDs shows present status.

## **Harmonics and Motor Stress**

The 38% measured Total Harmonic Distortion (THD) slightly exceeds the Trane TR1 Series VFD without line reactor. The approximate 1,500 peak volts measured far exceeds the level of MG1-Part 30, suggesting the need for inverter duty motors.

## **Trane TR1 Series VFD Selling Strategy**

Write and hold the specification for three-contactor bypass. This forces ABB into their traditional non-electronic bypass. Even a specification for two-contactor bypass and drive disconnect forces them into the more complex, three-box design shown here.

- The ACH is an industrial drive with an HVAC keypad.
- It does not offer a switching frequency that adjusts to load (ASFM) for quietest operation.
- It does not offer auto voltage reduction with load (AEO) for greatest efficiency.
- It does not offer automatic motor adaptation (AMA).
- It does not have a temperature controlled cooling fan for lowest drive noise and longest fan life.
- It does not have a two-zone PID to receive inputs from two separate signal sources.
- It does not have plenum rating for installation flexibility.
- The peak voltage to the motor is twice that of either TR1 Series VFD, suggesting that the ACH 400 will stress motor insulation.

## Detailed Competitive Analysis

Feature Voltage/Power Range	ABB ACH400 DC Link	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Vertical Configuration DC Link
Typical motor HP (208-240V, 1 phase input)	Not available	Not available	Not available
Typical motor HP (208-240V, 3 phase)	3 to 100 HP	1.5 to 60 HP	1.5 to 30 HP
Typical motor HP (380-460V)	3 to 400 HP	1.5 to 600 HP	1.5 to 60 HP
Typical motor HP 600V	Not available, use ACS600	1.5 to 300 HP	1.5 to 75 HP
Unit tested	3 HP 460 volt	3 HP 460 volt	3 HP 460 volt
<b>Drive Control Terminals</b>			
Number of Digital Inputs	5	8	8
Power Supply for Digital Inputs	24 V DC, 250 mA	24 V DC; 200 mA	24 V DC; 200 mA
Number of analog inputs	2	3	3
Number of Analog Voltage Inputs	2, selectable voltage or current	2	2
Number of Analog Current Inputs	2, shared with above	1	1
Power Supply for Analog Inputs	10 V DC; 10 mA	10 V DC; 17 mA	10 V DC; 17 mA
Number of Analog/Digital Outputs	1	2	2
Number of relay outputs	2 Form C; 1, 12-250 VAC, 10mA; 1, 0 to 30 VDC, 2 A	2; 1 Form A 30 V AC, 1A; 1 Form C 240 V AC, 2 A	2; 1 Form A 30 V AC, 1A; 1 Form C 240 V AC, 2 A
Additional relays	Not available	1 or 4 Form C	1 or 4 Form C
Control terminals removable	No	Yes	Yes
<b>Drive Functions</b>			
Max. ambient operating temp w/o derate	40°C w/o derate; 50°C w/ 10% derate	40°C NEMA 1	40°C NEMA 1
Switching frequency (carrier)	4, 8, 16 kHz	3 to 10 kHz <15 HP; 3 to 14 kHz 15 - 75 HP; 3 to 4.5 kHz >75 HP	3 to 10 kHz <15 HP; 3 to 14 kHz 15 - 75 HP; 3 to 4.5 kHz >75 HP
Automatic Switching Frequency Modulation	No	Yes	Yes
Overload capability	10%	10% for 60 sec	10% for 60 sec
Flying start	Yes	Yes, bi-directional	Yes, bi-directional
Switching on the output		Unlimited	Unlimited
Switching on the input		1x/min	1x/min
DC Link Reactor	Std 3%	Std 3%	Std 3%
Automatic Energy Optimization	No	Yes	Yes
Accel/decel time	0.1 sec to 1800 sec	to 3600 sec	to 3600 sec
Cooling fan control	No	Yes	Yes
Alternative ramp types (S-ramps)	Fast/Med/Slow (S-curves) and linear	None	None
Number of torque characteristics	2; linear and square	2	2
Automatic Motor Measurements	No	Yes, AMA	Yes, AMA
Resonance damping	Yes	Yes	Yes
Max. current limit	110% for 60 sec	110%	110%

Feature Voltage/Power Range	ABB ACH400 DC Link	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Vertical Configuration DC Link
<b>Drive Functions (cont.)</b>			
Band width for frequency bypass	2 bands; select high and low Hz; 1 Hz increments	4 bands, 0.0 to max. each	4 bands, 0.0 to max. each
Process control (PID)	One loop; choose one of two signals	Yes	Yes
PID anti wind-up function	No	Yes	Yes
Number of feedback signals accessible	1	2	2
Sleep mode	Yes	Yes	Yes
Run permissive	Yes	Yes	Yes
Fire mode – Drive	Yes, ignore keypad and BAS; and/or shift to bypass	No	No
<b>Drive Programming Functions</b>			
Quick menu	No	Yes	Yes
Display languages	12	9	9
Feedback square root extractor	No	Yes	Yes
Copy and transfer of individual drive parameters via keypad	Yes	Yes	Yes
Copy of data sets (within the drive)	Yes; 1 set	Yes	Yes
Fault reset attempts	0 to 5	Manual to infinite	Manual to infinite
<b>Drive Keypad</b>			
HOA key on Drive	Yes	Yes	Yes
Local remote key	No	Yes	Yes
Reverse key (indicates non-HVAC drive)	No	No	No
Number of lines of display	3	4	4
Possible number of process parameters display simultaneously	4	4	4
Alpha-numeric control panel	Yes	Yes	Yes
Keypad removable during operation	Yes NEMA 1 drive No as part of bypass package	Yes	Yes
Ease of drive use	Fair	Very easy	Very Easy
<b>Output Performance — 460 V</b>			
<b>16' Motor Leads</b>			
Turn On Peak Voltage	1540	760	720
NEMA Rise Time ( $\mu$ s) — 10%-90% DC	0.036	0.338	0.28
<b>96' Motor Leads</b>			
Turn On Peak Voltage	1480	860	800
<b>100% load</b>			
RMS current	3.93	3.81	3.81
<b>85% load</b>			
RMS current	3.36	3.33	3.21
<b>Output Performance — 460 V (cont.)</b>			
<b>67% load</b>			



Feature Voltage/Power Range	ABB ACH400 DC Link	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Vertical Configuration DC Link
RMS current	2.66	2.67	2.63
<b>Input Performance — 460 V</b>			
100% load			
- Stiff line			
RMS current	3.79	3.61	3.94
THD(I) — % of RMS	38.1%	33.6%	37.8%
- Soft line			
RMS current	3.4	3.45	4.09
THD(I) — % of RMS	34.1%	32.3%	35.5%
<b>Serial Bus Protocols</b>			
Johnson Control Metasys N2	Optional	Standard	Standard
Siemens Apogee FLN	Optional	Standard	Standard
Modbus RTU	Standard	Optional	Optional
LonWorks	Optional	Optional	Optional
BACnet	Not available	Optional	Optional
<b>PC Software</b>			
Windows Base PC Software	Yes	Yes	Yes
<b>Option Panel Features (3-contactor bypass)</b>			
Size of panel (w/o operators devices)	34"H x 15½"W x 9"D	30½"H x 25"W x 8½"D	39½"H x 9½"W x 8½"D
Layout of drive/panel	Side-by-side	Side-by-side	Drive-over-panel
Clearances, with bypass	2" each side	4" top; 0" sides; 0" bottom	4" top; 0" sides; 4" bottom
Mounting Area with Clearances - 3HP w/bypass	19½"W	25"W	9½"W
Weight of drive panel as tested	55 lbs	87 lbs	48 lbs
Drive fuses	Yes	Yes	Yes
Main fuses	No	No	No
Main circuit breaker	No	No	No
Control transformer primary fuse	Does not use cont trans	Yes	Yes
Control transformer secondary fuse	DC power supply	No	No
Under/over voltage protection	-35%	No under voltage relay	No under voltage relay
Fire mode in bypass	Yes Overrides motor overload	No	No
Communications in bypass	Yes	None	None
Conduit entry	Bottom	Top, side and bottom	Bottom
Ventilation openings - drive	Top and bottom	Top and bottom	Top and bottom
Ventilation openings - panel	Sides and top	None	Top and bottom
Panel switches	Drive, Bypass, Reset, Auto, Off, Hand	Drive/Off/Line/Test	Drive/Off/Line/Test
Panel lights	Ready, Enable, Automatic Transfer, Auto/Hand selection, Reset, Hand	Bypass On	Bypass On
Plenum rating -- drive and panel	No	Yes	Yes
Panel power flow schematic	Yes	None	None
<b>Option Panel Features (3-contactor bypass) (cont.)</b>			

Feature Voltage/Power Range	ABB ACH400 DC Link	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Vertical Configuration DC Link
Country of origin - drive	None "Made in Finland" label covered by another	Assembled in USA	Assembled in USA
Country of origin - panel	"Assembled in USA"	No statement	No statement
<b>Interrupt Rating Info</b>			
Power Interrupting Device	Main disconnect switch and drive disconnect switch	Disconnect switch	Disconnect switch
UL Panel Label	Panel shop "Enclosed Industrial Control Panel"	Panel shop "Enclosed Industrial Control Panel"	Panel shop "Enclosed Industrial Control Panel"
Panel Rating	No statement	No statement	No statement

## AC Tech MCH vs. Trane TR1 Series VFD

### AC Tech Company Background

AC Tech is a US company owned by Lenze of Hamlin, Germany. The MCH series of drives was designed by and is assembled by AC Tech in its facility in Uxbridge, Massachusetts. Employment in Uxbridge is about 170. AC Tech manufactures AC drives for many different industries. It manufactures drives for use on all of the world's voltages, and specializes in 600 volt drives for use in Canada. AC Tech has its largest HVAC market share in Canada.

Company Web Site: <http://actechdrives.com/>

### Product

The MCH is the variable torque version of their MC series of drives. The MCH is available in ratings through 250 HP @ 460 and 600 volts (75 HP @ 208 volts). AC Tech pioneered the use of intelligent power modules (IPMs) that incorporate many of the control and protection functions directly into the output transistors. This provides a simple and inexpensive drive. This simplicity is carried forward into all aspects of the MCH series. Both the drive and bypass are straightforward in their construction and operation. The drive's keypad has large, easy to operate buttons, and the functions are intuitive. In part this is because of the limited programming capability of the drive. There are only 84 parameters in total, and they are accessed sequentially. All models with bypass through 250 HP are vertical with the drive over the option enclosure. The control terminals are brought into the option enclosure eliminating the need for the customer to access the drive enclosure. Although a vertical configuration usually allows safe access to the drive when running in bypass, this is not the case with the MCH. The drive does not include any form of input reactor, and an external AC line reactor is highly recommended by AC Tech.



### AC Tech MCH Drive Features

Easy to set-up, easy to operate, and inexpensive are the main features of the AC Tech MCH. Space is required on both sides of the option panel for ventilation. A 24 V DC power supply for powering digital inputs, standard on most drives, is optional on the AC Tech. Only one digital input, one relay output and two digital outputs are provided.

### AC Tech Bypass Features

Simple rocker switches make selection of Hand/Off/Auto, Drive/Bypass/ Off/Test and On/Off/Drive Reset easy, and lights indicate the present function. With all control terminals located in the bypass panel, wiring is easy.

## **Trane TR1 Series VFD Selling Strategy**

The AC Tech is too basic for most applications. In addition, energy savings and HVAC specific features are totally lacking.

- It does not include, but effectively requires, an input line reactor.
- It does not offer a switching frequency that adjusts to load (ASF<sub>M</sub>). At carrier frequencies that do not require a de-rate, our 600 volt sample's motor is very noisy.
- It does not offer voltage reduction with load (AEO) for greatest efficiency. It only offers one variable torque curve.
- It does not offer automatic motor adaptation (AMA).
- It does not have a 24 V power supply to power its one digital input.
- It has a limited number of inputs and outputs.
- Only Modbus (standard) and Siemens FLN (optional) communications are known to be available.

