MAKING MODERN LIVING POSSIBLE

Drives and Soft Starters

Defining New Standards for the Water/Wastewater/Irrigation Markets

6

year warranty

DrivePro-tection covers accidental damage from electric anomalies, corrosion, lightning, etc.

100%

full load tested

Danfoss VLT® Drives are factory tested insuring the highest level of quality and reliability

www.danfossdrives.com

VLT® THE REAL DRIVE

Four decades of VFD technology evolution . . .

Welcome to the new generation Danfoss VLT® drive technology

Danfoss introduced the world's first mass-produced VFD in 1968. Our VLT® brand name has set the standard for quality drives ever since.

Below is a quick history (left to right):

VLT® 5

1 – 20 HP, 380 VAC (5 HP shown),
Oil-cooled design (5.3 gal. capacity)
Weight: 141 lbs.
First mass-produced AC drive ever made. Most popular in Europe, many units are still in use. Utilized PAM analog control principle.

VLT® 200

1 – 30 HP, 220 – 460 VAC (5 HP shown)
Weight: 77 lbs.
Analog control using PWM control principle. Modules for feature and performance enhancements included PID, ramp functions and isolation.

VLT® 3000

1 – 75 HP, 220 – 500 VAC (5 HP shown)
Weight: 36 lbs.
First digital drive with VVC control technology. LED control panel.
UL approved.

VLT® 3500

1 – 300 HP, 220 – 500 VAC (5 HP shown)
Weight: 29 lbs.
2nd generation VLT® 3500 featured new LCD control panel with increased software capabilities. Serial communication protocols offered.

VLT® 8000

1 – 600 HP, 200 – 600 VAC (5 HP shown)
Weight: 19 lbs.
Enhanced VVCPLUS, substantial size and weight reduction, many standard performance features that cost extra from other manufacturers.

VLT® AQUA Drive

- Provision for electronically controlled bypass or advanced controller options
- Unique cold plate and back-channel cooling technology
- Balanced DC-link reactors for reduced harmonics
- Field-installable or factory installed and tested option cards provide additional functionality
- Constructed for reduced RFI/EMI
- Surface mount components for compactness and reliability
- Hot-pluggable keypad with on-board memory and award-winning ergonomic design
- USB interface for easy connection to PC software suite
- Removable terminal strips, angled for easy access
- All power and control wires enter at the bottom of the enclosure
- Easy access to control terminals
- Removable, temperature-controlled fan for easy servicing

and focus on our customers' success

In house printed Circuit board manufacturing help Danfoss keep high quality standards

Danfoss VLT® Drives increase productivity

Since 1933, Danfoss has mastered advanced technology and provided their customers with competitive advantages and increased productivity. Being a market leader, Danfoss can offer you the tools to move forward and stay ahead in your field.

Advanced technology that is easy to use

Variable frequency drives – which allow standard AC motors to vary speed and torque in a very controlled way – are the core of our business. They increase the efficiency of automation systems, create energy savings and improve process control in a cost-effective way.

Dedicated to drives solutions

When considering drives, ask an expert's opinion. Danfoss has focused on providing drives and accessories for more than 40 years. We have accumulated a deep understanding of drives technologies, applications and customer needs.

- Danfoss has been mass producing AC drives longer than any other drive manufacturer
- We are an ISO 9001 certified manufacturer and our EMS (Environmental Management System) is ISO 14000 certified
- We are world renowned for superior quality, helpful service, and competitive pricing
- Danfoss products are a superior design – our products offer many design "extras" as standard built-in features, instead of extra cost, extra space add-ons
- Danfoss VLT® Drives is an exclusive drives manufacturer – it's all we do
- We provide fast turnaround on orders
- Application and technical information is available anywhere, anytime

Dependable people; dependable solutions

Danfoss VLT® Drives shares the common Danfoss core values:

- Our business is trust
- A very safe and reliable choice
- Passionate about technology
- Environmentally and socially responsible

Our entire business organization is built on a straightforward approach to customers and applications, vouching for every step from design, manufacturing, sales and delivery to commissioning and after-sale services.

It takes innovation to stay ahead

Customers are actively involved in the development and design of VLT® drives. Our newest VLT® platform is a case in point. Future demands on drives technology and performance are explored through dialogue, studies and field tests. The results are user-friendly and reliable operation, along with useful new features and sophisticated technology.

We regard our customers as long-term business associates. We work with them to solve their problems. Their success is our success.

We look forward to the opportunity to work with you.

Loves Park, IL

Graasten, Denmark

Holip, China

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VLT® AQUA Drive
VLT® AQUA Drive is the perfect match for pumps and blowers in modern water and wastewater systems, offering advanced application protective features. Available with cascade control of up to 8 pumps in fixed speed mode or master/follower mode.

PAGE 73

VLT® Drive Accessories
Options and Accessories for the FC 202 AQUA Option Cards, mounting options, output filters, and NEMA kits

PAGE 86

VLT® Micro Drive
A compact general purpose drive for AC motors up to 30 HP. It performs perfectly even in complex application setups and optimizes energy efficiency and operation.

PAGE 102

VLT® 2800 Drive
An extremely compact series of drives designed for side-by-side mounting and developed specifically for the low power market.

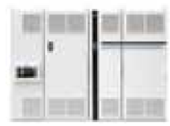
PAGE 120

VLT® Soft Starter MCD 500
A total motor-starting solution with advanced start, stop and protection features, Adaptive Acceleration Control, inside delta connection, 4 line graphical display and multiple programming setup menus.

PAGE 128

VLT® Soft Starter MCD 200
The VLT® Compact Starter MCD 200 is a compact and cost effective soft starter range for applications where direct-on-line starting is undesirable. MCD 200 is, because of its size and functionality, a good alternative to other reduced voltage starting methods such as star/delta starters.

PAGE 142



VLT® Low Harmonic Drive (LHD)
Meets the toughest harmonic requirements under all load/grid conditions. The Danfoss VLT® Low Harmonic Drive is the first solution combining an active filter and a drive in one package. The VLT® Low Harmonic Drive continuously regulates harmonic suppression according to the load and grid conditions without affecting the connected motor.

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VLT® Advanced Active Filter (AAF)
A flexible and adaptable solution for central or de-central harmonic mitigation. Danfoss Advanced Active Filters can compensate for individual Danfoss VLT® Drives as a compact integrated solution or can be installed as a compact stand-alone solution at a point of common coupling, compensating for multiple loads simultaneously. Danfoss Active Filters can operate at medium voltage level by means of a step-down transformer.

PAGE 152

VLT® Advanced Harmonic Filter AHF 005/010
The Danfoss Advanced Harmonic Filters have been specially designed to match the Danfoss Variable Frequency Drives. The solution is available in two variants, AHF 005 and AHF 010, connected in front of a Danfoss Variable Frequency Drive, the harmonic current distortion generated back to the mains is reduced to 5% and 10% Total Harmonic Current Distortion at full load.

PAGE 154

VLT® Multi-Pulse Drives
Robust and cost effective harmonic solutions for higher horsepower applications, multi-pulse drives offer reduced harmonics for demanding applications. Multi-pulse drives are a high efficiency Variable Frequency Drive built to the same modular design as the popular 6-pulse Danfoss VLT® drives.

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VLT® dV/dt Filters

dV/dt filters are placed between the variable frequency drive and the motor. They are differential-mode filters that reduce motor terminal phase-to-phase peak voltage spikes and reduce the rise time to a level that lowers the stress on the insulation of motor windings. dV/dt filters are smaller, weigh less and have a lower price compared to sine-wave filters.

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VLT® Sine-Wave Filters

Sine-wave filters are placed between the variable frequency drive and the motor. They are low-pass filters that suppress the switching frequency component from the variable frequency drive and smooth out the phase-to-phase output voltage of the variable frequency drive to make it sinusoidal. This reduces the motor insulation stress, bearing currents and eliminates the switching acoustic noise from the motor.

PAGE 162

VLT® Common Mode Filters

Common mode filters are placed between the variable frequency drive and the motor. They are nano-crystalline cores that mitigate high frequency noise in the motor cable (shielded or unshielded) and reduce bearing currents in the motor.

PAGE 164

VLT® Motion Control Tool (VLT® MCT 10)

For managing drive parameters in systems, the Motion Control Tool VLT® MCT 10 is the perfect tool to handle all drive-related data.

PAGE 166

VLT® Harmonics Calculation Software (MCT 31)

With VLT® MCT 31, you can determine whether harmonics will be an issue in your installation when drives are added. VLT® MCT 31 estimates the benefits of adding various harmonic mitigation solutions from the Danfoss product portfolio and calculates system harmonic distortion.

PAGE 168

VLT® Energy Box

With VLT® Energy Box software you can both theoretically in project face estimate and afterwards physically validate your real energy savings and reductions in your carbon footprint – from your desk.

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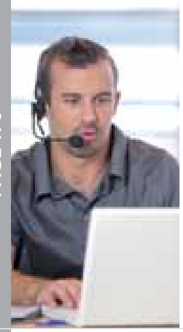


VLT® Service – Your way

DrivePro™ is an efficient productivity program tailored to meet your specific needs. All the necessary VLT® Service facilities are at your disposal, which will minimize downtime and increase productivity at your factory.

PAGE 172

Engineering and Technical Section

Technical Details and explanations of VFD's installation and issues regarding their usage and operation

VLT® AQUA Drive

Perfect
match for:

- Water supply
- Wastewater treatment
- Irrigation

Danfoss VLT® Drives' unequalled experience was used to make VLT® AQUA Drive the perfect match for AC motor driven applications in modern water and wastewater systems – also for retrofitting.

The Danfoss VLT® AQUA Drive is dedicated to water and wastewater applications. With a wide range of powerful standard and optional features, the VLT® AQUA Drive provides the lowest overall cost of ownership for water and wastewater applications.

Power range

1 x 200 – 240 V AC .... 1.5 – 30 HP
1 x 380 – 480 V AC .... 10 – 50 HP
3 x 200 – 240 V AC .... 1/3 – 60 HP
3 x 380 – 480 V AC ....1/2 – 1350 HP
3 x 525 – 600 V AC .... 1 – 125 HP
3 x 525 – 690 V AC .... 15 – 1600 HP

Manufactured to the highest quality standards
The VLT® AQUA Drive is a UL-listed product made in ISO 9001-2000 and ISO 14000 certified facilities.

Features	Benefits
Dedicated features	
Dry run detection	Protects the pump
Flow compensation function	Saves energy
2 step ramps (initial ramp)	Protects deep well pumps
Check valve ramp	Protects against water hammer and saves installed cost on soft close valves
Pipe fill mode	Eliminates water hammering
Built-in motor alternation feature	Duty-stand by operation, cost reduction
Sleep Mode	Saves energy
No/low flow detection	Protects the pump
End of pump-curve detection	Protects the pump, leakage detection
Pump cascade controller	Lower equipment cost
Back-channel cooling for frame D, E and F	Prolonged lifetime of electronics
Energy saving	**Less operation cost**
VLT® efficiency (98%)	Saves energy
Automatic Energy Optimization (AEO)	Saves 3 – 8% energy
Sleep Mode function	Saves energy
Master/follower control	Saves up to 15% energy
Auto Tuning of Staging Speeds	Smoothens the staging and saves energy
Flow Compensation	Saves Energy by self-adjusting the set-point
Reliable	**Maximum uptime**
Chassis, NEMA 1, NEMA 12, NEMA 4X enclosures	Outdoor mounting
All power sizes available in NEMA 12 enclosures	Broad usability in standard factory supplied enclosure
Password protection	Reliable operation
Mains disconnect switch	No need for external switch
Built-in RFI suppression	No need for external modules
Built-in Smart Logic Controller	Often makes PLC omissible
One Wire safe stop	Safe operation/less wiring
Max. ambient temperature up to 50°C/122°F without derating	Reduced need for cooling
User-friendly	**Save initial and operation cost**
Award winning control panel (LCP)	Effective commissioning and operation
One drive type for the full power range	Less learning required
Intuitive user interface	Time saved
Integrated Real Time Clock	Lower equipment cost
Modular design	Enables fast installation of options
Auto tuning of PI-controllers	Time saved
Payback time indication	Less worries

VLT® AQUA Drive General Specifications

Mains Supply (L1, L2, L3)

Supply voltage	200 – 240 V ±10% (180 – 264 V) 380 – 480 V ±10% (342 – 528 V) 525 – 600 V ±10% (472 – 660 V) 525 – 690 V ±10% (472 – 759 V)
Supply frequency	50/60 Hz
Max. imbalance temporary between mains phases	3.0% of rated supply voltage
True Power Factor (λ)	≥0.9 nominal at rated load
Displacement Power Factor (cosϕ)	near unity (> 0.98)
Switching on input supply L1, L2, L3 (power-ups) ≤ 10 HP L1, L2, L3 (power-ups) ≥ 15 HP	 maximum 2 times/min. maximum 1 time/min.
Environment according to EN60664-1	overvoltage category III/ pollution degree 2
The unit is suitable for use on a circuit capable of delivering not more than 100.000 RMS symmetrical Amperes, 240/480/600 V maximum.	

Motor Output (U, V, W)

Output voltage	0 – 100% of supply voltage
Output frequency	0 – 120 Hz
Switching on output	Unlimited
Ramp times	1 – 3600 sec.

Torque Characteristics

Starting torque (Constant torque)	maximum 110% for 60 sec.*
Starting torque	maximum 135% up to 0.5 sec.*
Overload torque (Constant torque)	maximum 110% for 60 sec.*
**Percentage relates to the nominal torque.*	

Cable Lengths and Cross Sections

Max. motor cable length, shielded	500 ft. (150 m)
Max. motor cable length, unshielded	1000 ft. (300 m)
Maximum cross section To motor, mains, load sharing and brake* To control terminals,	
Rigid wire	16 AWG /1.5 mm² (2 x 0.75 mm²
Flexible cable	18 AWG/1 mm²
Cable with enclosed core	20 AWG/0.5 mm²
To control terminals	24 AWG/0.25 mm²

**See Mains Supply table for more information.*

Protection and Features

- Electronic thermal motor protection against overload.
- Temperature monitoring of the heatsink ensures that the drive trips if the temperature reaches 203°F (95°C). ±5°C. An overload temperature cannot be reset until the temperature of the heatsink is below 158°F ±9° (70° C ±5°) (Guideline – these temperatures may vary for different power sizes, enclosures etc.). VLT® AQUA Drive has an auto derating function to avoid it's heatsink reaching 203°F (95°C).
- The drive is protected against short-circuits on motor terminals U, V, W.
- If a mains phase is missing, the drive trips or issues a warning (depending on the load).
- Monitoring of the intermediate circuit voltage ensures that the drive trips if the intermediate circuit voltage is too low or too high.
- The drive is protected against ground faults on motor terminals U, V, W.
- Electronic thermal motor protection against overload.
- Temperature monitoring of the heatsink ensures that the drive trips if the temperature reaches 203°F (95°C). ±5°C. An overload temperature cannot be reset until the temperature of the heatsink is below 158°F ±9° (70°C ±5°) (Guideline – these temperatures

Surroundings

Enclosure ≤10 HP	Protected Chassis/IP20, NEMA Type 12/IP55, NEMA 4X/IP66
Enclosure 15 HP – 125 HP	Protected Chassis/IP20, NEMA Type 1/IP21, NEMA Type 12/IP55, NEMA 4X/IP66
Enclosure >150 HP	Chassis/IP00, NEMA Type 1/IP21, NEMA Type 12/IP54
Enclosure kit available ≤125 HP	NEMA Type 1/IP21
Vibration test	1.0 g RMS
Max. relative humidity	5% – 95%(IEC 60 721-3-3; Class 3K3 (non-condensing) during operation
Aggressive environment (IEC 721-3-3), standard	class 3C2
Aggressive environment (IEC 721-3-3), optional	class 3C3
Ambient temperature	122°F (50°C)
Derating for high ambient temperature, see Design Guide section on special conditions	
Min. terminal load on 1-3 (NC), 1-2 (NO), 4-6 (NC), 4-5 (NO)	24 VDC 10 mA, 24 VAC 20 mA
Environment according to EN 60664-1	overvoltage category III/ pollution degree 2

1) IEC 60947 part 4 and 5
The relay contacts are galvanically isolated from the rest of the circuit by reinforced isolation (PELV).

VLT® AQUA Drive General Specifications

Analog Inputs

Number of analog inputs	2
Additional analog inputs available with: MCB 101 general purpose I/O option card MCB 109 advanced analog I/O option card	 2 3
Terminal number	53, 54
Modes	Voltage or current
Mode select	Switch S201 and switch S202
Voltage mode	Switch S201/switch S202 = OFF (U)
Voltage level	0 to +10 (scaleable)
Input resistance	approx. 10 kΩ
Max. voltage	±20 V
Current mode	Switch S201/switch S202 = ON (I)
Current level	0/4 to 20 mA (scaleable)
Input resistance	approx. 200 Ω
Max. current	30 mA
Resolution for analog inputs	10 bit (+ sign)
Accuracy of analog inputs	Max. error 0.5% of full scale
Bandwidth	200 Hz

The analog inputs are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

Pulse Inputs

Programmable pulse inputs	2
Additional pulse inputs available with MCB 101 general purpose I/O option card	3
Terminal number pulse/encoder	29, 33
Max. frequency at terminal 29, 33	110 kHz (Push-pull driven) 5 kHz (open collector)
Min. frequency at terminal 29, 33	4 Hz
Voltage level	see section on Digital input
Maximum voltage on input	28 VDC
Input resistance	approx. 4 kΩ
Pulse input accuracy (0.1 – 1 kHz)	Max. error: 0.1% of full scale

The pulse and encoder inputs (terminals 29, 32, 33) are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

Analog Output

Number of programmable analog outputs	1
Additional analog outputs available with: MCB 101 general purpose I/O option card MCB 109 advanced analog I/O option card	 1 3
Terminal number	42
Current range at analog output	0/4 – 20 mA
Max. load to common at analog output	500 Ω
Accuracy on analog output	Max. error: 0.5% of full scale
Resolution on analog output	8 bit

The analog output is galvanically isolated from the supply voltage (PELV) and other high voltage terminals.

Control Card, RS 485 Serial Communication

Terminal number	68 (P,TX+, RX+), 69 (N,TX-, RX-)
Terminal number	61 Common for terminals 68 and 69
Modbus RTU	standard

The RS 485 serial communication circuit is functionally separated from other central circuits and galvanically isolated from the supply voltage (PELV).

Digital Inputs:

Programmable digital inputs	4 (6)
Additional digital inputs available with MCB 101 general purpose I/O option card	3
Terminal number	18, 19, 27[1)], 29, 32, 33,
Logic	PNP or NPN
Voltage level	0 – 24 VDC
Voltage level, logic '0' PNP	<5 VDC
Voltage level, logic '1' PNP	>10 VDC
Voltage level, logic '0' NPN[2)]	>19 VDC
Voltage level, logic '1' NPN[2]	<14 VDC
Maximum voltage on input	28 VDC
Input resistance	approx. 4 kΩ

All digital inputs are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.
1) Terminals 27 and 29 can also be programmed as output.

Digital Output

Programmable digital/pulse outputs	2
Additional digital outputs available with: MCB 101 general purpose I/O option card	2
Terminal number	27, 29 [1)]
Voltage level at digital/frequency output	0 – 24 V
Max. output current (sink or source)	40 mA
Max. load at frequency output	1 kΩ
Max. capacitive load at frequency output	10 nF
Minimum output frequency at frequency output	0 Hz
Maximum output frequency at frequency output	32 kHz
Accuracy of frequency output	Max. error: 0.1% of full scale
Resolution of frequency outputs	12 bit

1) Terminal 27 and 29 can also be programmed as input.
The digital output is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

Control Card, 24 VDC Output

Terminal number	12, 13
Max. load	200 mA

The 24 VDC supply is galvanically isolated from the supply voltage (PELV), but has the same potential as the analog and digital inputs and outputs.

Control Card, 10 VDC Output

Terminal number	50
Output voltage	10.5 V ±0.5 V
Max. load	25 mA

The 10 VDC supply is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

VLT® AQUA Drive General Specifications

Relay Outputs

Programmable relay outputs	2
Additional relay outputs available with: MCB 105 relay option card	3
Relay 01 Terminal number	1-3 (break), 1-2 (make)
Max. terminal load (AC-1)1) on 1-3 (NC), 1-2 (NO) (Resistive load)	240 VAC, 2 A
Max. terminal load (AC-15)1) (Inductive load @ cosφ 0.4)	240 VAC, 0.2 A
Max. terminal load (DC-1)1) on 1-2 (NO), 1-3 (NC) (Resistive load)	60 VDC, 1A
Max. terminal load (DC-13)1) (Inductive load)	24 VDC, 0.1A
Relay 02 Terminal number	4-6 (break), 4-5 (make)
Max. terminal load (AC-1)1) on 4-5 (NO) (Resistive load)	400 VAC, 2 A
Max. terminal load (AC-15)1) on 4-5 (NO) (Inductive load @ cosφ 0.4)	240 VAC, 0.2 A
Max. terminal load (DC-1)1) on 4-5 (NO) (Resistive load)	80 VDC, 2 A
Max. terminal load (DC-13)1) on 4-5 (NO) (Inductive load)	24 VDC, 0.1A
Max. terminal load (AC-1)1) on 4-6 (NC) (Resistive load)	240 VAC, 2 A
Max. terminal load (AC-15)1) on 4-6 (NC) (Inductive load @ cosφ 0.4)	240 VAC, 0.2A
Max. terminal load (DC-1)1) on 4-6 (NC) (Resistive load)	50 VDC, 2 A
Max. terminal load (DC-13)1) on 4-6 (NC) (Inductive load)	24 VDC, 0.1 A
Min. terminal load on 1-3 (NC), 1-2 (NO), 4-6 (NC), 4-5 (NO)	24 VDC 10 mA, 24 VAC 20 mA
Environment according to EN 60664-1	overvoltage category III/ pollution degree 2

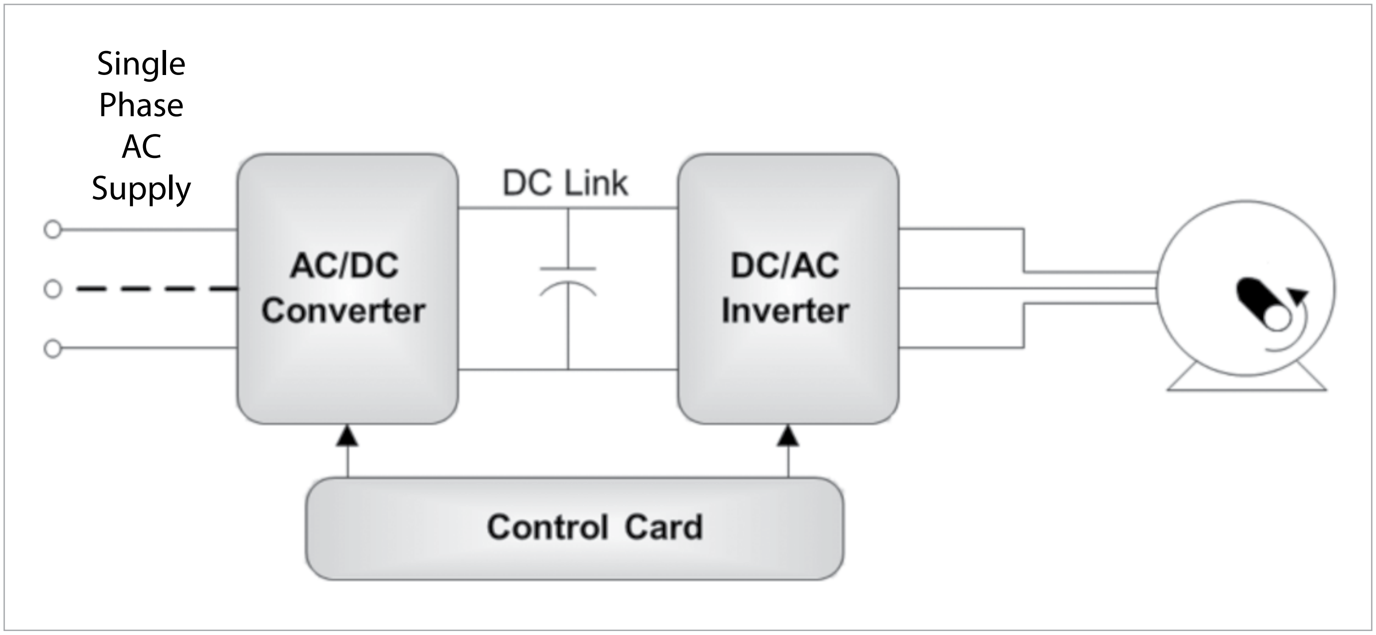
1) IEC 60947 part 4 and 5
The relay contacts are galvanically isolated from the rest of the circuit by reinforced isolation (PELV).

Control Characteristics

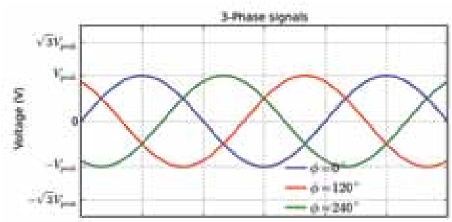
Resolution of output frequency at 0 – 1000 Hz	+/- 0.003 Hz
System response time (terminals 18, 19, 27, 29, 32, 33)	≤2 ms
Speed control range Open loop	1:100 of synchronous speed
Speed accuracy Open loop	30 – 4000 rpm: error ±8 rpm

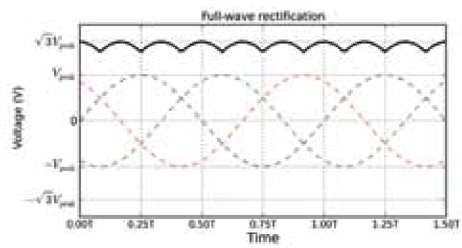
All control characteristics are based on a 4-pole asynchronous motor

VFDs for Phase Conversion

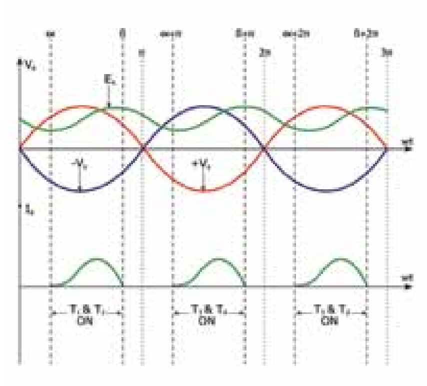


For applications such as lift stations, farming fields, small municipal lift stations, or any location where three phase power is not available, UL-listed phase-converting VLT® AQUA Drives can control three-phase motors using single phase 240V or 480V service. Since three phase motors are more readily available and less expensive, a variable frequency drive can be a cost-effective solution in these applications while providing an attractive alternative to conventional phase conversion devices. In addition, a drive provides numerous other benefits not available with traditional phase conversion units, including speed control, motor protection and energy savings. Traditionally a VFD is de-rated by 50% to perform this phase conversion function. Danfoss VLT® Drives has taken the next step by designing, labeling, and testing drives specifically for single phase operation without de-rating.





In a three phase VFD, the 3 phases are converted to DC and, as each phase is 120o apart, the DC is more uniform. With DC oils, the voltage and current are more stable and easier on the capacitors and IGBT's.



In a single phase or 2 phase input, the phases are out of phase or opposite and thus create a more pulsed DC bus. This affects the DC circuit and can lead to shorter capacitor life. This is why Danfoss created a dedicated line of single phase inverters with stronger capacitors and dc coils to insure long lifetime.

VLT® AQUA Drive

Current and power ratings

Single-phase						Three-phase												
1 x 200–240 VAC			1 x 380–480 VAC			3 x 200–240 VAC			3 x 380–480 VAC			3 x 525–600 VAC			3 x 525–690 VAC			
Output current [A]	Shaft Output HP	Shaft Output kW	Output current [A]	Shaft Output HP	Shaft Output kW	Output current [A]	Shaft Output HP	Shaft Output kW	Output current [A]	Shaft Output HP	Shaft Output kW	Output current [A] 575V	Shaft Output HP	Shaft Output kW	Output current [A] 575 V	Shaft Output HP	Shaft Output kW	
						1.8	1/3	0.25										PK25
						2.4	1/2	0.37	1	1/2								PK37
						3.5	3/4	0.55	1.4	3/4								PK55
						4.6	1	0.75	1.9	1	0.75	1.7	1	0.75				PK75
6.6	1.5	1.1				6.6	1.5	1.1	2.7	1.5	1.1	2.4	1.5	1.1				P1K1
7.5	2	1.5				7.5	2	1.5	3.1	2	1.5	2.7	2	1.5				P1K5
10.6	3	2.2				10.6	3	2.2	4.3	3	2.2	3.9	3	2.2				P2K2
12.5	4	3				12.5	4	3	5.7	4	3	4.9	4	3				P3K0
16.7	5	3.7				16.7	5	3.7										P3K7
									7.4	5	3.7	6.1	5	3.7				P4K0
24.2	7.5	5.5				24.2	7 1/2	5.5	9.9	7 1/2	5.5	9	7.5	5.5				P5K5
30.8	10	7.5	14.5	10	7.5	30.8	10	7.5	13	10	7.5	11	10	7.5				P7K5
			21	15	11	46.2	15	11	21	15	11	18	15	11				P11K
59.4	20	15				59.4	20	15	27	20	15	22	20	15				P15K
			34	25	18.5	74.8*	25*	18.5*	34	25	18.5	27	25	18.5				P18K
88	30	22				88	30	22	40	30	22	34	30	22				P22K
						115	40	30	52	40	30	41	40	30				P30K
			65	50	37	143	50	37	65*	50*	37*	52	50	37				P37K
						179	60	45	80	60	45	62	60	45	54	50	45	P45K
									105	75	55	83	75	55	73	60	55	P55K
									130	100	75	100	100	75	86	75	75	P75K
									160	125	90	131	125	90	108	100	90	P90K
									190	150	110				131	125	110	N110
									240	200	132				155	150	132	N132
									302	250	160				192	200	160	N160
									361	300	200				242	250	200	N200
									443	350	250				290	300	250	N250
									540	450	315				344	350	315	N315
									590	500	355							P355
									678	550	400				400	400	400	P400 N400
									730	600	450				450	450	450	P450
									780	650	500				500	500	500	P500
									890	750	560				570	560	600	P560
									1050	900	630				630	630	650	P630
									1160	1000	710				730	750	700	P710
									1380	1200	800				850	950	800	P800
									1530	1350	1000				945	1050	900	P900
															1060	1150	1000	P1M0
															1260	1350	1200	P1M2
															1415	1550	1400	P1M4

** 200-240v ac p18k & 380-480vac p37k Drives in Protected Chassis/IP20 are B4, NOT C3.*

Dimensions [in]

		Protected Chassis/IP20								
		A2	A3	B3	B4	C3	C4	D3h	D4h	E2
Height		10.6	10.6	15.7	20.4	20.7	26	35.8	44.2	60.9
Width	without C option	3.5	5.1	6.5	9.1	12.1	14.6	9.8	13.8	23
	with one C option	5.1	6.7	8.9						
Depth	without A or B option	8.1	8.1	9.8	9.5	13.1	13.1	14.8	14.8	19.6
	with A or B option	8.6	8.6	10.3						

		NEMA 1/IP21								
		A2†	A3†	B1	B2	C1	C2	D1h	D2h	E1
Height		14.6	14.6	18.9	25.6	26.8	30.3	35.5	43.6	78.7
Width	without C option	3.5	5.3	9.5	9.5	12.1	14.6	12.8	16.5	23.6
	with one C option	5.1	6.7							
Depth	without A or B option	8.1	8.1	10.2	10.2	12.2	13.2	15.0	15.0	19.4
	with A or B option	8.6	8.6							

	NEMA 12/IP55 & NEMA 4X/IP66						NEMA 12/IP54		
	A4	A5	B1	B2	C1	C2	D1h	D2h	E1
Height	14.2	16.5	25.6	25.6	26.8	30.3	35.5	43.6	78.7
Width	7.9	9.5	9.5	9.5	12.1	14.6	12.8	16.5	23.6
Depth	7.5	7.9	10.2	10.2	12.2	13.2	15	15	19.4

Drives available through 1350 HP. Note: some options may not be available on all drive sizes. Contact factory to ensure correct part number.
Standard drive and drive-with-bypass packages are available in a wide range of enclosure options, including Chassis, NEMA 1, NEMA 12 and NEMA 4X. In addition, Engineered Panel Solutions offer custom packages, including NEMA 3R and 4X enclosures for challenging environments.

VLT® AQUA Drive

The modular VLT® AQUA Drive is engineered for design simplicity and high performance.

Fieldbus options (A-option)

- Select any of the common fieldbus protocols

I/O, relay or safety (B-option)

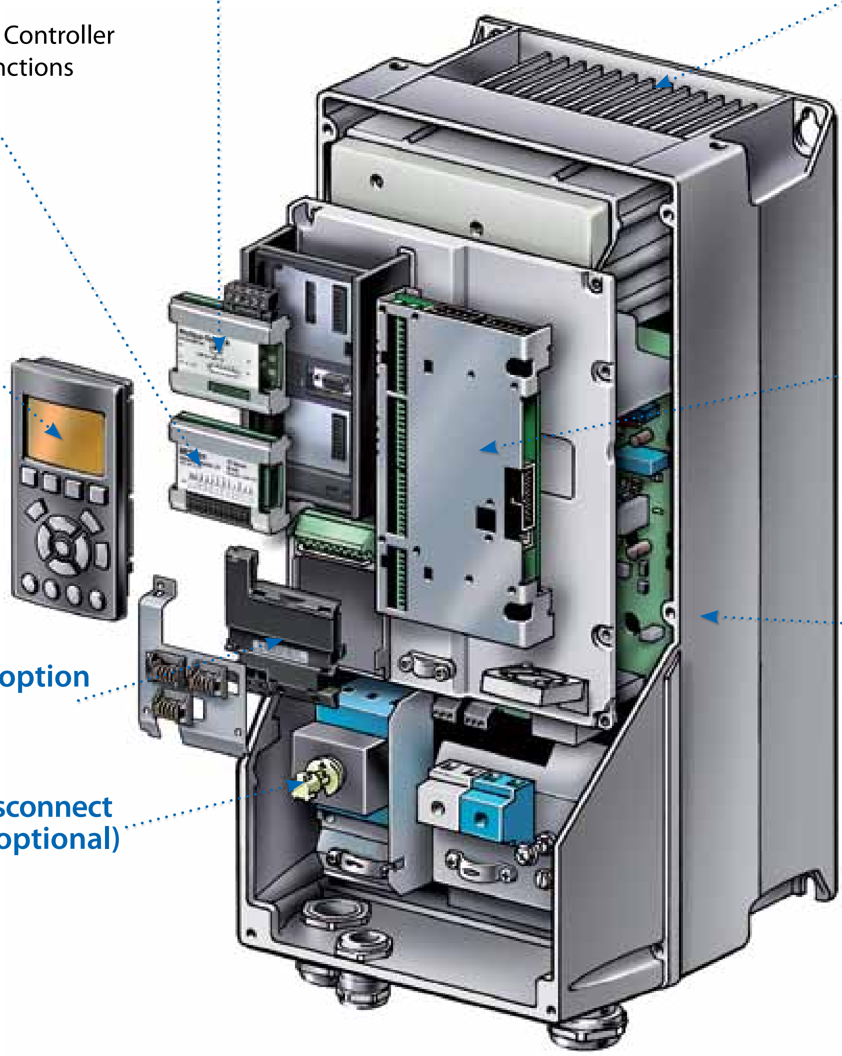
- I/O, Cascade Controller and relay functions

Local Control Panel (LCP)

- Six-line graphical LCP display

24V supply option (D-option)

AC mains disconnect and fusing (optional)



Unique cooling concept

- Improves efficiency
- Reduces contaminants in electronics

Advanced cascade controller option

- (C-option)

Conformal coated PCBs

- Durable in corrosive environments
- Meets stringent 3C2 level as standard
- Optional 3C3 level of conformal coating is available

VLT® AQUA Drive **Features**

VLT® AQUA Drive built-in intelligence increases performance in all water and wastewater applications.

Water and wastewater is a global business for Danfoss VLT® Drives. Our unequalled experience makes the VLT® AQUA Drive the perfect match for pumps and blowers in water and wastewater and irrigation systems. With a wide range of powerful standard and optional features designed specifically for water, wastewater, and irrigation applications, the VLT® AQUA Drive provides the lowest overall cost of ownership of any drive available.

Save energy

- High efficiency (>98%)
- Sleep Mode shuts off pumps when demand is low
- Automatic Motor Adaptation
- Automatic Energy Optimization produces typical savings of 3–5% (up to 15% possible)
- Flow compensation of setpoint
- Unique cooling concept

Save space

- Compact, modular design
- Built-in DC-link reactors for harmonic suppression – no need for external AC input line reactors
- Optional, integrated RFI filters throughout the power range
- Integrated disconnects and fusing

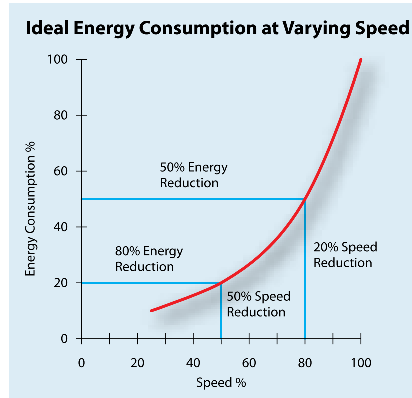
Save costs

Protect your system with a series of pump-specific features:

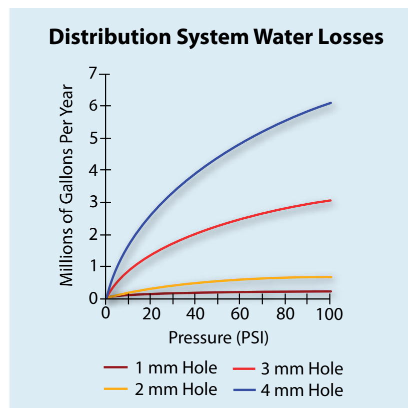
- Cascade controller
- Sensorless control
- Dry pump detection
- End of curve detection
- Motor alternation
- 2-step ramps (initial ramp)
- Safe stop
- Pipe fill mode
- Real-time clock
- Password protection
- Overload trip protection
- Smart logic controller
- User-selectable variable or constant torque operation
- NEMA 12/IP54/55 and NEMA 4X/IP66 outdoor-rated enclosures eliminate the need for separate enclosures

Save time

- Intuitive user interface with the new, award-winning local control panel (LCP)
- One drive type for the full power range
- Modular VLT® design enables fast installation of options
- Auto-tuning of PI controllers
- Robust design and efficient monitoring significantly reduce maintenance requirements.



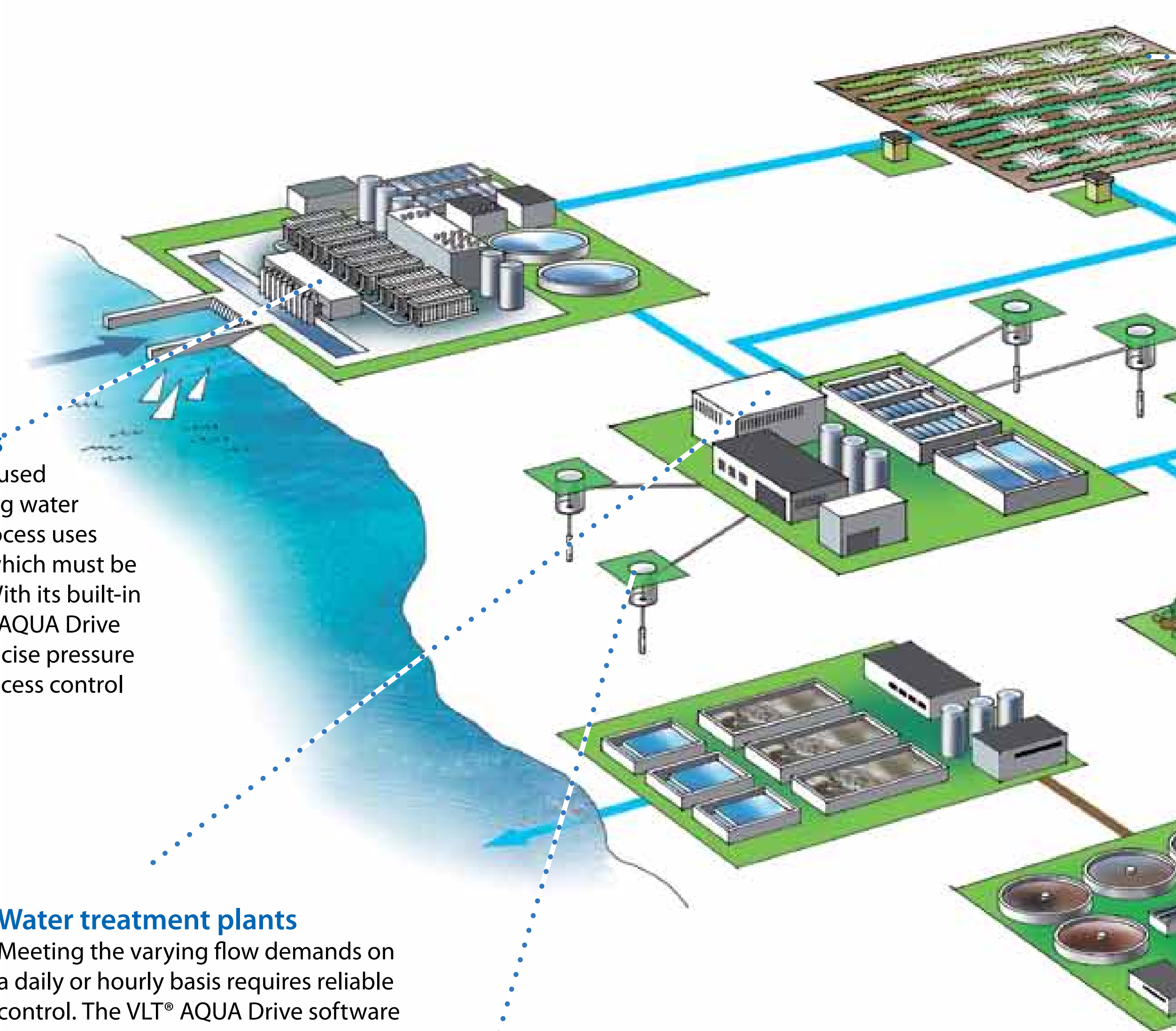
Energy savings using a VLT® AQUA Drive are achieved with even a modest reduction in speed.



Reducing water losses by lowering system pressure becomes increasingly effective as the size of line breaks increase.

VLT® AQUA Drive Applications

Designed for all water, wastewater and irrigation applications



Desalination plants

Desalination plants are used to provide clean drinking water from the ocean. The process uses high pressure pumps, which must be accurately controlled. With its built-in PID controller, the VLT® AQUA Drive ensures reliable and precise pressure control, maximizing process control and efficiency.

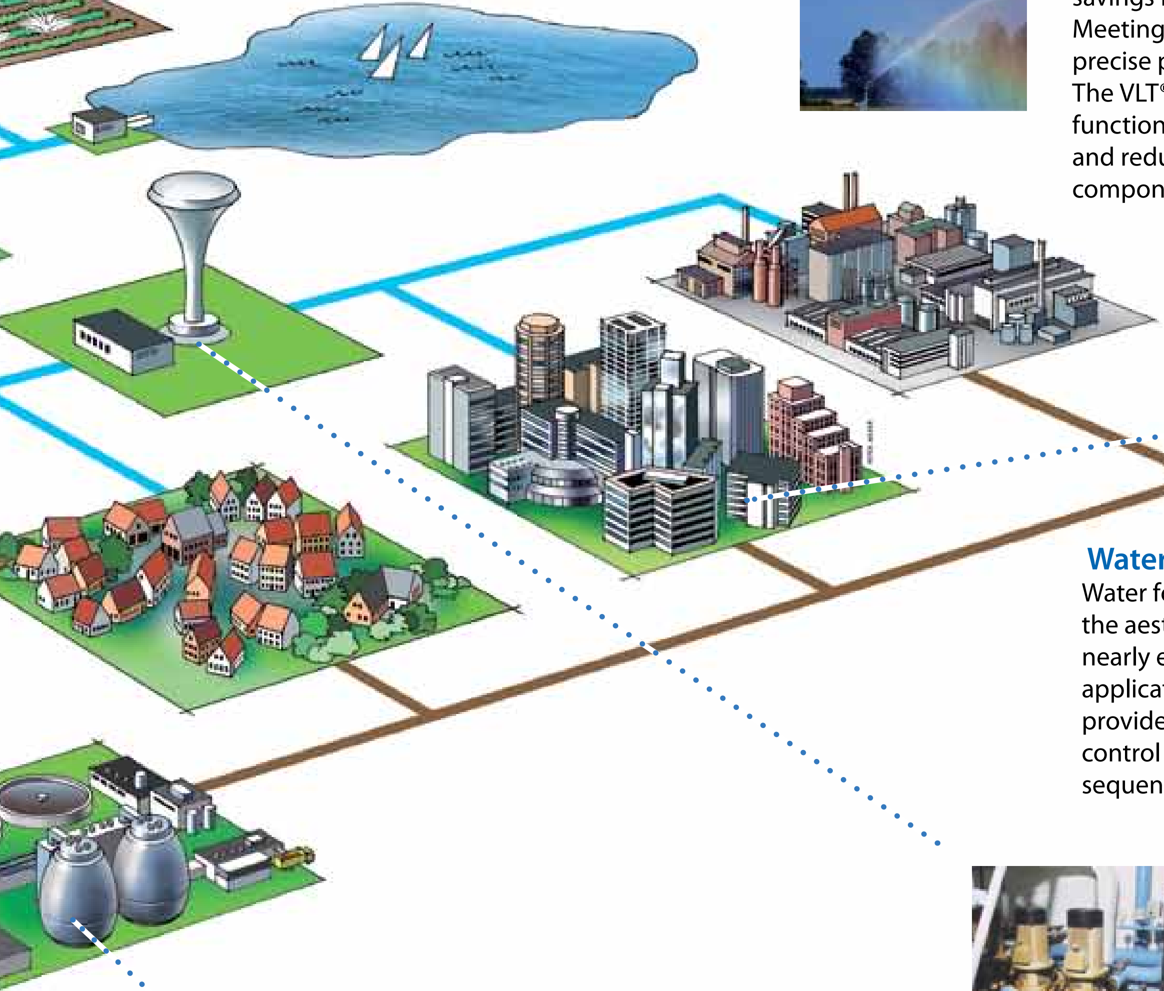
Water treatment plants

Meeting the varying flow demands on a daily or hourly basis requires reliable control. The VLT® AQUA Drive software provides unique pump control features that will help control even the most demanding applications.

Groundwater pumps

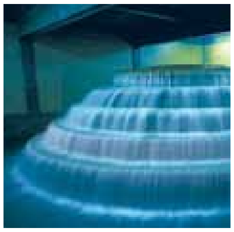
Submersible deep well pumps need rapid start capability, precise control and protection against running dry. The built-in dry pump detection, initial ramp and multiple parameter input make the VLT® AQUA Drive the perfect choice for these applications.

VLT® AQUA Drive **Applications**



Irrigation systems

The irrigation market is focusing more and more on efficiency and energy savings for water management. Meeting these demands requires precise pressure and flow control. The VLT® AQUA Drive offers a pipe fill function that prevents water hammer and reduces damage to pipes and components.



Water fountains and pools

Water fountains are used to enhance the aesthetics of buildings and parks nearly everywhere. In these applications, the VLT® AQUA Drive can provide energy efficiency, accurate control and even meticulously timed sequencing for a dramatic effect.

Distribution

As areas become more populated, the increasing demand for reliable and precise pressure control becomes a challenge to many communities. The VLT® AQUA Drive has innovative pumping functions to assist in maintaining precise pressure and flow while reducing system leakage and energy consumption. In many cases, it can also provide a cost-effective alternative to unsightly water towers.

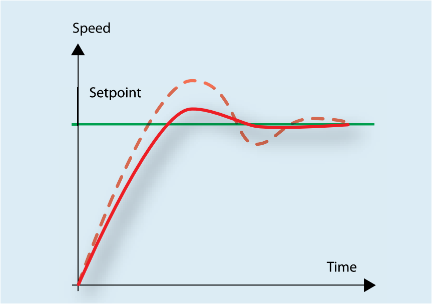
Wastewater plants

Fluctuations in flow can disrupt efficient process control, increase costs and equipment wear due to a higher number of starts and stops, and adversely affect effluent quality. Using the VLT® AQUA Drive on pumps, blowers and other equipment will lead to better process control and reduce energy consumption. The AQUA Drive can also provide tighter control of chemical feed pumps, mixers and other equipment.

Dedicated features for water/wastewater/irrigation applications

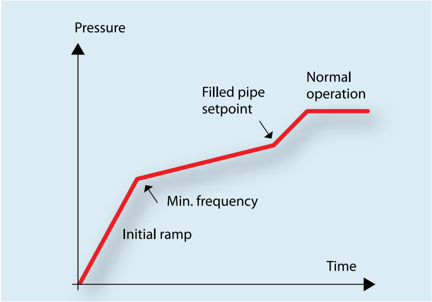
Save valuable start-up time – "Automatic tuning" of PI Controller

The VLT® AQUA Drive offers up to four separate PID loops for controlling multiple processes, each of which is automatically tuned to provide optimal performance. The drive monitors how the system reacts to corrections and learns from this data to quickly achieve precise and stable operation. Gain factors for PI are continuously adjusted to compensate for changing characteristics of the loads. Knowing the exact P and I settings at startup is not necessary, making commissioning easier.



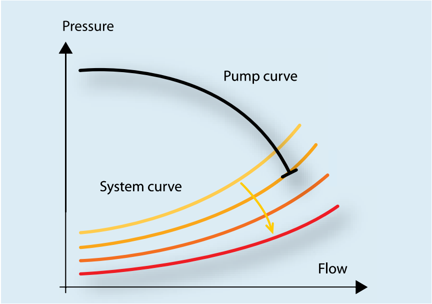
Reduce water hammer on empty pipes – Pipe Fill Mode

The VLT® AQUA Drive can provide controlled (closed loop) filling of pipes, preventing water hammer, burst water pipes and damage to sprinkler heads. This feature is particularly valuable in applications that are vulnerable to these types of damage, such as irrigation systems and water supply systems.



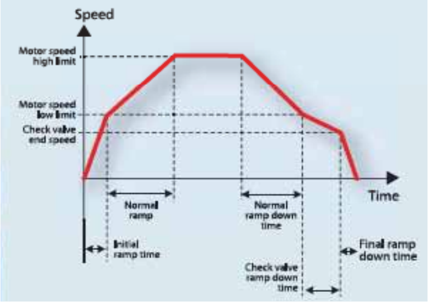
Know when there might be a problem – End of Pump Curve Detection

The VLT® AQUA Drive can detect breaks and leakage in supply lines by comparing pump speed with the system pressure. The drive can be set to trigger an alarm, shut off the pump, or perform some other programmed action whenever a pump is found running at full speed without creating the desired pressure—a situation that usually indicates a break in the system.



Open and close your check valves quietly and quickly – Check Valve Ramp

The Check Valve Ramp prevents water hammering as the pump stops and the check valve closes. The Check Valve Ramp slowly ramps down the pump speed around the value where the check valve ball is about to shut.



Prelube or blower function

The VLT® AQUA sends a digital signal after it has received a start command for up to 15 minutes before starting the equipment and will stop once started or maintain the signal until up to 15 minutes after the equipment has been stopped.

Know when your pump is pumping

Flow Confirmation – The VLT® AQUA monitors a digital input to verify flow or an open check valve. if after a programmalbe time the VLT® AQUA does not recieve the input, the drive trips with "No Flow Confirmation.

Operate your pump on a schedule

Real time clock – The VLT® AQUA has an internal time clock to operate your equipment at a programmable time for a programmable duration. the clock can operate at programmable times or days and can be programmed for 8 different time events. an optional battery back-up card (MCB 109) will keep time during power loss.

Control without transmitters

Sensorless Control – The VLT® AQUA can operate equipment without additional sensors for closed loop control. once the performance curve is programmed into the FC 202 AQUA, the unit can then operate without transmitters

Monitor energy usage

One of the main reasons for using a VLT® Series drive is the minimal payback time due to energy savings. The VLT® AQUA Drive comes with a unique feature that continuously displays the time remaining before the drive pays for itself.

Motor Alternation

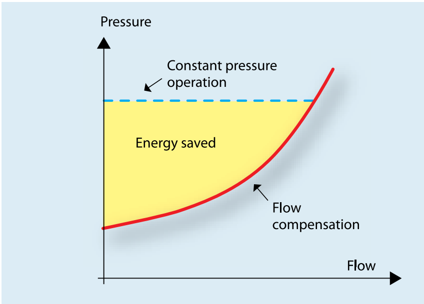
This built-in logic controls alternation between two pumps in duty/stand-by applications. Running the stand-by pump prevents sticking and lubricates the seals. An internal timer assures equal usage of the pumps.

Sleep Mode

Sleep Mode keeps pump wear and power consumption to an absolute minimum. In low flow situations, the VLT® AQUA Drive will boost the system pressure and then shut down the pump. It will continue to monitor the system pressure and restart when the pressure falls below the required level.

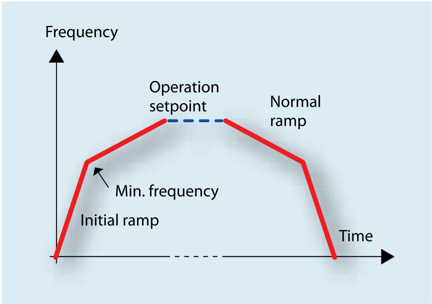
Maintain pressure on a large system – Flow compensation

The flow compensation feature of the VLT® AQUA Drive takes advantage of the fact that reduces friction losses with reduced flow. Using this information, the pressure setpoint is reduced as necessary, thereby saving energy.



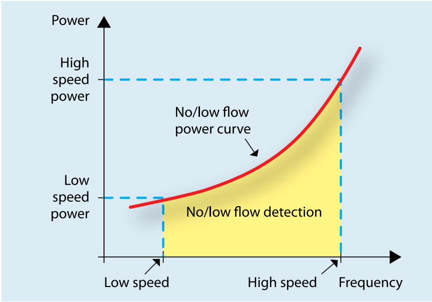
2 stage ramps for submersible or vertical turbine pumps – Initial/Final Ramp

Initial ramp provides rapid acceleration of pumps to a desired minimum speed, at which time the normal ramp takes over. This prevents damage to thrust bearings and overheating of the pump. The final ramp decelerates pumps to avoid unintended closure of check valves and water hammer.



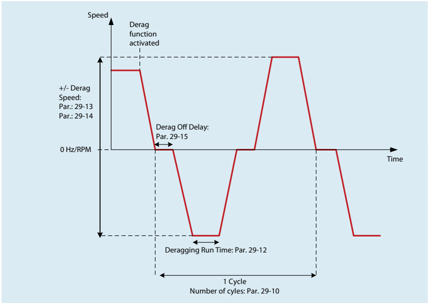
No Flow/Low Flow/Dry Pump – Dry Pump Protection

The VLT® AQUA Drive constantly evaluates the condition of the pump, based on internal frequency/power measurements. When power consumption drops too low – indicating a no or low flow situation – the VLT® AQUA Drive will shut down the pump.



Easily remove rags from impeller – Deragging feature

The VLT® AQUA Drive software feature offers proactive pump protection. The deragging can be configured as either a preventative or reactive action. It optimizes the efficiency of the pump by constantly monitoring the motor shaft power consumption relative to flow. In the reactive mode, the drive senses the beginning of a pump clog and will reverse spin the pump to ensure a clear path for the water. As a preventative action, the drive will periodically reverse the pump to ensure a clean pump, or screen.



VLT® AQUA Drive **Features**

Designed with the user in mind

The VLT® AQUA Drive maximizes system reliability with built-in protection against:

- System overloads
- Motor failures
- Motor and drive overheating
- Voltage disturbances
- Power surges
- Loss of phase
- Phase-to-phase and phase-to-ground short circuit
- Ground fault
- Switching on input/output
- Electrical disturbances
- Overvoltage
- Overcurrent
- Undervoltage
- External fault
- Overtemperature

Input line protection from extreme running conditions

Minimal harmonic distortion/ maximum power factor

DC-link reactors reduce the harmonic distortion currents that a variable frequency drive injects back into the AC line. The properly sized reactors in a VLT® AQUA Drive can reduce line harmonic currents by up to 40% of the fundamental current. This eliminates the need and cost of additional AC line reactors and their resultant line voltage reduction.

Line disturbances and transients

To protect itself from AC line voltage disturbances, the drive monitors all three phases and interrupts drive operation in the event of phase loss or imbalance. Transients on the AC line are suppressed by MOVs as well as zener diodes for extreme transients. Danfoss VLT® AQUA Drives meet VDE 0160 (European standard – 2.3 x line voltage for 1.3 msec) for transient protection.

Voltage sags and surges

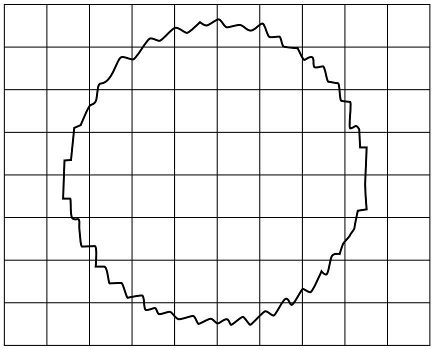
The VLT® AQUA Drive is designed for a wide range of operating conditions. The 480 V drive will operate from 342–528 VAC. The 230 V drives will operate on 180–264 VAC. 575 V drives will operate on 495–660 VAC and 690 V drives will operate on 472–759 VAC. Full rated motor voltage and torque can be delivered with voltage dips down to 10% under nominal AC line voltage. During an AC line drop-out, the VLT® AQUA Drive continues until the intermediate circuit voltage drops below the minimum stop level, which is typically 15% below the VLT® AQUA Drive's lowest rated supply voltage.

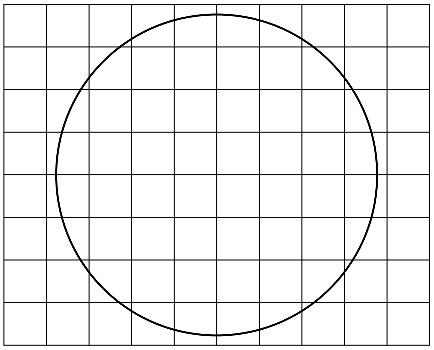
Output protection for longer motor life

VLT® AQUA Drives incorporate both DC-link reactors and motor output protection as standard design features. This provides short circuit protection and allows unlimited switching on the output without damage to the drive, eliminating the need for additional output reactors or switch interlocks.

The DC-link reactors improve overall efficiency by increasing the power factor and lowering the ripple current in the bus voltage providing an almost threefold increase in capacitor and drive life. As a result, motor operation is smooth and quiet and longer motor life can be expected.

Hall effect current transducers measure current flowing on all three motor phases. This provides highly responsive and accurate feedback to the VLT® control circuit for optimum motor protection and performance.





The diameter of the circle indicates the strength of the magnetic field of the motor while the uniformity of the circle indicates how well the VFD controls the magnetization. In lieu of a uniform circle, the addition of edges show that the VFD does not handle the magnetization control as it should and that the motor operation will be unstable causing increased motor torque cogging.

VLT® AQUA Drive **Features**

VVC^PLUS output switching pattern

Unique digital VVC^PLUS voltage vector control provides:

- A nearly perfect output sine wave that reduces the overshooting and undershooting of voltage and current generated by standard PWM drives
- Fully rated motor voltage at rated frequency
- Increased efficiency for both drive and motor
- Full motor performance without derating; no additional heating of motor windings
- Motor cable lengths up to 1000′ standard

Ground fault

The VLT® AQUA Drive provides complete protection from potentially damaging ground fault conditions on both the supply side and the motor side.

Short circuit

The VLT® AQUA Drive is protected against short circuits by measuring the current in each of the three motor phases. A short circuit between two output phases will shut down the drive as soon as the current exceeds the maximum value.

Thermal protection for the drive and motor

The ETR (Electronic Thermal Relay) is an open loop method built into the VLT® AQUA Drive software to guard against motor overheating, requiring no additional sensors or wiring. This function is UL recognized (Class 20) as an effective guard against motor thermal overload.

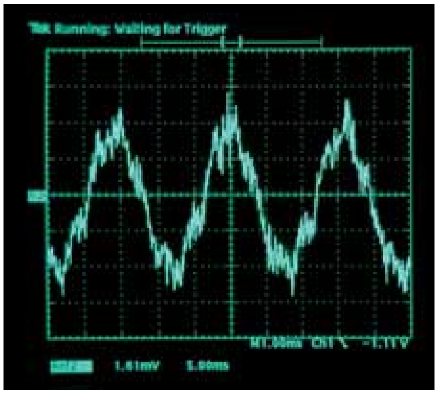
The VLT® AQUA Drive has built-in thermal protection and also accepts thermistor signal input from the motor to create closed loop thermal protection for the entire system.

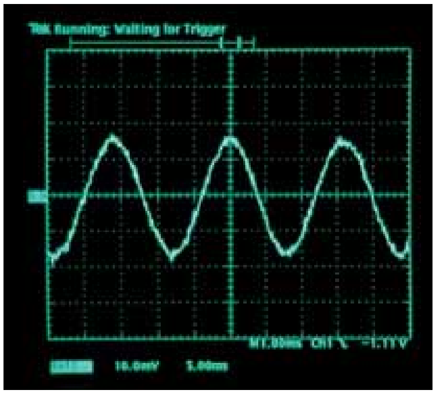
Minimize motor noise and heating with ASFM

With the ASFM (Adjustable Switching Frequency Modulation) function, the switching frequency is adjusted automatically in relation to the speed of the motor. As speed is reduced, the switching frequency increases to ensure optimally low motor noise and reduce motor heating.

Reduced installation cost

Dual DC-link reactors reduce the input RMS current to less than or equal to the output current. This greatly reduces the cable size requirement and the subsequent cost of installation.





Brand "X" PWM scope trace (top) compared to smoother VVC^PLUS scope trace (bottom).

VLT® AQUA Drive **Features**

Award-winning control panel

Input from our extensive user group significantly influenced the design and function of the new generation Local Control Panel. The removable LCP now comes with an improved user interface. Choose between eight built-in languages or have it customized with any language you like. The info button accesses virtually all information contained in the printed operation manual.

The Automatic Motor Adaptation (AMA), Quick Setup menu and large graphic display make commissioning and operation convenient and easy.

1 Graphical display

- Informative overview
- Six lines of display
- Graphical or numerical display of information
- Readout in user-selectable engineering units
- Select from up to 27 languages as standard
- Backlit for increased visibility

2 Quick Menus

- Danfoss-defined Quick Menu
- My Personal Menu allows users to define their own menus of commonly accessed parameters
- Changes Made Menu displays the parameters to which changes have been made
- Function Setup Menu provides quick setup for specific applications
- Logging Menu provides access to operation history

3 Illumination

- Illuminated LEDs indicate which function is active

4 Menu structure

- Based on the field-proven matrix system used in previous VLT® Series drives
- Menu shortcuts access specific functions
- Edit and operate in different setups simultaneously

5 Other benefits

- The keypad is removable during operation
- Upload/download setups between drives using the keypad
- Remote mounting kit available for panel installation
- Hand / off / auto buttons for easy switching between manual and automatic control

6 Additional buttons

- Info: an "onboard manual" that provides specific information about each parameter
- Cancel: exits current parameter without saving changes
- Alarm log: easy access to a list of all previous alarm conditions

design award winner

The VLT® AQUA Drive Local Control Panel won the international iF design award. The Danfoss LCP beat out 1000 entries from 34 countries in the "interface in communication" category.

VLT® AQUA Drive **Features**

Setup and display

The VLT® AQUA Drive makes setup and operation easy. With a remarkably user-friendly interface, intuitive menu structures and powerful tools that streamline installation and troubleshooting, the VLT® AQUA Drive saves valuable time, resulting in a lower overall cost of ownership.

- Transfer of parameters – Parameters can be programmed into one drive and downloaded to other drives via the drive's keypad or VLT® MCT 10 software.
- Remote mounting kit available – An optional kit allows remote mounting of the VLT® AQUA Drive keypad up to 10 feet away. Removal of the keypad does not affect the drive's NEMA 1 or NEMA 12 rating, and the gasketed keypad itself carries a NEMA 12 and NEMA 4X.
- Continuous monitoring with or without the keypad – With or without a keypad, the VLT® AQUA Drive's ON, WARNING and ALARM status lights are always visible.
- Plain language alarms and warnings – Alarms and warnings are displayed in easy-to-understand form, eliminating the need for decoding or referring to long tables in manuals.
- Complete programmability of display – The keypad's four line, backlit, alphanumeric display can be programmed to display four different measurements at a time. Choose from many options, including: °F, °C, %, RPM, frequency, gallons/min., ft.3/sec., or p.s.i.

PC software programming tools

VLT® MCT 10 motion control tool

VLT® MCT 10 facilitates programming by enabling control of entire parameter sets, including copying from one drive to another within the interface.

Based on the familiar Windows technology and format, VLT® MCT 10 is intuitive and easy to use. Project drive folders can be named and organized to closely match system layout. Word, Notepad, and other file types can be placed into the project folders where they are most relevant.

- Supports current Danfoss product line as well as legacy drive models

USB connectivity

The VLT® AQUA Drive can be remotely commissioned and monitored through a USB connection.

Danfoss Software can be downloaded by going to: www.danfoss.com/BusinessAreas/DrivesSolutions/Softwaredownload/

VLT® AQUA Drive Features

Protective features

With an unmatched combination of drive, motor, and system protection features, the VLT® AQUA Drive is the most cost-effective overall solution on the market. Designed and built for long-term, worry-free operation without the need for external devices to protect driven equipment, the VLT® AQUA Drive provides secure, reliable results, right out of the box.

System protection

No flow detection

Operation under dead head conditions provides no flow to the system and may damage the pump. Differential pressure switches or flow sensors to monitor flow increase the installation costs and add complexity. The VLT® AQUA Drive can automatically detect no flow situations and take the appropriate corrective action.

End of curve protection

The VLT® AQUA Drive can automatically detect over-flow conditions that indicate operation off the end of the pump curve. Its response can be customized to trigger an alarm and stop the pump, issue a warning while maintaining operation, or perform a variety of other functions to protect both the pump and the system.

Automated vibration avoidance

Fan and pump systems often have resonant speeds that must be avoided to reduce vibration and noise. The VLT® AQUA Drive automates the process of setting up frequency avoidance bands, minimizing system commissioning time.

Drive protection

Metal oxide varistors (MOVs) and capacitor snubbers in both the AC and DC input circuitry reduce the impact of voltage spikes on the input. In addition, a balanced pair of DC-link reactors between the input rectifier and the bank of DC-bus capacitors reduces the severity of any current surge resulting from abrupt changes in the AC supply line. Conformal coating is standard to protect electronic components in aggressive environments.

Motor protection

The VLT® AQUA Drive's built-in I^2T motor overload, thermistor input and motor preheat functions increase the life of the controlled motor without the added cost of separately supplied protection. The drive's built-in I^2T motor overload is UL-listed as a true overload device, eliminating the need for external motor protection hardware.

Harmonic mitigation

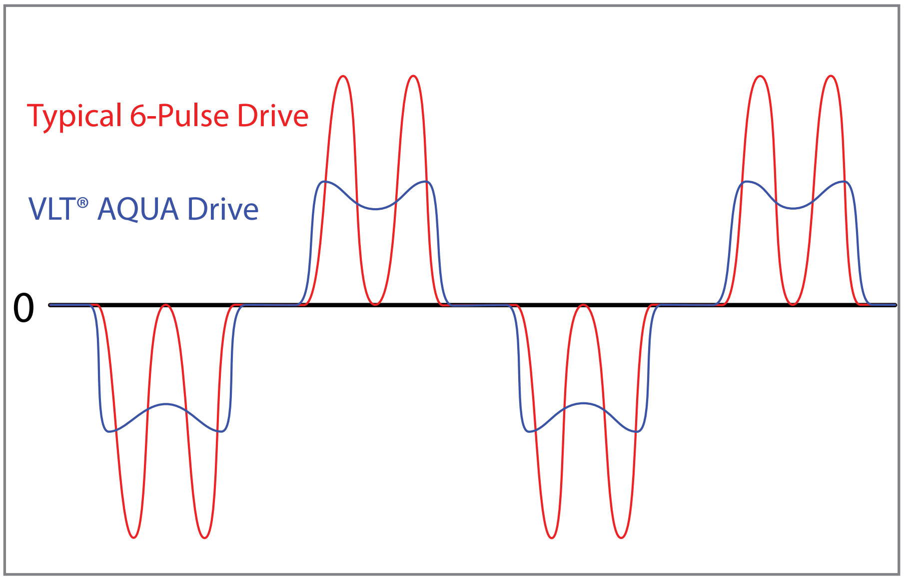
DC-link reactors limit harmonic distortion on the power line, reducing RMS input current by more than 40% compared to drives without input reactors.

Other drive manufacturers address harmonics with AC line reactors, usually external to the drive. Often, these optional AC line reactors are 50% larger than the DC-link reactors standard on the VLT® AQUA Drive. This results in significant additional heat generation and reduced efficiency. The harmonic performance of the DC-link reactors in the VLT® AQUA Drive is equal to that of a 5% AC line reactor, but without the associated voltage drop and efficiency losses.

MCT 31 harmonics calculation tool

MCT 31 calculates system harmonic distortion for both Danfoss and non-Danfoss VLT® Drives. It is also able to calculate the effects of using various additional harmonic reduction measures including Danfoss Advanced Harmonic Filtration.

- Project-oriented for simplified calculations on several transformers
- Easy to compare different harmonic solutions within the same project
- Supports current Danfoss product line as well as legacy drive models



VLT® AQUA Drives provide the lowest overall cost of ownership by including as standard DC-link reactors, which minimize harmonic current distortion without the need for external reactors.

VLT® AQUA Drive Features

Motor preheating function
The VLT® AQUA Drive can be programmed to introduce a small amount of current to the motor whenever it is at rest. This prevents condensation inside the motor, extending its life without the need for space heaters or other external equipment.

Intelligent heat management
Total separation between cooling air and electronics circulation air keeps electronics clean and cool, and provides a solution where heat needs to be removed outside the cabinets. A Through-Panel Mounting Kit is available for mounting the drive in the backplate of a cabinet.

Forced convection cooling
A fan blows cold air through the cooling ribs of the aluminum base. The channel is easily cleaned without touching electronics. All drives are equipped with forced convection cooling.

Wall mounted with forced cooling through the heatsink.

Through-panel mounting

Cold plate cooling
External cooling is possible through the back side of the aluminum base. The solid aluminum base is integrated with the back panel to provide high mechanical stability, efficient cooling and the option of cold plate operation. Cold plate cooling is available on all A frame size drives.

Back-channel cooling
The intelligent heat management of VLT® high power drives removes 85% of the heat losses via finned heat sinks, which transfer the heat to the back-channel cooling air. This back-channel is separated from the electronics area by an NEMA 12/IP54 seal. This method of cooling greatly reduces contamination of the control electronics area, resulting in longer life and higher reliability. The remaining 15% of heat losses are removed from the control electronics area using lower-volume door fans.

The excess heat from the back-channel is either dispersed into the control room or it can be directly removed from the building. An optional back-channel cooling duct kit is available to aid in the installation of IP00/Chassis drives into Rittal TS8 enclosures. Back-channel cooling is available on all D, E and F frame size drives.

Outdoor-rated VLT® AQUA Drives
Built to withstand harsh environments, an outdoor-rated enclosure and standard 1000-foot motor cable runs mean the VLT® AQUA Drive provides maximum mounting flexibility.

Suitable for outdoor or indoor installations that require protection against windblown dust and rain or splashing water, NEMA 4X/IP66-rated drives (available up to 125 HP) can be installed directly at the equipment location without a protective enclosure. All cast aluminium parts are powder coated with a durable epoxy that can stand up to most corrosive chemicals.

NEMA 4X/IP66 rated drives are the perfect solution for demanding applications, such as lift stations, pump stations, irrigation, and other outdoor applications.

Small footprint
Throughout the entire power range, all sizes of VLT® AQUA Drives are even smaller than comparable previous drives. No dimension has increased, and volumes are typically 20% smaller.

Back-channel cooling: A smart, dedicated kit allows chassis/IP00 enclosures to be mounted in Rittal cabinets so cool air removes 85% of excess heat without contact with the electronics.

VLT® AQUA Drive Packaged Panel Solutions

Danfoss packaged panel solutions are built in Milwaukee, Wisconsin.

Flexibility is the key to Danfoss packaged drive solutions. From our unique feature-rich standard packages to our Engineered Drive Systems, Danfoss supplies the package to meet the application. Our packaged solutions are all manufactured in UL-certified facilities, and supported by the same stringent manufacturing standards and warranties as VLT® Series drive products. Being your single source supplier of both VFDs and packaged solutions is just one more way that Danfoss reduces your total cost of ownership.

Typical package options

- Two-contactor bypass
- Three-contactor bypass
- Contactor motor selection
- Multiple motor operation
- Main input disconnect
- Main input fusing
- Drive fusing
- Input AC line reactors
- Output dV/dt filters
- 100,000 amp short circuit current rated package
- Common start/stop
- Control switches
- Indicator lights
- Meters
- System communications
- Auxiliary enclosure for customer-supplied equipment
- Multiple drives in a single enclosure
- NEMA 1, 12, 3R, or 4X to meet customer requirements

Vertical bypass units available with 3 Contactor bypass, circuit breaker, and drive fusing.

VLT® AQUA Drive Packaged Panel Solutions

Vertical and traditional mounting of bypass

Integrated fused disconnect package

- Why supply separate drives and fused disconnects when you can get them in the smallest, easiest package possible?
- Reduced installation cost & time
- Can be ordered with or without drive input fusing

Engineered drive systems

Custom enclosures, soft start bypass panel, custom wiring and pilot devices, or NEMA 1, 12, 4 and 4X panels. You name the package and we can engineer and build the unit.

Enhanced packages

VLT® AQUA Drives through 125 HP at 480 volts and 60 HP at 230 volts may also be supplied with a UL-listed Type 3R enclosure suitable for outdoor use. These weather-resistant enclosures allow the versatile VLT® AQUA Drive to be located with all of its options on a rooftop or other outdoor location. Enclosure fans help keep the drive within its temperature limits in high ambient temperatures, and a thermostatically controlled heater helps prevent condensation in cool, damp environments.

NEMA Type 3R enclosures are available for locations exposed to weather.

Panel solution products are packaged according to the functional requirements of the system, commonly referred to as Tier 1, 2 and 3 . Examples of Tier 1, 2 and 3 enclosure are shown below.

***Tier 1**: Drive or drive with fuse and/or disconnect.*

***Tier 2**: Drive with bypass or non-bypass drive with input AC line reactor, output LC filter and/or contactor motor selection.*

***Tier 3**: Drive with bypass and input AC line reactor, output LC filter and/or contactor motor selection.*

VLT® AQUA Drive **Packaged Panel Solutions**

Electro-Mechanical Bypass (EMB)

For users who prefer the traditional bypass control methods of relay logic and selector switches, Danfoss offers a standard drive and bypass package.

Door mounted operators

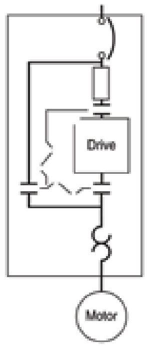
- Drive-Off-Bypass selector
- Bypass pilot light indication
- Test selection added with three contactor bypass units

24 VDC switch mode power supply

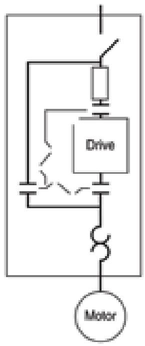
- Operates off of any two of the three input phases
- Continued drive operation at a reduced load when any input phase is lost
- Eliminates contactor dropout on voltage conditions as low as 70% of nominal voltage
- Eliminates the need for an undervoltage relay

Additional options

- Common start/stop available
- Run permissive available
- Automatic bypass with adjustable time delay is available
- Class 20 overload



3 Contactor bypass with circuit breaker main disconnect and drive fusing.



3 Contactor bypass with main disconnect and drive fusing.

VLT® AQUA Drive **Packaged Panel Solutions**

Circuit breaker main disconnect

Danfoss can supply a circuit breaker as the primary disconnect and overcurrent protection for the bypass. The Drive will continue to be protected with drive fusing.

Main fusing/drive fusing

Danfoss can supply fuses in conjunction with other options built into the standard drive enclosure, resulting in a compact solution with no increase in footprint size.

Drive fuses

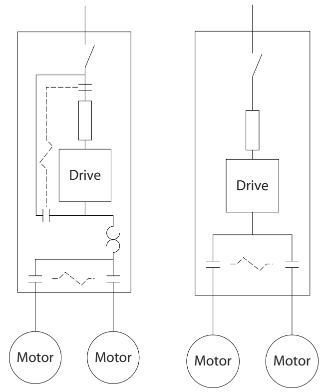
Drive fuses are located ahead of the drive and are a fast acting type. Drive fuses are standard in two-contactor and three-contactor bypasses, so there is no need to add them for bypass units. If drive fuses are required for any non-bypass configuration, order an Input Disconnect Switch and Input Fuse (see right).

Main fuses

Main fuses are used in panels containing a bypass. They are located ahead of the drive, the drive fuses, and the bypass. Main fuses are designed to protect the circuitry within the panel, but are not adequate to protect the drive. Main fuses are dual-element time delay type. These fuses mount within the bypass enclosure.

Contactor Motor Selection

Allows selection between two motors, either manually, or automatically from a remote signal. (Remote signal source not included.) A door-mounted Motor 1 – Auto – Motor 2 selector switch is provided. In the Auto mode, the motor is selected via two external, normally open contacts. Interlocking is provided to ensure soft-start if switching occurs while the drive is running. For proper motor overload protection, both motors must be the same size. Bypass can also be supplied, if required.



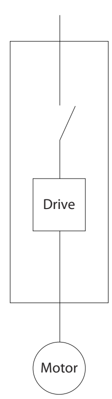
Contactor Motor Selection without Bypass requires a drive with Input Fuses and Disconnect. Contactor Motor Selection with Bypass requires a drive with bypass

Fuse/disconnect

Includes back plate if required and graphical control panel.

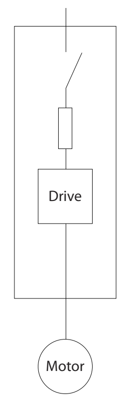
Input disconnect switch

A padlockable, defeatable, two-position rotary switch that allows the input line to the drive to be disconnected. For safety, the switch must be in the OFF position before the enclosure cover can be removed. Includes drive and disconnect switch. Disconnect switch mounts below the drive in an extended drive enclosure for 10 HP @ 460V and 3 HP @ 208V and smaller units. No increase in enclosure size for all larger units. For single motor applications only.



Input disconnect switch and input fuse

Includes drive, drive fuses, and disconnect switch. Disconnect switch and fuses mount below the drive in an extended drive enclosure for 10 HP @ 460V and 3 HP @ 208V and smaller units. No increase in enclosure size for all larger units. For single motor applications only.



Short circuit current rating

All VLT® AQUA Drives and drives with drive fuses and/or input disconnect switches are rated at 100,000 amps short circuit current rating. (100kA SCCR).

All other standard panels consisting of a VLT® AQUA Drive and options are labeled for 5kA SCCR.

Most requirements for a higher SCCR can be satisfied by a 100kA SCCR. We can optionally supply a bypass panel labeled for 100k SCCR. Main fuses (not circuit breaker) are always required for 100kA SCCR.

Please note that the SCCR is what is required to ensure that the panel's rating is sufficient for the source current available. This is not the same as amp interrupting capacity (AIC). AIC is a component rating, and cannot be used as the SCCR, which is a complete drive or panel rating.

VLT® AQUA Drive

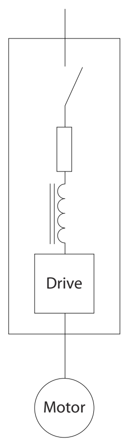
Input line reactor/output LC filter

Reactors and dV/dt filters are only available in a UL Type 1 option enclosure. This enclosure is identical in size to the option enclosure that can house the bypass. If a reactor and filter are both required, they will both be mounted in the same enclosure. Drives without a bypass must have the input disconnect option.

For panels with bypass and input line reactors and/or output LC Filters will require an additional enclosure. A total of two option enclosures will be supplied for drives including both a bypass and an input line reactor or output LC filter.

AC input line reactor

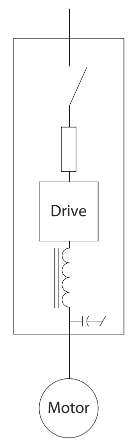
AC input line reactors are used in the input to the drive to filter line noise from the drive and drive noise from the line. An internal 5% dual DC-link reactor is standard on all drives, eliminating the need for AC line reactors in many applications. Available with Contactor Motor Selection on bypass units only.



Drive with Disconnect Switch, Drive Fuses, and Input Line Reactor

Output dV/dt filter

This low-pass filter allows the use of longer motor leads and reduces insulation stress especially on low horsepower motors without interphase insulation. Available with Contactor Motor Section on both bypass and drive only units.

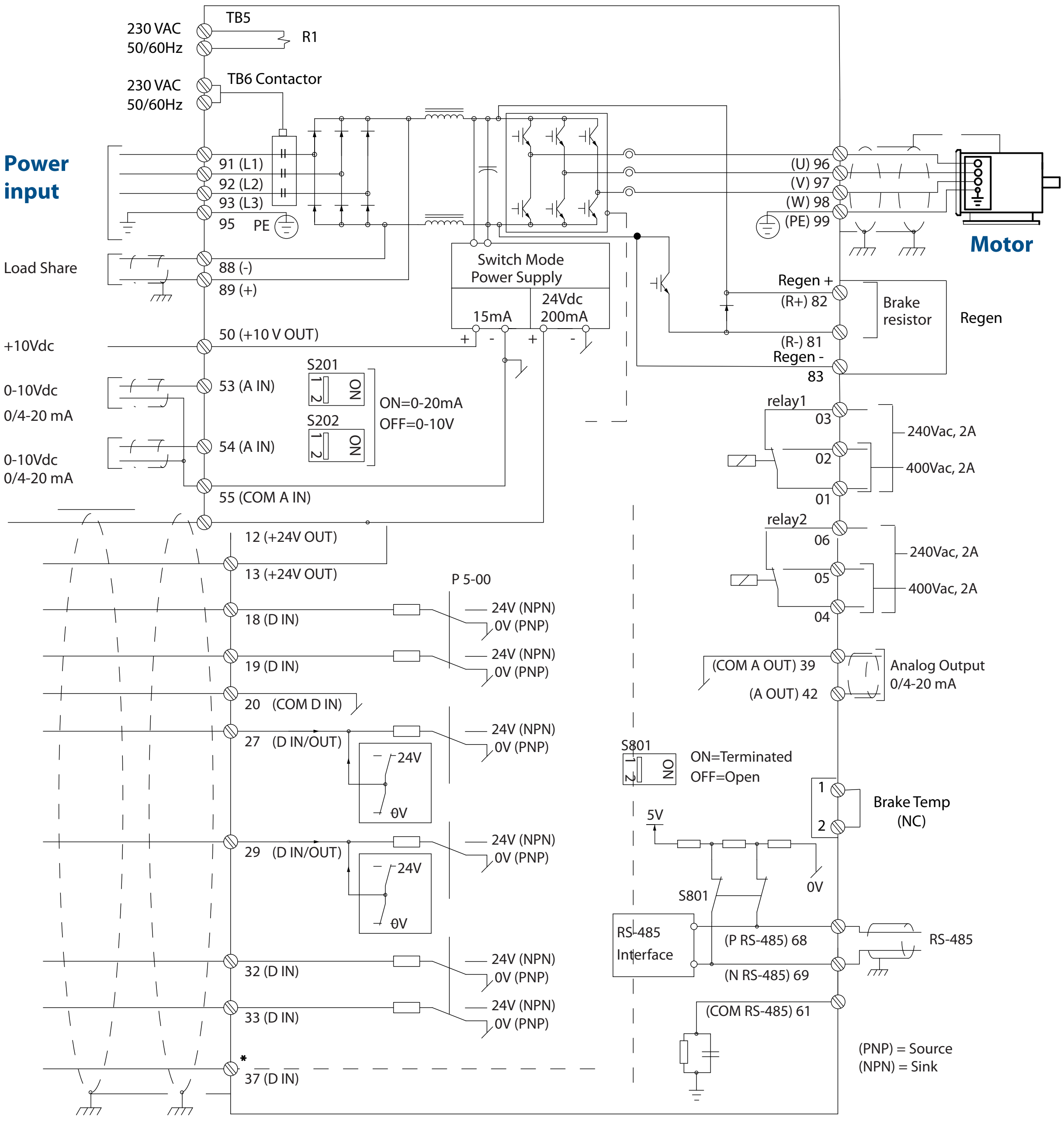


Drive with Disconnect Switch, Drive Fuses, and Output LC Filter

VLT® AQUA Drive

Connection diagram

This diagram shows a typical installation of the VLT® AQUA Drive.
The numbers represent the terminals on the drive.



VLT® AQUA Drive

VLT® AQUA Drives are available in numerous enclosure frame sizes illustrated at right and in several power ranges shown in the charts on the following pages.

Single Phase 200-240VAC

Output power – HP	Output Current – Amps		Continuous Output Power – kVA	Input Current – Amps	Estimated Power loss at max load – Watts	Output Frequency	Max Fuse Size – Amps	Weight – lbs.			Part Number Beginning	Protected Chassis/IP20	NEMA 1/IP21	NEMA 12/IP55	NEMA 4X/IP66
	Con-tinuous	Inter-mittent						Chassis	NEMA 1	NEMA 12/4X					
1 1/2	6.6	7.3	5	12.5	44		20	10.80	12.13	16.53	FC-202-P1K1-S2	A3	A3+	A5	A5
2	7.5	8.3	5	15	30		30		50.71		FC-202-P1K5-S2	n/a	B1	B1	B1
3	10.6	11.7	5	20.5	44		40		50.71		FC-202-P2K2-S2	n/a	B1	B1	B1
4	12.5	13.8	5	24	60		40		50.71		FC-202-P3K0-S2	n/a	B1	B1	B1
5	16.7	18.4	5	32	74	0-120 Hz	60		50.71		FC-202-P4K0-S2	n/a	B1	B1	B1
7.5	24.2	26.6	5	46	110		80		50.71		FC-202-P5K5-S2	n/a	B1	B1	B1
10	30.8	33.4	6.4	59	150		100		59.52		FC-202-P7K5-S2	n/a	B2	B2	B2
20	59.4	65.3	12.27	111	300		150		99.21		FC-202-P15K-S2	n/a	C1	C1	C1
30	88	96.8	18.3	172	440		200		143.30		FC-202-P22K-S2	n/a	C2	C2	C2

Three Phase 200-240VAC

Output power – HP	Output Current – Amps		Continuous Output Power – kVA	Input Current – Amps	Estimated Power loss at max load – Watts	Output Frequency	Max Fuse Size – Amps	Weight – lbs.			Part Number Beginning	Protected Chassis/IP20	NEMA 1/IP21	NEMA 12/IP55	NEMA 4X/IP66
	Con-tinuous	Inter-mittent						Chassis	NEMA 1	NEMA 12/4X					
1/3	1.8	1.98	0.65	1.6	21		10	10.80	12.13	21.38	FC-202-PK25-T2	A2	A2+	A4*	A4*
1/2	2.4	2.6	0.86	2.2	29		10	10.80	12.13	21.38	FC-202-PK37-T2	A2	A2+	A4*	A4*
3/4	3.5	3.9	1.26	3.2	42		10	10.80	12.13	21.38	FC-202-PK55-T2	A2	A2+	A4*	A4*
1	4.6	5.1	1.66	4.1	54		10	10.80	12.13	21.38	FC-202-PK75-T2	A2	A2+	A4*	A4*
1.5	6.6	7.3	2.38	5.9	63		20	10.80	12.13	21.38	FC-202-P1K1-T2	A2	A2+	A4*	A4*
2	7.5	8.3	2.7	6.8	82		20	10.80	12.13	21.38	FC-202-P1K5-T2	A2	A2+	A4*	A4*
3	10.6	11.7	3.82	9.5	116		20	10.80	12.13	21.38	FC-202-P2K2-T2	A2	A2+	A4*	A4*
4	12.5	13.8	4.5	11.3	155		32	14.55	16.53	29.76	FC-202-P3K0-T2	A3	A3+	A5	A5
5	16.7	18.4	6	15	185	0-120 Hz	32	14.55	16.53	29.76	FC-202-P3K7-T2	A3	A3+	A5	A5
7 1/2	24.2	26.6	8.7	22	269		63	26.46	50.71	50.71	FC-202-P5K5-T2	B3	B1	B1	B1
10	30.8	33.9	11.1	28	310		63	26.46	50.71	50.71	FC-202-P7K5-T2	B3	B1	B1	B1
15	46.2	50.8	16.6	42	447		63	26.46	50.71	50.71	FC-202-P11K-T2	B3	B1	B1	B1
20	59.4	65.3	21.4	54	602		80	51.81	59.52	59.52	FC-202-P15K-T2	B4	B2	B2	B2
25	74.8	82.3	26.9	68	737		125	51.81	99.21	99.21	FC-202-P18K-T2	B4	C1	C1	C1
30	88	96.8	31.7	80	845		125	77.16	99.21	99.21	FC-202-P22K-T2	C3	C1	C1	C1
40	115	126.5	41.4	104	1140		160	77.16	143.30	143.30	FC-202-P30K-T2	C3	C1	C1	C1
50	143	157.3	51.5	130	1353		200	110.23	143.30	143.30	FC-202-P37K-T2	C4	C2	C2	C2
60	179	196.9	61.2	154	1636		250	110.23	143.30	143.30	FC-202-P45K-T2	C4	C2	C2	C2

VLT® AQUA Drive

Single Phase 380-480VAC

Output power – HP	Output Current – Amps		Continuous Output Power – kVA	Input Current – Amps	Estimated Power loss at max load – Watts	Output Frequency	Max Fuse Size – Amps	Weight – lbs.			Part Number Beginning	Protected Chassis/IP20	NEMA 1/IP21	NEMA 12/IP55	NEMA 4X/IP66
	Con-tinuous	Inter-mittent						Chassis	NEMA 1	NEMA 12/4X					
10	14.5	15.4	11.6	30	300		63		50.71		FC-202-P7K5-S4	n/a	B1	B1	B1
15	21	23.1	16.7	41	440	0-120 Hz	80		59.52		FC-202-P11K-S4	n/a	B2	B2	B2
25	34	37.4	27.1	72	740		160		99.21		FC-202-P18K-S4	n/a	C1	C1	C1
50	65	71.5	51.8	135	1480		250		143.30		FC-202-P37K-S4	n/a	C2	C2	C2

Three Phase 380-480VAC

Output power – HP	Output Current – Amps		Continuous Output Power – kVA	Input Current – Amps	Estimated Power loss at max load – Watts	Output Frequency	Max Fuse Size – Amps	Weight – lbs.			Part Number Beginning	Protected Chassis/IP20	NEMA 1/IP21	NEMA 12/IP55	NEMA 4X/IP66
	Con-tinuous	Inter-mittent						Chassis	NEMA 1	NEMA 12/4X					
1/2	1.2	1.9	0.9	1	35		10	10.80	12.13	21.38	FC-202-PK37-T4	A2	A2+	A4*	A4*
3/4	1.6	2.6	1.3	1.4	42		10	10.80	12.13	21.38	FC-202-PK55-T4	A2	A2+	A4*	A4*
1	2.1	3.4	1.7	1.9	46		10	10.80	12.13	21.38	FC-202-PK75-T4	A2	A2+	A4*	A4*
1.5	2.7	3.0	2.4	2.7	58		10	10.80	12.13	21.38	FC-202-P1K1-T4	A2	A2+	A4*	A4*
2	3.4	3.7	2.7	3.1	62		10	10.80	12.13	21.38	FC-202-P1K5-T4	A2	A2+	A4*	A4*
3	4.8	5.3	3.8	4.3	88		20	10.80	12.13	21.38	FC-202-P2K2-T4	A2	A2+	A4*	A4*
4	6.3	6.9	5	5.7	116		20	10.80	12.13	21.38	FC-202-P3K0-T4	A2	A2+	A4*	A4*
5	8.2	9.0	6.5	7.4	124		20	10.80	12.13	21.38	FC-202-P4K0-T4	A2	A2+	A4*	A4*
7 1/2	11	12.1	8.8	9.9	187	0-120 Hz	32	14.55	16.53	31.31	FC-202-P5K5-T4	A3	A3+	A5	A5
10	14.5	15.4	11.6	13	255		32	14.55	16.53	31.31	FC-202-P7K5-T4	A3	A3+	A5	A5
15	21	23.1	16.7	19	278		63	26.46	50.71	50.71	FC-202-P11K-T4	B3	B1	B1	B1
20	27	29.7	21.5	25	392		63	26.46	50.71	50.71	FC-202-P15K-T4	B3	B1	B1	B1
25	34	37.4	27.1	31	465		63	26.46	50.71	50.71	FC-202-P18K-T4	B3	B1	B1	B1
30	40	44.0	31.9	36	525		63	51.81	59.52	59.52	FC-202-P22K-T4	B4	B2	B2	B2
40	52	57.2	41.4	47	698		80	51.81	59.52	59.52	FC-202-P30K-T4	B4	B2	B2	B2
50	65	71.5	51.8	59	739		100	51.81	99.21	99.21	FC-202-P37K-T4	B4	C1	C1	C1
60	80	88.0	63.7	73	843		125	77.16	143.30	143.30	FC-202-P45K-T4	C3	C1	C1	C1
75	105	115.5	83.7	95	1083		160	77.16	143.30	143.30	FC-202-P55K-T4	C3	C1	C1	C1
100	130	143.0	104	118	1384		250	110.23	143.30	143.30	FC-202-P75K-T4	C4	C2	C2	C2
125	160	176.0	128	145	1474		250	110.23	143.30	143.30	FC-202-P90K-T4	C4	C2	C2	C2

** if integral Fuses or Fused Disconnect are ordered then the frame will be A5. A2+ includes NEMA 1 Kit. A3+ includes NEMA 1 Kit.*

VLT® AQUA Drive (FC 202) 380-480 VAC

Output power – HP	Output Current – Amps		Output Power – kVA		Input Current – Amps	Estimated Power loss at max load – Watts	Output Frequency	Max External Input Mains Fuses – Amps	Weight – lbs.			Part Number Beginning	VLT® 6-Pulse		
	Con-tinuous	Inter-mittent	Con-tinuous	Inter-mittent					Chassis	NEMA 1	NEMA 12/4X		Chassis	NEMA 1	NEMA 12/4X
150	190	209	151	167	185	2257		315	135	135	135	FC-202N110T4	D3h	D1h	D1h
200	240	264	191	210	231	2719		350	135	135	135	FC-202N132T4	D3h	D1h	D1h
250	302	332	241	265	291	3622		400	135	135	135	FC-202N160T4	D4h	D2h	D2h
300	361	397	288	316	348	3561		550	275	300	300	FC-202N200T4	D4h	D2h	D2h
350	443	487	353	388	427	4558		630	275	275	275	FC-202N250T4	D4h	D2h	D2h
450	540	594	430	473	531	5703		700	487	487	580	FC-202P315T4	E2	E1	E1
500	590	649	470	517	580	6724			516	595	595	FC-202P355T4	E2	E1	E1
550	678	746	540	594	667	7819	0-120 Hz	900	520	600	600	FC-202P400T4	E2	E1	E1
600	730	803	582	640	718	8527			611	690	690	FC-202P450T4	E2	E1	E1
650	780	858	621	684	759	8876						FC-202P500T4		F1/F3	F1/F3
750	890	979	709	780	867	10424				2214	2214	FC-202P560T4		F1/F3	F1/F3
900	1050	1155	837	920	1022	11595		2000				FC-202P630T4		F1/F3	F1/F3
1000	1160	1276	924	1017	1129	13213			n/a			FC-202P710T4		F1/F3	F1/F3
1200	1380	1518	1100	1209	1344	16229				2748	2748	FC-202P800T4		F2/F4	F2/F4
1350	1530	1683	1219	1341	1490	16624		2500				FC-202P1M0T4		F2/F4	F2/F4

VLT® AQUA Drive Performance Data

VLT® AQUA Drive (FC 202) 600 V Motor Nominal Voltage 575 VAC

Output power – HP	Output Current – Amps		Continuous Output Power – kVA	Input Current – Amps	Estimated Power loss at max load – Watts	Output Frequency	Max Fuse Size – Amps	Weight – lbs.			Part Number Beginning	VLT® 6-Pulse		
	Con-tinuous	Inter-mittent						Chassis	NEMA 1	NEMA 12/4X		Chassis	NEMA 1	NEMA 12/4X
1	1.7	1.9	1.7	1.7	35		10	14.33	15.65	21.38	FC-202-PK75-T6	A2	A2+	A5
1.5	2.4	2.6	2.4	2.4	50		10	14.33	15.65	21.38	FC-202-P1K1-T6	A2	A2+	A5
2	2.7	3	2.7	2.7	65		10	14.33	15.65	21.38	FC-202-P1K5-T6	A2	A2+	A5
3	3.9	4.3	3.9	3.9	92		20	14.33	15.65	21.38	FC-202-P2K2-T6	A2	A2+	A5
4	4.9	5.4	4.9	4.9	122		20	14.33	15.65	21.38	FC-202-P3K0-T6	A2	A2+	A5
5	6.1	6.7	6.1	6.1	145		20	14.33	15.65	21.38	FC-202-P4K0-T6	A2	A2+	A5
7.5	9	9.9	9	9	195		32	14.55	16.53	31.31	FC-202-P5K5-T6	A3	A3+	A5
10	11	12.1	11	11	261		32	14.55	16.53	31.31	FC-202-P7K5-T6	A3	A3+	A5
15	18	20	17.9	18	225	0-120 Hz	40	26.46	50.71	50.71	FC-202-P11K-T6	B3	B1	B1
20	22	24	21.9	22	285		40	26.46	50.71	50.71	FC-202-P15K-T6	B3	B1	B1
25	27	30	26.9	27	329		50	26.46	50.71	50.71	FC-202-P18K-T6	B3	B1	B1
30	34	37	33.9	34	460		60	51.81	59.52	59.52	FC-202-P22K-T6	B4	B2	B2
40	41	45	40.8	41	560		80	51.81	59.52	59.52	FC-202-P30K-T6	B4	B2	B2
50	52	57	51.8	52	740		100	51.81	59.52	59.52	FC-202-P37K-T6	B4	B2	B2
60	62	68	61.7	62	860		150	77.16	77.16	77.16	FC-202-P45K-T6	C3	C1	C1
75	83	91	82.7	83	890		160	77.16	77.16	77.16	FC-202-P55K-T6	C3	C1	C1
100	100	110	99.6	100	1020		225	110.23	110.23	110.23	FC-202-P75K-T6	C4	C2	C2
125	131	144	130.5	131	1130		250	110.23	110.23	110.23	FC-202-P90K-T6	C4	C2	C2

VLT® AQUA Drive (FC 202) 575 V Motor Nominal Voltage 551-690 VAC

Output power – HP	Output Current – Amps		Output Power – kVA		Input Current – Amps	Estimated Power loss at max load – Watts	Output Frequency	Max External Input Mains Fuses – Amps	Weight – lbs.			Part Number Beginning	VLT® 6-Pulse		
	Con-tinuous	Inter-mittent	Con-tinuous	Inter-mittent					Chassis	NEMA 1	NEMA 12/4X		Chassis	NEMA 1	NEMA 12/4X
125	131	144	130	144	124	1891		250	135	135	135	FC-202N110T7	D3h	D1h	D1h
150	155	171	154	170	151	2230		315	135			FC-202N132T7	D3h	D1h	D1h
200	192	211	191	210	189	2617		350	135	135	135	FC-202N160T7	D3h	D1h	D1h
250	242	266	241	265	234	3197		350	275	275	275	FC-202N200T7	D4h	D2h	D2h
300	290	319	289	318	286	3757		400	275	275	275	FC-202N250T7	D4h	D2h	D2h
350	344	378	343	377	339	4307		500	275	275	275	FC-202N315T7	D4h	D2h	D2h
400	400	440	398	438	390	4756		550	275	275	275	FC-202N400T7	D4h	D2h	D2h
450	450	495	448	493	434	4974		700	487	580	580	FC-202P450T7	E2	E1	E1
500	500	550	498	548	482	5623	0-120 Hz		487			FC-202P500T7	E2	E1	E1
600	570	627	568	624	549	7018		900	520	600	600	FC-202P560T7	E2	E1	E1
650	630	693	627	690	607	7793				690	690	FC-202P630T7	E2	E1	E1
750	730	803	727	800	711	8933				2214 for P710, P800, P900		FC-202P710T7		F1/F3	F1/F3
950	850	935	847	931	828	10310					2214	FC-202P800T7		F1/F3	F1/F3
1050	945	1040	941	1035	920	11692		2000	611			FC-202P900T7		F1/F3	F1/F3
1150	1060	1166	1056	1161	1032	12909				2748 for P1M2 and P1M4	2748	FC-202P1M0T7		F2/F4	F2/F4
1350	1260	1386	1255	1380	1227	15358						FC-202P1M2T7		F2/F4	F2/F4
1550	1415	1557	1409	1550	1378	17602						FC-202P1M4T7		F2/F4	F2/F4

VLT® AQUA Drive Performance Data

VLT® AQUA Drive (FC 202) 690 V Motor Nominal Voltage 551-690 VAC

Output power – kW	Output Current – Amps		Output Power – kVA		Input Current – Amps	Estimated Power loss at max load – Watts	Output Frequency	Max External Input Mains Fuses – Amps	Weight – lbs.			Part Number Beginning	VLT® 6-Pulse		
	Con-tinuous	Inter-mittent	Con-tinuous	Inter-mittent					Chassis	NEMA 1	NEMA 12/4X		Chassis	NEMA 1	NEMA 12/4X
110	131	144	157	172	128	1951	0-120 Hz	250	181			FC-202N110T7	D3h	D1h	D1h
132	155	171	185	204	155	2303		315				FC-202N132T7	D3h	D1h	D1h
160	192	211	229	252	197	2707		350	201	230	230	FC-202N160T7	D3h	D1h	D1h
200	242	266	289	318	240	3320		350	247	277	277	FC-202N200T7	D4h	D2h	D2h
250	290	319	347	381	296	3899		400	271	301	301	FC-202N250T7	D4h	D2h	D2h
315	344	378	411	452	352	4485		500	304	334	334	FC-202N315T7	D4h	D2h	D2h
400	400	440	478	526	400	4924		550	334	364	364	FC-202N400T7	D4h	D2h	D2h
450	450	495	538	592	434	5128		700	487	580	580	FC-202P450T7	E2	E1	E1
500	500	550	598	657	482	5794						FC-202P500T7	E2	E1	E1
560	570	627	681	749	549	7221		900	520	600	600	FC-202P560T7	E2	E1	E1
630	630	693	753	828	607	8017			611	690	690	FC-202P630T7	E2	E1	E1
710	730	803	872	960	711	9212		2000	n/a	2214	2214	FC-202P710T7		F1/F3	F1/F3
800	850	935	1016	1117	828	10659						FC-202P800T7		F1/F3	F1/F3
900	945	1040	1129	1242	920	12080						FC-202P900T7		F1/F3	F1/F3
1000	1060	1166	1267	1394	1032	13305				2748	2748	FC-202P1M0T7		F2/F4	F2/F4
1200	1260	1386	1506	1656	1227	15865						FC-202P1M2T7		F2/F4	F2/F4
1400	1415	1557	1691	1860	1378	18173						FC-202P1M4T7		F2/F4	F2/F4

VLT® AQUA Drive **Index**

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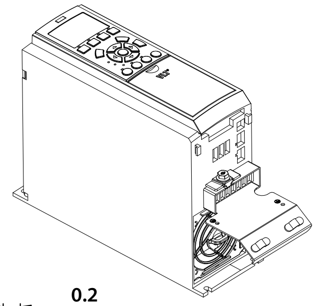
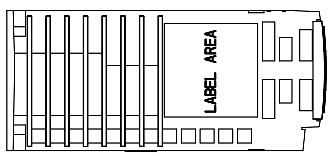
VLT® AQUA Drive Mechanical Specifications

A2 Frame Size	
Protected Chassis/IP20	No option card; bottom cable entry
Dimensions: in (mm)	Weight: 10.4 – 10.8 lbs. (4.7 – 4.9 kg)





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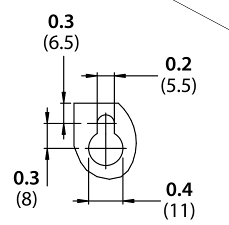
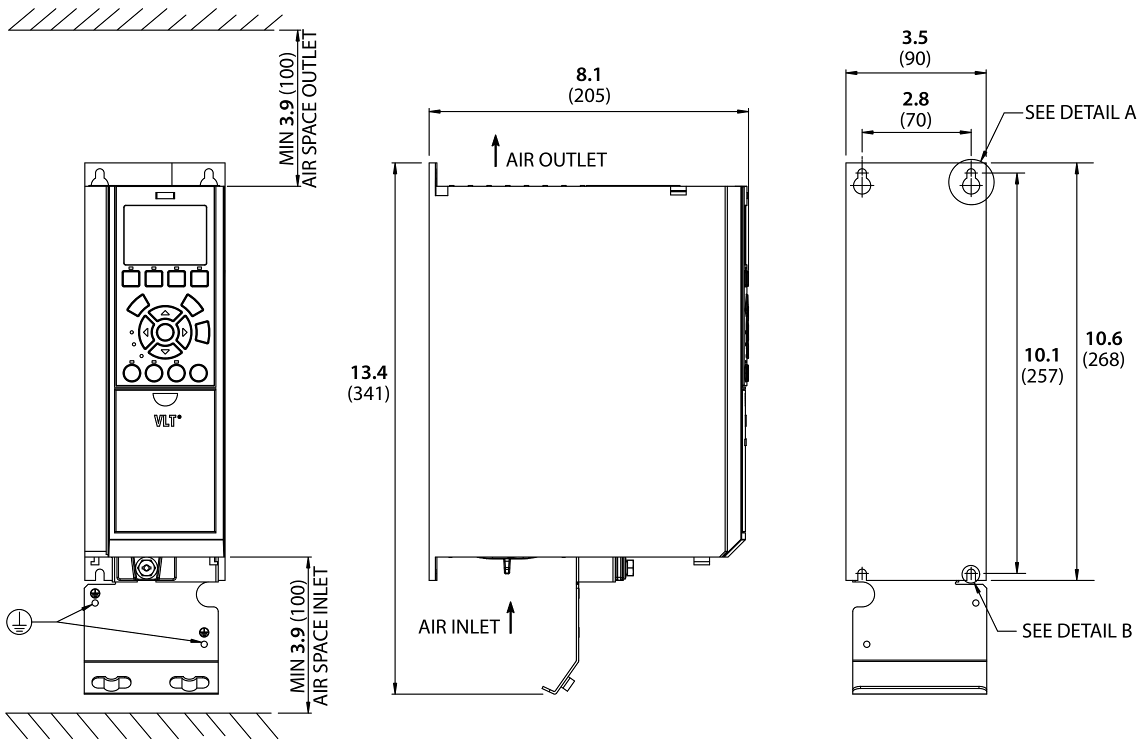
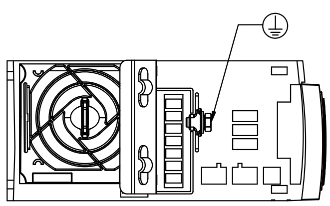
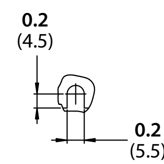


DETAIL A



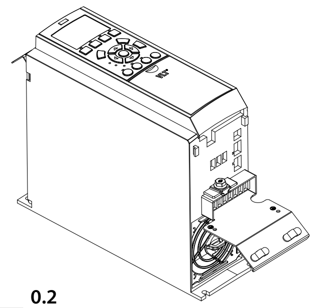

BOTTOM VIEW

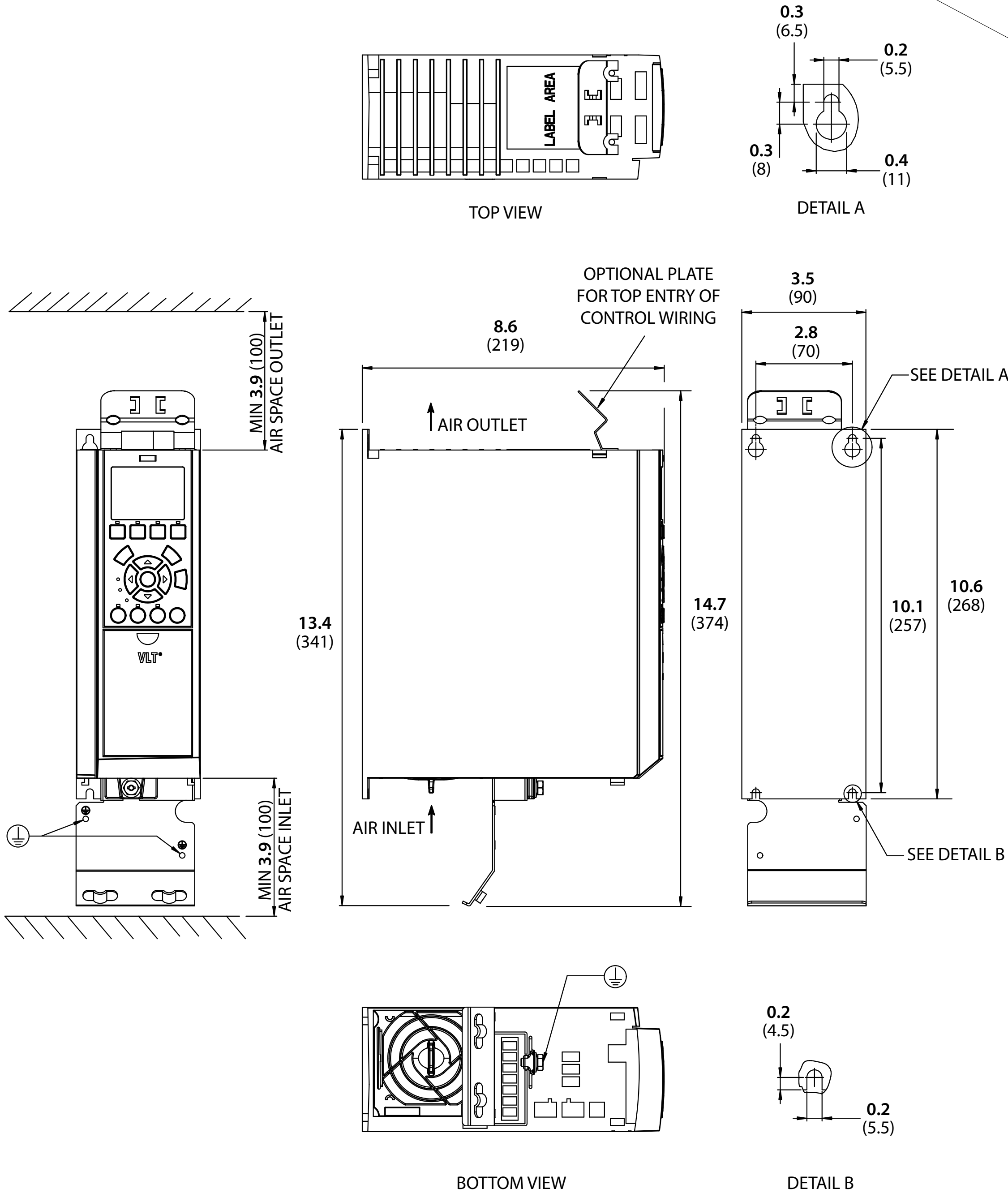


DETAIL B

VLT® AQUA Drive **Mechanical Specifications**

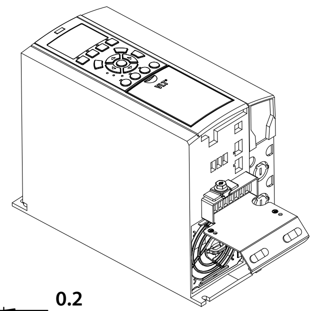
A2 Frame Size	
Protected Chassis/IP20	A and/or B option card; top cable entry
Dimensions: in (mm)	Weight: 10.4 – 10.8 lbs. (4.7 – 4.9 kg)

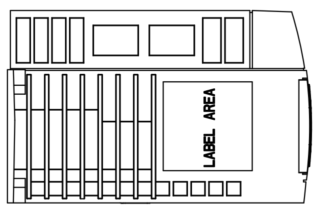




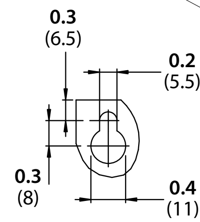
VLT® AQUA Drive Mechanical Specifications

A2 Frame Size	
Protected Chassis/IP20	C option card; bottom cable entry
Dimensions: in (mm)	Weight: 10.4 – 10.8 lbs. (4.7 – 4.9 kg)

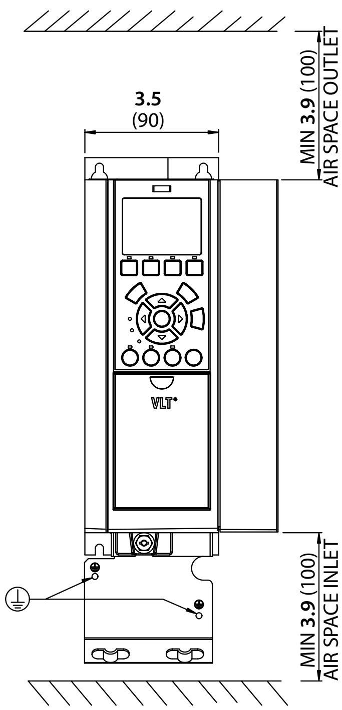


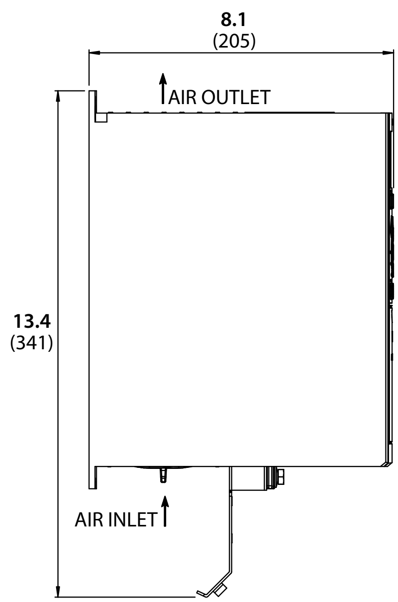


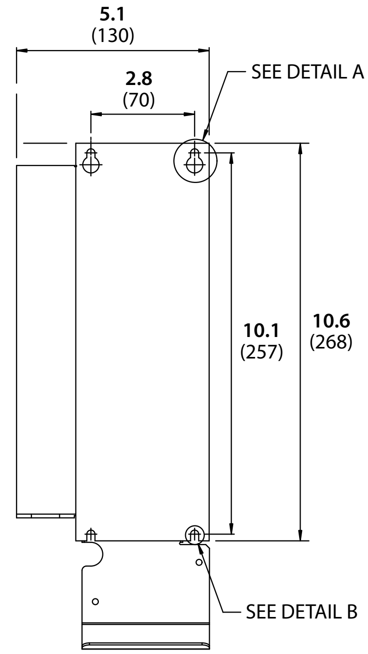
TOP VIEW

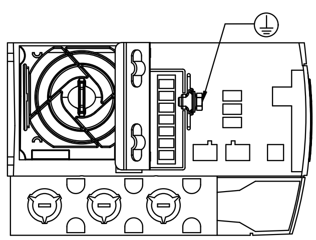


DETAIL A

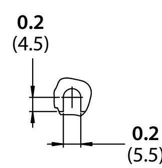








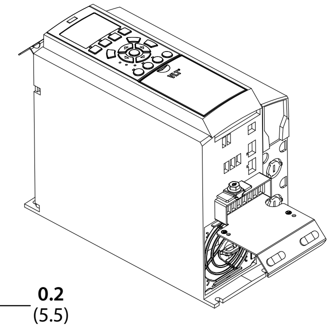
BOTTOM VIEW

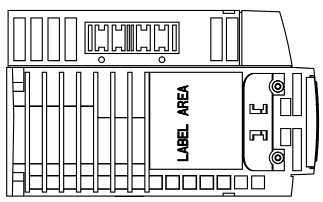


DETAIL B

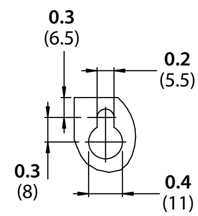
VLT® AQUA Drive Mechanical Specifications

A2 Frame Size	
Protected Chassis/IP20	A and/or B option card; C option card; top cable entry
Dimensions: in (mm)	Weight: 10.4 – 10.8 lbs. (4.7 – 4.9 kg)

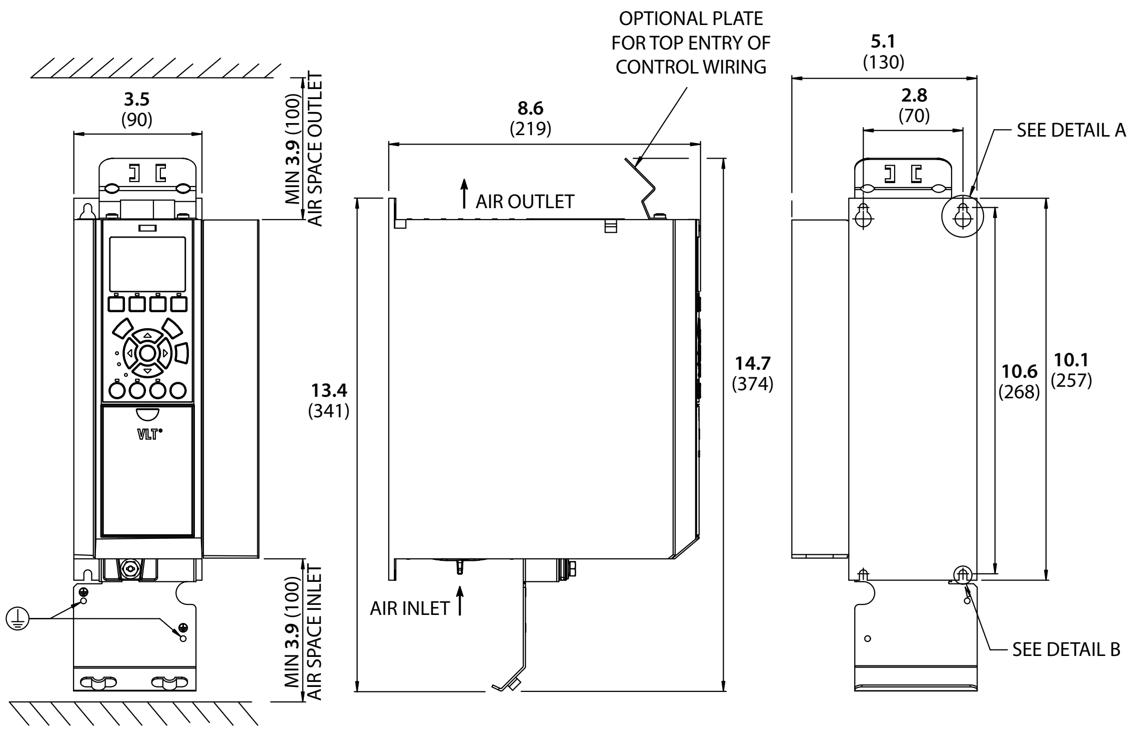


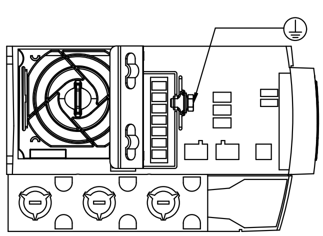


TOP VIEW

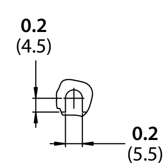


DETAIL A





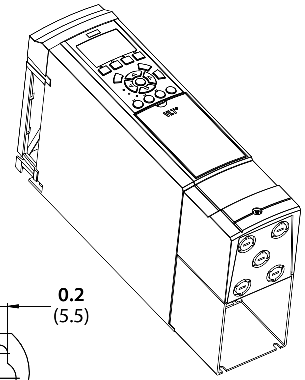
BOTTOM VIEW

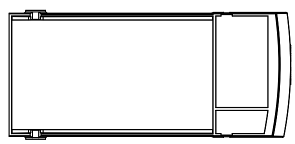


DETAIL B

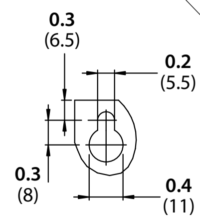
VLT® AQUA Drive Mechanical Specifications

A2 Frame Size	
NEMA 1/IP21	No option card; bottom cable entry
Dimensions: in (mm)	Weight: 10.4 – 10.8 lbs. (4.7 – 4.9 kg) NEMA 1 Kit: 1.3 lbs. (0.6 kg)

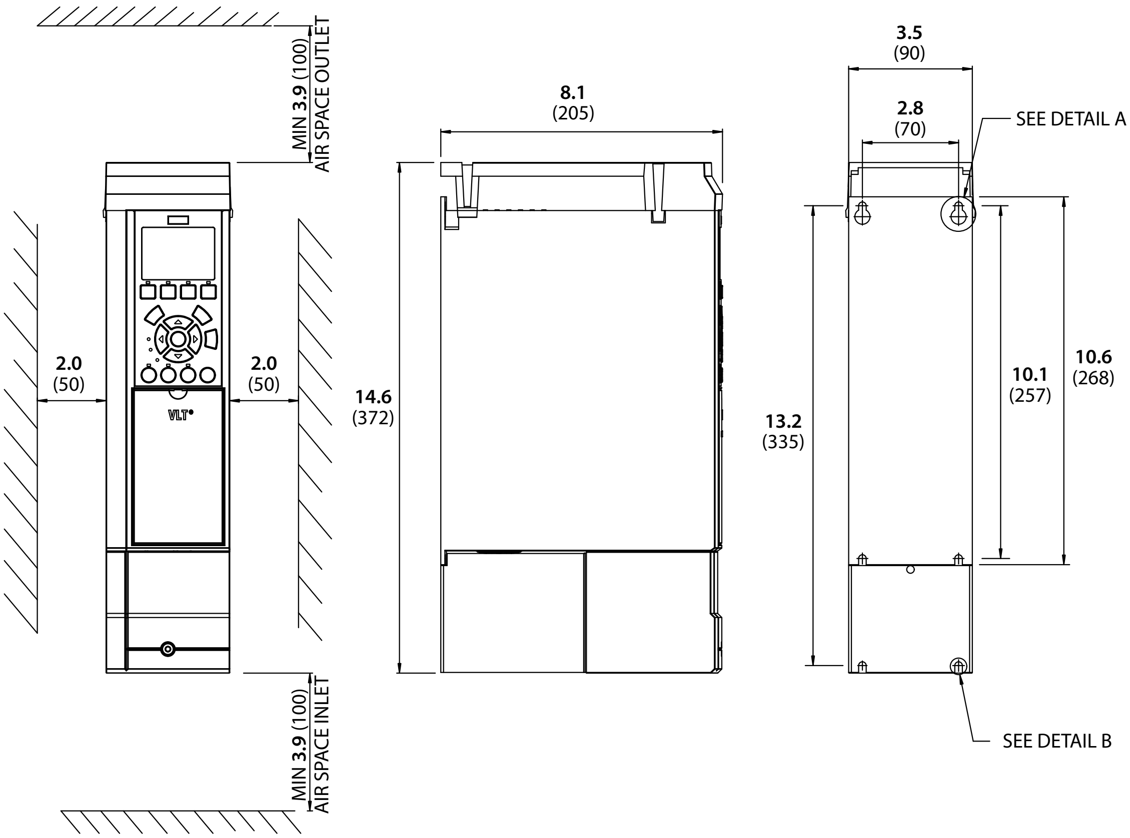


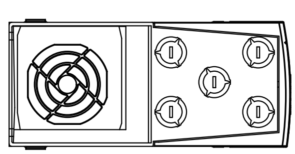


TOP VIEW



DETAIL A





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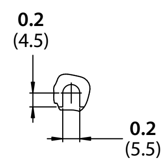
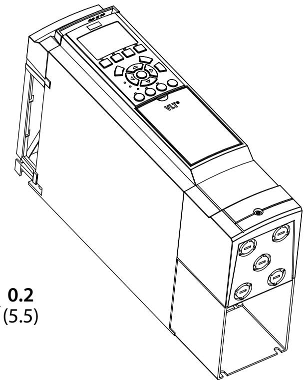
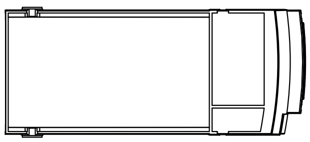


DETAIL B

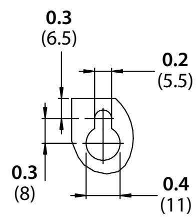
VLT® AQUA Drive Mechanical Specifications

A2 Frame Size	
Protected Chassis/IP20 with NEMA 1 kit	A and/or B option card; bottom cable entry
Dimensions: in (mm)	Weight: 10.4 – 10.8 lbs. (4.7 – 4.9 kg) NEMA 1 Kit: 1.3 lbs. (0.6 kg)

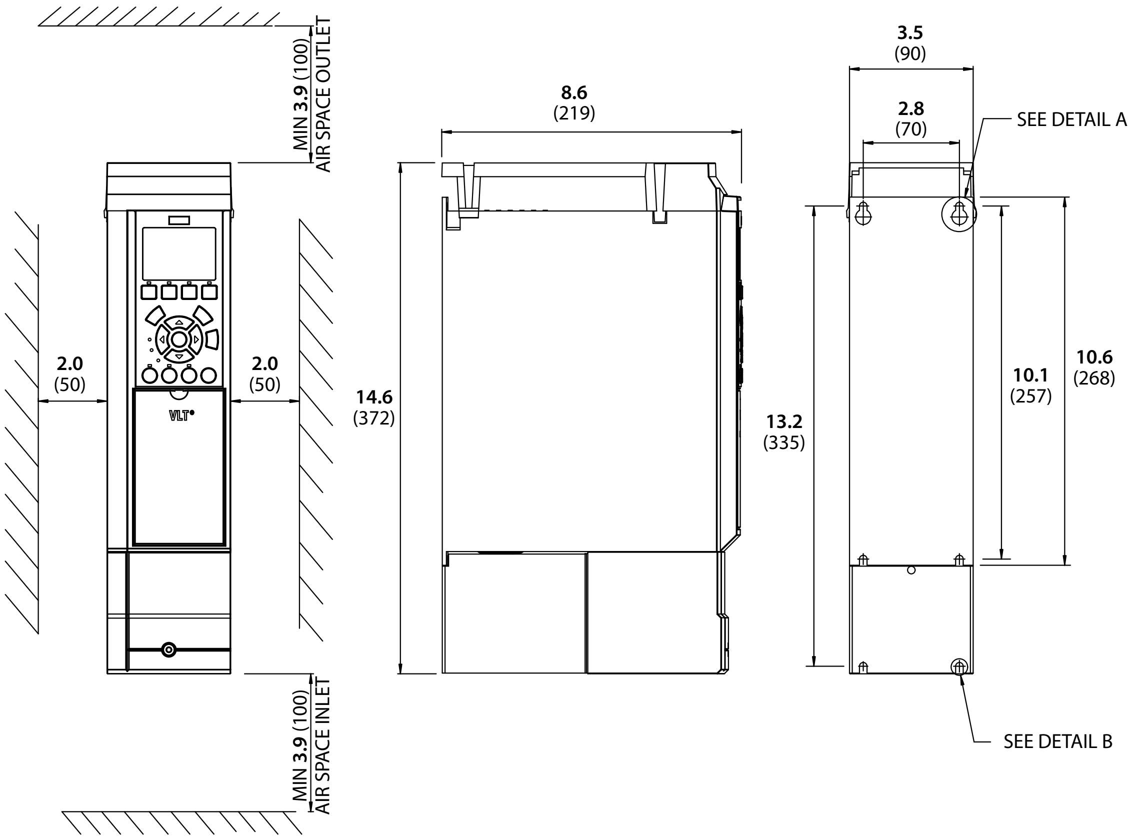


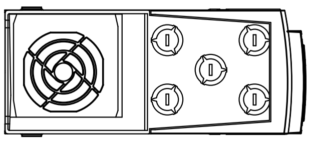


TOP VIEW

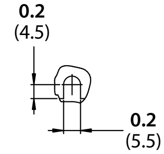


DETAIL A





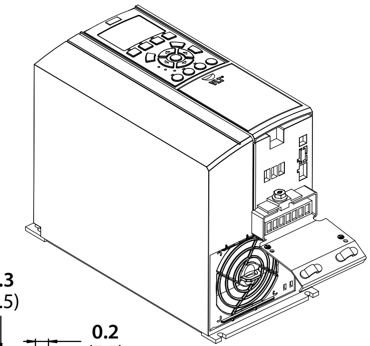
BOTTOM VIEW

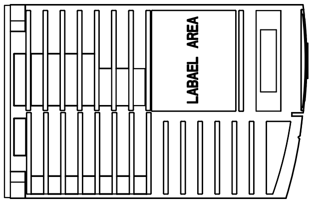


DETAIL B

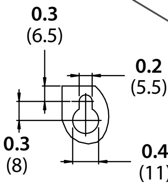
VLT® AQUA Drive Mechanical Specifications

A3 Frame Size	
Protected Chassis/IP20	No option card; bottom cable entry
Dimensions: in (mm)	Weight: 14.3 – 14.6 lbs. (6.5 – 6.6 kg)

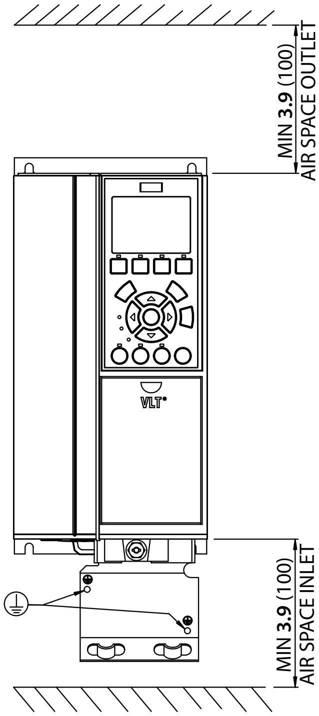


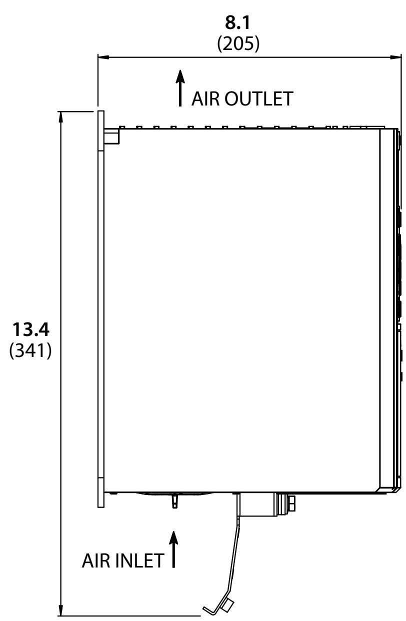


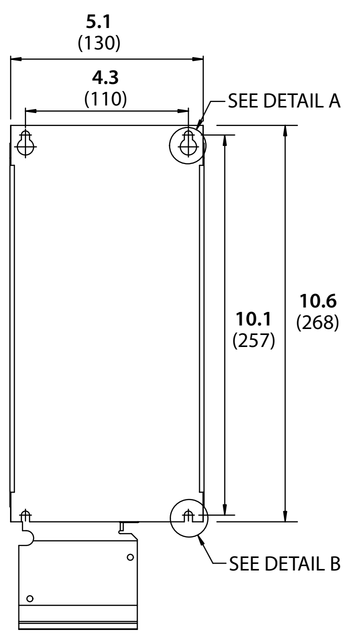
TOP VIEW

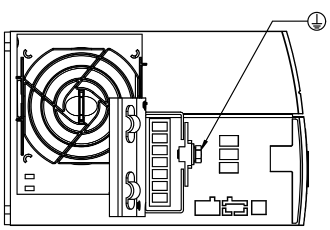


DETAIL A

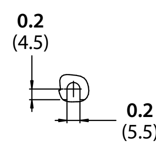








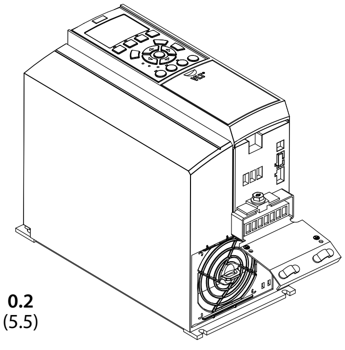
BOTTOM VIEW

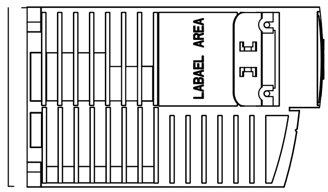


DETAIL B

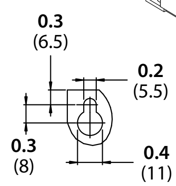
VLT® AQUA Drive **Mechanical Specifications**

A3 Frame Size	
Protected Chassis/IP20	A and/or B option card; top cable entry
Dimensions: in (mm)	Weight: 14.3 – 14.6 lbs. (6.5 – 6.6 kg)

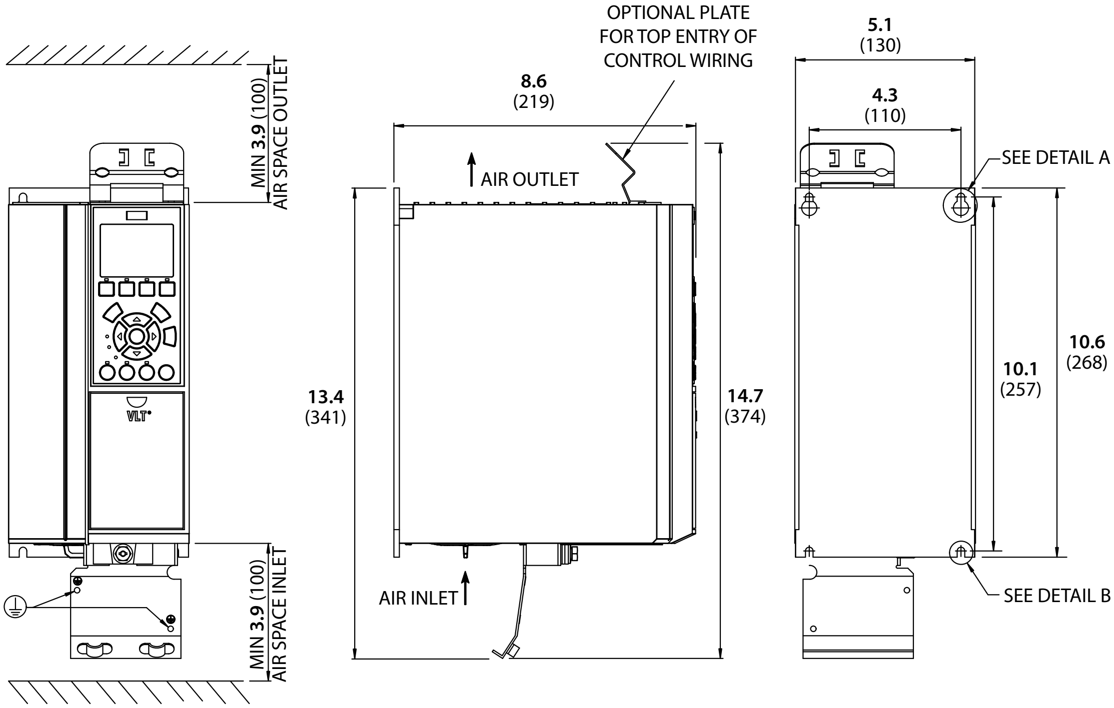


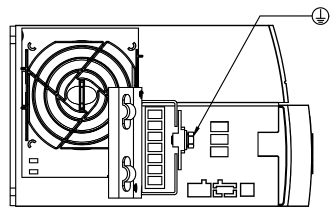


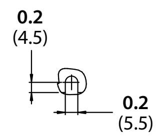
TOP VIEW



DETAIL A



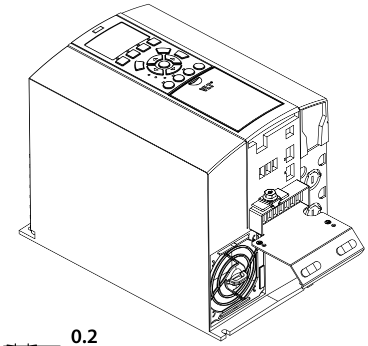

BOTTOM VIEW

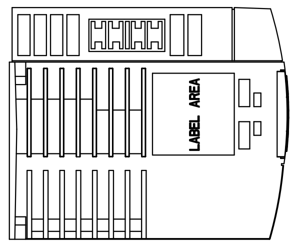


DETAIL B

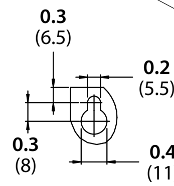
VLT® AQUA Drive Mechanical Specifications

A3 Frame Size	
Protected Chassis/IP20	C option card; bottom cable entry
Dimensions: in (mm)	Weight: 14.3 – 14.6 lbs. (6.5 – 6.6 kg)

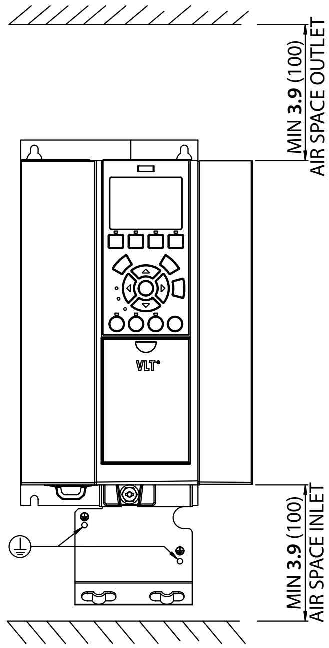


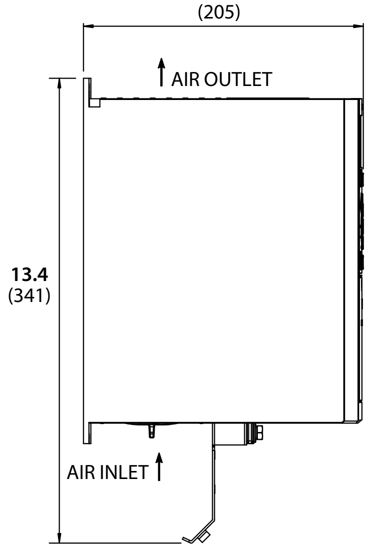


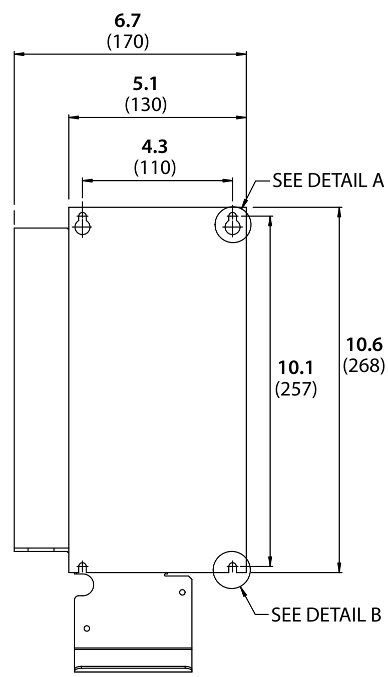
TOP VIEW

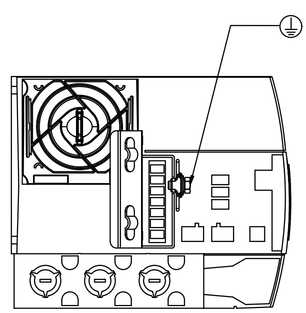


DETAIL A

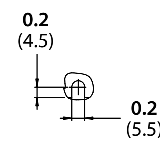








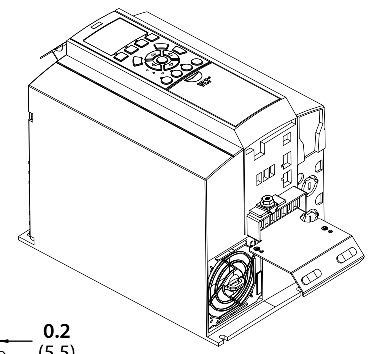
BOTTOM VIEW

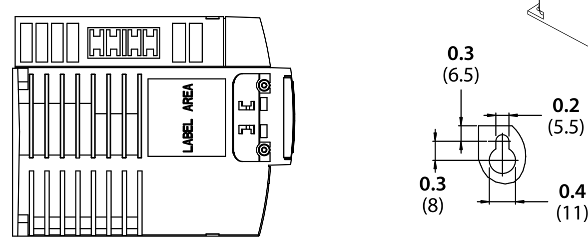


DETAIL B

VLT® AQUA Drive Mechanical Specifications

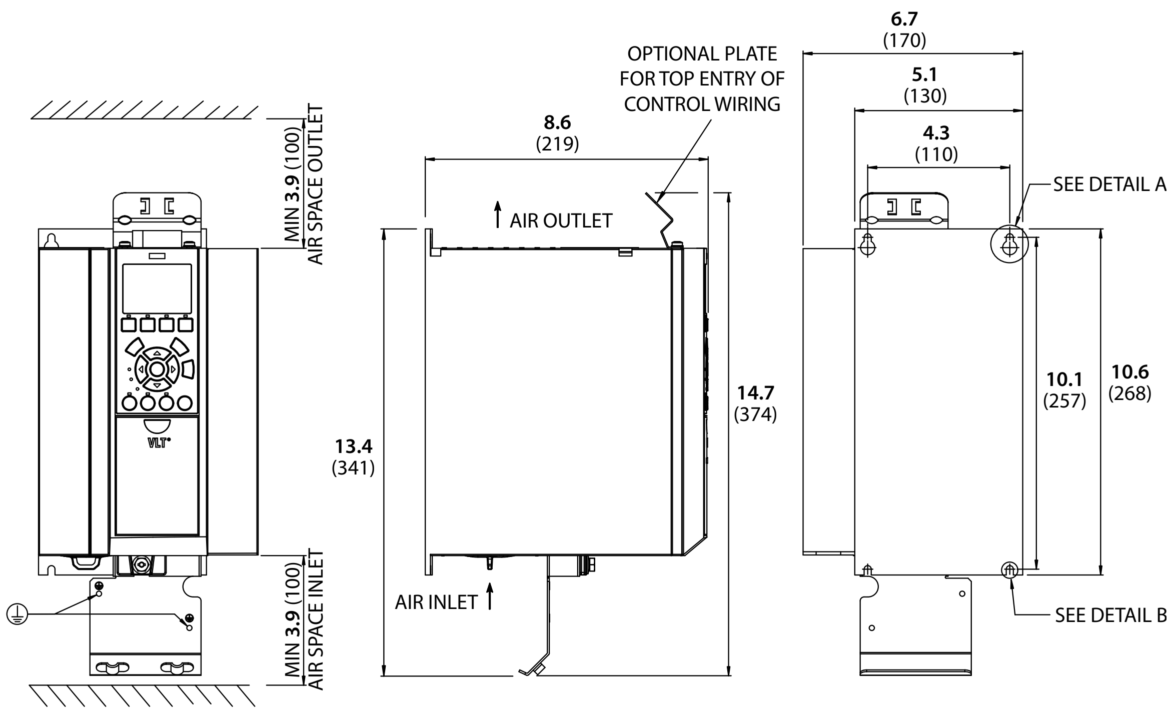
A3 Frame Size	
Protected Chassis/IP20	A and/or B option card; C option card; top cable entry
Dimensions: in (mm)	Weight: 14.3 – 14.6 lbs. (6.5 – 6.6 kg)

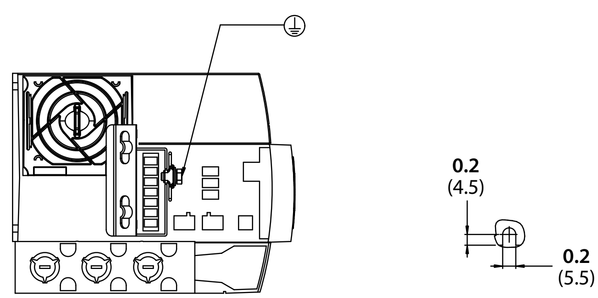




TOP VIEW

DETAIL A



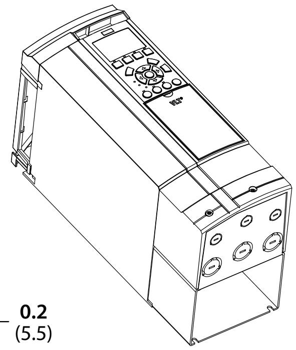


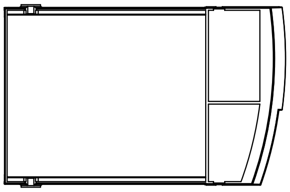
BOTTOM VIEW

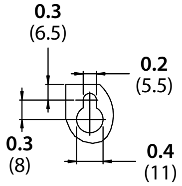
DETAIL B

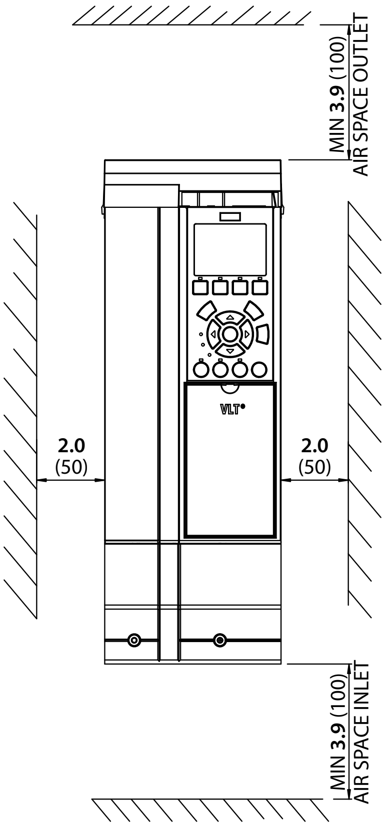
VLT® AQUA Drive Mechanical Specifications

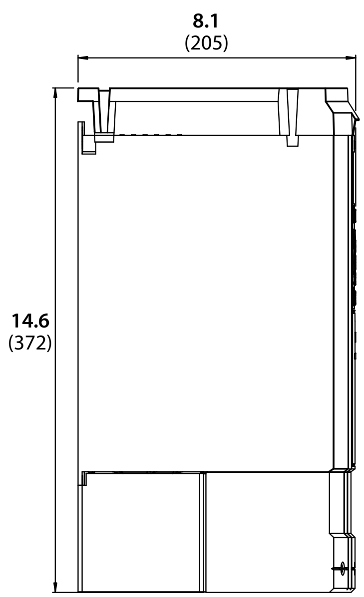
A3 Frame Size	
Protected Chassis/IP20 with NEMA 1 kit	No option card; bottom cable entry
Dimensions: in (mm)	Weight: 14.3 – 14.6 lbs. (6.5 – 6.6 kg) NEMA 1 Kit: 2 lbs. (0.9 kg)

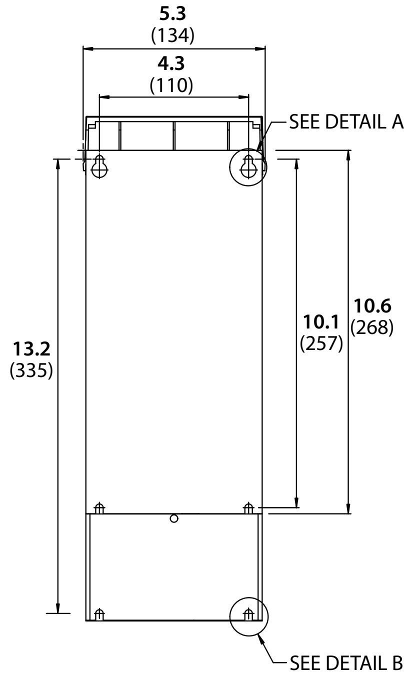


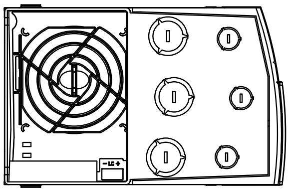


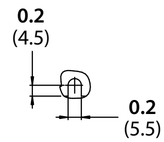






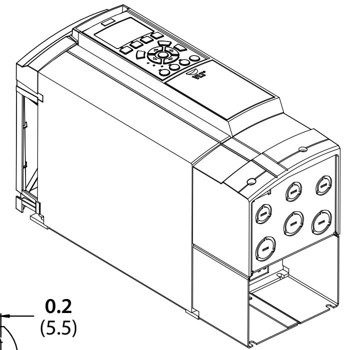


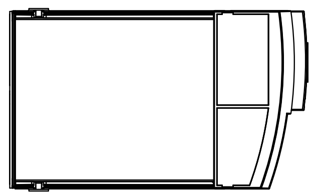




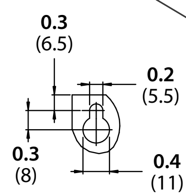
VLT® AQUA Drive Mechanical Specifications

A3 Frame Size	
Protected Chassis/IP20 with NEMA 1 kit	A and/or B option card; bottom cable entry
Dimensions: in (mm)	Weight: 14.3 – 14.6 lbs. (6.5 – 6.6 kg) NEMA 1 Kit: 2 lbs. (0.9 kg)

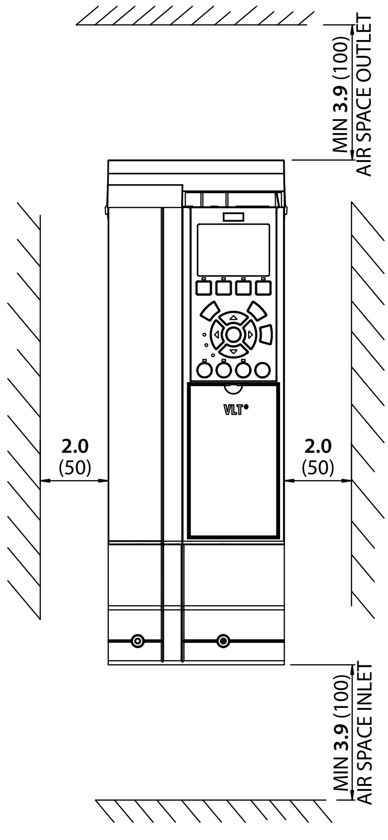


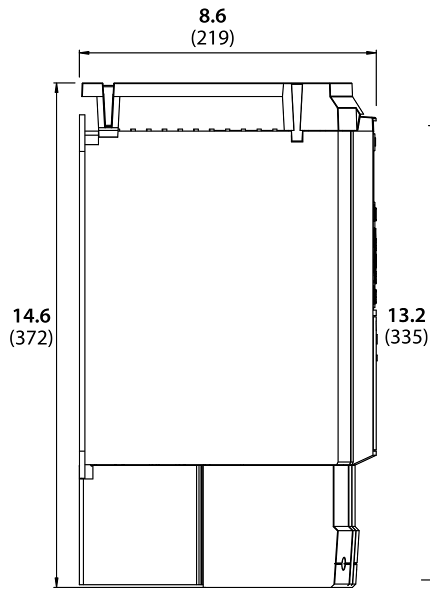


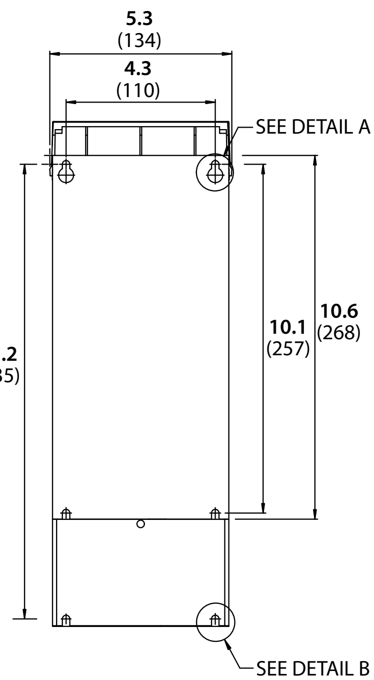
TOP VIEW

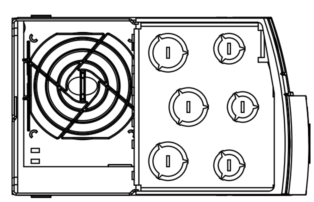


DETAIL A

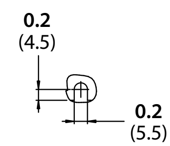








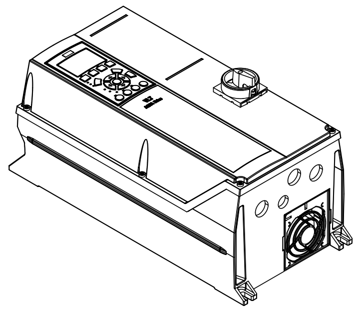
BOTTOM VIEW

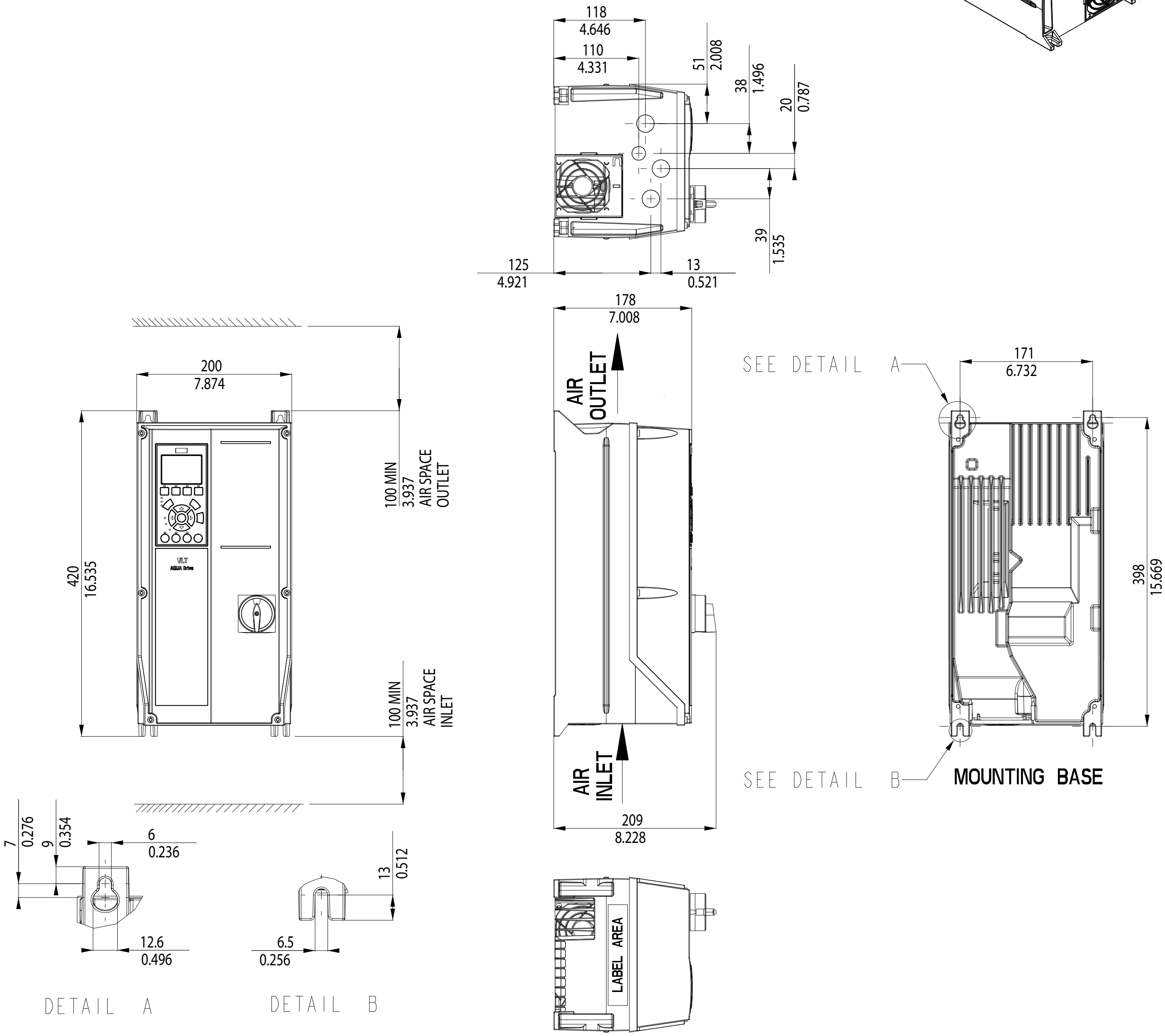


DETAIL B

VLT® AQUA Drive Mechanical Specifications

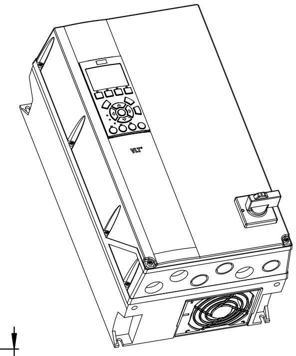
A4 Frame Size	
NEMA 12/IP55 & NEMA 4X/IP66	(Optional mains disconnect lock-out switch shown)
Dimensions: mm (in)	Weight: 22-24 lbs. (9.7 kg)

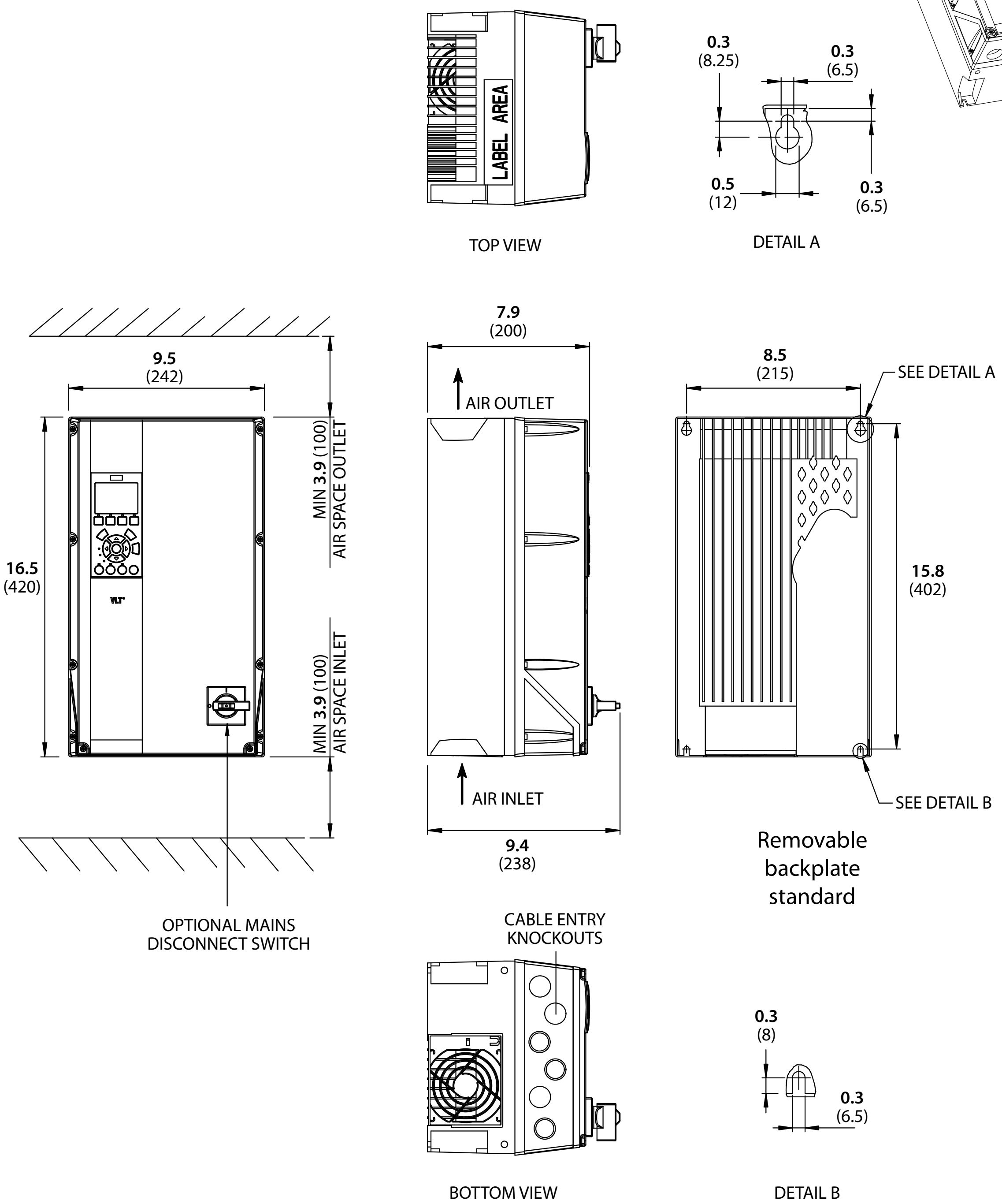




VLT® AQUA Drive Mechanical Specifications

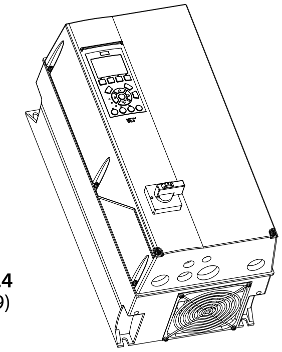
A5 Frame Size	
NEMA 12/IP55 & NEMA 4X/IP66	(Optional mains disconnect lock-out switch shown)
Dimensions: in (mm)	Weight: 29.8 – 31.3 lbs. (13.5 – 14.2 kg)

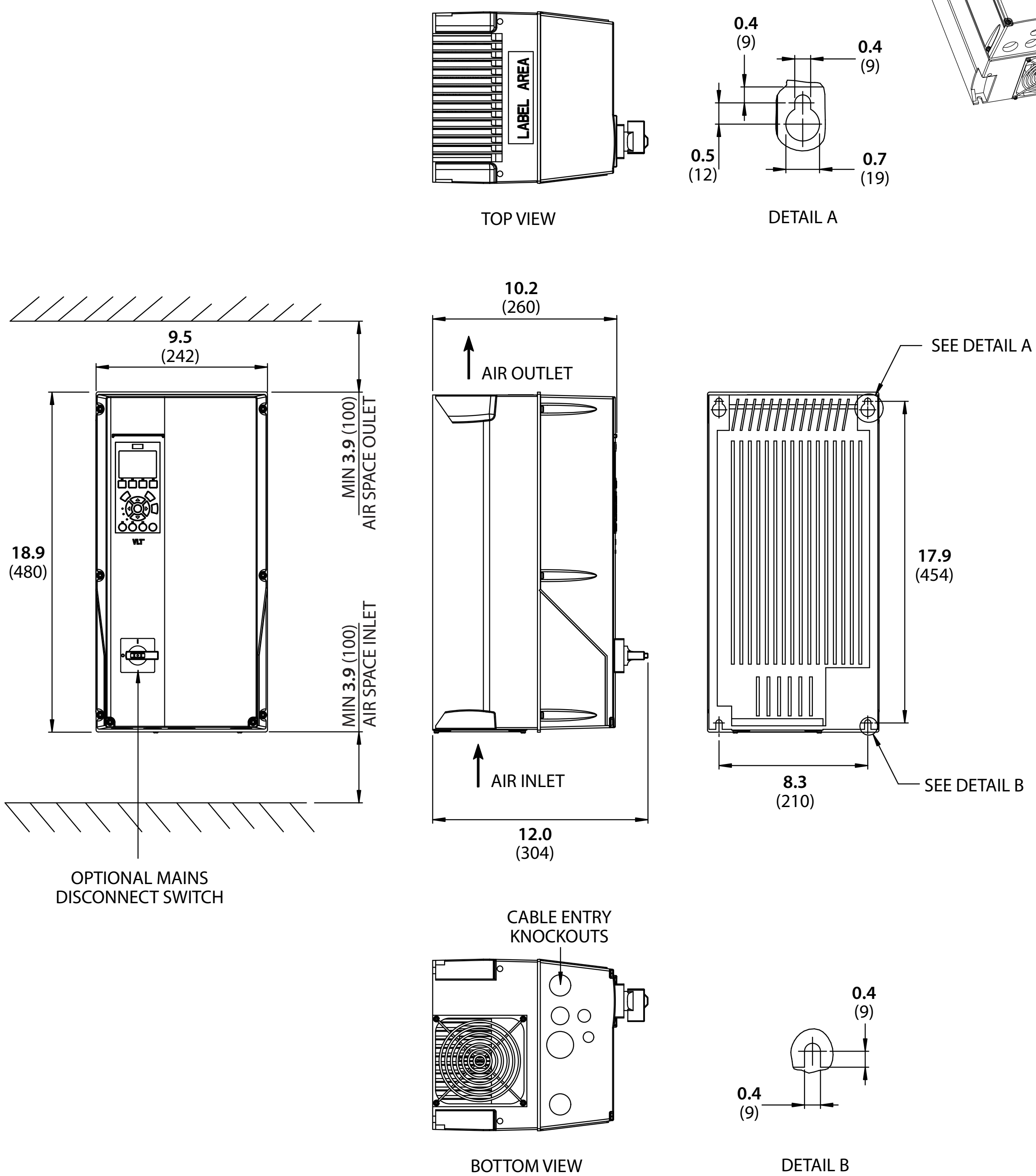




VLT® AQUA Drive Mechanical Specifications

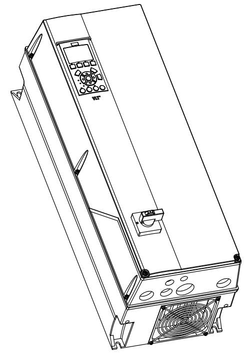
B1 Frame Size	
NEMA 1 & NEMA 12/IP55 & NEMA 4X/IP66	(Optional mains disconnect lock-out switch shown)
Dimensions: in (mm)	Weight: 51 lbs. (23 kg)

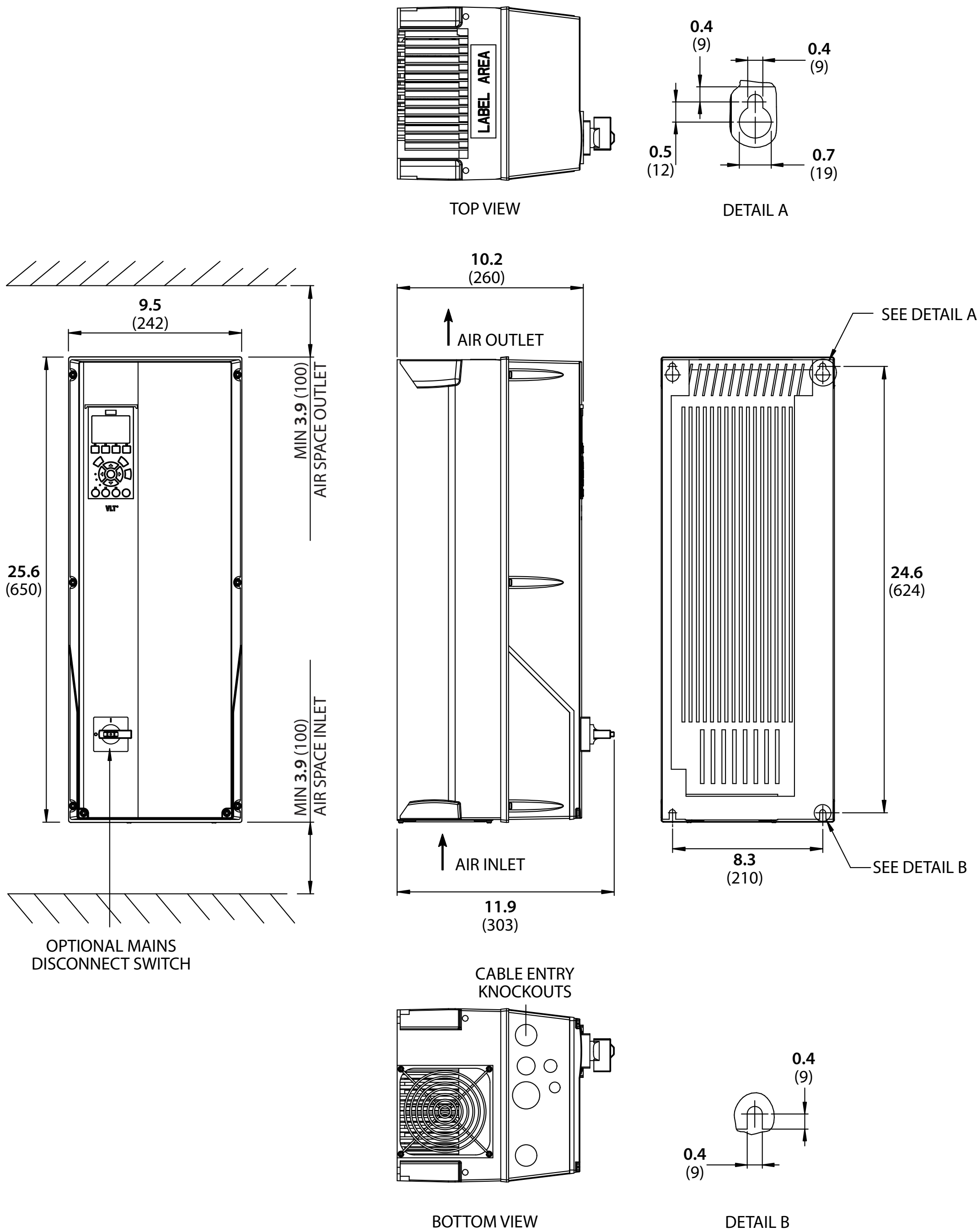




VLT® AQUA Drive Mechanical Specifications

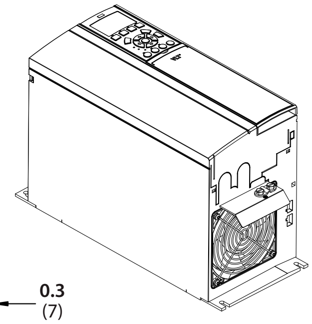
B2 Frame Size	
NEMA 1 & NEMA 12/IP55 & NEMA 4X/IP66	(Optional mains disconnect lock-out switch shown)
Dimensions: in (mm)	Weight: 60 lbs. (27 kg)