## Detailed Competitive Analysis

Feature Voltage/Power Range	AC Tech MCH AC Line	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Vertical Configuration DC Link
Typical motor HP (208-240V, 1 phase input)	Not available	Not available	Not available
Typical motor HP (208-240V, 3 phase)	1 to 75 HP	1.5 to 60 HP	1.5 to 30 HP
Typical motor HP (380-460V)	1 to 250 HP	1.5 to 600 HP	1.5 to 60 HP
Typical motor HP 600V	1 to 250 HP	1.5 to 300 HP	1.5 to 75 HP
Unit tested	3 HP 600 volt	3 HP 460 volt	3 HP 460 volt
<b>Drive Control Terminals</b>			
Number of Digital Inputs	1	8	8
Power Supply for Digital Inputs	Opt. w/bypass	24 V DC; 200 mA	24 V DC; 200 mA
Number of analog inputs	2	3	3
Number of Analog Voltage Inputs	1	2	2
Number of Analog Current Inputs	1	1	1
Power Supply for Analog Inputs	10 V DC	10 V DC; 17 mA	10 V DC; 17 mA
Number of Analog/Digital Outputs	2 digital only	2	2
Number of relay outputs	1 Form C max 28 V DC, 120 V AC, 2 A; 2nd opt	2; 1 Form A 30 V AC, 1A; 1 Form C 240 V AC, 2 A	2; 1 Form A 30 V AC, 1A; 1 Form C 240 V AC, 2 A
Additional relays	1	1 or 4 Form C	1 or 4 Form C
Control terminals removable	No	Yes	Yes
<b>Drive Functions</b>			
Max. ambient operating temp w/o derate	40°C	40°C NEMA 1	40°C NEMA 1
Switching frequency (carrier)	2.5 to 14 kHz	3 to 10 kHz <15 HP; 3 to 14 kHz 15 - 75 HP; 3 to 4.5 kHz >75 HP	3 to 10 kHz <15 HP; 3 to 14 kHz 15 - 75 HP; 3 to 4.5 kHz >75 HP
<b>Drive Functions (cont.)</b>			
Automatic Switching Frequency Modulation	No	Yes	Yes
Overload capability	20% for 60 sec	10% for 60 sec	10% for 60 sec
Flying start	Yes	Yes, bi-directional	Yes, bi-directional
Switching on the output	No. "Can cause severe damage."	Unlimited	Unlimited
Switching on the input		1x/min	1x/min
DC Link Reactor	None	Std 3%	Std 3%
Automatic Energy Optimization	No	Yes	Yes
Accel/decel time	0.1 to 3600 sec	to 3600 sec	to 3600 sec
Cooling fan control	No	Yes	Yes
Alternative ramp types (S-ramps)	No	None	None
Number of torque characteristics	Starting Torque Boost	2	2
Automatic Motor Measurements	No	Yes, AMA	Yes, AMA
Resonance damping	No	Yes	Yes
Max. current limit	120% for 60 sec	110%	110%
Auto ramp Up/Down	No	Yes	Yes
Band width for frequency bypass	0.00 to 10.00 Hz	4 bands, 0.0 to max. each	4 bands, 0.0 to max. each

Feature Voltage/Power Range	AC Tech MCH AC Line	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Vertical Configuration DC Link
Process control (PID)	Yes	Yes	Yes
PID anti wind-up function	No	Yes	Yes
Number of feedback signals accessible	2	2	2
Sleep mode	No	Yes	Yes
Run permissive	No	Yes	Yes
Fire mode - Drive	No	No	No
<b>Drive Programming Functions</b>			
Quick menu	No	Yes	Yes
Display languages	1; others optional	9	9
Feedback square root extractor	No	Yes	Yes
Copy and transfer of individual drive parameters via keypad	No	Yes	Yes
Copy of data sets (within the drive)	Yes, 1 set	Yes	Yes
Fault reset attempts	0 Manual only	Manual to infinite	Manual to infinite
<b>Drive Keypad</b>			
HOA key on Drive	Yes	Yes	Yes
Local remote key	No	Yes	Yea
Reverse key (indicates non-HVAC drive)	No	No	No
Number of lines of display	2	4	4
Possible number of process parameters display simultaneously	2	4	4
Alpha-numeric control panel	Yes	Yes	Yes
Keypad removable during operation	No	Yes	Yes
Ease of drive use	No	Very easy	Very Easy
<b>Output Performance — 600 V</b>			
<b>10' Motor Leads</b>			
Turn On Peak Voltage	1350	920	
NEMA Rise Time (µs) — 10%-90% DC	0.076	0.282	
<b>90' Motor Leads</b>			
Turn On Peak Voltage	1730	1080	
NEMA Rise Time (µs) — 10%-90% DC	0.071	0.202	
<b>Serial Bus Protocols</b>			
Johnson Control Metasys N2	Future option	Standard	Standard
Siemens Apogee FLN	Optional	Standard	Standard
Modbus RTU	Standard	Optional	Optional
LonWorks	Future option	Optional	Optional
BACnet	Not available	Optional	Optional
<b>PC Software</b>			
Windows Base PC Software	No	Yes	Yes
<b>Option Panel Features (3-contactor bypass)</b>			
Size of panel (w/o operators devices)	25"H x 12"W x 9"D	30½"H x 25"W x 8½"D	39½"H x 9½"W x 8½"D

Feature Voltage/Power Range	AC Tech MCH AC Line	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Vertical Configuration DC Link
Layout of drive/panel	Drive over panel	Side-by-side	Drive-over-panel
Clearances, with bypass	2" < 5Hp; 4" 5-20 HP; 6" 25-60 HP; 8" 75+	4" top; 0" sides; 0" bottom	4" top; 0" sides; 4" bottom
Mounting Area with Clearances - 3HP w/bypass	16"W	25"W	9½"W
Weight of drive panel as tested	37 lbs	87 lbs	48 lbs
Drive fuses	Yes	Yes	Yes
Main fuses	Yes	No	No
Main circuit breaker	No	No	No
Control transformer primary fuse	Yes	Yes	Yes
Control transformer secondary fuse	No	No	No
Under/over voltage protection	No under voltage relay	No under voltage relay	No under voltage relay
Fire mode in bypass	No	No	No
Communications in bypass	No	None	None
Conduit entry	Top, sides and bottom	Top, side and bottom	Bottom
Ventilation openings - drive	Sides	Top and bottom	Top and bottom
Ventilation openings - panel	Sides	None	Top and bottom
Panel switches	Hand/Off/Auto; Off/Drive, Test/Drive/normal; Off (reset)/Drive normal/Drive Bypass	Drive/Off/Line/Test	Drive/Off/Line/Test
Panel lights	Bypass Mode, Drive Mode, Power, Safety Circuit Fault	Bypass On	Bypass On
Plenum rating -- drive and panel	No	Yes	Yes
Panel power flow schematic	No	None	None
<b>Option Panel Features (3-contactor bypass) (cont.)</b>			
Country of origin - drive	No statement	Assembled in USA	Assembled in USA
Country of origin - panel	No statement	No statement	No statement
<b>Interrupt Rating Info</b>			
Power Interrupting Device	Disconnect switch, bypass fuses, drive fuses	Disconnect switch	Disconnect switch
UL Panel Label	Panel shop "Enclosed Industrial Control Panel"	Panel shop "Enclosed Industrial Control Panel"	Panel shop "Enclosed Industrial Control Panel"
Panel Rating	Suitable for use On a line of not more than 5000A RMS	No statement	No statement

## Cutler Hammer HV 9000 vs. Trane TR1 Series VFD

### Cutler Hammer Company Background

Cutler Hammer is a business unit of Eaton Corporation. Eaton has about 50,000 employees around the world. Cutler Hammer brand labels Vacon drives. Vacon is a relatively new company founded in 1993. It has about 500 employees and is located in Vaasa, Finland. Cutler Hammer markets a broad line of electrical power and control products. Eaton also owns Westinghouse and folded its product lines into the Cutler Hammer unit.

Company Web Site: <http://www.cutler-hammer.eaton.com/>  
<http://www.vacon.com/>

### Product

The HV9000 is a variable torque drive. The HV9000 is available in ratings through 400 HP @ 460 and 600 volts, and through 100 HP @ 208 volts. Cutler Hammer is known for its motor control centers and the design and construction of this product reflects that heritage. Rugged, big, heavy and expensive are the first impressions of this product. The drive is not designed for HVAC, and the keypad gives the user little help in operating the drive, with only Start, Stop, Enter and Reset and directional arrow keys. The option panel for the three-contactor bypass offers only Hand/Off/Auto and Inv/Bypass switches with no indicating lights. The drive is mounted inside the option enclosure with the keypad removed from the drive and permanently mounted in the option enclosure door. Despite having three contactors, no "Test" position is offered. This is possibly because of the inherent danger of servicing box-in-a-box designs with high voltage components all around the drive.



### HV 9000 Drive Features

The HV9000 drive is a modern, compact, full featured industrial drive. It offers a large number of inputs and outputs, and offers most of the features of a high-line drive. Its 10kHz default switching frequency helps assure a quiet motor without derate. It does, however, lack automatic motor tuning. It is not designed for HVAC, and therefore lacks many HVAC features including automatic energy optimization, cooling fan control, run permissive, and has only one PID loop. The drive does offer a provision for fire mode. A parameter set can be uploaded into the drive, but the keypad cannot be used to transfer parameters to other drives as it is fixed in the option enclosure.

### HV 9000 Bypass Features

The three-contactor bypass is very basic. The only functional indication of operation is the switch position. The optional Johnson Controls N2 communication is housed in its own enclosure inside the option enclosure. The wide enclosure requires an additional 1" on each side for ventilation.

### Harmonics and Motor Stress

The 63% measured THD on a stiff line with the optional AC line reactor is nearly double that of the TR1's. The peak voltage with 16' motor leads is within MG1-Part 30 standards, but at 96' is above, suggesting the need for inverter duty motors when long leads are used.



## **Trane TR1 Series VFD Selling Strategy**

- The HV9000 is an industrial drive.
- As well as lacking H/O/A and Local/Remote functions, the HV9000 keypad is not intuitive and does not offer a quick menu.
- The drive lacks AEO, ASFM, and AMA.
- The drive lacks run permissive for damper control.
- The drive is neither a product of Eaton nor Cutler Hammer, but a brand labeled product of Vacon of Finland, a relatively young company.
- All of the HVAC serial communications are optionally available, but apparently as costly adders.
- Only one process parameter can be viewed at a time.
- Harmonic distortion is significantly greater than with the TR1 Series VFD, even when equipped with a 3% input line reactor.
- Peak voltage can exceed NEMA standards for general purpose motors, especially at longer lead lengths.