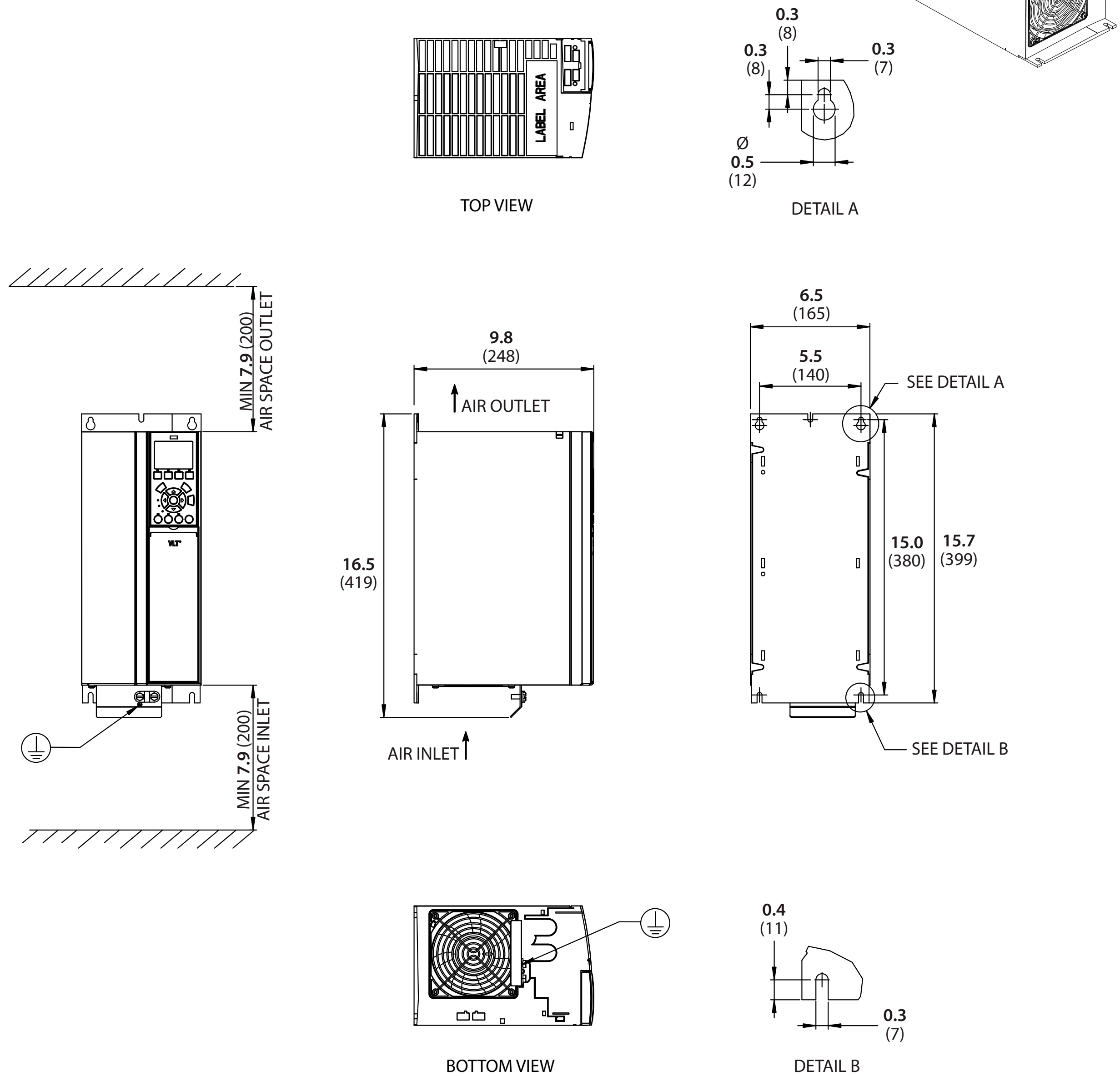




VLT® AQUA Drive Mechanical Specifications

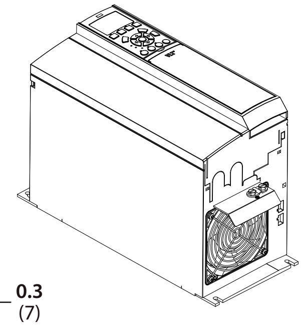
B3 Frame Size	
Protected Chassis/IP20	No option card; bottom cable entry
Dimensions: in (mm)	Weight: 26 – 30 lbs. (12 – 14 kg)

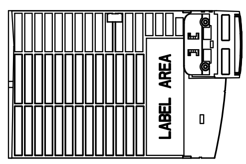




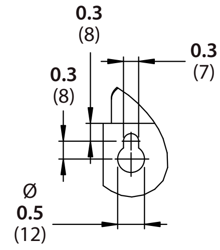
VLT® AQUA Drive **Mechanical Specifications**

B3 Frame Size	
Protected Chassis/IP20	A and/or B option card; top cable entry
Dimensions: in (mm)	Weight: 26 – 30 lbs. (12 – 14 kg)

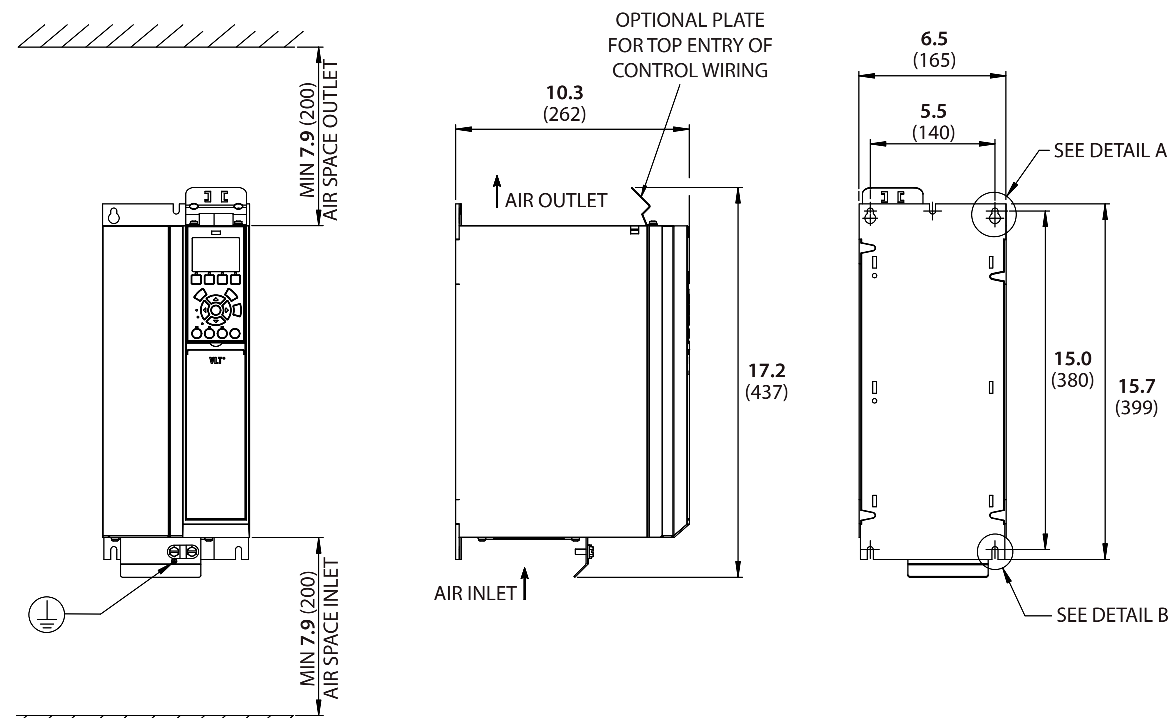


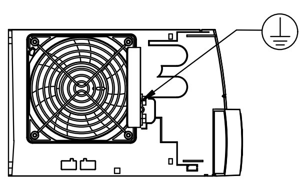


TOP VIEW

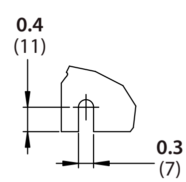


DETAIL A





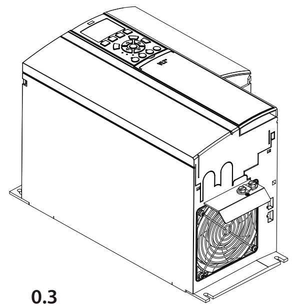
BOTTOM VIEW

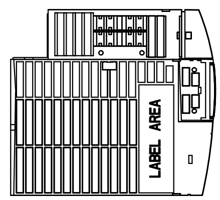


DETAIL B

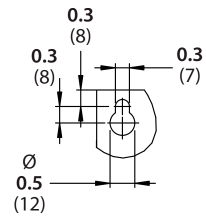
VLT® AQUA Drive Mechanical Specifications

B3 Frame Size	
Protected Chassis/IP20	C option card; bottom cable entry
Dimensions: in (mm)	Weight: 26 – 30 lbs. (12 – 14 kg)

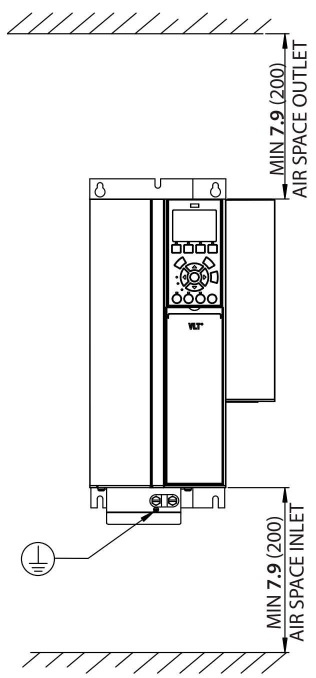


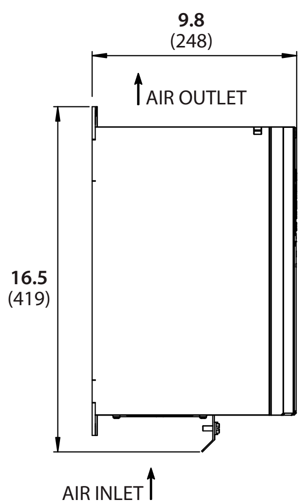


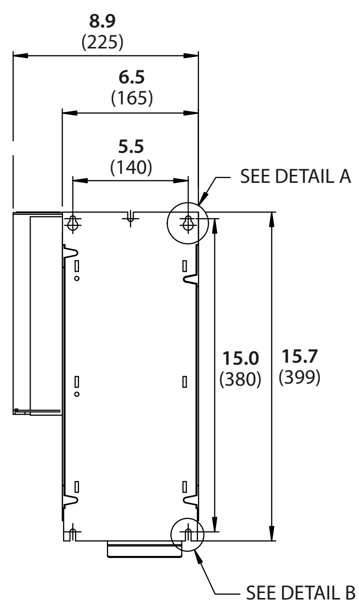
TOP VIEW

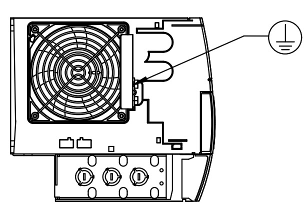


DETAIL A

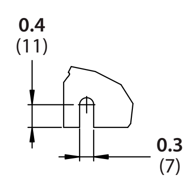








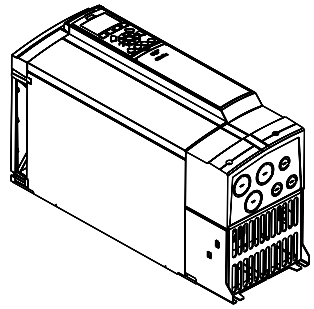
BOTTOM VIEW

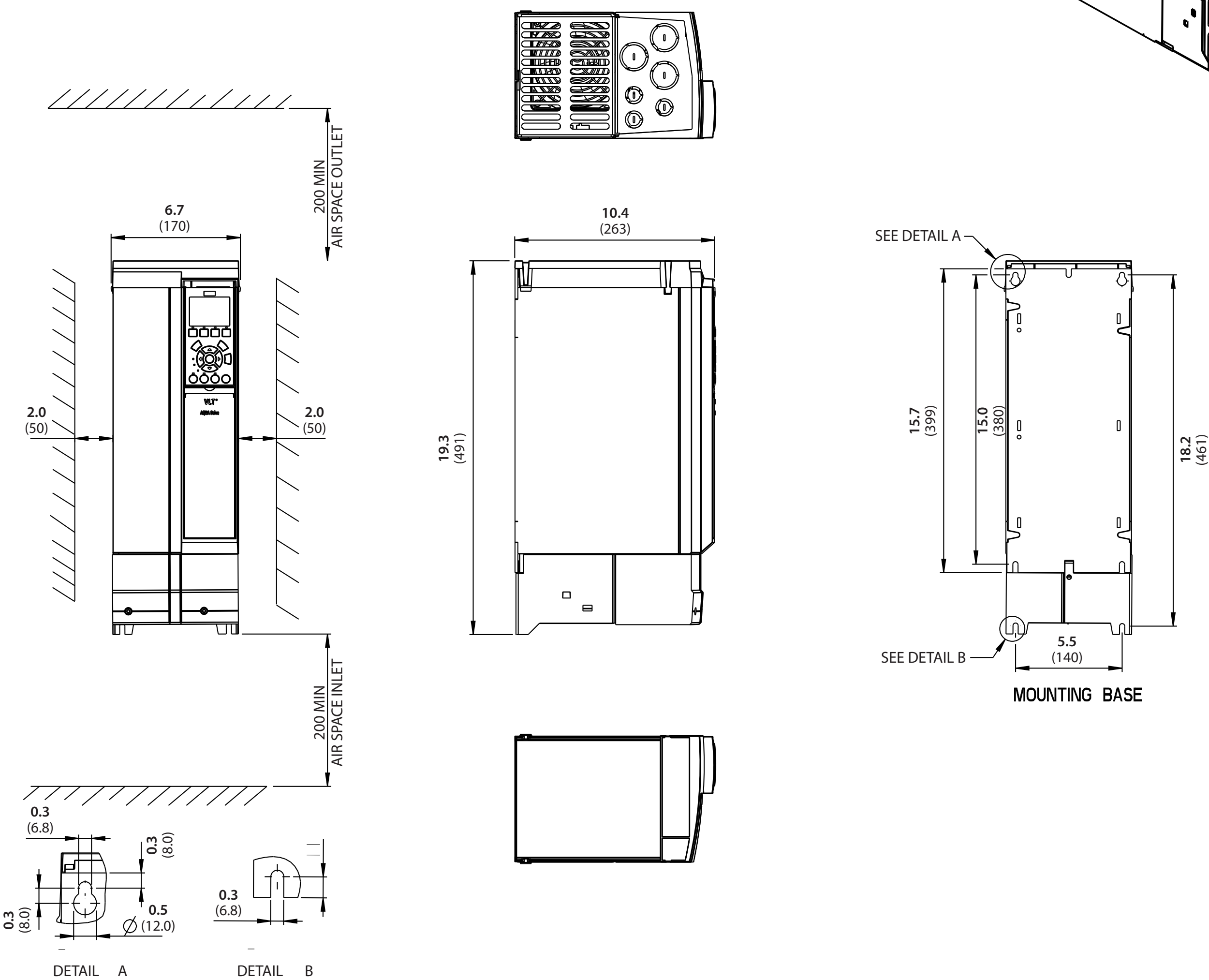


DETAIL B

VLT® AQUA Drive Mechanical Specifications

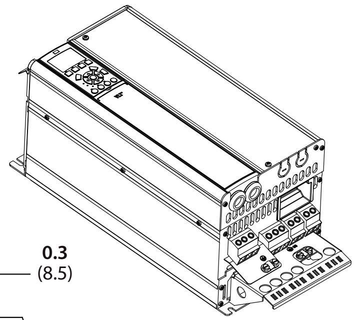
B3 Frame Size	
Protected Chassis/IP20 with NEMA 1 kit	A and/or B option card; top cable entry
Dimensions: in (mm)	Weight: 26 – 30 lbs. (12 – 14 kg)

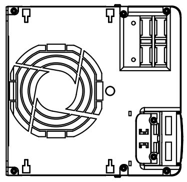




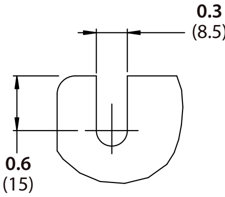
VLT® AQUA Drive Mechanical Specifications

B4 Frame Size	
Protected Chassis/IP20	
Dimensions: in (mm)	Weight: 53 lbs. (24 kg)

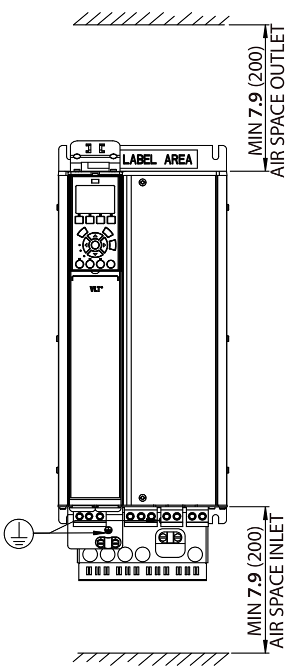


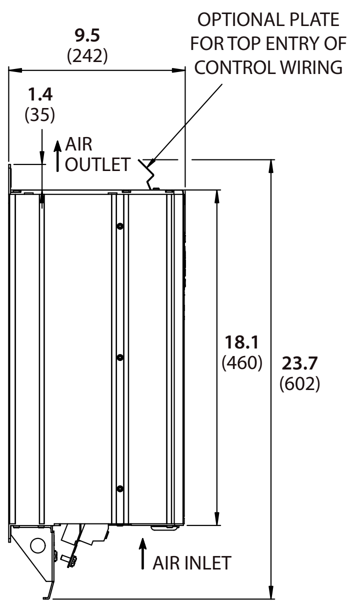


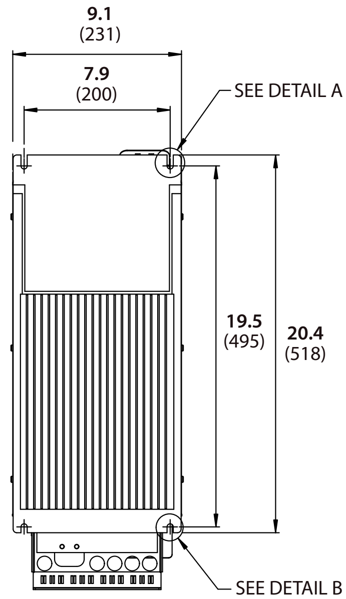
TOP VIEW

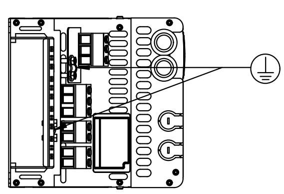


DETAIL A

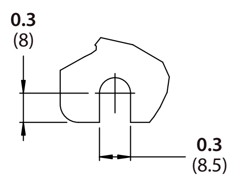








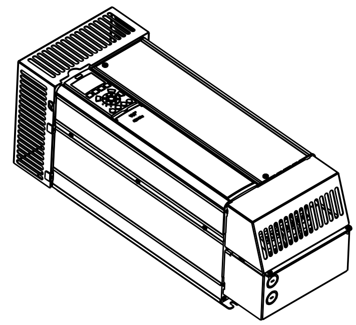
BOTTOM VIEW

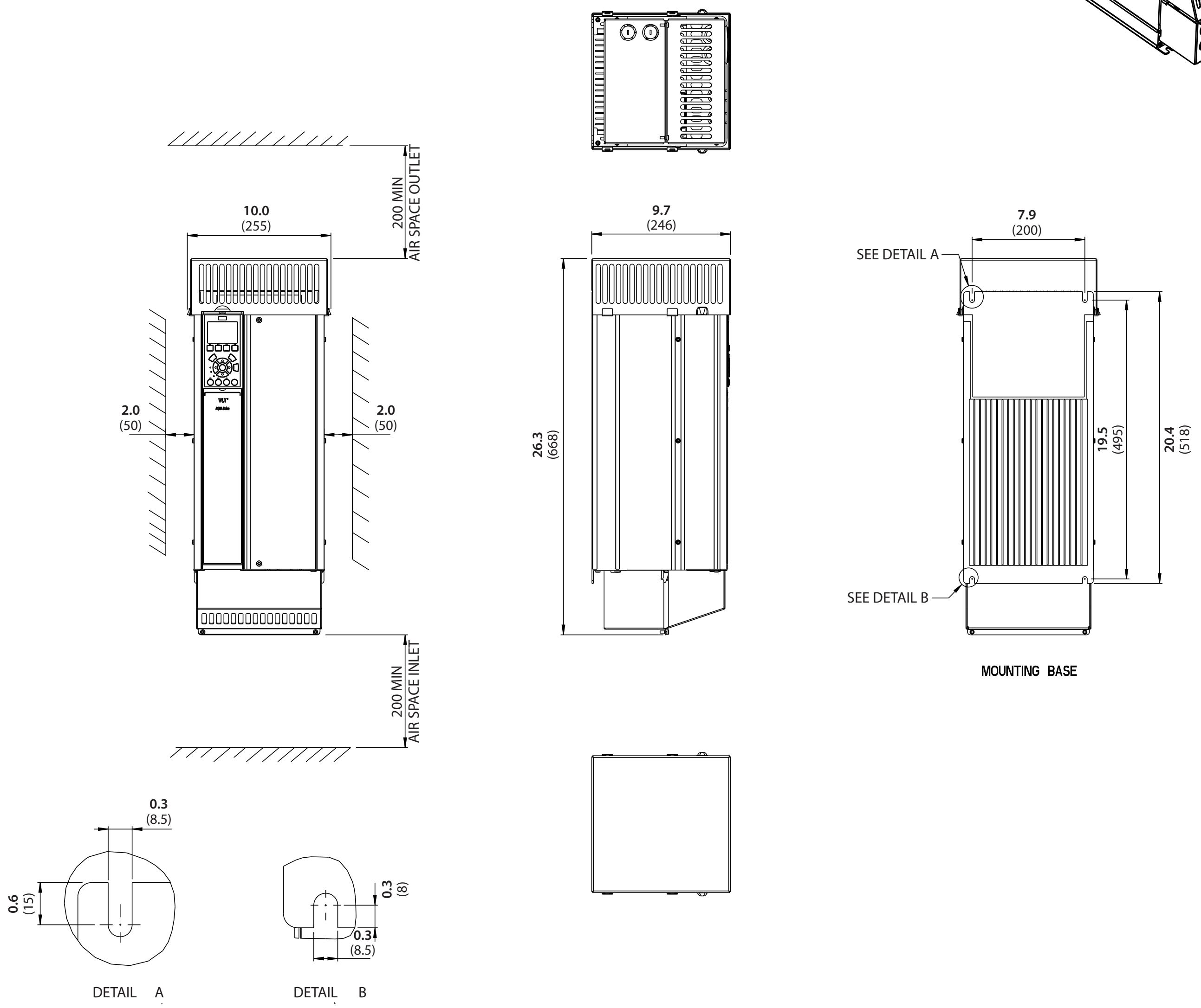


DETAIL B

VLT® AQUA Drive Mechanical Specifications

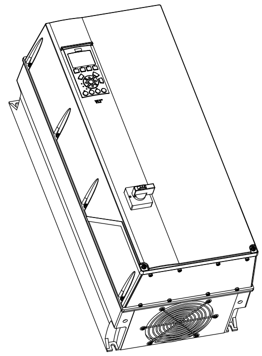
B4 Frame Size	
Protected Chassis/IP20 with NEMA 1 Kit	
Dimensions: in (mm)	Weight: 53 lbs. (24 kg)

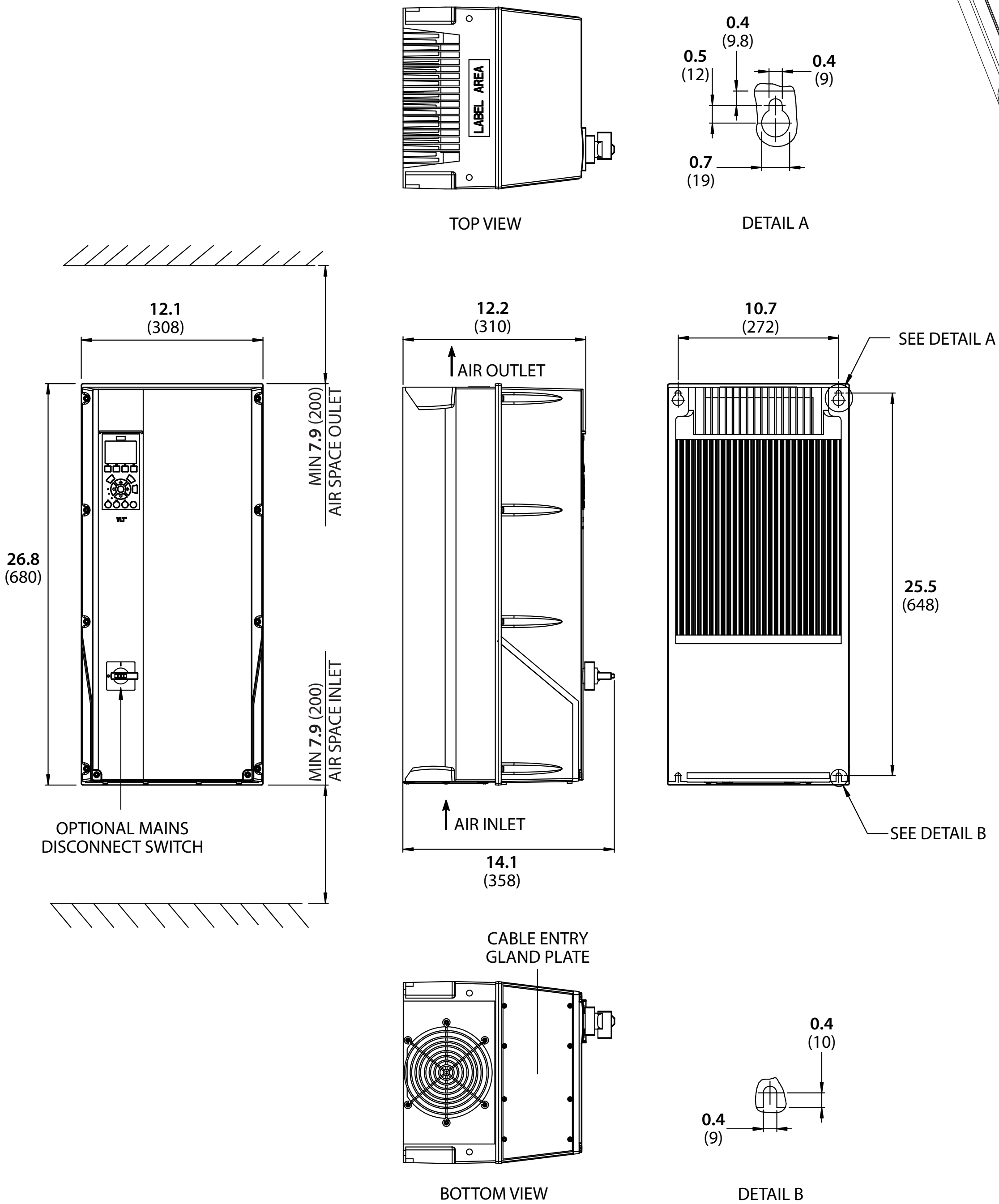




VLT® AQUA Drive Mechanical Specifications

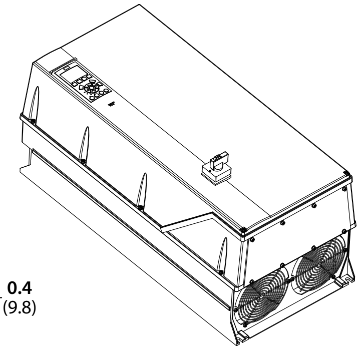
C1 Frame Size	
NEMA 1 & NEMA 12/IP55 & NEMA 4X/IP66	(Optional mains disconnect lock-out switch shown)
Dimensions: in (mm)	Weight: 95 – 99 lbs. (43 – 45 kg)

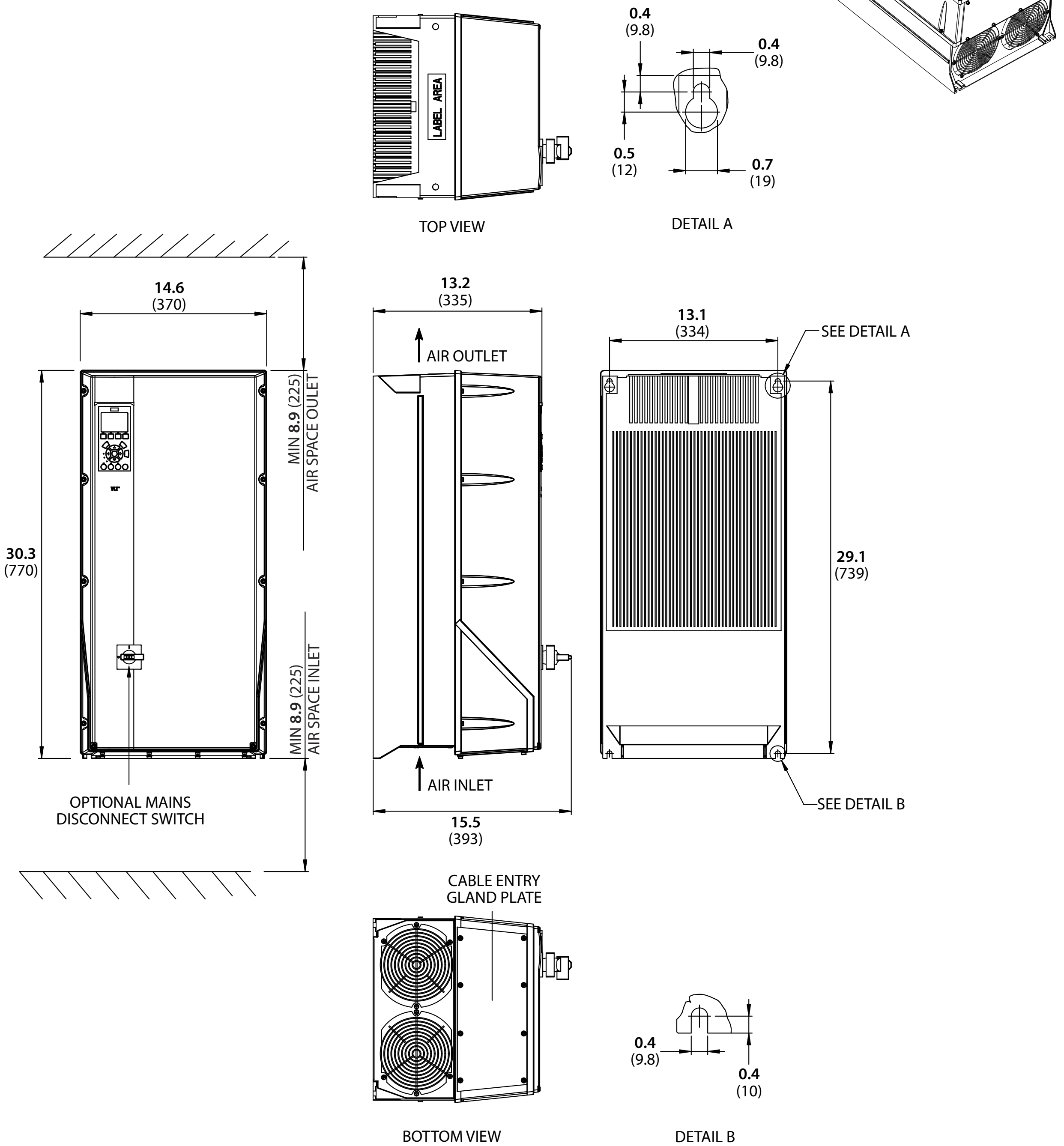




VLT® AQUA Drive Mechanical Specifications

C2 Frame Size	
NEMA 1 & NEMA 12/IP55 & NEMA 4X/IP66	(Optional mains disconnect lock-out switch shown)
Dimensions: in (mm)	Weight: 134 – 143 lbs. (61 – 65 kg)



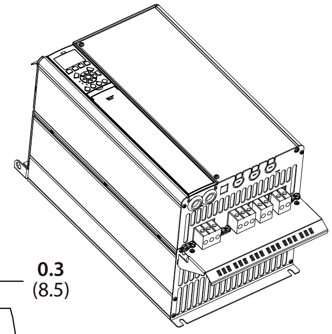


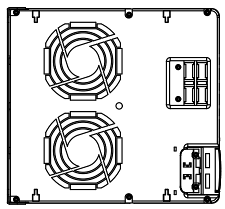
VLT® AQUA Drive **Mechanical Specifications**

C3 Frame Size

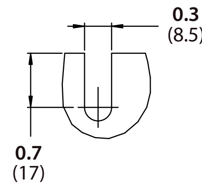
Protected Chassis/IP20

Dimensions: in (mm)	Weight: 77 lbs. (35 kg)

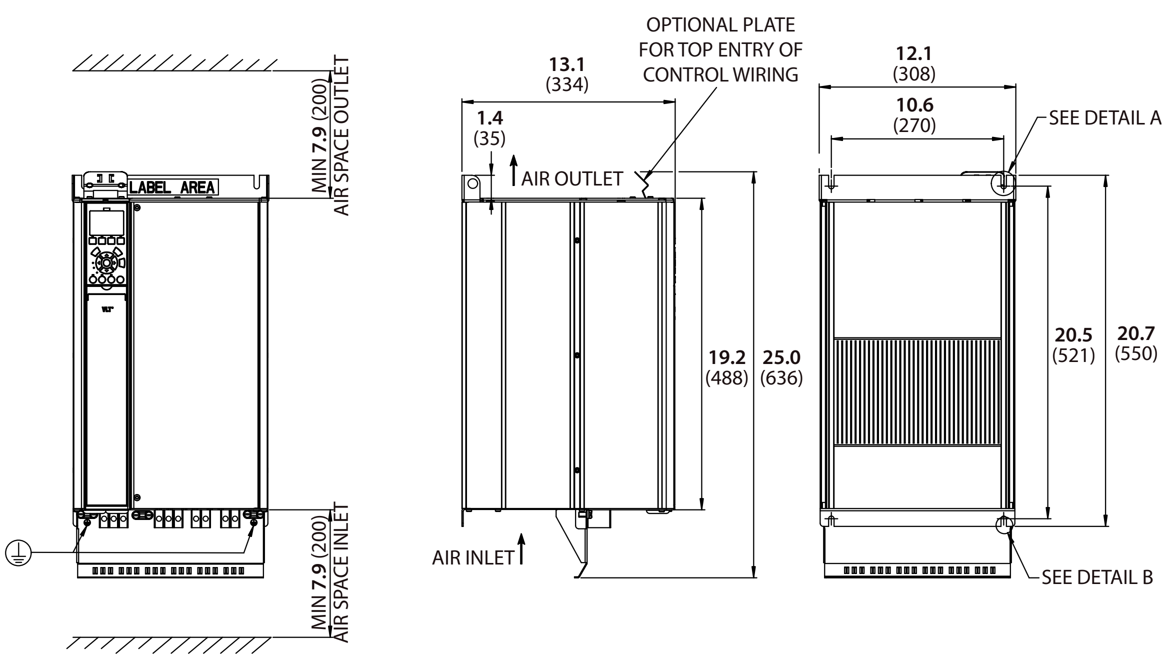


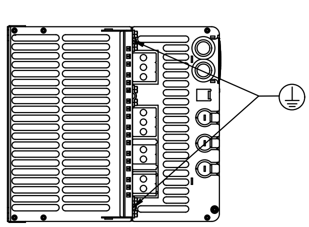


TOP VIEW

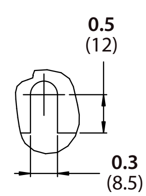


DETAIL A





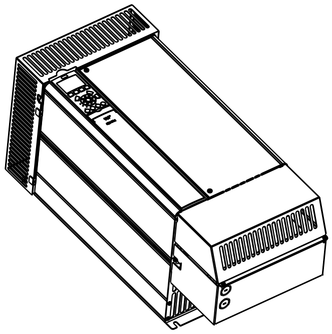
BOTTOM VIEW

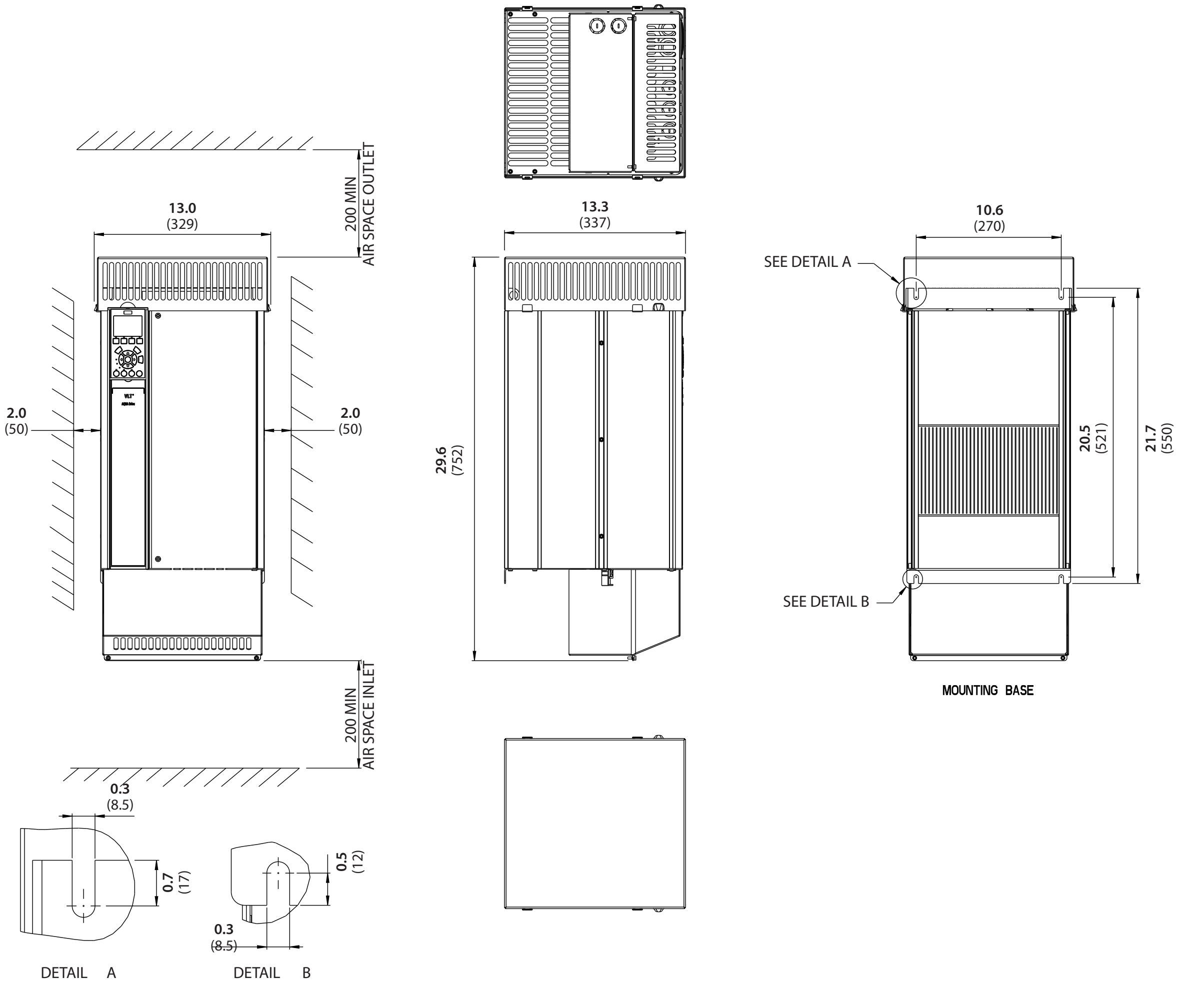


DETAIL B

VLT® AQUA Drive Mechanical Specifications

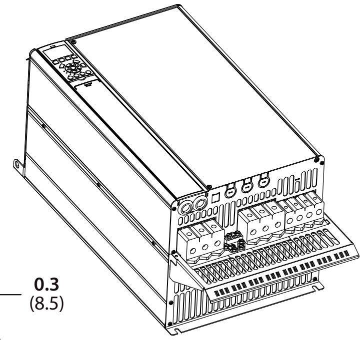
C3 Frame Size	
Protected Chassis/IP20 with NEMA 1 Kit	
Dimensions: in (mm)	Weight: 77 lbs. (35 kg)

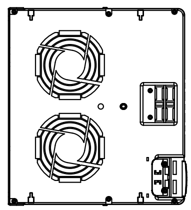




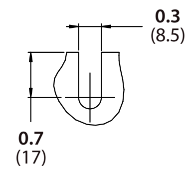
VLT® AQUA Drive **Mechanical Specifications**

C4 Frame Size	
Protected Chassis/IP20	
Dimensions: in (mm)	Weight: 110 lbs. (50 kg)

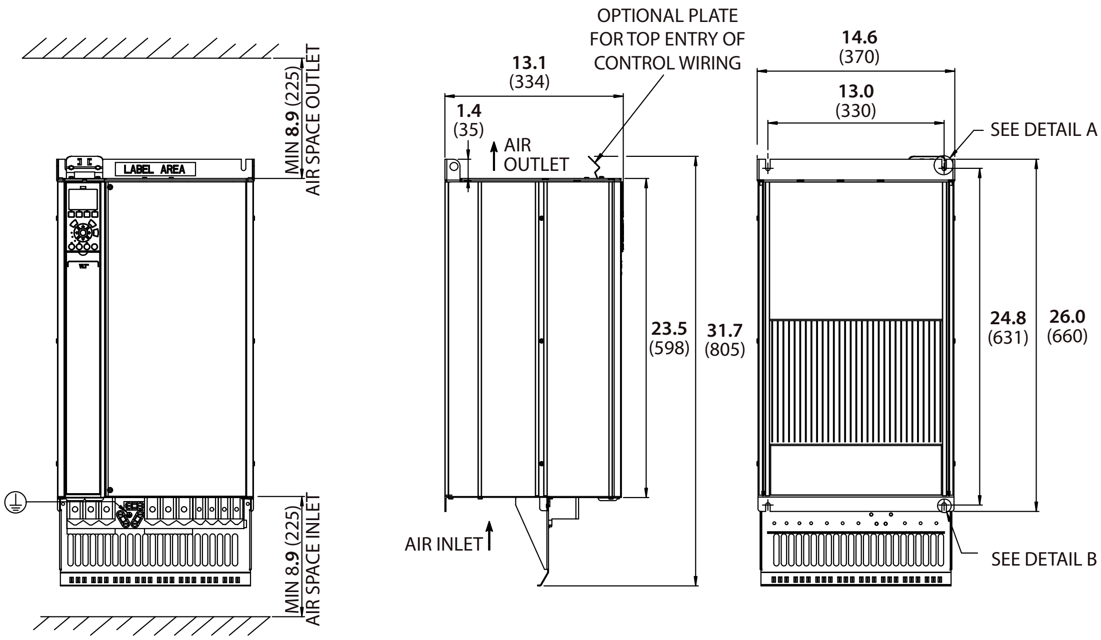


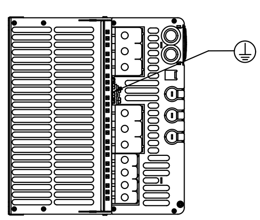


TOP VIEW

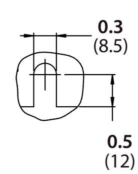


DETAIL A





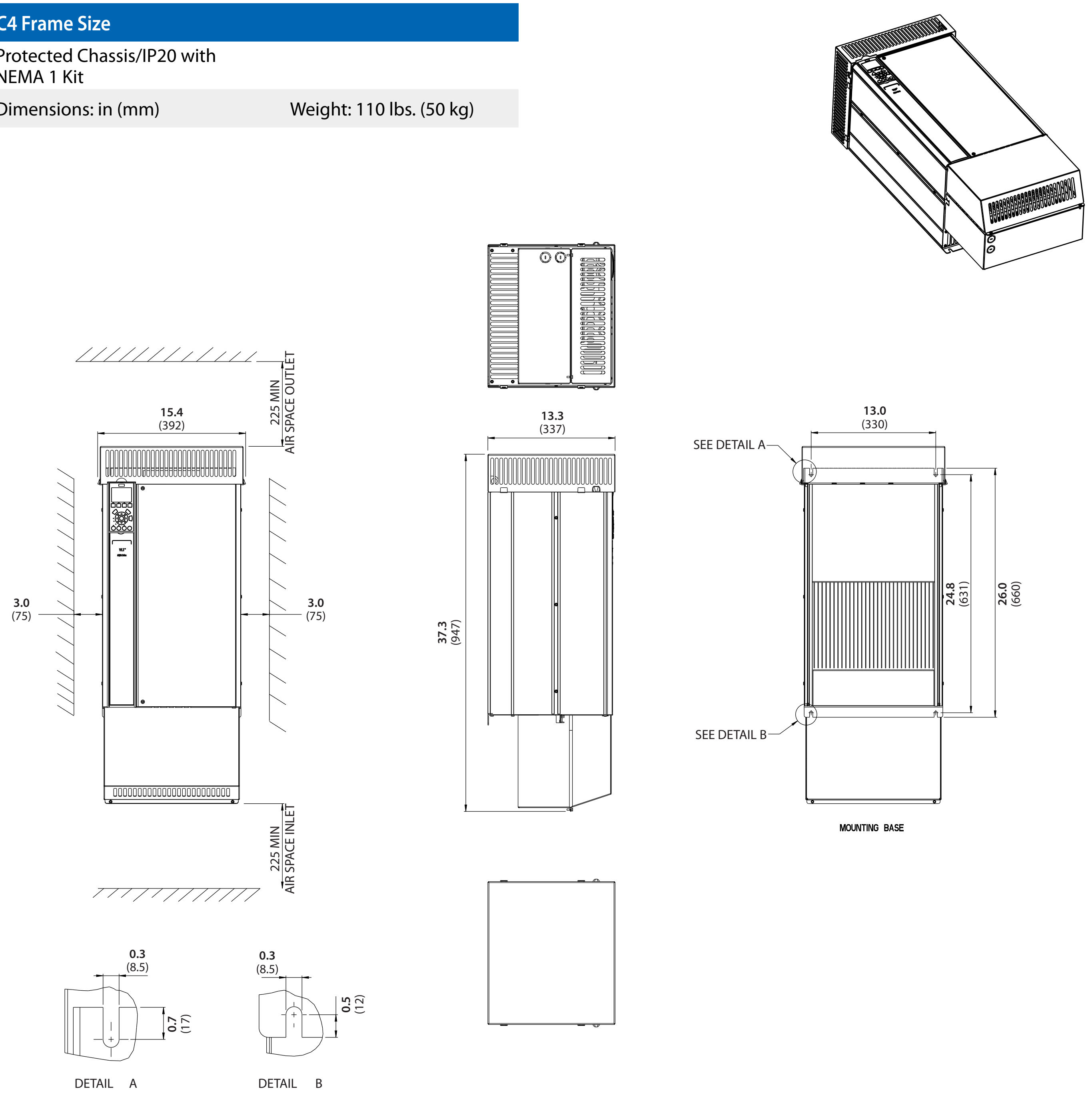
BOTTOM VIEW



DETAIL B

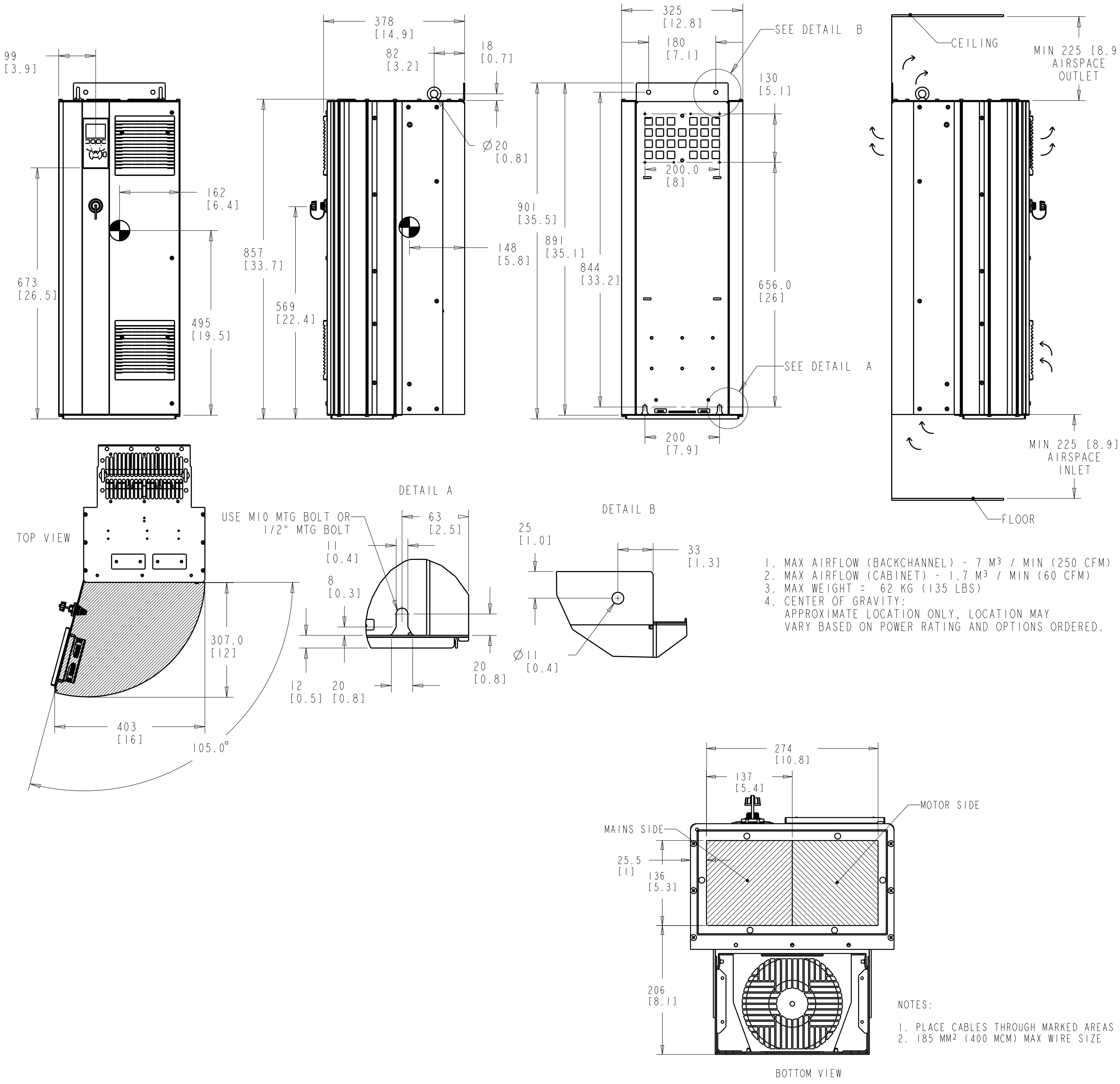
VLT® AQUA Drive **Mechanical Specifications**

C4 Frame Size	
Protected Chassis/IP20 with NEMA 1 Kit	
Dimensions: in (mm)	Weight: 110 lbs. (50 kg)



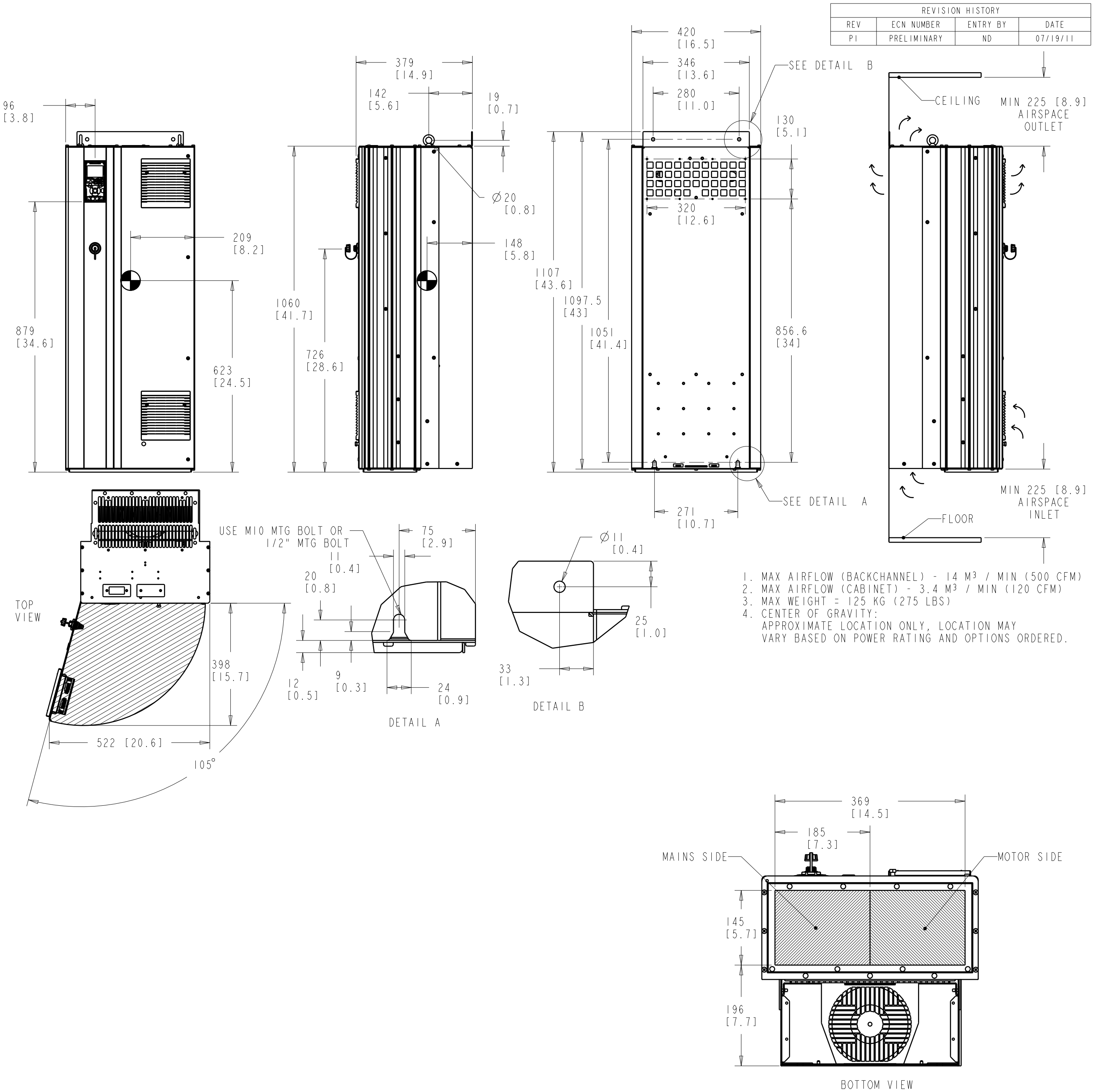
VLT® AQUA Drive Mechanical Specifications

D1H Frame Size	
NEMA 1/IP21 & NEMA 12/IP54	Optional door mounted USB port shown
Dimensions: mm (in)	Weight 135 lbs. (62 kg)



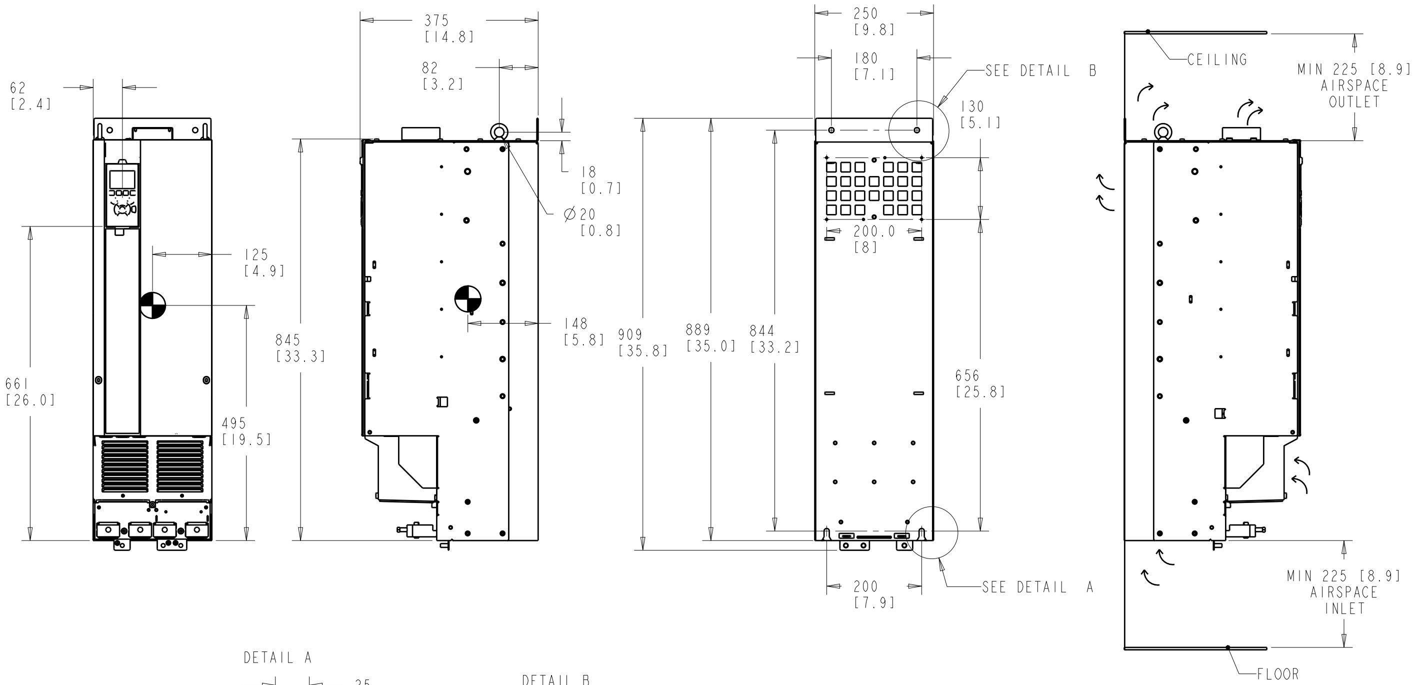
VLT® AQUA Drive Mechanical Specifications

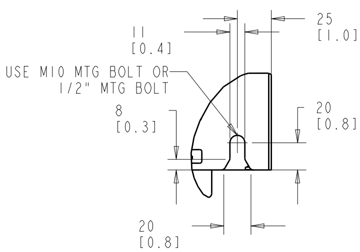
D2H Frame Size	
NEMA 1/IP21 & NEMA 12/IP54	Optional door mounted USB port shown
Dimensions: mm (in)	Weight 275lbs. (125 kg)

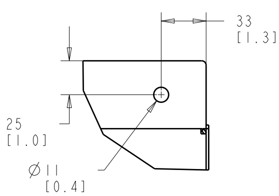


VLT® AQUA Drive **Mechanical Specifications**

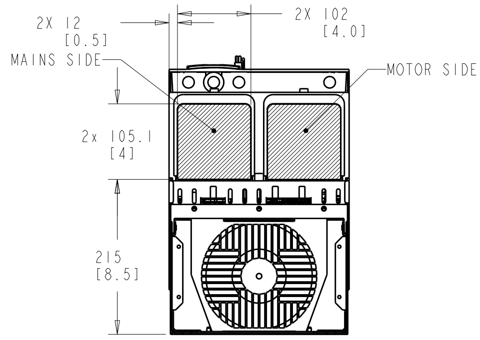
D3H Frame Size	
Protected Chassis/IP20	
Dimensions: mm (in)	Weight 135 lbs. (62 kg)







1. MAX AIRFLOW (BACKCHANNEL) - 7 M^3/MIN (250 CFM)
2. MAX AIRFLOW (CABINET) - 1.7 M^3/MIN (60 CFM)
3. MAX WEIGHT = 62 KG (135 LBS)
4. CENTER OF GRAVITY:
   APPROXIMATE LOCATION ONLY, LOCATION MAY VARY BASED ON POWER RATING AND OPTIONS ORDERED.



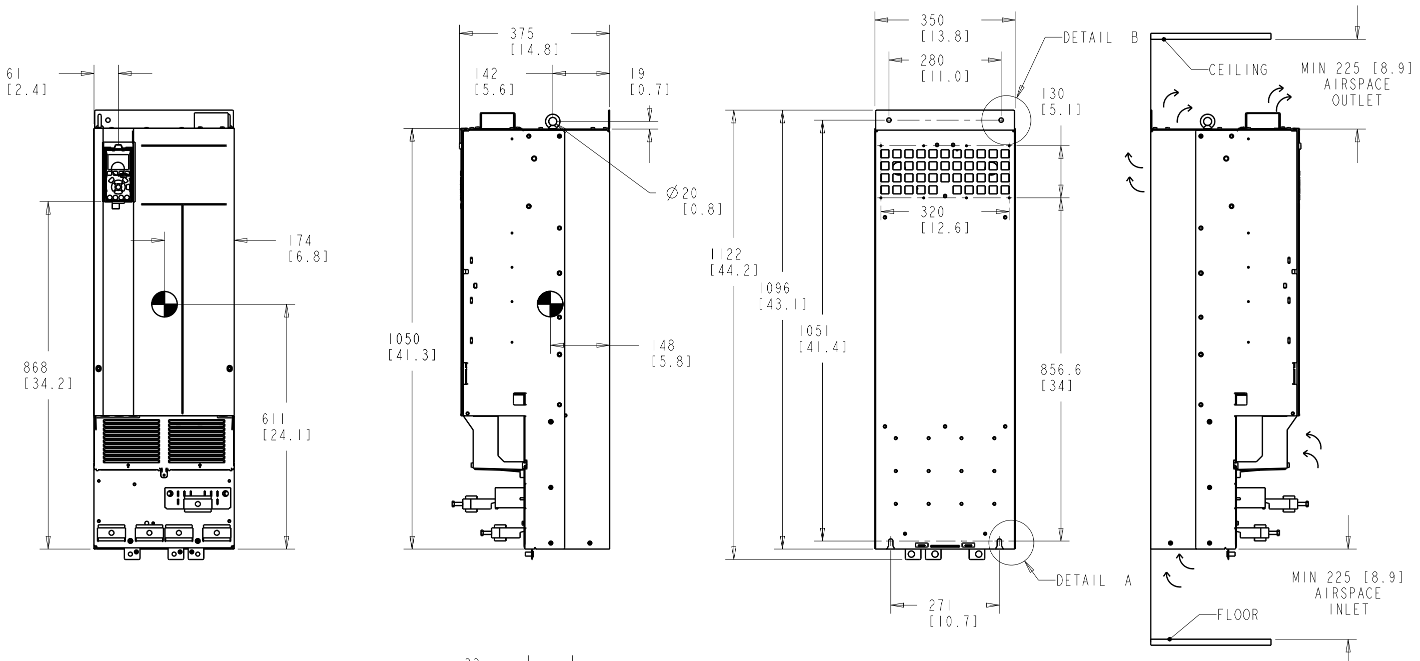
BOTTOM VIEW

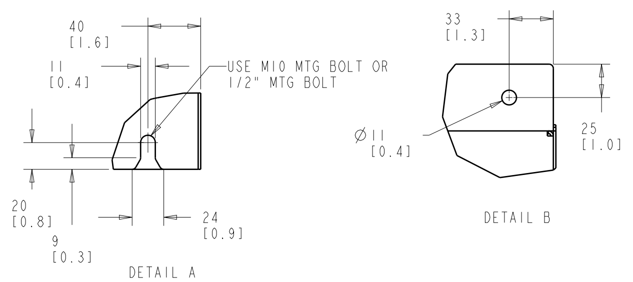
VLT® AQUA Drive **Mechanical Specifications**

D4H Frame Size

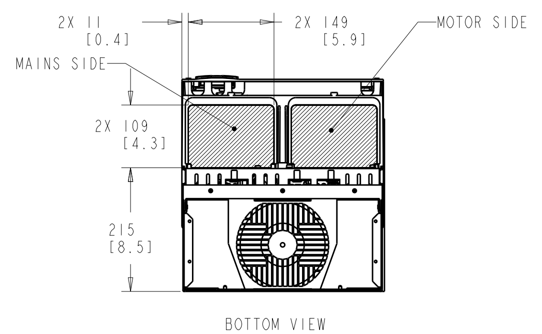
Protected Chassis/IP20

Dimensions: mm (in) Weight 275lbs. (125 kg)



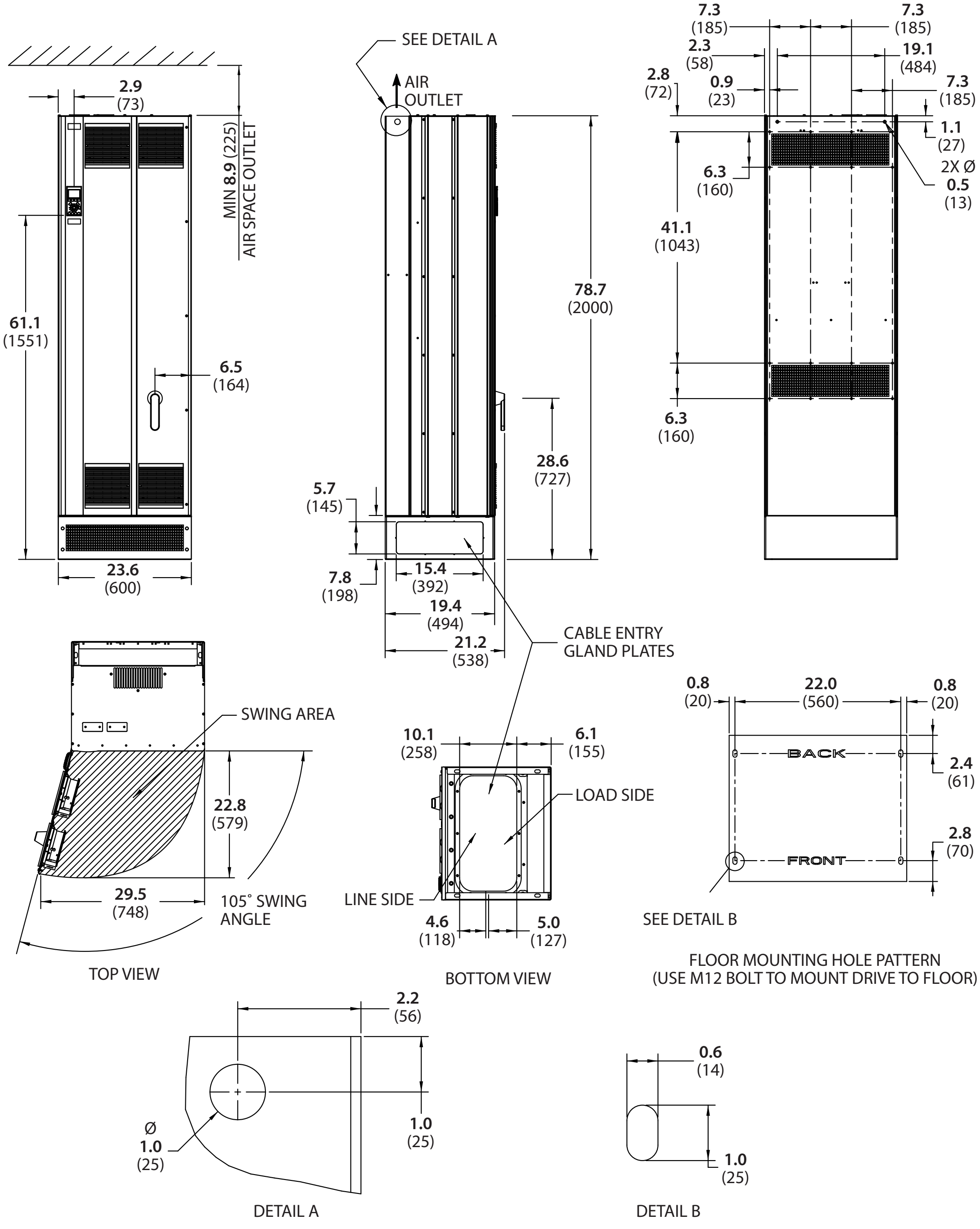


1. MAX AIRFLOW (BACKCHANNEL) - 14 M³/MIN (500 CFM)
2. MAX AIRFLOW (CABINET) - 3.4 M³/MIN (120 CFM)
3. MAX WEIGHT = 125 KG (275 LBS)
4. CENTER OF GRAVITY:
   APPROXIMATE LOCATION ONLY, LOCATION MAY
   VARY BASED ON POWER RATING AND OPTIONS ORDERED.



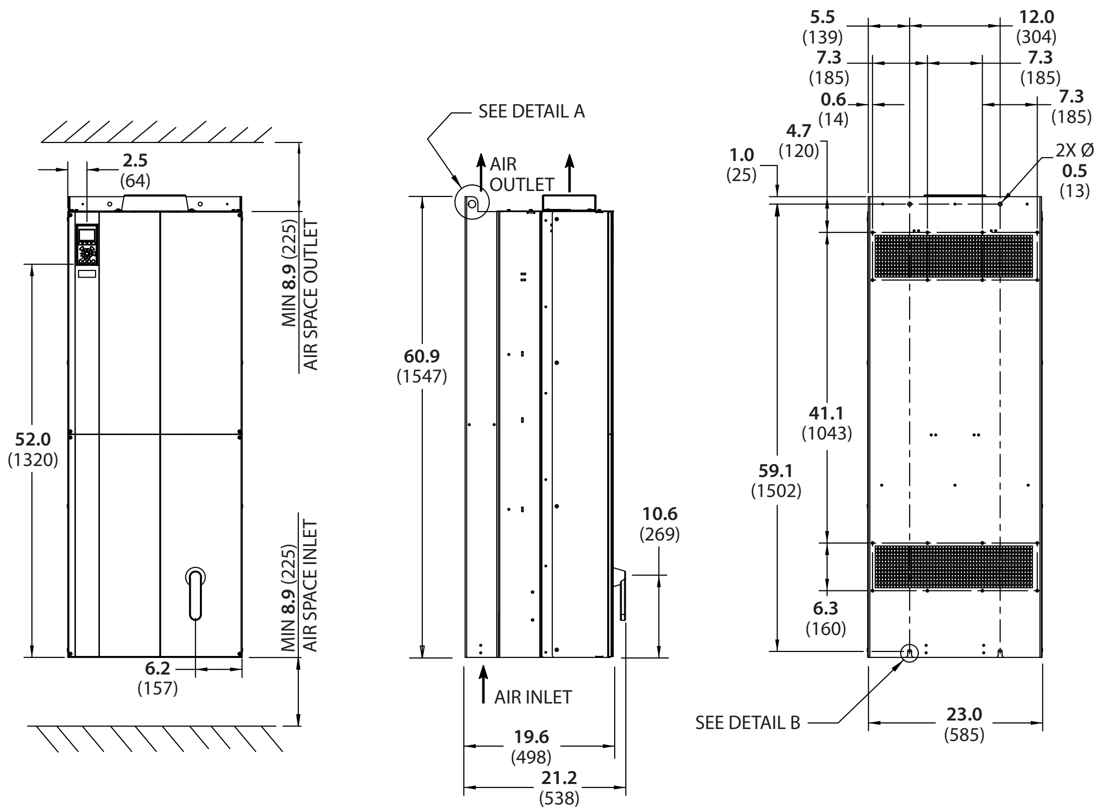
VLT® AQUA Drive Mechanical Specifications

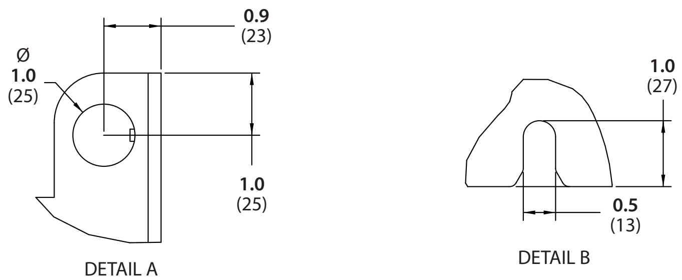
E1 Frame Size	
NEMA 1/IP21 & NEMA 12/IP54	Optional mains disconnect lock-out switch shown
Dimensions: in (mm)	Weight: 580 – 690 lbs. (263 – 313 kg)



VLT® AQUA Drive **Mechanical Specifications**

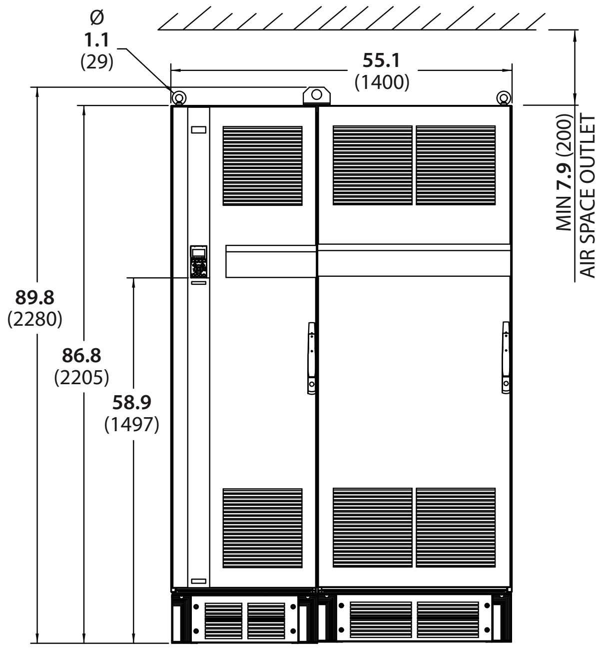
E2 Frame Size	
Open Chassis/IP00	(Optional mains disconnect lock-out switch shown)
Dimensions: in (mm)	Weight: 487 – 611 lbs. (221 – 277 kg)

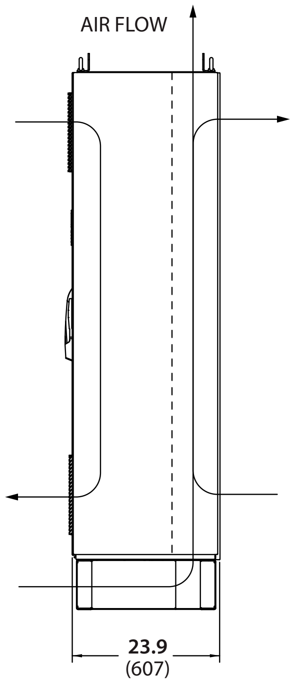


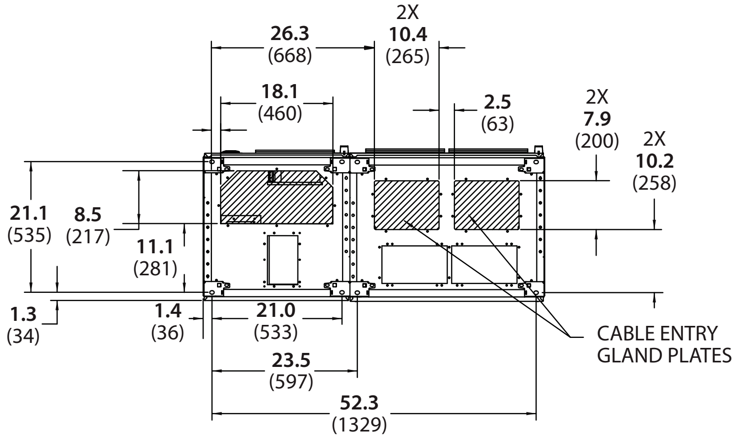


VLT® AQUA Drive Mechanical Specifications

F1 Frame Size	
NEMA 1/IP21 & NEMA 12/IP54	(Optional mains disconnect lock-out switch shown)
Dimensions: in (mm)	Weight: 2,214 lbs. (1,004 kg)



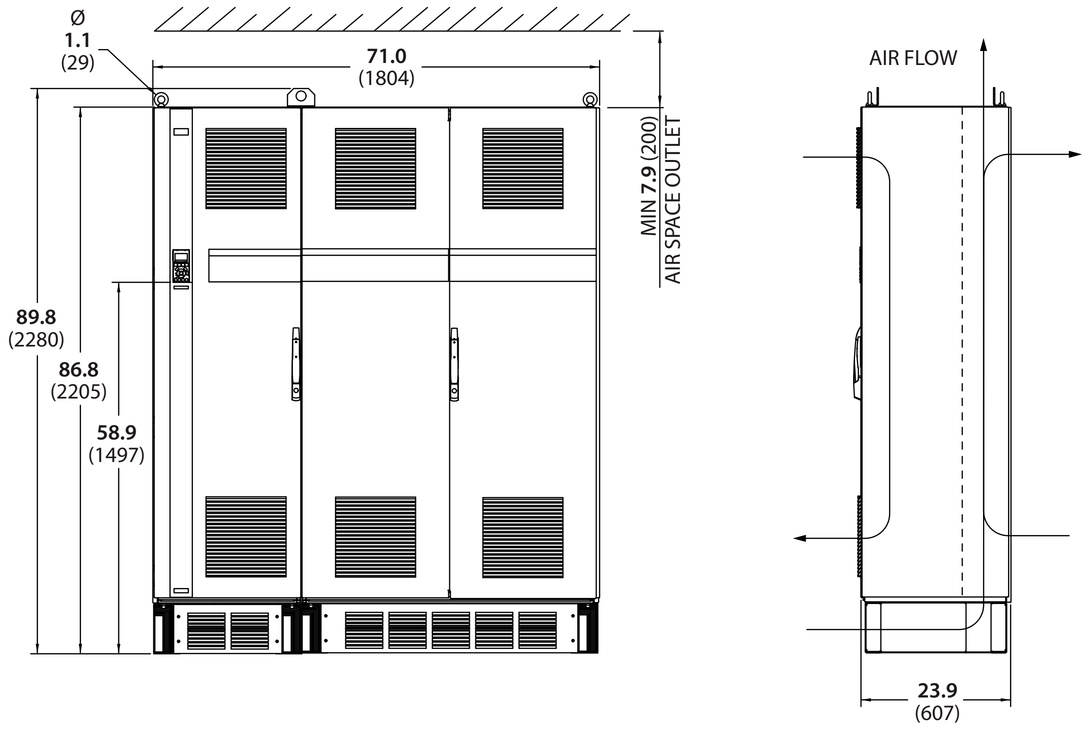


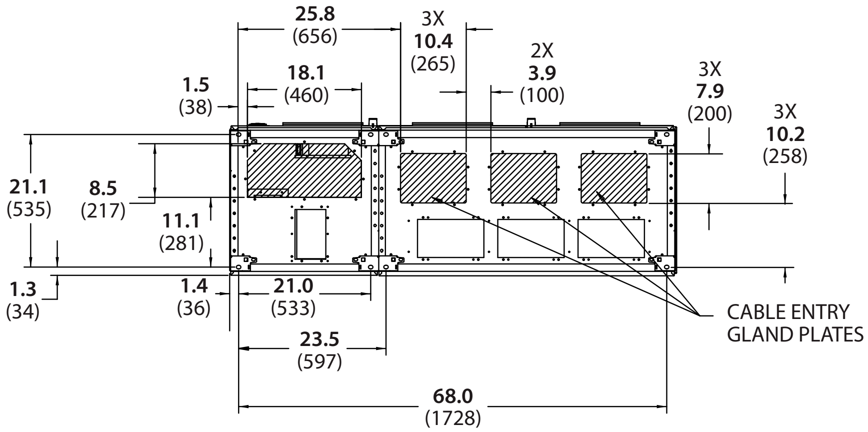


BOTTOM VIEW

VLT® AQUA Drive Mechanical Specifications

F2 Frame Size	
NEMA 1/IP21 & NEMA 12/IP54	(Optional mains disconnect lock-out switch shown)
Dimensions: in (mm)	Weight: 2,748 lbs. (1,246 kg)

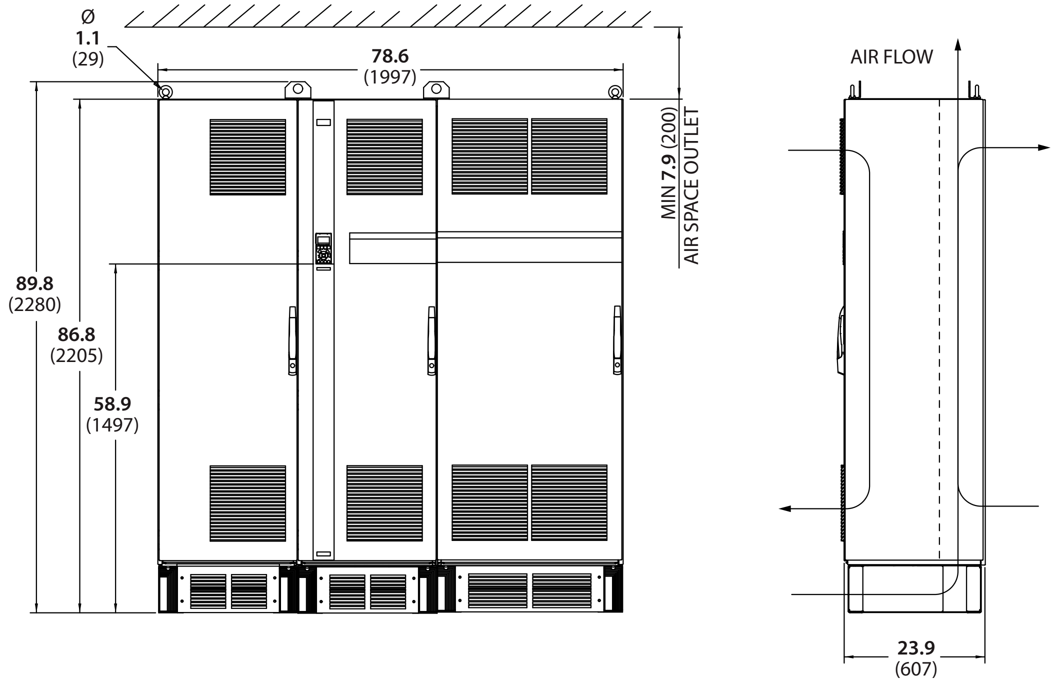


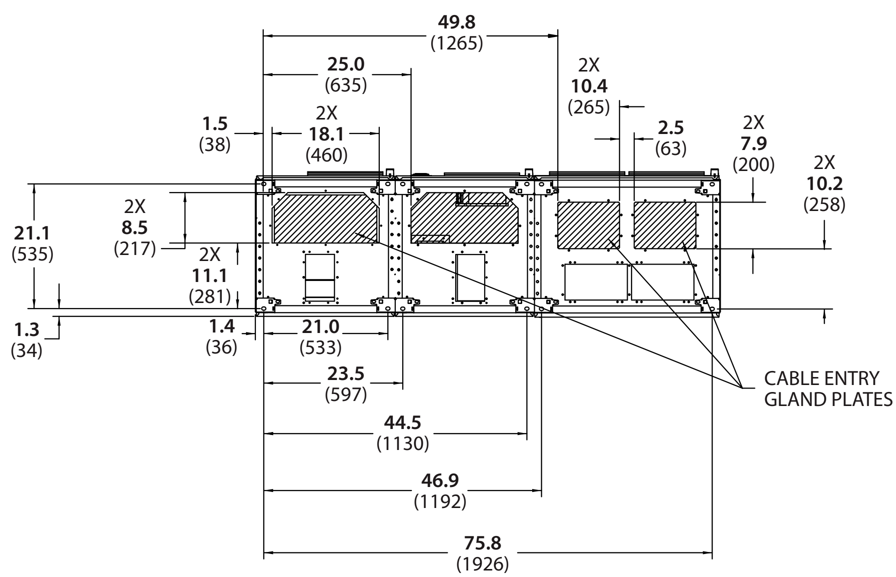


BOTTOM VIEW

VLT® AQUA Drive Mechanical Specifications

F3 Frame Size	
NEMA 1/IP21 & NEMA 12/IP54	(Optional mains disconnect lock-out switch shown)
Dimensions: in (mm)	Weight: 2,214 lbs. (1,004 kg)

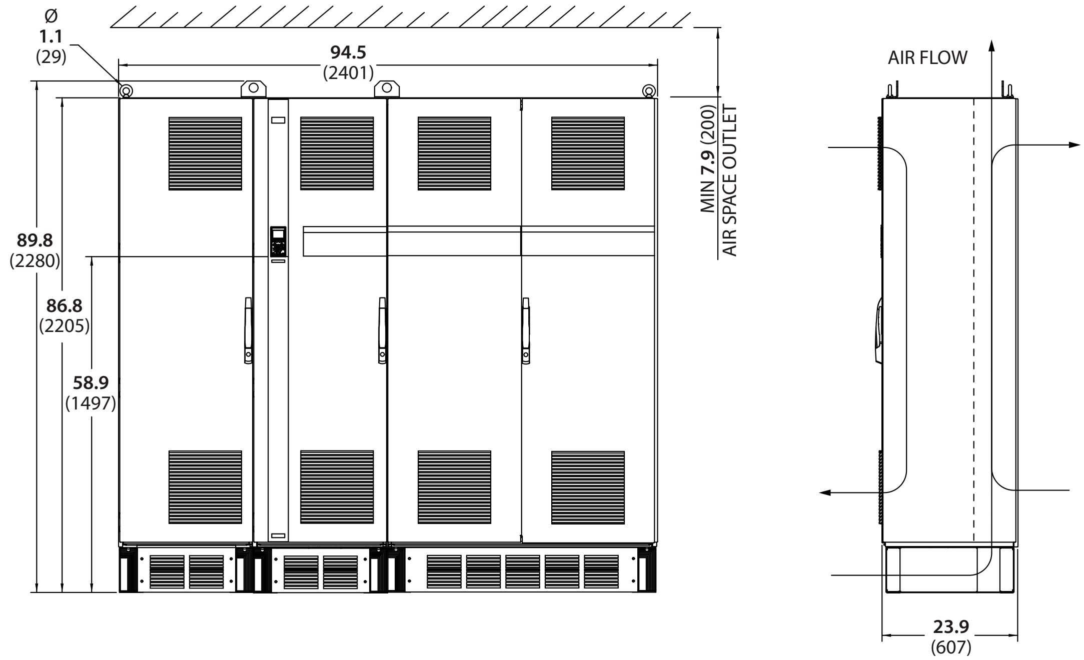


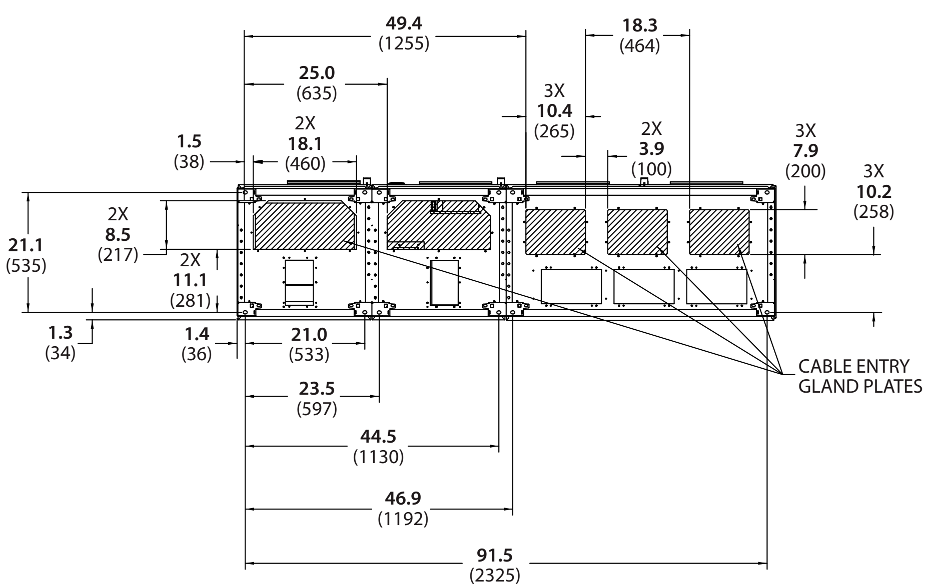


BOTTOM VIEW

VLT® AQUA Drive Mechanical Specifications

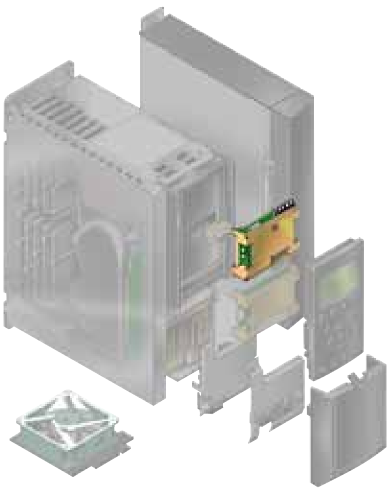
F4 Frame Size	
NEMA 1/IP21 & NEMA 12/IP54	(Optional mains disconnect lock-out switch shown)
Dimensions: in (mm)	Weight: 2,748 lbs. (1,246 kg)





BOTTOM VIEW

VLT® AQUA Drive Options and Accessories



Fieldbus options/accessories (A-Card)

The VLT® AQUA Drive is available with a variety of fieldbus products which are available as factory-installed options or as field-installed accessories.