## Detailed Competitive Analysis

Feature Voltage/Power Range	Cutler Hammer HV9000 (Vacon drive) AC Line	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
Typical motor HP (208-240V, 1 phase input)	to 75	Not available	Not available
Typical motor HP (208-240V, 3 phase)	to 100 HP	1.5 to 60 HP	1.5 to 30 HP
Typical motor HP (380-460V)	to 400 HP	1.5 to 600 HP	1.5 to 60 HP
Typical motor HP 600V	to 400 HP	1.5 to 300 HP	1.5 to 75 HP
Unit tested	3 HP 460 volt	3 HP 460 volt	3 HP 460 volt
<b>Drive</b>			
<b>Control Terminals</b>			
Number of Digital Inputs	6	8	8
Power Supply for Digital Inputs	24 V DC; 100 mA	24 V DC; 200 mA	24 V DC; 200 mA
Number of analog inputs	3	3	3
Number of Analog Voltage Inputs	1	2	2
Number of Analog Current Inputs	2	1	1
Power Supply for Analog Inputs	10 V DC; 16 mA	10 V DC; 17 mA	10 V DC; 17 mA
Number of Analog/Digital Outputs	2 analog, 1 digital	2	2
Number of relay outputs	2 Form C	2; 1 Form A 30 V AC, 1A; 1 Form C 240 V AC, 2 A	2; 1 Form A 30 V AC, 1A; 1 Form C 240 V AC, 2 A
Additional relays	Option; 250 V AC, 2 A	1 or 4 Form C	1 or 4 Form C
Control terminals removable	Yes	Yes	Yes
<b>Drive Functions</b>			
Max. ambient operating temp w/o derate	40°C	40°C NEMA 1	40°C NEMA 1
Switching frequency (carrier)	1 to 16 kHz; default 10	3 to 10 kHz <15 HP; 3 to 14 kHz 15 - 75 HP; 3 to 4.5 kHz >75 HP	3 to 10 kHz <15 HP; 3 to 14 kHz 15 - 75 HP; 3 to 4.5 kHz >75 HP
Automatic Switching Frequency Modulation	No	Yes	Yes
Overload capability	10%	10% for 60 sec	10% for 60 sec
Flying start	Yes	Yes, bi-directional	Yes, bi-directional
Switching on the output		Unlimited	Unlimited
Switching on the input		1x/min	1x/min
DC Link Reactor	None	Std 3%	Std 3%
Automatic Energy Optimization	No	Yes	Yes
Accel/decel time	0.1 to 3000 sec	to 3600 sec	To 3600 sec
Cooling fan control	No	Yes	Yes
Alternative ramp types (S-ramps)	Yes	None	None
Number of torque characteristics	3; linear, squared, programmable	2	2
Automatic Motor Measurements	No	Yes, AMA	Yes, AMA
Resonance damping	No	Yes	Yes
Max. current limit	110% for 60 sec	110%	110%
Auto ramp Up/Down	Yes	Yes	Yes

Feature Voltage/Power Range	Cutler Hammer HV9000 (Vacon drive) AC Line	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
<b>Drive Functions (cont.)</b>			
Band width for frequency bypass	3 bands; select high and low Hz, .1 Hz increments	4 bands, 0.0 to max. each	4 bands, 0.0 to max. each
Process control (PID)	PI one loop	Yes	Yes
PID anti wind-up function	No	Yes	Yes
Number of feedback signals accessible	1	2	2
Sleep mode	Yes	Yes	Yes
Run permissive	No	Yes	Yes
Fire mode - Drive	Yes	No	No
<b>Drive Programming Functions</b>			
Quick menu	No	Yes	Yes
Display languages	7	9	9
Feedback square root extractor	Yes	Yes	Yes
Copy and transfer of individual drive parameters via keypad	No	Yes	Yes
Copy of data sets (within the drive)	Yes, 1 set	Yes	Yes
Fault reset attempts	0 to 10	Manual to infinite	Manual to infinite
<b>Drive Keypad</b>			
HOA key on Drive	No	Yes	Yes
Local remote key	No	Yes	Yes
Reverse key (indicates non-HVAC drive)	No	No	No
Number of lines of display	3	4	4
Possible number of process parameters display simultaneously	1	4	4
Alpha-numeric control panel	Yes	Yes	Yes
Keypad removable during operation	Fixed in option panel door	Yes	Yes
Ease of drive use	Fair	Very easy	Very Easy
<b>Output Performance — 460 V</b>			
<b>16' Motor Leads</b>			
Turn On Peak Voltage	860	760	720
NEMA Rise Time ( $\mu$ s) — 10%-90% DC	0.214	0.338	0.28
<b>96' Motor Leads</b>			
Turn On Peak Voltage	1220	860	800
NEMA Rise Time ( $\mu$ s) — 10%-90% DC	0.142	0.808	0.502
<b>100% load</b>			
RMS current	3.87	3.81	3.81
<b>85% load</b>			
RMS current	3.25	3.33	3.21
<b>67% load</b>			
RMS current	2.68	2.67	2.63

Feature Voltage/Power Range	Cutler Hammer HV9000 (Vacon drive) AC Line	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
<b>Input Performance — 460 V</b>			
100% load			
- Stiff line			
RMS current	4.75	3.61	3.94
THD(I) — % of RMS	62.5%	33.6%	37.8%
- Soft line			
RMS current	3.86	3.45	4.09
<b>Serial Bus Protocols</b>			
Johnson Control Metasys N2	Optional	Standard	Standard
Siemens Apogee FLN	Optional	Standard	Standard
Modbus RTU	Optional	Optional	Optional
LonWorks	Optional	Optional	Optional
BACnet	Not available	Optional	Optional
<b>PC Software</b>			
Windows Base PC Software	Yes	Yes	Yes
<b>Option Panel Features (3-contactor bypass)</b>			
Size of panel (w/o operators devices)	25"H x 19"W x 12"D	30½"H x 25"W x 8½"D	39½"H x 9½"W x 8½"D
Layout of drive/panel	Box-in-a-box	Side-by-side	Drive-over-panel
Clearances, with bypass	4" top; 2" bottom; 1" side	4" top; 0" sides; 0" bottom	4" top; 0" sides; 4" bottom
Mounting Area with Clearances - 3HP w/bypass	21"W	25"W	9½"W
Weight of drive panel as tested	92 lbs	87 lbs	48 lbs
Drive fuses	No	Yes	Yes
Main fuses	No	No	No
Main circuit breaker	Yes	No	No
Control transformer primary fuse	Yes	Yes	Yes
Control transformer secondary fuse	Yes	No	No
Under/over voltage protection	No under voltage relay	No under voltage relay	No under voltage relay
Fire mode in bypass	No	No	No
Communications in bypass	No	None	None
Conduit entry		Top, side and bottom	Bottom
Ventilation openings - drive	NA	Top and bottom	Top and bottom
Ventilation openings - panel	Front/rear at top w/ shield	None	Top and bottom
Panel switches	Hand/Off/Auto, Inv/Bypass	Drive/Off/Line/Test	Drive/Off/Line/Test
Panel lights	None	Bypass On	Bypass On
Plenum rating -- drive and panel	No	Yes	Yes
Panel power flow schematic	No	None	None
Country of origin - drive	Made in Finland	Assembled in USA	Assembled in USA
Country of origin - panel	No statement	No statement	No statement

Feature Voltage/Power Range	Cutler Hammer HV9000 (Vacon drive) AC Line	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
<b>Interrupt Rating Info</b>			
Power Interrupting Device	Circuit breaker	Disconnect switch	Disconnect switch
UL Panel Label	"Listed Power Conversion Equipment"	Panel shop "Enclosed Industrial Control Panel"	Panel shop "Enclosed Industrial Control Panel"
Panel Rating	No rating	No statement	No statement

## Rockwell (Reliance) VTAC9 vs. Trane TR1 Series VFD

### Company Background

Rockwell Automation is headquartered in Milwaukee, WI and consists primarily of the operating companies of Allen Bradley, Reliance Electric and Dodge. The VTAC series of drives were products of Reliance Electric of Cleveland, OH, although it is now branded Rockwell. The VTAC9 is assembled in Sumner, IA and Mequon, WI. Rockwell employs about 23,000 worldwide. Traditionally Allen Bradley and Reliance have sold AC drives through separate sales offices and each has a significant HVAC market share.

Company Web Site: <http://www.reliance.com/>

### Product

The VTAC9 is Rockwell's new HVAC drive. It is available in ratings through 100 HP @ 460 V, and 10 HP @ 208 volts. There are no 600 volt models at the present. Models through 25 HP @ 460 V (10 HP @ 208 V) are vertical as shown. Larger models are side-by-side. The vertical package has a very neat, well-designed appearance, and is very compact. No additional options can be accommodated in this enclosure, however. No DC link reactor is included in drives of 5 HP @ 460 and below (3HP @ 208 V), but an AC line reactor is available in the option enclosure. The power flow schematic and its LED indicators make it very easy to see what mode the control is in at all times. All customer connections are made in the option enclosure.

### Drive Features

The drive offers an adequate number of inputs and outputs and most of the features of a quality drive. It can sense heat sink temperature and automatically reduce carrier frequency to prevent over temperature faults. All drives and motors, when bought together, will be warranted for 36 months. The keypad on one drive can be set up to monitor any drive connected to it through a network. The carrier frequency can be set to 10kHz, but derates over 4kHz. Up to three process parameters can be displayed at one time. The keypad can be remotely mounted, or removed when the drive is in run in Auto. A quick menu is provided. No communication capability is standard. All are



### Bypass Features

The three-contactor bypass is very easy to use and the power flow schematic on the cover is useful. Equipped with the optional AC line reactor, there is no space in the option enclosure for other options. It is plenum rated for both the drive and option panel. The package has common run/stop for drive and bypass, fire mode for drive and bypass, and auto bypass. The panel has as standard a 100,000 AIC rating for direct connection to high capacity lines.

### Harmonics and Motor Stress

The 82% measured THD with a stiff line is over twice as high as the TR1 Series VFD without a line reactor. The VTAC9 drive does not have a DC link reactor, an important omission. The peak voltage at short lead length is low, but exceeds MG1-Part 30 recommendations suggesting the need for inverter duty motors at longer lead lengths.

## Trane TR1 Series VFD Selling Strategy

- Any serial communication requires an optional circuit board installed in the drive. Take advantage of built in-protocols when possible on the TR1 Series VFD.
- It does not offer a switching frequency that adjusts to load (ASFM) or automatic energy optimization (AEO). Leverage these built in TR1 Series VFD capabilities.
- It does not allow parameters to be copied to another drive. Leverage the ability of the TR1 Series VFD to do program upload-download.
- It does not allow space for any additional options in the enclosure including drive fuses. Specify drive fuses, standard on the TR1 Series VFD.
- An optional line reactor must be added to control harmonic distortion to the levels of drives that contain a DC link reactor.

## Detailed Competitive Analysis

Feature Voltage/Power Range	Rockwell VTAC9 (Reliance drive) no reactor	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
Typical motor HP (208-240V, 1 phase input)	Not available	Not available	Not available
Typical motor HP (208-240V, 3 phase)	3 to 10 HP	1.5 to 60 HP	1.5 to 30 HP
Typical motor HP (380-460V)	5 to 100 HP	1.5 to 600 HP	1.5 to 60 HP
Typical motor HP 600V	Not available	1.5 to 300 HP	1.5 to 75 HP
Unit tested	3HP 460 V rated panel; 5 HP rated drive	3 HP 460 volt	3 HP 460 volt
<b>Drive Control Terminals</b>			
Number of Digital Inputs	6	8	8
Power Supply for Digital Inputs	24 V DC; 150 mA	24 V DC; 200 mA	24 V DC; 200 mA
Number of analog inputs	2	3	3
Number of Analog Voltage Inputs	2 , selectable voltage or current	2	2
Number of Analog Current Inputs	2, shared with above	1	1
Power Supply for Analog Inputs	10 V DC	10 V DC; 17 mA	10 V DC; 17 mA
Number of Analog/Digital Outputs	2	2	2
Number of relay outputs	2 Form C	2; 1 Form A 30 V AC, 1A; 1 Form C 240 V AC, 2 A	2; 1 Form A 30 V AC, 1A; 1 Form C 240 V AC, 2 A
Additional relays	NA	1 or 4 Form C	1 or 4 Form C
Control terminals removable	No	Yes	Yes
<b>Drive Functions</b>			
Max. ambient operating temp w/o derate	40°C NEMA 1 and 12, 50°C chassis	40°C NEMA 1	40°C NEMA 1
Switching frequency (carrier)	2 to 10 kHz; 4 kHz default derate over kHz	3 to 10 kHz <15 HP; 3 to 14 kHz 15 - 75 HP; 3 to 4.5 kHz >75 HP	3 to 10 kHz <15 HP; 3 to 14 kHz 15 - 75 HP; 3 to 4.5 kHz >75 HP
Automatic Switching Frequency Modulation	No	Yes	Yes
Overload capability	10% for 60 sec, 50% for 3 sec	10% for 60 sec	10% for 60 sec
Flying start	Yes	Yes, bi-directional	Yes, bi-directional
Switching on the output		Unlimited	Unlimited
Switching on the input		1x/min	1x/min
DC Link Reactor	No; Opt <7½HP	Std 3%	Std 3%
Automatic Energy Optimization	No	Yes	Yes
Accel/decel time	0.1 to 3600 sec	to 3600 sec	to 3600 sec
Cooling fan control	No	Yes	Yes
Alternative ramp types (S-ramps)	Infinite User enters values	None	None
Number of torque characteristics	2	2	2
Automatic Motor Measurements	Yes, stator resistance and flux current	Yes, AMA	Yes, AMA
Resonance damping	No	Yes	Yes
Max. current limit	110% for 60 sec	110%	110%
Auto ramp Up/Down	Yes	Yes	Yes