VLT® Modbus RTU

Modbus RTU is a standard Protocol built-in to every FC 202 AQUA drive. Modbus is a serial communications protocol that follows the Modbus Organization standards. It is used to connect a supervisory control and data acquisition (SCADA) system with a remote terminal unit (RTU)

VLT® MCA 101 Profibus

Supported by all major PLC vendors, PROFIBUS DP V1 gives you a high level of availability and compatibility with future versions.

- Fast and efficient communication, advanced diagnosis and autoconfiguration of process data via GSD files
- Acyclic parameterization using PROFIBUS DP V1, PROFIdrive or Danfoss FC profi e state machines, PROFIBUS DP V1, Master Class 1 and 2

VLT® MCA 104 DeviceNet

Based on Producer/Consumer technology, DeviceNet offers robust, efficient data handling.

- Allows the user to select the nature and timing of reported information
- Certified by ODVA to meet the stringent ODVA standard
- ADR (Auto Device Recovery) Compatible

VLT® Profinet RT MCA 120

The VLT® PROFINET Option offers connectivity to PROFINET based networks via the PROFINET Protocol. The option is able to handle a single connection with an Actual Packet Interval down to 1 ms in both directions, positioning it among the fastest performing PROFINET devices in the market.

- Built-in web server for remote diagnosis and reading out of basic drive parameters
- An e-mail notificator can be configured for sending an e-mail message to one or several receivers, if certain warnings or alarms occur, or have cleared again
- TCP/IP for easy access to Drive configuration data from VLT® MCT 10
- FTP (File Transfer Protocol) file up and download
- Support of DCP (discovery and configuration protocol)

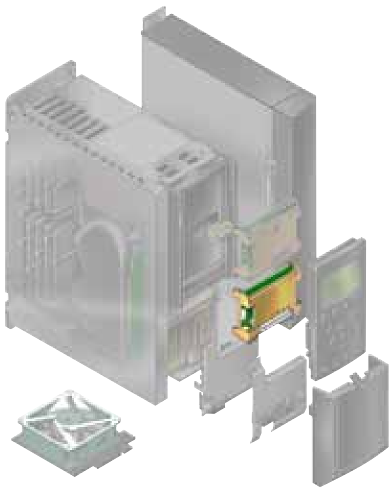
VLT® MCA 121 EtherNet IP

Provides the network tools to deploy standard Ethernet technology for manufacturing applications while enabling Internet and enterprise connectivity.

- Built-in advanced switch with diagnostic functions and two ports for line topology
- Built-in web server and e-mail client for service notification
- Transparent socket channel
- Certified by ODVA to meet the stringent ODVA standard

	Option Order Code*	Accessory Part Number	
		Conformal Coated to 3C2	Conformal Coated to 3C3
MCA 101 Profibus	A0	130B1100	130B1200
MCA 104 DeviceNet	A4	130B1102	130B1202
VLT® Profinet RT MCA 120	AL	130B1135	130B1235
MCA 121 Ethernet	AN	130B1119	130B1219
MVA 122 Modbus TCP/IP	AQ	130B1196	130B1296

VLT® AQUA Drive **Options and Accessories**



Application Options/Accessories (B-Card)

The VLT® AQUA Drive is available with several added-functionality application products which are available as factory-installed options or as field-installed accessories.

VLT® MCB 101 General Purpose I/O

Offers an extended number of control inputs and outputs:

- 3 digital inputs 0–24 V: Logic '0' < 5 V; Logic '1' >10V
- 2 analog inputs 0–10 V: Resolution 10 bit plus sign
- 2 digital outputs NPN/PNP push pull
- 1 analog output 0/4–20 mA
- Spring-loaded connection
- Separate parameter settings

VLT® MCB 105 Relay

Extend the relay functions of the VLT® AQUA Drive with 3 extra relay outputs.

Max. terminal load:

- AC-1 Resistive load 240V AC: 2A
- AC-15 Inductive @ cos φ 0.4: 0.2A
- DC-1 Resistive load 240V AC: 1A
- DC-13 Inductive @ cos φ 0.4: 0.1A

Min. terminal load:

- DC 5 V: 10 mA
- Max. switch rate at rated load/min. load: 6 min^{-1}/20 sec^{-1}
- Protected control cable connection
- Spring-loaded connection of control wires
- Selection of relay functions in parameter settings

VLT® MCB 109 Analog I/O

- Provides battery back-up of clock function on control card
- Extension of analog I/O selection
- Support Extended PID controllers

VLT® MCB 114 sensor inputs

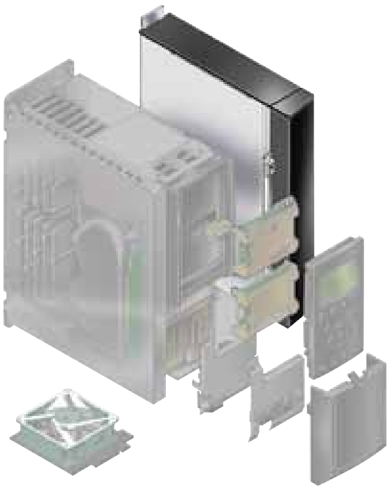
- 1 Analog Input 0/4-20mA
- Input Impedance <200Ω
- Sample rate 1kHz
- 3 – PT100/1000 2 or 3 wire

	Option Order Code*	Accessory Part Number	
		Conformal Coated to 3C2	Conformal Coated to 3C3
MCB 114 PTC Sensor input card	B4	130B1172	130B1272
MCB 101 I/O	BK	130B1125	130B1212
MCB 105 Relay	BP	130B1110	130B1210
MCB 109 Analog I/O	AO	130B1143	130B1243

		MCB 101	MCB 105	MCB 109	MCB 114
I/O	FC 200	GP I/O	Relay	Analog I/O	Sensor Input
Digital Input	6*	+3			
Digital Output	2*	+2			
Analog Input	2	+2		+3 (0-10V)	+1
Analog Output	1	+1		+3 (0-10V)	
Relay-form c	2		+3		
Real Time Clock Battery Back-up				1	
PT100/PT1000					+3

** 2 Digital inputs can be configured as Digital Outputs.*

VLT® AQUA Drive Options and Accessories



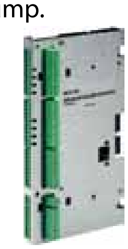
VLT® MCO 101 Extended Cascade Controller (B-Card)

Extends the capabilities of the standard Cascade Controller built into VLT® Series drives:

- Provides 3 additional relays for staging of additional motors
- Provides accurate flow, pressure, and level control for optimizing the efficiency of systems that use multiple pumps or blowers
- Master/Follower mode runs all blowers/pumps at the same speed, potentially reducing the energy consumption to less than half that of valve throttling or traditional, across-the-line on/off cycling
- Lead pump alternation assures that pumps or blowers are used equally

VLT® MCO 102 Advanced Cascade Controller (C-Card)

The Advanced Cascade Controller option provides the capability to control multiple pumps configured in parallel in a way that makes them appear as a single larger pump.

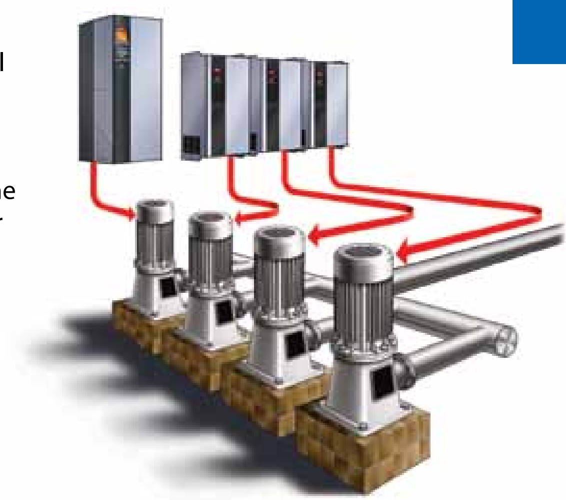


Using the Advanced Cascade Controller individual pumps are automatically turned on (staged) and turned off (destaged) as needed to satisfy the required system output for flow or pressure. The speed of the pumps connected to the VLT® AQUA Drives is also controlled to provide a continuous range of system output.

The Advanced Cascade Controller option card controls up to five parallel pumps. The controller provides constant pressure or level control in such systems, and reduces water hammer and energy consumption. The controller also eliminates the need for PLCs and external controllers.

The Advanced Cascade Controller is available as a factory-installed option or as field-installed accessory, and is designed for a variety of applications including:

- Pressure booster pump systems
- Tank level control
- Pressure control
- Lift station pump control
- Irrigation and fire pump systems
- Wastewater blower systems

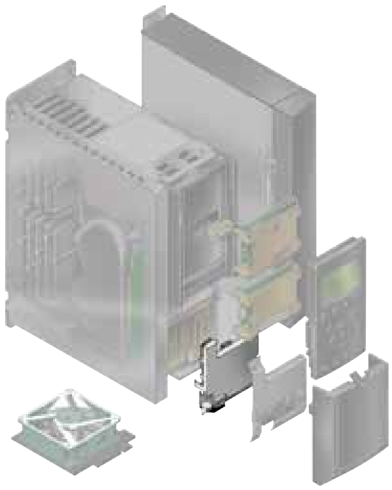


This illustration depicts a typical VLT® AQUA Drive installation utilizing the Cascade Controller option. The controller is being used in conjunction with MCD Series Soft Starters to operate one to four pumps as demand requires.

Function	VLT® AQUA Standard	EXTENDED MCO 101 Option B	ADVANCED MCO 102 Option C
VLT® AQUA Relays	2	2+3	2+8
Maximum number of pumps to control Variable Speed Constant speed (softstarter or across the line)	 1 2	 6 6	 8 8
BASIC functionality	X	X	X
Master-Follower		X	X
Maximize system efficiency		X	X
Stage/De-Stage operation Automatic Tuning for best efficiency Automatic for minimum surge/sag		 X X	 X X
Runtime priority		X	X
Alternating lead pump with one relay per pump (only old and new lead pump to stop)	X (2)	X (4)	
Alternating lead pump at staging			X (4)
Control of unequal sized pumps		X	X
Operation hours counter for relays	X		
Operation hours counter for both relays and pumps		X	X

If you use the Extended Controller, which fits in the "B" option slot, you cannot add additional I/O to the VLT® AQUA
If you use the Advanced Controller, which fits in the "C" option slot, you can add additional I/O to the VLT® AQUA

	Option Order Code*	Accessory Part Number	
		Conformal Coated to 3C2	Conformal Coated to 3C3
MCO 101 Extended Cascade Controller	BY	130B1118	130B1218
MCO 102 Advanced Cascade Controller	C5	130B1154	130B1254



DC Input Option/Acccessory (D Card)

VLT® MCB 107 External 24 VDC Supply

Enables connection of external DC supply to keep the control section and any option installed active despite interruption of AC power.

- Input voltage range: 24 V DC +/- 15% (max. 37 V in 10 sec.)
- Max. input current: 2.2 A
- Max. cable length: 75 m
- Input capitance load: < 10 uF
- Power-up delay: < 0.6 s

	Option Order Code*	Accessory Part Number	
		Conformal Coated to 3C2	Conformal Coated to 3C3
MCB 107 External 24 VDC Supply	D0	130B1108	130B1208

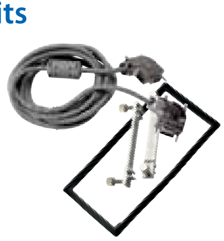
VLT® AQUA Drive Options and Accessories

Faceplate Options/Accessories

VLT® AQUA Drives can be configured with three different HMI (faceplate) configurations:

- Graphic (far left)
- Numeric (center)
- Blank (right)
- Faceplate configurations are available as a factory-installed option or as a field-installed accessory.

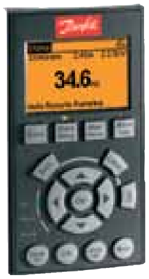
MCF 102 LCP Panel Mounting Kits



The LCP mounting kit enables the LCP to be mounted in an IP 65 cabinet front.

- 3m cable
- Gasket for sealing
- Finger screws for easy fitting
- Supports LCP 101 and LCP 102

LCP 102 Graphical Local Control Panel



- Multi-language display
- VLT® AQUA Drive status messages
- Quick menu for easy startup
- Parameter setting and explanation of parameter function
- Full parameter backup and copy function
- Alarm logging
- Info button explains the function of the selected item on display
- Hand operated start-stop or selection of Automatic mode
- Reset function
- Trend graphing

USB extension cord kit

USB extension cord kit allows access to the drive via laptop computer without opening the drive. It can be door mounted (D frames to F frames) or bottom mounted (A frames to C Frames) depending on the frame drive it is mounted.

	Option Order Code*	Accessory Part Number
LCP 101 Numerical Faceplate	N	130B1124
LCP 102 Graphical Faceplate	G	130B1107
LCP 103 Blank Faceplate	X	130B1077
MCF 102 Panel Mounting Kit (Includes fastener, 10 ft. (3m) cable, and gasket)	–	130B1117
MCF 102 Panel Mounting Kit with Numerical Faceplate	–	130B1113
MCF 102 Panel Mounting Kit with Graphical Faceplate	–	130B1114
LCP cable 10 ft. (3m)	–	175Z0929
Hardened USB Cable Extension for NEMA 4X/IP66 – USB extension, 350 mm cable – USB extension, 650 mm cable	 – –	 130B1155 130B1156

VLT® AQUA Drive Options and Accessories

Kits to fit your application

F-frame top entry kit motor cables

To use this kit, the drive must be ordered with the common motor terminal option. The kit includes everything to install a top entry cabinet on the motor side (right side) of the F-frame VLT® drive.

Cables	Frame	Cabinet width	Kit part number
Motor	F1/F3	15.75 in (400 mm)	176F1838
Motor	F1/F3	23.6 in (600 mm)	176F1839
Motor	F2/F4	15.75 in (400 mm)	176F1840
Motor	F2/F4	23.6 in (600 mm)	176F1841
Motor	F8, F9, F10, F11, F12, F13	*Contact factory*	

F-frame top entry kit mains cables

The kits include everything required to install a top entry section onto the mains side (left side) of a Danfoss F-frame VLT® variable frequency drive.

Cables	Frame	Cabinet width	Kit part number
Mains	F1/F2	15.75 in (400 mm)	176F1832
Mains	F1/F2	23.6 in (600 mm)	176F1833
Mains	F3/F4 with disconnect	15.75 in (400 mm)	176F1834
Mains	F3/F4 with disconnect	23.6 in (600 mm)	176F1835
Mains	F3/F4 without disconnect	15.75 in (400 mm)	176F1836
Mains	F3/F4 without disconnect	23.6 in (600 mm)	176F1837
Mains	F8, F9, F10, F11, F12, F13	*Contact factory*	

Common motor terminal kits

The common motor terminal kits provide the bus bars and hardware required to connect the motor terminals from the paralleled inverters to a single terminal (per phase) to accommodate the installation of the motor-side top entry kit. This kit is equivalent to the common motor terminal option of a drive. This kit is not required to install the motor-side top entry kit if the common motor terminal option was specified when the drive was ordered.

This kit is also recommended to connect the output of a drive to an output filter or output contactor. The common motor terminals eliminate the need for equal cable lengths from each inverter to the common point of the output filter (or motor).

Frame	Kit part number
F1/F3	176F1845
F2/F4	176F1846

Back-channel duct kit

Back-channel duct kits are offered for conversion of the D and E frames. They are offered in two configurations – top and bottom venting and top only venting. Available for the D3, D4 and E2 frames.

In bottom out top		
Kit number	Description	Instruction number
176F3627	D3h (1800 mm)	
176F3628	D4h (1800 mm)	
176F3629	D3h (2000 mm)	177R0456
176F3630	D4h (2000 mm)	177R0457
176F1850	E2 78.7in (20000 mm)	
176F0299	E2 86.6in (2200 mm)	

VLT® AQUA Drive Options and Accessories

NEMA-3R Rittal and welded enclosures

The kits are designed to be used with the IP 00/Chassis drives to achieve an enclosure rating of NEMA-3R or NEMA-4. These enclosures are intended for outdoor use to provide a degree of protection against inclement weather.

NEMA-3R (welded enclosures)			
Kit number	Description	Instruction number	Additional documents/ drawings
176F0296	D3 Kit	175R1068	175R1069
176F0295	D4 Kit	175R1068	175R1069
176F0298	E2 Kit	175R1068	175R1069
NEMA-3R (Rittal enclosures)			
176F3633	D3h	177R0460	
176F3634	D4h	177R0461	
176F1852	E2 Kit	1755922	175R5921

Pedestal kit

The pedestal kit is a 15.75 in (400 mm) high pedestal for the D1h and D2h frames that allow the drives to be floor mounted. The front of the pedestal has openings for input air to the power components.

Kit number	Description	Additional documents/ drawings
176F3631	D1h	177R0452
176F3632	D2h	177R0453

Top and bottom covers for back-channel cooling

These kits are designed to be used for redirecting the back-channel air flow. Factory back-channel cooling directs air the bottom of the drive and out the top. The kit allows the air to be directed in and out the back of the drive.

Kit number	Description	Instruction number
176F3648	D1h	177R0458
176F3649	D2h	177R0459
176F3625	D3h	177R0454
176F3626	D4h	177R0455
176F1776	E2 Frame	
176F1862	E	176F1945
176F1861	F1/F2F1/F2	176F1946

Top only back-channel cooling kit

Kit for installation of the top section only of the back-channel cooling. A 7.87in (200 mm) vented pedestal is also required.

Frame	Kit part number
D3/D4	176F1775
E2	176F1776
D1h/D3h	176F3409
D2h/D4h	176F3410

IP 20 conversion kit

This kit is for use with the D3, D4, and E2 (IP00) frames. After installation, the drive will have an enclosure rating of IP20.

Frame	Kit part number	Terminal cover height
D3/D4	176F1779	254 mm (10 inch.)
E2	176F1884	254 mm (10 inch.)

VLT® AQUA Drive Options and Accessories

Dedicated options, fieldbusses and applications

Available on frames	
D E F	**Enclosure with stainless steel back-channel** For additional protection from corrosion in harsh environments, units can be ordered in an enclosure that includes a stainless steel back-channel, heavier plated heatsinks and an upgraded fan. This option is recommended in salt-air environments near the ocean.
D E	 **Mains shielding** Lexan® shielding mounted in front of incoming power terminals and input plate to protect from accidental contact when the enclosure door is open.
F	 **Space heaters and thermostat** Mounted on the cabinet interior of F frames, space heaters controlled via automatic thermostat prevents condensation inside the enclosure. The thermostat default settings turn on the heaters at 10°C (50°F) and turn them off at 15.6°C (60°F).
F	 **Cabinet light with power outlet** A light can be mounted on the cabinet interior of F frames to increase visibility during servicing and maintenance. The light housing includes a power outlet for temporarily powering laptop computers or other devices. Available in two voltages: ▪ 230 V, 50 Hz, 2.5 A, CE/ENEC ▪ 120 V, 60 Hz, 5 A, UL/cUL

VLT® AQUA Drive Options and Accessories

Available on frames

RFI filters

VLT® Series drives feature integrated Class A2 RFI filters as standard. If additional levels of RFI/EMC protection are required, they can be obtained using optional Class A1 RFI filters, which provide suppression of radio frequency interference and electromagnetic radiation in accordance with EN 55011.

On F-frame drives, the Class A1 RFI filter requires the addition of the options cabinet. Marine use RFI filters are also available.

A B C D E F

Loadsharing terminals

These terminals connect to the DC-bus on the rectifier side of the DC-link reactor and allow for the sharing of DC bus power between multiple drives. The F-frame loadsharing terminals are sized for approximately 1/3 the power rating of the drive. Consult the factory for loadsharing limits based on the specific drive size and voltage.

A B C D E F

Fuses

Fuses are highly recommended for fast-acting current overload protection of the variable frequency drive. Fuse protection will limit drive damage and minimize service time in the event of a failure.

A B C D E F

Disconnect

A door-mounted handle allows for the manual operation of a power disconnect switch to enable and disable power to the drive, increasing safety during servicing. The disconnect is interlocked with the cabinet doors to prevent them from being opened while power is still applied.

A B C D E F

Circuit Breakers

A circuit breaker can be remotely tripped but must be manually reset. Circuit breakers are interlocked with the cabinet doors to prevent them from being opened while power is still applied. When a circuit breaker is ordered as an option, fuses are also included for fast-acting current overload protection of the variable frequency drive.

All bypass panels D F

Available on frames

F

Contactors

An electrically controlled contactor switch allows for the remote enabling and disabling of power to the drive. An auxiliary contact on the contactor is monitored by the Pilz Safety if the IEC Emergency Stop option is ordered.

F

24 VDC power supply

- 5 Amp, 120 W, 24 VDC
- Protected against output overcurrent, overload, short circuits, and overtemperature
- For powering customer-supplied accessory devices such as sensors, PLC I/O, contactors, temperature probes, indicator lights, and/or other electronic hardware
- Diagnostics include a dry DC-ok contact, a green DC-ok LED, and a red overload LED

F

External temperature monitoring

Designed for monitoring temperatures of external system components, such as the motor windings and/or bearings. Includes eight universal input modules plus two dedicated thermistor input modules. All ten modules are integrated into the drive's safe-stop circuit and can be monitored via a fieldbus network (requires the purchase of a separate module/bus coupler).

Universal inputs (5)
Signal types:

- RTD inputs (including Pt100), 3-wire or 4-wire
- Thermocouple
- Analogue current or analog voltage

Additional features:

- One universal output, configurable for analog voltage or analogue current
- Two output relays (N.O.)
- Dual-line LC display and LED diagnostics
- Sensor lead wire break, short-circuit, and incorrect polarity detection
- Interface setup software
- If 3 PTC are required, MCB112 control card option must be added.

Additional external temperature monitors:

- This option is provided in case you need more than the MCB114 and MCB 112 provides.

VLT® AQUA Drive Options and Accessories

Steel Backplates		
Part #	Type	Description
130B3150	MCF108	Backplate A4
130B1098	MCF108	Backplate A5
130B3383	MCF108	Backplate B1
130B3397	MCF108	Backplate B2
130B3910	MCF108	Back plate C1
130B3911	MCF108	Back plate C2

Stainless Steel Backplates (Type 304)		
Part #	Type	Description
130B3158	MCF108	Backplate A4/ NEMA 4X/IP66
130B3242	MCF108	Backplate, A5, NEMA 4X/IP66
130B3434	MCF108	Backplate/ B1, NEMA 4X/IP66
130B3465	MCF108	Backplate B2, NEMA 4X/IP66
130B3468	MCF108	Backplate C1, NEMA 4X/ IP66
130B3491	MCF108	Backplate C2, NEMA 4X/ IP66

Weather Shield		
Part #	Type	Description
130B4598		A4 – B2 Frames
130B4597		C1 – C2 Frames

130B4597

Through Panel Mount Kit

Allows the drive to be mounted through the back of a panel wall so that cooling air can remove the heat without the risk of damaging electronics with dust, heat, moisture, or corrosive elements. For use with NEMA 1/IP21 and NEMA 12/IP55 units with the front cover removed.

The drive can be mounted with the heatsink exposed in a duct with a cooling airstream provided by external fans either dedicated for the purpose or as part of a process close to the drive. If this configuration is used, the drive's built-in fan can be removed.

If the drive is not mounting into a duct with an existing airflow, adding a backplate (purchased separately) creates a duct through which the drive's built-in fan can force cooling air over the heatsink.

Through Panel Mount Kit				
Fits Frame	Height	Width	Depth	Part Number
A5	20.1	13.1	4.7	130B1028
B1	22.4	13.1	5.9	130B1046
B2	29.1	13.1	5.9	130B1047
C1	30.6	15.2	6.3	130B1048
C2	33.7	17.6	6.3	130B1049

VLT® AQUA Drive **Options and Accessories**

MCF 101 NEMA 1/IP21 Option/Accessory Kit

Used for installations in dry environments. The NEMA 1/IP21 kit is available as factory-installed option or as a field-installed accessory.

- Available for frame sizes A2 and A3 (0.33–10 HP)
- Can be used with or without mounted option modules
- NEMA 1/IP 21 on top side

MCF 104 Profibus Adaptor Sub-D9 Connector

Uses a Phoenix type connector to connect to the Profibus Fieldbus Option (MCA 101) and provides a Sub D plug-in connection in place of screw type termination.

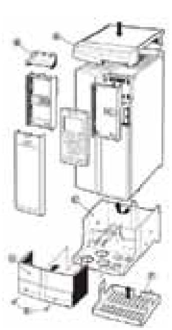
Part Number: 130B1112

Decoupling Plate for Fieldbus Cables

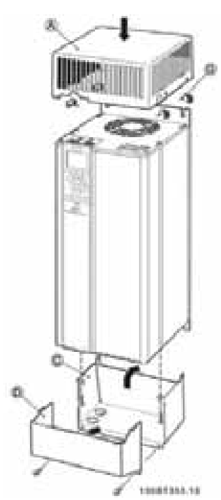
Makes fieldbus mounting robust.

Part Number: 130B0524

A Frames



B and C Frames



NEMA 1 Option Kits for IP20 A, B and C Frames

Fits Frame	HP Range (High Overload)			Height	Width	Depth	Part Number
	230V	460V	600V				
A2	1/3 to 3	1/2 to 5	–	14.6	3.5	8.1	130B1112
							130B1132*
A3	4 to 5	7-1/2 to 10	1 to 10	14.6	5.1	8.1	130B1123
							130B1133*
B3	7.5 – 15	15 – 25	15 – 25	20.6	6.5	9.8	130B1187
B4	20-25	30 – 50	30 – 50	28.6	9.1	9.8	130B1189
C3	30-40	60-75	60-75	31.1	12.1	13.1	130B1191
C4	50-60	100-125	100-125	39.7	14.6	13.1	130B1193

** Top Only subtract 3.1 from height.*

VLT® AQUA Drive **Options and Accessories**

PC Software

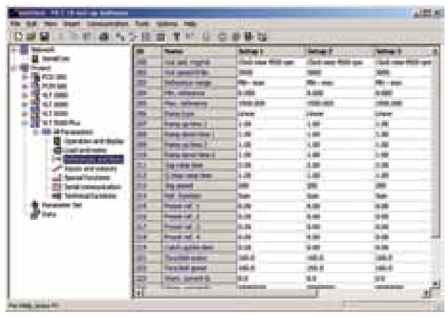
VLT® MCT 10 (Motion Control Tools)

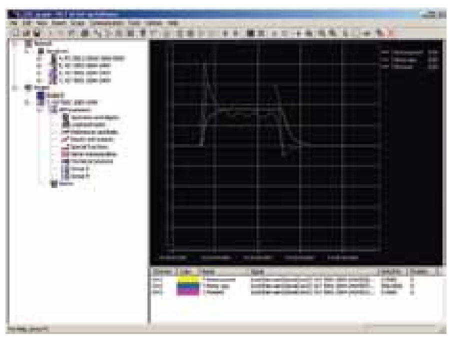
Offering advanced programming functionality for all Danfoss drive products, VLT® MCT 10 greatly reduces programming and commissioning times.

Drives are managed in a standard folder-based user interface that's familiar and easy to understand. Parameter settings for each drive are contained in a single file, simplifying setup and the duplication of parameter sets between drives.

MCT-10 Basic version is available free of charge from the Danfoss web site. The Advanced edition, which offers a higher level of functionality, is available from your Danfoss sales partner.

- SyncPos programming
- On-line and off-line commissioning
- On-board help files for each drive parameter
- Logging of alarms and warnings for improved system performance and documentation
- MCT-10 Conversion Wizards simplify drive conversion projects
- Real-time data collection using the MCT-10 Scope function
- Access to the VLT® AQUA Drive's internal data buffer, providing up to four channels of high speed (down to 1 millisec) data collection
- Simplified programming of the VLT® AQUA Drive's Smart Logic Controller using graphical programming tools
- Drive upgrade tools





VLT® MCT 10 allows setting of parameters in an easy-to-navigate interface (right) and provides graphical data collection and programming tools (far right).

MCT 31 (Harmonics Calculation Tool)

MCT 31 calculates system harmonic distortion for both Danfoss and non-Danfoss VLT® Drives. It is also able to calculate the effects of using various additional harmonic reduction measures including Danfoss Advanced Harmonic Filtration.

- Project oriented for simplified calculations on several transformers
- Easy to compare different harmonic solutions within the same project
- Supports current Danfoss product line as well as legacy drive models

VLT® Micro Drive

Perfect

match for:

- Pumping applications
- Irrigation
- Chemical feed

The VLT® Micro Drive is a general purpose drive that can control AC motors up to 30 HP. It's a small drive with maximum strength and reliability.

VLT® Micro Drive is a full member of the VLT® family sharing the overall quality of design, reliability and user-friendliness.

Due to high quality components and genuine VLT® solutions, VLT® Micro Drive is extremely reliable.

RoHS compliant

The VLT® Micro Drive is manufactured with respect for the environment, and it complies with the RoHS Directive.

Power range

1 phase 200–240 V AC	1/4 to 3 HP
3 phase 200–240 V AC	1/3 to 5 HP
3 phase 380–480 V AC	1/2 to 30 HP

Manufactured to the highest quality standards
The VLT® Micro Drive is a UL-listed product made in ISO 9001-2000 and ISO 14000 certified facilities.

Features	Benefits
User friendly	
Minimum commissioning	Saves time
Mount – connect – go!	Minimum effort – minimum time
Copy settings via local control panel	Easy programming of multiple drives
Intuitive parameter structure	Minimal manual reading
Complies with VLT® software	Saves commissioning time
Self-protecting features	Lean operation
Process PI-controller	No need for external controller
Automatic Motor Tuning	Ensure optimal match between drive and motor
150% motor torque up to 1 minute	Plenty of brake-away and acceleration torque
Flying start (catch a spinning motor)	Doesn't trip when started on a spinning (freewheeling) motor
Electronic Thermal Relay (ETR)	Replaces external motor protection
Smart Logic Controller	Often makes PLC unnecessary
Built-in RFI filter	Saves cost and space
Energy saving	**Less operation cost**
Energy efficiency 98%	Minimizes heat loss
Automatic Energy Optimization (AEO)	Saves 5-15% energy in HVAC applications
Reliable	**Maximum uptime**
Ground fault protection	Protects the drive
Over temperature protection	Protects the motor and drive
Short circuit protection	Protects the drive
Optimum heat dissipation	Longer lifetime
Unique cooling concept with no forced air flow over electronics	Problem-free operation in harsh environments
High quality electronics	Low lifetime cost
High quality capacitors	Tolerates uneven mains supply
All drives full load tested from factory	High reliability
Dust resistant	Increased lifetime
RoHS compliant	Protects the environment
Designed for WEEE	Protects the environment

VLT® Micro Drive **Features**

Coated PCB standard for harsh environments.

Power options

Danfoss VLT® Drives offers a range of external power options for use together with our drives in critical networks or applications:

- VLT® Advanced Harmonic Filter: For applications where reducing harmonic distortion is critical.

PC software tools

- VLT® MCT 10: Ideal for commissioning and servicing the drive including guided programming of cascade controller, real time clock, smart logic controller and preventive maintenance.
- VLT® Energy Box: Comprehensive energy analysis tool, shows the drive payback time.
- MCT 31: Harmonics calculations tool.

Mains Supply (L1, L2, L3)	
Supply voltage	1 x 200–240 V ±10% 3 x 200–240 V ± 10% 3 x 380–480 V ± 10%

Output Data (U, V, W)	
Output voltage	0–100% of supply voltage
Output frequency	0–200 Hz (VVC+ mode) 0–400 Hz (V/Hz mode)
Switching on output	Unlimited
Ramp times	0.05–3600 sec.

Digital Inputs	
Programmable inputs	5
Logic	Selectable sourcing high (24 V) or sinking low (0 V)
Voltage level	0–24 V
Maximum voltage on input	28 VDC
Input Resistance	Approx. 4 kΩ

Pulse Inputs	
Programmable pulse inputs	1
Voltage level	0–24 VDC (PNP positive logic)
Pulse input accuracy (0.1–110 kHz)	Max. error: 0.1% of full scale
Pulse input frequency	20–5000 Hz

Analog Input	
Analog inputs	2
Modes	1 current/1 voltage or current
Voltage level	0–10 V (scaleable)
Current level	0/4–20 mA (scaleable)

Analog Output	
Programmable analog outputs	1
Current range at analog output	0/4–20 mA
Max. load to common at analog output	500 Ω
Accuracy on analog output	Max. error: 1% of full scale

On-Board Power Supply	
Output voltage	10.5 ± 0.5 V
Max. load 10 V 24 V	 25 mA 200 mA

Relay Outputs	
Programmable relay outputs	1
Max. terminal load Resistive Inductive	 240 VAC, 2 A 250 VAC, 0.2 A

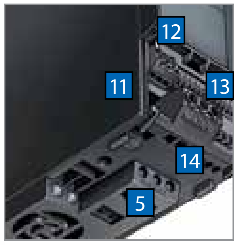
Cable Lengths	
Max. motor cable length Shielded Unshielded	 50 ft. (15 m) 165 ft. (50 m)

Environmental Operating Conditions	
Enclosure	Protected Chassis/IP20 standard; NEMA 1 and IP21 optional
Vibration test	0.7 g
Max. relative humidity	5%–95% (IEC 721-3-3; Class 3K3 (non-condensing) during operation
Aggressive environment	(IEC 721-3-3), coated class 3C3
Ambient operating temperature	Max. 122°F
24-hour average operating temperature	Max. 104°F
Min. ambient temperature During full-scale operation At reduced performance	 32°F 14°F
Temperature during storage/transport	-13 – 149/158°F

Protection and Features

- Electronic thermal motor protection against overload
- Temperature monitoring of the heat sink protects the drive from overheating
- The drive is protected against short-circuits on motor terminals U, V, W
- The drive is protected against ground fault on motor terminals U, V, W

VLT® Micro Drive **Features**



1 **Well protected IP20 enclosure with NEMA/UL Type 1 kit optional**
No forced airflow through electronics

2 **Removable cover for convenient access to control terminals**

3 **High quality capacitors**

4 **RFI Filter**

5 **DC-link access**

6 **Hot-pluggable LCP**

7 **LCD display**

8 **Potentiometer**

9 **EIA-485 connection**

10 **Customer relay screw terminals**
Wire inlet from the bottom

11 **Safety ground**
Min. 10 AWG accessible from front

12 **I/O terminals**

13 **Mains screw terminals**

14 **Motor screw terminals**

Ready– Set – Go!

The VLT® Micro Drive offers unsurpassed reliability, user-friendliness and condensed functionality that is extremely easy to commission. Connect motor and power cables, turn the control knob, and watch the motor speed change. Approximately 100 parameters are available to optimize energy efficiency and operation.

VLT® Micro Drive **Features**

Inputs and outputs

- 5 programmable digital inputs
- Activation based on switching high or sinking low (0-24 VDC)
- Pulse input 20–5000 Hz
- 1 analog input (0–10 V or 0–20 mA)
- 1 analog input 0–20 mA
- Thermistor input (analog/digital)
- 1 analog output 0–20 mA
- 1 Relay 240 VAC, 2 A
- RS-485 port with FC or Modbus RTU protocol

Small drive – high performance	
Process PI controller	Removes need for external controller
Automatic Energy Optimization (AEO)	Lowers energy consumption
Automatic Motor Tuning (AMT)	Utilizes motor's full potential
150% motor torque up to 1 minute	Removes need for bigger drive
Flying start (catch a spinning motor)	Provides smooth starts without tripping
Electronic Thermal Relay (ETR)	Replaces external motor protection
Smart Logic Controller	Helps automate application
Built-in RFI filter	Minimizes radio frequency disturbances

User friendly	
Plug-and-play	Streamlined installation
Minimal commissioning requirements	Quicker startup
Settings can be copied via the local control panel	Easy setup of multiple drives
Intuitive parameter structure	Minimal manual reading
Compatible with VLT® MCT 10 Setup Software	Faster startup and greater control of large installations

Reliable	
Optimal heat dissipation	Longer lifetime
High quality electronics/capacitors	Low lifetime cost
All drives full-load tested from factory	High reliability
Ground fault, temperature and short circuit protection	High level of protection without the need for external devices
Circuit boards well protected and coated	Increased robustness

VLT® Micro Drive Features

Ensured reliability and maximum uptime

True side-by-side mounting

A compact bookstyle design allows space-saving mounting without derating.

Built-in brake functions

With built-in DC and AC brake functions, the VLT® Micro Drive can transform kinetic energy in the application into braking power to slow the motor. A brake chopper is built into all VLT® Micro Drives 2 HP and up.

Minimal penetration of dust

The VLT® Micro Drive is designed to separate forced ventilation air from the electronics. Printed circuit boards are well protected inside the drive.

Built-in RFI protection

A built-in RFI filter limits radio disturbance from motor cables, allowing for 50’ motor cables (shielded).

Built-in smart logic controller

The smart logic controller is a simple yet very clever way to enable the drive, motor and application to work together.

The smart logic controller is able to monitor any parameter that can be characterized as “true” or “false.” This includes digital commands and also logic expressions, which allows even sensor outputs to influence the operation. For example, temperature, pressure, flow, time, load, frequency, voltage and other parameters can be combined with the operators “>”, “<”, “=”, “and” and “or” form logic expressions that are false or true.

That is why Danfoss calls it a “logic” controller. As a result, you can program the controller to react to most any event.

Designed for robust operation in a variety of applications

Coated electronics are standard

All VLT® Micro Drives come with conformally coated circuit boards for greater longevity and reliability in harsh operating environments.

Energy efficiency 98%

High-quality VLT® power modules ensure low power losses, resulting in cooler operation.

Intelligent heat management

Heat from the power semiconductors is transferred through the heatsink to the external airflow, which is routed through the cooling fins. This minimizes the air exchange inside the enclosure and protects the control circuitry from dirt and other contaminants.

122˚F (50˚C) ambient temperature

Highly efficient cooling allows for operation in high ambient temperatures.

VLT® Micro Drive **Features**

Hot-pluggable display

Control panels shown actual size: 3.3"H x 2.6"W x 0.8"D (D = 1.1" with potentiometer)

Packed with features

- LCP copy function – transfer parameter settings from one drive to another
- Parameter numbers and values visible simultaneously
- Unit indications (A., V, Hz, RPM, %, s, HP and kW)
- Rotation direction indication
- Setup and status indications
- Removable during operation
- Hand-Off-Auto (H-O-A) buttons for ease of operation

Quick Menus

- Easy access to parameters commonly used in startup procedures
- PI controller parameters grouped for easy access

Large, bright display

- Easy to read from a distance
- H-O-A operation buttons illuminated when active

User-friendly menu structure

- Uses the same familiar and proven format as other VLT® Series drives
- Easy shortcuts for the experienced user
- Edit and operate in different setups simultaneously

Control Panel Options

Two control panels are available for either local or remote mounting:

- LCP 11 with UP/DOWN buttons for speed setting *(NEMA 12 protection when remotely mounted)*
- LCP 12 with rotary potentiometer for speed setting *(NEMA 1 protection)*

VLT® Micro Drive

Mounting brackets included

FC 51 MICRO 200 – 240VAC Single Phase

230V HP	Input Current	Output Current	Chassis/IP20 W	Chassis/IP20 H	Chassis/IP20 D	Frame	Heat Output Watts	Part * Number
1/4	3.3	1.2					16	132F0001
1/2	6.1	2.2	2.8	5.9	5.8	M1	25	132F0002
1	11.6	4.2					44	132F0003
2	18.7	6.8	3.0	7.1	6.6	M2	67	132F0005
3	26.4	9.6	3.5	9.4	7.6	M3	85	132F0007

FC 51 MICRO 200 – 240VAC Three Phase

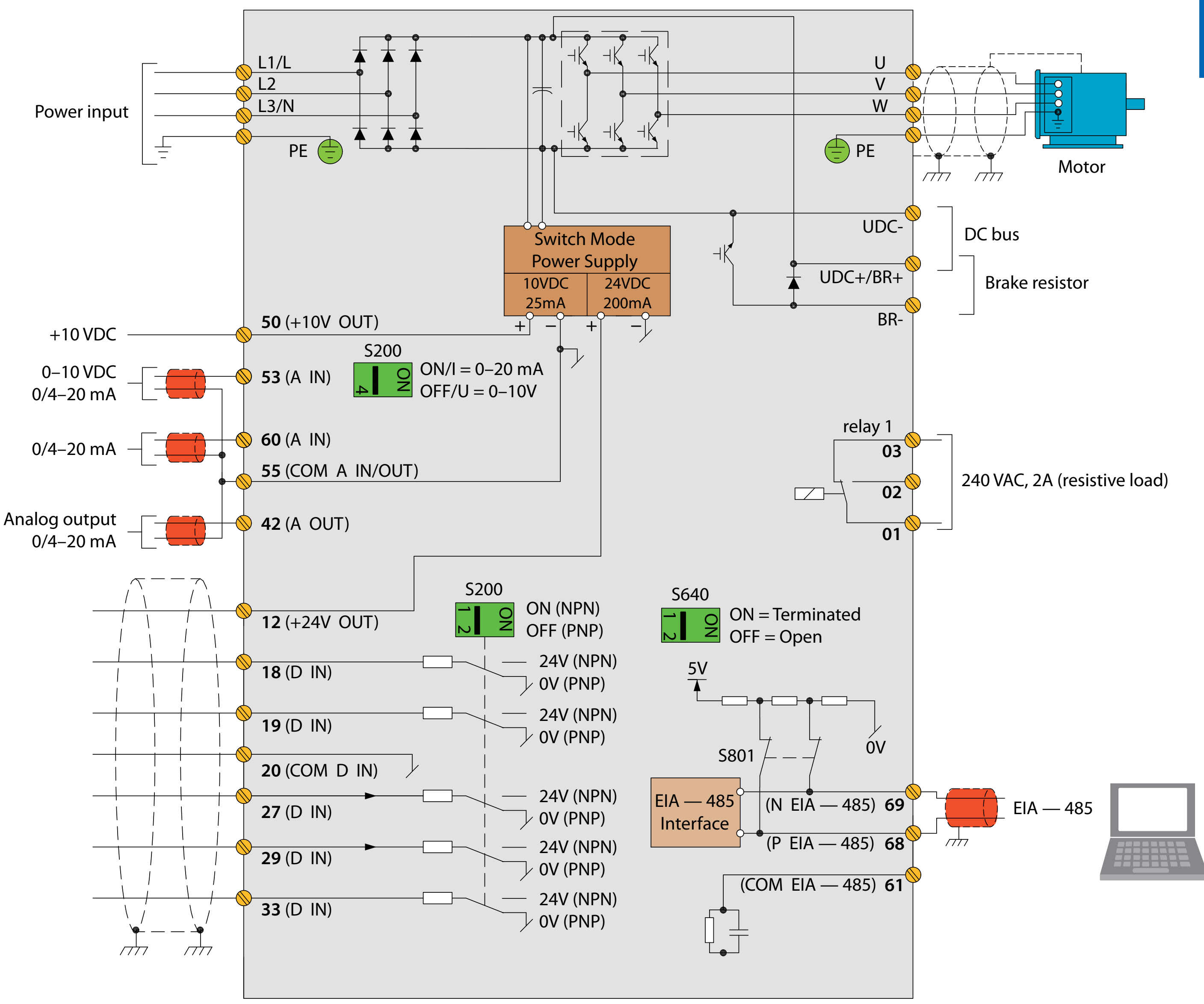
230V HP	Input Current	Output Current	Chassis/IP20 W	Chassis/IP20 H	Chassis/IP20 D	Frame	Heat Output Watts	Part * Number
1/3	2.4	1.5					20	132F0008
1/2	3.5	2.2	2.8	5.9	5.8	M1	25	132F0009
1	6.7	4.2					44	132F0010
2	10.9	6.8	3.0	7.1	6.6	M2	67	132F0012
3	15.4	9.6	3.5	9.4	7.6	M3	85	132F0014
5	24.3	15.2					122	132F0016

FC 51 MICRO 380-480VAC Three Phase

460V HP	Input Current	Output Current	Chassis/IP20 W	Chassis/IP20 H	Chassis/IP20 D	Frame	Heat Output Watts	Part * Number
1/2	1.7	1.1	2.8	5.9	5.8	M1	25	132F0017
1	3	2.1					44	132F0018
2	5.1	3.4	3.0	7.1	6.6	M2	56	132F0020
3	7.3	4.8					81	132F0022
4	9.9	6.3					101	132F0024
5	12.4	8.2	3.5	9.4	7.6	M3	133	132F0026
7.5	16.6	11					167	132F0028
10	21.4	14					218	132F0030
15	29	21	4.9	11.5	9.5	M4	342	132F0058
20	31	27					454	132F0059
25	36	34	6.5	13.2		M5	428	132F0060
30	37.5	40					520	132F0061

VLT® Micro Drive **General Specifications**

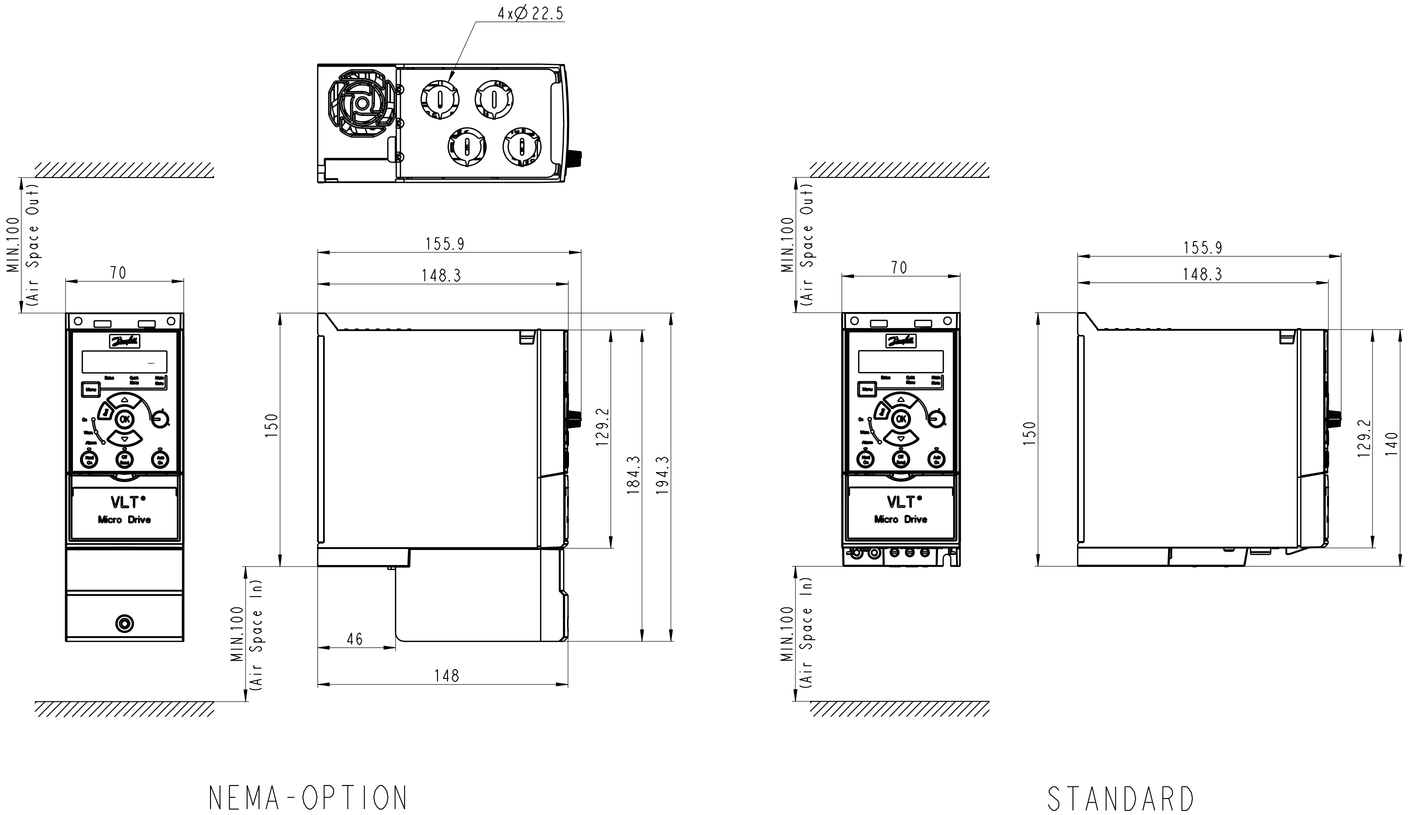
Connections



(PNP) = Active sourcing to terminal 12 (+24V)
(NPN) = Active sinking to terminal 20 (0V)

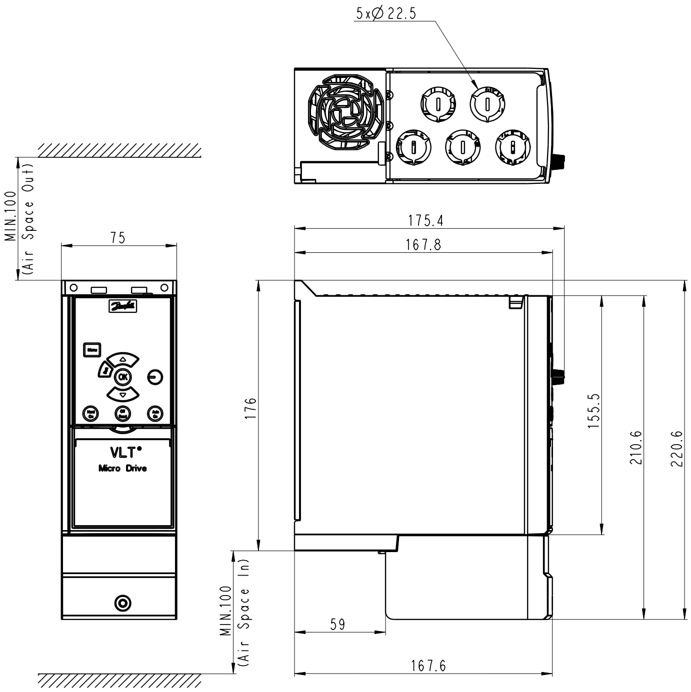
VLT® Micro Drive General Specifications

M1 Frame	
Protected Chasis/IP20	
Dimensions: mm	Weight: 2.42 lbs. (1.1kg)

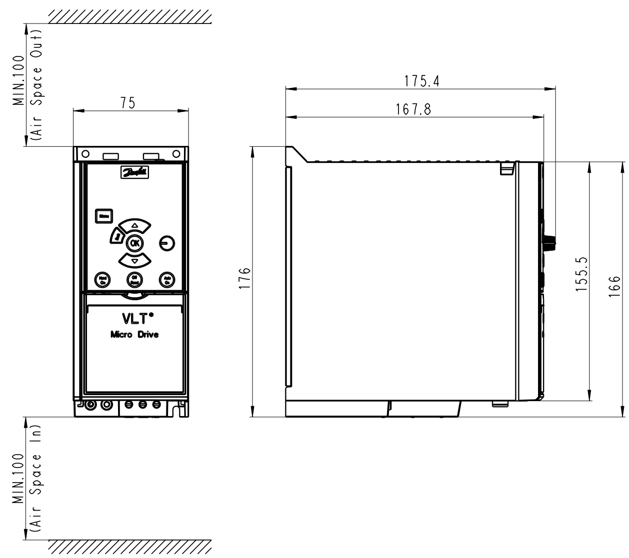


VLT® Micro Drive General Specifications

M2 Frame	
Protected Chassis/IP20	
Dimensions: mm	Weight: 3.52 lbs. (1.6 kg)



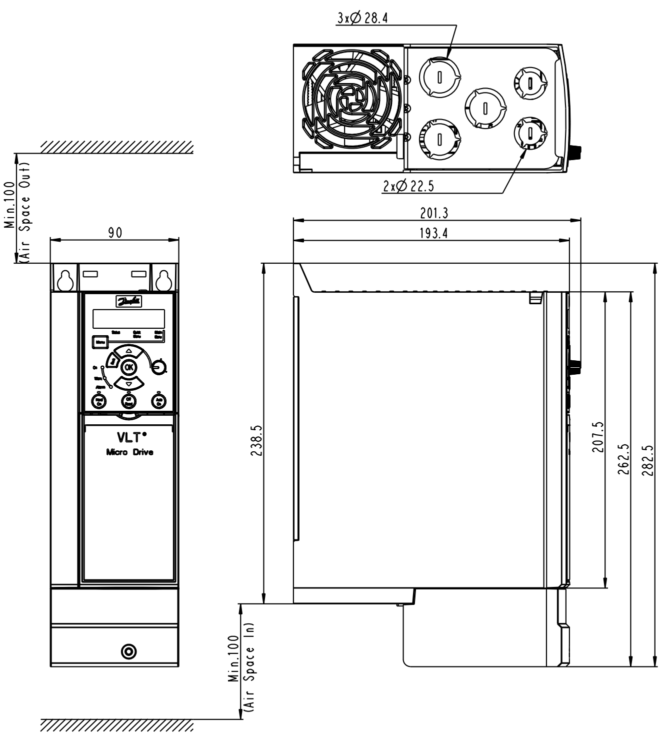
NEMA-OPTION



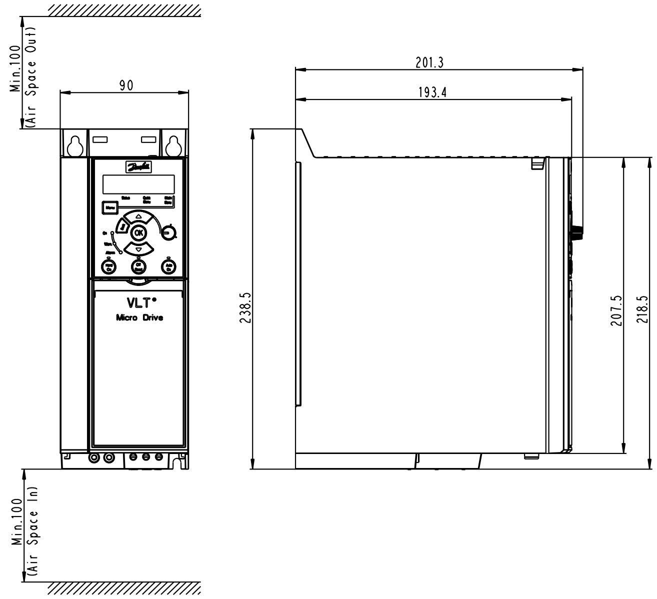
STARDAND

VLT® Micro Drive **General Specifications**

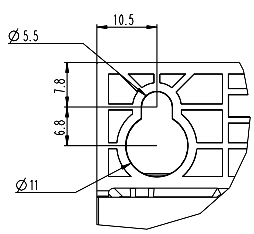
M3 Frame	
Protected Chassis/IP20	
Dimensions: mm	Weight: 6.6 lbs. (3 kg)



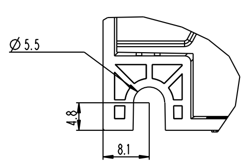
NEMA-OPTION



STANDARD



DETAIL A
SCALE 2:1

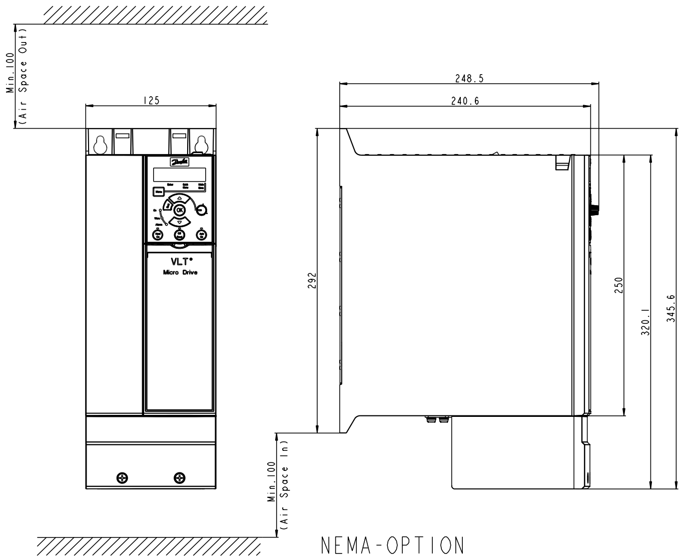


DETAIL B
SCALE 2:1

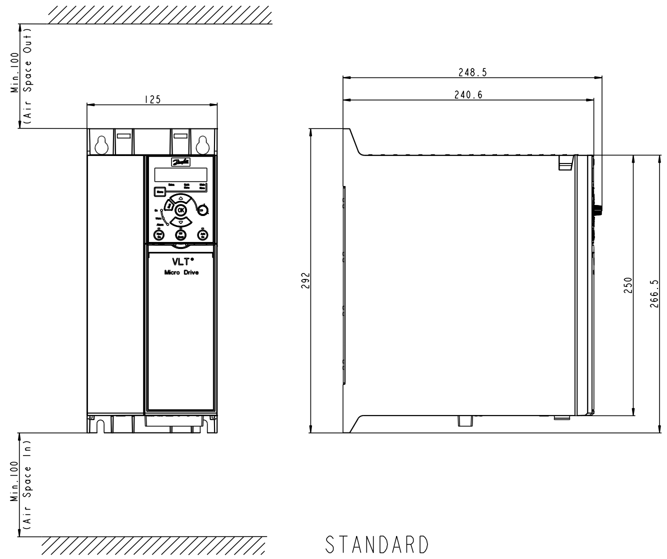
Contact Danfoss for M3 NEMA 1/IP21 dimensions.

VLT® Micro Drive General Specifications

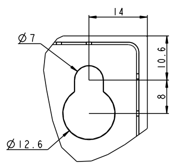
M4 Frame	
Protected Chassis/IP20	
Dimensions: mm	Weight: 13.2 lbs. (6 kg)



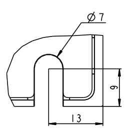
NEMA-OPTION



STANDARD



DETAIL A
SCALE 2:1



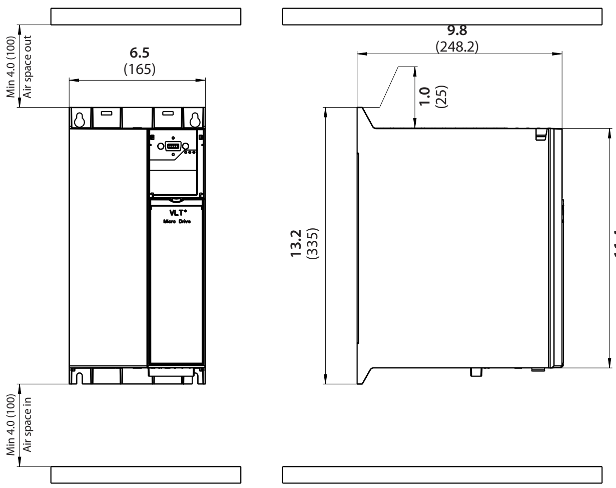
DETAIL B
SCALE 2:1

VLT® Micro Drive General Specifications

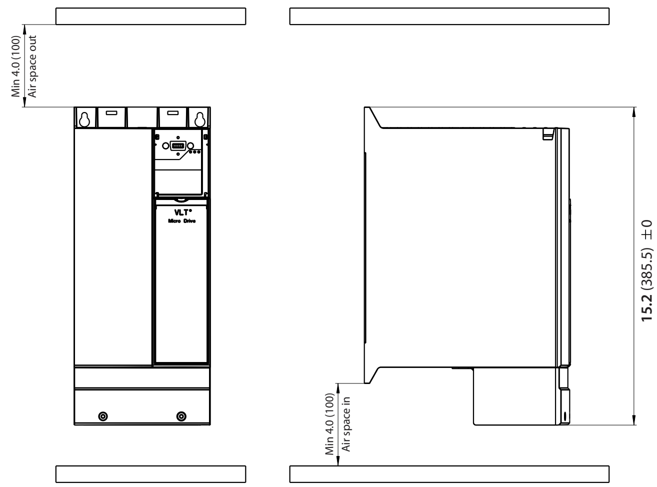
M5 Frame

Protected Chassis/IP20

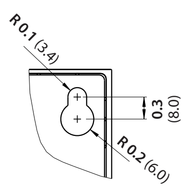
Dimensions: in (mm)	Weight: 20.9 lbs. (9.5 kg)



Standard



Standard+NEMA option



DETAIL A

VLT® Micro Drive Accessories

VLT® MCT 10 (Motion Control Tools)

Offering advanced programming functionality for all Danfoss drive products, VLT® MCT 10 greatly reduces programming and commissioning times.

Drives are managed in a standard folder-based user interface that's familiar and easy to understand. Parameter settings for each drive are contained in a single file, simplifying setup and the duplication of parameter sets between drives.

VLT® MCT 10 Basic version is available free of charge from the Danfoss web site. The Advanced edition, which offers a higher level of functionality, is available from your Danfoss sales partner. Both versions require an RS485 drive.

- On-line and off-line commissioning
- On-board help files for each drive parameter
- Logging of alarms and warnings for improved system performance and documentation
- VLT® MCT 10 Conversion Wizards simplify drive conversion projects
- Real-time data collection using the VLT® MCT 10 Scope function
- Access to the VLT® Micro's internal data buffer, providing up to four channels of high speed (down to 1 millisec) data collection
- Simplified programming of the VLT® Micro's Smart Logic Controller using graphical programming tools
- Drive upgrade tools

Part Number. 130B1000

Brake Resistors

Brake resistor(s) must be used in conjunction with the dynamic brake to dissipate the heat/power regenerated by the motor during deceleration or overhauling load. Braking energy is only absorbed into the brake resistor. Brake resistors must be ordered separately and field installed by the customer.

Contact Danfoss if brake resistors are required for your application.

VLT® Micro Drive **Accessories**

Remote Mounting Kit

A dedicated mounting kit is available for mounting the local control panel (LCP) in a cabinet door. Includes 10' cable.

Part Number: 132B0102

VLT® Control Panels

LCP 11 w/o potentiometer. . . . 132B0100
LCP 12 with potentiometer . . . 132B0101
LCP Blank Cover. 132B0131

NEMA 1 Kits

For M1 frame 132B0103
For M2 frame 132B0104
For M3 frame 132B0105
For M4 frame 132B0120
For M5 frame 132B0121

Decoupling Plate Kit

For M1 and M2 frames 132B0106
For M3 frame 132B0107

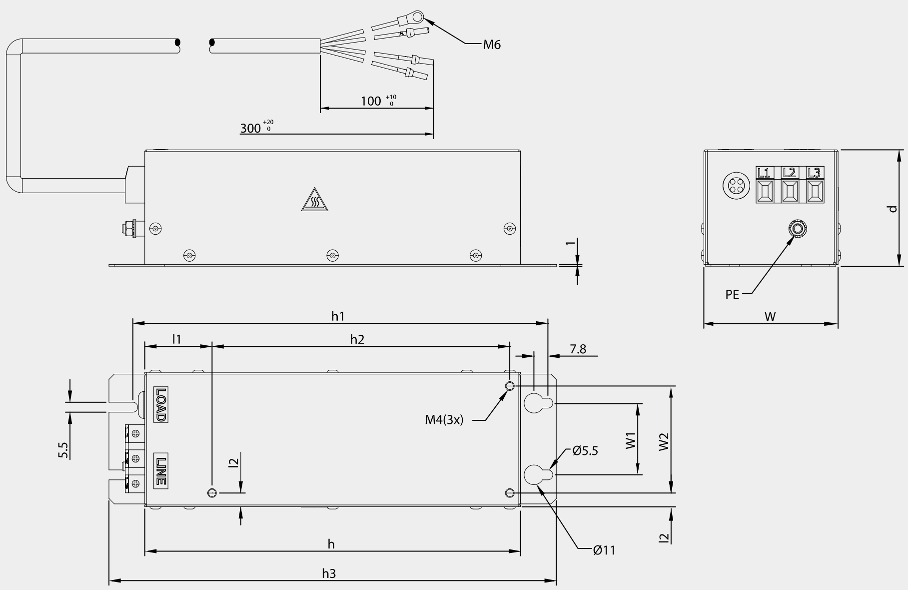
IP21 Kit

For M1 frame 132B0108
For M2 frame 132B0109
For M3 frame 132B0110

DIN Rail Mounting Kit

For M1 frame 132B0111

Dimensions



Frame	M1	M2	M3	Unit
w	2.76	2.95	3.54	in
d	2.17	2.56	2.72	in
h	7.48	8.27	11.81	in
h3	9.06	9.84	13.39	in
w1	1.57	1.57	2.19	in
h1	8.39	9.17	12.72	in
w2	2.17	2.32	2.72	in
h2	5.51	6.56	8.90	in
l1	1.77	1.52	2.68	in
l2	0.30	0.31	0.37	in
PE	M6	M6	M6	metric
Weight	4.41	6.61	11	kg

VLT® Line Filter MCC 107

Perfect
match for:
- Meeting harmonics recommendations
- Soft power grid
- Multiple drives with one filter

The VLT® Micro Drive Line Filter combines a harmonic filter and an EMC filter to improve the low frequency and high frequency performance of the line current to the VLT® Micro Drive.

Increased drive lifetime

Reducing the voltage ripple on the DC link will result in higher reliability and longer drive lifetime. Under similiar running conditions (temperature, load), the expected lifetime of the DC capacitors may be extended by 2-3 times.

Improved power-factor

The VLT® Line Filter will reduce the RMS value of line current. A smaller line current means higher true power-factor (PF). Typically, line current can be reduced by more than 40% and improve PF from 0.4 to 0.7 for single-phase drives and 0.47 to 0.9 for three-phase drives.

Improved high frequency conduction EMC performance

The VLT® Line Filter ensures compliance with EN55011 class A1 for up to 150 ft. of motor cable, and class B up to 30 ft. of motor cable. That means the VLT® Micro Drive + VLT® Line Filter, has an outstanding EMC performance in the micro- inverter class, even with relatively long motor cables.

High immunity against grid disturbances

The line filter will reduce the harmonic current drawn from the grid By reducing THiD by over 50% for both single phase drives and three phase drives. With the line filter, the performance of the immunity to the power surges and transients will be greatly improved.

Line Filter MCC 107 Option for FC51	Part Number
M1 200-240v 1ø – .25-.50 HP	130B2522
M1 200-240v 1ø – 1 HP	130B2533
M1 200-480v 3ø – .25 – 1 HP	130B2523
M2 200-240v 1ø – 2 HP	130B2525
M2 380-480v 3ø – 2 HP	130B2524
M2 200-240v 3ø- 1.5 – 2 HP & 380-480v 3ø – 3 HP	130B2526
M3 200-240v 1ø – 3 HP	130B2530
M3 200-240v 3ø – 4 HP & 380-480v 3ø – 7.5 HP	130B2528
M3 200-240v 3ø – 3 HP & 380-480v 3ø – 5 HP	130B2531
M3 200-240v 3ø – 5 HP & 380-480v 3ø – 10 HP	130B2527
M3 380-480v 3ø – 4.0 HP	130B2529

Features	Benefits
Reduces the voltage ripple on the DC link	Increased drive lifetime
Reduces the RMS value of line current	Improved power-factor
Compliant with EN55011 class A1 up to 50 m of motor cable, and class B up to 10 m of motor cable	Improved high frequency conduction EMC performance
The line filter will reduce the harmonic current drawn from the grid.	High immunity against grid disturbances
Can be used for filtering several small VLT® Micro Drives	One filter for several drives

VLT® 2800 Drive

Perfect
match for:
- Conveyors
- Centrifuges
- Dosing pumps
- Compressors

The VLT® 2800 series has been developed for the low power market. The drive is extremely compact and prepared for side-by-side mounting. The concept is modular with a power module and a control module.

The VLT® 2800 series is designed for stable operation in industrial environments.

Power range

1/3 x 200 – 240V 1/2 – 5 HP
3 x 380 – 480V 3/4 – 25 HP

With 160% overload torque (normal overload)

Features	Benefits
Automatic Motor Tuning	▪ Ensure optimal match between drive and motor ▪ Increasing performance
PID-controller	▪ Optimum process control
Interrupt start/stop	▪ High repeatability of positional accuracy
Dry run detection	▪ No need for specific detection equipment
Fieldbus communication	▪ Allows for control and surveillance of the drives from a PC or a PLC ▪ Profibus and DeviceNet are available
Reliable	**Maximum uptime**
Built-in RFI filter	▪ Compliance with the EMC standard EN 55011 1A
Enhanced sleep mode	▪ Excellent control for shutting down the pump at low flow
Max. ambient temperature 45°C without derating	▪ No external cooling or oversizing necessary
User-friendly	**Saves commissioning and operating cost**
Quick Menu	▪ Easy to use
Pipe Fill mode	▪ Prevents water hammering
Fieldbus communication	▪ Allows for control and surveillance of the drives from a PC or a PLC ▪ Profibus and DeviceNet are available

c UL US

Manufactured to the highest quality standards
The VLT® 2800 Drive is a UL-listed product made in ISO 9001-2000 and ISO 14000 certified facilities.

VLT® 2800 Drive Specifications

PC software tools

- VLT MCT 10: Ideal for commissioning and servicing the drive
- MCT 31: Harmonics calculations tool

RFI filter

The RFI filter ensures that the variable frequency drive will not disrupt other electrical components that are connected to the mains and might cause operating disruption.

By fitting an RFI 1B filter module between the mains supply and the VLT® 2800, the solution complies with the EMC norm EN 55011-1B.

Mains supply (L1, L2, L3)	
Supply voltage	200-240 V ±10%, 380-480 V ±10%
Supply frequency	50/60 Hz
Displacement Power Factor (cos φ) near unity	(> 0.98)
Switching on input supply L1, L2, L3	1–2 times/min.

Output data (U, V, W)	
Output voltage	0–100% of supply voltage
Switching on output	Unlimited
Ramp times	1–3600 sec.
Closed loop	0–132 Hz

Digital inputs	
For start/stop, reset, thermistor, etc.	5
Logic	PNP or NPN
Voltage level	0 – 24 VDC

Analog input	
No. of analog inputs	2
Voltage level	-10 to +10 V (scaleable)
Current level	0/4 to 20 mA (scaleable)

Pulse inputs	
No. of pulse inputs	2
Voltage level	0 – 24 V DC (PNP positive logic)
Pulse input accuracy	(0.1–110 kHz)

Digital output	
No. of digital outputs	1

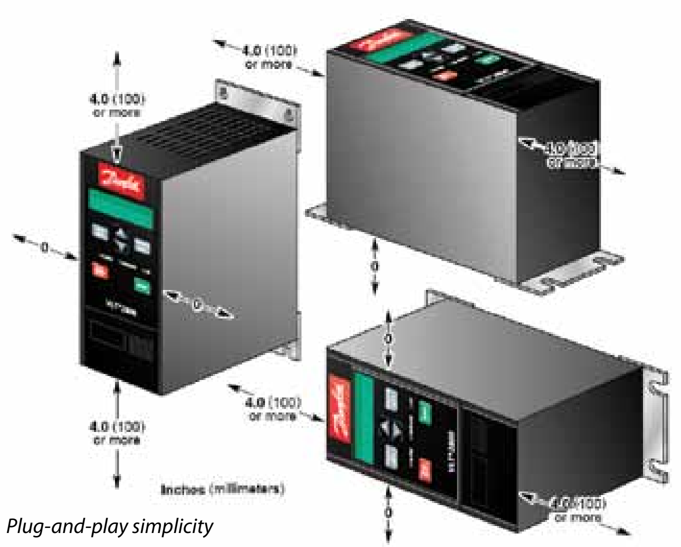
Analog output	
Programmable analog outputs	1
Current range	0/4 – 20 mA

Relay outputs	
No. of relay outputs	1

Fieldbus communication
RS485

Ambient temperature
50˚C

VLT® 2800 Drive **Features**



Plug-and-play simplicity

Exceptional performance has made the VLT® 2800 the one to beat among general purpose drives. Over the years, the VLT® 2800 has proven to be dependable, versatile and easy to operate and commission. Packed with functionality at an attractive price, the VLT® 2800 can be a reliable asset in many applications.

Value-packed

Over one million sold worldwide:

- Compact
- No side clearance required
- Cold plate cooling technology
- Built-in DC-link reactor for harmonics reduction
- PID Controller

Easy to operate

- Quick Menu includes parameters needed for quick startup
- Hot-pluggable display with copy function available as option
- VLT® MCT 10 setup software can greatly simplify installation and startup

Intelligent

- Bus communication options include DeviceNet, Profibus DP, and built-in Modbus RTU and Metasys N2
- Precise stop
- Pump functions
- Wobble functions

Rugged and reliable

- Robust, with die-cast chassis and efficient heat dissipation
- Protected against line transients
- 24-hour support, local service
- 100% ground fault protection
- Protected from switching on input and output
- Galvanic isolation
- Output short circuit protection – survives even short circuit of motor cables and short circuit of signal cables
- No derating – operates at full load and full speed in temperatures up to 104°F (40°C)
- Complies with the EMC norm EN 55011 Class 1A and 1B (with RFI filter)

Single-phase line supply

Available up to 5 HP, single-phase VLT® 2800 Series drives can be wired to plug into a standard single-phase outlet. These drives can then be connected to three-phase pumps, fans, blowers, and more. It's just like getting three-phase power from a standard 220–240V power socket.

Flexible mounting

The VLT® 2800 is designed for flexible mounting. A ventilated heatsink allows drive units to be mounted side-by-side or even horizontally.

User friendly

Entering motor data in the Quick Menu via the control panel is often all it takes to get up and running.

Hand-Off-Auto

This software function is actually three functions in one, all operated as a one-button control:

Auto (normal mode)

The drive is controlled by external or local reference signals, analog, digital inputs or fieldbus reference (e.g., current or voltage, such as 0 – 10 V or 4 – 20 mA).

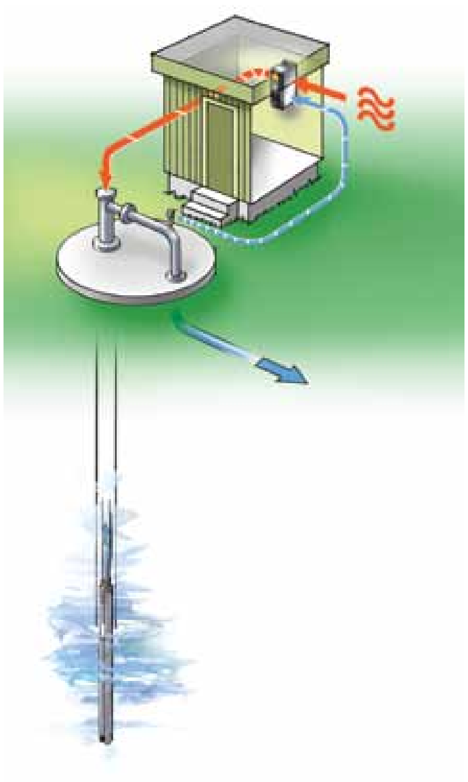
Hand

In this mode, the application can be controlled manually from the keypad, temporarily ignoring external reference signals. The hand mode is useful for commissioning or in case of error in an external controller/sensor. Transition from Auto to Hand is smooth. Up/down arrows provide speed reference control on the LCP (Local Control Panel).

Off

The stop button allows the application to be stopped locally for servicing of the drive (e.g., for changing parameters).

VLT® 2800 Drive **Features**



Water features dry pump detection

New features improve pump operation significantly, offering improved energy savings and greater pump protection. VLT® 2800 Series drives can detect when the pump has run dry and shut it down before damage can occur.

- Automatic or manual restart
- Programmable restart delay up to one hour
- Shutdown at low or no flow
- Operates in open or closed loop

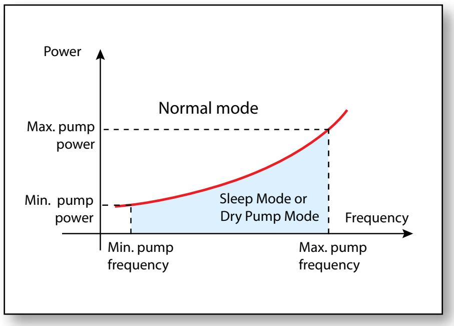
Pipe fill mode

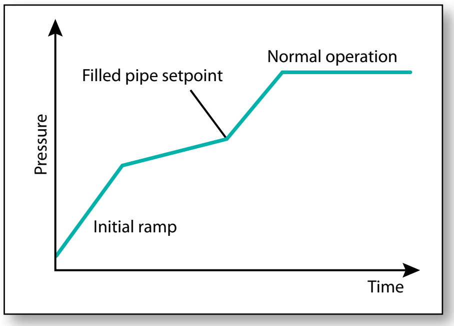
Provides controlled filling of pipes, preventing water hammer, burst water pipes and damage to sprinkler heads. Pipe fill mode is particularly valuable in applications that are vulnerable to these types of damage, such as irrigation or water supply systems. Once up to speed, the drive's PID loop utilizes an input signal to match the desired line pressure in the system.

Enhanced sleep mode

When using pumps with flat pump curves or when the suction pressure varies, this feature provides excellent control for shutting down the pump at low flow, thus saving energy.

- Automatic restart after shutdown based on pressure
- Boost function increases pressure prior to shutdown
- Operates in closed loop





VLT® 2800 Drive General Specifications

Mains Supply (L1, L2, L3)

Supply voltage VLT® 2803-2840 220 – 240 V (N, L1)	1 x 220/230/240 V ±10%
200 – 240 V	3 x 200/208/220/230/240 V ±10%
VLT® 2805-2882 380-480 V	3 x 380/400/415/440/480 V ±10%
VLT® 2805-2840 (R5)	380/400 V +10%
Supply frequency	50/60 Hz ±3 Hz
Max. imbalance on supply voltage	±2.0% of rated supply voltage
True Power Factor (λ)	0.90 nominal at rated load
Displacement Power Factor (cos φ)	near unity (>0.98)
Number of connections at supply input L1, L2, L3	2 times/min.
Max. short-circuit value	100,000 A

See Design Guide section on Special Conditions.

Output Data (U, V, W)

Output voltage	0 – 100% of supply voltage
Output frequency	0.2 – 132 Hz, 1 – 1000 Hz
Rated motor voltage 200 – 240 V units 380 – 480 V units	 200/208/220/230/240 V 380/400/415/440/460/480 V
Rated motor frequency	50/60 Hz
Switching on output	Unlimited
Ramp times	0.02 – 3600 sec.

Torque Characteristics

Starting torque (parameter 101 Torque characteristic = Constant torque)	160% in 1 min.*
Starting torque (parameter 101 Torque characteristics = Variable torque)	160% in 1 min.*
Starting torque (parameter 119 High starting torque)	180% for 0.5 sec.
Overload torque (parameter 101 Torque characteristic = Constant torque)	160%*
Overload torque (parameter 101 Torque characteristic = Variable torque)	160%*

Percentage relates to VFD's nominal current.
** VLT® 2822 & 2840 1Ø 220 V only 110% in 1 min.*

Control Card, Digital Inputs

Number of programmable digital inputs	5
Terminal number	18, 19, 27, 29, 33
Voltage level	0 – 24 VDC (PNP positive logic)
Voltage level, logic '0'	<5 VDC
Voltage level, logic '1'	>10 VDC
Maximum voltage on input	28 VDC
Input resistance (terminals 18, 19, 27, 29)	approx. 4 kΩ
Input resistance (terminal 33)	approx. 2 kΩ

All digital inputs are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals. See Design Guide section on Galvanic Isolation.

Control Card, Analog Inputs

Number of analog voltage inputs	1
Terminal number	53
Voltage level	0 – 10 VDC (scaleable)
Input resistance	approx. 10 kΩ
Max. voltage	20 V
Number of analog current inputs	1 pcs.
Terminal number	60
Current level	0/4 – 20 mA (scaleable)
Input resistance	approx. 300 Ω
Max. current	30 mA
Resolution for analog inputs	10 bit
Accuracy of analog inputs	Max. error 1% of full scale
Scan interval	13.3 msec

The analog inputs are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

Control Card, Pulse Inputs

Number of programmable pulse inputs	1
Terminal number	33
Max. frequency at terminal 33	67.6 kHz (Push-pull) 5 kHz (open collector)
Min. frequency at terminal 33	4 Hz
Voltage level	0 – 24 VDC (PNP positive logic)
Logic '0'	<5 VDC
Logic '1'	>10 VDC
Maximum voltage on input	28 VDC
Input resistance	approx. 2 kΩ
Scan interval	13.3 msec
Resolution	10 bit
Accuracy 100 Hz – 1 kHz) terminal 33 1 kHz – 67.6 kHz) terminal 33	 Max. error: 0.5% of full scale Max. error: 0.1% of full scale

The pulse input (terminal 33) is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

VLT® 2800 Drive General Specifications

Control Card, Digital/Frequency Output

Number of programmable digital/pulse outputs	1
Terminal number	46
Voltage level at digital/frequency output	0 – 24 VDC (O.C PNP)
Max. output current at digital/frequency output	25 mA.
Max. load at digital/frequency output	1 kΩ
Max. capacity at frequency output	10 nF
Minimum output frequency at frequency output	16 Hz
Maximum output frequency at frequency output	10 kHz
Accuracy on frequency output	Max. error: 0.2% of full scale
Resolution on frequency output	10 bit

The digital output is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

Control Card, Analog Output

Number of programmable analog outputs	1
Terminal number	42
Current range at analog output	0/4 – 20 mA
Max. load to common at analog output	500 Ω
Accuracy on analog output	Max. error: 1.5% of full scale
Resolution on analog output	10 bit

The analog output is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

Control Card, 24 VDC Output

Terminal number	12
Max. load	130 mA

The 24 VDC supply is galvanically isolated from the supply voltage (PELV), but has the same potential as the analog and digital inputs and outputs.

Control Card, 10 VDC Output

Terminal number	50
Output voltage	10.5 V ±0.5 V
Max. load	15 mA

The 10 VDC supply is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

Control Card, RS 485 Serial Communication

Terminal number	68 (TX+, RX+), 69 (TX-, RX-)
Terminal number 67	+5 V
Terminal number 70	Common for terminals 67, 68 and 69

Full galvanic isolation. See Design Guide section on Galvanic Isolation. For DeviceNet units, see VLT® 2800 DeviceNet manual, MG.90.BX.YY.

Relay Outputs[1)]

Number of programmable relay outputs	1
Terminal number, control card (resisitvie and inductive load)	1-3 (break), 1-2 (make)
Max. terminal load (AC1) on 1-3, 1-2, control card	250 VAC, 2 A, 500 VA
Max. terminal load (DC1 (IEC 947) on 1-3, 1-2, control card	25 VDC, 2 A /50 VDC, 1A, 50 W
Min. terminal load (AC/DC) on 1-3, 1-2, control card	24 VDC 10 mA, 24 VAC 100 mA

The relay contact is separated from the rest of the circuit by strengthened isolation.
Note: Rated values resistive load – cosphi >0.8 for up to 300,000 operations. Inductive loads at cosphi 0.25 approximately 50% load or 50% life time.

Cable Lengths and Cross Sections

Max. motor cable length Shielded cable	130 ft. (40 m)
Unshielded cable	250 ft. (75 m)
Shielded cable and motor coil	330 ft. (100 m)
Unshielded cable and motor coil	660 ft. (200 m)
Shielded cable and RFI/1B filter	200 V, 330 ft. (100 m) 400 V, 80 ft. (25 m)
Shielded cable and RFI 1B/LC filter	400 V, 80 ft. (25 m)
Max. cross section to: Motor	see next section.
Control wires, rigid wire	1.5 mm²/16 AWG (2 x 0.75 mm²)
Control cables Flexible cable	1 mm²/18 AWG
Cable with enclosed core	0.5 mm²/20 AWG

When complying with EN 55011 1A and EN 55011 1B the motor cable must in certain instances be reduced.

VLT® 2800 Drive General Specifications

Control Characteristics	
Frequency range	0.2 – 132 Hz, 1 – 1000 Hz
Resolution of output frequency	0.013 Hz, 0.2 – 1000 Hz
Repeat accuracy of Precise start/stop(terminals 18, 19)	±0.5 msec
System response time (terminals 18, 19, 27, 29, 33)	26.6 msec
Speed control range Open loop	1:10 of synchronous speed
Closed loop	1:120 of synchronous speed
Speed accuracy Open loop	150 – 3600 rpm: Max. error of ±23 rpm
Closed loop	30 – 3600 rpm: Max. error of ±7.5 rpm

All control characteristics are based on a 4-pole asynchronous motor.

Surroundings	
Enclosure	IP20
Enclosure with options	NEMA 1
Vibration test	0.7 g
Max. relative humidity	5% – 93% during operation
Ambient temperature	Max. 113°F (45°C) 24-hour average max. 104°F (40°C)
Derating for high ambient temperature	See special conditions in the Design Guide
Min. ambient temperature During full-scale operation	32°F (0°C)
At reduced performance	14°F (-10°C)
Temperature during storage/transport	-13°F (-25°C) to 149/158°F (65/70°C)
Max. altitude above sea level	1000 m
Derating for high air pressure	see special conditions in the Design Guide
EMC standards Emission	EN 61081-2, EN 61800-3, EN 55011
Immunity	EN 50082-1/2, EN 61000-4-2, EN 61000-4-3, EN 61000-4-4, EN 61000-4-5, EN 61000-4-6, EN 61800-3

See Design Guide section on Special Conditions.

Protection and Features:

- Electronic thermal motor protection against overload.
- Temperature monitoring of the power module ensures that the drive cuts out if the temperature reaches 212°F (100°C). An overload temperature cannot be reset until the temperature of the power module is below 158°F (70°C).
- The drive is protected against short-circuits on motor terminals U, V, W.
- If a mains phase is missing, the drive will cut out.
- Monitoring of the intermediate circuit voltage ensures that the drive cuts out if the intermediate circuit voltage is too low or too high.
- The drive is protected against ground fault on motor terminals U, V, W.

VLT® 2800 Drive Drive Performance Data

1Ø 220 – 240 VAC; 3Ø 200 – 240 VAC

VLT® Type			2803	2805	2807	2811	2815
Typical Shaft Output		[HP]	0.5	0.75	1.0	1.5	2.0
Output Current							
Continuous		[A]	2.2	3.2	4.2	6.0	6.8
Intermittent (60 sec)		[A]	3.5	5.1	6.7	9.6	10.8
Max. Input Current							
Continuous	1Ø, 220 – 240 VAC	[A]	5.9	8.3	10.6	14.5	15.2
	3Ø, 200 – 240 VAC	[A]	2.9	4.0	5.1	7.0	7.6
Intermittent	1Ø, 220 – 240 VAC	[A]	9.4	13.3	16.7	23.2	24.3
(60 sec)	3Ø, 200 – 240 VAC	[A]	4.6	6.4	8.2	11.2	12.2
Environment							
Estimated Power Loss at Rated Max. Load	240 VAC	[W]	24	35	48	69	94
Enclosure			Protected Chassis/IP20 (NEMA 1 opt)				
Weight		[lbs.]	4.4	4.4	4.4	4.4	4.4

VLT® Type			2822	2822 (T2*)	2840	2840 (T2*)
Typical Shaft Output		[HP]	3.0	3.0	5.0	5.0
Output Current						
Continuous		[A]	9.6	9.6	16.0	16.0
Intermittent (60 sec)		[A]	10.6	15.3	17.6	25.6
Max. Input Current						
Continuous	1Ø, 220 – 240 VAC	[A]	22.0	–	31.0	–
	3Ø, 200 – 240 VAC	[A]	8.8	8.8	14.7	14.7
Intermittent	1Ø, 220 – 240 VAC	[A]	24.3	–	34.5	–
(60 sec)	3Ø, 200 – 240 VAC	[A]	9.7	14.1	16.2	23.5
Environment						
Estimated Power Loss at Rated Max. Load		[W]	125	125	231	231
Enclosure	1Ø, 220 – 240 VAC		Protected chassis/IP20 (NEMA 1 opt) (NEMA 1 std on 2840 T2 only)			
Weight		[lbs.]	13.2	8.2	40.7	13.2

**2822 and 2840 T2 versions are 3Ø only.*

VLT® 2800 Drive **Drive Performance Data**

3Ø 380 – 480 VAC

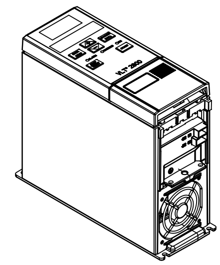
VLT® Type			2805	2807	2811	2815	2822	2830
Typical Shaft Output		[HP]	0.75	1.0	1.5	2.0	3.0	4.0
Output Current								
Continuous		[A]	1.7	2.1	3.0	3.7	5.2	7.0
Intermittent (60 sec)		[A]	2.7	3.3	4.8	5.9	8.3	11.2
Max. Input Current								
Continuous		[A]	1.6	1.9	2.6	3.2	4.7	6.1
Intermittent		[A]	2.6	3.0	4.2	5.1	7.5	9.8
Environment								
Estimated Power Loss at Rated Max. Load	460 VAC	[W]	28	38	55	75	110	150
Enclosure			Protected chassis/IP20 (NEMA 1 opt)					
Weight		[lbs.]	4.6	4.6	4.6	4.6	8.2	8.2

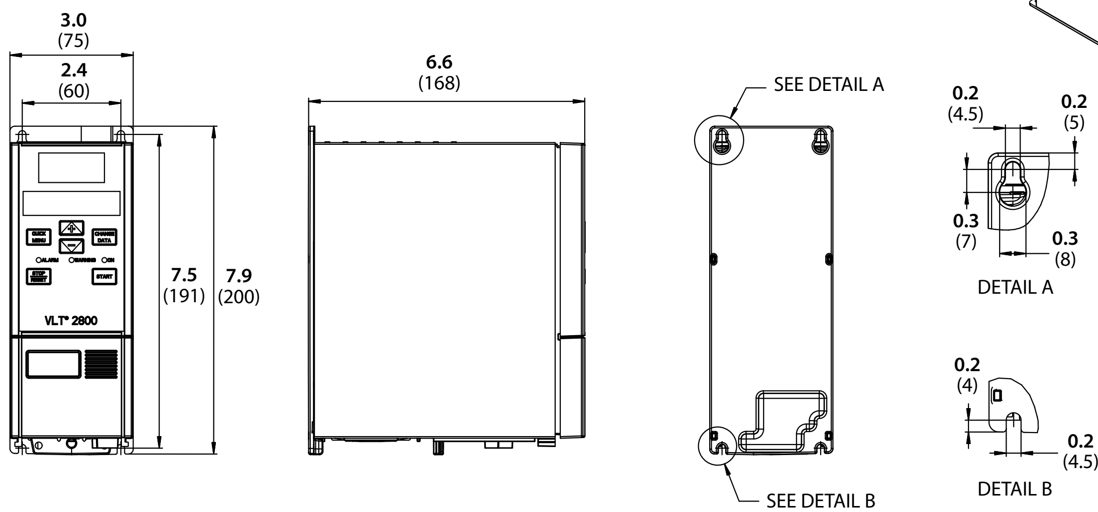
VLT® Type		2840	2855	2875	2880	2881	2882
Typical Shaft Output	[HP]	5.0	7.5	10	15	20	25
Output Current							
Continuous	[A]	9.1	12.0	16.0	24.0	32.0	37.5
Intermittent	[A]	14.5	19.2	25.6	38.4	51.2	60.0
Max. Input Current							
Continuous	[A]	8.1	10.6	14.9	24.0	32.0	37.5
Intermittent	[A]	13.0	17.0	23.8	38.4	51.2	60.0
Environment							
Estimated Power Loss at Rated Max. Load	[W]	200	275	372	412	562	693
Enclosure		Protected chassis/IP20 (NEMA 1 opt)			Protected chassis/IP20 NEMA 1		
Weight	[lbs.]	8.2	13.2	13.2	40.7	40.7	40.7

VLT® 2800 Drive Mechanical Dimensions

Protected Chassis/IP20

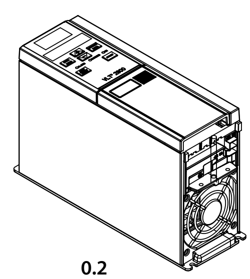
VLT® 2803 – 2815 (1/2 – 2 HP) 200 – 240 VAC
VLT® 2805 – 2815 (3/4 – 2 HP) 380 – 480 VAC
in (mm)

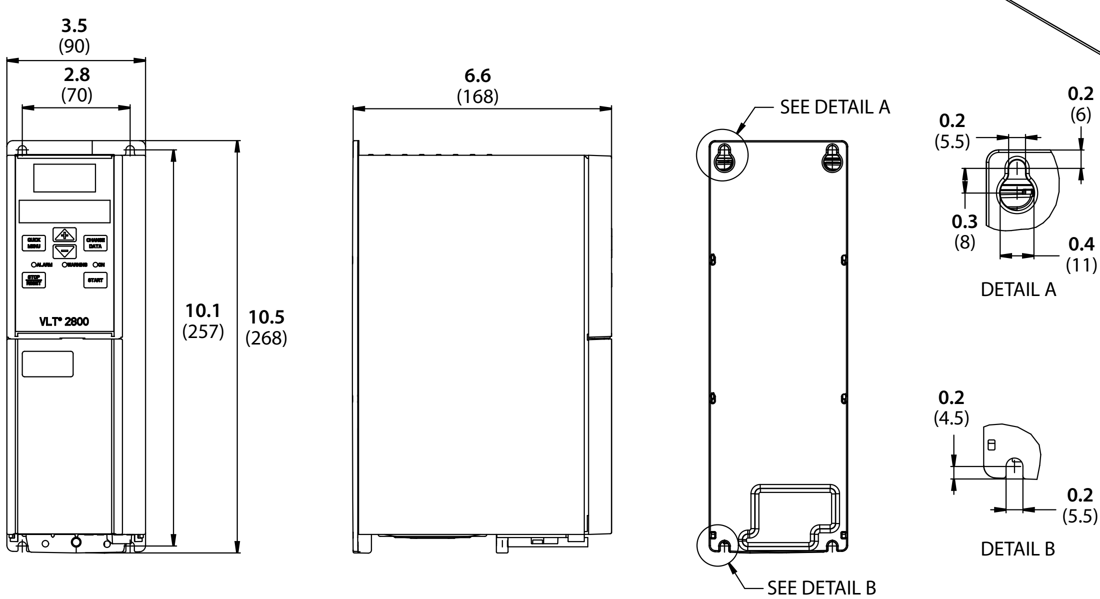




Protected Chassis/IP20

VLT® 2822 (T2) (3 HP) 3Ø 200 – 240 VAC
VLT® 2822 – 2840 (3 – 5 HP) 380 – 480 VAC
in (mm)

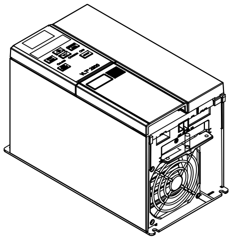


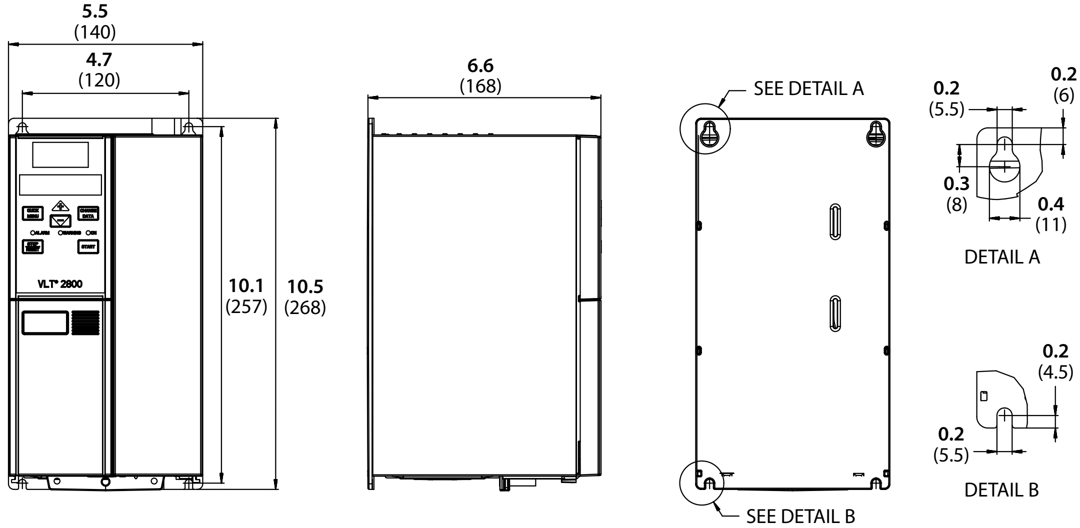


VLT® 2800 Drive Mechanical Dimensions

Protected Chassis/IP20

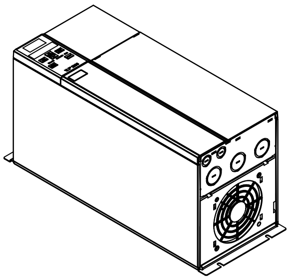
VLT® 2822 (3 HP) 1Ø/3Ø 220 – 240 VAC
VLT® 2840 (T2) (5 HP) 3Ø 200 – 240 VAC
VLT® 2855 – 2875 (7.5 – 10 HP) 380 – 480 VAC
in (mm)

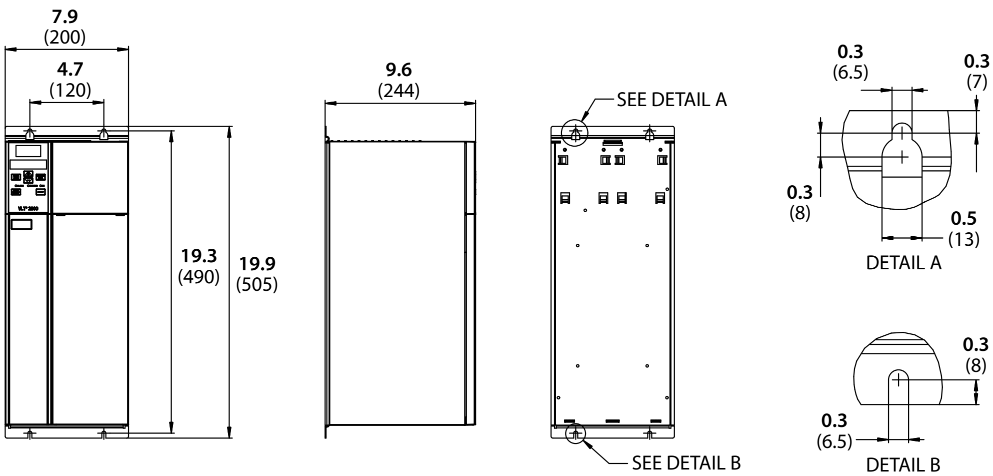




NEMA 1/IP21

VLT® 2840 (5 HP) 1Ø/3Ø 220 – 240 VAC
VLT® 2880 – 2882 (15 – 25 HP) 380 – 480 VAC
in (mm)





Phone 1-800-432-6367

VLT® 2800 Drive Options and Accessories

Profibus Control Card Option

Profibus is a fieldbus system, which can be used for linking automation devices such as sensors and actuators with the controls by means of a two-conductor cable.

Using the Profibus option, the Danfoss drive always acts as a follower to the master PC or PLC. It exchanges information and commands such as "speed reference," "start/stop" of motor, "reverse" operation, etc. The drive acknowledges receipt by transmitting status signals, such as "running," "on reference," "motor stopped" and so on to the PC/PLC. The VLT® 2800 Series drive may also transmit fault indications, alarms and warnings to the PC/PLC.

The Profibus option card communicates according to the Profibus Protocol Standard DIN 19245 parts 1, 2 and 3. This means that it can communicate with all PC/PLCs that comply with this standard, but it does not necessarily mean that all services available in the Profibus standard are supported. The VDI/VDE 3689 Profibus Profile for Variable Speed Drives is a subset of Profibus part 2 – FMS – which only supports the services relevant to speed control applications. PROFIDRIVE is an implementation of VDI/VDE 3689 profile created by Danfoss and a number of other companies.

Option Order Code	
F10	With Profibus DP (3 MB)
F12	With Profibus DP (12 MB)

DeviceNet Control Card Option

DeviceNet fieldbus systems can be used for linking automation devices such as sensors and actuators with the controls by means of a four-wire conductor cable.

DeviceNet is a factory installed option available on all VLT® 2800 Series drive models. This option supports a ±10 VDC reference signal and provides inputs for quadrature encoder signal. The baud rate and address are set in the VLT® 2800 parameter menu.

Option Order Code	
F30	With DeviceNet

LCP-2 Remote Control Panel Kit

The VLT® 2800 Series has an optional LCP-2 keypad available for remote programming/commissioning and operation, mountable up to 10 ft. (3 m) from the unit. The LCP-2 keypad is a full alphanumeric display that provides concise programming and clear monitoring of drive and application parameters during operation. The separate mounting kit includes all the necessary hardware to mount the LCP-2 to satisfy NEMA 12 requirements.

VLT® MCT 10 (Motion Control Tools)

Offering advanced programming functionality for all Danfoss drive products, VLT® MCT 10 greatly reduces programming and commissioning times.

Drives are managed in a standard folder-based user interface that's familiar and easy to understand. Parameter settings for each drive are contained in a single file, simplifying setup and the duplication of parameter sets between drives.

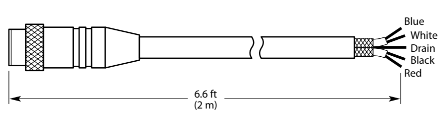
VLT® MCT 10 Basic version is available free of charge from the Danfoss web site. The Advanced edition, which offers a higher level of functionality, is available from your Danfoss sales partner. Both versions require an RS485 drive.

- On-line and off-line commissioning
- On-board help files for each drive parameter
- Logging of alarms and warnings for improved system performance and documentation
- VLT® MCT 10 Conversion Wizards simplify drive conversion projects
- Real-time data collection using the VLT® MCT 10 Scope function
- Access to the VLT® 2800's internal data buffer, providing up to four channels of high speed (down to 1 millisec) data collection
- Simplified programming of the VLT® 2800's Smart Logic Controller using graphical programming tools
- Drive upgrade tools

ODVA Approved Drop Cable Accessory

An ODVA approved 6.6 foot (2 meter) drop cable is available as a separate accessory for use with the DeviceNet Control Card option.

Part Number: 195N3113



VLT® 2800 Drive Options and Accessories

Motor Coil Accessory

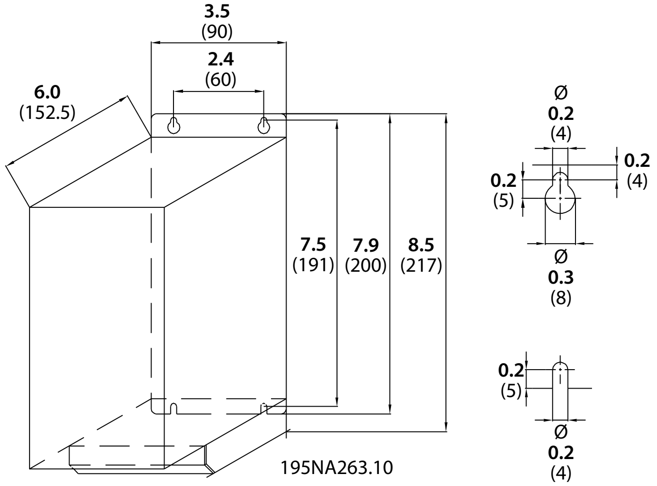
The use of motor coils allows unlimited switching on the output. Typically, this is an essential feature for applications utilizing multiple motors or switchgear in the motor line for items such as bypass circuits.

An added benefit of the motor coil is that it permits the use of motor cable up to 650 ft. (The standard VLT® 2800 drive allows cables up to 130 ft.) Motor coils do not meet RFI emission requirements.

Motor coils come in IP20 enclosures, mounted directly beside the drive. The motor coil accessory is available on all VLT® 2800 models.

Part Number: 195N3110

Motor Coil Specifications	
Max. motor cable length	650 ft. (200 m) unshielded; 300 ft. (100 m) shielded
Enclosure	IP20
Min. distance between VLT® and module	Side by side
Min. space above and below	4 in (100 mm)
Max. nominal input current	16 A RMS
Max. voltage	480 VAC
Approvals	VDE, UL/cUL



VLT® 2800 Drive Options and Accessories

RFI Options and Accessories

The switching of a variable frequency drive's power components causes deviations in the voltage and current of the AC line. These deviations contain elements of high frequencies that may disturb equipment sharing the power line or radiate to nearby equipment. High frequencies in the 150 kHz to 30 MHz range are identified as RFI (radio frequency interference).

When properly used, RFI filters prevent interference currents from transmitting back onto the AC power lines in accordance to the European Community (CE) requirements.

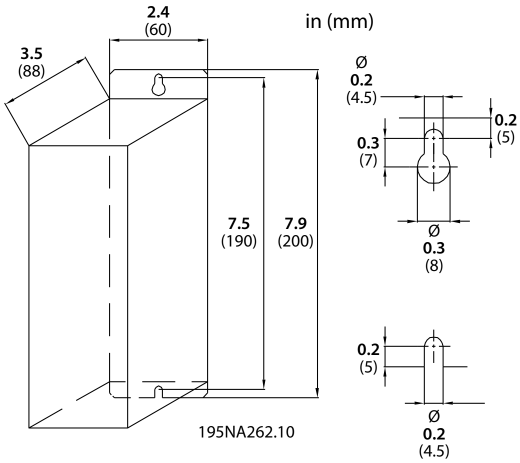
As a built-in option, both RFI Class 1, Group A and Group B filters are available.

The Class 1, Group B filter or the RFI 1B/LC filter accessories are ordered separately and are mounted directly alongside of the drive (see illustrations). The RFI 1B/LC filter is a dual purpose filter which serves to meet stringent Class 1, Group B RFI requirements as well as reducing acoustic motor noise.

Built-in RFI 1A and 1B Filter Options

The built-in RFI options comply with the EMC norm EN 55011 Class 1A and 1B.

Option Order Code	
R1	With built-in 1A filter (VLT® 2803 – 2875)
R3	With built-in 1B filter (VLT® 2880 – 2882)



RFI 1B Filter Accessory	
Max. motor cable length VLT® 2800 200-240 V VLT® 2800 380-480 V	 300 ft. (100 m) shielded 25 ft. (25 m) shielded
Enclosure	IP20
Min. distance between VLT® and module	Side by side
Min. space above and below	4 in. (100 mm)
Max. nominal input current	16 A RMS
Max. voltage	480 VAC
Max. voltage to ground	380 VAC
Approvals	VDE, UL/cUL

Part Number: **195N3103**

VLT® 2800 Drive Options and Accessories

RFI 1B/LC Filter Accessory		
Power Rating	4.0 A	9.1 A
Max. motor cable length	1000 ft. (300 m) unshielded	500 ft. (150 m) shielded
Enclosure	IP20	IP20
Min. distance between VLT® and module	Side by side	Side by side
Min. space above and below	4 in. (100 mm)	4 in. (100 mm)
Dimensions – H x W x D	7.87 x 2.95 x 6.61 in. (200 x 75 x 168)	10.12 x 3.54 x 6.61 in. (257 x 90 x 168 mm)
Max. nominal input current	16 A RMS	16 A RMS
Max. voltage	480 VAC	480 VAC
Max. voltage to ground	380 VAC	380 VAC
Approvals	VDE, UL/cUL	VDE, UL/cUL

Part Number:	**195N3100**	**195N3101**

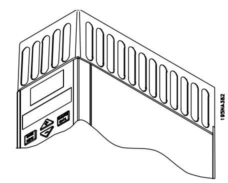
VLT® 2800 Drive Options and Accessories

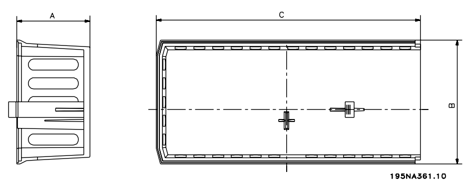
Brake Resistor Accessories

Brake resistor(s) must be used in conjunction with the dynamic brake to dissipate the heat/power regenerated by the motor during deceleration or overhauling load. Braking energy is only absorbed into the brake resistor. Brake resistors must be ordered separately and field installed by the customer.

IP21 Cover Accessory

Allows the VLT® 2800 to meet IP21 enclosure requirements. Contact Danfoss if brake resistors are required for your application.



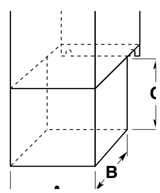


NEMA UL Type 1 Terminal Cover Accessory

All models up to 5 HP (200 – 240 VAC) and 10 HP (380 – 480 VAC) can be fitted with an optional protective attachment to the base of the drive to convert the unit to a NEMA UL Type 1 rating. The NEMA 1 Kit option is ordered as a separate order number, and is specifically designed as a field upgrade kit.

VLT® 2880-2882 drives meet NEMA 1 requirements as standard.

Part Number	Dimensions – in (mm)		
	A	B	C
195N1900	3.0 (75)	3.4 (86)	2.3 (59)
195N1901	3.5 (90)	3.5 (90)	2.4 (60)
195N1902	5.5 (140)	3.4 (86)	3.1 (79)



Model	HP	VAC	Part Number
VLT® 2803	0.5	200 – 240	195N1900
VLT® 2805	0.75	All	195N1900
VLT® 2807	1	All	195N1900
VLT® 2811	1.5	All	195N1900
VLT® 2815	2	All	195N1900
VLT® 2822	3	All	195N1901
VLT® 2830	4	380 – 480	195N1901
VLT® 2840	5	380 – 480	195N1901
VLT® 2840	5	200 – 240	195N1902
VLT® 2855	7.5	380 – 480	195N1902
VLT® 2875	10	380 – 480	195N1902

Part Number	Dimensions – in (mm)		
	A	B	C
195N2179	1.85 (47)	3.15 (80)	6.69 (170)
195N2180	1.85 (47)	3.74 (95)	6.69 (170)
195N2181	1.85 (47)	5.71 (145)	6.69 (170)
195N2182	1.85 (47)	8.07 (205)	9.65 (245)

Model	HP	VAC	Part Number
VLT® 2803	0.5	200 – 240	195N2179
VLT® 2805	0.75	All	195N2179
VLT® 2807	1	All	195N2179
VLT® 2811	1.5	All	195N2179
VLT® 2815	2	All	195N2179
VLT® 2822 (T2)	3	200 – 240	195N2180
VLT® 2822	3	200 – 240	195N2181
VLT® 2822	3	380 – 480	195N2180
VLT® 2830	4	380 – 480	195N2180
VLT® 2840 (T2)	5	200 – 240	195N2181
VLT® 2840	5	200 – 240	195N2182
VLT® 2840	5	380 – 480	195N2180
VLT® 2855	7.5	380 – 480	195N2181
VLT® 2875	10	380 – 480	195N2181
VLT® 2880	15	380 – 480	195N2182
VLT® 2881	20	380 – 480	195N2182
VLT® 2882	25	380 – 480	195N2182

Soft starts: Protects processes, products and equipment with smooth motor control

An AC motor switched directly on to the mains power supply will struggle to reach its nominal speed as quickly as possible.

This draws maximum current from the power supply and accelerates the application with its maximum torque. Depending on the application, this can cause different problems.

Applications like pumps, conveyers, centrifuges and bandsaws must be started slowly, and sometimes stopped slowly, to prevent mechanical shocks such as water hammer, and strains on bands, couplings and shafts.

Principle of Phase Angle Control

A soft starter is an electronic device that regulates the voltage to the motor and this provides a smooth transition from standstill to full speed operation of the application.

VLT® Soft Starters all use the principle of phase angle control: Back-to-back coupled thyristors ramp up the motor voltage.

In some VLT® Soft Starters, current transformers measure the motor current, providing feedback for starting current control but also for numerous motor and application protection functions.

VLT® Soft Starters cover a comprehensive range

Soft starting and stopping can be controlled in a number of ways depending on the application. Some applications require non-linear voltage ramp-up and the voltage ramp is therefore related to the actual current drawn. Conversely, a band-saw usually requires a quick stop function provided by a DC brake.

Then again, a number of applications require a kick-start torque for an instantaneous period of time followed by a soft ramp-up acceleration. VLT® Soft Starters cover all of these applications and much more.

VLT® Soft Starters

VLT® Soft Starter MCD 500

- Fully featured Soft Starter for motors up to 1100 HP
- Total motor starting solution
- Advanced protection features
- Adaptive Acceleration Control
- Inside Delta connection
- 4 line graphical display
- Multiple programming setup menus

VLT® Soft Starter MCD 200

- Compact Soft Starter for motors up to 150 HP
- Voltage ramps, current limit start and intregrated motor protection
- Integral bypass design reduces heat dissipation
- Wide power range with advanced accessory modules

VLT® Soft Starter MCD 500

Perfect
match for:
- Pumps
- Blowers
- Centrifuges
- Any Motor that does not need speed control

VLT® Soft Starter MCD 500 is a total motor starting solution. Current transformers measure motor current and provide feedback for controlled motor ramp profiles.

AAC, Adaptive Acceleration Control, automatically employs the best starting and stopping profile for the application.

Adaptive Acceleration Control means, that for each start and stop, the soft starter compares and adapts the process to the chosen profile fitting to the application.

VLT® Soft Starter MCD 500 has a four line graphical display and a logic keypad making programming easy. Advanced setup is possible displaying operational status.

Three menu systems: Quick Menu, Application Setup and Main Menu provide optimum programming approach.

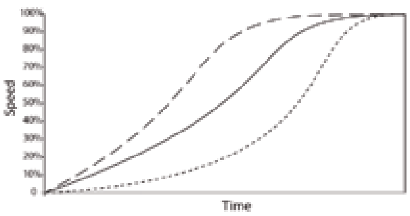
Power range

21 – 1600 A, 10 HP – 1000 HP
(1600 HP inside Delta Connection)
Versions for 200 – 690 VAC

Features	Benefits
AAC Adaptive Acceleration Control	Automatically adapts to the chosen starting and stopping profile
Adjustable bus bars allow for both top and bottom entry (360–1600 A, 160–850 kW)	Space saving, less cable cost and easy retrofitting
DC injection braking distributed evenly over three phases	Less installation cost and less stress on the motor
Conformal Coated Circuit Boards	Protects electronics from corrosion
Inside Delta (6-wire connection)	Smaller soft starter can be selected for the application
Log menus, 99 events and trip log provide information on events, trips and performance	Eases analysis of the application
Auto Reset	Less down-time
Jog (slow-speed operation)	Application flexibility
Second-order thermal model	Allows motors to be used to their full potential without damage from overloading
Internal bypass contactors (21–215 A, 10 HP to 150 HP)	Saves space and wiring compared to external bypass Very little heat dissipates when running. Eliminates costly external fans, wiring or bypass contactors
Auto-start/stop clock	Application flexibility
Compact size – amongst the smallest in their class	Saves space in cabinets and other application setups
4-line graphical display	Optimum programming approach and setup for viewing operational status
Multiple programming setup (Standard Menu, Extended Menu, Quick Set)	Simplifies the programming, but still holding to maximum flexibility
Multiple languages	Serving the whole world

Manufactured to the highest quality standards
The MCD 500 Drive is a UL-listed product made in ISO 9001-2000 and ISO 14000 certified facilities.

VLT® Soft Starter MCD 500 Specifications



AAC Profiles

Fully featured Soft Starter for motors up to 1000 kW

- Total motor starting solution
- Advanced start, stop and protection features
- Adaptive Acceleration Control
- Inside Delta connection
- 4-line graphical display
- Multiple programming setup menus

Optional

- Modules for serial communication:
  - DeviceNet
  - Profibus
  - Modbus RTU
  - USB
- Remote operator kit
- PC software:
  - WinMaster
  - MCT10

Features	Benefits
Danfoss "FC" menu structure and button interface concept	Proven logical access ensuring easy set-up
Parameter upload/ download	Saves time, simplifies set-up
Same user interface as VLT® Soft Starter MCD 500	Effective, simple and flexible
Adjustable multiple monitoring views	You see what you want to see
Door mount IP 65 (NEMA 12)	Reliable in harsh environment
Speaks your language	Comfortable setup
3 metre cable	Remote Operation
New output on MCD 500	Simple to connect Communication port on MCD 500 available also with LCP

Mains voltage (L1, L2, L3)	
MCD5-xxxx-T5	200 VAC ~ 525 VAC (± 10%)
MCD5-xxxx-T7	380 VAC ~ 690 VAC (± 10%)
MCD5-xxxx-T7	380 VAC ~ 600 VAC (± 10%) (inside delta connection)

Control voltage (terminals A4, A5, A6)	
CV1 (A5, A6)	24 VAC/VDC (± 20%)
CV2 (A5, A6)	110~120 VAC (+ 10% / - 15%)
CV2 (A4, A6)	220~240 VAC (+ 10% / - 15%)
Mains frequency	50/60 Hz (± 10%)
Rated insulation voltage to ground	600 VAC
Rated impulse withstand voltage	4 kV
Form designation	Bypassed or continuous, semiconductor motor starter form 1

Short circuit capability	
Coordination with semiconductor fuses	Type 2
Coordination with HRC fuses	Type 1
MCD 500-0021B to 0215B	Prospective current of 65 kA
MCD 500-0245C	Prospective current of 85 kA
MCD 500-1200C to 1600C	Prospective current of 100 kA

Electromagnetic capability (compliant with EU Directive 89/336/EEC)	
EMC Emissions (Terminals 13 & 14)	IEC 60947-4-2 Class B and Lloyds Marine No. 1 Specification
EMC Immunity	IEC 60947-4-2

Outputs	
Relay Outputs	10A @ 250 VAC resistive, 5A @ 250 VAC AC15 pf 0.3
Programmable Outputs	
Relay A (13, 14)	Normally open
Relay B (21, 22, 24)	Changeover
Relay C (33, 34)	Normally open
Analog Output (07, 08)	0 – 20 mA or 4 – 20 mA (selectable)
Maximum load	600 Ω (12 VDC @ 20 mA) (accuracy ± 5%)
24 VDC Output (16, 08) Maximum load	200 mA (accuracy ± 10%)

Environmental	
Protection MCD5-0021B ~ MCD5-0105B	Protected Chassis/IP20 & NEMA 1
Protection MCD5-0131B ~ MCD5-1600C	Open Chassis/IP00, UL Indoor Open Type
Operating temperature	-10°C to 60°C, above 40°C with derating
Storage temperature	-25°C to + 60°C
Operating Altitude	0 – 1000 m, above 1000 m with derating
Humidity	5% to 95% Relative Humidity
Pollution degree	Pollution Degree 3

Heat Dissipation	
During start	4.5 watts per ampere

Dimensions

Current rating [A]	Weight [lbs.]	Height [in]	Width [in]	Depth [in]	Frame size
21, 37, 43 and 53	9.24	11.61	5.91	7.20	G1
68	9.9				
84, 89 and 105	10.78		8.39		
131, 141, 195 and 215	32.78	17.24	10.83	9.84	G2
245	52.58	18.11	15.35	10.98	G3
360, 380 and 428	77	27.13	16.93	11.89	G4
595, 619, 790 and 927	99				
1200, 1410 and 1600	264	33.70	23.03	14.33	G5

"Jog" function on the VLT® Soft Starter MCD 500

Background

In the Danfoss VLT® Series of variable frequency drives, the Jog function is known as: A constant frequency or speed different from nominal motor speed.
Jog speed can be defined in a VFD in a parameter with the transition from actual speed to jog speed following a set ramp. Jog can be activated through a digital input, bus command, or a pushbutton on a VFD.

The new Danfoss VLT® Soft Starter MCD 500 will be introduced with the "JOG" function, but how does that work?

Question?

The VLT® Soft Starter MCD 500 is a Soft Starter and thus only capable of one speed; the nominal motor speed. So what is going on??
At first you might think that the VLT® Soft Starter MCD 500 is producing the jog function by reducing the voltage to the motor and thus increasing the slip in the motor.
However, everyone knows the principle of speed control by reducing voltage and the big disadvantages of this.
The MCD 500 does not use voltage control, it uses a much more unique solution.

The function of the Soft Starter

The basic principle of a soft starter is that it reduces the motor voltage in the start up phase. This voltage reduction is done by cutting the sine wave. The later the cut comes on the sine wave the more voltage is available to the motor thus taking the motor up to full speed.

The "Jog" function

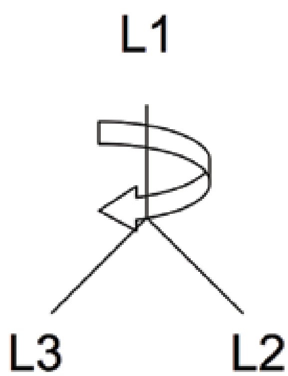
This "Jog" function simply applies (5) positive waves and completely cuts the negative and then applies (5) negative waves and cuts the positive waves.

In this way the motor sees a reduced voltage with ~10% frequency (see diagram below)

Summary

The JOG function is done by using a complicated algorithm in the software that allows the MCD 500 to run a motor at 10% of full speed.

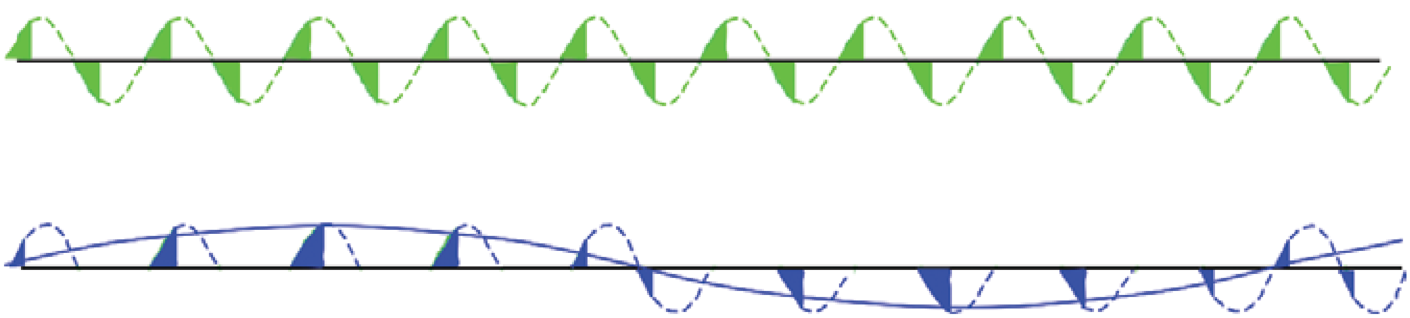
In order for MCD 500 to Jog, it must fire on the +Voltage part of the sine wave, then fire on the –Voltage part of the sine wave. This makes the motor run at slower speed (JOG)



+V Jog: L1, L2, L3
-V Jog: L1, L3, L2

JOG Reverse is done by changing the order of the firing on Phase 3. Firing on the –V part first changes the phases order from L1, L2, L3 to L1, L3, L2.

A unique advantage to The VLT® Soft Starter MCD 500.



VLT® Soft Starter MCD 500

Control Voltage

CV1 = 24 VAC/VDC

CV2 = 110 or 220 VAC

200 – 525 V (T5)

Frame	Description	Rating		Current Ratings				Bypass	Part Number	
		kW	HP	Light AC – 53b 3-30 : 330	Med AC – 53b 4-20 : 340	Heavy AC – 53b 4.5-30 : 330	Severe Duty AC – 53b;4.5-20:430 55°C	Non Bypass	CV1	CV2
G1B No Fan	MCD5-0021B-T5-G1X-20-CV_	7.5	10	21	17	15	13.8	BP	175G5500	175G5525
	MCD5-0037B-T5-G1X-20-CV_	15	20	37	31	26	24.2	BP	175G5501	175G5526
	MCD5-0043B-T5-G1X-20-CV_	18.5	25	43	37	30	28.9	BP	175G5502	175G5527
	MCD5-0053B-T5-G1X-20-CV_	22	30	53	46	37	35.7	BP	175G5503	175G5528
	MCD5-0068B-T5-G1X-20-CV_	30	40	68	55	47	41.2	BP	175G5504	175G5529
	MCD5-0084B-T5-G1X-20-CV_	37	50	84	69	58	52	BP	175G5505	175G5530
	MCD5-0089B-T5-G1X-20-CV_	45	60	89	74	61	54.8	BP	175G5506	175G5531
	MCD5-0105B-T5-G1X-20-CV_	55	75	105	95	78	70.1	BP	175G5507	175G5532
G2B	MCD5-0131B-T5-G2X-00-CV_	60	80	131	106	90	80	BP	175G5508	175G5533
	MCD5-0141B-T5-G2X-00-CV_	75	100	141	121	97	84.4	BP	175G5509	175G5534
	MCD5-0195B-T5-G2X-00-CV_	90	125	195	160	134	117.9	BP	175G5510	175G5535
	MCD5-0215B-T5-G2X-00-CV_	110	150	215	178	149	132.8	BP	175G5511	175G5536
G3C	MCD5-0245C-T5-G3X-00-CV_	132	175	245/255	195/201	171/176	151.7/156.8	NBP	175G5512	175G5537
G4C	MCD5-0360C-T5-G4X-00-CV_	160	200	360/360	303/310	259/263	235.6/242	NBP	175G5513	175G5538
	MCD5-0380C-T5-G4X-00-CV_	185	250	380/380	348/359	292/299	265.8/276.5	NBP	175G5514	175G5539
	MCD5-0428C-T5-G4X-00-CV_	220	300	428/430	355/368	301/309	271.7/283.5	NBP	175G5515	175G5540
	MCD5-0595C-T5-G4X-00-CV_	300	400	595/620	515/540	419/434	384.1/405.7	NBP	175G5516	175G5541
	MCD5-0619C-T5-G4X-00-CV_	315	500	619/650	532/561	437/455	396.6/420.7	NBP	175G5517	175G5542
	MCD5-0790C-T5-G4X-00-CV_	400	600	790/790	694/714	567/579	523.3/542.4	NBP	175G5518	175G5543
	MCD5-0927C-T5-G4X-00-CV_	500	700	927/930	800/829	644/661	591.3/619.1	NBP	175G5519	175G5544
G5C	MCD5-1200C-T5-G5X-00-CV_	600	800	1200/1200	1135/1200	983/1071		NBP	175G5520	175G5545
	MCD5-1410C-T5-G5X-00-CV_	700	900	1410/1410	1187/1319	1023/1114		NBP	175G5523	175G5546
	MCD5-1600C-T5-G5X-00-CV_	800	1000	1600/1600	1433/1600	1227/1353		NBP	175G5524	175G5547

380 – 690 V (T7)

Frame	Description	Rating		Current Ratings				Bypass	Part Number	
		kW	HP	Light AC – 53b 3-30 : 330	Med AC – 53b 4-20 : 340	Heavy AC – 53b 4.5-30 : 330	Severe Duty AC – 53b;4.5-20:430 55°C	Non Bypass	CV1	CV2
G1B	MCD5-0021B-T7-G1X-20-CV_	7.5	10	21	17	15	13.8	BP	175G5548	175G5571
	MCD5-0037B-T7-G1X-20-CV_	15	20	37	31	26	24.2	BP	175G5549	175G5572
	MCD5-0043B-T7-G1X-20-CV_	18.5	25	43	37	30	28.9	BP	175G5550	175G5573
	MCD5-0053B-T7-G1X-20-CV_	22	30	53	46	37	35.7	BP	175G5551	175G5574
	MCD5-0068B-T7-G1X-20-CV_	30	40	68	55	47	41.2	BP	175G5552	175G5575
	MCD5-0084B-T7-G1X-20-CV_	37	50	84	69	58	52	BP	175G5553	175G5576
	MCD5-0089B-T7-G1X-20-CV_	45	60	89	74	61	54.8	BP	175G5554	175G5577
	MCD5-0105B-T7-G1X-20-CV_	55	75	105	95	78	70.1	BP	175G5555	175G5578
G2B	MCD5-0131B-T7-G2X-00-CV_	60	80	131	106	90	80	BP	175G5556	175G5579
	MCD5-0141B-T7-G2X-00-CV_	75	100	141	121	97	84.4	BP	175G5557	175G5580
	MCD5-0195B-T7-G2X-00-CV_	90	125	195	160	134	117.9	BP	175G5558	175G5581
	MCD5-0215B-T7-G2X-00-CV_	110	150	215	178	149	132.8	BP	175G5559	175G5582
G3C	MCD5-0245C-T7-G3X-00-CV_	132	175	245/255	195/201	171/176	151.7/156.8	NBP	175G5560	175G5583
G4C	MCD5-0360C-T7-G4X-00-CV_	160	200	360/360	303/310	259/263	235.6/242	NBP	175G5561	175G5584
	MCD5-0380C-T7-G4X-00-CV_	185	250	380/380	348/359	292/299	265.8/276.5	NBP	175G5562	175G5585
	MCD5-0428C-T7-G4X-00-CV_	220	300	428/430	355/368	301/309	271.7/283.5	NBP	175G5563	175G5586
	MCD5-0595C-T7-G4X-00-CV_	300	400	595/620	515/540	419/434	384.1/405.7	NBP	175G5564	175G5587
	MCD5-0619C-T7-G4X-00-CV_	315	500	619/650	532/561	437/455	396.6/420.7	NBP	175G5565	175G5588
	MCD5-0790C-T7-G4X-00-CV_	400	600	790/790	694/714	567/579	523.3/542.4	NBP	175G5566	175G5589
	MCD5-0927C-T7-G4X-00-CV_	500	700	927/930	800/829	644/661	591.3/619.1	NBP	175G5567	175G5590
G5C	MCD5-1200C-T7-G5X-00-CV_	600	800	1200/1200	1135/1200	983/1071		NBP	175G5568	175G5591
	MCD5-1410C-T7-G5X-00-CV_	700	900	1410/1410	1187/1319	1023/1114		NBP	175G5569	175G5592
	MCD5-1600C-T7-G5X-00-CV_	800	1000	1600/1600	1433/1600	1227/1353		NBP	175G5570	175G5593

VLT® Soft Starter MCD 500

Accessories	
Remote Keypad	175G3061
Remote Operator & Interface Kit	175G9004
MCD Modbus RTU Module	175G9000
MCD Profibus Module	175G9001
MCD DeviceNet Module	175G9002
MCD USB Module	175G9009

IP 20 Finger Guard Kit	
MCD5-0068B-MCD5-0105B (G2)	175G5662
MCD5-0131B-MCD5-0215B (G3)	175G5663
MCD5-0245B-MCD5-0927B (G4)	175G5664
MCD5-1200B-MCD5-1600B (G5)	175G5665

Control Panel VLT® LCP 501

- Same user interface as VLT® Soft Starter MCD 500
- Plug & play with MCD 500
- Copy/ paste of parameters
- Multiple monitoring setup
- Door-mount kit – 3m cable
- IP65 (NEMA 12/IP65)

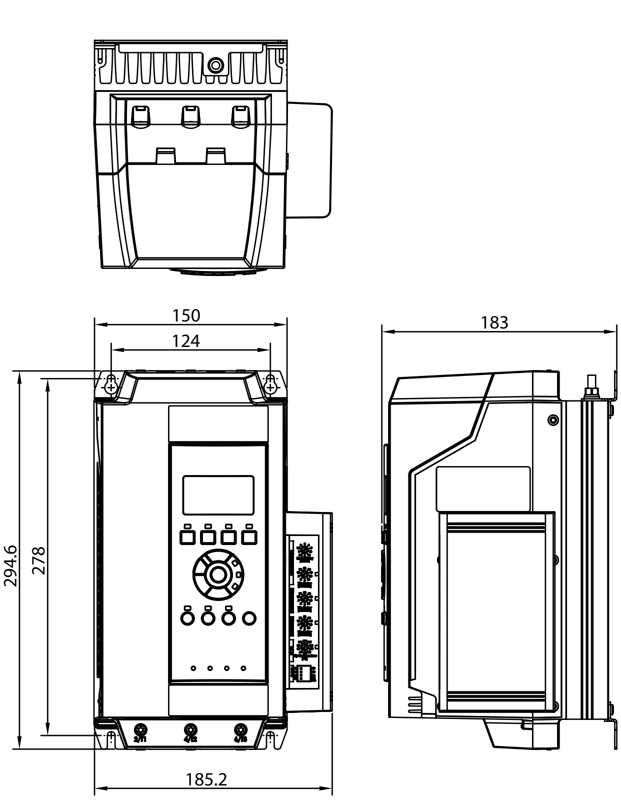
Part Number: 175G0096

VLT® Soft Starter MCD 500
Mechanical Specifications

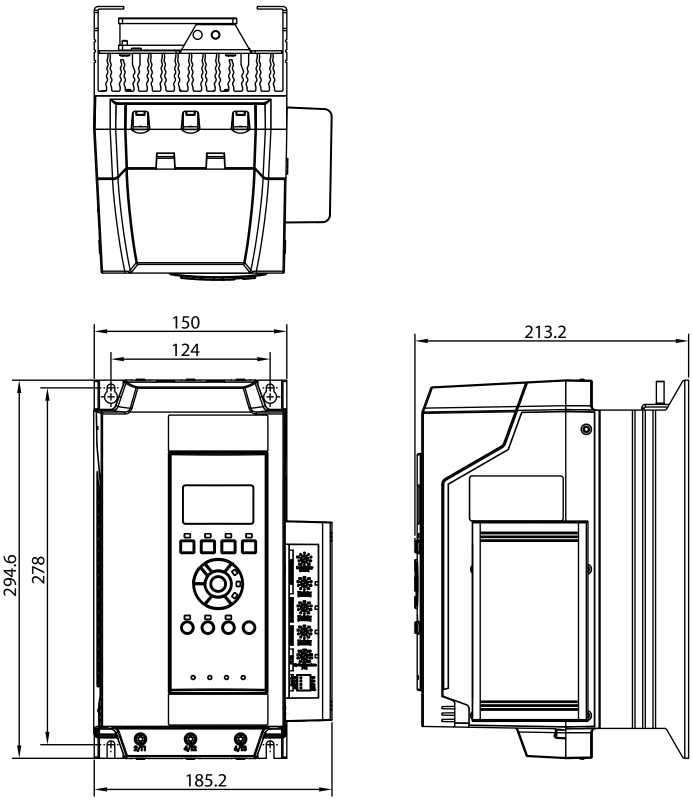
G1 Frame

Protected Chassis/IP20

Dimensions: mm	Weight: 9.3 – 10.8 lbs. (4.2 – 4.9 kg)



MCD500 G1 (7kW to 22kW)

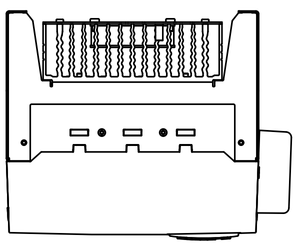


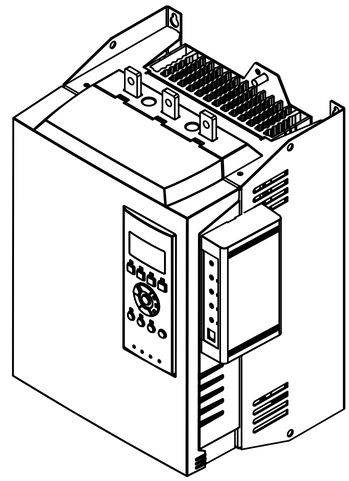
MCD500 G1 (30kW to 55kW)

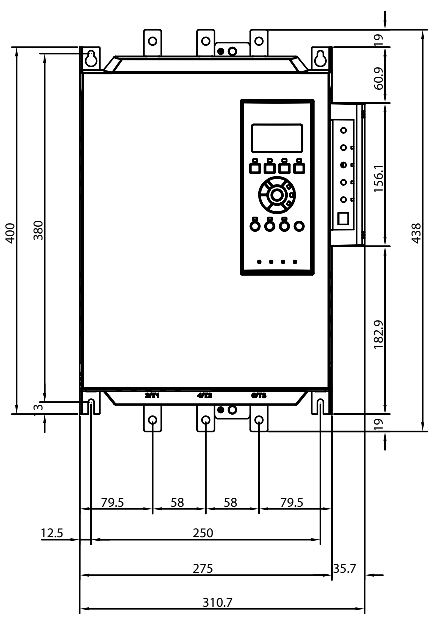
VLT® Soft Starter MCD 500

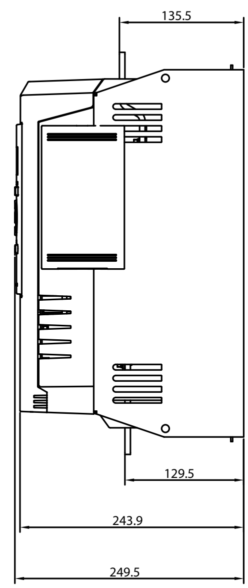
Mechanical Specifications

G2 Frame	
Chassis/IP00	
Dimensions: mm	Weight: 32.8 lbs. (14.9 kg)







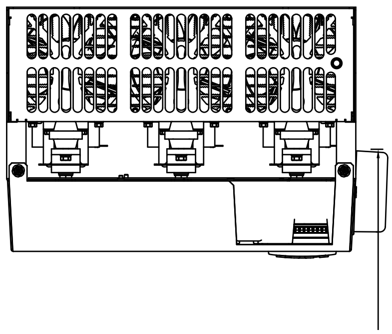


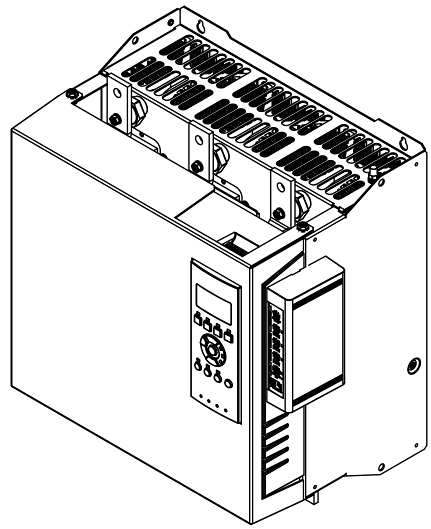
VLT® Soft Starter MCD 500
Mechanical Specifications

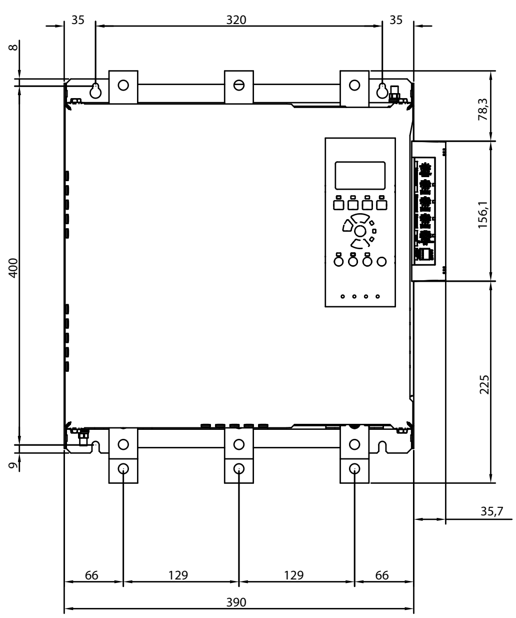
G3 Frame

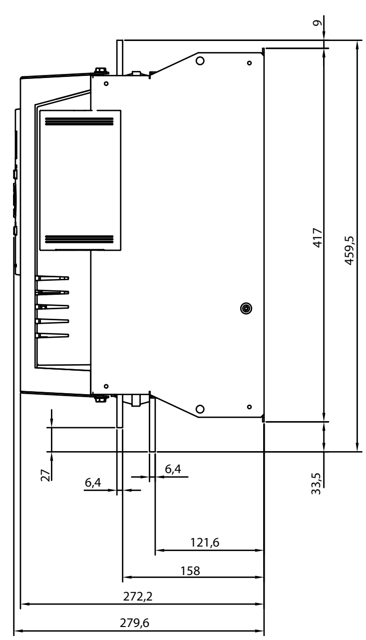
Chassis/IP00

Dimensions: mm	Weight: 52.7 lbs. (23.9 kg)









For additional drawings, contact Danfoss.

VLT® Soft Starter MCD 200

Perfect
match for:

– Pumps
– Blowers
– Centrifuges
– Any Motor that does not need speed control

The VLT® Compact Starter MCD 200 from Danfoss includes two families of soft starters in the power range from 10 HP to 150 HP.

AC motors often cause one or more serious problems during startup acceleration. MCD 200 Series electronic soft starters control motor current to provide a smooth start. When is the MCD 200 the correct fit for your application? Anytime one or more of the following apply:

- High starting current, often causing an unacceptable load on the AC line
- Shock load on gear and other transmission elements, causing unnecessary wear on mechanical parts
- Fast acceleration and deceleration, causing unstable process conditions (e.g., in conveyors)
- Utility regulations prohibit line-starting of motors

The Danfoss MCD 201 and 202 soft starters are the optimum solution to all these problems for AC motors ranging from 10-200 HP.

	MCD 201	MCD 202
Concept	▪ Physically compact starter providing basic soft start and stop functionality	▪ Physically similar to MCD 201, but provides enhanced soft start and motor protection functionality in addition to all the most common soft start and soft stop features
Start/stop Adjustments	3 adjustments: ▪ Timed voltage ramp-up ▪ Adjustable initial torque ▪ Timed voltage ramp-down	8 adjustments: ▪ Current limit (250 – 450%) ▪ Current ramp-up (2 – 25 seconds) plus initial current (150 – 250%) ▪ Ramp down (1 – 20 seconds) ▪ Motor FLC (50 – 100%) ▪ Motor trip class (10, 15, 20) ▪ Maximum start time (0 – 20 seconds) ▪ Phase rotation protection ▪ Auxiliary relay function (trip, run)
Protection		▪ Motor overload (adjustable trip class) ▪ Excess start time ▪ Reverse phase rotation ▪ Motor thermistor input ▪ Shorted SCR – no start ▪ Supply fault – no start
Outputs	1 output relay: ▪ Line contactor control	2 output relays: ▪ Line contactor control ▪ Run contactor or trip function
Optional Remote Operator	▪ Pushbutton control ▪ Starter status LED ▪ Trip code display	▪ Pushbutton control ▪ Starter status LED ▪ Trip code display ▪ Motor current ▪ Motor current display ▪ Motor temperature display
Optional Network Functionality	▪ Operational control ▪ Status monitoring	▪ Operational control ▪ Status monitoring ▪ Performance monitoring

c UL US

Manufactured to the highest quality standards
The MCD 200 Series is a UL-listed product made in ISO 9001-2000 and ISO 14000 certified facilities.

VLT® Soft Starter MCD 200

Unlike traditional solutions, the MCD 200 soft starters offers a wide range of benefits for motor and equipment operation as a whole, including:

- Flexible control of starting current and torque
- Smooth control of current and voltage without any steps or transients
- Frequent start/stop operation without mechanical damage
- Flexibility to changes in the start conditions, increasing flexibility in the application
- Soft stop control for extending the motor deceleration time

Easy-to-Use Interface

The built-in potentiometers allow setting of parameters for simplified setup and easy operation. The dedicated remote operator kit accessory provides remote access to parameters, LED display, and monitoring of motor current.

Working Principle

Motor voltage is controlled by means of a phase cut principle. Two thyristors in each phase perform the power switching, enabling the starter to handle high starting torque and frequent starts/stops. Current transformers measure the motor current, providing feedback for constant current control of motor starting and also for numerous motor and application protection functions.

MCD 201 and MCD 202 soft starters share a common power and mechanical design, but offer different levels of functionality. MCD 201 soft starters provide TVR (Timed Voltage Ramp) starting and stopping control and are designed for use with an external motor protection device. MCD 202 soft starters provide Current Limit starting control, TVR soft stop and include a range of motor protection functions.
MCD 200 Series soft starters include an integral bypass function that bypasses the soft starter SCRs during run. This minimizes heat dissipation during run and makes the MCD 200 suitable for installation within non-ventilated enclosures without the need for an external bypass contactor.

Common Functionality and Features

- 200 – 440 or 200 – 575 VAC 50/60 Hz supply voltage
- 10 – 150 HP @ 480 VAC; 15 – 200 HP @ 575 VAC
- Internal SCR bypass contactors allow installation within motor control enclosures with no need for extra ventilation of external bypass contactors
- Cover larger HP motors
- Protected Chassis/IP20 (up to 100 amps); Open Chassis/IP00 (above 100 amps)
- Smaller than most comparable soft starters
- Equal functionality to market leaders, but with superior communication options
- Easy DIN rail mount for sizes up to 40 HP
- 2-wire or 3-wire start/stop control; programmable via 3 rotary switches
- Reset push button
- Ready and run (on, off or flashing) LED status indicators

Options:

- Modbus module for serial communication
- Remote operator kit
- MCD PC software can be used for networks of up to 99 soft starters (each soft starter connected to the network requires a Modbus module or a remote operator kit)

VLT® Soft Starter MCD 200

Line Supply (L1, L2, L3)

MCD 200-xxx-T4-xxx	3 x 200 VAC ~ 440 VAC (+10% / - 15%)
MCD 200-xxx-T6-xxx	3 x 200 VAC ~ 575 VAC (+10% / - 15%)
Supply frequency (at start)	45 Hz - 66 Hz

Control Supply (A1, A2, A3)

MCD 200-xxx-xx-CV1	24 VAC/VDC (±20%)
MCD 200- xxx-xx-CV3	110 – 240 VAC (+10% / - 15%) or 380 – 440 VAC (+10% / - 15%)

Control Inputs

Start Terminal N1	Normally Open, 300 VAC max.
Stop Terminal N	Normally Closed, 300 VAC max.

Relay Outputs

Main Contactor Terminals 13 & 14	Normally Open 6 A, 30 VDC resistive/2 A, 400 VAC, AC11
Programmable Relay Terminals 23 & 24	Normally Open 6 A, 30 VDC resistive/2 A, 400 VAC, AC11

Environmental

Degree of protection MCD 200-007 to MCD 200-055 MCD 200-075 to MCD 200-110	 Protected Chassis/IP20 Open Chassis/IP00
Operating Temperatures	14°F – 140°F (-10°C – +60°C)
Humidity	5% to 95% Relative Humidity
Pollution Degree	Pollution Degree 3
Vibration	IEC 60068 Test Fc Sinusoidal 4 Hz – 13.2 Hz: ± 0.04 in (±1 mm) displacement 13.2 Hz – 100 Hz: ±0.0015 lb (±0.7 g)

EMC Emission

Equipment class (EMC)	Class A
Conducted radio frequency emission	0.15 MHz – 0.5 MHz: <90 dB (µV) 0.5 MHz – 5 MHz: <76 dB (µV) 5 MHz – 30 MHz: 80 – 60 dB (µV)
Radiated radio frequency emission	30 MHz – 230 MHz: <30 dB (µV/m) 230 MHz – 1000 MHz: <37 dB (µV/m)

This product has been designed for Class A equipment. Use of the product in domestic environments may cause radio interference, in which case the user may be required to employ additional mitigation methods.

EMC Immunity

Electrostatic discharge	4 kV contact discharge, 8 kV air discharge
Radio frequency electromagnetic field	0.15 MHz – 1000 MHz: 140 dB (µV)
Rated impulse withstand voltage (Fast transients 5/50 ns)	2 kV line to ground
Rated insulation voltage (Surges 1.2/50 µs – 8/20 ms)	2 kV line to ground, 1 kV line to line
Voltage dip and short time interruption	100 ms (at 40% nominal voltage)

Short Circuit

Rated short circuit current MCD 200-007 to MCD 200-037	5 kA
MCD 200-045 to MCD 200-110	10 kA

Heat Dissipation

During Start	10 Btu/hr/amp (3 watts/amp)
During Run	<13.7 Btu/hr (4 watts)

Standards Approvals

C	IEC 60947-4-2
UL/C-UL	UL508
CE	IEC 60947-4-2
CCC	GB 14048.6

Phone 1-800-432-6367

VLT® Soft Starter MCD 200

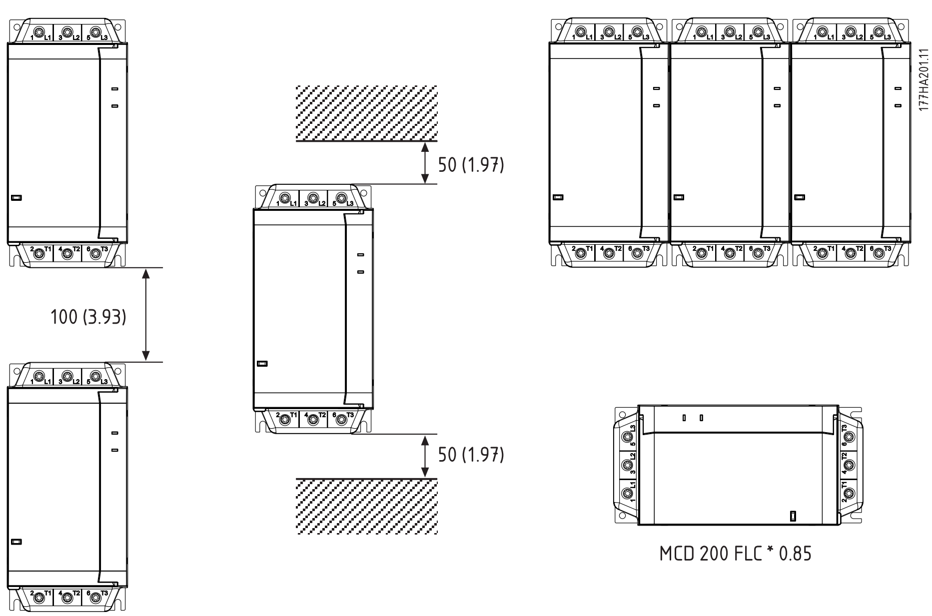
General Specifications

Ventilation

The MCD 201/202 Soft Starter includes an integral bypass function that bypasses the soft starter's SCRs during run.

This minimizes heat dissipation during run and makes the MCD 200 suitable for installations within non-ventilated enclosures, with no need for an external bypass contactor.

Mechanical Installation



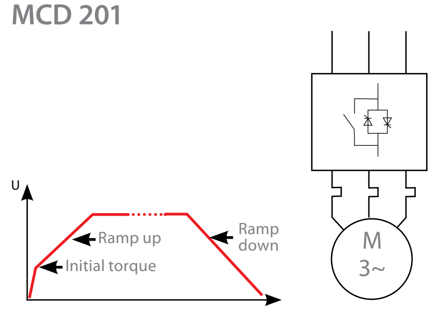
MCD 201/202	Din Rail	Foot Mounting
MCD 20x-007 ~ MCD 200-030	1.18 in. (30 mm)	Yes
MCD 20x-037 ~ MCD 200-110	Not available	Yes

Cable Size

	mm² (AWG)						mm² (AWG)	
	MCD 200-007 ~ MCD 200-030		MCD 200-037 ~ MCD 200-055		MCD 200-075 ~ MCD 200-110		MCD 200-007 ~ MCD 200-110	
	10 - 35 (8 - 2)	14 (0.55) mm (inch)	25 - 50 (4 - 1/0)	14 (0.55) mm (inch)	N.A.	11 (0.43) 26 (1.02) 8.5 (0.33) mm (inch)	0.14 - 1.5 (26 - 16)	6 (0.24) mm (inch)
	10 - 35 (8 - 2)		25 - 50 (4 - 1/0)		N.A.		0.14 - 1.5 (26 - 16)	
	Torx (T20) 3 - 5 Nm. 2.2 - 3.7 ft-lb.		Torx (T20) 4 - 6 Nm. 2.9 - 4.4 ft-lb.		N.A.		N.A.	
	7 mm 3 - 5 Nm 2.2 - 3.7 ft-lb		7 mm 4 - 6 Nm 2.9 - 4.4 ft-lb		N.A.		3.5 mm 0.5 Nm max. 4.4 lb-in max.	

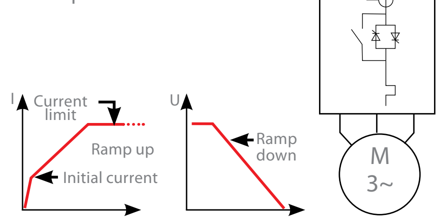
177HA245.11

MCD 201



MCD 202

MCD 202 provides enhanced soft start functionality and various motor protection features

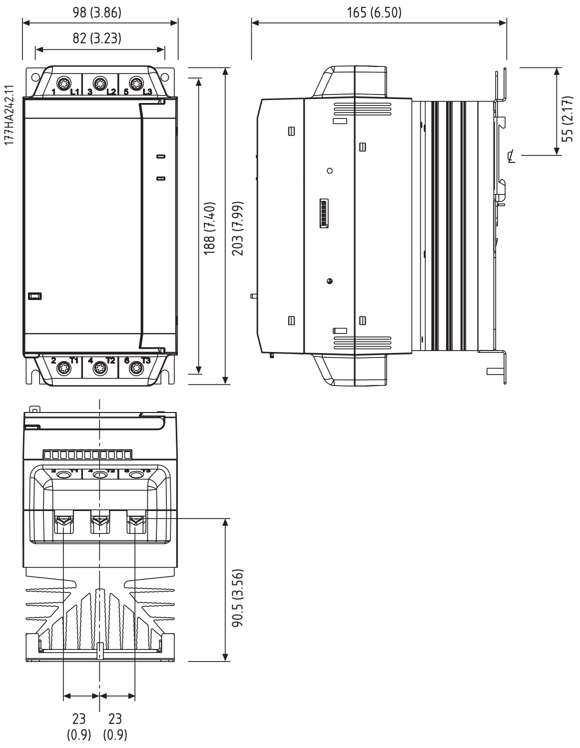


VLT® Soft Starter MCD 200 **Dimensions**

MCD 201-007 ~ MCD 201-030
Protected Chassis/IP20
4.8 lb (2.2 kg)

MCD 202-007 ~ MCD 202-030
Protected Chassis/IP20
5.3 lb (2.4 kg)

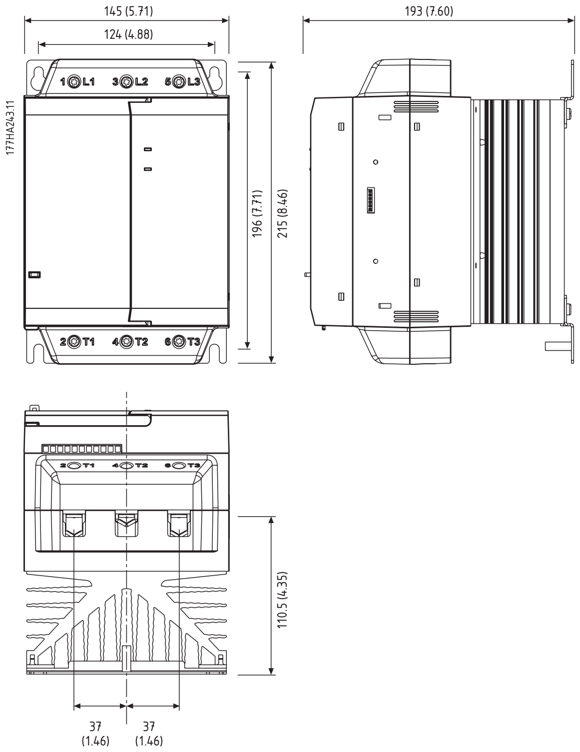
mm (in)



MCD 201-037 ~ MCD 201-055
Protected Chassis/IP20
8.8 lb (4.0 kg)

MCD 202-037 ~ MCD 202-055
Protected Chassis/IP20
9.5 lb (4.3 kg)

mm (in)



VLT® Soft Starter MCD 200 Dimensions

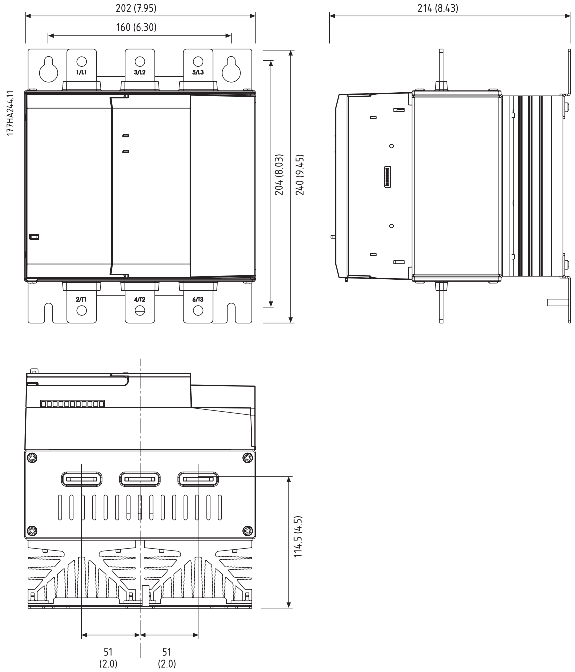
MCD 201-075 ~ MCD 201-110

Open Chassis
13.5 lb (6.1 kg)

MCD 202-075 ~ MCD 202-110

Open Chassis
15.0 lb (6.8 kg)

mm (in)



VLT® Starters

VLT® Soft Starter MCD 200 **Options**

Remote Operation

Remote operation of MCD Soft Starters is facilitated by the dedicated remote operator kit. The operator (IP54/NEMA12) is mounted on the cabinet front and allows remote control, status indication and motor monitoring of an individual MCD Soft Starter using RS485 serial communication. It incorporates the following features:

Model Size	MCD 201	MCD 202
Start/stop/quick stop, reset	•	•
LED for start, run, trip	•	•
Trip codes	•	•
Current display		•
Motor temp. display		•
4 – 20 mA output		•

Description	Part Number
Remote Keypad	175G9004

Serial Communication

The RS485 serial link can be used to control operation when the starter is in either local or remote mode. MCD 201 and MCD 202 come with optional plug-in modules for serial communication.

Description	Part Number
AS-i	175G9003
DeviceNet	175G9002
Modbus RTU	175G9000
Profibus	175G9001
Finger Guard Kit for IP00 units	175G9007

VLT® Soft Starter MCD 200
Ordering Information

Control Voltage
CV1 = 24 VAC/DC
CV3 = 110-240 VAC/380-440 VAC

MCD 201/202 (T4) 200 – 440 VAC

Model Size	Encl.	HP Rating @ Designated VAC and Normal Current			Current Rating*		Order Number			
							MCD 201		MCD 202	
		208	230	480	Normal	Heavy	T4-CV1	T4-CV3	T4-CV1	T4-CV3
MCD 20x-007	IP20	5	5	10	18	17	175G5176	175G5165	175G5220	175G5209
MCD 20x-015	IP20	10	10	20	34	30	175G5177	175G5166	175G5221	175G5210
MCD 20x-018	IP20	–	–	25	42	36	175G5178	175G5167	175G5222	175G5211
MCD 20x-022	IP20	15	15	30	48	40	175G5179	175G5168	175G5223	175G5212
MCD 20x-030	IP20	20	20	40	60	49	175G5180	175G5169	175G5224	175G5213
MCD 20x-037	IP20	25	25	50	75	65	175G5181	175G5170	175G5225	175G5214
MCD 20x-045	IP20	–	30	60	85	73	175G5182	175G5171	175G5226	175G5215
MCD 20x-055	IP20	30	40	75	100	96	175G5183	175G5172	175G5227	175G5216
MCD 20x-075	IP00	40	50	100	140	120	175G5184	175G5173	175G5228	175G5217
MCD 20x-090	IP00	60	60	125	170	142	175G5185	175G5174	175G5229	175G5218
MCD 20x-110	IP00	–	75	150	200	165	175G5186	175G5175	175G5230	175G5219

MCD 201/202 (T6) 200 – 575 VAC

Model Size	Encl.	HP Rating @ Designated VAC and Normal Current				Current Rating*		Order Number			
								MCD 201		MCD 202	
		208	230	480	575	Normal	Heavy	T6-CV1	T6-CV3	T6-CV1	T6-CV3
MCD 20x-007	IP20	5	5	10	15	18	17	175G5198	175G5187	175G5242	175G5231
MCD 20x-015	IP20	71/2/10	71/2/10	20	30	34	30	175G5199	175G5188	175G5243	175G5232
MCD 20x-018	IP20	–	–	25	40	42	36	175G5200	175G5189	175G5244	175G5233
MCD 20x-022	IP20	15	15	30	40	48	40	175G5201	175G5190	175G5245	175G5234
MCD 20x-030	IP20	20	20	40	50	60	49	175G5202	175G5191	175G5246	175G5235
MCD 20x-037	IP20	25	25	50	60	75	65	175G5203	175G5192	175G5247	175G5236
MCD 20x-045	IP20	–	30	60	75	85	73	175G5204	175G5193	175G5248	175G5237
MCD 20x-055	IP20	30	40	75	100	100	96	175G5205	175G5194	175G5249	175G5238
MCD 20x-075	IP00	40/50	50	100	125	140	120	175G5206	175G5195	175G5250	175G5239
MCD 20x-090	IP00	60	60	125	150	170	142	175G5207	175G5196	175G5251	175G5240
MCD 20x-110	IP00	–	75	150	200	200	165	175G5208	175G5197	175G5252	175G5241

** Normal duty rating is 104°F (40°C) ambient, 3000 ft., 6 seconds ramp time, 400%*
Heavy duty rating is 104°F (40°C) ambient, 3000 ft., 20 seconds ramp time, 400%

Harmonic mitigation

The mains voltage supplied by electricity utilities to homes, businesses and industry should be a uniform sinusoidal voltage with a constant amplitude and frequency.

This ideal situation is no longer found in any power grid. This is mainly because consumers take non-sinusoidal current from the grid or have a non-linear characteristic, e.g. strip lights, light dampers, energy-saving bulbs and variable frequency drives.

Because of the constantly increasing use of non-linear loads, deviations become increasingly serious.

Irregular power supplies influence the performance and operation of electrical equipment, so motors, variable frequency drives and transformers must be more highly rated to maintain proper operation.

How feedback occurs

The distortion of the sinusoidal curve shape of the supply network as a result of the intermittent use of electricity by the consumers connected to it is called “network feedback”.

Experts refer to the relative harmonic content of a network on the basis of Fourier analysis and calculate it to 2.5 kHz for 50 Hz, corresponding to the 50th harmonic oscillation.

A Fourier analysis is a decomposition of the non-sinusoidal current wave-form into the sum of sinusoidal signals with various frequencies and amplitudes.

Harmonic current distortion is caused by the rectifier part of the variable speed drive, typically a 6-pulse diode rectifier. The harmonic currents can be described as reactive current adding to the active current.

The amount of harmonic current distortion is often described as a percentage of the fundamental current also known as total harmonic current distortion (THiD).

Consequences

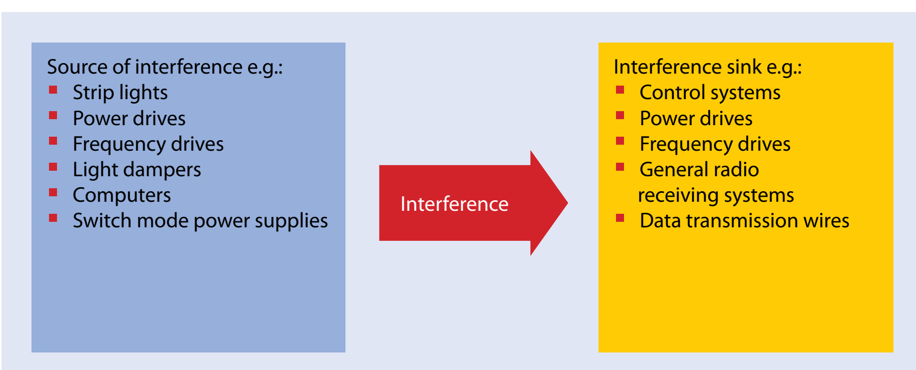
Excessive distortion causes malfunctions. Most common is pre-aging of electronic control systems, computers and control devices.

The most common effect is not noticeable immediately but will, over time, increase the system cost as equipment has to be replaced more offen than otherwise.

High harmonic content causes an overall lower efficiency, loads idle compensating systems and may even cause their destruction. Harmonic current distortion is increasing the root mean square current and if not taken into account can result in overheating of components such as the supply transformer or cables.

Reducing feedback

Feedback from electronic power control systems can be reduced. In Danfoss variable frequency drives*, it is as standard limited by built-in filter elements.
If it is necessary to reduce the harmonic content in the mains network further, for example in the case of weak networks or emergency power operation, a network analysis can indicate appropriate measures, as described later in the brochure.



Harmonic mitigation

Harmonic reduction techniques

To avoid potential problems or to comply with standards such as product standard EN 1000-3-12,system standard EN 61000-2-4 or recommendations such as IEEE 519-1992 or G5/4 several different harmonic reduction techniques for variable speed drives exist.

The most common solutions are:

- AC-coils
- DC-coils
- Multi-pulse (12- and 18-pulse)
- Active filtering
- Passive filtering

DC as standard

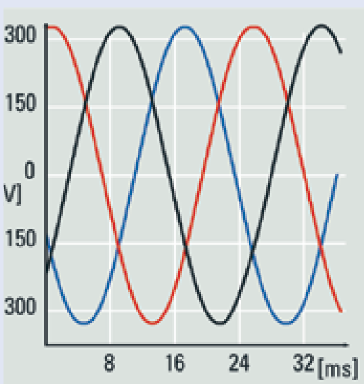
The VLT® AQUA Drive series have built-in chokes. This dramatically reduces network feedback and ensures the drives comply with the limits of EN 61000-3-12.

With this robustly designed intermediate circuit, these drives series operate in a stable and highly dynamic manner even during voltage disruption and under poor mains conditions.

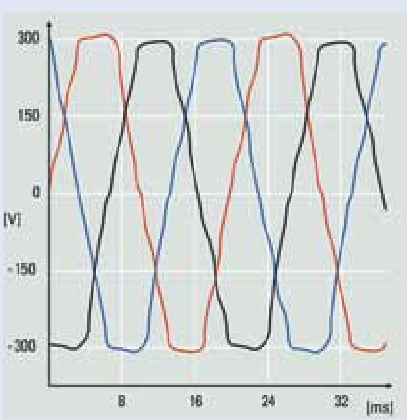
AC-coils

The most common and easiest harmonic reduction technique is probably the use of AC-coils in front of the drive.

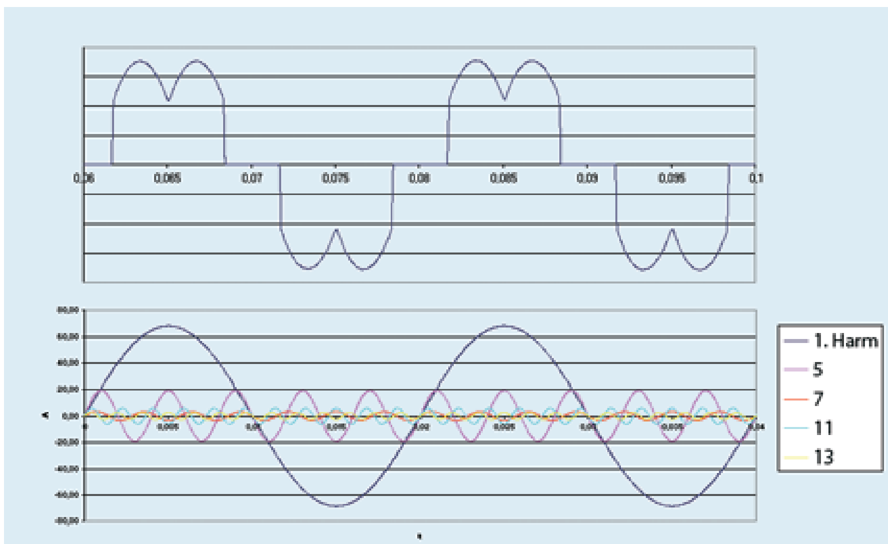
The AC-coils smoothes the line current drawn by the drive. Thereby, a significantly lower current distortion can be achieved compared to a basic frequency drive without coils. Similar effects can be obtained with DC-coils. Moreover, the DC-coils are, compared to AC-coils, smaller in size, have higher efficiency and no reduction of the DC-link voltage.



Normally the voltage in supply grids is not ideally sinusoidal.



Measurements show clear distortion of the mains voltage as the reaction to non-linear consumers. The first indication of harmonic distortion is „flat-topped" voltage shape.



Any periodic function can be described as the sum of a series of sine-wave functions (called a "Fourier transformation") The figure shows the current drawn by a typical drive with dc coils. Underneath it is deconstructed into pure sinus curves. All but the blue curve represents distortion – unwanted and often harmful currents.

Benefits for both AC and DC-coils

- Standard and often build-in
- RMS is dramatically reduced
- Practicable/Easy
- Cost included in drive

DC benefits

- Less frequency across coil giving lower losses then AC-coils (higher efficiency)
- More stable DC-voltage
  - longer capacitor life (smaller DC-ripple)
  - More stable motor control
- Smaller foot print

Harmonic mitigation solutions

Passive Harmonic filtration

Many different passive harmonic filters exist. They are combinations of coils and capacitors tuned to the individual drive. The different passive filters are either tuned for individual harmonic cancellation or for reduction of a range of frequencies.

Passive harmonic filters offer a practical solution to harmonic mitigation on power systems with a large concentration of non-linear loads connected to the same distribution transformer. Like multi-pulse drives, passive filters have a performance depending on the loading, and grid stability.

The mitigation performance of VLT® Advanced Harmonic Filter AHF 010 or AHF 005 are comparable to 12- or 18-pulse solutions respectively but have a higher immunity against loads changes, voltage imbalance and/or voltage pre-distortion.