Feature Voltage/Power Range	Rockwell VTAC9 (Reliance drive) no reactor	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
<b>Drive Functions (cont.)</b>			
Band width for frequency bypass	3 bands; 0.1 Hz increments	4 bands, 0.0 to max. each	4 bands, 0.0 to max. each
Process control (PID)	PI 1 loop	Yes	Yes
PID anti wind-up function	Yes	Yes	Yes
Number of feedback signals accessible	1	2	2
Sleep mode	Yes	Yes	Yes
Run permissive	Yes	Yes	Yes
Fire mode - Drive	Yes -- set purge speed	No	No
<b>Drive Programming Functions</b>			
Quick menu	Yes	Yes	Yes
Display languages	6	9	9
Feedback square root extractor	Yes	Yes	Yes
Copy and transfer of individual drive parameters via keypad	No	Yes	Yes
Copy of data sets (within the drive)	Yes; 3 sets	Yes	Yes
Fault reset attempts	0 to 9	Manual to infinite	Manual to infinite
<b>Drive Keypad</b>			
HOA key on Drive	Yes	Yes	Yes
Local remote key	Yes	Yes	Yes
Reverse key (indicates non-HVAC drive)	No	No	No
Number of lines of display	7	4	4
Possible number of process parameters display simultaneously	3	4	4
Alpha-numeric control panel	Yes	Yes	Yes
Keypad removable during operation	Yes, if not in hand	Yes	Yes
Ease of drive use	Very easy	Very easy	Very Easy
<b>Output Performance — 460 V</b>			
<b>16' Motor Leads</b>			
Turn On Peak Voltage	740	760	720
NEMA Rise Time ( $\mu$ s) — 10%-90% DC	0.388	0.338	0.28
<b>96' Motor Leads</b>			
Turn On Peak Voltage	1400	860	800
NEMA Rise Time ( $\mu$ s) — 10%-90% DC	0.116	0.808	0.502
<b>100% load</b>			
RMS current	3.87	3.81	3.81
<b>85% load</b>			
RMS ms current	3.32	3.33	3.21
<b>67% load</b>			
RMS current	2.71	2.67	2.63

Feature Voltage/Power Range	Rockwell VTAC9 (Reliance drive) no reactor	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
<b>Input Performance — 460 V</b>			
100% load			
- Stiff line			
RMS current	6.48	3.61	3.94
THD(I) — % of RMS	81.9%	33.6%	37.8%
- Soft line			
RMS current	3.9	3.45	4.09
THD(I) — % of RMS	55.4%	32.3%	35.5%
<b>Serial Bus Protocols</b>			
Johnson Control Metasys N2	Optional	Standard	Standard
Siemens Apogee FLN	Optional	Standard	Standard
Modbus RTU	Optional	Optional	Optional
LonWorks	Optional	Optional	Optional
BACnet	Optional	Optional	Optional
<b>PC Software</b>			
Windows Base PC Software	No	Yes	Yes
<b>Option Panel Features (3-contactor bypass)</b>			
Size of panel (w/o operators devices)	33"H x 8½"W x 9"D	30½"H x 25"W x 8½"D	39½"H x 9½"W x 8½"D
Layout of drive/panel	Drive over panel	Side-by-side	Drive-over-panel
Clearances, with bypass	4" top; 6" bottom; 2" left side, .75" right side	4" top; 0" sides; 0" bottom	4" top; 0" sides; 4" bottom
Mounting Area with Clearances - 3HP w/bypass	11.25"W	25"W	9½"W
Weight of drive panel as tested	36 lbs	87 lbs	48 lbs
Drive fuses	No	Yes	Yes
Main fuses	Yes, as part of disconnect	No	No
Main circuit breaker	No	No	No
Control transformer primary fuse	Yes	Yes	Yes
Control transformer secondary fuse	No	No	No
Under/over voltage protection	No under voltage relay	No under voltage relay	No under voltage relay
Fire mode in bypass	Yes	No	No
Communications in bypass	No	None	None
Conduit entry	Bottom	Top, side and bottom	Bottom
Ventilation openings - drive	Sides, bottom open into panel	Top and bottom	Top and bottom
Ventilation openings - panel	Sides and bottom	None	Top and bottom
Panel switches	Hand/Off/Auto, Drive/Test/Bypass	Drive/Off/Line/Test	Drive/Off/Line/Test
Panel lights	Ready, Interlock open, Running on drive, Purge, Tripped, Running on bypass	Bypass On	Bypass On
Plenum rating -- drive and panel	Yes	Yes	Yes
Panel power flow schematic	Yes, shows Ready, Interlock Open,	None	None

Feature Voltage/Power Range	Rockwell VTAC9 (Reliance drive) no reactor	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
	Running on Drive, Purge, Tripped, Running on Bypass		
Country of origin - drive	"Mfg in USA"	Assembled in USA	Assembled in USA
Country of origin - panel	No statement	No statement	No statement
<b>Interrupt Rating Info</b>			
Power Interrupting Device	Fused disconnect (one piece)	Disconnect switch	Disconnect switch
UL Panel Label	"UL Industrial Control Equipment"	Panel shop "Enclosed Industrial Control Panel"	Panel shop "Enclosed Industrial Control Panel"
Panel Rating	Interrupt rating 100 KA	No statement	No statement



## Saftronics FPC5010S (GP 10 Series) vs. Trane TR1 Series VFD

### Company Background

Saftronics is an independent, relatively small US company located in Fort Myers, FL. Saftronics manufactures AC and DC drives and soft starters. At the beginning of 2003, Saftronics acquired Fincor which is now a subsidiary of Saftronics. Fincor also manufactures AC and DC drives for industrial applications.

Company Web Site: <http://www.saftronics.com/>

### Product

The FPC5010S uses a Saftronics GP10 General Purpose drive. This is actually the GE/Fuji AF300 drive. Historically Saftronics has brand labeled Yaskawa drives for HVAC applications, but this arrangement ended when Yaskawa started to sell drives directly in the US. Saftronics offers the FPC5010S in ratings through 800 HP @ 460 volts (150 HP @ 208 volts). It is not available for 600 volt applications. Models through 150 HP @ 460 volts, (75 HP @ 208 volts) are vertical as shown. Larger units are side-by-side. The smaller vertical units have a neat, clean appearance, but 6" of side clearance from the option enclosure is required. The FPC5010 series of three-contactor bypass panels provides bypass with conventional selector switches. It was not evaluated. The FPC5010S series of three contactor bypass panels is unique. It is designed to transfer the drive to the line when the required speed and load exceeds pre-set levels. They call this "Smart Bypass". This will occur at 90+% of speed. It is said to increase efficiency up to 5% and reduce harmonics when it is transferred to the line. If the transfer point is 95% speed, a fan would only consume 85% to 90% of full speed power on the drive, but would increase to 100% power when transferred. Only if the transfer is made at 98+% is there any savings potential. Harmonics will be less across the line, but almost all the run time will be at lower speeds when the drive is operating. In addition, the input power factor will always be higher when the drive is powering the motor.



### Drive Features

As its name states, the GP10 is a general purpose drive, lacking H/O/A, and Local/Remote. However it compensates for this by transferring these functions to the bypass controller. With the exception of a need for a FWD (or REV) command from the keypad when in HAND, the product is totally run from the bypass panel. The drive is said to run at 50°C, but that requires removing the top cover that gives it a NEMA 1 rating. Serial communications are available in modules that mount between the drive and the keypad. The wiring is external to the drive enclosure. The drive will not run in HAND with the module in place, a fact not documented by the literature.

### Bypass Features

The bypass controller works well. The membrane switches contain LEDs to indicate their status, and the schematic clearly shows operation.

### **Harmonics and Motor Stress**

The measured THD is approximately the same as that of the TR1 Series VFD with both stiff and soft lines. The tested unit contains an optional DC link reactor. The peak voltage measurements are above those of the TR1's, and at or above the limits of MG1-Part 30, suggesting that inverter duty motors would be required for acceptable motor life. The Smart Bypass does not reduce current draw at 100%.

### **Trane TR1 Series VFD Selling Strategy**

The special Smart Bypass makes little sense. It can be overridden, if desired, and that likely is the best suggestion. It is unclear what the repeated shock of drive-to-line and back transfers will do to the contactors, motor and driven equipment. Cost of operation can only increase.

- Expose the flaws of the energy savings and harmonics control.
- The drive does not offer ASFM features
- Serial communications is optional and precludes HAND operation.
- There is no room for any other options in the option enclosure.
- Access to REV on the drive keypad may cause harm.

## Detailed Competitive Analysis

Feature Voltage/Power Range	Safronics FPC5010 S (GE Fuji drive) External DC Link	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
Typical motor HP (208-240V, 1 phase input)	Not available	Not available	Not available
Typical motor HP (208-240V, 3 phase)	.25 to 150 HP	1.5 to 60 HP	1.5 to 30 HP
Typical motor HP (380-460V)	.5 to 800 HP	1.5 to 600 HP	1.5 to 60 HP
Typical motor HP 600V	None	1.5 to 300 HP	1.5 to 75 HP
Unit tested	3 HP 460 volt "Smart Bypass"	3 HP 460 volt	3 HP 460 volt
<b>Drive Control Terminals</b>			
Number of Digital Inputs	9	8	8
Power Supply for Digital Inputs	24 V; 3.2 mA	24 V DC; 200 mA	24 V DC; 200 mA
Number of analog inputs	2	3	3
Number of Analog Voltage Inputs	2 , selectable voltage or current	2	2
Number of Analog Current Inputs	2, shared with above	1	1
Power Supply for Analog Inputs	10 V DC	10 V DC; 17 mA	10 V DC; 17 mA
Number of Analog/Digital Outputs	2	2	2
Number of relay outputs	Drive (1); Bypass (5) Form C 250 V, 10 A	2; 1 Form A 30 V AC, 1A; 1 Form C 240 V AC, 2 A	2; 1 Form A 30 V AC, 1A; 1 Form C 240 V AC, 2 A
Additional relays	NA	1 or 4 Form C	1 or 4 Form C
Control terminals removable	No	Yes	Yes
<b>Drive Functions</b>			
Max. ambient operating temp w/o derate	40°C NEMA 1; 50°C w/ top cover off	40°C NEMA 1	40°C NEMA 1
Switching frequency (carrier)	0.75 to 15 kHz	3 to 10 kHz <15 HP; 3 to 14 kHz 15 - 75 HP; 3 to 4.5 kHz >75 HP	3 to 10 kHz <15 HP; 3 to 14 kHz 15 - 75 HP; 3 to 4.5 kHz >75 HP
Automatic Switching Frequency Modulation	No	Yes	Yes
Overload capability	35%	10% for 60 sec	10% for 60 sec
Flying start	Yes, bi-directional	Yes, bi-directional	Yes, bi-directional
Switching on the output		Unlimited	Unlimited
Switching on the input		1x/min	1x/min
DC Link Reactor	Not in drive	Std 3%	Std 3%
Automatic Energy Optimization	Yes	Yes	Yes
Accel/decel time	0.01 to 3600 sec	to 3600 sec	to 3600 sec
Cooling fan control	Yes	Yes	Yes
Alternative ramp types (S-ramps)	Yes	None	None
Number of torque characteristics	4, linear and square	2	2
Automatic Motor Measurements	Yes	Yes, AMA	Yes, AMA
Resonance damping	No	Yes	Yes
Max. current limit	150% for 60 sec	110%	110%
Auto ramp Up/Down	Yes	Yes	Yes
Band width for frequency bypass	3 bands, 0 to 30 Hz each	4 bands, 0.0 to max. each	4 bands, 0.0 to max. each
Process control (PID)	Yes	Yes	Yes