Multi-pulse

12- and 18-pulse rectifiers have for many years been considered the standard solution to reduce harmonic distortion from drives. In theory, the 5th and 7th harmonic currents (for 18-pulse also the 11th and 13th) are cancelled by phase shifting transformers and the use of two (or three) six-pulse diode rectifiers. However, a significant disadvantage of the multi-pulse harmonic reduction technique is the sensitivity to non-ideal supply voltage. Since some voltage imbalance or harmonic background distortion is always present, a complete cancellation of the 5th and 7th (11th and 13th) is never really achieved.

Especially at currents lower than 300 – 400 A, the Danfoss AHF filter offers a low cost alternative to 12-and 18-pulse drives even with improved harmonic performance.

Active filtering

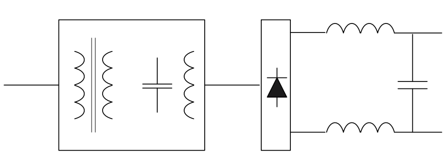
Active filters are very effective in reducing harmonic oscillations up to 2 kHz, and are used as an alternative to built-in DC or AC-coils or other passive filters.

For active filtering as for Low Harmonic Drives and for Active Front End drives, consideration must be given to the effects above 2 kHz, generated by these units themselves.

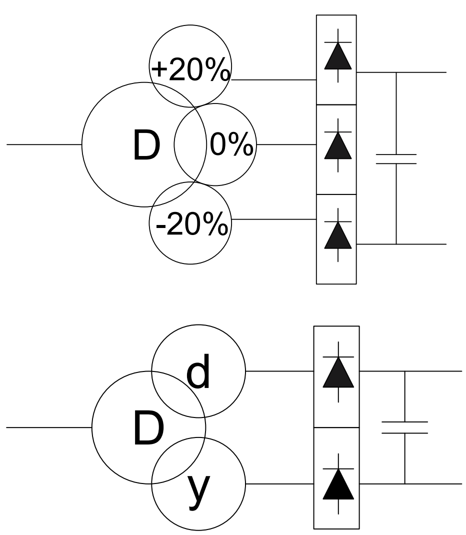
They make further measures necessary to keep the mains supply clean. Standard limits in this higher frequency range are still at the planning stage.

The switching frequencies of active filters will cause a peak at the switching frequency of the filter itself. This is above the range of current norms, but higher order disturbance is of equal importance.

Users should ask manufacturers specifically about emission values and counter-measures to secure the operational safety of their plant .



Advanced Harmonic Filter



Multi-Pulse Drives

Harmonic mitigation solutions

VLT® Low Harmonic Drive

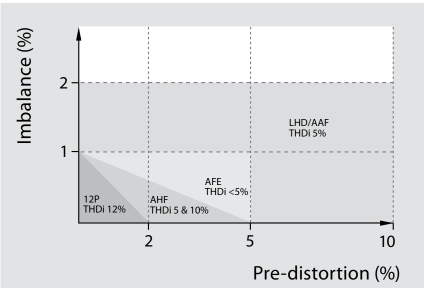
VLT® Low harmonic drives are often Active front end drives where the diode rectifier of the drive is exchanged for a controlable IGBT module allowing energy to be injected back into the line.

The Danfoss VLT® Low Harmonic Drive however is a combination of an Active Filter and a standard AC-drive. It is designed with the fewest possible components in the main current path.

The active mitigation circuit is a parallel path that injects current in counter phase to the unwanted current components of the drive. With few components in the main current path, a high efficiency is achieved compared to other harmonic solutions. Unlike the premium price of an AFE, the Danfoss VLT® Low Harmonic Drive Solution is competitively priced an d offers a cost competitive solution when compared to passive filters.

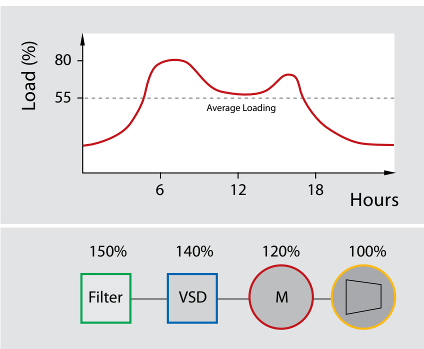
Active filtration keeps harmonics disturbance low for the full load range. The VLT® Low Harmonic Drive still has the side effect of slightly increased EMC disturbance like other active solutions, but offers additional Power Factor correction which may be preferred.

Harmonic mitigation considerations



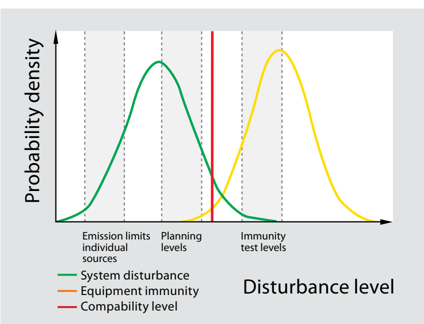
Imbalance and pre-distortion

The harmonic mitigation performance of the different solutions depends on the grid quality.
The higher the imbalance and pre-distortion, the more harmonic the equipment has to suppress. The graph shows at what pre-distortion and imbalance level each technology can keep its guaranteed THDi performance.



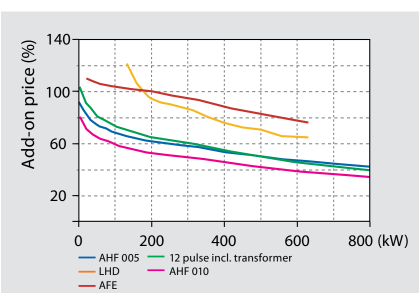
Over-sizing

Published filter data are all given at 100% loading but filters are seldom run at full load due to over-sizing and load profile.
Serial mitigation equipment must always be sized for the maximum current, but be aware of the duration of part load operation and evaluate the different filter types accordingly. Over-sizing gives poor mitigation performance and high running costs. It is also a waste of money.



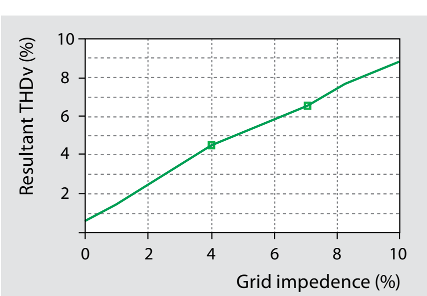
Standards compliance

Keeping equipment immunity higher than system distortion ensures trouble free operation.
Most standards set restrictions on total voltage distortion according to a planned level, often between 5% and 8%.
Equipment immunity is, in most cases, far higher: for drives, between 15-20%. However, this influences product life adversely.



Power size vs. initial costs

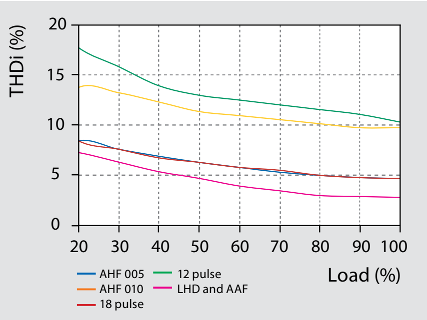
Compared to the variable frequency drive, the different solutions have different add-on prices depending on power size.
The passive solutions in general offer the lowest initial cost and as the complexity of the solutions increase, so does the price.



System impedance

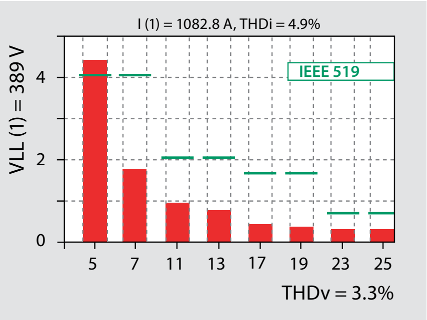
As an example, a 550Hp FC 202 drive on a 1000 kVA transformer with 5% impedance results in ~5% THDv (total harmonic voltage distortion) at ideal grid conditions, whereas the same drive on a 1000 kVA, 8% imp. transformer leads to 50% higher THDv, around 7.5%.

Harmonic mitigation considerations



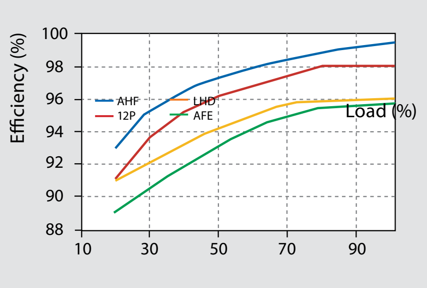
Harmonic performance

Each harmonic mitigation technology has its own THDi characteristic which is load dependent.
These characteristics are set at ideal grid conditions without pre-distortion and with balanced phases.
Variations hereof will result in higher THDi values.



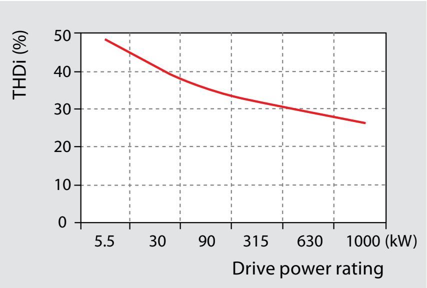
Fulfilling the standards

To determine whether or not the harmonic pollution of a given application/grid exceeds a specific standard, many complex calculations must be done. With the help from free Danfoss MCT 31 harmonic calculation software, this is made easy and less time consuming.



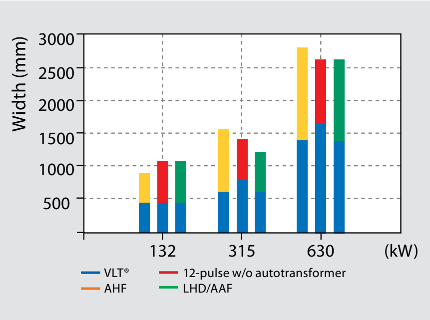
System efficiency

The running cost is mainly determined by the overall system efficiency.
This depends on the individual products, true power-factors and efficiencies.
Active solutions tend to keep the true power-factor independent of load and grid variations. On the other hand, active solutions are less efficient than passive solutions.



Total Harmonic distortion

Each drive generates its own total harmonic current distortion (THDi) which depends on the grid conditions. The bigger the drive is in relation to the transformer the smaller the THDi.



Wall space

In many applications the amount of available wall space is limited and must be utilized to the greatest extent possible.
Based on different technologies, the various harmonic solutions each have their optimum size and power relationship.

VLT® Drives

VLT® Low Harmonic Drive (LHD)

Optimized

for:

- VLT® AQUA Drive FC 202
- IEEE 519 Harmonic Requirements
- Simple Installation

The Danfoss VLT® Low Harmonic Drive is the first solution combining an active filter and a drive in one package.

The VLT® Low Harmonic Drive continuously regulates harmonic mitigation according to the load and grid conditions without affecting the connected motor.

The Total Harmonic Current Distortion is reduced to less then 3% on grids with balanced mains and minimum pre-distortion and to less than 5% on grids with high harmonic distortion and 2% phase unbalance. As individual harmonics also fulfil toughest harmonic requirements, the VLT® Low Harmonic Drive meets all present harmonic standards and recommendations.

Unique features such as sleep mode and back-channel cooling offers unmatched energy efficiency for Low Harmonic Drives.

The VLT® Low Harmonic Drive requires the same set-up and installation as a standard VLT® drive and out of the box it ensures optimum harmonic performance.

The VLT® Low Harmonic Drive features the same modular construction as our standard high power drives and shares similar features: Built-in RFI filters, coated PCB and user-friendly programming.

Voltage range

- 380 – 480 V AC

Power range

- 250 – 1000 HP
  (Matching drive frames D, E and F)

Enclosure

- NEMA 1/IP21
- NEMA12 /IP54

Manufactured to the highest quality standards
The VLT® LHD Drive is a UL-listed product made in the USA in ISO 9001-2000 and ISO 14000 certified facilities.

Specifications	
THiD* at:	
▪ 40% load	< 5.5%
▪ 70% load	< 3.5%
▪ 100% load	< 3%
Efficiency* at:	
▪ 40% load	> 93%
▪ 70% load	> 95%
▪ 100% load	> 96%
True power factor* at:	
▪ 40% load	> 98%
▪ 70% load	> 98%
▪ 100% load	> 98%
Ambient temperature	40° C without derating
Cooling	Back-channel air cooling

** Measured at balanced grid without pre-distortion*

Norms and recommendations	Compliance
IEEE519	Always
IEC61000-3-4 (above 75 A)	Always

VLT® Low Harmonic Drive (LHD)

Line Power Supply 3 x 380 – 480 VAC

	P160	P200	P250	P315	P355	P400	P450	P500	P560	P630	P710
Typical Shaft output (HP)	250	300	350	450	500	550	600	650	750	900	1000
Enclosure Nema 1/IP21 & Nema 12/IP54	D13	D13	D13	E9	E9	E9	E9	F18	F18	F18	F18
Output Current											
Continuous 460/480VAC (A)	302	361	443	540	590	678	730	780	890	1050	1160
Intermittent (60 second overload) 460/480VAC (A)	332	397	487	594	649	746	803	858	979	1155	1276
Continuous KVA	241	288	353	430	470	540	582	621	709	837	924
Input Current											
Continuous Current 460/480VAC (A)	291	348	427	531	580	667	718	759	867	1022	1129
Max Cable Size Motor	2 x 300 MCM	2 x 300 MCM	2 x 300 MCM	4 x 500 MCM	4 x 500 MCM	4 x 500 MCM	4 x 500 MCM	8 x 300 MCM	8 x 300 MCM	8 x 300 MCM	8 x 300 MCM
Max Cable Line Side								8 x 500 MCM	8 x 500 MCM	8 x 500 MCM	8 x 500 MCM
Max input fuses (A)	400	500	630	700	900	900	900	1600	1600	2000	2000
Power loss at max load (W)	11000	13000	14000	16000	17500	19500	21000	27000	30000	33000	38000
Weight	836 lbs (380kg)	836 lbs (380kg)	893 lbs (406kg)	1300 lbs (596 kg)	1370 lbs (623 kg)	1421 lbs (646 kg)	1422 lbs (646 kg)	4420 lbs (2009 kg)	4421 lbs (2009 kg)	4422 lbs (2009 kg)	4423 lbs (2009 kg)
Efficiency	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%	96%
Output Frequency	0-120Hz	0-120Hz	0-120Hz	0-120Hz	0-120Hz	0-120Hz	0-120Hz	0-120Hz	0-120Hz	0-120Hz	0-120Hz

Airflow

The necessary airflow over the heat sink must be secured. The flow rate is shown below.

Enclosure protection	Frame size	Door fan(s)/Top fan airflow	Heatsink fan(s)
		Total airflow of multiple fans	Total airflow of multiple fans
IP21/NEMA 1	D13	510 m^3/h (300 cfm)	2295 m^3/h (1350 cfm)
IP54/NEMA 12	E9	680 m^3/h (400 cfm)	2635 m^3/h (1550 cfm)
	E9	680 m^3/h (400 cfm)	2975 m^3/h (1750 cfm)
IP21/NEMA 1	F18	4900 m^3/h (2884 cfm)	6895 m^3/h (4060 cfm)

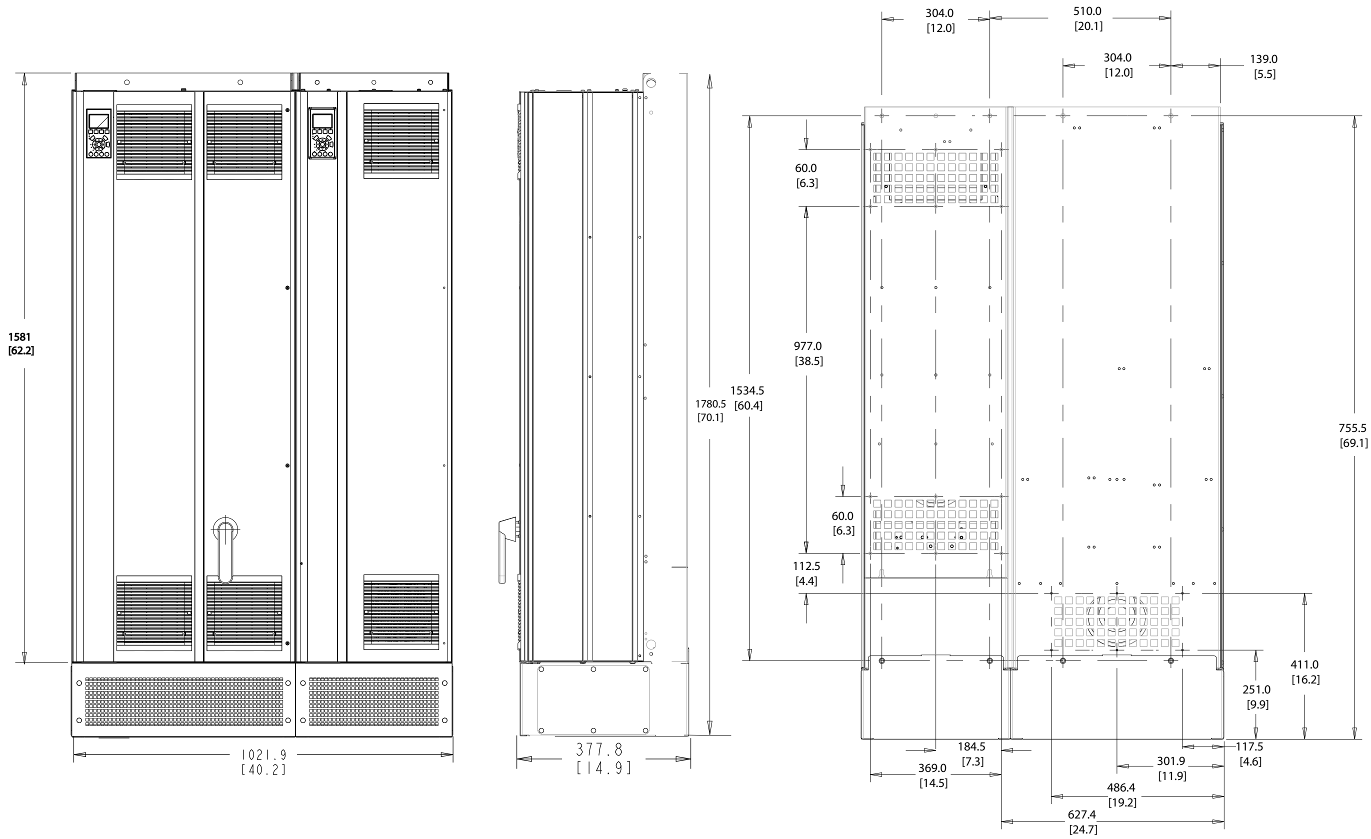
Heatsink Air Flow

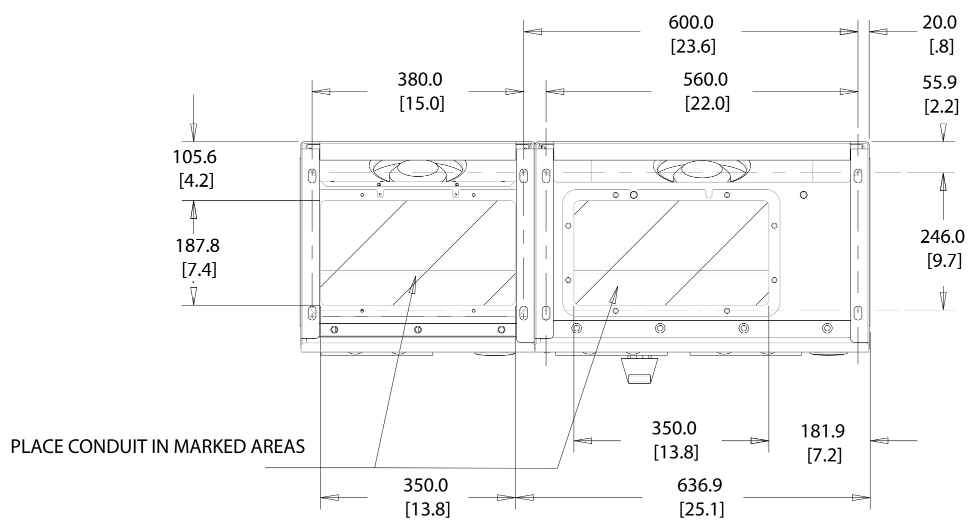
VLT® Low Harmonic Drive (LHD)
Mechanical Specifications

D13 Frame

NEMA 1/IP21 & NEMA 12/IP54

Dimensions: mm (in)	Weight: 860 lbs/390 kg



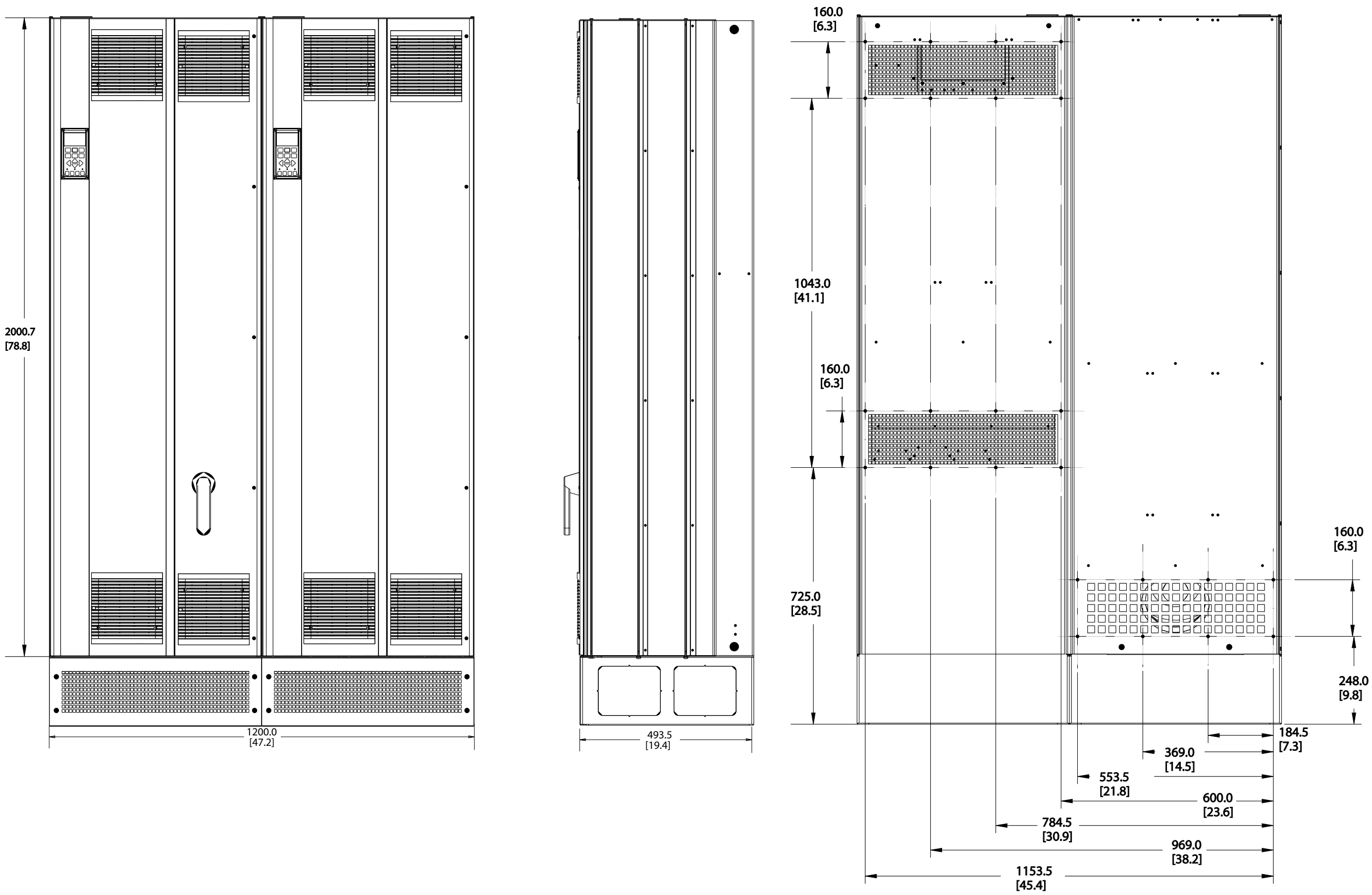


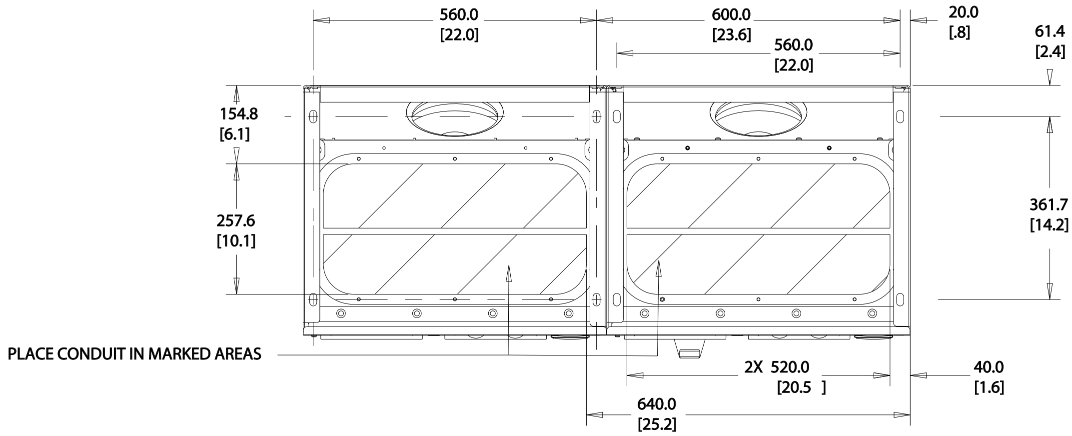
Mechanical Specifications

E9 Frame

NEMA 1/IP21 & NEMA 12/IP54

Dimensions: mm (in)	Weight: 1490 lbs/676 kg



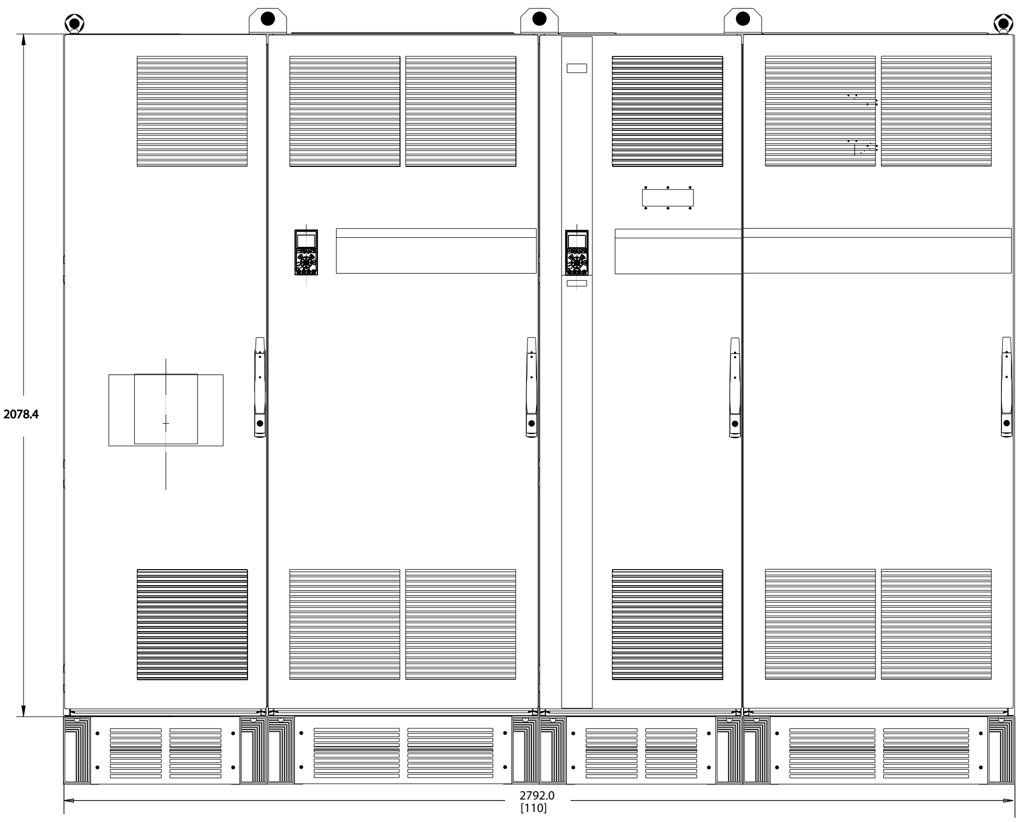


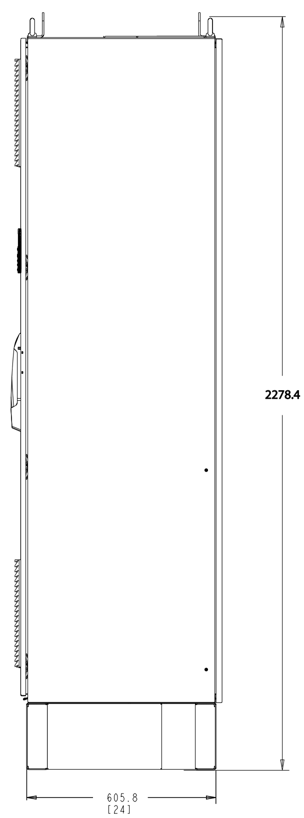
VLT® Low Harmonic Drive (LHD)
Mechanical Specifications

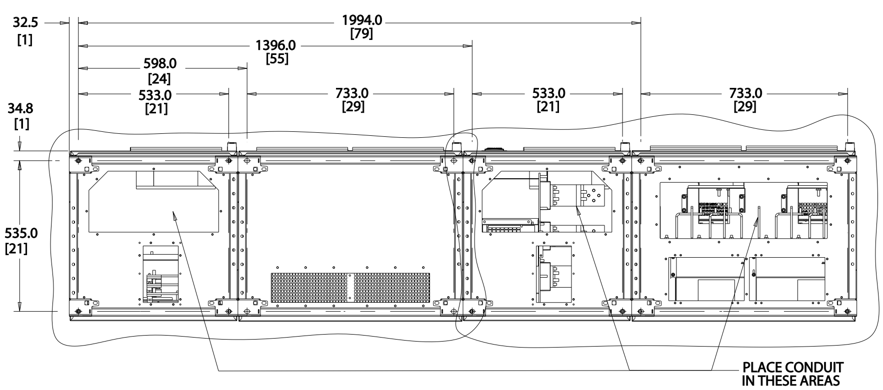
F18 Frame

NEMA 1/IP21 & NEMA 12/IP54

Dimensions: mm (in) Weight: 4198 lbs/1900 kg







BOTTOM VIEW

Cable entries viewed from the bottom of the frequency converter

1) Mains cable connection

2) Motor cable connection

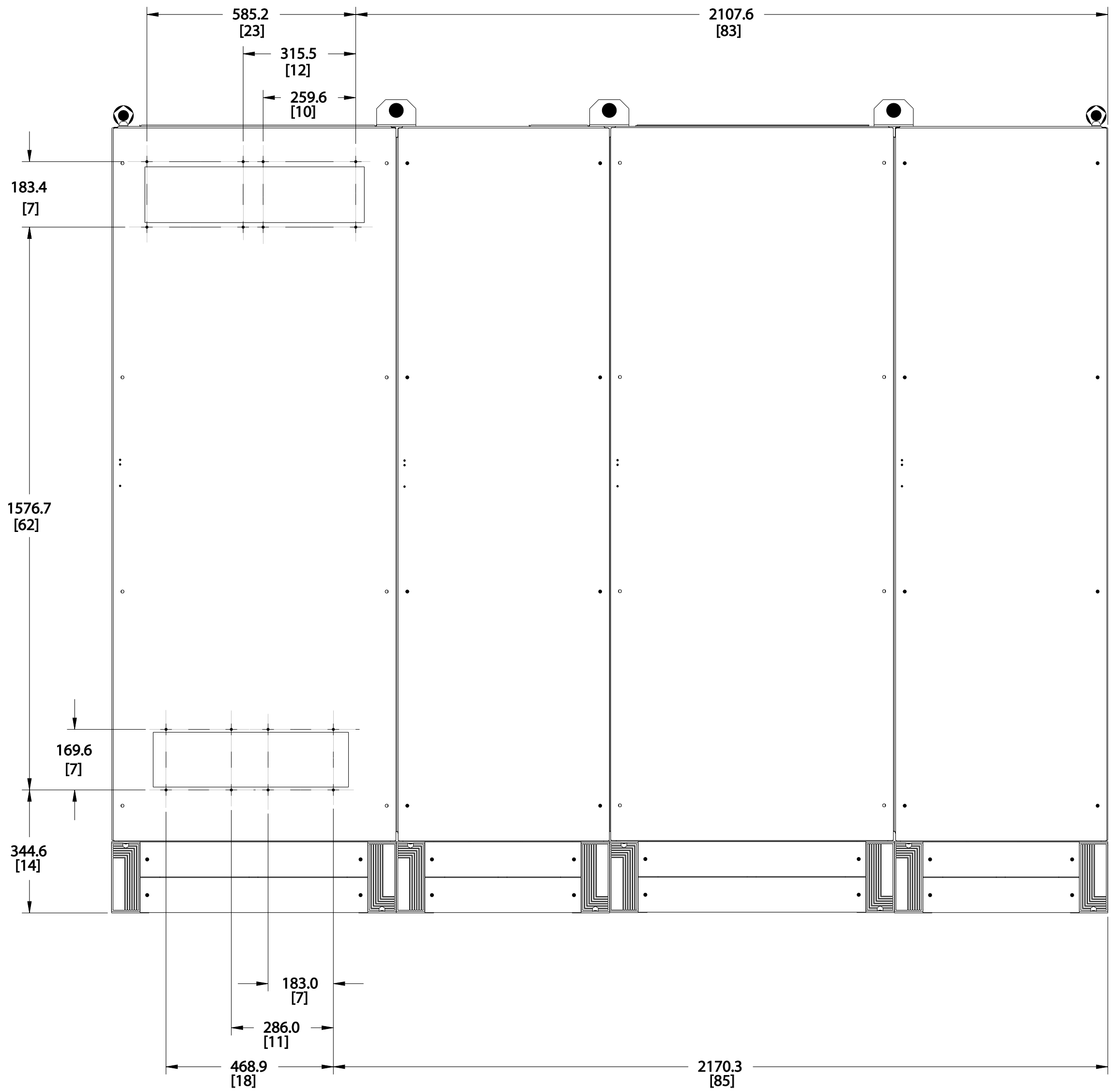
VLT® Low Harmonic Drive (LHD)

Mechanical Specifications

F18 Frame

NEMA 1/IP21 & NEMA 12/IP54

Dimensions: mm (in)	Weight: 4198 lbs/1900 kg



VLT® Drives

VLT® Advanced Active Filter (AAF 006)

Perfect
match for:

- IEEE 519 Installations
- Individual Harmonic correction
- Overall harmonic correction
- Power Factor improvement

Manufactured to the highest quality standards
The VLT® AAF 006 Drive is a UL-listed product made in ISO 9001-2000 and ISO 14000 certified facilities.

A flexible and adaptable solution for central or de-central harmonic mitigation.

Danfoss Advanced Active Filters can compensate for individual Danfoss VLT® Drives or can be installed as a compact stand-alone solution at a common point of coupling, compensating for several loads simultaneously.

Consequently the filter ensures optimal harmonic suppression independent of the number of loads and their individual load profile. In addition the active filter corrects the power factor and balances the phase load providing an optimal energy utilization.

This improves the system efficiency and increases the grid robustness to avoid downtime.

The extensive re-use of proven VLT® components and the modular construction ensures a high reliability and at the same time offers high energy efficiency, back-channel cooling and high enclosure grades without size increase.

Features	Benefits
Reliable	**Maximum uptime**
100% factory tested Conformally Coated Printed Circuit Boards (3C3 rating) >90% components re-used from proven VLT® FC series	Low failure rate
Innovative cooling concept	Prolonged lifetime of electronics
User-friendly and flexible	**Saves commissioning and operating cost**
Innovative programming possibilities	Low running expenses
Modular design	Easy serviceability
Wide range of options	Low initial investment High degree of customization
Energy saving	**Lower operation costs**
High efficiency Sleep mode and progressive switching freq. Power factor correction	Low running expenses

The VLT® Advanced Active Filter is easily controlled via the user-friendly LCP, sharing design and programming structure with the Danfoss VLT® Drives series.

Without removing the existing equipment, the VLT® Advanced Active Filter is easily retrofitted into the existing installation, where harmonics are increased because of large non-linear load additions.

Voltage range
380 – 480 V AC 50 – 60 Hz

Current range
190 A, 250 A, 310 A, 400 A.
Up to 4 units can be paralleled for higher power.

Enclosure degree
- IP 21/NEMA Type 1
- IP 54/NEMA Type 12

VLT® Advanced Active Filter (AAF 006)

Options

The following options are available:
- RFI filters
- Disconnect
- Fuses
- Mains shielding

Specifications	
THiD* at: ▪ 40% load ▪ 70% load ▪ 100% load	 < 7% < 5.5% < 5%
Efficiency* at: ▪ 40% load ▪ 70% load ▪ 100% load	 > 95% > 98% > 98%
True power factor* at: ▪ 40% load ▪ 70% load ▪ 100% load	 > 0.98 > 0.98 > 0.98
Ambient temperature	45°C
Cooling	Back-channel air cooling

** Measured at balanced grid without pre-distortion and with VLT® drive matching full load demand*

Norminal Voltage

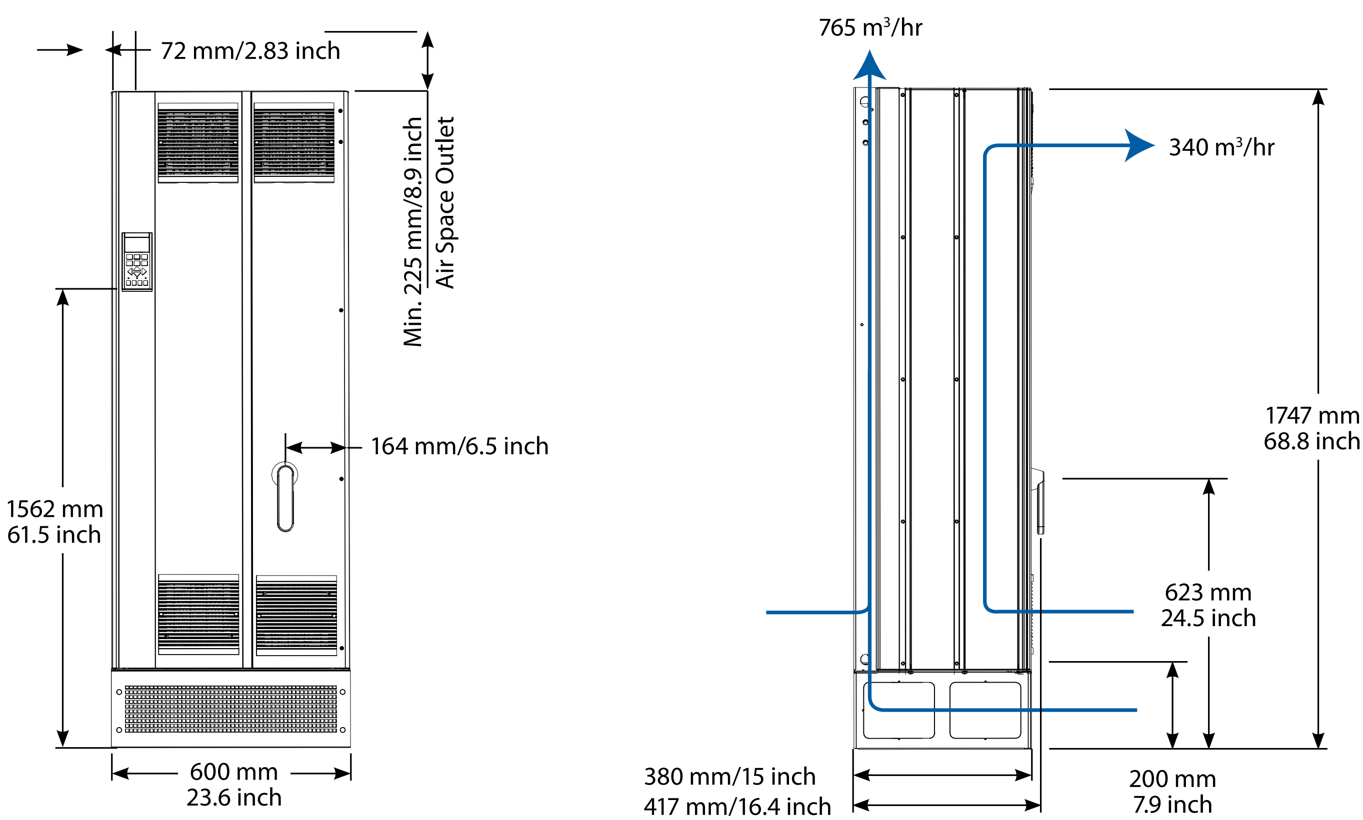
Frame size		D	E	E	E
Type		A190	A250	A310	A400
400 V – Corrected current					
Continuous	[A]	190	250	310	400
Intermittent*	[A]	209	275	341	440
460 V – Corrected current					
Continuous	[A]	190	250	310	400
Intermittent*	[A]	209	275	341	440
480 V – Corrected current					
Continuous	[A]	150	200	250	320
Intermittent*	[A]	165	220	275	352
500 V – Corrected current					
Continuous	[A]	95	125	155	200
Intermittent*	[A]	105	138	171	220
Estimated maximum power loss	[kW]	5	7	9	11.1
Efficiency	[%]	96	96	96	96
Recommended fuse and disconnect**	[A]	350	630	630	900
Copper cable data:					
Maximum cross-section	[mm²]	2 x 150	4 x 240	4 x 240	4 x 240
	[AWG]	2 x 300 mcm	4 x 500 mcm	4 x 500 mcm	4 x 500 mcm
Minimum cross-section	[mm²]	70	120	240	2 x 95
	[AWG]	2/0	4/0	2 x 3/0	2 x 3/0

** 1 minute every 10 minutes (automatically regulated)*
*** Built-in options are recommended*

Total Current [A]	Max. individual harmonic compensation [A]							
	I_5	I_7	I_{11}	I_{13}	I_{17}	I_{19}	I_{23}	I_{25}
190	119	85	55	48	34	31	27	24
250	158	113	72	63	45	40	36	32
310	196	140	90	78	56	50	45	40
400	252	180	115	100	72	65	58	50

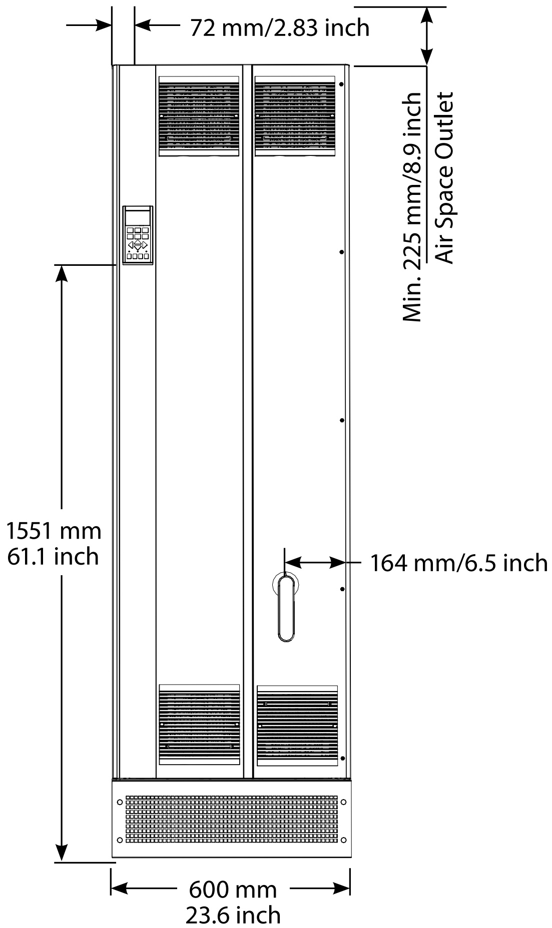
VLT® Advanced Active Filter (AAF 006)
Mechanical Specifications

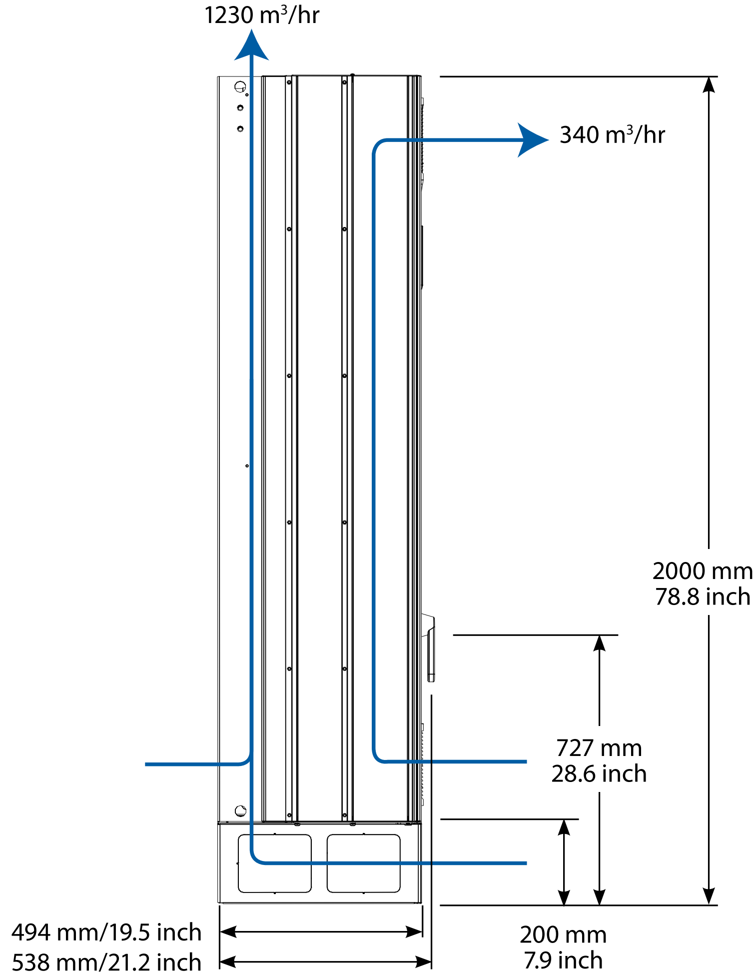
D Frame	
NEMA 1/IP21 & NEMA 12/IP54	
Dimensions: mm (in)	Weight: 1008 lbs/458 kg



VLT® Advanced Active Filter (AAF 006)
Mechanical Specifications

E Frame	
NEMA 1/IP21 & NEMA 12/IP54	
Dimensions: mm (in)	Weight: 525 lbs/238 kg





VLT® Drives

VLT® Advanced Harmonic Filter (AHF)

Optimized harmonic performance with the VLT® FC series up to 350 HP.

Perfect
match for:
- Meeting IEEE 519
- Simple installations
- Retrofit applications

The Danfoss Advanced Harmonic Filters have been specially designed to match the Danfoss Variable Frequency Drive for unmatched performance and design.

Compared to traditional harmonic trap filters they offer a smaller foot print and higher harmonic reduction.

The solution is available in two variants, AHF 005 and AHF 010. When connected in front of a Danfoss VLT® Variable Frequency Drive, the harmonic current distortion generated back to the mains is reduced to 5% and 10% Total Harmonic Current Distortion at full load.

With a >98% efficiency the passive Advanced Harmonic Filters offer cost effective and very robust harmonic solutions specifically for power up to 350 HP.

As stand-alone options the advanced harmonic filters feature a compact housing that is easily integrated into existing panel space. This makes them well-suited for retrofit applications with limited adjustments of the Variable Frequency Drive.

Features	Benefits
Reliable	**Maximum uptime**
100% factory tested Based on proven and tested filter concept	Low failure rate
Energy saving	**Lower operation costs**
High efficiency Electrically matched to the individual VLT® FC drives	Low running expenses
Design	**Compact and aesthetic enclosure**
Innovative coil design Side-by-side mounting Optimized for mounting in panels	Smaller footprint Less wall space needed
Easy commissioning	Low commissioning costs
Enclosure size and colour matches	Danfoss look and feel

Line Voltage
- 380 – 415 V AC (50 and 60 Hz)
- 440 – 480 V AC (60 Hz)
- 500 – 575V (60 Hz)
- 690 V (50 Hz)

Filter current
- 10 A – 480 A (380 – 415 V, 50/60 Hz)
- 10 A – 436 A (440 – 480 V, 60 Hz)
- 15 A – 296 A (600 V, 60 Hz)
- 15 A – 296 A (500-690 V, 50 Hz)
- (Modules can be paralleled for higher power)

Enclosure degree
- Open Chassis/IP00
- Protected Chassis IP/20

Manufactured to the highest quality standards
The AHF Advanced Harmonic Filter is a UL-listed product made in ISO 9001-2000 and ISO 14000 certified facilities.

VLT® Advanced Harmonic Filter (AHF)
Options and Accessories

AHF Advanced Harmonic Filters

AHF005	AHF010	Enclosure Rating	Current Rating	Motor Power	VLT® Power and Current Ratings		Losses		Acoustic noise	Frame size	
			A	HP	FC Rating	A	AHF005 W	AHF010 W	dBA	AHF005	AHF010
130B1787	130B1770	IP00	10	5	PK37-P4K0	1-7.4	131	93	<70	X1	X1
130B1752	130B1482	IP20									
130B1788	130B1771	IP00	14	10	P5K5-P7K5	9.9 – 13	184	188	<70	X1	X1
130B1753	130B1483	IP20									
130B1789	130B1772	IP00	19	15	P11K	19	258	206	<70	X2	X2
130B1754	130B1484	IP20									
130B1790	130B1773	IP00	25	20	P15K	25	298	224	<70	X2	X2
130B1755	130B1485	IP20									
130B1791	130B1774	IP00	31	25	P18K	31	335	233	<72	X3	X3
130B1756	130B1486	IP20									
130B1792	130B1775	IP00	36	30	P22K	36	396	242	<72	X3	X3
130B1757	130B1487	IP20									
130B1793	130B1776	IP00	48	40	P30K	47	482	374	<72	X3	X3
130B1758	130B1488	IP20									
130B1794	130B1777	IP00	60	50	P37K	59	574	352	<72	X4	X4
130B1759	130B1491	IP20									
130B1795	130B1778	IP00	73	60	P45K	73	688	374	<72	X4	X4
130B1760	130B1492	IP20									
130B1796	130B1779	IP00	95	75	P55K	95	747	428	<75	X5	X5
130B1761	130B1793	IP20									
130B1797	130B1780	IP00	118	100	P75K	118	841	488	<75	X5	X5
130B1762	130B1494	IP20									
130B1798	130B1781	IP00	154	125	P90K	154	962	692	<75	X6	X6
130B1763	130B1495	IP20									
130B1799	130B1782	IP00	183	150	P110	183	1080	743	<75	X6	X6
130B1764	130B1496	IP20									
130B1900	130B1783	IP00	231	200	P132	231	1194	864	<75	X7	X7
130B1765	130B1497	IP20									
130B2200	130B1784	IP00	291	250	P160	291	1288	905	<75	X7	X7
130B1766	130B1498	IP20									
130B2257	130B1785	IP00	355	300	P200	348	1406	952	<75	X7	X7
130B1768	130B1499	IP20									
130B3168	130B3166	IP00	380			376	1510	1175	<75	X8	X7
130B3167	130B3165	IP20									
130B2259	130B1786	IP00	436	350	P250	436	1852	1542	<77	X8	X8
130B1769	130B1751	IP20									

NEMA 1 Kit Option

Enclosure	Part Number	NEMA 1 Enclosure AHF Dimensions				
		a	b	c	d	e
X1	130B3274	4.72	6.30	12.97	13.56	8.48
X2	130B3275	7.48	7.09	17.07	17.66	10.14
X3	130B3276	5.71	8.27	21.40	21.99	9.92
X4	130B3277	9.06	9.06	22.58	21.99	13.50
X5	130B3278	9.06	9.84	26.83	27.42	13.50
X6	130B3279	11.81	10.63	26.83	27.42	16.14
X7	130B3281	11.81	12.60	31.36	31.95	18.05
X8	130B3282	15.75	13.78	31.36	31.95	21.77

Chassis Dimensions

Enclosure	Dimensions		
	H	W	D
X1	13.07	7.48	8.11
X2	17.72	9.13	9.76
X3	23.39	14.88	9.53
X4	24.57	14.88	13.11
X5	29.09	16.46	13.11
X6	30.63	16.46	23.46
X7	35.79	18.43	17.68
X8	35.87	18.43	21.38

Backplate Option

Enclosure	Dimensions
X1	130B3283
X2	130B3284
X3	130B3285
X4	130B3286
X5	130B3287
X6	130B3287
X7	130B3288
X8	130B3288

VLT® Multi-Pulse Drives

Optimized

for:

– VLT® AQUA Drive FC 202

Robust and cost effective harmonic solution for the higher power range. The Danfoss VLT® multi-pulse drive offers reduced harmonics for demanding applications.

The VLT® multi-pulse is a high efficiency variable frequency drive which is built with the same modular design as the popular 6-pulse Danfoss VLT® AQUA multi-pulse drives. It is offered with similar drive options and accessories and can be configured according to customer need.

Together with the needed 30°-phase shifting transformer the solution provides durability and reliability at a low cost.

Multi-pulse drives can eliminate the 5th, 7th, 11th, 13th, and 17th harmonics and results in a THiD of around 5 – 12% at full load.

The needed transformer makes this solution ideal for applications where stepping down from medium voltage is required or where isolation from the grid is needed.

The Danfoss VLT® multi-pulse drive provides harmonic reduction without adding capacitive or inductive components which often require network analysis to avoid potential system resonance problems.

Features	Benefits
Reliable	**Maximum uptime**
Maintenance free	No running expenses
Durability	Long lifetime
Coated PCBs	Environmental robustness
100% factory tested	Low failure rate
Back-channel cooling	Prolonged lifetime of electronics
Design	**Easy operation and user-friendly set-up**
Modular design	Easy serviceability
Same easy programming as a 6-pulse drive	User-friendly operation
Standard award-winning control panel (LCP) Available in 27 languages	Effective commissioning and operation

Voltage Range

- 380 – 690 V

Enclosure

- IP 21/NEMA Type 1
- IP 54/NEMA Type 12

Options

The following options are available:

- RFI filters
- Disconnect
- Fuses
- Mains shielding
- Feedback and I/O options
- Fieldbus options
- dV/dt filters
- Sine wave filters
- Circuit Breaker Disconnect Bypass

Manufactured to the highest quality standards

The VLT® AQUA Drive is a UL-listed product made in ISO 9001-2000 and ISO 14000 certified facilities.

VLT® Output Filters

Why use output filters?

- Protection of motor insulation
- Reduction of motor acoustic noise
- Reduction of high frequency electromagnetic noise in the motor cable
- Reduction of Bearing currents and shaft voltage

Application Areas

dV/dt Filter

- Applications with frequent regenerative braking
- Motors that are not rated for variable frequency drive operation and not complying with IEC 600034-25
- Motors placed in aggressive environments or running at high temperatures
- Applications with risk of flash over
- Retrofit applications or using general purpose motors not complying with IEC 600034-17
- Application with short motor cables (less than 15 m)
- 690 V applications

Sine-wave Filter

- Applications where the acoustic switching noise from the motor has to be eliminated
- Retro fit installtions with old motors using poor insulation
- Applications with frequent regenerative braking and motors that do not comply with IEC 600034-17
- Motor is in an aggressive environment or is running at high temperatures
- Applications with motor cables between 150 m – 300 m (screened or unscreened). Use of motor cables longer than 300 m is application dependant
- Applications with increased service intervals on the motor
- 690 V applications with general purpose motors
- Step-up applications or other applications where the variable frequency drive feeds a transformer

High-Frequency Common Mode Core Filters

- Applications with unshielded motor cables
- Should not be used as the sole mitigation measure

Reduction of Motor Acoustic Noise

1. The magnetic noise produced by themotor core, through magnetostriction
2. The noise produced by the motor bearings
3. The noise produced by the motor ventilation

When a motor is fed by a variable frequency drive, the pulsewidth modulated (PWM) voltage applied to the motor causes additional magnetic noise at the switching frequency and harmonics of the switching frequency (mainly the double of the switching frequency). In some applications this is not acceptable. In order to eliminate this additional switching noise, a sine-wave filter should be used. This will filter the pulse shaped voltage from the variable frequency drive and provide a sinusoidal phase-to-phase voltage at the motor terminals.

Performance criteria	dV/dt Filters	Sine-wave Filters	High-frequency Common Mode Filters
Motor insulation stress	Up to 100 m cable (shielded/unshielded) complies with the requirements of IEC60034-17* (general purpose motors). Above this cable length the risk of "double pulsing" increases.	Provides a sinusoidal phase-to-phase motor terminal voltage. Complies with IEC-60034-17* and NEMA-MG1 requirements for general purpose motors with cables up to 500 m (1 km for frame size D and above).	Does not reduce motor insulation stress.
Motor bearing stress	Slightly reduced, mainly in high power motors.	Reduces bearing currents caused by circulating currents. Does not reduce common-mode currents (shaft currents).	Reduces bearing stress by limiting common mode high-frequency currents.
EMC performance	Eliminates motor cable ringing. Does not change the emission class. Does not allow longer motor cables as specified for the variable frequency drive's built-in RFI filter.	Eliminates motor cable ringing. Does not change the emission class. Does not allow longer motor cables as specified for the variable frequency drive's built-in RFI filter.	Reduces high-frequency emissions (above 1 MHz). Does not change the emission class of the RFI filter. Does not allow longer motor cables as specified for the variable frequency drive.
Max. motor cable length	100 m...150 m With guaranteed EMC performance: 150 m screened Without guaranteed EMC performance: 150 m unscreened	With guaranteed EMC performance: 150 m shielded and 300 m unshielded (only conducted emissions). Without guaranteed EMC performance: up to 500 m (1 km for frame size D and above).	300 m screened (frame size D, E, F), 300 m unscreened
Acoustic motor switching noise	Does not eliminate acoustic switching noise from the motor.	Eliminates acoustic switching noise from the motor caused by magnetostriction.	Does not eliminate acoustic switching noise.
Relative size	15 – 50% (depending on power size)	100%	5 – 15%
Relative price	50%	100%	None

**Not 690 V*

VLT® Drives

VLT® Power Option dV/dt Filter

Perfect match for:

- Applications with short motor cables (up to 500 ft.)
- Applications with older motors
- Aggressive environments

dV/dt filters reduce the dV/dt values on the motor terminal phase-to-phase voltage – an issue that is important for short motor cables.

dV/dt filters are differential-mode filters which reduce motor terminal phase-to-phase peak voltages spikes and reduce the rise time to a level that lowers the stress on the insulation of motor windings.

Compared to sine-wave filters, the dV/dt filters have a cut-off frequency above the switching frequency. The voltage at the motor terminals is still PWM pulse shaped, but the rise time and Upeak are reduced. They are smaller, weigh less and have a lower price compared to sine-wave filters. Furthermore, because of the smaller inductance and capacitance, the dV/dt filters introduce a negligible reactance between inverter and motor and are therefore suitable for high dynamic applications.

Manufactured to the highest quality standards

The VLT® dV/dt Filter is a UL-listed product made in ISO 9001-2000 and ISO 14000 certified facilities.

Features	Benefits
Reduces dV/dt stresses	Increases motor service interval
Lowers the magnetic interference propagation on surrounding cables and equipment	Trouble-free operation
Low voltage drop makes dV/dt filters the ideal solution for highly dynamic applications with flux vector regulation	Small size and cost compared to sine-wave filters

Superior compared to output chokes

Output chokes cause undamped oscillations at the motor terminals which increase the risk of double pulsing and over-voltages higher than twice the DC link voltage.
The dV/dt filters are low-pass L-C filters with a well defined cut-off frequency. Therefore the ringing oscillations at the motor terminals are damped and there is a reduced risk of double pulsing and voltage peaks.

Quality and Design

All dV/dt filters are designed and tested for operation with the VLT® AQUA Drive FC 202. They are designed to match the look and quality of the VLT® FC series drives.

Advantages

- Compatible with all control principles, including flux and WC+
- Parallel filter installation is possible for applications in the high power range

Range

3 x 200 – 690 V (up to 880 A)

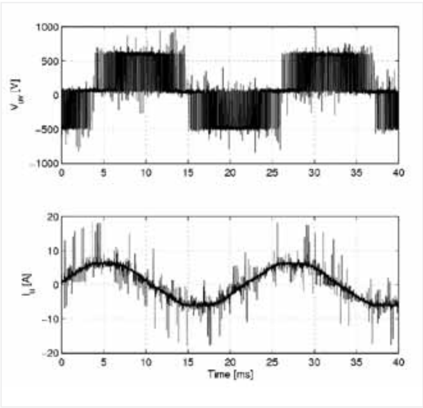
Enclosures

- Open Chassis/IP00
- Protected Chassis/IP20
- NEMA 12/IP54

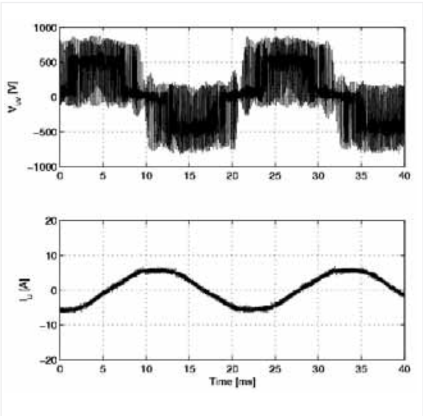
Mounting

- Side by side mounting with the drive
- Filters wall mounted up to 480 A (380 V) and floor mounted above that size

VLT® Power Option dV/dt Filter

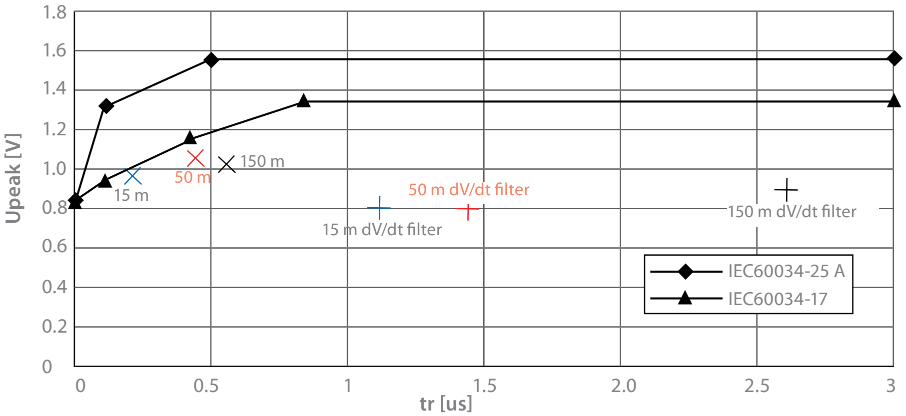


Voltage and current without filter



Voltage and current with filter

dV/dt limit curves

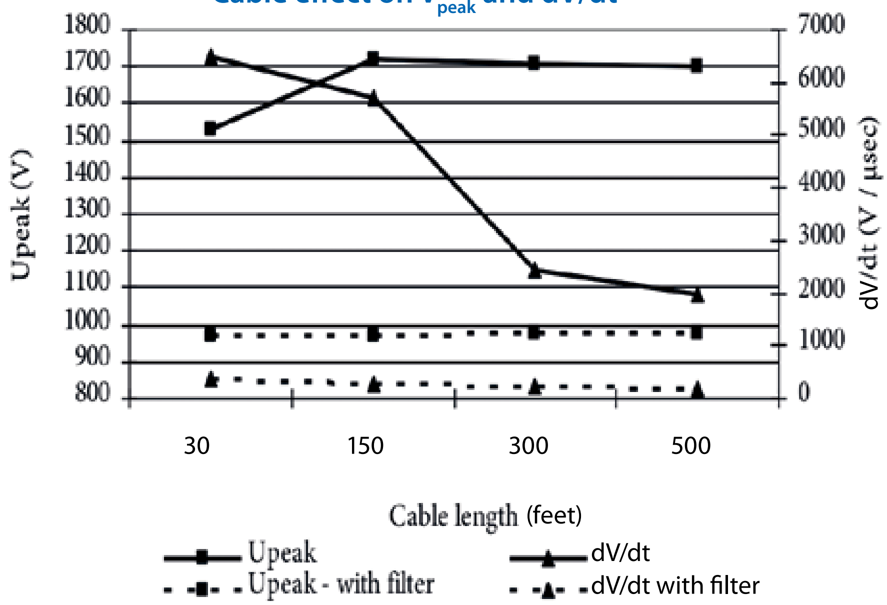


The dV/dt value decreases with the motor cable length whereas the peak voltage increases. Therefore it is recommended to use sine-wave filters in installations with motor cable lengths above 150 m.

Performance Criteria	dV/dt filters
Motor insulation stress	Up to 300 ft. (100 m) cable (shielded/unshielded) complies with the requirements of IEC60034-17* (general purpose motors). Above this cable length the risk of "double pulsing" increases.
Motor bearing stress	Slightly reduced, mainly in high power motors.
EMC performance	Eliminates motor cable ringing. Does not change the emission class. Does not allow longer motor cables as specified for the Variable Frequency Drive's built-in RFI filter.
Max. motor cable length	300 ft.-500 ft. (100 m-150 m) With guaranteed EMC performance: 500 ft. (150 m) shielded Without guaranteed EMC performance: 500 ft. (150 m) unshielded
Acoustic motor switching noise	Does not eliminate acoustic switching noise from the motor.
Relative size	15 – 50% (depending on power size).
Relative price	50%

**Not 690 V*

Cable effect on V_{peak} and dV/dt



VLT® Power Option dV/dt Filter

Specifications	
Voltage rating	3 x 200-690 V
Nominal current @ 50 Hz	up to 880 A. F-frame current ratings are achieved by filter paralleling, one filter per inverter module
Motor frequency derating	50 Hz Inominal 60 Hz 0.94 x Inominal 100 Hz 0.75 x Inominal
Minimum switching frequency	no limit
Maximum switching frequency	nominal switching frequency of the respective FC 102, 202 or 302
Overload capacity	160% for 60 seconds, every 10 min.
Enclosure degree	Chassis/IP00, Protected Chassis/IP 20 for wall-mounted, NEMA 1/IP23 for floor mounted. NEMA 1/IP21 available for wall-mounted using separate kits
Ambient temperature	14°F to 113°F/ -10° to +45°C
Storage temperature	-13°F to 140°F/ -25° to +60°C
Transport temperature	-13°F to 158°F/ -25° to +70°C
Maximum ambient temperature (with derating)	131°F/ 55°C
Maximum altitude without derating	3280 ft./1000 m
Maximum altitude with derating	13,120 ft./ 4000 m
Derating with altitude 5%/1000 m MTBF	1481842 h
FIT	1,5 106/h
Tolerance of the inductance	± 10%
Degree of pollution EN61800-5-1	II
Overvoltage category EN61800-5-1	III
Environmental Conditions Load	3K3
Environmental Conditions Storage	1K3
Environmental Conditions Transport	2K3
Noise level	< variable frequency drive
Approvals	CE (EN61558, VDE 0570), RoHS, cULus file E219022 (pending)

dV/dt Filters

IP00	Filter	Current rating (Amp)		Filter Losses (W)	Dimensions (in)			
		460/480V @ 60Hz	575/600V @ 60Hz		H	W	D	Weight
130B2835	MCC102A40KTME00B	40	32	37	11.61	4.52	6.69	
130B2838	MCC102A80KTME00B	80	58	130	15.15	6.1	8.66	
130B2841	MCC102A105TME00B	105	94	145	15.55	6.1	8.66	
130B2844	MCC102A160TME00B	160	131	205	17.51	7.28	9.25	
130B2847	MCC102A303TME00B	303	242	315	9.25	11.81	7.48	
130B2849	MCC102A460TME00B	443	344	398	9.25	11.81	9.84	
130B2851	MCC102A645TME00B	590	500	550	10.62	13.77	9.84	
130B2853	MCC102A800TME00B	780	660	850	11.14	15.74	11.41	

IP20/23	Filter	Current rating (Amp)		Filter Losses (W)	Dimensions (in)			
		460/480V @ 60Hz	575/600V @ 60Hz		H	W	D	Weight
130B2836	MCC102A40KTME20B	40	32	37	14.56	4.64	9.52	
130B2839	MCC102A80KTME20B	80	58	130	18.7	6.18	8.66	
130B2842	MCC102A105TME20B	105	94	145	18.7	6.22	8.66	
130B2845	MCC102A160TME20B	160	131	205	20.66	7.4	9.25	
130B2848	MCC102A303TME23B	303	242	315	16.73	27.55	7.48	
130B2850	MCC102A460TME23B	443	344	398	16.73	27.55	9.84	
130B2852	MCC102A645TME23B	590	500	550	16.73	27.55	9.84	
130B2854	MCC102A800TME23B	780	660	850	31.18	37	11.41	

VLT® Power Option Sine-wave Filter

Perfect match for:

- Applications with older motors
- Aggressive environments
- 690 V applications with general purpose motors
- Motor cable length above 500 ft.

Sine-wave output filters are low-pass filters that suppress the switching frequency component from the drive and smooth out the phase-to-phase output voltage of the drive to become sinusoidal. This reduces the motor insulation stress and bearing currents.

Sine-wave output filters are low-pass filters that suppress the switching frequency component from the drive and smooth out the phase-to-phase output voltage of the drive to become sinusoidal. This reduces the motor insulation stress and bearing currents.

By supplying the motor with a sinusoidal voltage waveform, the switching acoustic noise from the motor is also eliminated.

Features	Benefits
Supplies the motor with a sinusoidal voltage waveform	Prevents flashover in motor windings
Eliminates over-voltages and voltage spikes caused by cable reflections	Protects the motor insulation against premature aging
Reduces electromagnetic interference by eliminating pulse reflection caused by current ringing in the motor cable. This allows the use of unshielded motor cables in some applications.	Trouble-free operation
Eliminates acoustic noise in motor	Noiseless motor operation
Reduces high frequent losses in motor	Prolongs service interval of motor

Thermal losses and bearing currents

The sinusoidal voltage supply to the motor reduces hysteresis thermal losses in the motor. Since the motor insulation lifetime is dependent on the motor temperature, the sine-wave filter prolongs the lifetime of the motor.

The sinusoidal motor terminal voltage from the sine-wave filter furthermore has the advantage of suppressing bearing currents in the motor. This reduces the risk of flashover in the motor bearings and thereby also contributes to extended motor lifetime and increased service intervals.

Quality and Design

All filters are designed and tested for operation with the VLT® AQUA Drive FC 202. They are rated for the nominal switching frequency of the VLT® FC series and therefore no derating of the drive is needed.

The enclosure is designed to match the look and quality of the VLT® FC series drives.

Advantages

- Compatible with all control principles including flux and VVC+
- Parallel filter installation is possible for applications in the high power range

Range

3 x 200 – 500 V, 2.5 – 800 A
3 x 525 – 690 V, 13 – 660 A

Enclosures

- Open Chassis/IP00
- Protected Chassis/IP20
- NEMA 1/IP23

Mounting

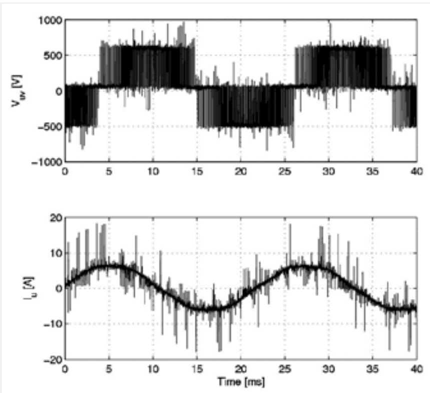
- Side by side mount with the drive up to 75 A (500 V)

c UL us

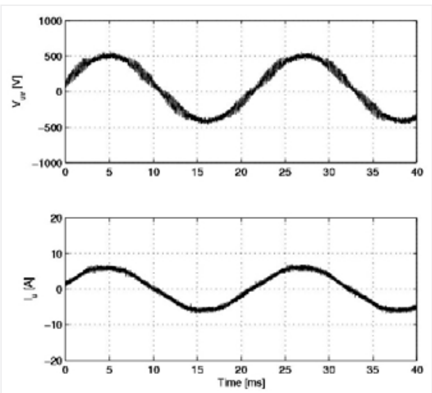
Manufactured to the highest quality standards

The VLT® Sine-Wave Filter is a UL-listed product made in ISO 9001-2000 and ISO 14000 certified facilities.

VLT® Power Option Sine-wave Filter

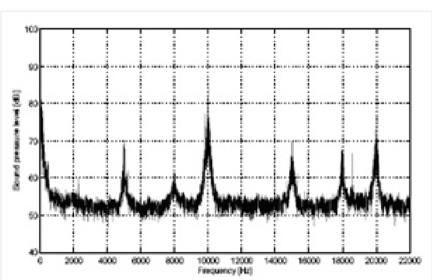


Voltage and current without filter

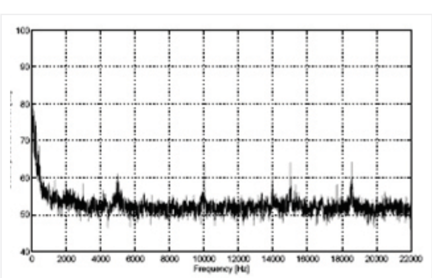


Voltage and current with filter

Relative sound pressure measurements from the motor with and without sine-wave filter



No filter



With sine-wave filter

Specifications	
Voltage rating	3 x 200-500V and 500-690V AC
Nominal current @ 50 Hz	up to 800A (500V) and 660A (690V). F-frame current ratings are achieved by filter paralleling, one filter per inverter module
Motor frequency derating	50 Hz Inominal 60 Hz 0.94 x Inominal 100 Hz 0.75 x Inominal
Minimum switching frequency	nominal switching frequency of the respective FC 202 x 0.80
Maximum switching frequency	8 kHz
Overload capacity	160% for 60 seconds, every 10 min.
Enclosure degree	IP00, IP 20 for wall-mounted, IP23 for floor mounted. IP21/ NEMA 1 available for wall-mounted using separate kits
Ambient temperature	14°F to 113°F/ -10° to +45°C
Storage temperature	-13°F to 140°F/ -25° to +60°C
Transport temperature	-13°F to 158°F/ -25° to +70°C
Maximum ambient temperature (with derating)	131°F/ 55°C
Maximum altitude without derating	3280 ft./1000 m
Maximum altitude with derating	13,120 ft./ 4000 m
Derating with altitude 5%/1000 m MTBF	1481842 h
FIT	1,5 106/h
Tolerance of the inductance	± 10%
Degree of pollution EN61800-5-1	II
Overvoltage category EN61800-5-1	III
Environmental Conditions Load	3K3
Environmental Conditions Storage	1K3
Environmental Conditions Transport	2K3
Noise level	< variable frequency drive
Approvals	CE (EN61558, VDE 0570), RoHS, cULus file E219022 (pending)

Performance Criteria	Sine-wave filters
Motor insulation stress	Provides a sinusoidal phase-to-phase motor terminal voltage. Complies with IEC-60034-17* and NEMA-MG1 requirements for general purpose motors with cables up to 500 m (1 km for frame size D and above).
Motor bearing stress	Reduces bearing currents caused by circulating currents. Does not reduce common-mode currents (shaft currents).
EMC performance	Eliminates motor cable ringing. Does not change the emission class. Does not allow longer motor cables as specified for the variable frequency drive's built-in RFI filter.
Max. motor cable length	With guaranteed EMC performance: 150 m shielded and 300 m unshielded (only conducted emissions). Without guaranteed EMC performance: up to 500 m (1 km for frame size D and above).
Acoustic motor switching noise	Eliminates acoustic switching noise from the motor caused by magnetostriction.
Relative size	100%
Relative price	100%

*Not 690 V

VLT® Power Option Sine-wave Filter

Sine-Wave Filters

IP00	3x240-500 VAC	Output Current Rating			Dimensions (in)			Filter Loss (w)
		@50Hz	@60Hz	@100Hz	Height	Width	Depth	
130B2404	MCC101A2K5T3E00A	2.5	2.5	2	7.13	2.95	8.07	60
130B2406	MCC101A4K5T3E00A	4.5	4	3.5	7.13	2.95	8.07	65
130B2408	MCC101A8K0T3E00A	8	7.5	5.5	9.69	3.54	8.07	80
130B2409	MCC101A10KT3E00A	10	9.5	7.5	9.69	3.54	8.07	90
130B2411	MCC101A17KT3E00A	17	16	13	9.69	5.12	8.07	115
130B2412	MCC101A24KT3E00A	24	23	18	10.24	5.91	10.24	150
130B2413	MCC101A38KT3E00A	38	36	28.5	14.96	5.91	10.24	160
130B2281	MCC101A48KT3E00A	48	45.5	36	18.11	6.69	10.24	260
130B2282	MCC101A62KT3E00A	62	59	46.5	21.26	6.69	10.24	280
130B2283	MCC101A75KT3E00A	75	71	56	21.26	6.69	10.24	330
130B3179	MCC101A115T3E00B	115	109	86	20.47	18.50	13.15	470
130B3182	MCC101A180T3E00B	180	170	135	22.83	18.50	12.24	650
130B3184	MCC101A260T3E00B	260	246	195	20.47	19.69	15.75	850
130B3186	MCC101A410T3E00B	410	390	308	20.47	19.69	19.29	1150
130B3188	MCC101A510T3E00B	510	456	360	20.47	19.69	19.29	1450
130B3191	MCC101A660T3E00B	660	627	495	24.41	24.41	22.95	2000
130B3193	MCC101A800T3E00B	800	712	562	24.41	24.41	22.95	3000

IP20/23	3x240-500 VAC	Output Current Rating			Dimensions (in)			Filter Loss (w)
		@50Hz	@60Hz	@100Hz	Height	Width	Depth	
130B2439	MCC101A2K5T3E20A	2.5	2.5	2	7.13	2.95	8.07	60
130B2441	MCC101A4K5T3E20A	4.5	4	3.5	7.13	2.95	8.07	65
130B2443	MCC101A8K0T3E20A	8	7.5	5.5	9.69	3.54	8.07	80
130B2444	MCC101A10KT3E20A	10	9.5	7.5	9.69	3.54	8.07	90
130B2446	MCC101A17KT3E20A	17	16	13	9.69	5.12	8.07	115
130B2447	MCC101A24KT3E20A	24	23	18	10.24	5.91	10.24	150
130B2448	MCC101A38KT3E20A	38	36	28.5	14.96	5.91	10.24	160
130B2307	MCC101A48KT3E20A	48	45.5	36	18.11	6.69	10.24	260
130B2308	MCC101A62KT3E20A	62	59	46.5	21.26	6.69	10.24	280
130B2309	MCC101A75KT3E20A	75	71	56	21.26	6.69	10.24	330
130B3181	MCC101A115T3E23B	115	109	86	36.14	35.59	29.76	470
130B3183	MCC101A180T3E23B	180	171	135	36.14	35.59	29.76	650
130B3185	MCC101A260T3E23B	260	247	195	36.14	35.59	29.76	850
130B3187	MCC101A410T3E23B	410	390	308	36.14	35.59	29.76	1150
130B3189	MCC101A510T3E23B	510	456	360	45.71	48.19	37.60	1450
130B3192	MCC101A660T3E23B	660	627	495	45.71	48.19	37.60	2000
130B3194	MCC101A800T3E23B	800	712	562	45.71	48.19	37.60	3000

IP00	3x525-690 VAC	Output Current Rating			Dimensions (in)			Filter Loss (w)
		@50Hz	@60Hz	@100Hz	Height	Width	Depth	
130B3195	MCC101A13KT7E00B	13	12	9	18.31	4.53	8.86	115
130B4112	MCC101A28KT7E00B	28	26	21	19.88	6.10	10.63	150
130B4114	MCC101A45KT7E00B	45	42	33	24.61	6.10	14.57	250
130B4116	MCC101A76KT7E00B	76	72	57	20.47	18.50	13.07	475
130B4118	MCC101A115T7E00B	115	109	86	20.47	18.50	13.39	750
130B4121	MCC101A165T7E00B	165	156	124	18.50	19.69	15.75	1100
130B4125	MCC101A260T7E00B	260	246	195	21.06	24.41	18.11	1300
130B4129	MCC101A360T7E00B	360	314	270	25.98	31.50	24.02	1800
130B4152	MCC101A430T7E00B	430	407	323	25.98	31.50	24.02	2150
130B4154	MCC101A530T7E00B	530	502	398	25.98	31.50	26.93	2400
130B4156	MCC101A660T7E00B	660	625	496	27.17	31.50	28.07	3000

IP00	3x525-690 VAC	Output Current Rating			Dimensions (in)			Filter Loss (w)
		@50Hz	@60Hz	@100Hz	Height	Width	Depth	
130B3195	MCC101A13KT7E00B	13	12	9	18.31	4.53	8.86	115
130B4112	MCC101A28KT7E00B	28	26	21	19.88	6.10	10.63	150
130B4114	MCC101A45KT7E00B	45	42	33	24.61	6.10	14.57	250
130B4116	MCC101A76KT7E00B	76	72	57	20.47	18.50	13.07	475
130B4118	MCC101A115T7E00B	115	109	86	20.47	18.50	13.39	750
130B4121	MCC101A165T7E00B	165	156	124	18.50	19.69	15.75	1100
130B4125	MCC101A260T7E00B	260	246	195	21.06	24.41	18.11	1300
130B4129	MCC101A360T7E00B	360	314	270	25.98	31.50	24.02	1800
130B4152	MCC101A430T7E00B	430	407	323	25.98	31.50	24.02	2150
130B4154	MCC101A530T7E00B	530	502	398	25.98	31.50	26.93	2400
130B4156	MCC101A660T7E00B	660	625	496	27.17	31.50	28.07	3000

VLT® Common Mode Filters

High-frequency common-mode core kit reduce electromagnetic interference and eliminate bearing damage by electrical discharge.

High-frequency common-mode (HF-CM) cores are special nanocrystalline magnetic cores which have superior filtering performance compared to regular ferrite cores. They act like a common-mode inductor (between phases and ground).

Installed around the three motor phases (U, V, W), they reduce high-frequency common-mode currents. As a result, high-frequency electromagnetic interference from the motor cable is reduced. However, the core kit should not be used as the sole mitigation measure, and even when the cores are used, the EMC installation rules shall be followed.

Prevent motor bearing currents

The most important function is to reduce high-frequency currents associated with electrical discharges in the motor currents.

These discharges contribute to the premature wear-out and failure of motor bearings. By reducing or even eliminating discharges, the wear-out of the bearings is reduced and the lifetime extended. Thus, maintenance and down-time costs are lowered.

Features	Benefits
High-performance nanocrystalline magnetic material	Effective reduction of electrical discharges in the motor bearings Reduces bearing wear-out, maintenance costs and down-time Reduces high-frequency electromagnetic interference from the motor cable
Oval shape Scalable solution: longer cables handled by stacking more cores	Easy to install in restricted places such as the VLT® enclosure or the motor terminal box
Only 4 core sizes cover the entire VLT® power range	Easy logistics, fast delivery and comprehensible product program Allows the addition to a service tool-kit
Low investment	Cost-effective alternative to, for example, sine-wave filters if the only phenomena to be mitigated is bearing wear-out through electrical discharge

Ideal for retrofitting

Bearing current problems are most often discovered after commissioning. Therefore, the cores have an oval shape which makes them ideal for retrofitting and for installation in restricted places.

Only 4 variants cover the entire VLT® product range making it possible to carry these valuable aids in a service tool kit.

A flexible solution

The cores can be combined with other output filters, and especially in combination with dV/dt filters they offer a low cost solution for protection of both motor bearings and insulation.

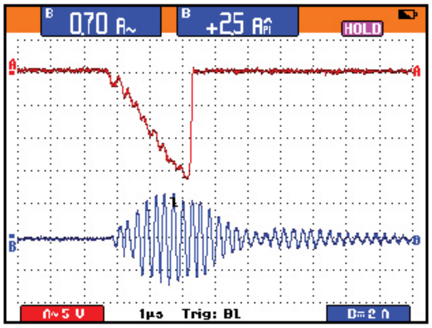
Product range

- Available for all power sizes from 1/4 HP to 1900 HP
- 4 core sizes cover the entire VLT® power range

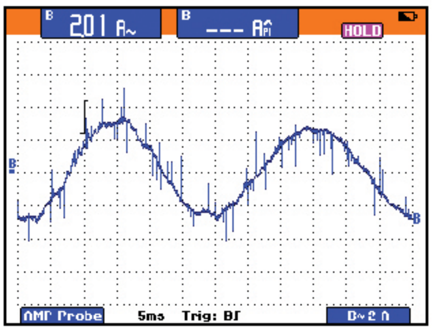
HF-CM selector

The cores can be installed at the variable frequency drive's output terminals (U, V, W) or in the motor terminal box. When installed at the variable frequency drive's terminals, the HF-CM kit reduces bearing stress and high-frequency electromagnetic interference from the motor cable. The number of cores depends on motor cable length and variable frequency drive voltage. A selection table is shown to the right.

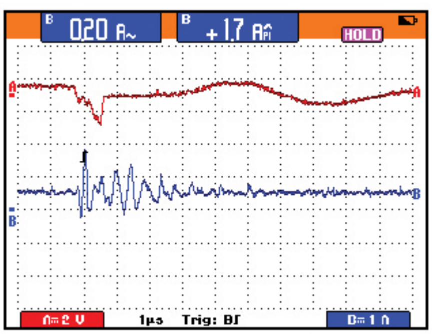
VLT® Common Mode Filters



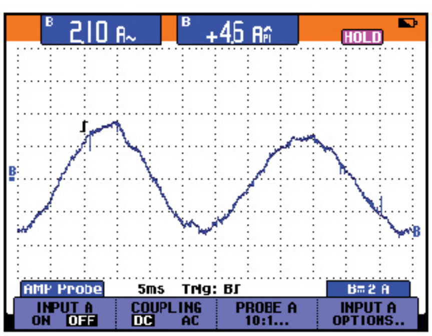
Shaft voltage and bearing current without HF-CM



Grounding current without HF-CM



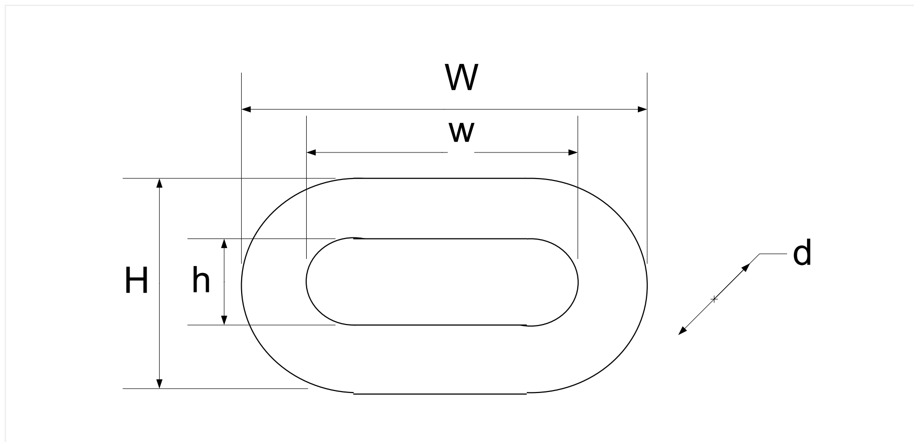
Shaft voltage and bearing current with HF-CM



Grounding current with HF-CM core

Cable length [m]	A and B frame		C frame		D frame		E and F frame	
	T5	T7	T5	T7	T5	T7	T5	T7
165 ft. (50 m)	2	4	2	2	2	4	2	2
330 ft. (100 m)	4	4	2	4	4	4	2	4
500 ft. (150 m)	4	6	4	4	4	4	4	4
1000 ft. (300 m)*	4	6	4	4	4	6	4	4

** Longer cable lengths are easily handled by stacking more HF-CM cores.*

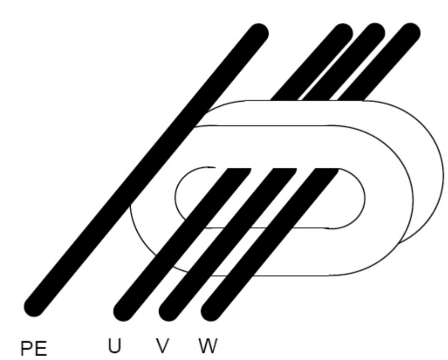


Ordering numbers and dimensions

Ordering numbers for the core kits (2 cores per package) are given in the table below.

VLT® Frame Size	Danfoss ordering number	Core dimension [in]					Weight	Packaging dimension
		W	w	H	h	d	[kg]	[in]
A and B	130B3257	2.36	1.69	1.57	0.98	0.87	0.25	5.12 x 3.94 x 2.76
C	130B3258	4.02	2.72	2.40	1.10	1.46	1.6	7.48 x 3.94 x 2.76
D	130B3259	7.44	5.63	4.96	3.15	1.46	2.45	9.25 x 7.48 x 5.51
E and F	130B3260	12.01	9.80	5.79	3.74	1.46	4.55	11.42 x 10.24 x 4.33

Installation



The HF-CM cores are easy to install: Simply pass the three motor phase leads (U, V, W) through the cores.

VLT® Motion Control Tool (VLT® MCT 10)

Perfect
tool for:
– Commissioning
– Servicing
– Programming

The VLT® Motion Control Tool, VLT® MCT 10, is ideal for commissioning and servicing the drive including guided programming of cascade controller, real-time clock, smart logic controller and preventive maintenance.

The setup software provides easy control of details as well as a general overview of systems, large or small. The tool handles all drive series, VLT® Advanced Active Filters and VLT® Soft Starter related data.

Features	Benefits
One PC tool for all tasks	Save time
"Explorer-like" view	Easy to use
Option programming	Save time
Online and offline commissioning	Flexible and save cost
Scope & logging	Easy and fast analyzing – less downtime
Alarm history	Easy fault finding
Multiple interfaces	Easy connection
USB connection	Easy connection
Flexible Ethernet connection	Easy connection – save time (utilizing all Danfoss Ethernet based fieldbus options)

More efficient service organization

- Scope & logging: analyse problems easily
- Read out alarms, warnings and fault log in one view.
- Compare saved project with on-line drive
- Update drive or option firmware. One tool handling all *(to be supported in January)*

More efficient commissioning

- Off-line commissioning off site
- Save/send/mail projects anywhere
- Easy field-bus handling, multiple drives in project file. Enables service organization to be more efficient

Basic version

- Off –line commissioning (max. 4 drives)
- Scope & Graph (max. 2 channels)
- Multiple fieldbus support
- Alarm history in saved projects
- MCO 305 support
- Graphical Smart Logic Controller
- Graphical Clock functions, Timebased Actions, Preventive Maintenance and Basic Cascade Controller (FC 102/FC 202 only)
- Update drive support to support new firmware (future compatible)
- FC drive conversion (FC 102/FC 202 & FC 300 series)

Advanced version

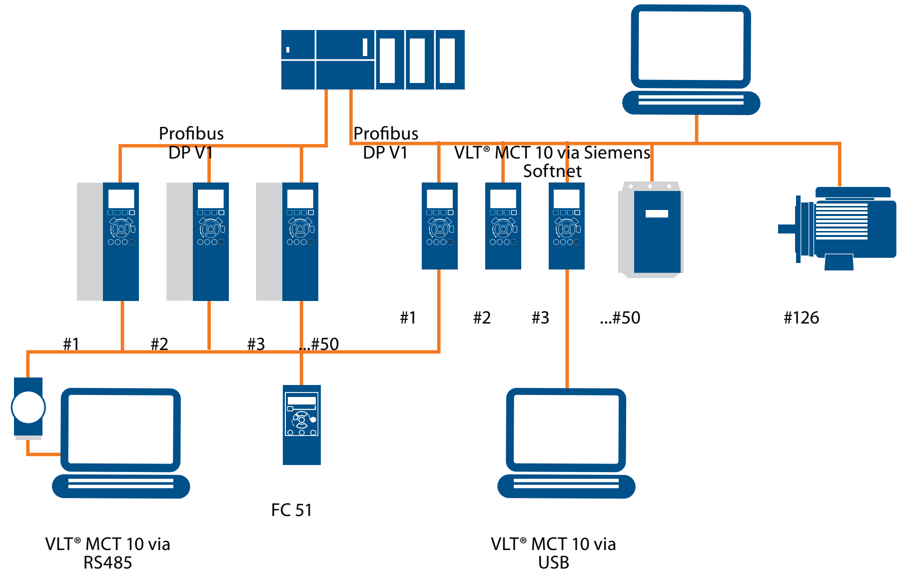
- Basic version functionality +
- No limitation in number of drives
- Scope & Graph (max. 8 channels)
- Real Time Logging from drive
- Motor Database
- Graphical Sensorless pump control
- Graphical Extended Cascade Controller (FC-202 only)
- Full Customer Specific Initialization File support *(to be supported in January)*
- Full drive password protection support (To be supported in January)

VLT® Motion Control Tool VLT® MCT 10

Fieldbusses
- ProfiBus DP-V1
- RS485
- USB
- Ethernet-TSC

Internet download
http://www.danfoss.com/drives

System requirements
- MS Windows® NT 4.0, 2000, XP, Vista or 7
- Pentium III 350 MHz or better
- 512 MB RAM or better
- 200 MB free hard disk space
- CD-ROM drive
- VGA or XGA graphic adapter



VLT® Software

VLT® Harmonics Calculation Software (MCT 31)

Perfect
tool for:

- Application specific simulations
- Various Power Supply sources
- Norm compliance indication
- Project Documentation

With VLT® MCT 31, you can determine whether harmonics will be an issue in your installation when drives are added. VLT® MCT 31 estimates the benefits of adding various harmonic mitigation solutions from the Danfoss product portfolio and calculates system harmonic distortion.

Save money and reduce running costs

On the basis that it is better to avoid a problem rather than cure one after it happens, it is preferable to calculate the effect of installing non-linear loads before doing so, to estimate the degree of harmonic distortion that may result.

Trying to achieve this on a spreadsheet basis can be time consuming and inaccurate.

To help, Danfoss offers free to download, the VLT® Harmonic Calculation Tool MCT 31, a simple to use and fast software tool for calculating the harmonic disruption from your existing or intended drives installation.

A fast estimate is vital as, in this case, more is not better, simply more costly, so the MCT 31 can help save money when selecting harmonic mitigation solutions.

Simply over-specifying a harmonic mitigation solution will lead to unnecessary initial cost escalation and increased running expenses.

Features	Benefits
Explore-like view	Easy to use
Simple simulation model with less parameters	Easy to use and fast simulation – save time
Configurable for various Power supply sources	Matching all customer needs
One tool supporting all Danfoss harmonic mitigation solutions	Matching all customer needs
Configurable Norm compliance indication	Save time
User configurable Report gation solutions	Project documentation
Simulate the setup before installation	Save time and money. Prevent problems appear later

Calculate the harmonic disturbance

The MCT 31 tool can easily be used to evaluate the expected grid quality and includes a range of passive and active counter-measures which can be selected to ease system stress.

The power quality impact of electronic devices can be estimated in the frequency range up to 2.5 kHz, depending on the system configuration and standard limits.

The analysis includes indication of compliance with various standards and recommendations.

The Windows-like interface of the MCT 31 tool makes possible intuitive operation of the software. It is built with a focus on user-friendliness and the complexity is limited to system parameters that are normally accessible.

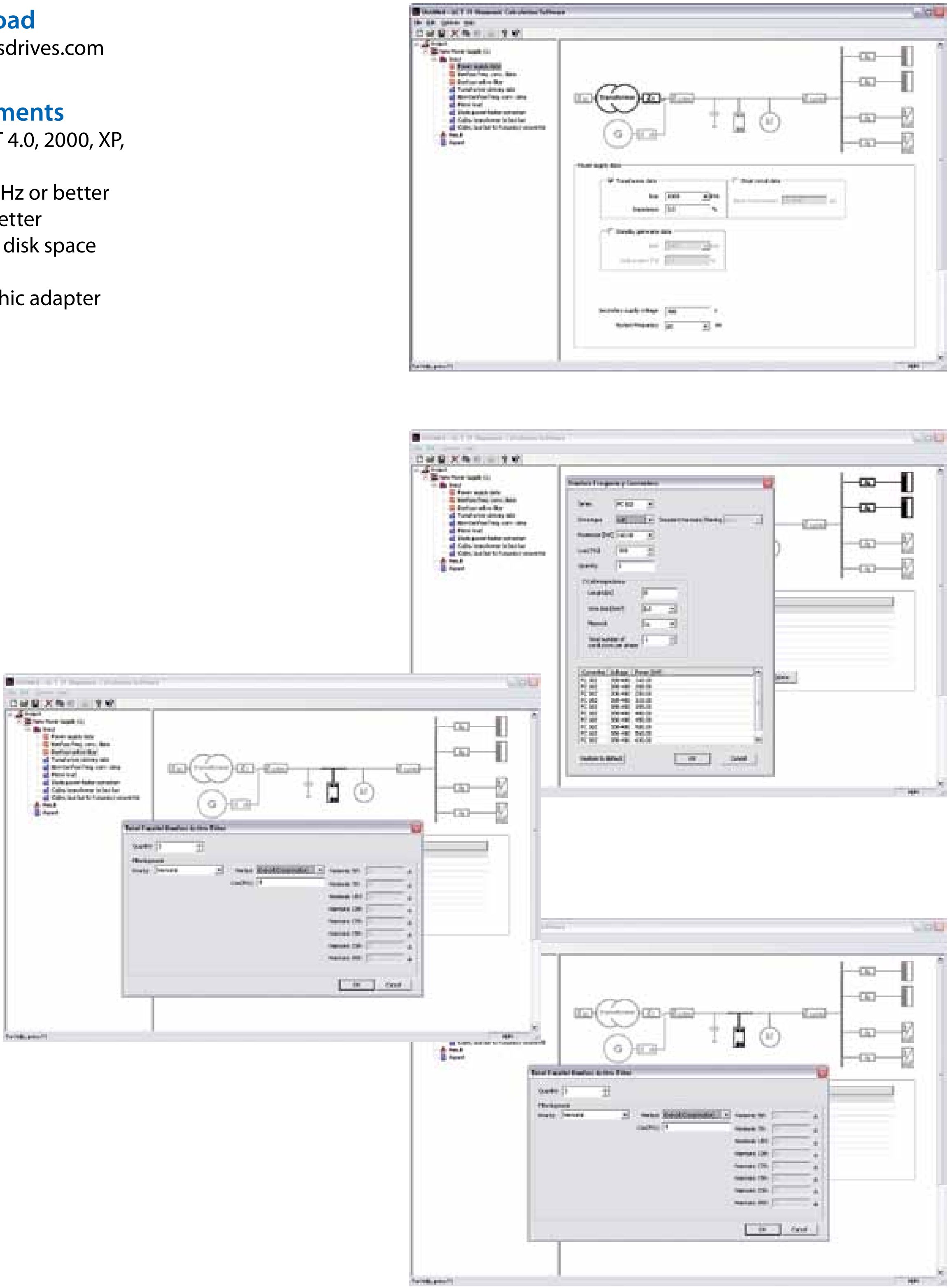
The Danfoss VLT® frequency converter and mitigation equipment data is already pre-loaded, allowing fast data entry.

Your local Danfoss consultant will be very happy to provide all the assistance you need to evaluate your power quality and advice in the selection of the correct mitigation for your circumstances.

VLT® Harmonics Calculation Software (MCT 31)

Internet download
http://www.danfossdrives.com

System requirements
- MS WindowsR NT 4.0, 2000, XP, Vista or 7
- Pentium III 350 MHz or better
- 512 MB RAM or better
- 200 MB free hard disk space
- CD-ROM drive
- VGA or XGA graphic adapter



VLT® Energy Box

Perfect

tool for:

- Designing HVAC installations
- Obtaining energy savings
- Calculating pay-back time

With VLT® Energy Box software you can both theoretically in project face estimate and afterwards physically validate your real energy savings and reductions in your carbon footprint – from your desk.

VLT® Energy Box makes energy consumption calculations of fan, pump and cooling tower applications driven by VLT® HVAC Drives from Danfoss and compares it with alternative methods of flow control.

The program compares the total operation costs of various traditional systems compared to operation of the same system with a VLT® HVAC Drive.

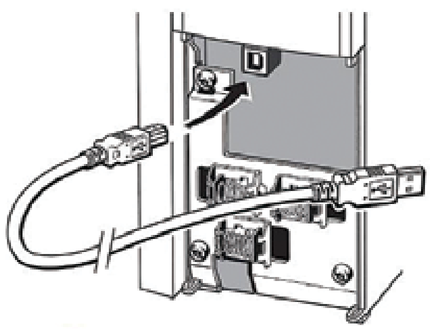
With VLT® Energy Box software you can both theoretically in project face estimate and afterwards physically validate your real energy savings and reductions in your carbon footprint – also from your desk.

The VLT® Energy Box communicates with the drives through the USB/ RS485 protocol and can read all data about duty cycles and energy consumptions.

Data about duty cycles and energy consumptions can be requested remotely from the VLT® HVAC Drive, making it easy to monitor your energy savings and return on investment. Monitoring via fieldbus often makes energy meters omissible.

The software allows you to upload real trend and energy data, to present multiple systems in one report and to calculate energy consumption for cooling towers.

Features	Benefits
Estimate savings	Make purchase decision easy
Calculates pay back based on investments and annual costs	Economical overview
Generates a report	Easy communication
Special cooling tower mode based on climate data	Easy calculation
Possible to adjust climate region to local conditions	More accurate calculations
Download of energy data from the drive via serial communication and USB	Facilitates the drives payback function Visualize actual load profile
Covers several projects and systems in same file	Generation of common project report



Complete financial analysis

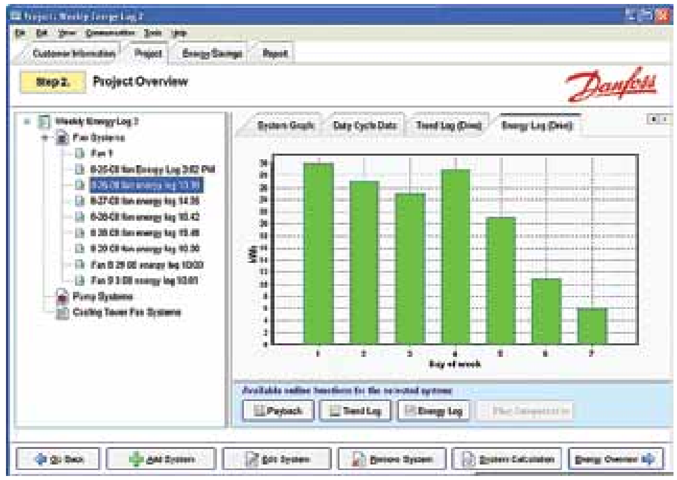
VLT® Energy Box provides a complete financial analysis including:

- Initial cost for the drive system and the alternative system
- Installation and hardware costs
- Annual maintenance costs and any utility company incentives for installation of energy conservation products
- Payback time and accumulated savings are calculated

VLT® Energy Box

No nonsense

Since VLT® Energy Box both estimates and afterwards measures the real energy savings, it is a very trustworthy means for calculating projects involving many fans, pumps and cooling towers. You can simply install a single VLT® HVAC Drive and check the actual savings to exactly calculate the benefits from installing VLT® HVAC Drives on the other applications.



Considers local conditions

VLT® Energy Box use local weather data in its calculations for cooling towers.

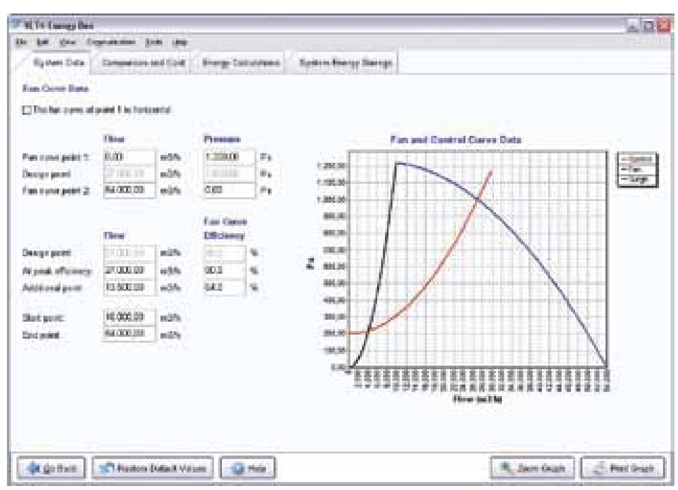
Data from weather zones around the Globe are pre-installed, but the user is free to adjust these data according to local conditions.

Specify the curve

Energy Box offers an advanced mode to specify the fan or pump curve in more detail. The fan or pump (equipment) curve can be adjusted to match almost any shape.

Choose flow and pressure points to generate an equipment curve similar to the published fan or pump curve over the relevant section of the curve using the mechanical flow control method.

The program will not allow calculations in regions that are in a surge region or beyond the end of the curve.



Service and support VLT® DrivePro™

Professional Drives Support

DrivePro Service Plans provide a complete drives support solution, freeing customers' time and resources to focus on their core business activities.

DrivePro services deliver increased efficiency and productivity of variable speed systems. DrivePro coverage plans provide a fixed-cost solution against unforeseen risks and quick response in the event of a malfunction. The nationwide network of DrivePro professionals ensures support is available locally.

Danfoss customers also have full access to the DrivePro call center. One toll- free call provides direct access to the Danfoss factory technical support specialists, 8:00 to 5:00 CST and emergency support 24 hours per day, 365 days a year.

Service you can rely on 24/7 – around the world

Sales and Service

Contacts worldwide. Helping to optimize your productivity, improve your maintenance, and control your finances.

- 24/7 availability
- Local hotlines, local language and local stock

The Danfoss service organization is present in more than 100 countries – ready to respond whenever and wherever you need, around the clock, 7 days a week.

Find your local expert team on **www.danfossdrives.com**

24 hours
7 days a week

DrivePro Service Plans

DrivePro-Extended Warranty purchased with the drive provides the industry's longest coverage, up to six years.

DrivePro-SC Service Contract ensures long-term service coverage beyond the warranty period for drives up to 10 years old.

DrivePro-tection provides an additional measure of security by covering accidental drive damage such as lightning strikes.

DrivePro-SU Start-Up ensures maximum utilization and efficiency of Danfoss VLT® Drives.

DrivePro Depot Repair Service provides professional reconditioning and factory testing of Danfoss VLT® Drives at a flat rate.

DrivePro Spare Parts ensure Danfoss VLT® Drives high performance levels are retained after repairs or maintenance work is completed.

DrivePro PLUS drive replacement contracts provide a quick, turn-key solution for replacing aging drives that are no longer economical to repair. Professional installation, startup service and extended warranty are included.

DrivePro SmartStep provides a comprehensive and affordable migration program for customers with large numbers of legacy model or multiple brand drives. This program combines the benefits of the latest technology Danfoss VLT® Drives with professional installation, startup and coverage for a fixed periodic fee. SmartStep is a very flexible and sensible way to upgrade drive systems on a budget.

DrivePro EnLease provides end customers with alternative financing for drives and services.

DrivePro-PM Preventive Maintenance provides scheduled service to optimize the variable speed system performance and ensure the longest possible drive life.

Danfoss DrivePro–tection provides the on-site solution

Emergency response expense threatens your budget.

Downtime expense and hassle of many types of accidental drive damage are minimized.
One call provides quick and complete response from the leaders in variable frequency drive technology and support.

DrivePro-tection

DrivePro-tection coverage is available at the time of drive purchase for periods up to six years.
Coverage is also available for older, installed drives up to 10 years from date of manufacture. Contact Danfoss for details.

Coverage

- Line anomalies – including lightning strikes
- Load anomalies
- Accidental exposure to moisture or corrosives
- Accidental collision or other physical damage
- Defects in product material or workmanship
- Normal product wear

Product misapplication, vandalism, facility disasters, chronic problems due to the application and shipping damage are not included

Support

Onsite Repair is provided by factory trained and authorized service technicians

- Replacement drive material
- Drive repair labor
- Travel expense

Onsite Service DrivePro-tection contracts available for most Water applications in the US and Canada. Contact Danfoss DrivePro sales for details.

Engineering and Technical Section for Water/Wastewater/Irrigation

The Danfoss engineering and technical section is aimed at engineering firms, municipalities, associations, plant engineers and electrical engineers actively involved in water and wastewater technology. It is conceived as a comprehensive aid for facility designers and project engineers whose scope of responsibility includes the project engineering of variable speed systems using Variable Frequency Drives.

For this purpose, our specialists have coordinated the contents of this engineering section with facility services designers in the industry in order to provide answers to important questions and achieve the greatest possible benefits for property owners/developers and/or contracting authorities. The descriptions in the individual sections are intentionally concise. They are not intended to serve as extensive explanations of technical matters, but instead to point out the relevant issues and specific requirements for project engineering. In this way, the engineering and technical section provides assistance in the project engineering of frequency controlled drives and in the assessment of the products of various manufacturers of Variable Frequency drives.

Project engineering of variable speed drives often gives rise to questions that are not directly related to the actual tasks of a Variable Frequency Drive. Instead, they relate to the integration of these devices into the drive system and the overall facility. For this reason, it is essential to consider not only the Variable Frequency Drive, but also the entire drive system. This system consists of a motor, a Variable Frequency Drive, cabling, and the general conditions of the ambient situation, which includes the AC mains supply and the environmental conditions.

Project engineering and layout of variable speed drive systems are of decisive importance. The decisions made by the facility services designer or project engineer at this stage are crucial with regard to the quality of the drive system, operating and maintenance costs, and reliable,

Anyone involved in the project engineering of Variable Frequency Drives should give careful consideration to the general technical conditions of these devices.

trouble-free operation. Well conceived project engineering beforehand helps avoiding undesirable side effects during subsequent operation of the drive system.

This engineering guide is an ideal tool for achieving the best possible design reliability and thereby contributing to the operational reliability of the overall system.

The engineering and technical section is divided into two parts. The first part provides background information on the use of Variable Frequency Drives in general. This includes the topics of energy efficiency, reduced life cycle costs and longer service life.

The second part of this engineering section guides you through the four essential steps in the design and project engineering of a system and provides tips on retrofitting speed control capability in existing systems. It addresses the factors you must pay attention to in order to achieve reliable system operation – the selection and dimensioning of the mains power supply, the ambient and environmental conditions, the motor and its cabling and the selection and dimensioning of the Variable Frequency Drive – and gives you all the information you need regarding these aspects.

Basics
Reducing costs and increasing convenience

Compared with mechanical speed control systems, electronic speed control can save a lot of energy and substantially reduce wear. Both of these factors significantly reduce operating costs. The more often drive systems are operated (or must operate) under partial load, the higher the potential savings in terms of energy and maintenance costs. Due to the high potential for energy savings, the extra cost of an electronic speed control system can be recovered within a few months. In addition, modern systems have an extremely positive effect on many aspects of system processes and overall system availability.

High energy saving potential

With an electronic speed control system, the flow, pressure or differential pressure can be matched to the actual demand. In practice, systems operate predominantly under partial load rather than full load. In case of fans, pumps or compressors with variable torque characteristics, the extent of the energy savings depends on the difference between partial-load and full-load operation. The larger this is, the less time is required to recover the investment. It is typically around 12 months.

Start-up current limiting

Starting equipment across the line generates peak currents that can be up to six to eight times greater than the rated current. Some of today's premium efficient motors can draw 10-12 times full load amps. Variable Frequency Drives limit the starting current to the rated motor current. In this way they eliminate across the line peaks and avoid voltage sags due to shock loading of the supply network. Eliminating these current peaks reduces the connected load of the pump system as seen by the electricity supplier, which reduces provision costs and eliminates the need for other unknown power controllers.

Reduced system wear

Variable Frequency Drives start and stop motors gently and smoothly. Unlike motors operated across the line, motors driven by Variable Frequency Drives do not cause torque or load shocks. This reduces the stress on the entire mechanical system (motor, gearbox, clutch, pump/blower) and piping system, including the seals. In this way, speed control significantly reduces wear and prolongs the lifetime of the system. Maintenance and repair costs are lower thanks to longer operating periods and lower material wear.

Optimal operating point adjustment

The efficiency of water and wastewater handling systems depends on the best efficiency point. This point varies depending on system capacity utilization. The system works more efficiently when it runs closer to the best efficiency point. Thanks to their continuously variable speed, Variable Frequency Drives can drive the system as close to the Best efficiency point as possible.

Extended control range

Variable Frequency Drives allow motors to be operated in the "oversynchronous" range (output frequency above 50 Hz). This allows the output power to be boosted briefly. The extent to which oversynchronous operation is possible depends on the maximum output current and overload capacity of the Variable Frequency Drive. In practice, pumps are often operated at a frequency of 87 Hz. The motor manufacturer must always be consulted regarding motor suitability for oversynchronous operation.

Lower noise generation

Systems running under partial load are quieter. Speed-controlled operation significantly reduces acoustic noise generation.

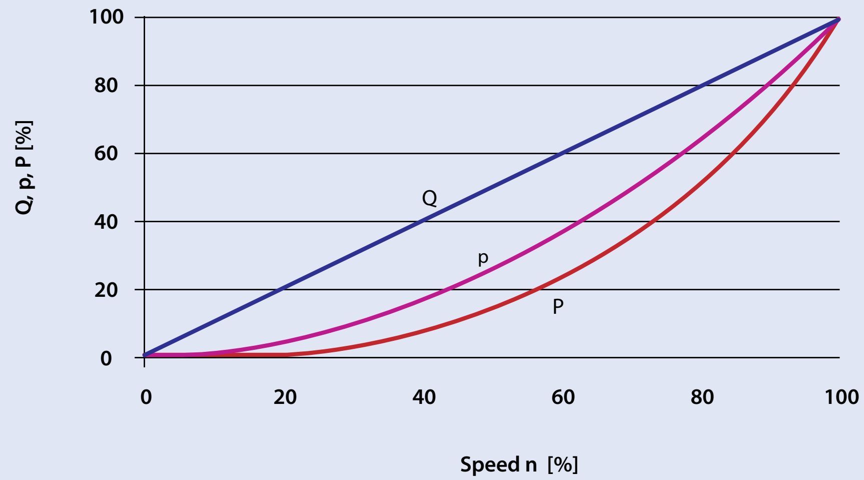
Increased lifetime

Drive systems operating under partial load suffer less wear, which translates into longer service life. The reduced, optimized pressure also has a beneficial effect on the piping.

Retrofitting

Variable Frequency Drives can usually be retrofitted in existing drive systems with little effort.

Speed control saves energy



Proportionality rules of fluid flow machines. Due to the physical relationships, the throughput Q, pressure p and power P are directly dependent on the machine speed with fluid flow machines.

The energy saving potential when a Variable Frequency Drive is used depends on the type of load being driven and the optimization of the efficiency of the pump or the drive by the Variable Frequency Drive, as well as how much time the system operates under partial load. Domestic water and wastewater systems are designed for rarely-occurring peak loads, so they are usually operated under partial load.

Centrifugal pumps and fans offer the largest potential for energy savings. They fall in the class of fluid flow machines with variable torque curves, which are subject to the following proportionality rules.

The flow increases linearly with increasing speed (rpm), while the pressure increases quadratically and the power consumption increases cubically.

The decisive factor for energy savings is the cubic relationship between rpm and power consumption. A pump running at half its rated speed, for example, needs only one-eighth of the power necessary for operation at its rated speed. Even small reductions in speed thus lead to significant energy savings. For example, a 20% speed reduction yields 50% energy savings. The main benefit of using a Variable Frequency Drive is that speed control does not waste power (unlike regulation with a throttle valve or damper, for example), but instead adjusts the motor power to match exactly the actual demand.

Additional energy savings can be achieved by optimizing the efficiency of the pump or drive with Variable Frequency Drive operation. The voltage control characteristic (V/f curve) supplies the right voltage to the motor for every frequency (and thus motor speed). In this way, the controller avoids motor losses resulting from excessive reactive current.

***Remark:** Danfoss VLT® Variable Frequency Drives optimise energy demand even further. The Automatic Energy Optimization (AEO) function constantly adjusts the current motor voltage so the motor runs with the highest possible efficiency. In this way, the VLT® AQUA Drive always adapts the voltage to the actual load conditions it measures. The additional energy saving potential amounts to an extra 3 to 5%.*

Boosting cost effectiveness

Life cycle cost (LCC) analysis

Until a few years ago, plant engineers and operators only considered procurement and installation costs when selecting a pump system. Today a full analysis of all costs is becoming increasingly common. Under the name "life cycle cost" (LCC), this form of analysis includes all costs incurred by pump systems during their operational life.

A life cycle cost analysis includes not only the procurement and installation costs, but also the costs of energy, operation, maintenance, downtime, the environment, and disposal. Two factors – energy cost and maintenance cost – have a decisive effect on the life cycle cost. Operators look for innovative controlled pump drives in order to reduce these costs.

Reducing energy costs

One of the largest cost factors in the life cycle cost formula is the energy cost. This is especially true when pump systems run more than 2000 hours per year.

LCC = Cic + Cin + Ce + Co + Cm + Cs + Cenv + Cd

C_{ic} = initial capital cost (procurement cost)

C_{in} = installation and commissioning costs

C_e = energy cost

C_o = operating cost

C_m = maintenance cost

C_s = downtime and lost production costs

C_{env} = environmental cost

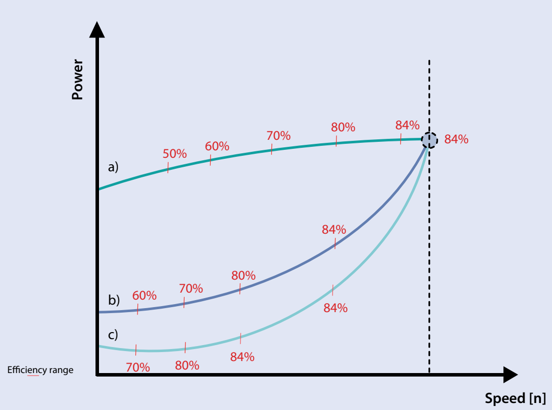
C_d = decommissioning and disposal costs

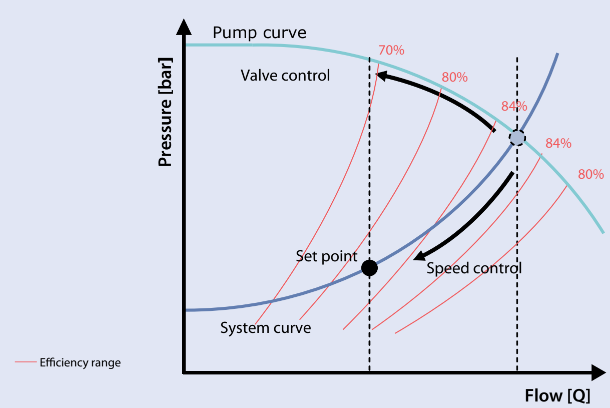
Life cycle cost calculation

Most existing pump systems have substantial dormant energy saving potential. This arises from the fact that most pump drives are overdimensioned because they are designed for worst-case conditions. The volumetric flow is often regulated by a throttle valve. With this form of regulation, the pump always runs at full capacity and thus consumes energy unnecessarily.

This is comparable to driving a car with the engine always running at full throttle and using the brakes to adjust the speed.

Modern, intelligent Variable Frequency Drives offer ideal means to reduce energy consumption as well as maintenance costs.





a) Valve control: η decreases
b) Actual speed control: η curve not aligned to system curve
c) Optimal speed control: η curve nearly matches system curve

In addition to the pump and system characteristic curves, this plot shows several efficiency levels. Both valve control and speed control cause the operating point to move out of the optimum efficiency range.

Achieving potential savings in practice

The descriptions in the first part of this design manual focus primarily on the fundamentals and potential savings in water and wastewater technology.

Among other things, they deal with life cycle costs, reducing energy consumption and reducing energy costs and reducing service and maintenance costs. Your task now is to carry out considered, intelligent design in order to achieve these potential benefits in reality.

To this end, the second part of this manual guides you through the design process in four steps.

The following sections:
- Mains systems
- Ambient and environmental conditions
- Motors and cables
- Variable Frequency Drives give you all the information about characteristics and data that you need for component selection and dimensioning in order to ensure reliable system operation.

In places where more detailed knowledge is advantageous, we provide references to additional documents in addition to the basic information in this manual.

The checklist included at the end of this manual, which you can fold out or tear out, is also a handy aid where you can tick off the individual steps. This gives you a quick and easy overview of all relevant design factors.

By taking all these factors into account, you put yourself in an ideal position to design a reliable and energy-efficient system.

Four steps to an optimal system
Step 1: Practical aspects of AC mains systems

Recognizing the actual mains configuration

The first letter indicates the connection between ground and the power-supply equipment (generator or transformer):

T – Direct connection of a point with ground (Latin: terra);
I – No point is connected with ground (isolation), except perhaps via high impedance. The second letter indicates the connection between ground and the electrical device being supplied:
T – Direct connection of a point with ground
N – Direct connection to neutral at the origin of installation, which is connected to the ground

TN networks

In a **TN** grounding system, one of the points in the generator or transformer is connected with ground, usually the star point in a three-phase system. The body of the electrical device is connected with ground via this ground connection at the transformer.

The conductor that connects the exposed metallic parts of the consumer is called protective ground (PE). The conductor that connects to the star point in a three-phase system, or that carries the return current in a single-phase system, is called neutral (N). Variants of TN systems unclude:
TN–S – PE and N are separate conductors that are connected together only near the power source. This arrangement is the current standard for most residential and industrial electric systems in North America and Europe.
TN–C – A combined PEN conductor fulfills the functions of both a PE and an N conductor. Rarely used.

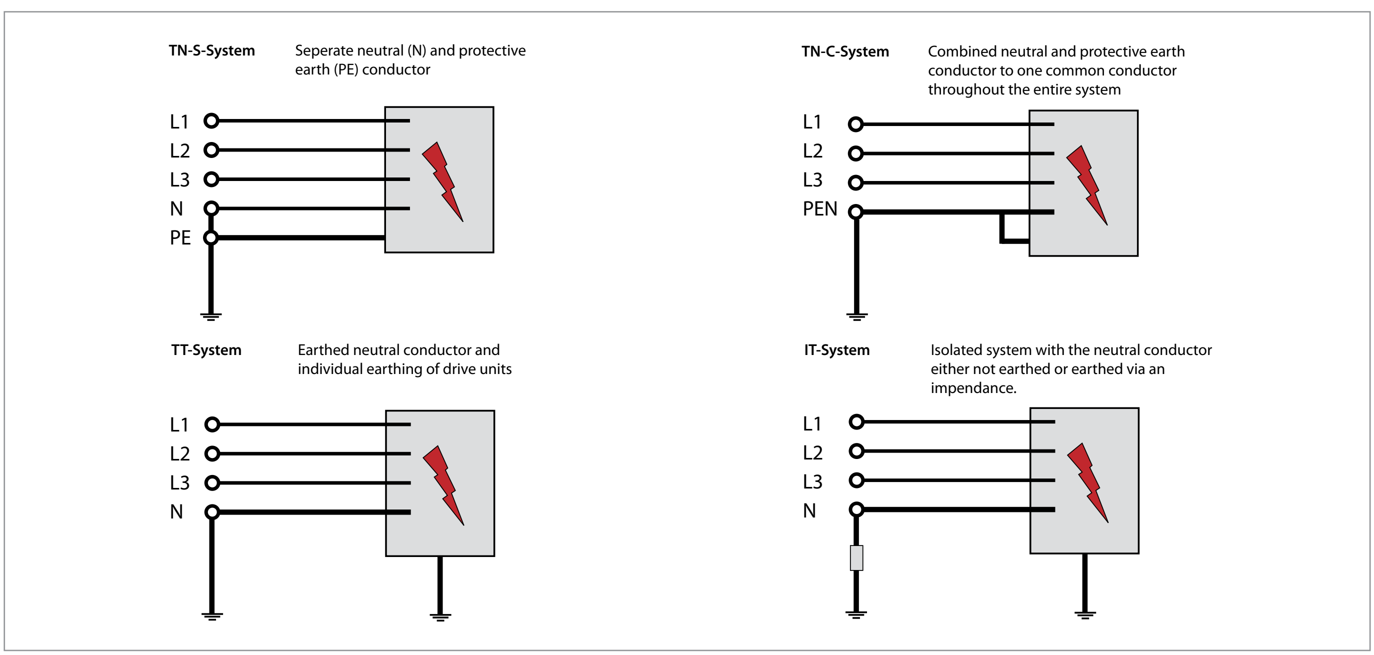
TT Networks

In a **TT** grounding system, the protective ground connection of the consumer is provided by a local connection to ground, independent of any ground connection at the generator.

The big advantage of the TT grounding system is the fact that it is clear of high and low frequency noises that come through the neutral wire from various electrical equipment connected to it. This is why TT has always been preferable for special applications like telecommunication sites that benefit from the interference-free grounding. Also, TT does not have the risk of a broken neutral.

IT network

In an **IT** network, the distribution system has no connection to ground at all, or it has only a high impedance connection. In such systems, an insulation monitoring device is used to monitor the impedance.



Forms of electrical mains systems according to EN 50310/HD 384.3

Practical aspects of electromagnetic compatibility (EMC)

Every electrical device generates electrical and magnetic fields that affect its direct environment to a certain extent.

The magnitude and consequences of these effects depend on the power and the design of the device. In electrical machinery and systems, interactions between electrical or electronic assemblies may impair or prevent reliable, trouble-free operation. It is therefore important for operators, designers and plant engineers to understand the mechanisms of these interactions. Only then will they be able to take appropriate, cost-effective countermeasures at the design stage.

This is because the cost of suitable measures increases with each stage of the process.

Electromagnetic effects work in both directions

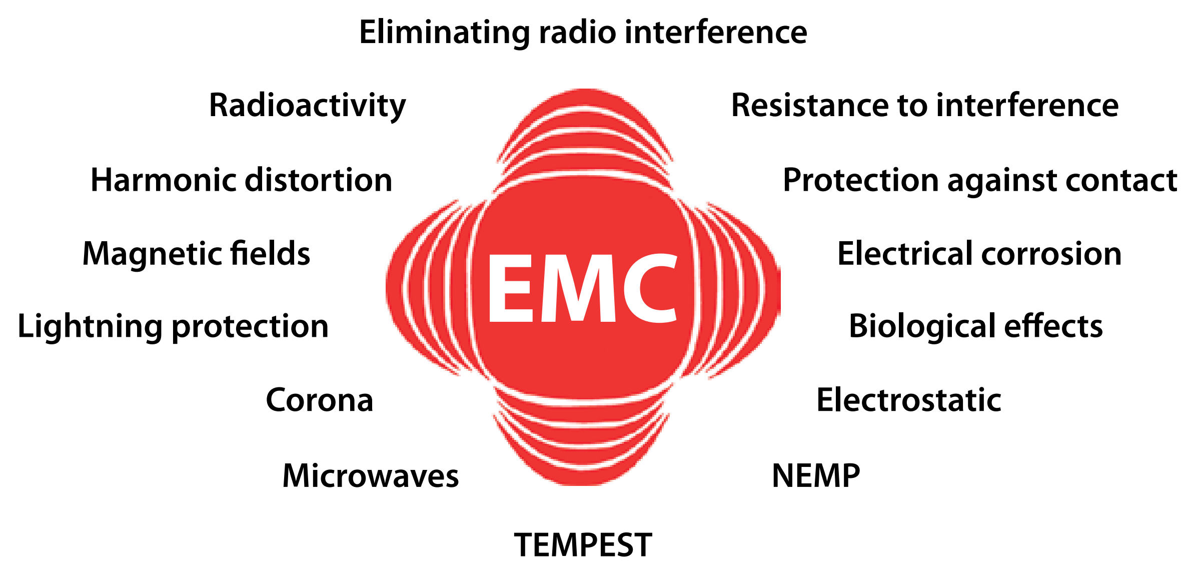
System components affect each other: every device generates interference and is affected by interference. In addition to the type and amount of interference an assembly generates, it is characterised by its immunity to interference from nearby assemblies.

The responsibility rests with the operator

Previously, the manufacturer of a component or assembly for electrical drives had to take countermeasures to comply with statutory standards. With the introduction of the EN 61800-3 standard for variable-speed drive systems, this responsibility has been transferred to the end user or operator of the system. Now manufacturers only have to offer solutions for operation conforming to the standard. Remedying any interference that may occur (in other words, using these solutions), along with the resulting costs, is the responsibility of the operator.

Two possible means of reduction

Users and plant engineers have two options for ensuring electromagnetic compatibility. One option is to stop interference at the source by minimising or eliminating the emitted interference. The other option is to increase the interference immunity of the device or system affected by interference by preventing or substantially reducing the reception of interference.



Electromagnetic compatibility (EMC) encompasses a wide variety of factors. The most significant factors in drive engineering are mains interference, RFI suppression and interference immunity.

Technical

Practical aspects of electromagnetic compatibility (EMC)

Distinguishing between conducted and radiated interference

There are always interactions when several systems are present. Experts distinguish between the interference source and the interference sink, which in practice usually means the device causing the interference and the device affected by it. All types of electrical and magnetic quantities can potentially cause interference. For example, interference may take the form of mains harmonics, electrostatic discharges, rapid voltage fluctuations, high-frequency interference or interference fields. In practice, mains harmonics are often referred to as mains interference, harmonic overtones or simply harmonics.

Coupling mechanisms between electrical circuits

Now you're probably wondering how interference is transmitted. As a form of electromagnetic emission, it can essentially be transmitted by conductors, electric fields, or electromagnetic waves. In technical terms, these are called conductive, capacitive and/or inductive coupling, and radiation coupling, which means an interaction between different circuits in which electromagnetic energy flows from one circuit to another one.

Conductive coupling

Conductive coupling occurs when two or more electrical circuits are connected to one another by a common conductor, such as a potential equalisation cable.

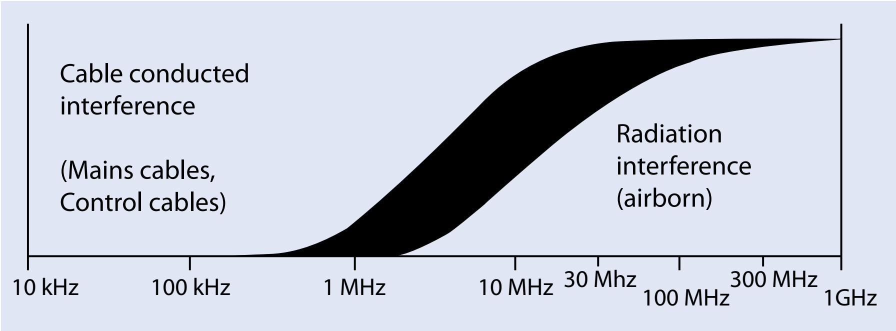
Capacitive coupling

Capacitive coupling results from voltage differences between the circuits.
Inductive coupling occurs between two current-carrying conductors.

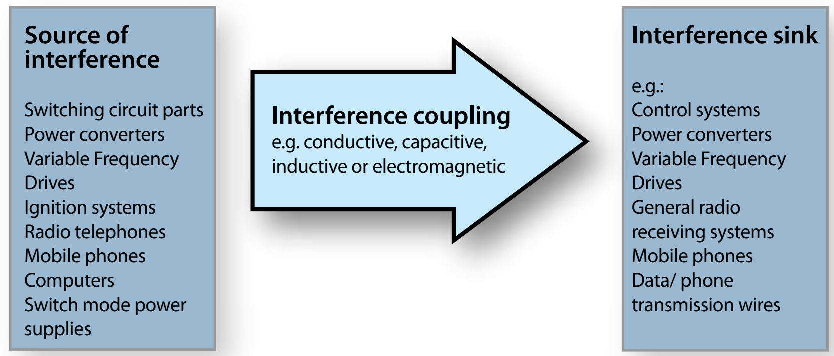
Radiation coupling

Radiation coupling occurs when an interference sink is located in the far-field region of an electromagnetic field generated by an interference source. For the purpose of electromagnetic analysis, the standard specifies 30 MHz as the boundary between conductive coupling and radiation coupling. This corresponds to a wavelength of 10 meters. Below this frequency, electromagnetic interference is mainly propagated through conductors or coupled by electrical or magnetic fields. Above 30 MHz, wires and cables act as antennas and emit electromagnetic waves.

Interference diffusion paths



Electromagnetic interference occurs over the entire frequency range, but the propagation paths and form of diffusion vary.



Overview of coupling paths for electromagnetic interference and typical examples

Variable Frequency Drives and EMC

Low-frequency effects (conductive) → Mains interference/harmonics

High-frequency effects (radiation) → Radio frequency interference (emission of electromagnetic fields)

Practical aspects of mains power quality

Low-frequency mains interference

Supply networks at risk

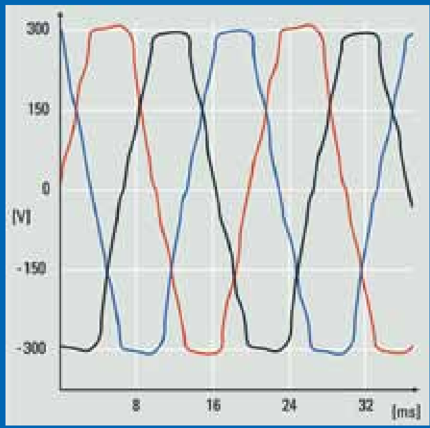
The mains voltage supplied by electricity companies to homes, businesses and industry should be a uniform sinusoidal voltage with constant amplitude and frequency. This ideal situation is no longer found in public power grids. This is due in part to loads that draw non-sinusoidal currents from the mains or have non-linear characteristics, such as PCs, television sets, switching power supplies, energy-efficient lamps, and Variable Frequency Drives. Mains power quality will decline even more in the future due to the European energy network, higher grid utilization and reduced investments. Deviations from the ideal sinusoidal waveform are therefore unavoidable and permissible within certain limits.

Facility services designers and operators have an obligation to keep mains interference to a minimum. But what are the limits and who specifies them?

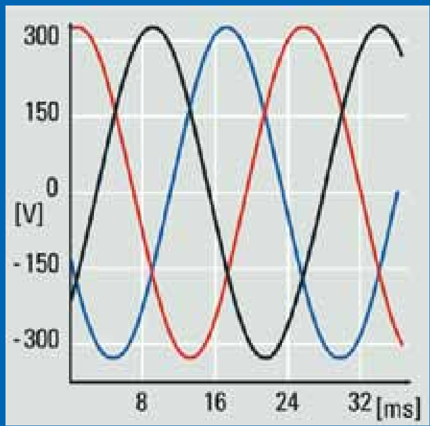
Quality assured by statutory provisions

Standards, directives and regulations are helpful in any discussion regarding clean, high-quality mains power. In most of Europe the basis for the objective assessment of the quality of mains power is the Electromagnetic Compatibility of Devices Act. European standards EN 61000-2-2, EN 61000-2-4 and EN 50160 define the mains voltage limits that must be observed in public and industrial power grids.

The EN 61000-3-2 and 61000-3-12 standards are the regulations concerning mains interference generated by connected devices. Facility operators must also take the EN 50178 standard and the connection conditions of the electricity company into account in the overall analysis. The basic assumption is that compliance with these levels ensures that all devices and systems connected to electrical distribution systems will fulfil their intended purpose without problems.



Measurements show distinct distortion of the mains voltage waveform due to interference from nonlinear loads.



The ideal situation of a sinusoidal mains voltage is rarely found nowadays in our mains grids.

How mains interference occurs

Specialists refer to the distortion of the sinusoidal waveform in mains systems caused by the pulsating input currents of the connected loads as “mains interference” or “harmonics”. They also call this the harmonic content on the mains, which is derived from Fourier analysis, and they assess it up to 2.5 kHz, corresponding to the 50th harmonic of the mains frequency.

The input rectifiers of Variable Frequency Drives generate this typical form of harmonic interference on the mains. Where Variable Frequency Drives are connected to 60-Hz mains systems, the third harmonic (180 Hz), fifth harmonic (300 Hz) or seventh harmonic (420 Hz) are considered.
This is where the effects are the strongest. The total harmonic content is also called the total harmonic distortion (THD).

Technical

Practical aspects of low-frequency mains interference

Analyzing mains interference

To avoid excessive impairment of mains power quality, a variety of reduction, avoidance and compensation methods can be used with systems or devices that generate harmonic currents. Mains analysis programs, such as VLT® MCT 31 Harmonic Calculation software, can be used for system analysis as early as the design stage. In this way, operators can consider and test specific countermeasures beforehand and ensure subsequent system availability.

***Remark:** Danfoss has a very high level of EMC expertise and many years of experience in this area. We convey this experience to our customers by means of training courses, seminars, workshops and in everyday practice in the form of EMC analyzes with detailed evaluation or mains calculations.*

***Note:** Excessive harmonic content puts a load on power factor correction equipment and may even case its destruction. For this reason, they should be fitted with chokes.*

VLT® MCT 31 estimates the harmonic current and voltage distortion of your application and determines if harmonic filtering is needed. In addition the software can calculate the effect of adding mitigation equipment and if your system complies with various standards.

Effects of mains interference

Harmonics and voltage fluctuations are two forms of low-frequency conducted mains interference. They have a different appearance at their origin than at any other point in the mains system where a load is connected.

Consequently, the mains feed, mains structure and loads must all be taken into account collectively when assessing mains interference.
The effects of an elevated harmonic level are described below.

Undervoltage warnings

- Incorrect voltage measurements due to distortion of the sinusoidal mains voltage.
- Reduced mains power capacity

Higher losses

- Harmonics take an additional share of the active power, apparent power and reactive power
- Shorter lifetime of devices and components, for example as a result of additional heating effects due to resonances.
- Malfunction or damage to electrical or electronic loads (such as a humming sound in other devices). In the worst case, even destruction.
- Incorrect measurements because only true-RMS instruments and measuring systems take harmonic content into account.

Are interference-free Variable Frequency Drives available?

Every Variable Frequency Drive generates mains interference. However, the present standard only considers the frequency range up to 2 kHz. For this reason, some manufacturers shift the mains interference into the region above 2 kHz, which is not addressed by the standard, and advertise them as „interference-free" devices. Limits for this region are currently being studied.

Practical aspects of mains interference reduction

Options for reducing mains interference

Generally speaking, mains interference from electronic power controllers can be reduced by limiting the amplitude of pulsed currents. This improves the power factor λ (lambda). To avoid excessive impairment of mains power quality, a variety of reduction, avoidance or compensation methods can be used with systems and devices that generate harmonics.

- Chokes at the input or in the DC link of Variable Frequency Drives
- Slim DC links
- Rectifiers with 12, 18 or 24 pulses per cycle
- Passive filters
- Active filters
- Active front end and VLT® Low Harmonic Drives

Chokes at the input or in the DC link

Even simple chokes can effectively reduce the level of harmonics fed back into the mains system by rectifier circuits as mains interference. Variable Frequency Drive manufacturers usually offer them as supplementary options or retrofits.

The chokes can be connected ahead of the Variable Frequency Drive (on the feed side) or in the DC link after the rectifier. As the inductance has the same effect in either location, the attenuation of the mains interference is independent of where the choke is installed.

Each option has advantages and drawbacks. Input chokes are more expensive, larger, and generate higher losses than DC chokes. Their advantage is that they also protect the rectifier against mains transients. DC chokes are located in the DC link. They are more effective, but they usually cannot be retrofitted. With these chokes, the total harmonic distortion from a B6 rectifier can be reduced from a THD of 80% without chokes to approximately 40%. Chokes with a U_k of 4% have proven to be effective for use in Variable Frequency Drives. Further reduction can only be achieved with specially adapted filters.

Rectifier with Multiple pulses per cycle

Rectifier circuits with a high number of pulses per cycle (12, 18 or 24) generate lower harmonic levels. They have often been used in high-power applications in the past.

However, they must be fed from special transformers with multiple phase-offset secondary windings that provide all the necessary power to the rectifier stage. In addition to the complexity and size of the special transformer, the disadvantages of this technology include higher investment costs for the transformer and the Variable Frequency Drive.

Passive filters

Where there are especially stringent harmonic distortion limit requirements, passive mains interference filters are available as options. They consist of passive components, such as coils and capacitors.

Series LC circuits specifically tuned to the individual harmonic frequencies and connected in parallel with the load reduce the total harmonic distortion (THD) at the mains input to 10% or 5%. Filter modules can be used with individual Variable Frequency Drives or groups of Variable Frequency Drives. To obtain the best possible results with a harmonic filter, it must be matched to the input current actually drawn by the Variable Frequency Drive.

In terms of circuit design, passive harmonic filters are installed ahead of a Variable Frequency Drive or a group of Variable Frequency Drives.

Advantages of passive filters

This type of filter offers a good price/performance ratio. At relatively low cost, the operator can obtain a reduction in harmonic levels comparable to what is possible with 12- or 18-pulse/cycle rectifiers. The total harmonic distortion (THD) can be reduced to 5%.

Passive filters do not generate interference in the frequency range above 2 kHz. As they consist entirely of passive components, there is no wear and they are immune to electrical interference and mechanical stress.

Drawbacks of passive filters

Due to their design, passive filters are relatively large and heavy. Filters of this type are very effective in the load range of 80–100%. However, the capacitive reactive power increases with decreasing load and it is recommended that you disconnect the filter capacitors in no-load operation or when operating on a generator.

Remark: Danfoss VLT® Variable Frequency Drives are equipped with DC link chokes as standard. They reduce the mains interference to a THDi of about 40%.

Practical aspects of mains interference reduction

Active filters

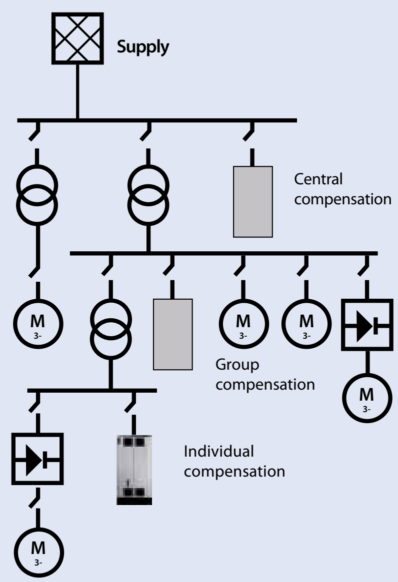
When requirements with regard to mains interference are even more stringent, active electronic filters are used. Active filters are electronic absorption circuits that the user connects in parallel with the harmonic generators. They analyze the harmonic current generated by the nonlinear load and supply an offsetting compensation current. This current fully neutralises the corresponding harmonic current at the connection point.
The degree of compensation is adjustable. In this way harmonics can be almost completely compensated if so desired, or (perhaps for economic reasons) only to the extent necessary to enable the system to comply with statutory limits. Here again it must be borne in mind that these filters operate with clock frequencies and produce mains interference in the 4–18 kHz range.

Advantages of active filters

Operators can incorporate active filters at any desired location in the mains system as central measures, depending on whether they wish to compensate individual drives, entire groups, or even an entire distribution system. It is not necessary to provide a separate filter for each Variable Frequency Drive. The total harmonic distortion drops to a THD level ≤ 4%.

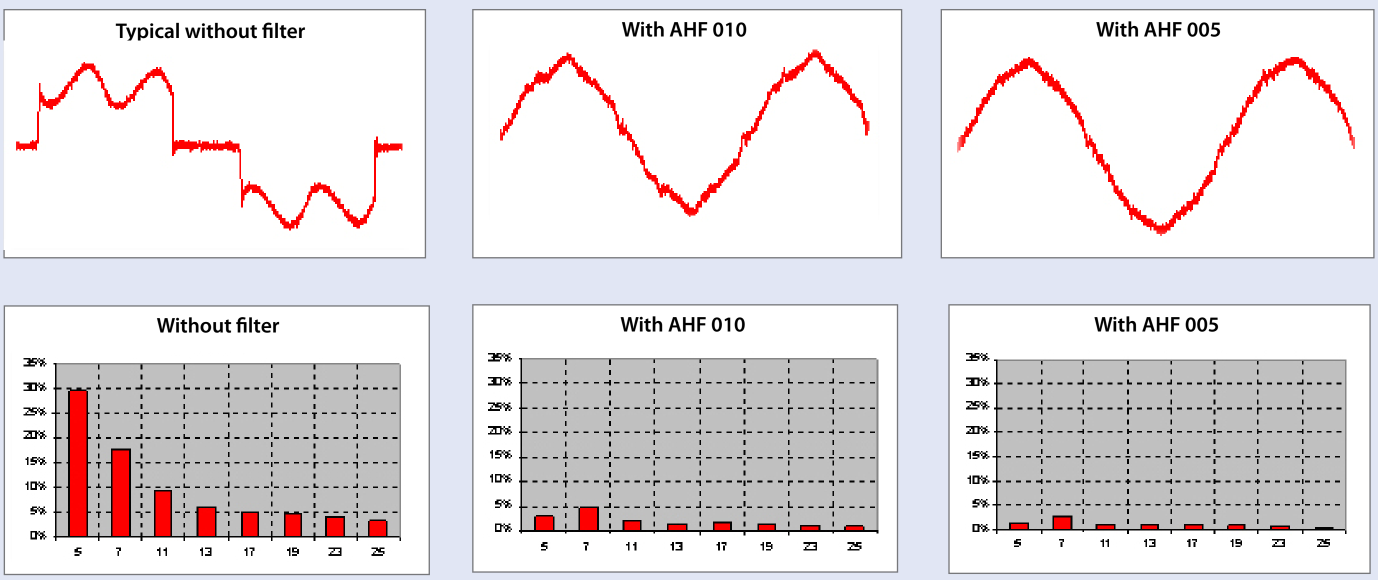
Drawbacks of active filters

One drawback is the relatively high investment cost. In addition, these filters are not effective above the 25th harmonic level. The effects above 2 kHz generated by the filters themselves must also be taken into account with active filter technology. They may require further measures to keep the mains system clean.



Active filters can be installed at any desired point in the mains system, depending on whether they should provide compensation for individual drives, entire groups, or even entire mains systems.

Current and Distortion Spectrum at Full Load

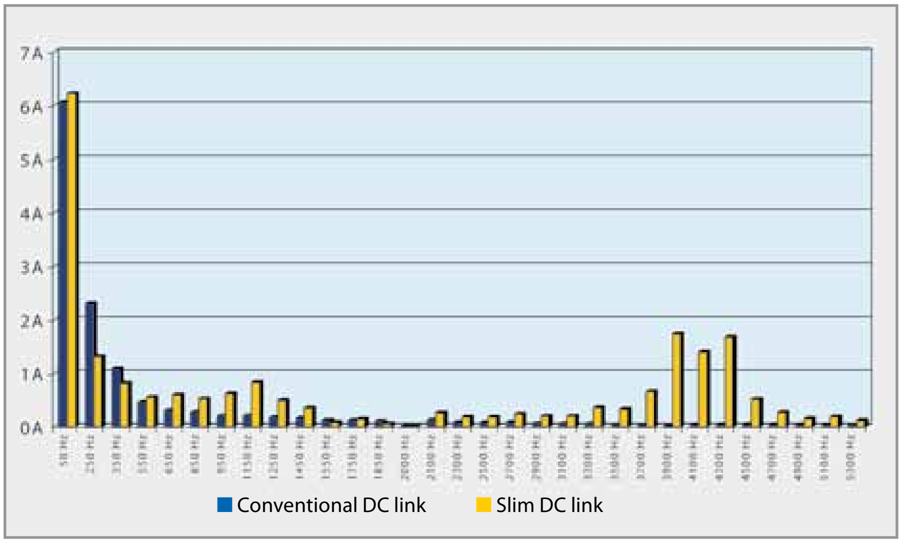


Advanced Harmonic Filters (AHF) reduce the total harmonic current distortion to 5% or 10% at 100% load.

Practical aspects of Mains interference reduction

Slim DC link

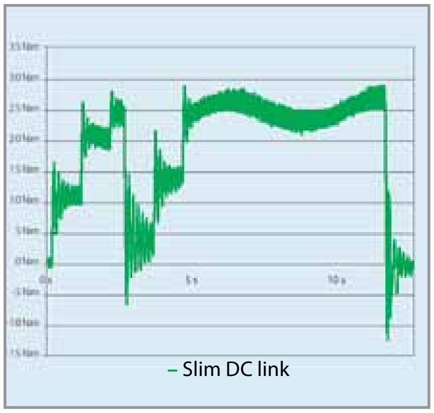
Recent years have seen the increasing availability of Variable Frequency Drives with a"slim" DC link. In this approach, manufacturers greatly reduce the capacitance of the DC link capacitors. Even without a choke, this reduces the fifth harmonic of the current to a THD level below 40%. However, it causes mains interference in the high frequency range that would otherwise not occur. Due to the broad frequency spectrum of devices with slim DC links, there is a greater risk of resonances with other components connected to the mains, such as fluorescent lamps or transformers. Devising suitable measures is correspondingly time-consuming and very difficult.



Drives with slim DC links generate higher harmonic levels, especially in the higher frequency ranges.

In addition, drives with slim DC links have weaknesses on the load side. With drives of this sort, load variations result in significantly larger voltage variations. As a result, they have a greater tendency to oscillate in response to load variations on the motor shaft. Load shedding is also difficult. During load shedding the motor acts as a generator with high peak voltages. In response to this, devices with lean DC links shut down faster than conventional devices in order to protect against destruction due to overload or overvoltage. Due to the small or zero capacitance, drives with slim DC links are not good at riding through mains dropouts. As a rule of thumb, a slim DC link has around 10% of the capacitance of a conventional DC link.

In addition to mains interference due to the input current, drives with slim DC links pollute the mains with the switching frequency of the motor-side inverter. This is clearly visible on the mains side due to the low or zero capacitance of the DC link.



Active Front End

`Low Harmonic Drives´ (LHD) is often used when describing Active Front End (AFE) drives. However, this is a bit misleading as Low Harmonic Drives might cover many different technologies and include both passive and active mitigation. Active Front End drives have IGBT switches on the drive input circuits that replaces conventional rectifiers. These circuits use semiconductor devices with fast switching characteristics to force the input current to be approximately sinusoidal and they are very effective in attenuating low-frequency mains interference. Like Variable Frequency Drives with slim DC links, they generate mains interference in the high frequency range.

An active front end is the most expensive approach to reducing mains interference, since it amounts to a supplementary, full-fledged Variable Frequency Drive that is able to feed power back into the mains system. The low harmonic drive option does not offer this capability and is accordingly somewhat less costly.

Practical aspects of mains interference reduction

Advantages of AFE

The total harmonic distortion drops to a THD level of <4% in the range of the 3rd to the 50th harmonics. Four-quadrant operation is possible with AFE devices, which means that the braking power of the motor can be fed back into the mains system.

Drawbacks of AFE

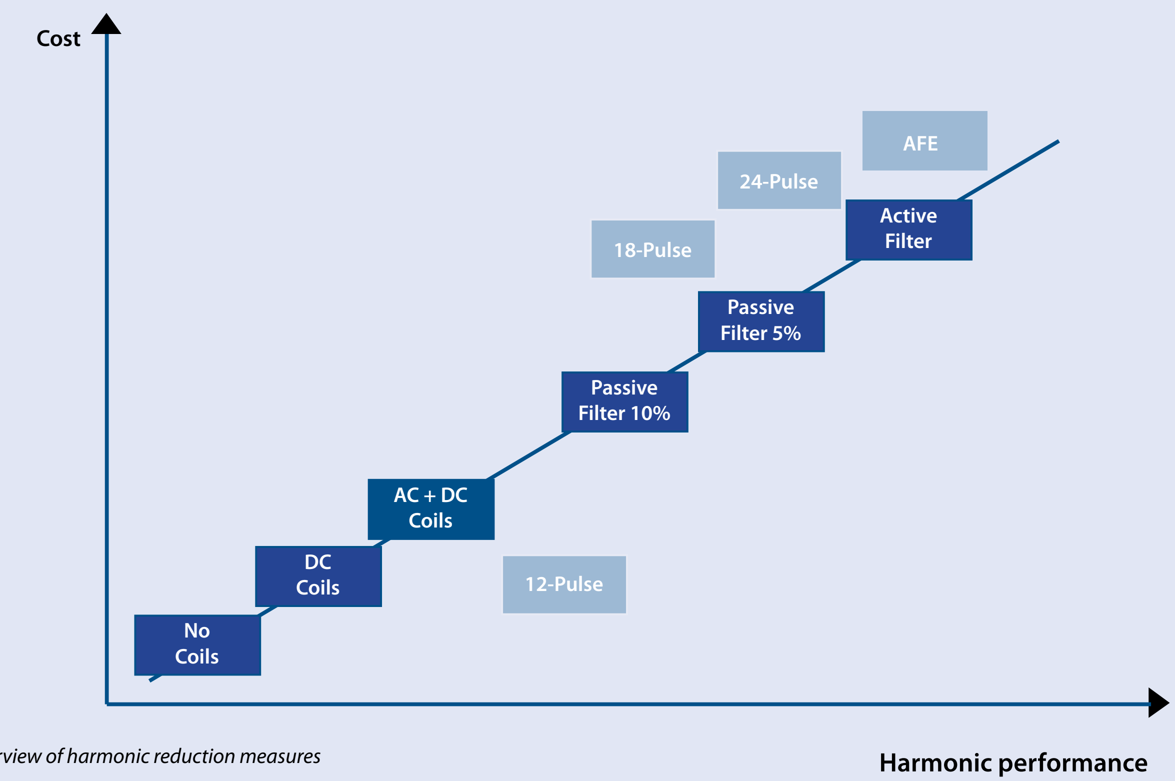
The technical complexity of the devices is very high, which leads to very high investment costs. In principle, AFE devices consist of two Variable Frequency Drives, with one supplying power to the motor and the other to the mains system. Due to the increased circuit complexity, the efficiency of the Variable Frequency Drive is lower in motor operation. The power loss may be 40 to 50% higher than that of Variable Frequency Drives with uncontrolled rectifiers.

An AFE always needs a higher DC link voltage for proper operation. In many cases this higher voltage is passed on to the motor, resulting in higher stress on the motor insulation. If the DC links of the AFE devices are not separated, filter failure results in failure of the entire device.

Another drawback is the clock frequency used by the devices for input current correction. It lies in the range of 3 to 6 kHz.
Good (and relatively complex) devices filter out this clock frequency before feeding power into the mains system. The currently applicable standards and statutes do not cover this frequency range. Currently available mains analyzers usually do not acquire data in this frequency range and thus do not allow the effects to be measured.

However, they can be seen in all devices operating on the affected mains system, such as in the form of increased input current with power supplies. The effects will only become noticeable in later years.
Consequently, operators should specifically ask manufacturers about emission levels and countermeasures in the interest of the operational reliability of their own systems.

Note: There is nothing that specifies that series production devicces must conform to the limits defined in EN 61000-3-12. It is entirely possible for a drive to conform to these limits only in combination with a supplementary filter.



Overview of harmonic reduction measures

Practical aspects of high-frequency interference (RFI)

Radio frequency interference

Variable Frequency Drives generate variable rotating field frequencies at corresponding motor voltages due to variable-width rectangular current pulses. The steep pulse edges contain high-frequency components. Motor cables and Variable Frequency Drives radiate these components and conduct them into the mains system via the cable.

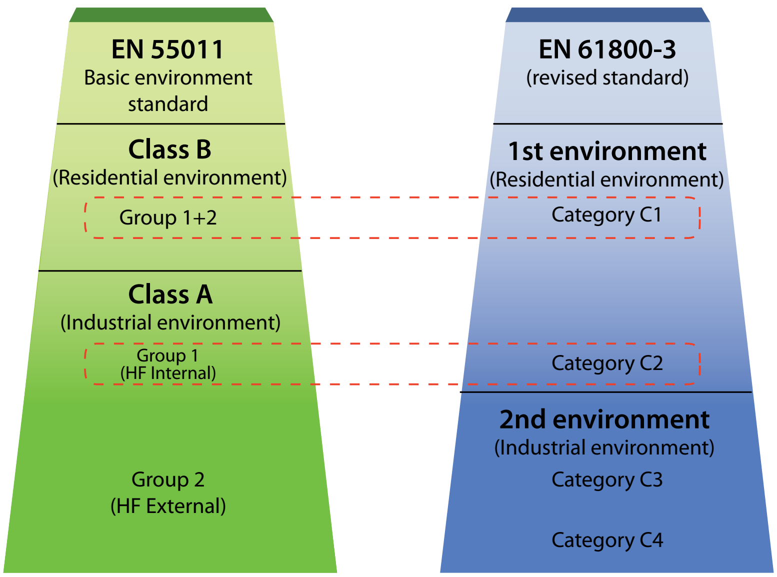
Manufacturers use radio frequency interference (RFI) filters (also called mains filters or EMC filters) to reduce the level of this type of interference on the mains feed.

They serve to protect devices against high-frequency conducted interference (noise immunity) and to reduce the amount of high-frequency interference emitted by a device over the mains cable or by radiation from the mains cable.

The filters are intended to limit these interference emissions to a specified statutory level, which means that as much as possible they should be fitted in the equipment as standard. As with mains chokes, with RFI filters the quality of the filter to be used must be clearly defined.

Specific limits for interference levels are defined in the EN 61800-3 product standard and the EN 55011 generic standard.

Comparision of interference levels



Comparison of the new categories C1 to C4 defined by the EN 61800-3 product standard and classes A and B of the EN 55011 environment standard.

EN 61800-3 product standard (2005-07) for electrical drive systems

Classification by category	C1	C2	C3	C4
Environment	1st Environment	1st or 2nd Environment (operator decision)	2nd Environment	2nd Environment
Voltage/current	< 1000 V			> 1000 V In > 400 A Connection to IT network
EMC expertise	No requirement	Installation and commissioning by an EMC expert		EMC plan required
Limits according to EN 55011	Class B	Class A1 (plus warning notice)	Class A2 (plus warning notice)	Values exceed Class A2

Classification of the new categories C1 to C4 of the EN 61800-3 product standard

Standards and directives define limits

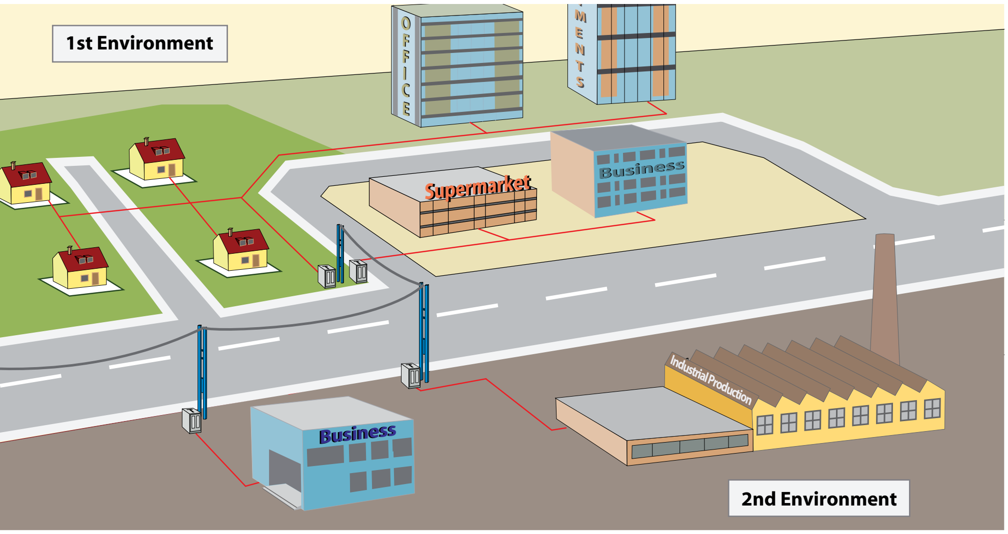
Two standards must be observed for the comprehensive assessment of radio frequency interference. The first is the EN 55011 environment standard, which defines the limits according to the basic environment: either industrial (classes A1 and A2) or residential (class B). In addition, the EN-61800-3 product standard for electrical drive systems, which came into effect in June 2007, defines new categories (C1 to C4) for device application areas.

Although they are comparable to the previous classes in terms of limits, they allow a wider range of application within the scope of the product standard.

Note:
The FC 202 AQUA meets EN61800-3, 61000-6-3/4, EN55011, IEC 61800-3. Filter Class A2 standard.

Note:
Facility operators must comply with EN 55011 in case of problems. Drive manufacturers must conform to EN 61800-3.

Practical aspects of 1st and 2nd environment



Classification of operating environments in 1st and 2nd and special environments in which the operator is allowed a choice.

The operating site is the decisive factor

The limits for each environment are specified by the corresponding standards, but how are devices assigned to the different environment types? Here again the EN 55011 and EN 61800-3 standards provide information regarding electrical drive systems and components.

1st Environment/ Class B: Residential environment

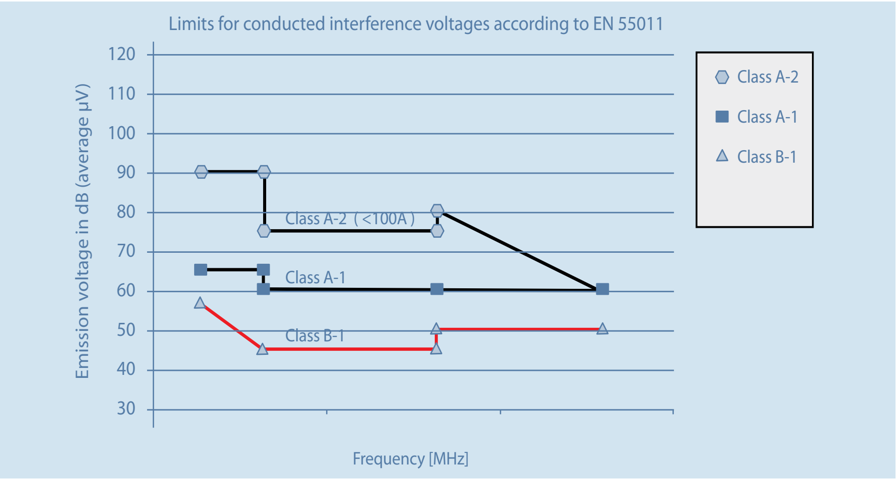
All operating sites directly connected to the public low voltage power grid, including light industrial areas, are classified as residential or business and commercial environments. They do not have their own high-voltage or medium-voltage distribution transformers for a separate mains system. The environment classifications apply both inside and outside buildings. Some examples are business areas, residential buildings and residential areas, restaurant and leisure businesses, car parks, entertainment facilities and sports facilities.

2nd Environment/ Class A: Industrial environment

Industrial environments are operating sites that are not connected directly to the public low-voltage power grid, but instead have their own high-voltage or medium-voltage distribution transformers. They are also defined as such in the land register and are characterised by specific electromagnetic conditions:

- the presence of scientific, medical or industrial devices;
- switching of large inductive and capacitive loads;
- occurrence of strong magnetic fields (for example, due to high currents).

The environment classifications apply both inside and outside the buildings.



Special environments

Here the users may decide which type of environment to classify their facility in. This presumes that the area has its own medium-voltage transformer and is clearly demarcated from other areas. Within this area, the user is personally responsible for ensuring the electromagnetic compatibility necessary to enable the trouble-free operation of all devices under certain conditions. Some examples of special environments are shopping centres, supermarkets, filling stations, office buildings and warehouses.

No compromises

If a Variable Frequency Drive that does not conform to Category C1 is used, the device must be provided with a warning notice. This is the responsibility of the user or the operator. In case of interference, experts always base interference elimination on the limits defined for classes A1/A2 and B in the EN 55011 generic standard according to the operating environment. The cost of remedying EMC problems is borne by the operator. The user is ultimately responsible for the appropriate classification of devices with respect to these two standards.

Practical aspects of mains protection measures

Power factor correction

Power factor correction equipment serves to reduce the phase shift (φ) between the voltage and the current and moves power factor closer to unity (cos φ). This is necessary when a large number of inductive loads, such as motors or lamp ballasts, are used in an electrical distribution system. Depending on the design of the DC link, Variable Frequency Drives do not draw any reactive power from the mains system or generate any phase shift. They have a cos φ of approximately 1. For this reason, users of speed-controlled motors do not have to take them into account when dimensioning any power factor correction equipment that may be necessary. However, the current drawn by the phase correction equipment rises because Variable Frequency Drives generate harmonics. The load on the capacitors increases as the number of harmonic generators increases, and they heat up more. For these reasons, the operator must fit chokes in power factor correction equipment. These chokes also prevent resonances between load inductances and the capacitance of the power factor correction equipment.

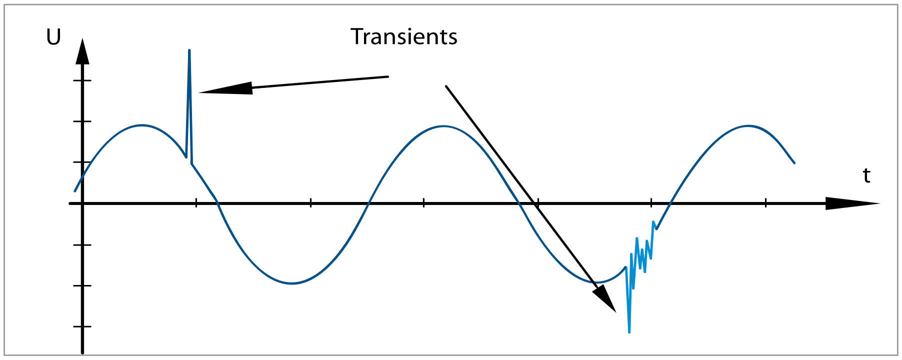
Drives with cos j < 1 also require chokes in the power factor correction equipment. The user must take the higher reactive power level into account when dimensioning the cables.

Mains transients

Transients are brief voltage peaks in the range of a few thousand volts. They can occur in all types of power distribution systems, in both industrial and residential environments.

Lightning strikes are a common cause of transients. However, they are also caused by switching large loads on line or off line or switching other equipment, such as power factor correction equipment. Short circuits, tripping of circuit breakers in power distribution systems, and inductive coupling between parallel cables can also cause transients.

The EN 61000-4-1 standard describes the forms of these transients and how much energy they contain. Their harmful effects can be limited by various methods. Gas-filled surge arresters and spark gaps are used to provide first-level protection against high-energy transients. For second-level protection, most electronic devices use voltage-dependent resistors (varistors) to attenuate transients. Variable Frequency Drives also utilise this method.



Lighting strikes are the most frequent cause of mains transients in water and wastewater treatment plants.

Practical aspects of operation with a transformer or standby generator

Maximum transformer utilization

In low-voltage systems (480 V, 575 V and 690 V), operators may use speed-controlled drives with ratings up to around1 MW. A transformer converts the voltage of the medium-voltage grid to the required voltage.
In the public power grid (environment 1: residential environment) this is the responsibility of the electricity company.

In industrial mains systems (environment 2: industrial environment; usually 480 V or 690 V), the transformer is located on the premises of the end user, who is also responsible for feeding power to the user's facility.

Transformer load

In case of transformers that supply power to Variable Frequency Drives, it must be borne in mind that the use of Variable Frequency Drives and other rectifier loads causes the generation of harmonics that put an extra reactive power load on the transformer.

This causes higher losses and additional heating. In the worst case, this can lead to the destruction of the transformer. Intelligent vector groups (several transformers connected together) may also generate harmonics under certain conditions.

Power quality

To ensure the quality of the mains power in accordance with the applicable standards, you need to know how much Variable Frequency Drive load the transformer can handle.

Mains analysis programs such as the VLT® MCT 31 Harmonic Calculation software provide an exact indication of how much Variable Frequency Drive load a transformer can supply in a specific system.

Remark: *All Variable Frequency Drives in the VLT® AQUA Drive series are equipped with integrated mains interference chokes as standard.*

Operation with a standby generator

Operators use backup power systems when the continued operation of mains-powered devices is necessary even in the event of mains failure. They are also used when the available mains connection cannot provide sufficient power. Operation in parallel with the public power grid is also possible in order to achieve higher mains power. This is common practice when heat is also needed, such as with combined heat and power units. They take advantage of the high efficiency that can be achieved with this form of energy conversion. When backup power is provided by a generator, the mains impedance is usually higher than when power is taken from public grid. This causes the total harmonic distortion to increase. With proper design, generators can operate in a system containing harmonic generators.

In practice, this means that when the system is switched from mains operation to generator feed, the harmonic load can usually be expected to increase.

Facility services designers and operators should calculate or measure the increase in the harmonic load in order to ensure that the power quality conforms to regulations and thereby to prevent problems and equipment failure.

Asymmetric loading of the generator must be avoided, since it causes increased losses and may cause the total harmonic distortion to increase. A 5/6 stagger of the generator winding attenuates the fifth and seventh harmonics, but it allows the third harmonic to increase. A 2/3 stagger reduces the third harmonic.

If possible, the operator should disconnect power factor correction equipment because resonances may occur in the system. Chokes or active absorption filters can attenuate harmonics. Resistive loads operated in parallel also have an attenuating effect, while capacitive loads operated in parallel create an additional load due to unpredictable resonance effects.

If these phenomena are taken into account, a mains system fed by a generator can power a certain proportion of Variable Frequency Drives while still maintaining the specified power quality. A more precise analysis is possible using mains analysis software, such as the VLT® MCT 31 Harmonic Calculation software.

In case of operation with harmonic generators, the limits are set as follows:

B2 and B6 rectifiers	→	max. 20% of rated generator load
B6 rectifier with choke	→	max. 20–35% of rated generator load depending on the composition
Controlled B6 rectifier	→	max. 10% of rated generator load

The above maximum load figures are recommended guideline values, which based on experience allow trouble-free facility operation.

Step 2: Practical aspects of ambient and environmental conditions

The right installation location

Long service life and maximum uptime time are achieved by ensuring proper cooling and clean airflow within a Variable Frequency Drive (VFD). Consequently, selection of the installation location and conditions has a significant effect on the lifetime of a Variable Frequency Drive.

MCC mounting versus wall mounting

There is not a clear-cut answer to the question of whether a Variable Frequency Drive should be mounted in an MCC or on the wall. Both options have their advantages and disadvantages.

MCC mounting has an advantage of all the electrical and electronic components being located in close proximity and protected within the enclosure. The MCC also comes fully assembled as a complete unit for installation in the facility.

A drawback to the MCC configuration is that the components may interfere with each other, due to their close proximity within the MCC. Which means that particular attention must be paid to using an EMC-compliant layout. In addition, the installation cost for motor cables will be higher because the Variable Frequency Drive and motor are typically further apart from each other than when using wall or onsite installation.

MCC mounting for drives may not be the most ideal design and may require modifications to make them fit in the available space.

Most drives use bottom feed and exit for their power wiring. An MCC bucket also requires an "upside down" mounting for the VFD. Most drives are designed with their heat sink mounted at the rear of the drive. However, this is typically where the vertical bus is mounted within the MCC, thus not allowing for efficient mounting and cooling of the drive. In order to overcome this situation, the VFD must be rotated and/or flipped so that the heatsink can exhaust air and heat through the front of the MCC door. This also requires that the power leads must now enter through the top of the VFD.

In addition, MCC's are built to house many across-the-line starters and other electrical equipment. But, the typical MCC design does not allow for proper circulation of air which will make the drive run hot and tend to shortening their life expectancy.

MCC's are designed with wireways for routing all of the output motor leads within the structure. Since VFD's produce a pulsed AC output signal, this may induce stray electrical "noise" into other loads.