Feature Voltage/Power Range	Saftronics FPC5010 S (GE Fuji drive) External DC Link	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
<b>Drive Functions (cont.)</b>			
PID anti wind-up function	Yes	Yes	Yes
Number of feedback signals accessible	1	2	2
Sleep mode	No	Yes	Yes
Run permissive	Yes	Yes	Yes
Fire mode - Drive	Bypass fire mode ignores OL	No	No
<b>Drive Programming Functions</b>			
Quick menu	No	Yes	Yes
Display languages	1	9	9
Feedback square root extractor	No	Yes	Yes
Copy and transfer of individual drive parameters via keypad	Yes	Yes	Yes
Copy of data sets (within the drive)	No	Yes	Yes
Fault reset attempts		Manual to infinite	Manual to infinite
<b>Drive Keypad</b>			
HOA key on Drive	NA-control from bypass	Yes	Yes
Local remote key	NA-control from bypass	Yes	Yes
Reverse key (indicates non-HVAC drive)	Yes	No	No
Number of lines of display	3 LCD; 1 LED	4	4
Possible number of process parameters display simultaneously	1	4	4
Alpha-numeric control panel	Yes	Yes	Yes
Keypad removable during operation	Not in Hand	Yes	Yes
Ease of drive use	Good	Very easy	Very Easy
<b>Output Performance — 460 V</b>			
<b>16' Motor Leads</b>			
Turn On Peak Voltage	1000	760	720
NEMA Rise Time ( $\mu$ s) — 10%-90% DC	0.06	0.338	0.28
<b>96' Motor Leads</b>			
Turn On Peak Voltage	1360	860	800
NEMA Rise Time ( $\mu$ s) — 10%-90% DC	0.064	0.808	0.502
<b>100% load</b>			
RMS current	3.96	3.81	3.81
<b>85% load</b>			
RMS current	3.41	3.33	3.21



Feature Voltage/Power Range	Saftronics FPC5010 S (GE Fuji drive) External DC Link	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
67% load			
RMS current	2.75	2.67	2.63
<b>Input Performance — 460 V</b>			
100% load			
- Stiff line			
RMS current	3.59	3.61	3.94
THD(I) — % of RMS	34.6%	33.6%	37.8%
- Soft line			
RMS current	3.51	3.45	4.09
THD(I) — % of RMS	30.7%	32.3%	35.5%
<b>Serial Bus Protocols</b>			
Johnson Control Metasys N2	Optional	Standard	Standard
Siemens Apogee FLN	Optional	Standard	Standard
Modbus RTU	Optional	Optional	Optional
LonWorks	Not available	Optional	Optional
BACnet	Not available	Optional	Optional
<b>PC Software</b>			
Windows Base PC Software	Yes	Yes	Yes
<b>Option Panel Features (3-contactor bypass)</b>			
Size of panel (w/o operators devices)	27"H x 10"W x 11"D	30½"H x 25"W x 8½"D	39½"H x 9½"W x 8½"D
Layout of drive/panel	Drive over panel	Side-by-side	Drive-over-panel
Clearances, with bypass	12" top; 6" side; 0" bottom	4" top; 0" sides; 0" bottom	4" top; 0" sides; 4" bottom
Mounting Area with Clearances - 3HP w/bypass	22"W	25"W	9½"W
Weight of drive panel as tested	56 lbs	87 lbs	48 lbs
Drive fuses	No	Yes	Yes
Main fuses	Yes	No	No
Main circuit breaker	No	No	No
Control transformer primary fuse	Yes	Yes	Yes
Control transformer secondary fuse	Yes	No	No

Feature Voltage/Power Range	Saftronics FPC5010 S (GE Fuji drive) External DC Link	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
<b>Option Panel Features (3-contactor bypass) (cont.)</b>			
Under/over voltage protection	No under voltage relay	No under voltage relay	No under voltage relay
Fire mode in bypass		No	No
Communications in bypass	Yes	None	None
Conduit entry	None	Top, side and bottom	Bottom
Ventilation openings - drive	Sides, bottom open into panel	Top and bottom	Top and bottom
Ventilation openings - panel	Sides	None	Top and bottom
Panel switches	VFD Off/Hand/Auto/Test, Bypass Off/On/Smartdrive Test/Drive, Bypass Speed Up/Down; "Emergency Bypass On/Off" switch inside panel	Drive/Off/Line/Test	Drive/Off/Line/Test
Panel lights	VFD Off, Auto, Test, Hand; Hand Speed Up; Hand Speed Down; Bypass Off, On, Smart Bypass; Alarms -- Motor Overload, Damper Closed, Fire alarm, VFD Fault, Freeze Stat, Reserved	Bypass On	Bypass On
Plenum rating -- drive and panel	No	Yes	Yes
Panel power flow schematic	Yes, shows Main Power, Input Contactor, VFD Output Contactor, Bypass Contactor, Bypass Contactor, Smart Bypass Active	None	None
Country of origin - drive	"Made in Mexico"	Assembled in USA	Assembled in USA
Country of origin - panel	No statement	No statement	No statement
<b>Interrupt Rating Info</b>			
Power Interrupting Device	Disconnect switch and main fuses	Disconnect switch	Disconnect switch
UL Panel Label	Panel shop "Enclosed Industrial Control Panel"	Panel shop "Enclosed Industrial Control Panel"	Panel shop "Enclosed Industrial Control Panel"
Panel Rating	No rating	No statement	No statement

## Siemens SED2 vs. Trane TR1 Series VFD

### Company Background

Siemens is a German-based company, and is the world's largest industrial automation company. Siemens has about 480,000 employees around the world. Drives and motors are a part of Siemens' automation group. Siemens does not presently have a significant share in any US drive market, however they are entering the US HVAC drive market through their automation group.

Company Web Site: <http://www.us.sbt.siemens.com/HVP/Drives/>

### Product

The SED2 was introduced in 2002. It is available in ratings through 125 HP @ 460 and 600 volts (60 HP @ 208 volts). The SED2 is an industrial drive but with a generic keypad and the flexibility to include many HVAC features.



### Drive Features

The SED2 is a modern, compact, full featured general purpose drive. It offers a large number of inputs and outputs and most of the features of a high-line drive. Two keypads are available, the BOP (Basic Operator Panel), and the Advanced Operator Panel (AOP). When ordered for HVAC applications, the BOP is supplied. Navigating, parameter setting and hand operation with the standard keypad is relatively difficult. With the standard BOP keypad, only one meter display can be shown at a time. Parameters cannot be uploaded to/from the drive or from drive to drive. The drive does offer automatic motor tuning, but does not have the HVAC features of automatic switching frequency modulation or automatic energy optimization. It does offer sleep mode, but not run permissive. The drive lacks a DC link reactor.

### Bypass Features

The vertical bypass design, used for all but the very largest sizes, raises the drive up above the bypass enclosure to allow airflow to the drive. All control terminal connections are brought into the bypass enclosure. The bypass enclosure has a key latch. The key cannot be removed in the unlocked position. An input line reactor or output load reactor will fit in the enclosure, but not both. An input line reactor may often be desirable as no DC link reactor is supplied. The bypass panel is basic, consisting of only a Drive Test ON/OFF switch, a DRIVE/OFF/BYPASS switch and a BYPASS ON light. Auto bypass, common run/stop and fire mode (run in bypass regardless of other inputs) are provided as standard. Main fuses are provided.

### Harmonics and Motor Stress

The measured THD with both stiff and soft lines slightly exceeds the levels of the TR1 Series VFD without line reactor. The SED2 tested has an optional line reactor. The approximate 1500 peak volts measured far exceeds the level of MG1-Part 30, suggesting the need for inverter duty motors.

### **Trane TR1 Series VFD Selling Strategy**

Siemens, a huge global company, is a newcomer to AC and HVAC drives in the US. Their experience and number of long-term installations in the US is limited.

- The SED2 is an industrial drive.
- As well as lacking H/O/A and Local Remote on the keypad, the standard keypad is not intuitive and does not offer a quick menu.
- The drive lacks run permissive for damper control.
- Only one process parameter can be viewed at a time, and the number of items is very limited.
- The drive lacks ASFM and AEO.
- The drive has no DC link inductor. The claimed low harmonics are not backed up by our testing.
- Peak voltage to the motor is among the highest tested.

## Detailed Competitive Analysis

Feature Voltage/Power Range	Siemens SED2 AC Line, Small Caps	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
Typical motor HP (208-240V, 1 phase input)	Not available	Not available	Not available
Typical motor HP (208-240V, 3 phase)	.5 to 60 HP	1.5 to 60 HP	1.5 to 30 HP
Typical motor HP (380-460V)	1 to 125 HP	1.5 to 600 HP	1.5 to 60 HP
Typical motor HP 600V	1 to 125 HP	1.5 to 300 HP	1.5 to 75 HP
Unit tested	3 HP 460 volt	3 HP 460 volt	3 HP 460 volt
<b>Drive Control Terminals</b>			
Number of Digital Inputs	6	8	8
Power Supply for Digital Inputs	24 V DC; 50 mA	24 V DC; 200 mA	24 V DC; 200 mA
Number of analog inputs	2	3	3
Number of Analog Voltage Inputs	2 , selectable voltage or current	2	2
Number of Analog Current Inputs	2, shared with above	1	1
Power Supply for Analog Inputs	10 V DC	10 V DC; 17 mA	10 V DC; 17 mA
Number of Analog/Digital Outputs	2	2	2
Number of relay outputs	2 Form C; 30 V DC 5 A; or 240 V DC 2 A	2; 1 Form A 30 V AC, 1A; 1 Form C 240 V AC, 2 A	2; 1 Form A 30 V AC, 1A; 1 Form C 240 V AC, 2 A
Additional relays	NA	1 or 4 Form C	1 or 4 Form C
Control terminals removable	No	Yes	Yes
<b>Drive Functions</b>			
Max. ambient operating temp w/o derate	40°C; derate to 50% at 50°C	40°C NEMA 1	40°C NEMA 1
Switching frequency (carrier)	4kHz to 16kHz, 2kHz increments	3 to 10 kHz <15 HP; 3 to 14 kHz 15 - 75 HP; 3 to 4.5 kHz >75 HP	3 to 10 kHz <15 HP; 3 to 14 kHz 15 - 75 HP; 3 to 4.5 kHz >75 HP
Automatic Switching Frequency Modulation	No	Yes	Yes
Overload capability	10% for 60 sec	10% for 60 sec	10% for 60 sec
Flying start	Yes	Yes, bi-directional	Yes, bi-directional
Switching on the output		Unlimited	Unlimited
Switching on the input		1x/min	1x/min
DC Link Reactor	No	Std 3%	Std 3%
Automatic Energy Optimization	No	Yes	Yes
Accel/decel time	to 650 sec	to 3600 sec	to 3600 sec
Cooling fan control	No	Yes	Yes
Alternative ramp types (S-ramps)	Programmable	None	None
Number of torque characteristics	7	2	2
Automatic Motor Measurements	Yes	Yes, AMA	Yes, AMA
Resonance damping	Yes	Yes	Yes
Max. current limit	110%	110%	110%
Auto ramp Up/Down	Yes	Yes	Yes
Band width for frequency bypass		4 bands, 0.0 to max. each	4 bands, 0.0 to max. each
Process control (PID)	Yes	Yes	Yes

Feature Voltage/Power Range	Siemens SED2 AC Line, Small Caps	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
<b>Drive Functions (cont.)</b>			
PID anti wind-up function	No	Yes	Yes
Number of feedback signals accessible	1	2	2
Sleep mode	Yes	Yes	Yes
Run permissive	No	Yes	Yes
Fire mode - Drive	Switches to bypass	No	No
Ride-through (tested) B4 UV fault indicated			
<b>Drive Programming Functions</b>			
Quick menu	Yes, 13 parameters	Yes	Yes
Display languages	1 (std); 7 (opt)	9	9
Feedback square root extractor	No	Yes	Yes
Copy and transfer of individual drive parameters via keypad	No (std); Yes (opt)	Yes	Yes
Copy of data sets (within the drive)	No (std); Yes, 10 sets (opt)	Yes	Yes
Fault reset attempts	10	Manual to infinite	Manual to infinite
<b>Drive Keypad</b>			
HOA key on Drive	Yes	Yes	Yes
Local remote key	Yes	Yes	Yes
Reverse key (indicates non-HVAC drive)	No	No	No
Number of lines of display	1 (std) 4 (opt)	4	4
Possible number of process parameters display simultaneously	1(std); 5 (opt)	4	4
Alpha-numeric control panel	No (std) Yes (opt)	Yes	Yes
Keypad removable during operation	Yes	Yes	Yes
Ease of drive use	Poor (with std keypad)	Very easy	Very Easy
<b>Output Performance — 460 V</b>			
<b>16' Motor Leads</b>			
Turn On Peak Voltage	1440	760	720
NEMA Rise Time ( $\mu$ s) — 10%-90% DC	0.026	0.338	0.28
<b>96' Motor Leads</b>			
Turn On Peak Voltage	1500	860	800
NEMA Rise Time ( $\mu$ s) — 10%-90% DC	0.036	0.808	0.502
<b>100% load</b>			
RMS current	4.03	3.81	3.81
<b>85% load</b>			
RMS current	3.39	3.33	3.21
<b>67% load</b>			
RMS current	2.74	2.67	2.63
<b>Input Performance — 460 V</b>			

Feature Voltage/Power Range	Siemens SED2 AC Line, Small Caps	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
100% load			
- Stiff line			
RMS current	3.72	3.61	3.94
THD(I) — % of RMS	43.0%	33.6%	37.8%
- Soft line			
RMS current	3.64	3.45	4.09
THD(I) — % of RMS	37.7%	32.3%	35.5%
<b>Serial Bus Protocols</b>			
Johnson Control Metasys N2	Standard	Standard	Standard
Siemens Apogee FLN	Optional	Standard	Standard
Modbus RTU	Optional	Optional	Optional
LonWorks	Optional	Optional	Optional
BACnet	Not available	Optional	Optional
<b>PC Software</b>			
Windows Base PC Software	No	Yes	Yes
<b>Option Panel Features (3-contactor bypass)</b>			
Size of panel (w/o operators devices)	37:H x 12½W x 9"D	30½"H x 25"W x 8½"D	39½"H x 9½"W x 8½"D
Layout of drive/panel	Drive over panel	Side-by-side	Drive-over-panel
Clearances, with bypass	6" top; 4" side (1" beyond panel); 0" bottom	4" top; 0" sides; 0" bottom	4" top; 0" sides; 4" bottom
Mounting Area with Clearances - 3HP w/bypass	14½"W	25"W	9½"W
Weight of drive panel as tested	42 lbs	87 lbs	48 lbs
Drive fuses	No	Yes	Yes
Main fuses	Yes	No	No
Main circuit breaker	No	No	No
Control transformer primary fuse	Yes	Yes	Yes
Control transformer secondary fuse	Yes	No	No
Under/over voltage protection	No under voltage relay	No under voltage relay	No under voltage relay
Fire mode in bypass	Yes	No	No
Communications in bypass	No	None	None
Conduit entry	Top and bottom	Top, side and bottom	Bottom
Ventilation openings - drive	Bottom	Top and bottom	Top and bottom
Ventilation openings - panel	Sides	None	Top and bottom
Panel switches	Drive Test ON/OFF, Drive/Off/Bypass,	Drive/Off/Line/Test	Drive/Off/Line/Test
Panel lights	Bypass ON	Bypass On	Bypass On
Plenum rating -- drive and panel	No	Yes	Yes
Panel power flow schematic	No	None	None

Feature Voltage/Power Range	Siemens SED2 AC Line, Small Caps	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
Country of origin - drive	"Made in EU (United Kingdom)"	Assembled in USA	Assembled in USA
Country of origin - panel	No statement Carton says "Made in USA"	No statement	No statement
<b>Interrupt Rating Info</b>			
Power Interrupting Device	Disconnect switch, main fuses	Disconnect switch	Disconnect switch
UL Panel Label	No panel label, drive has UL Power Conversion Equipment label	Panel shop "Enclosed Industrial Control Panel"	Panel shop "Enclosed Industrial Control Panel"
Panel Rating	No rating	No statement	No statement





## Square D EconoFlex ALTIVAR 58 vs. Trane TR1 Series VFD

### Company Background

Square D is a part of Schneider Electric, a global corporation headquartered in Paris, France. Square D drives are from another Schneider Electric company, Telemecanique, also of France. Telemecanique's AC drives are called ALTIVAR plus a series number, and Square D's HVAC packages are called EconoFlex. The drive used in most EconoFlex packages is the ALTIVAR 58. Square D is a major supplier of electrical distribution, industrial control and automation products. Motor control centers, switches and circuit breakers are among their well known products. Square D has sold AC drives for decades, but has never had a dominant position.

Company Web Site: <http://www.squared.com/>



### Product

The EconoFlex ALTIVAR 58 is available through 100 HP @ 460 V (50 HP @ 208 V). For drives between 125 and 400 HP @ 460 V, the ALTIVAR 66 will be used. The ALTIVAR 66 was not evaluated. 600 volt units are not available in either series.

### Drive Features

The ALTIVAR 58 is an industrial drive. The keypad is not easy to operate nor intuitive, but its FWD/REV key gives away its industrial nature. Compared to most competitors, it is a little short on the number of digital and analog inputs and outputs. Drives under 30 HP do not have a DC link reactor. No serial communication is standard. Parameters cannot be uploaded to the drive, and cannot be transferred to other drives. Automatic motor tuning and "Energy Eco" voltage reduction are offered, but not automatic switching frequency modulation, sleep mode, nor run permissive. Multiple levels of programming lockout are offered. They may have some industrial uses, but only seem to be in the way.

### Bypass Features

The drive used in the Econo-flex is a true chassis. The keypad is remotely mounted in the option enclosure door. It is not removable. The box-in-box design creates a relatively large, massive, sturdy appearing product. This looks like the product of a motor control center manufacturer. The side clearances specified for the enclosure require a relatively large amount of wall space. There are no panel lights to show bypass function.

### Harmonics and Motor Stress

The measured THD is high as expected on a drive with neither a DC link reactor nor an AC line reactor. The peak motor voltage is far above MG1-Part 30 levels, suggesting the need for inverter duty motors for acceptable motor life.

### **Trane TR1 Series VFD Selling Strategy**

Although Square D is an old and respected name in the US, the Telemecanique drive currently used is relatively unknown.

- The drive is not designed for HVAC.
- The bypass panel is very spartan, not even giving an indication that the product is running in bypass. The drive display is also spartan.
- Like all of the box-in-a-box designs, servicing the drive while running in bypass is hazardous because exposed high voltage components surround the drive.
- The lack of input coils in all drives under 30 HP is a concern in many applications.
- Any serial communications, even the popular N2 or FLN will require optional equipment.
- Acceptable harmonics levels will probably require an optional AC line reactor. High peak voltage is harder to control, probably requiring inverter duty motors for acceptable life.

## Detailed Competitive Analysis

Feature Voltage/Power Range	Square D Econo-Flex Altivar 58 (Telemecanique drive) No Reactor	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
Typical motor HP (208-240V, 1 phase input)	Not available	Not available	Not available
Typical motor HP (208-240V, 3 phase)	1 to 50 HP	1.5 to 60 HP	1.5 to 30 HP
Typical motor HP (380-460V)	1 to 100 HP	1.5 to 600 HP	1.5 to 60 HP
Typical motor HP 600V	not available	1.5 to 300 HP	1.5 to 75 HP
Unit tested	3 HP 460 volt	3 HP 460 volt	3 HP 460 volt
<b>Drive Control Terminals</b>			
Number of Digital Inputs	5	8	8
Power Supply for Digital Inputs	24 V DC	24 V DC; 200 mA	24 V DC; 200 mA
Number of analog inputs	3	3	3
Number of Analog Voltage Inputs	1	2	2
Number of Analog Current Inputs	1; 1 programmable	1	1
Power Supply for Analog Inputs	10 V DC, 10 mA	10 V DC; 17 mA	10 V DC; 17 mA
Number of Analog/Digital Outputs	2	2	2
Number of relay outputs	1 Form C, 2 A @ 120 V; 1 Form A, 2 A @ 120 V	2; 1 Form A 30 V AC, 1A; 1 Form C 240 V AC, 2 A	2; 1 Form A 30 V AC, 1A; 1 Form C 240 V AC, 2 A
Additional relays	None	1 or 4 Form C	1 or 4 Form C
Control terminals removable	Yes	Yes	Yes
<b>Drive Functions</b>			
Max. ambient operating temp w/o derate	40°C NEMA 1	40°C NEMA 1	40°C NEMA 1
Switching frequency (carrier)	4, 8, 12, 16 kHz Derate above 8 kHz	3 to 10 kHz <15 HP; 3 to 14 kHz 15 - 75 HP; 3 to 4.5 kHz >75 HP	3 to 10 kHz <15 HP; 3 to 14 kHz 15 - 75 HP; 3 to 4.5 kHz >75 HP
Automatic Switching Frequency Modulation	No	Yes	Yes
Overload capability	10% for 60 sec	10% for 60 sec	10% for 60 sec
Flying start	Yes	Yes, bi-directional	Yes, bi-directional
Switching on the output	No	Unlimited	Unlimited
Switching on the input		1x/min	1x/min
DC Link Reactor	Opt. < 30 HP	Std 3%	Std 3%
Automatic Energy Optimization	Yes "Energy Eco"	Yes	Yes
Accel/decel time	1 to 999 sec	to 3600 sec	to 3600 sec
Cooling fan control	No	Yes	Yes
Alternative ramp types (S-ramps)	Yes, 3	None	None
Number of torque characteristics	None, with "Energy Eco"	2	2
Automatic Motor Measurements	Yes	Yes, AMA	Yes, AMA
Resonance damping		Yes	Yes
Max. current limit	200%	110%	110%
Auto ramp Up/Down	Yes	Yes	Yes
Band width for frequency bypass	5 Hz, fixed	4 bands, 0.0 to max. each	4 bands, 0.0 to max. each

Feature Voltage/Power Range	Square D Econo-Flex Altivar 58 (Telemecanique drive) No Reactor	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
<b>Drive Functions (cont.)</b>			
Process control (PID)	Yes	Yes	Yes
PID anti wind-up function	No	Yes	Yes
Number of feedback signals accessible	2	2	2
Sleep mode	No	Yes	Yes
Run permissive	No	Yes	Yes
Fire mode - Drive	Yes (smoke purge)	No	No
Ride-through (tested) B4 UV fault indicated			
<b>Drive Programming Functions</b>			
Quick menu	No	Yes	Yes
Display languages	5	9	9
Feedback square root extractor	No	Yes	Yes
Copy and transfer of individual drive parameters via keypad	No	Yes	Yes
Copy of data sets (within the drive)	No	Yes	Yes
Fault reset attempts	1	Manual to infinite	Manual to infinite
<b>Drive Keypad</b>			
HOA key on Drive	No	Yes	Yes
Local remote key	No	Yes	Yes
Reverse key (indicates non-HVAC drive)	Yes	No	No
Number of lines of display	3	4	4
Possible number of process parameters display simultaneously	1	4	4
Alpha-numeric control panel	Yes	Yes	Yes
Keypad removable during operation	Fixed in option panel door	Yes	Yes
Ease of drive use	Fair	Very easy	Very Easy
<b>Output Performance — 460 V</b>			
<b>16' Motor Leads</b>			
Turn On Peak Voltage	1360	760	720
NEMA Rise Time ( $\mu$ s) — 10%-90% DC	0.046	0.338	0.28
<b>96' Motor Leads</b>			
Turn On Peak Voltage	1420	860	800
NEMA Rise Time ( $\mu$ s) — 10%-90% DC	0.058	0.808	0.502
<b>100% load</b>			
RMS current	4	3.81	3.81
<b>85% load</b>			
RMS current	3.34	3.33	3.21
<b>67% load</b>			
RMS current	2.67	2.67	2.63

Feature Voltage/Power Range	Square D Econo-Flex Altivar 58 (Telemecanique drive) No Reactor	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
<b>Input Performance — 460 V</b>			
100% load			
- Stiff line			
RMS current	6.5	3.61	3.94
THD(I) — % of RMS	82.7%	33.6%	37.8%
- Soft line			
RMS current	4.12	3.45	4.09
THD(I) — % of RMS	56.6%	32.3%	35.5%
<b>Serial Bus Protocols</b>			
Johnson Control Metasys N2	Optional	Standard	Standard
Siemens Apogee FLN	Not available	Standard	Standard
Modbus RTU	Optional	Optional	Optional
LonWorks	Optional, thru Modbus	Optional	Optional
BACnet	Not available	Optional	Optional
<b>PC Software</b>			
Windows Base PC Software		Yes	Yes
<b>Option Panel Features (3-contactor bypass)</b>			
Size of panel (w/o operators devices)	32"H x 14"W x 12"D	30½"H x 25"W x 8½"D	39½"H x 9½"W x 8½"D
Layout of drive/panel	Box-in-a-box with chassis drive	Side-by-side	Drive-over-panel
Clearances, with bypass	6" top, 6" bottom, 3" sides	4" top; 0" sides; 0" bottom	4" top; 0" sides; 4" bottom
Mounting Area with Clearances - 3HP w/bypass	20"W	25"W	9½"W
Weight of drive panel as tested	79 lbs	87 lbs	48 lbs
Drive fuses	No	Yes	Yes
Main fuses	No	No	No
Main circuit breaker	Yes	No	No
Control transformer primary fuse	Yes	Yes	Yes
Control transformer secondary fuse	Yes	No	No
Under/over voltage protection	No under voltage relay	No under voltage relay	No under voltage relay
Fire mode in bypass	Yes	No	No
Communications in bypass	No	None	None
Conduit entry	Top and bottom	Top, side and bottom	Bottom
Ventilation openings - drive	Chassis	Top and bottom	Top and bottom
Ventilation openings - panel	Sides and bottom	None	Top and bottom
Panel switches	Test/Normal switch, AFC/Off/Bypass switch	Drive/Off/Line/Test	Drive/Off/Line/Test
Panel lights	None	Bypass On	Bypass On

Feature Voltage/Power Range	Square D Econo-Flex Altivar 58 (Telemecanique drive) No Reactor	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
Plenum rating -- drive and panel	No	Yes	Yes
Panel power flow schematic	None	None	None
Country of origin - drive	No statement	Assembled in USA	Assembled in USA
Country of origin - panel	"Made in USA"	No statement	No statement
<b>Interrupt Rating Info</b>			
Power Interrupting Device	Circuit breaker; 100,000 VA interrupt rating on CB	Disconnect switch	Disconnect switch
UL Panel Label	"UL Industrial Control Equipment" label on drive and same label on panel	Panel shop "Enclosed Industrial Control Panel"	Panel shop "Enclosed Industrial Control Panel"
Panel Rating	5KA short circuit rating, 10 and 22 K AIC opt.	No statement	No statement





## Toshiba E-3 vs. Trane TR1 Series VFD

### Company Background

Toshiba is a Tokyo, Japan based corporation that manufactures various high technology products. Its North American activities are handled by Toshiba America Incorporated, with 10,000 employees in North America. Toshiba's drive and motor products for North America are headquartered in Toshiba's Houston, TX facility.

Company Web Site: <http://www.tic.toshiba.com/>

### Product

The Toshiba E-3 is available through 125 HP @ 460 and 600 V (60 HP @ 208 V). The E-3 has HVAC specific features, but is a relatively mature product.



### Drive Features

The drive has only one relay output. It does offer automatic switching modulation, running a high carrier frequency at a low speed and load. It will reduce carrier frequency with load down to 8 kHz at full load. It also offers AMA-like motor tuning, automatic voltage reduction at light loads, and run permissive. No serial communications are standard. Parameters can be uploaded into the drive, but cannot be transferred to other drives as the keypad is not removable. The display is only a one line seven-segment display, limiting the amount of information that can be displayed. The keypad is relatively easy to navigate, however. The drive is said to be plenum rated, but there is no indication that the panel is. Drives of less than 25 HP do not have a DC link reactor.

### Bypass Features

The drive, relatively wide and in a square-cornered, steel enclosure, is a natural for use with a vertical "integrated style" panel. The package has an attractive, utilitarian look. The bypass enclosure has an effective interlock with the drive door. However, the bypass enclosure is secured only by suitcase-style latches than can be opened without a tool. There is a provision for padlocks in the latches. The panel's On/Off/Test switch, Inverter/Off/Bypass switch, and Bypass On light offer simple, effective control. The unit we evaluated contains a "factorymade" bypass. Many Toshiba bypass units are made by third-party panel shops. We understand that there is an extra charge for the UL panel shop label on factory made panels. Our panel has no UL panel shop label.

### Harmonics and Motor Stress

Although the bypass panel includes a 3% line reactor, the 54% and 41% THD for stiff and soft lines respectively are relatively high values. This shows that harmonics control is better accomplished by a DC link reactor, usually internal to the drive, than an AC line reactor which may be added to any drive. The peak motor voltages are above MG1-Part 30 values, and far above those of any of the TR1's tested. This indicates that motor life may be a concern with the E-3.

### **Trane TR1 Series VFD Selling Strategy**

Time has passed the E-3 by. With its basic seven segment, one-line display, and relatively high harmonic distortion and peak voltage, it is clear that there are better, more modern choices.

- The lack of a DC inductor under 25 HP, and high harmonic distortion even with an optional AC reactor is a source of concern.
- Peak voltages exceed NEMA standards for general purpose motors and are harder to control than input harmonics. Inverter duty motors are probably required for acceptable life.
- Any serial communication, even the popular N2 or FLN, will require optional equipment.
- It does not allow parameters to be copied to another drive.
- The quality of third-party panel shops is always a question. Whether the panel is factory-built or third-party built, insist upon the UL panel shop label on the panel in addition to the UL label on the drive.

## Detailed Competitive Analysis

Feature Voltage/Power Range	Toshiba E-3 AC Line	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
Typical motor HP (208-240V, 1 phase input)	Not available	Not available	Not available
Typical motor HP (208-240V, 3 phase)	3 to 60 HP	1.5 to 60 HP	1.5 to 30 HP
Typical motor HP (380-460V)	5 to 125 HP	1.5 to 600 HP	1.5 to 60 HP
Typical motor HP 600V	5 to 125 HP	1.5 to 300 HP	1.5 to 75 HP
Unit tested	5HP 460 volt	3 HP 460 volt	3 HP 460 volt
<b>Drive Control Terminal</b>			
Number of Digital Inputs	8	8	8
Power Supply for Digital Inputs	24 V DC, 50 mA	24 V DC; 200 mA	24 V DC; 200 mA
Number of analog inputs	3	3	3
Number of Analog Voltage Inputs	2	2	2
Number of Analog Current Inputs	1 current or voltage	1	1
Power Supply for Analog Inputs	10 V DC	10 V DC; 17 mA	10 V DC; 17 mA
Number of Analog/Digital Outputs	1	2	2
Number of relay outputs	1, Form C, 250 V AC, 2A	2; 1 Form A 30 V AC, 1A; 1 Form C 240 V AC, 2 A	2; 1 Form A 30 V AC, 1A; 1 Form C 240 V AC, 2 A
Additional relays	None	1 or 4 Form C	1 or 4 Form C
Control terminals removable	No	Yes	Yes
<b>Drive Functions</b>			
Max. ambient operating temp w/o derate	40°C NEMA 1; 50°C w/ top cover off	40°C NEMA 1	40°C NEMA 1
Switching frequency (carrier)	0.5 to 15kHz, self adjusting, derate above 8 kHz	3 to 10 kHz <15 HP; 3 to 14 kHz 15 - 75 HP; 3 to 4.5 kHz >75 HP	3 to 10 kHz <15 HP; 3 to 14 kHz 15 - 75 HP; 3 to 4.5 kHz >75 HP
Automatic Switching Frequency Modulation	Yes, hi at low speed	Yes	Yes
Overload capability	10% for 2400 sec	10% for 60 sec	10% for 60 sec
Flying start	No	Yes, bi-directional	Yes, bi-directional
Switching on the output	No	Unlimited	Unlimited
Switching on the input		1x/min	1x/min
DC Link Reactor	Opt < 25 HP	Std 3%	Std 3%
Automatic Energy Optimization	Yes	Yes	Yes
Accel/decel time	to 6000 sec	to 3600 sec	to 3600 sec
Cooling fan control	Yes	Yes	Yes
Alternative ramp types (S-ramps)	Yes (programmable)	None	None
Number of torque characteristics	6	2	2
Automatic Motor Measurements	Yes	Yes, AMA	Yes, AMA
Resonance damping	No	Yes	Yes
Max. current limit	110%	110%	110%
Auto ramp Up/Down	Yes, decel	Yes	Yes
Band width for frequency bypass	3 bands, 0 to 30 Hz	4 bands, 0.0 to max. each	4 bands, 0.0 to max. each
Process control (PID)	Yes	Yes	Yes
PID anti wind-up function	No	Yes	Yes

Feature Voltage/Power Range	Toshiba E-3 AC Line	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
<b>Drive Functions (cont.)</b>			
Number of feedback signals accessible	1	2	2
Sleep mode	No	Yes	Yes
Run permissive	Yes	Yes	Yes
Fire mode - Drive	Yes (select speed)	No	No
Ride-through (tested) B4 UV fault indicated			
<b>Drive Programming Functions</b>			
Quick menu	No	Yes	Yes
Display languages	1	9	9
Feedback square root extractor	No	Yes	Yes
Copy and transfer of individual drive parameters via keypad	No	Yes	Yes
Copy of data sets (within the drive)	Yes (1)	Yes	Yes
Fault reset attempts	Manual to 10	Manual to infinite	Manual to infinite
<b>Drive Keypad</b>			
HOA key on Drive	No	Yes	Yes
Local remote key	No	Yes	Yes
Reverse key (indicates non-HVAC drive)	No	No	No
Number of lines of display	1, 7-segment LED	4	4
Possible number of process parameters display simultaneously	1	4	4
Alpha-numeric control panel	No	Yes	Yes
Keypad removable during operation	Non-removable	Yes	Yes
Ease of drive use	Good	Very easy	Very Easy
<b>Output Performance — 460 V</b>			
<b>16' Motor Leads</b>			
Turn On Peak Voltage	1360	760	720
NEMA Rise Time ( $\mu$ s) — 10%-90% DC	0.03	0.338	0.28
<b>96' Motor Leads</b>			
Turn On Peak Voltage	1260	860	800
NEMA Rise Time ( $\mu$ s) — 10%-90% DC	0.4	0.808	0.502
<b>100% load</b>			
RMS current	3.96	3.81	3.81
<b>85% load</b>			
RMS current	3.45	3.33	3.21
<b>67% load</b>			
RMS current	2.72	2.67	2.63
<b>Input Performance — 460 V</b>			
<b>100% load</b>			
<b>- Stiff line</b>			
RMS current	4.39	3.61	3.94

Feature Voltage/Power Range	Toshiba E-3 AC Line	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
THD(I) — % of RMS	53.8%	33.6%	37.8%
- Soft line			
RMS current	3.62	3.45	4.09
THD(I) — % of RMS	41.4%	32.3%	35.5%
<b>Serial Bus Protocols</b>			
Johnson Control Metasys N2	Optional	Standard	Standard
Siemens Apogee FLN	Optional	Standard	Standard
Modbus RTU	Optional	Optional	Optional
LonWorks	Optional	Optional	Optional
BACnet	Not available	Optional	Optional
<b>PC Software</b>			
Windows Base PC Software	Yes	Yes	Yes
<b>Option Panel Features (3-contactor bypass)</b>			
Size of panel (w/o operators devices)	43"H x 8½"W x 10"D	30½"H x 25"W x 8½"D	39½"H x 9½"W x 8½"D
Layout of drive/panel	Drive over panel	Side-by-side	Drive-over-panel
Clearances, with bypass	8" top, 8" bottom, 2" sides	4" top; 0" sides; 0" bottom	4" top; 0" sides; 4" bottom
Mounting Area with Clearances - 3HP w/bypass	12½"W	25"W	9½"W
Weight of drive panel as tested	62 lbs	87 lbs	48 lbs
Drive fuses	No	Yes	Yes
Main fuses	No	No	No
Main circuit breaker	Yes	No	No
Control transformer primary fuse	Yes	Yes	Yes
Control transformer secondary fuse	Yes	No	No
Under/over voltage protection	No under voltage relay	No under voltage relay	No under voltage relay
Fire mode in bypass	No	No	No
Communications in bypass	None	None	None
Conduit entry	Bottom	Top, side and bottom	Bottom
Ventilation openings - drive	Sides and bottom open into panel	Top and bottom	Top and bottom
Ventilation openings - panel	Sides	None	Top and bottom
Panel switches	On/Off/Test switch, Inv/Off/Byp switch	Drive/Off/Line/Test	Drive/Off/Line/Test
Panel lights	Bypass On	Bypass On	Bypass On
Plenum rating -- drive and panel	Yes - drive	Yes	Yes
Panel power flow schematic	None	None	None

Feature Voltage/Power Range	Toshiba E-3 AC Line	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
Country of origin - drive	"Manufactured in USA of foreign and domestic components"	Assembled in USA	Assembled in USA
Country of origin - panel	No statement	No statement	No statement
<b>Interrupt Rating Info</b>			
Power Interrupting Device	Circuit breaker	Disconnect switch	Disconnect switch
UL Panel Label	"Listed Industrial Control Equipment" on drive. Panel shop label opt; not on our unit	Panel shop "Enclosed Industrial Control Panel"	Panel shop "Enclosed Industrial Control Panel"
Panel Rating	"Suitable for use On... 5000A RMS" on panel	No statement	No statement



## Yaskawa E7 Series vs. Trane TR1 Series VFD

### Company Background

Yaskawa Electric Corporation of Japan has been in business since 1915, and claims to be the world's largest manufacturer of servos, inverters, machine controllers, and robotics. Yaskawa Electric America is headquartered in Waukegan, IL with its drives division in neighboring Oak Brook, IL. Yaskawa formerly sold drives through brand label arrangements with Magnetek, Safronics and Omron. Through these organizations, Yaskawa obtained a significant market share in industry, and a lesser market share in HVAC drives in North America.

Company Web Site: <http://www.drives.com/>



### Product

The E7 series is a new product, introduced in 2002. It is the HVAC version of a product platform. The E7 is available in ratings through 500 HP @ 460 V (150 HP @ 208 V). 600 volt drives are not available. Bypasses are available through 250 HP. Twelve-pulse models are also available. The drive is mounted inside the option enclosure with the keypad removed from the drive and permanently mounted in the option enclosure door. Like all box-in-a-box designs, the E7 is relatively dangerous to service when running in Test position, provided, with un-shrouded high power surrounding the inverter.

### Drive Features

The drive is thoroughly modern and full featured. The display can show up to five lines of data. Up to three meters can be displayed at once. The keypad is relatively easy to navigate. Automatic motor measurements, automatic energy optimization, thermally controlled cooling fan, two feedback PI control, sleep mode, run permissive, fire mode in drive and bypass, plenum rating of drive (not bypass), and quick menu are all provided. Standard serial communications include N2, FLN, and Modbus RTU. However, as with many Japanese drives, a DC reactor is not included at ratings less than 40 HP.

### Bypass Features

The box-in-box bypass is relatively large. Ventilation requirements increase its effective width. The bypass control panel includes three switches, including the Hand/Auto selection that others make at the drive. Bypass control is very easy. Six bypass panel lights give status; some are redundant with drive panel indications. Those intimidated with inverter keypads will like this arrangement.

### Harmonics and Motor Stress

The measured THD, with both a stiff and a soft line, is high as expected on a drive with neither a DC link inductor nor an input line reactor. The peak motor voltage on both long and short leads is higher than the TR1's and higher than NEMA MG1- Part 30 allows, suggesting that motor life is a concern.



### **Trane TR1 Series VFD Selling Strategy**

The E7 is a modern, full-featured drive lacking little in features or keypad control compared with TR1 Series VFD. Because the keypad is fixed in the bypass door, transferring parameters from drive to drive, available in the base drive, is prevented when equipped with bypass.

- Specify the TR1 Series VFD with integrated bypass for a narrower package.
- The standard TR1 Series VFD without an AC line reactor will provide better harmonics control than the E7 with optional AC line reactor. This eliminates the need for the TR1 Series VFD side-by-side enclosure in most applications.
- As tested, the TR1's peak motor voltage is significantly below the MG1-Part 30 level of 1000 volts, and the E7 is significantly above. The E7 should always be used with inverter duty motors, and motor life may be an issue.
- Although usually less important to motor life than peak voltage, the rise time of the E7 is also very short. A long rise time is desirable, and the TR1's rise times are 5 to 10 times longer.

## Detailed Competitive Analysis

Feature Voltage/Power Range	Yaskawa E7 No Reactor	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
Typical motor HP (208-240V, 1 phase input)	Not available	Not available	Not available
Typical motor HP (208-240V, 3 phase)	.5 to 150 HP	1.5 to 60 HP	1.5 to 30 HP
Typical motor HP (380-460V)	.5 to 500 HP	1.5 to 600 HP	1.5 to 60 HP
Typical motor HP 600V	Not available	1.5 to 300 HP	1.5 to 75 HP
Unit tested	3 HP 460 volt	3 HP 460 volt	3 HP 460 volt
<b>Drive Control Terminals</b>			
Number of Digital Inputs	5	8	8
Power Supply for Digital Inputs	15 V DC; 20 mA	24 V DC; 200 mA	24 V DC; 200 mA
Number of analog inputs	2	3	3
Number of Analog Voltage Inputs	1	2	2
Number of Analog Current Inputs	1	1	1
Power Supply for Analog Inputs	15 V DC; 20 mA	10 V DC; 17 mA	10 V DC; 17 mA
Number of Analog/Digital Outputs	3	2	2
Number of relay outputs	3; 2 Form A; 1 Form C	2; 1 Form A 30 V AC, 1A; 1 Form C 240 V AC, 2 A	2; 1 Form A 30 V AC, 1A; 1 Form C 240 V AC, 2 A
Additional relays	None	1 or 4 Form C	1 or 4 Form C
Control terminals removable	No	Yes	Yes
<b>Drive Functions</b>			
Max. ambient operating temp w/o derate	40°C NEMA 1	40°C NEMA 1	40°C NEMA 1
Switching frequency (carrier)	15 kHz	3 to 10 kHz <15 HP; 3 to 14 kHz 15 - 75 HP; 3 to 4.5 kHz >75 HP	3 to 10 kHz <15 HP; 3 to 14 kHz 15 - 75 HP; 3 to 4.5 kHz >75 HP
Automatic Switching Frequency Modulation	No	Yes	Yes
Overload capability	10% for 60 sec	10% for 60 sec	10% for 60 sec
Flying start	Yes - bi-directional	Yes, bi-directional	Yes, bi-directional
Switching on the output	No	Unlimited	Unlimited
Switching on the input		1x/min	1x/min
DC Link Reactor	Opt < 50 HP	Std 3%	Std 3%
Automatic Energy Optimization	Yes	Yes	Yes
Accel/decel time	to 6000 sec	to 3600 sec	to 3600 sec
Cooling fan control	Yes	Yes	Yes
Alternative ramp types (S-ramps)	Yes	None	None
Number of torque characteristics	16	2	2
Automatic Motor Measurements	Yes	Yes, AMA	Yes, AMA
Resonance damping	Yes	Yes	Yes
Max. current limit	150%	110%	110%
Auto ramp Up/Down	Yes	Yes	Yes
Band width for frequency bypass	0 to 20 Hz	4 bands, 0.0 to max. each	4 bands, 0.0 to max. each
Process control (PID)	PI only	Yes	Yes
PID anti wind-up function	Yes	Yes	Yes

Feature Voltage/Power Range	Yaskawa E7 No Reactor	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
<b>Drive Functions (cont.)</b>			
Number of feedback signals accessible	2	2	2
Sleep mode	Yes	Yes	Yes
Run permissive	No	Yes	Yes
Fire mode - Drive	Yes	No	No
Ride-through (tested) B4 UV fault indicated			
<b>Drive Programming Functions</b>			
Quick menu	Yes	Yes	Yes
Display languages	7	9	9
Feedback square root extractor	Yes	Yes	Yes
Copy and transfer of individual drive parameters via keypad	Yes	Yes	Yes
Copy of data sets (within the drive)	No	Yes	Yes
Fault reset attempts	Manual to 10	Manual to infinite	Manual to infinite
<b>Drive Keypad</b>			
HOA key on Drive	Yes	Yes	Yes
Local remote key	No	Yes	Yes
Reverse key (indicates non-HVAC drive)	No	No	No
Number of lines of display	5	4	4
Possible number of process parameters display simultaneously	3	4	4
Alpha-numeric control panel	Yes	Yes	Yes
Keypad removable during operation	No	Yes	Yes
Ease of drive use	Good	Very easy	Very Easy
<b>Output Performance — 460 V</b>			
<b>16' Motor Leads</b>			
Turn On Peak Voltage	1160	760	720
NEMA Rise Time ( $\mu$ s) — 10%-90% DC	0.066	0.338	0.28
<b>96' Motor Leads</b>			
Turn On Peak Voltage	1240	860	800
NEMA Rise Time ( $\mu$ s) — 10%-90% DC	0.076	0.808	0.502
<b>100% load</b>			
RMS current	3.89	3.81	3.81
<b>85% load</b>			
RMS current	3.54	3.33	3.21
<b>67% load</b>			
RMS current	3.1	2.67	2.63
<b>Input Performance — 460 V</b>			
<b>100% load</b>			

Feature Voltage/Power Range	Yaskawa E7 No Reactor	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
<b>- Stiff line</b>			
RMS current	6.5	3.61	3.94
THD(I) — % of RMS	82.3%	33.6%	37.8%
<b>- Soft line</b>			
RMS current	4.31	3.45	4.09
THD(I) — % of RMS	55.9%	32.3%	35.5%
<b>Serial Bus Protocols</b>			
Johnson Control Metasys N2	Standard	Standard	Standard
Siemens Apogee FLN	Standard	Standard	Standard
Modbus RTU	Standard	Optional	Optional
LonWorks	Optional	Optional	Optional
BACnet	Optional	Optional	Optional
<b>PC Software</b>			
Windows Base PC Software	Yes	Yes	Yes
<b>Option Panel Features (3-contactor bypass)</b>			
Size of panel (w/o operators devices)	32"H x 19"W x 13½"D	30½"H x 25"W x 8½"D	39½"H x 9½"W x 8½"D
Layout of drive/panel	Box-in-a-box	Side-by-side	Drive-over-panel
Clearances, with bypass	0" top; 0" sides; 0" bottom	4" top; 0" sides; 0" bottom	4" top; 0" sides; 4" bottom
Mounting Area with Clearances - 3HP w/bypass	19"W	25"W	9½"W
Weight of drive panel as tested	95 lbs	87 lbs	48 lbs
Drive fuses	No	Yes	Yes
Main fuses	No	No	No
Main circuit breaker	Yes	No	No
Control transformer primary fuse	Yes	Yes	Yes
Control transformer secondary fuse	No	No	No
Under/over voltage protection	No under voltage relay	No under voltage relay	No under voltage relay
Fire mode in bypass	Yes	No	No
Communications in bypass	None	None	None
Conduit entry	Top, sides, bottom	Top, side and bottom	Bottom
Ventilation openings - drive	Chassis	Top and bottom	Top and bottom
Ventilation openings - panel	Door	None	Top and bottom
Panel switches	Test/Normal switch, Bypass/Drive switch, Hand/Off/Auto switch	Drive/Off/Line/Test	Drive/Off/Line/Test
Panel lights	Drive Run, Drive Fault, Control Power ON, Smoke Purge, Bypass Run, Motor OL/Safties Fault	Bypass On	Bypass On
Plenum rating -- drive and panel	No	Yes	Yes
Panel power flow schematic	None	None	None
Country of origin - drive	No statement	Assembled in USA	Assembled in USA
Country of origin - panel	No statement	No statement	No statement

Feature Voltage/Power Range	Yaskawa E7 No Reactor	TR1 Series VFD Side-by-side AC Line & DC Link	TR1 Series VFD Integrated DC Link
<b>Interrupt Rating Info</b>			
Power Interrupting Device	Circuit breaker	Disconnect switch	Disconnect switch
UL Panel Label	Panel shop "Enclosed Industrial Control Panel"	Panel shop "Enclosed Industrial Control Panel"	Panel shop "Enclosed Industrial Control Panel"
Panel Rating	No statement	No statement	No statement



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