Servicing drives mounted inside an MCC may also present a problem because the "custom" installation to allow for proper airflow and power connections tend to make them more difficult to access.

Wall-mounting provides better EMC protection because the VFD can be mounted in closer proximity to the motor.

Motor cable runs will be reduced in length and accordingly represent significantly lower installation cost. The slightly higher cost of a Variable Frequency Drive with a NEMA 12/IP54 or NEMA 4X/IP66 enclosure can easily be offset by the reduced cabling and installation cost.

Variable Frequency Drives can be installed centrally (in a cabinet) or locally (close to the motor). Both options have advantages and drawbacks.

Technical

Practical aspects of enclosure ratings

Danfoss Variable Frequency Drives are available with three different protection ratings:

- IP00 or IP20 for cabinet installation
- NEMA1/IP21 for wall mounting
- NEMA 12/IP54 or IP55 for wall mounting
- NEMA 4X/IP66 for critical ambient conditions, such as extremely high (air) humidity or high concentrations of dust or aggressive gases

IP rating structure according to IEC 60529

		Against penetration by solid foreign objects			Against water penetration with harmful effect
First digit	0	(not protected)	Second digit	0	(not protected)
	1	≥ 50 mm diameter		1	Drops falling vertically
	2	12.5 mm diameter		2	Drops at 15° angle
	3	2.5 mm diameter		3	Spraying water
	4	≥ 1.0 mm diameter		4	Splashing water
	5	Dust protected		5	Water jets
	6	Dust-tight		6	Powerful water jets
				7	Temporary immersion
				8	Long-term immersion

Missing digits are replaced by "x".

	NEMA Enclosure type					
IP First Character	1	2	3, 3R	4, 4X	12	IP Second Character
IP0_						IP_0
IP1_						IP_1
IP2_						IP_2
IP3_						IP_3
IP4_						IP_4
IP5_						IP_5
IP6_						IP_6
						IP_7
						IP_8

Protection against conditions	NEMA Type					
	1	3	3R	4	4X	12
Access to hazardous parts	x	x	x	x	x	x
Ingress of solid falling objects	x	x	x	x	x	x
Ingress of water, rain, sleet, or snow		x	x	x	x	x
Ingress of circulating non-combustible dust, fibers, or other flying objects		x	x	x	x	x
Ingress of settling non-combustible dust, fibers, or other flying objects				x	x	x
Ingress of water hose down or splashing				x	x	
Oil or coolant seepage						x
Corrosive agents					x	

Practical aspects of cooling design

Compliance with ambient temperature specifications

External climatic conditions and ambient conditions have a distinct effect on the cooling of all electrical and electronic components in a control room or cabinet.

Minimum and maximum ambient temperature limits are specified for all Variable Frequency Drives. These limits are usually determined by the electronic components that are used. For example, the ambient temperature of the electrolytic capacitors installed in the DC link must remain within certain limits due to the temperature dependence of their capacitance. Although Variable Frequency Drives can operate at temperatures down to -10°C, manufacturers only guarantee proper operation at rated load with temperatures of 0°C or higher. This means that you should avoid using them in areas subject to frost, such as uninsulated rooms.

You should also not exceed the maximum temperature limit. Electronic components are sensitive to heat.

According to the Arrhenius equation, the lifetime of an electronic component decreases by 50% for every 10°C that it is operated above its design temperature. This is not limited to devices that are installed in cabinets. Even devices with NEMA 12/ IP54/IP55 or NEMA 4X/IP66 protection ratings can only be used within the ambient temperature ranges specified in the manuals. This sometimes requires air conditioning of installation rooms or cabinets. Avoiding extreme ambient temperatures prolongs the life of Variable Frequency Drives and thereby the reliability of the overall system.

Cooling

Variable Frequency Drives dissipate power in the form of heat. The amount of power dissipation in watts is stated in the technical data of the Variable Frequency Drive. Operators should take suitable measures to remove the heat dissipated by the Variable Frequency Drive from the cabinet, for example by means of cabinet fans. The required air flow is stated in the manufacturer documentation. Variable Frequency Drives must be mounted such that the cooling air can flow unhindered through the device's cooling fins.

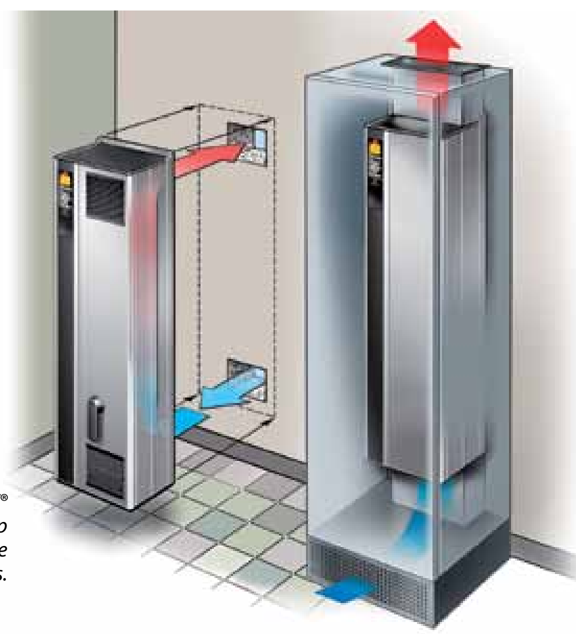
Particularly with IP20 devices in cabinets, there is a risk of inadequate air circulation due to the closely spaced mounting of cabinet components, which causes the formation of heat pockets. See the manuals for the correct mounting distances, which must always be observed.

Relative humidity

Although some Variable Frequency Drives can operate properly at relatively high humidity (Danfoss units up to 95% relative humidity), condensation must always be avoided. There is a specific risk of condensation when the Variable Frequency Drive or some of its components are colder than moist ambient air. In this situation, the moisture in the air can condense on the electronic components.

When the device is switched on again, the water droplets can cause short circuits in the device. This usually occurs only with Variable Frequency Drives that are disconnected from the mains. For this reason, it is advisable to install a cabinet heater in situations where there is a real possibility of condensation due to ambient conditions. Alternatively, operating the Variable Frequency Drive in standby mode (with the device constantly connected to the mains) can help reduce the risk of condensation. However, you should check whether the power dissipation is sufficient to keep the circuitry in the Variable Frequency Drive dry.

Note: *Some manufacturers specify minimum side clearances as well as minimum top and bottom clearances. Observe these specifications.*



The intelligent cooling design of VLT® Variable Frequency Drives remove up to 85% of the dissipated heat from the device enclosure via cooling ducts.

Practical aspects of aggressive environments

Environment Parameter	Unit	Class				
		3C1	3C2 (standard)		3C3 (optional)	
			Mean value	Max. value	Mean value	Max. value
Sea salt	ppm	None	Salt mist		Salt mist	
Sulphur dioxide	ppm	0.1	0.3	1.0	5.0	10
Hydrogen sulphide	ppm	0.01	0.1	0.5	3.0	10
Chlorine	ppm	0.01	0.1	0.3	0.3	1.0
Hydrogen chloride	ppm	0.01	0.1	0.5	1.0	5.0
Hydrogen fluoride	ppm	0.003	0.01	0.03	0.1	2.0
Ammonia	ppm	0.3	1.0	3.0	10	35
Ozone	ppm	0.01	0.05	0.1	0.1	0.3
Nitroge Oxides	ppm	0.1	0.5	1.0	3.0	9.0

Classification according to IEC 60721-3-3; average values are anticipated long-term values.
Maximum values are transient peak values that do not occur longer than 30 minutes per day.

Aggressive atmosphere or gases

Aggressive gases, such as hydrogen sulphide, chlorine or ammonia, are often present in sewage treatment plants or swimming pools. Contamination of the cooling air can cause the gradual decomposition of electronic components and PCB tracks in Variable Frequency Drives. Electronic devices in electrical systems or cabinets are especially susceptible. If the ambient air is contaminated in this manner, the operator or plant engineer should either install the Variable Frequency Drive in a location where the possibility of contamination can reliably be excluded (a different building, a sealed cabinet with a heat exchanger, etc.) or order devices whose circuit boards are coated with a special protective varnish that is resistant to the aggressive gases.

A clear sign of an aggressive atmosphere is the corrosion of copper. If it quickly turns dark, forms blisters or even decomposes, circuit boards or devices with a supplementary coating should be used. The specific media and media concentrations that a coating can resist are described in international standard IEC 60721-3-3.

Note: *You should consider in the design and project engineering phase where the cooling air for the electronic equipment will come from.*
For example, in a sewage treatment plant you should avoid drawing air from the inflow area, and with a swimming pool you should avoid drawing air from the water treatment area.

Remark: *VLT® AQUA Drive units come standard with class 3C2 coating.*
High power comes standard with 3C3.

Practical aspects of aggressive environments

Dust exposure

Installation of Variable Frequency Drives in environments with high dust exposure is often unavoidable in practice. This dust forms deposits everywhere and penetrates into even the smallest cracks. This affects not only locally mounted Variable Frequency Drives (wall or frame mount) with NEMA 12/IP54/IP55 or NEMA 4X/IP66 protection rating, but also cabinet-mounted devices with Open Chassis/IP00, Protected Chassis/IP20, or NEMA 1 protection rating.

The three aspects described below must be taken into account when Variable Frequency Drives are installed in such environments.

Reduced cooling

The dust forms deposits on the surface of the device and inside the device on the circuit boards and the electronic components. These deposits act as insulation layers and hamper heat transfer from the components to the ambient air. This reduces the cooling capacity. The components become warmer. This causes accelerated aging of the electronic components, and the service life of the affected Variable Frequency Drive decreases. The same thing happens when dust deposits form on the heat sink on the back of the Variable Frequency Drive.

Cooling fans

The air flow for cooling Variable Frequency Drives is produced by cooling fans, which are usually located on the back of the device. The fan rotors have small bearings into which dust penetrates and acts as an abrasive. This leads to fan failure due to bearing damage.

Filter mats

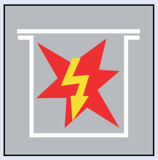
High-power Variable Frequency Drives in particular are equipped with cooling fans that expel hot air from the interior of the device. Above a certain size, these fans are fitted with filter mats that prevent the entry of dust into the device. These filter mats quickly become clogged when they are used in very dusty environments, and the fans are no longer able to cool adequately the components inside the Variable Frequency Drive.

Note: *Under the conditions described above, it is advisable to clean the Variable Frequency Drive during periodic maintenance. Blow the dust off the heat sink and fans and clean the filter mats.*

Practical aspects of potentially explosive atmospheres

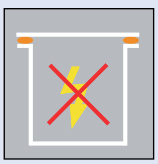
Potentially explosive atmospheres

Ex d: **Flameproof protection**



With ignition protection class "d", the device is designed to ensure that if a spark occurs in a protected area (such as inside an enclosure), it cannot leave the protected area.

Ex e: Increased safety



With ignition protection class "e", the protection consists of preventing the occurrence of sufficient energy to cause sparking.

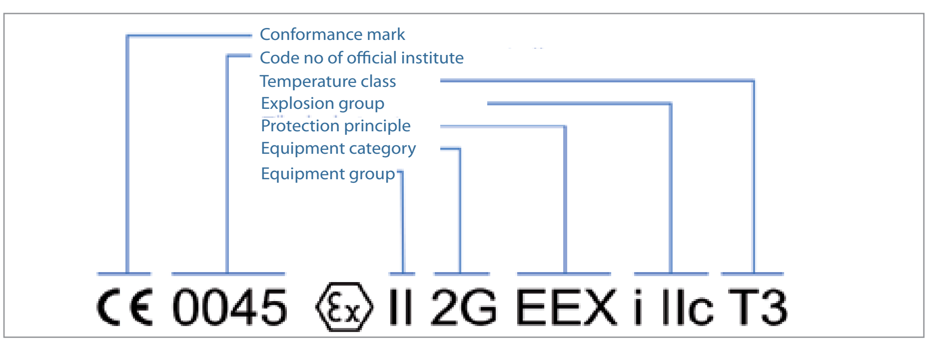
Note: Never install a Variable Frequency Drive directly in an area with a potentially explosive atmosphere. It must be installed in a cabinet outside this area. Using a sine-wave filter at the output of the Variable Frequency Drive is also recommended because it attenuates the voltage rate of rise dV/dt and the peak voltage Upeak. The connected motor cable should be kept as short as possible due to the voltage drop in the cable.

Remark: Danfoss VLT® AQUA Drive Variable Frequency Drives with the MCB 112 option have PTB-certified motor thermistor sensor monitoring capability for potentially explosive atmospheres. Shielded motor cables are not necessary when VLT® Variable Frequency Drives are operated with sine-wave output filters.

Drive systems often operate in potentially explosive atmospheres. One example is the inflow area of a sewage treatment plant. If Variable Frequency Drives are used for speed control of drives in such areas, the facility must fulfil special conditions. The basis for this is provided by EU Directive 94/9/EC, which is called the ATEX directive. It describes the use and operation of equipment and protective devices in potentially explosive atmospheres. This directive harmonises regulations and requirements throughout the EU for the operation of electrical and electronic devices in potentially explosive atmospheres, such as may be caused by dust or gases.

If Variable Frequency Drives are used to control motors in potentially explosive atmospheres, these motors must be equipped with temperature monitoring using a PTC temperature sensor. Motors with ignition protection class "d" or "e" may be used. These ignition protection classes differ in terms of how the ignition of an explosive medium is prevented. In practice, Variable Frequency Drives are rarely used with "e" class motors. This combination must be approved as an unit, which involves elaborate and expensive type testing. However, the PTB in Braunschweig (Germany) has developed a new approval procedure that will make the use of speed controllers with class "e" motors considerably more attractive in the future. The new concept calls for the acceptance of only the motor itself, while additionally defining specific requirements for thermal monitoring in the EC type test certification process. For instance, speed-dependent current limiting is required in addition to the usual certified PTC thermistor monitoring, in order to deal with the reduced cooling of self-ventilated motors with variable speed control.

Although this does not require separate approval of class "d" motors, feeding cables into the "d" area is very complicated. Motors with protection class "de" are the most widely used. In this case the motor itself has a "d" ignition protection class, while the connection space is implemented in compliance with the "e" ignition protection class. The restriction on the "e" connection space consists of the maximum voltage that may be fed into this space. Due to pulse-width modulation of the output voltage, most Variable Frequency Drive outputs have peak voltages that exceed the allowable limits of class "e" ignition protection. In practice, using a sine-wave filter at the Variable Frequency Drive output has proven to be an effective way to attenuate the high peak voltages.



Labelling of devices for operation in potentially explosive atmospheres in accordance with the ATEX product directive (94/9/EC)

Step 3:
Practical aspects of motors and cabling

Minimum efficiency performance classes for motors

The US has enacted the Energy Independence and Security Act of 2007 (EISA) to define efficiency of electric motors. The National Electrical Manufacturers Association (NEMA) actively participated in crafting major provisions on EISA. A critical provision that NEMA focused on was increased motor efficiency levels. The Motor Generator section of NEMA joined forces with the American Council for an Energy Efficient Economy to draft and recommend new motor efficiency regulations covering both general purpose and some categories of definite and special purpose electrical motors.

Simultaneously, The International Electrotechnical Commission (IEC) passed standard IEC 60034-30 (2008), which defines energy-efficiency classes for single-speed, three-phase, and 50- and 60-hertz (Hz) induction motors. The standard is part of an effort to unify motor testing standards, efficiency requirements and product labeling requirements so that motor purchasers worldwide have the ability to easily recognize premium-efficiency products. Industrial energy managers responsible for offshore facilities and end-users purchasing replacements for failed IEC or metric motors that are imported with equipment packages should be aware of these new efficiency standards.

The new full-load efficiency standards apply to most worldwide industrial continuous-duty motors with the following parameters:

- Single-speed, three-phase, and 50 Hz and 60 Hz
- 2, 4, and 6 poles (3,600; 1,800; and 1,200 RPM at 60 Hz)
- Rated output from 0.75 to 375 (1 to 500 horsepower)
- Rated voltage up to 1,000 volts
- Rated on the basis of either duty type S1 (continuous duty) or S3 (intermittent duty) with a rated cyclic duration factor of 80 percent or higher
- Capable of operating direct online

New IEC 60034-30 (2008) efficiency classes and comparable efficiency levels.

New International Efficiency (IE) Classes	Efficiency Levels	Comparison
IE1	Standard efficiency	Efficiency levels comparable to the existing EFF2 in Europe
IE2	High efficiency	Efficiency levels comparable to the existing EFF1 in Europe and identical to the U.S. EPAct for 60 Hz
IE3	Premium efficiency	New efficiency class in Europe and identical to NEMA Premium® in the United States for 60 Hz

The standard also reserves an IE4 class (Super Premium Efficiency) for the future. The following motors are excluded from the new efficiency standard:

- Motors made solely for inverter operation
- Motors completely integrated into a machine (pump, fan or compressor) that cannot be tested separately from the machine.

For 60 Hz operation, the IE2 and IE3 minimum full-load efficiency values are virtually identical to the North American National Electrical Manufacturers Association (NEMA) Energy Efficient and Premium Efficiency motor standards, respectively.

The IEC & NEMA minimum full-load efficiency standards are higher for 60 Hz motors than for 50 Hz motors. This is because as long as the motor torque is constant, I2R or winding resistance losses are the same at 50 Hz and 60 Hz. The motor output power, however, increases linearly with speed, increasing by 20 percent when the frequency is increased from 50 Hz to 60 Hz. In general, the 60 Hz efficiency is about 2.5 percent to 0.5 percent greater than the 50 Hz values. The efficiency gain is greater for smaller motor power ratings.

Step 3:
Practical aspects of motors and cabling

Design of premium efficiency motors

Design of Premium Efficiency Motors needs special knowledge, experience and test facilities, equipped with precision instrumentation. The task of design is, to get the efficiency up by minimizing and balancing the single losses, especially those created in the stator coils, the stator iron (magnetizing) and the losses within the rotor by slip. In comparison to standard electrical motors compliant e.g. to IE1 for IE3 motor manufacturing, more iron and copper material are used. IE3 motors are heavier and physically bigger, than IE1 motors. Typically use of higher slot fill in the copper winding, use of thinner laminations of improved steel properties, reducing the air gap, better design of cooling fan, use of special and improved bearings etc. can ensure higher efficiency in the motors.

Unifying worldwide efficiency classifications

To show compliance with these new efficiency standards, motors must be tested in accordance with the newly adopted IEC 60034-2-1 testing protocol. This procedure provides test results that are largely compatible with those obtained by the North American IEEE 112B and CSA 390 test methods.

The new standard also requires that the motor efficiency class and nominal motor efficiency be labeled on the motor nameplate and given in product literature and motor catalogs in the following format: IE3 94.5%.

New minimum energy performance standards

While the IEC sets guidelines for motor testing and efficiency classes, the organization does not regulate efficiency. With the new efficiency standards in place, the European Commission Eco-design Regulatory Committee recommended in March 2009 that electric motors with an output power of 0.75 to 375 kilowatts (kW) equal or exceed new mandatory Minimum Energy Performance Standards (MEPS). The MEPS, expected to be adopted in June 2009, are set at the following levels:

- IE2 by June 16, 2011
- IE3 by January 1, 2015
  (for motors >= 10 HP, or IE2 with an adjustable-speed drive)
- IE3 for all motors by January 1, 2017
  (or IE2 with an adjustable speed drive)

Adoption of the MEPS by the European Commission will put them on a path similar to that taken by the United States in the Energy Independence and Security Act (EISA) of 2007. This act increases the U.S. MEPS for 1- to 200-horsepower, 1,200, 1,800 and 3,600 RPM general-purpose motors from the Energy Policy Act of 1992 Energy Efficient (IE2 equivalent) levels to NEMA Premium Efficiency (IE3) levels by December 2010. EISA also establishes an Energy Efficient (IE2) level for motors with output power ratings of 201 to 500 hp.

Practical aspects of IE classification of motors

Schedule for MEPS implementation

The schedule in the EU ordinance provides for a staged increase in motor efficiency requirements. After the scheduled dates, all three-phase motors subject to the ordinance must fulfil the requirements of the specified efficiency class if they are to be marketed in Europe.

IE2 motors powered by drives are also accepted as an MEPS alternative to the planned IE3 class. Compliance with class IE3 or the alternative of IE2 with a drive must be ensured at the operating site.

	Power	MEPS	MEPS alternative
Starting 16 June 2011	1-500 HP	IE2	-
Starting 1 January 2015	1-10 HP	IE2	-
	10-500 HP	IE3	IE2 with drive
Starting 1 January 2017	1-500 HP	IE3	IE2 with drive

Schedule for MEPS implementation

Compliance with EN 50347 mounting dimension specifications

Synchronous three-phase motors conforming to classes IE2 and IE3 are often larger than motors with lower efficiency. This can lead to problems in the replacement of older motors.

Most IE2 motors conform to the shaft heights and fixing dimensions standardised by EN 50347, but the construction form is often longer. In many cases, small 50-Hz IE3 Premium Class motors will not conform to the EN 50347 mounting dimensions.

Facility operators should take heed of this in their motor replacement schemes.Alternative to IE3: IE2 plus Drive.

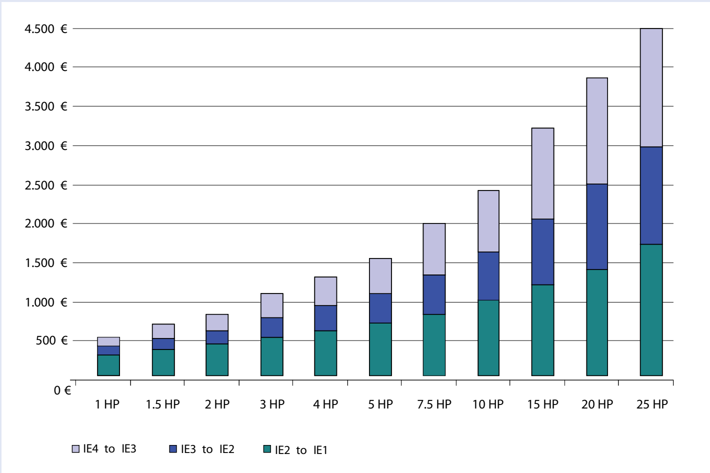
	Motor		
	IE1	IE2	IE3
Shaft height (EN 50347)	Yes	Yes	Larger
Fixing dimensions (EN 50347)	Yes	Yes	Larger
Motor length	Yes	Longer	Larger

It is currently expected that class IE2 and IE3 synchronous three-phase motors will not be able to conform to the mounting dimensions defined in EN 50347.

Cost-effectiveness

A justified question with regard to the introduction of IE motors is: how cost-effective are they? The higher efficiency is in part achieved by employing a higher proportion of active materials in the motors. Depending on the motor size, you can assume that a motor with a better efficiency class costs approximately 10 to 20% more.

In practice, this additional cost can often be recovered quickly. The chart shows the energy cost advantage of an IE motor compared to an IE motor in the next class. This simplified analysis is based on continuous operation at the rated load, 60,000 operating hours, and an electricity price of $0.08 per kilowatt-hour.



Energy cost advantage of an IE motor relative to the next IE class

***Note:** The U.S. Energy Independence and Security Act of 2007 (EISA) can be viewed and downloaded from: http://www.epa.gov/lawsregs/laws/eisa.html*

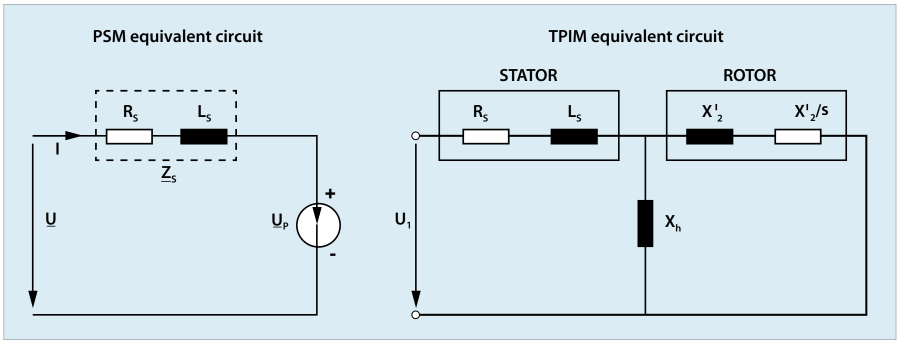
Practical aspects of EC and PM motors

Many names for the same technology

It takes a lot of effort to increase the efficiency of a three-phase induction motor (TPIM). This makes permanent-magnet synchronous motors a good alternative. Compared with induction motors offering similar efficiency (e.g. IE 3), they are significantly more compact.

In practice, as a user you will encounter various subcategories of these motors with different names. The abbreviations “PM” (permanent magnet) and “PMSM” (permanent magnet synchronous motor) are often used in the industry, while the designations “EC” (electronically commutated) and “BLDC” (brushless direct current) are more commonly used in building automation.

The variety and diversity of names given to permanent magnet motors can be illustrated by taking EC motors as an example. EC motors are usually used as servo motors or stepper motors in industrial applications. With a small, compact frame size, they cover a power range extending to approximately 300 watts. The most common supply voltage is 24 V. The situation is different in fan systems for building automation. There, single-phase and three-phase EC motors operate in compact fan units for applications with power requirements in the single-figure kilowatt range.



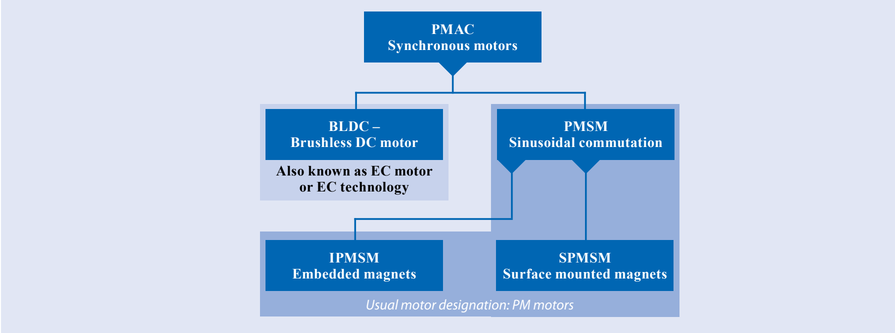
Comparison of the simplified equivalent circuits shows that PM/EC motors do not have any rotor losses. This yields a higher level of efficiency compared to three-phase motors.

The technology

Due to the built-in permanent magnets, permanently excited motors do not need a separate excitation winding. However, they need an electronic controller that generates a rotating field. Operation directly from the mains is generally not possible, or in many case only with reduced efficiency. To drive the motor, the controller (e.g. a Variable Frequency Drive) must be able to constantly determine the current position of the rotor. Two methods are used for this, either with or without feedback on the current rotor position provided by a sensor or an encoder.

High efficiency

Using permanent magnets in the rotor virtually eliminates rotor losses in the motor. This results in increased efficiency.



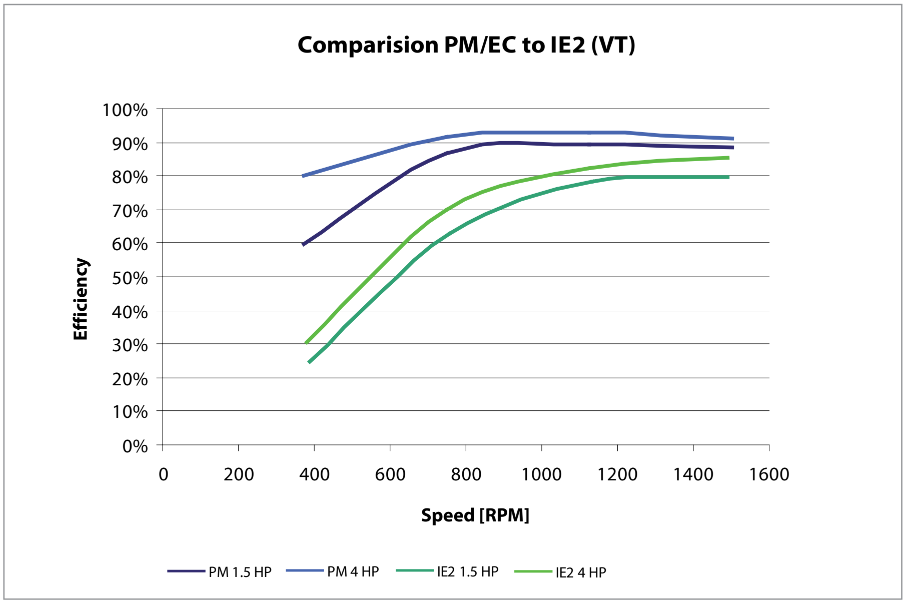
PMAC = Permanent Magnet AC; BLDC = Brushless DC; PMSM = Permanent Magnet Synchronous Motor; IPMSM = Interior PMSM (embedded magnets); SPMSM = Surface PMSM (magnets mounted on rotor)

The Danfoss EC+ concept allows PM motors with IEC standard dimensions to be used with Danfoss VLT® Variable Frequency Drives. Danfoss has integrated the necessary control algorithm in the existing VLT® Drive series. This means that there are no changes for the operator. After entering the relevant motor data, the user benefits from the high motor efficiency of EC technology.

Advantages of the EC+ concept

- Free choice of motor technology: PM or asynchronous with the same Variable Frequency Drive
- Device installation and operation remain unchanged
- Manufacturer independence in the choice of all components
- Superior system efficiency thanks to a combination of individual components with optimum efficiency
- Retrofitting of existing systems possible
- Wide range of rated powers for standard and PM motors

Practical aspects of EC and PM motors



The diagram shows values measured by an independent university. Losses for the required control electronics are included in the figures.

Oversynchronous operation

In theory, it is possible to operate an EC or PM motor above its rated frequency or rated speed, as long as this is allowed by the manufacturer. With a TPIM, this is called oversynchronous operation or operation with field weakening. Field weakening allows the motor to be operated at a higher speed, but with lower output shaft torque. In contrast to TPIMs, with EC or PM motors field weakening can only be achieved by using suitable drive signals. As with TPIMs, this reduces the output shaft torque.

The motor manufacturer must be consulted to determine whether a particular motor is suitable for supersynchronous operation.

With regard to the Variable Frequency Drive, this type of operation does not present a problem unless the back EMF (ElectroMotiveForce) generated by the EC or PM motor due to the permanent magnets exceeds the allowable DC link voltage of the drive.

For example, a motor with a back EMF of 240 V at 1,200 rpm can be operated at speeds up to 3,600 rpm with a Variable Frequency Drive having a maximum allowable DC link voltage of 900 V. Although the motor can be operated at even higher speeds, this poses a risk of electrical failure of the drive in the event of a fault because the voltage is higher than 900 V. For example, this could happen if there is a mains drop-out.

Standard IEC enclosure

Many applications employ three-phase induction motors whose installation dimensions and frame sizes comply with the specifications of IEC EN 50487 or IEC 72.

However, other types of construction have been used for most PM motors up to now. Servo motors are typical examples. With their compact construction and long rotors, they are Optimized for highly dynamic processes.

To allow the high efficiency of permanent magnet motors to be utilised in existing industrial applications, PM motors are now available with standard IEC motor enclosures. This allows older-model standard three-phase induction motors (TPIMs) to be replaced by motors with higher efficiency in existing systems. This also enables mechanical engineering and plant engineering firms to use motors with higher efficiency without requiring any design changes to existing machines.

For compatibility reasons, both forms of PM motors are commercially available.

Option 1: Same frame size
The PM/EC motor and the TPIM have the same frame size.

Example: A 4 HP TPIM can be replaced by an EC/PM motor of the same size.

Option 2: Same power rating
The PM/EC motor and the TPIM have the same power rating. In theory, a PMSM can be made smaller than a TPIM with a comparable power rating. Depending on the frame size, the power density of a PM/EC motor is approximately 1.5 to 2 times that of a TPIM.

Example 1: A 4 HP TPIM can be replaced by an EC/PM motor with the same frame size as a 2 HP motor.

Example 2: A 4 HP TPIM can be replaced by an EC/PM Motor with the same frame size and about an 8 HP rating.

However, a controller is always necessary to drive a PM/EC motor.

Practical aspects of motor suitability for Variable Frequency Drive operation

Selection criteria

The following aspects must be taken into consideration in connection with motors controlled by Variable Frequency Drives:

- Insulation stress
- Vearing stress
- Thermal stress

Insulation stress

Operating a motor with frequency control imposes higher stress on the motor winding than direct mains operation This is primarily due to the steep pulse edges (dV/dt) and the motor cable, depending on cable length, type, routing, etc.

The steep pulse edges result from the rapidly switching semiconductor devices in the inverter stage of the Variable Frequency Drive. They operate at a high switching frequency in the range of 2 to 20 kHz with very short switching times in order to reproduce a sinusoidal waveform.

In combination with the motor cable, these steep pulse edges are responsible for the following effects at the motor:

- High pulse voltages VLL on the motor terminals put additional stress on the interwinding insulation
- Higher pulse voltages between the windings and the laminations ÛLE put additional stress on the slot insulation
- Higher voltages between the windings Ûwdg put significantly higher stress on the insulation of the wire in the windings.

Bearing stress

Under unfavourable conditions, VFD-controlled motors may fail due to bearing damage caused by bearing currents. Current flows in a bearing when the voltage across the bearing lubrication gap is high enough to penetrate the insulation layer formed by the lubricant. If this happens, imminent failure of the bearing is signalled by increasingly louder bearing noise. Bearing currents of this sort include high-frequency eddy currents, ground currents and EMD currents (spark erosion).

Which of these currents may lead to bearing damage depends on the following factors:

- The mains voltage at input of the Variable Frequency Drive
- The steepness of the pulse edges (dV/dt)
- The type of motor cable
- Electrical shielding
- System grounding
- Motor size
- The grounding system of the motor housing and the motor shaft.

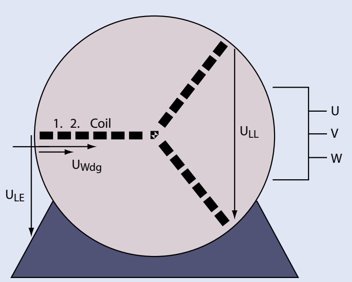
Bearing currents can be reduced by the following measures:

- Fitting output filters (output chokes, dV/dt filters, or sine-wave filters)
- Fitting electrically insulated bearings
- Good grounding of all metallic system components with low-impedance connections
- Shielded motor cables
- Fitting a DC suppression filter.

Thermal stress

Operation with a Variable Frequency Drive increases the power dissipation in the motor. The additional harmonic content causes iron losses and current heat losses in the stator and rotor. The magnitude of the losses depends on the amplitude and frequency of the harmonics of the drive frequency. The additional current heat losses in the rotor depend on the slot geometry. Iron losses and current heat losses in motors are not load-dependent. The additional losses in the motor cause higher thermal stress on the winding insulation. However, with modern Variable Frequency Drives the additional heating of standard motors (up to frame size 315) is comparable to the additional warming due to mains voltage tolerances and is therefore negligible. Manufacturers sometime specify a derating factor for trans-standard motors (frame size 355 and above).

If the drive is not able to generate the full mains voltage at the rated mains frequency, it is advisable to select a motor with Class F insulation. Operating a motor at a voltage lower than with direct mains operation increases the motor temperature by up to 10°C.



Pulse voltages appear in the motor at the motor terminals (V_{LL}) and between the windings and the lamination stack (U_{LE}). There is also a voltage stress between the windings (U_{wdg}).

Note: Request confirmation from the motor manufacturer that the motor is designed for operation with a Variable Frequency Drive and confirmation of the allowable operating speed range (minimum and maximum rpm).

Note: Bearing currents result from the action of the entire system, consisting of the Variable Frequency Drive, motor, cable and grounding.

Practical aspects of output filters

Sine-wave and dV/dt filters

The output filter options include sine-wave and dV/dt filters. Unlike sine-wave filters, the only task of dV/dt filters is to reduce the steepness of the pulse edges. They are simpler in design than sine-wave filters (smaller inductances and capacitances) and are therefore less expensive. Sine-wave filters, which are also called motor filters or LC filters, may optionally be fitted to the outputs of Variable Frequency Drives. They smooth the rectangular voltage pulses at the output to convert them into a nearly sinusoidal output voltage.

Functions and tasks of sine-wave filters

- Reducing the voltage rate of rise
- (dV/dt) at the motor terminals
- Reducing peak voltage $\hat{U}_{LL}$
- Reducing motor noise
- Allowing longer motor cables to be used
- Improving EMC characteristics
- When used with Danfoss frequency drives, sine-wave filters enable operation with unshielded motor cables in compliance with EN 61800-3 RFI category C2

When are sine-wave filters used?

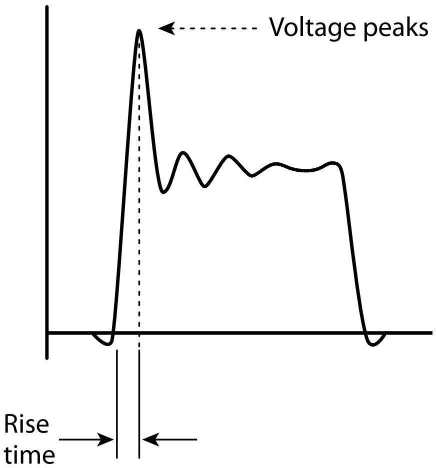
- With wet-running pumps
- With very long motor cables (including situations where this is neces sary due to parallel operation)
- With well pumps
- With motors lacking good inter winding insulation
- Whenever standard motors are not used (consult motor manufacturer)

Retrofitting

If a facility operator converts older-model motors previously powered directly from the mains to speed control operation and retrofits them with a Variable Frequency Drive, it is always advisable to use a sine-wave filter unless the motor datasheet indicates that the windings are designed for operation with a Variable Frequency Drive. When renovations are being carried out, it is often worthwhile to replace old low-efficiency motors with new energy-efficient motors. A supplementary sine-wave filter is not necessary in such cases. The new motors usually pay for themselves very quickly due to reduced energy costs.

	dV/dt filter	Sine-wave filter	Common mode filter
Motor insulation stress	Reduced – longer motor cables can be used	Reduced – longer motor cables can be used	No reduction
Motor bearing stress	Slightly reduced	Reduced circulating currents but not synchronous currents	Reduced synchronous currents
Electromagnetic compatibility	Eliminates harmonics in motor cable. No change in EMC class	Eliminates harmonics in motor cable. No change in EMC class	Reduced high-frequency emissions (above 1 MHz). No change in EMC class
Maximum motor cable length, EMC compliant	Depends on manufacturer FC 202: max. 500 ft. shielded	Depends on manufacturer FC 202: max. 500 ft. shielded or max. 1000 ft. unshielded	Depends on manufacturer FC 202: max. 500 ft. shielded
Max. motor cable length, not EMC compliant	Depends on manufacturer FC 202: max. 500 ft. unshielded	Depends on manufacturer FC 202: max. 1500 ft. unshielded	Depends on manufacturer FC 202: max. 1000 ft. unshielded
Motor noise at switching frequency	No effect	Reduced	No effect
Relative size (compared to Drive)	15–50% (depends on power)	100%	5–15%
Voltage drop	0.5%	4–10%	None

Practical aspects of peak voltage on motors



When a transistor in the inverter bridge switches, the voltage across the motor increases by a dV/dt ratio depending on:

- the motor cable (type, cross-section, length screened or unscreened)
- inductance

The natural induction causes an overshoot UPEAK in the motor voltage before it stabilizes itself at a level depending on the voltage in the intermediate circuit. The rise time and the peak voltage UPEAK affect the service life of the motor. If the peak voltage is too high, especially motors without phase coil insulation are affected. If the motor cable is short (a few meters), the rise time and peak voltage are lower.

If the motor cable is long (300 ft.), the rise time and peak voltage increases. In motors without phase insulation paper or other insulation reinforcement suitable for operation with voltage supply (such as a variable frequency drive), fit a sine-wave filter on the output of the variable frequency drive.

200V

FC 202	Rating	Cable length [Ft]	voltage [V]	Rise time [µsec]	Vpeak [kV]	dV/dt [kV/µsec]
P7K5T2	10 HP	16	230	0.13	0.51	3.09
		165	230	0.23		2.034
		325	230	0.54	0.58	0.865
		500	230	0.66	0.56	0.674
P11KT2	15 HP	120	240	0.264	0.624	1.89
		450	240	0.536	0.596	0.889
		500	240	0.568	0.568	0.8
P15KT2	20 HP	100	240	0.556	0.65	0.935
		325	240	0.592	0.594	0.802
		500	240	0.708	0.587	0.663
P18KT2	25 HP	120	240	0.244	0.608	1.993
		450	240	0.568	0.58	0.816
		500	240	0.72	0.574	0.637
P22KT2	30 HP	120	240	0.244	0.608	1.993
		450	240	0.568	0.58	0.816
		500	240	0.72	0.574	0.637
P30KT2	40 HP	50	240	0.194	0.626	2.581
		165	240	0.252	0.574	1.822
		500	240	0.488	0.538	0.882
P37KT2	50 HP	100	240	0.3	0.598	1.594
		325	240	0.536	0.566	0.844
		500	240	0.776	0.546	0.562
P45KT2	60 HP	100	240	0.3	0.598	1.594
		325	240	0.536	0.566	0.844
		500	240	0.776	0.546	0.562

Practical aspects of peak voltage on motors

480V

FC 202	Rating	Cable length [Ft]	voltage [V]	Rise time [µsec]	Vpeak [kV]	dV/dt [kV/µsec]
P1K5T4	2 HP	16	400	0.64	0.69	0.862
		165	400	0.47		0.985
		500	400	0.76	1.045	0.947
P4K0T4	5 HP	16	400	0.172	0.89	4.156
		165	400	0.31		2.564
		500	400	0.37	1.19	1.77
P7K5T4	10 HP	16	500	0.04755	0.739	8.035
		165	500	0.207		4.548
		500	500	0.6742	1.03	2.828
P11KT4	15 HP	165	480	0.192	1.3	5.416
		325	480	0.612	1.3	1.699
		500	480	0.512	1.29	2.015
P15KT4	20 HP	120	480	0.396	1.21	2.444
		325	480	0.844	1.23	1.165
		500	480	0.696	1.16	1.333
P18KT4	25 HP	120	480	0.396	1.21	2.444
		325	480	0.844	1.23	1.165
		500	480	0.696	1.16	1.333
P22KT4	30 HP	120	480	0.312		2.846
		325	480	0.556	1.25	1.798
		500	480	0.608	1.23	1.618
P30KT4	40 HP	165	480	0.288		3.083
		325	480	0.492	1.23	2
		500	480	0.468	1.19	2.034
P37KT4	50 HP	325	480	0.68	1.24	1.426
		500	480	0.712	1.2	1.334
P45KT4	60 HP	16	480	0.368	1.27	2.853
		165	480	0.536	1.26	1.978
		500	480	0.712	1.2	1.334
P55KT4	75 HP	165	480	0.256	1.23	3.847
		165	480	0.328	1.2	2.957
		500	480	0.96	1.15	1.052
P90KT4	125 HP	16	480	0.371	1.17	2.523
P110 – P250, T4	150 – 350 HP	325	400	0.34	1.04	2.447
P315 – P1M0, T4	450 – 1200 HP	325	400	0.61	0.942	1.233

690V

FC 202	Rating	Cable length [Ft]	voltage [V]	Rise time [µsec]	Vpeak [kV]	dV/dt [kV/µsec]
P110 – P400, T7	110 – 400 kW	100	575	0.23	1.313	2.75
		100	690 [1)]	1.72	1.329	0.64
P450 – P1M2, T7	450 – 1200 kW	100	690	0.57	1.611	2.261
		100	575	0.25		2.51
		100	690 [1)]	1.13	1.629	1.15

[1)] *With Danfoss dV/dt filter.*

Technical

Practical aspects of motor cables

Rated voltage

Peak voltages up to three times the DC link voltage in the Variable Frequency Drive occur in the motor cable. They severely stress the motor cable and the motor insulation. The stress is higher if the Variable Frequency Drive output does not have a dV/dt filter or sine-wave filter.

For this reason, the rated voltage specification of the motor cables should be at least U0/U = 0.6/1 kV. High-voltage insulation testing of cables with this specification is usually performed with a test voltage of at least 3,500 V AC and usually 4,000 V AC, and in practice they have proven to have good resistance to insulation breakdown.

Cable dimensioning

The required cross section of the motor cable depends on the output current of the Variable Frequency Drive, the ambient temperature, and the type of cable installation. Overdimensioning the wire cross section to allow for harmonics is not necessary.

For the selection and dimensioning of cables and conductors, EN 60204-1 and VDE 0113-1 provide current capacity data for wire cross sections up to 120 mm^2. If larger wire cross sections are necessary, useful information can be found in VDE 0298-4.

Motor cable length

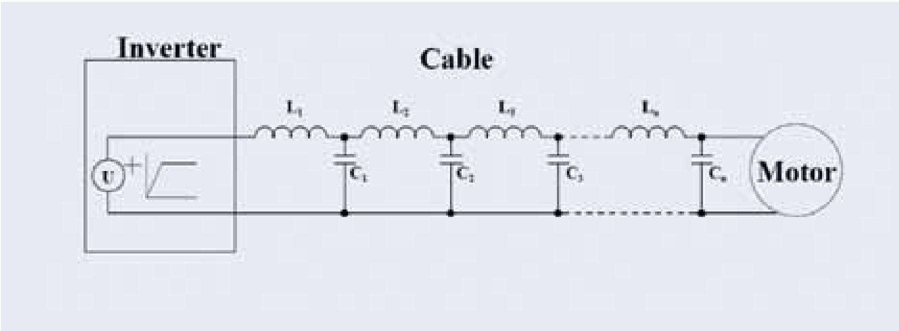
Long motor cables are often found in water and wastewater treatment plants. Variable Frequency Drives and pumps are often installed more than 300 ft. (100 m) apart. In such cases the voltage drop over the cable must be taken into account in cable dimensioning.

Design the system so the full output voltage reaches the motor, even with a long motor cable. The length of the motor cable that can be connected to a standard Variable Frequency Drive is typically 150 ft. to 300 ft. (50 to 100 m). Even with these cable lengths, products from some manufacturers cannot provide the full output voltage at the motor.

If users need cables longer than 300 ft. (100 m), there are only a few manufacturers that can meet this requirement with standard products. Otherwise it is necessary to provide supplementary motor chokes or output filters.

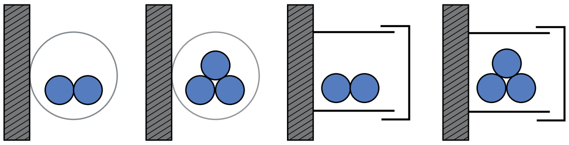
Motor Cable

Cable can be represented as a string of series/parallel inductors and capacitors

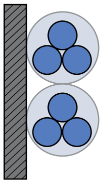


A pulse travels at a speed equal to (1/ √LC) m/s

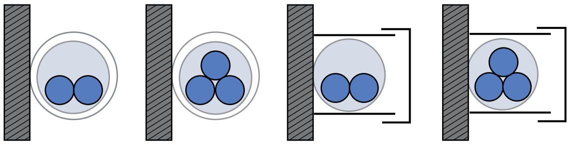
Abstract of EN 60204-1 current rating of wire cross sections



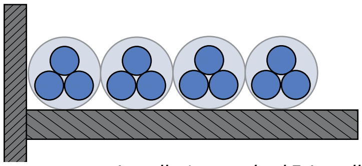
Installation method B1: Conductors in conduit or closed wiring ducts



Installation method C: Direct installation on or in walls and/or ceilings or in cable trays



Installation method B2: Multiconductor cable or multiconductor sheathed cable in conduit or closed wiring ducts



Installation method E: Installation in open air and in cable trays

Practical aspects of motor cables

Energy savings

The voltage drop over a motor cable, as well as the resulting heat dissipation, is nearly proportional to its length and dependent on the frequency.

Accordingly, you should keep cable runs as short as possible and dimension the wire cross-sections no larger than is electrically necessary.

Cables with suitable shielding

Shielded cables should have a shield coverage of at least 80%.

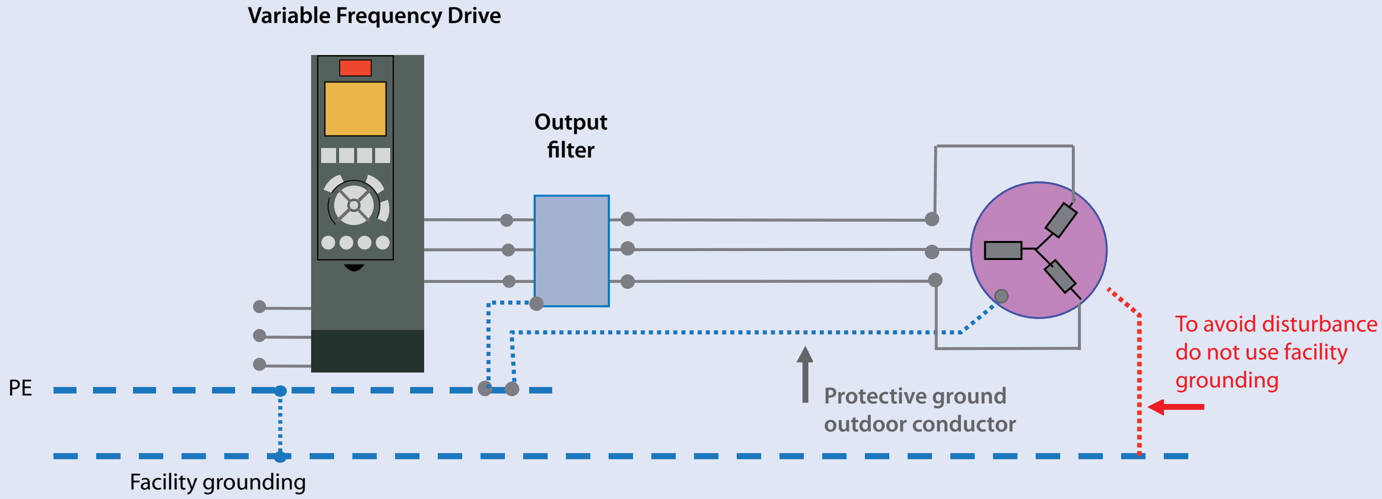
AWG	Area		NEC copper wire ampacity with 60/75/90°C insulation
	(kcmil)	(mm2)	
0000 (4/0)	212	107	195/230/260
000 (3/0)	168	85	165/200/225
00 (2/0)	133	67.4	145/175/195
0 (1/0)	106	53.5	125/150/170
1	83.7	42.4	110/130/150
2	66.4	33.6	95/115/130
3	52.6	26.7	85/100/110
4	41.7	21.2	70/85/95
5	33.1	16.8	
6	26.3	13.3	55/65/75
7	20.8	10.5	
8	16.5	8.37	40/50/55
9	13.1	6.63	
10	10.4	5.26	30/35/40 (but use a 30 A OCPD)
11	8.23	4.17	
12	6.53	3.31	25/25/30 (but use a 20 A OCPD)
13	5.18	2.62	
14	4.11	2.08	20/20/25 (but use a 15 A OCPD)
16	2.58	1.31	—/—/18
18	1.62	0.823	—/—/14
20	1.02	0.518	
24	0.404	0.205	

Note: Consult the manufacturer regarding the lengths of cables that may be connected to the Variable Frequency Drive and the expected voltage drop.

With a standard VLT® AQUA Drive Variable Frequency Drive, you can connect a shielded cable up to 500 ft. long or an unshielded cable up to 300 m long and still have the full voltage at the motor.

Practical aspects of grounding

The importance of grounding



A grounding plan should always be generated for every system or facility.

Grounding measures are generally imperative in order to fulfil the statutory requirements of the EMC and Low Voltage directives. They are a prerequisite for the effective use of other measures, such as shielding and filters. Other measures are of no benefit without good grounding. For this reason, the grounding arrangements must be checked and verified for proper EMC implementation before retrofitting shielding or filters and as the first step in troubleshooting.

Electrically conductive materials

Operators must ensure that metallic surfaces are grounded with low-impedance connections. In terms of EMC, the decisive factor is not the cross-section of the conductor but instead its surface area, since high-frequency currents flow on the surface due to the skin effect. The portion with the smallest conductor surface area is what limits the ability to drain leakage currents. Grounded surfaces have a shielding effect and reduce the amplitude of ambient electromagnetic fields.

Star-configured grounding system

All grounded points and components must be connected to the central grounding point as directly as possible, such as by means of a potential equalisation rail. This results in an grounding system in which all connection points are connected radially to the grounding point. This grounding point must be defined unambiguously.

Contact points

After paint and corrosion have been removed, connections must be made to contact points using a large surface area. Serrated washers are better for this purpose than plain washers. Tin-plated, zinc-plated or cadmium-plated components should be used in preference to painted components. Multiple contacts for the shield connection must be provided in connectors.

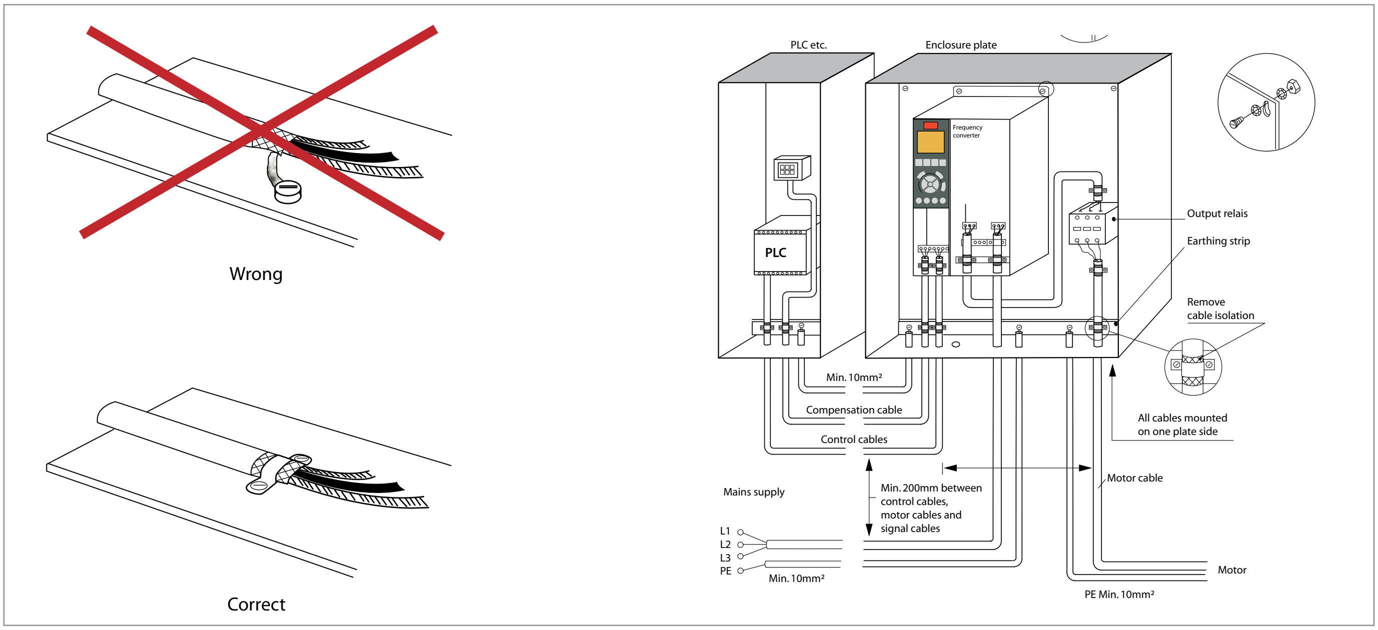
Conductor surface area

A large conductor surface area for draining high-frequency currents can be obtained by using fine stranded wire, such as high-flexibility instrument wire, or by using special grounding straps or cables. Braided grounding straps are often used nowadays in practice; they replace the rigid conductors used in the past. These straps have a significantly higher surface area with the same cross-section.

Note: System grounding has a substantial effect on smooth, trouble-free facility operation. Ground loops must be avoided. Good potential equalisation is essential. Generate a suitable grounding plan as early as the design and projecting engineering stage.

Practical aspects of shielding

The importance of shielding



The purpose of shielding is to reduce the magnitude of radiated interference (which may affect adjacent systems or components) and to improve the interference immunity of individual devices (immunity to interference from external sources).

Implementation of shielding measures in existing systems (e.g. cable replacement or additional enclosures) is possible only at considerable expense. Manufacturers of Variable Frequency Drives usually provide suitable information regarding compliance with statutory limits, which also includes information on additional measures that may be necessary, such as shielded cables.

Variable Frequency Drives generate steep-edged pulses on their outputs. These pulses contain high-frequency components (extending into the gigahertz range), which cause undesirable radiation from the motor cable. This is why shielded motor cables must be used. The task of the shield is to "capture" the high-frequency components and conduct them back to the interference source, in this case the Variable Frequency Drive.

Shielded cables and wiring

Even good shielding that complies with the limits does not fully eliminate the radiation. In the near-field region, you can expect to find electromagnetic fields that components and system modules located in this environment must be able to withstand without any degradation of their operation. Here the standard requires conformance to the limits at a specified distance (e.g. 30 dB at a distance of 10 m for Class B). With regard to the level of the allowable limit, the standard distinguishes between use in 1st environment (residential environment) and 2nd environment (industrial environment). For detailed information, see "The operating site is the decisive factor" section of this manual on page 188.

Shield connection

The cable shield must be connected all the way around to achieve effective cable shielding. EMC (grounding) cable glands or grounding cable clamps can be used for this purpose. They fully surround the shield and connect it to ground over a large area. The shield must be routed directly to the grounding point and clamped firmly over a large area and the connection should be kept as short as possible at each end of the cable.

All other connection methods degrade the effectiveness of the shield. Users often twist the shield braid into a pigtail and use a clamping terminal to connect it to ground. This form of connection creates a high transfer impedance for high-frequency signal components, which causes interference to be radiated from the shield instead of being fed back to the source. As a result, the shielding effect may be reduced by as much as 90%.

Shield gaps

Shield gaps such as terminals, switches or contactors must be bridged by connections with the lowest possible impedance and the largest possible surface area.

Practical aspects of shielding

Ground connection
The ground connection of a shield is crucial for its effectiveness. For this reason, serrated washers or split washers must be fitted under enclosure assembly screws and painted surfaces must be scraped clean in order to obtain a low-impedance contact. Anodised aluminium enclosures, for example, provide inadequate ground bonding if plain washers are used under the fastening screws. Ground and ground leads should be made from wire with a large cross-section, or better yet from multi-cored grounding wire. If wire cross-sections less than 10 mm² are used with low-power motors, a separate PE line with a cross-section of at least 10 mm² must be run from the Drive to the motor.

Motor supply cable
In order to comply with radio frequency interference limits, cables between Variable Frequency Drives and motors must be shielded cables with the shield connected to the equipment **at both ends**.

Signal cable
The distance between the motor cable and the signal cable should be more than 8 in., and the mains cable and motor cable should be routed separately as much as possible. Interference effects decrease significantly with increasing distance. Additional measures (such as divider strips) are essential with smaller separations. Otherwise interference may be coupled in or transferred. Control cable shields must be connected at both ends in the same way as motor cable shields. In practice, single-ended grounding may be considered in exceptional cases. However, it is not recommended.

Types of shields
Variable Frequency Drive manufacturers recommend using shielded cable to shield the wiring between the Variable Frequency Drive and the motor. Two factors are important for selection: the shield coverage and the type of shielding.

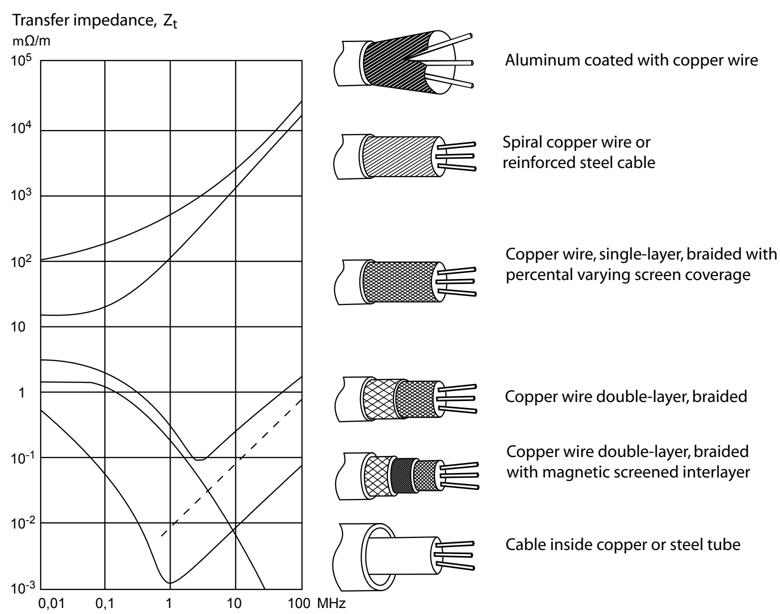
The shield coverage, which means the amount of cable surface covered by the shield, should be at least 80%.

With regard to the shield type, a single-layer braided copper shield has proven to be extremely effective in practice. Here it is important that the shield is braided. By contrast, a wound copper wire shield (such as type NYCWY) leaves long slit-shaped areas uncovered, and HF components can easily escape through these gaps. The surface area for leakage currents is also significantly smaller.

Shielding is available in bulk for retrofitting. It can be pulled over the cable to provide the desired shielding effect. For short connections, metal hoses or pipes can be used as an alternative. Cable ducts can replace shielding only under certain conditions (a radiation-proof duct with good cover contact and a good connection between the duct components and ground).

Cables with double shielding further improve the attenuation of emitted and radiated interference. The inner shield is connected at one end, while the outer shield is connected at both ends. Twisted conductors reduce magnetic fields.

Shielded cables with twisted conductors can be used for signal lines. The attenuation of the magnetic field increases from around 30 dB with a single shield to 60 dB with a double shield and to approximately 75 dB if the conductors are also twisted.



There are many types of shielded cable. Only some of them are suitable for use with Variable Frequency Drives.

Step 4: Practical aspects of Variable Frequency Drive selection

Basic design

In practice, designers and operators often select Variable Frequency Drives solely on the basis of their rated power in kilowatts. However, Variable Frequency Drives must always be selected on the basis of the actual rated motor current I_{nom} under the highest system load. This selection criterion is more reliable because motor output power depends on the mechanical shaft load instead of the electrical input power.

The motor efficiency is also not taken into account. By contrast, the rated capacity of Variable Frequency Drives (in kilowatts) is based on the rated power P_{nom} of four-pole motors.

In addition, motors in the same power class may have different rated currents, depending on the motor manufacturer and the efficiency class. For example, the rated current of a 15 HP motor is
21 A. However, the rated current alone is not sufficient to determine the corresponding electrical input power. The Variable Frequency Drive must also supply a sufficiently high motor voltage. With a 480 V mains system, this means a full 480 V at 60 Hz on the motor terminals. There are still Variable Frequency Drives on the market that are not able to achieve this. The output voltage is reduced due to voltage drops in the filters, chokes and motor cable. If the output voltage is reduced to 390 V, for example, the motor needs more current to produce the required power. As the losses increase quadratically with the current, the motor heats up more, which reduces its service life. Of course, the user must also take the increased current demand into account in the design.

Remark: A special modulation method is used in VLT® AQUA Drive units to provide the full motor voltage. Even with 10% undervoltage on the mains, the rated motor voltage and rated motor torque are maintained.

Constant or variable torque

The load driven by the motor is the key factor for selecting the right Variable Frequency Drive. A distinction must be made between loads whose torque characteristic increases quadratically with increasing speed (such as centrifugal pumps and fans) and loads that can require high torque from the motor over their entire working range, even at low speeds (such as Roots blowers).

Most drive systems in water and wastewater treatment plants have a load curve that increases quadratically with speed until the rated torque is reached. In order to achieve efficiency-Optimized operation under these load conditions, the Variable Frequency Drive provides a motor voltage that increases quadratically with the motor rotating field frequency.

For applications with a constant high torque, in most cases it is also necessary to consider the requirement for acceleration or start-up under heavy load. In this case, the Variable Frequency Drive must be able to supply extra drive power to the motor for a short time, in addition to the rated motor torque, for example to enable a pump in which sludge has collected and deposited to overcome the resulting static friction. This briefly available maximum torque is called overload torque.

In applications that do not need start-up torque significantly higher than the rated motor torque, a relatively low overload capacity is generally adequate (for example, Roots blowers with unloaded start-up require only 110% of the rated motor torque).

Note: Displacement pumps, Roots blowers and compressors are not classified as fluid flow machines. Due to their operating principle, Variable Frequency Drives for use with such equipment should be designed for constant torque.

Practical aspects of load curves for various applications

Characteristic curves and applications

Constant-torque applications

Normal starting torque (110% overload)

Dosing pumps
Roots blowers
Surface ventilators
Circulation pumps
Lateral channel compressors

High starting torque [150% overload]

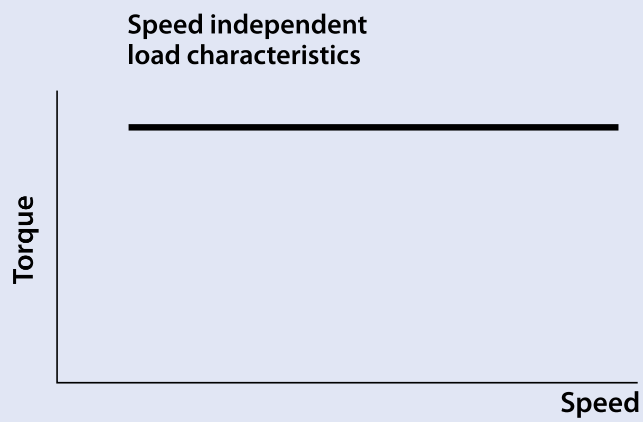
Axial piston compressors
Rotary piston compressors
Eccentric screw pumps (observe starting torque)
Piston pumps
Stirrers and mixers
Sludge dewatering presses
Compressors (except turbocompressors)
Displacement pumps
Gear pumps
Gearwheel rotary valves

Variable-torque applications

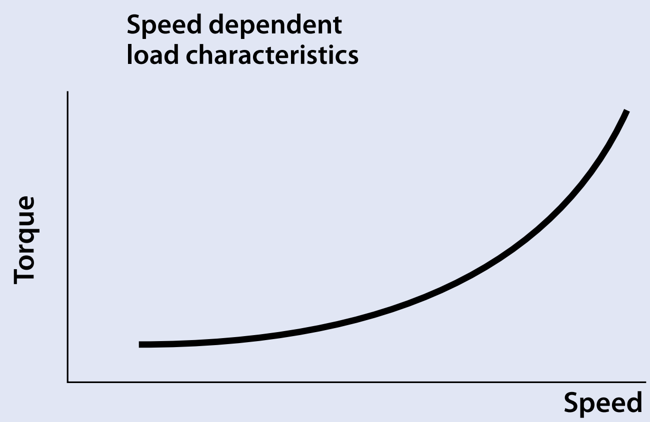
Centrifugal pumps
Well pumps[1]
Pressure booster pumps
Filter feed pumps
Groundwater pumps
Hot water pumps
Heating pumps (primary and secondary circuit)
Ducted impeller pumps (solids)
Cooling water pumps (primary and secondary circuit)
Cistern pumps
Sludge recirculation pumps
Sump pumps[1]
Turbocompressors
Submersed pumps[1]
Surplus sludge pumps
Fans

Note: Ask the pump or motor manufacturer for the torque characteristic curve.

Constant torque



Variable torque



Practical aspects of multi-motor operation (special case)

Design

If the operator's objective is to run several motors in parallel from the same Variable Frequency Drive, the following factors must be taken into account in the design:

The rated currents and powers of the motors must be added together.

Selection of a suitable frequency Drive is based on the two sums power and current.

For motor protection, the operator must connect the PTC thermistors of the motors in series, and the Variable Frequency Drive will then monitor this series-connected signal.

The connected motors operate the same in terms of their rated speed. This means that the drive drives all of them at the same frequency and with the same voltage.

Note: Due to the fact that the resistances of the series-connected PTC thermistors add together, there is no point in using the thermistor monitoring capability of the Variable Frequency Drive for motor protection if more than two motors are operated in parallel.

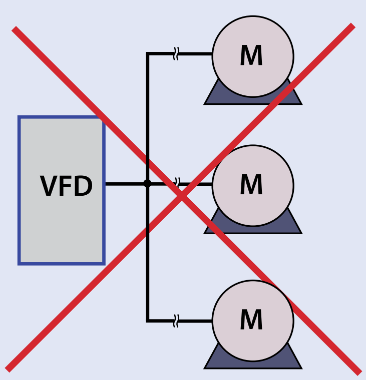
Cable routing

To be avoided with multi-motor operation: Parallel conductors cause additional capacitance. For this reason, users should always avoid this type of connection.

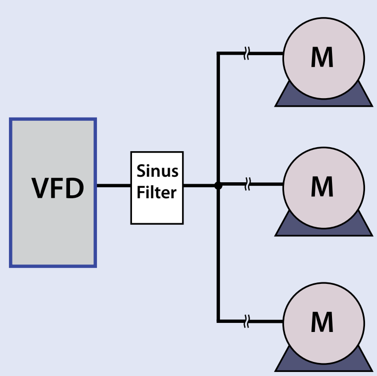
The working currents drop because the LC filter blocks the clock frequency. This allows the motors to be connected in parallel. The motor cables may also be routed together over longer distances if necessary.

Recommended for multi-motor operation: daisy-chain the motor cable from one motor to the next.

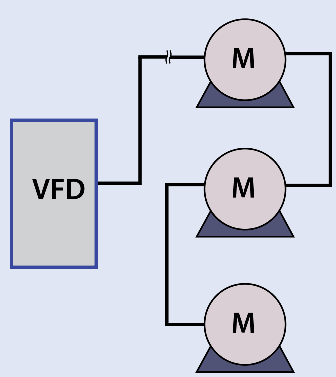
To be avoided



Recommended



Recommended



Practical aspects of EMC measures

Putting theory into practice

All Variable Frequency Drives are wideband interference sources, which means they emit interference over a wide frequency range. Facility operators can reduce the amount of interference emitted by Variable Frequency Drives by taking suitable measures. For example, they can ensure trouble-free facility operation by using RFI filters and mains chokes.

With some makes, these components are already installed in the Variable Frequency Drive. With other makes, the plant engineer must allow additional space (which is always at a premium) for this in the cabinet.
For general information regarding EMC, low-frequency mains interference and radio-frequency interference, see page 179 of this manual.

Note: Good-quality Variable Frequency Drives are equipped with good RFI protection and mains interference reduction components as standard. These components account for approximately 15 to 20% of the price of a Variable Frequency Drive.

Radio frequency interference

Practical recommendations

See page 187 of this manual for extensive information on radio frequency interference. The main objective in practice is to obtain systems that operate stably without interference between their components. Nevertheless, it often happens that after remodelling and/or the introduction of new components, it is no longer possible to make sensitive measurements without interference and/or the instrument signals are corrupted. These pitfalls are exactly what must be avoided.

In order to achieve a high level of interference immunity, it is therefore advisable to use Variable Frequency Drives with high-quality RFI filters. They should fulfil the category C1 requirements specified in the EN 61800-3 product standard and thereby conform to the Class B limits of the EN 55011 generic standard.

Additional warning notices must be placed on the Variable Frequency Drive if RFI filters that do not correspond to category C1, but instead only category C2 or lower, are used. The responsibility ultimately rests with the operator.

As mentioned on page 187, in case of problems the inspection authority will always base its recommendations for eliminating interference on the A1/A2 and B limits for interference defined in the EN 55011 generic standard according to the operating environment. The operator bears the costs of remedying EMC problems. The operator is ultimately responsible for the appropriate classification of devices with respect to these two standards.

Due to the use of cables to transmit signals and power, conductive interference can easily spread to other parts of the system or facility if adequate measures are not taken. By contrast, interference radiated directly from the device or the cable is spatially confined. Its intensity decreases with every centimetre of distance away from the interference source. For this reason, installation of the drive in a suitable cabinet in compliance with EMC rules is usually sufficient to limit radiated interference. However, the system operator should always provide a suitable filter to limit conducted interference.

Two approaches to RFI filters

In practice, there are two approaches to RFI filters. Some manufacturers install RFI filters in their equipment as standard, while other manufacturers offer them as options. Built-in filters not only save a lot of space in the cabinet, but also eliminate additional costs for fitting, wiring and material. However, the most important advantage is the perfect EMC conformance and cabling of integrated filters.

Optional external RFI filters installed ahead of the Variable Frequency Drive also cause an additional voltage drop. In practice, this means that the full mains voltage is not present at the Variable Frequency Drive input and overdimensioning may be necessary. Costs are incurred for assembly, cabling and the material, and EMC conformance is not tested.
Another significant factor is the maximum length of the connected motor cable for which the Variable Frequency Drive still complies with the EMC limits. In practice, this can range from 3 feet to 150 feet. Better RFI filters are necessary with longer cable lengths.

Note: To ensure interference-free operation of the drive system, you should always use a category C1 RFI filter. VLT® AQUA Drive units are supplied as standard with built-in RFI filters conforming to category C1 (EN 61800-3) for use with 480 V mains systems and power ratings up to 125 HP or category C2 for power ratings of 150 to 900 HP. VLT® AQUA Drive units conform to C1 with shielded motor cables up to 150 ft. or C2 with shielded motor cables up to 500 ft.

Practical aspects of EMC measures

Mains interference

The DC link affects mains interference

See page 181 for a description of the fundamental aspects of low frequency mains interference and measures to reduce it. The increasing use of rectifier loads aggravates the occurrence of mains interference. Rectifiers draw non-sinusoidal currents from the mains. Mains interference due to Variable Frequency Drives comes primarily from the capacitors in the DC link due to their charging currents. Here the current always flows in brief pulses near the peaks of the mains voltage. Due to the high current, the mains voltage sags somewhat during brief intervals and the mains voltage is no longer sinusoidal. To keep the mains power clean, it is present necessary to limit the fifth harmonic of the current to a level of approximately 40% THD. The requirements are described in the EN 61000-3-12 standard.

In application scenarios in which the operator must reduce mains interference to a THD level less than 10% or 5%, optional filters and active measures may be used in order almost fully to attenuate mains interference from the equipment.

Reduction measures

Various options are available to facility operators in order to restrict mains interference. They can be classified into passive and active measures, and they differ in particular in terms of project engineering.

Mains chokes

The usual and least expensive way to reduce mains interference is to install chokes either in the DC link or at the input of the Variable Frequency Drive. Fitting a mains choke in the Variable Frequency Drive extends the duration of current flow for charging the DC link capacitors, reduces the current amplitude, and significantly reduces the distortion of the mains voltage (lower mains interference). The degree of distortion of the mains voltage depends on the quality of the mains system (transformer impedance and line impedances). The figures in the following table can be regarded as a guideline for the connected Variable Frequency Drive load (or other three-phase rectifier load) as a percentage of the rated power of the supply transformer. If the maximum value is exceeded, you should consult the Variable Frequency Drive manufacturer.

In addition to reducing mains interference, mains chokes increase the life of the DC link capacitors because they are charged more gently due to the limitation of the current peaks. Mains chokes also improve the ability of the Variable Frequency Drive to withstand the stress of mains transients. Wire cross sections and mains fuse or circuit breaker ratings can be smaller due to the lower input currents. However, chokes add to the cost and take up space.

Remark: A mains choke in the form of a DC link choke is integrated in all VLT® AQUA Drive Variable Frequency Drives as standard. This reduces the THD from 80% to 40%, thereby fulfilling the requirement of EN 61000-3-12. The effect is therefore comparable to that of a three-phase mains choke (UK 4%). There is no voltage drop that must be compensated by the Variable Frequency Drive; the full voltage (230 V or 480 V) is available to the motor.

The above maximum load figures are recommended guideline values, which based on experience allow trouble-free facility operation.

Practical aspects of EMC measures

A low harmonic drive Variable Frequency Drive is a Variable Frequency Drive with a built-in active filter that acts on the mains.

Rectifiers with 12, 18, or 24 pulses per cycle

In practice, Variable Frequency Drives with rectifiers having a large number of pulses per cycle are primarily found in the higher power range. They require special transformers for proper operation.

Passive filters

Passive harmonic filters, which consist of LC circuits, can be used in all situations. They have high efficiency, typically around 98.5% or better. The devices are very robust and, with the exception of cooling fans if present, usually maintenance-free. The following must be borne in mind with passive filters. If they are operated with no load, they act as capacitive reactive power sources due to the circulating current flowing in the filter. Depending on the specific application, it may be worthwhile to use a group of filters, possibly with selective connection and disconnection.

Active filters, active front ends and low harmonic drives

An innovative approach, based on improved semiconductor devices and modern microprocessor technology, is to use active electronic filter systems. They constantly measure the mains power quality and use an active current source to feed specific waveforms into the mains system. The net result is a sinusoidal current. Compared with the previously described filter options, the architecture of this new generation of filters is complex because they require fast, high-resolution data acquisition and high computing power.

It is not possible to make a basic recommendation regarding any of the mains interference reduction measures mentioned here. What is important is to make the right decisions during the design and project engineering stage in order to obtain a drive system with high availability, low mains interference, and low radio frequency interference. In any case, the following factors must be carefully analyzed before taking any decisions regarding the reduction measures to be used:

- Mains analysis
- Exact overview of the mains topology
- Space constraints in the available electrical equipment rooms
- Options for main distribution or subdistribution systems

Note: With the complex active measures there is a risk of totally missing the mark,since these measures have the serious drawback that they cause interference in the frequency range above 2 kHz (see page 184).

Practical aspects of residual current devices

AC/DC residual current protective devices

In the United States, the National Electrical Code requires GFCI devices intended to protect people to interrupt the circuit if the leakage current exceeds a range of 4–6 mA of current within 25 ms. A GFCI device which protects equipment (not people) is allowed to trip as high as 30 mA of current; this is known as an Equipment Protective Device (EPD). Europe commonly uses RCD's that have trip currents of 10–300 mA.

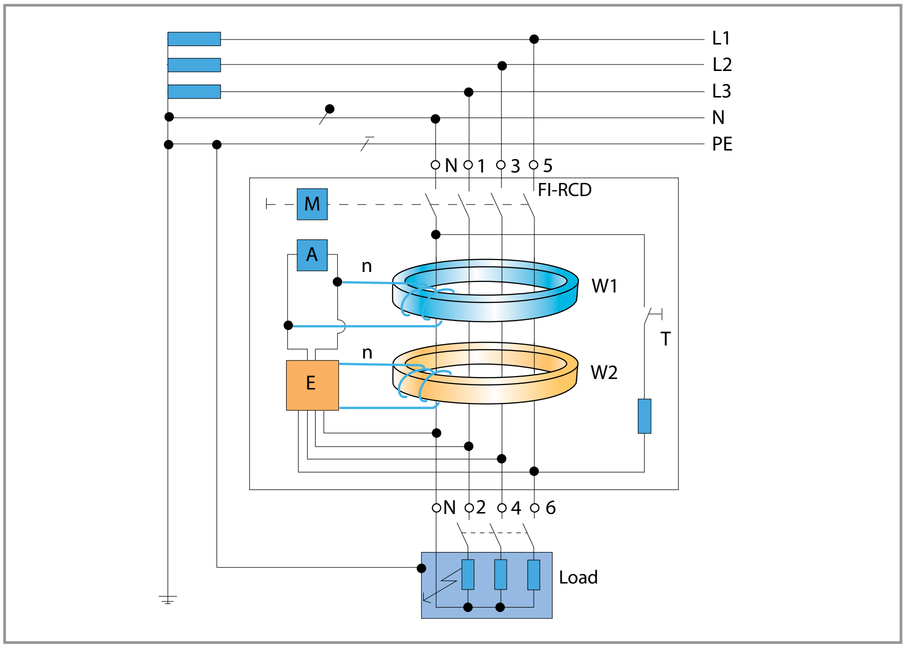
Rules and regulations differ widely from country to country. In the US, the National Electrical Code requires GFCIs for underwater swimming pool lights; construction sites; bathrooms and outdoor areas; garages; near hot tubs or spas; hotel bathrooms; kitchen counter receptacles crawl spaces and unfinished basements; wet bar sinks; laundry sinks.

An RCD alone will not detect overload conditions, phase to neutral short circuits or phase-to-phase short circuits (see three phase electric power). Over-current protection (fuse or circuit breaker) must be provided. Circuit breakers that combine the functions of an RCD with overcurrent protection respond to both types of fault. These are known as RCBOs, and are available in 1, 2, 3 and 4 pole configurations. RCBOs will typically have separate circuits for detecting current imbalance and for overload current but will have a common interrupting mechanism.

Ground Fault Circuit Interrupter (GFCI) and Residual Current Breaker with Overload (RCBO) are devices which combines Residual Current Device (RCD) with a Circuit Breaker or miniature circuit breaker (MCB) which both detects supply imbalance and limits the current that may supplied.

Electrical sockets with included RCDs are becoming common. In the U.S. these are required by law in wet areas.

If it is desired to protect an individual circuit an RCBO (Residual-current Circuit Breaker with Overcurrent protection) can be used. This incorporates an RCD and a miniature circuit breaker in one device.



Technical

Practical aspects of grounding and motor protection

Grounding measures in practice

Grounding measures are described in detail in the “Motors and cabling” section of Step 3 (page 208).
If the application requires external filters, they must be fitted as close to the Variable Frequency Drive as possible. The cable between the filter and the equipment should be a shielded cable, and the filter should be connected to the ground conductor on the mains side and the equipment side. It is also recommended to mount the filter flush with the surface and provide a low-impedance connection between the filter housing and ground.

Filters generate leakage currents that can be considerably higher than the rated value in case of a fault (phase drop-out or asymmetric load). To avoid hazardous voltages, filters must therefore be grounded before power is switched on. With leakage currents of 3.5 mA and above, in accordance with EN 50178 or EN 60335 either:

- the cross-section of the protective ground conductor must be 10 mm² or more;
- or the protective ground conductor must be monitored for an open circuit;
- or a second protective ground conductor must be installed in addition.

The leakage currents here are high-frequency interference signals. This requires grounding with low-impedance links bonded to a large surface area and connected to ground potential by the shortest possible route.

Note: Even the best measures to counter mains interference and radio frequency interference are of no use if their implementation in the installation does not conform to good EMC practice. Interference problems are inevitable in such cases.

Motor protection and motor PTC thermistor

Variable Frequency Drives assume the task of protecting the motor against excessive current. Thermistor sensors or thermal cutouts in the motor winding are used to provide the best possible motor protection. The signal is monitored via suitable input terminals on the Variable Frequency Drive.
Thermistors compliant with DIN 44081 or DIN 44082 are designed to have a resistance within a certain range at the rated response temperature (RRT) (RRT – 5°C < 550 Ω; RRT + 5°C > 1330 Ω). Many drives have functions suitable for monitoring such thermistors. In the case of motors operated in explosion hazard areas, thermistor monitoring is allowed only with certified trip devices (see page 30).

The protective function of motor protection switches is limited to direct mains operation. In electrical systems with Variable Frequency Drives, they can only provide motor protection in an emergency situation when the Variable Frequency Drive is bypassed by a suitable circuit. The motor protection function of the switch is ineffective with Variable Frequency Drive operation. Nevertheless, with proper dimensioning it can be put to good use with drive-driven motors as a sort of three-phase circuit breaker that only protects the wiring.

Remark: Many Variable Frequency Drives have a supplementary function called “thermal motor image”. The motor temperature is calculated from the motor data and the amount of power transferred to the motor. This function is usually implemented very conservatively and tends to trigger earlier than absolutely necessary. The actual ambient temperature at the start of the calculation process is usually not taken into account. However, this function can be used to provide a simple form of basic protection if no other form of motor protection is available.

Note: With VLT® AQUA Drive, terminals 50 and 54 are normally designated for connecting thermistors. This port is suitable for motor temperature monitoring using three to six PTC bead thermistors (standard configuration: three beads per motor).

Practical aspects of operator control and data display

Simple operating concept

The basic technology of all Variable Frequency Drives is the same, so ease of use is a decisive factor. Many functions, as well as integration in machines or systems, require a simple operating concept. It must fulfil all requirements for easy and reliable configuration and installation.
The options range from simple and inexpensive numerical displays to convenient control panels that display data in text form. Simple control panels are adequate for the basic task of observing operating parameters such as current or voltage.

By contrast, control panels with convenience features allow the display to show additional parameters or present them all at the same time.
Clear grouping of functions and easy manual operation are also possible, as well as options for access via software,
a field bus, or even remote maintenance using a modem or the Internet.
A modern Variable Frequency Drive should be able to combine all of the operating concepts mentioned below in a single device or to make them possible and it should at least allow switching between manual and remote control at all times.

design award winner

This control panel won the international iF Design Award for user friendliness in 2004. The LCP 102 was selected for this distinction from among 1000 entries from 34 countries in the category "man-machine and communication interfaces".

Graphic control panels offer ease of use and can display information in plain text.

Easy commissioning
Features such as Danfoss Smart Start considerably simplify the start-up of drives. It guides the user through the basic drive settings.

Practical aspects of operator control and data display

Operation under local control

The basic requirement is support for local operation using a local control panel. Even in the era of networked communication, there are many tasks that require the ability to control the equipment directly – such as commissioning, testing, process optimization and on-site maintenance activities in facilities.

In each of these cases, the operator or technician may need to be able to alter local values in order to incorporate the changes in the system directly and perform related tasks, such as fault diagnosis. For this purpose, the control panel should provide a simple and intuitive man-machine interface.

Clear display

The ideal solution is a graphic display, since it allows the user to select the preferred language for the user interface and the basic display mode can show the essential parameters of the actual application.

To maintain clarity, this status information must be limited to the essential parameters and it must be possible to adapt or change the parameters at all times. It is also helpful to be able to block or hide certain functions according to the knowledge level of the operator and to limit parameter display and the ability to modify parameters to what is actually necessary for process adjustment and control.

With the large number of functions provided by modern Variable Frequency Drives, which often have several hundred parameters for optimal adaptation, this reduces operator errors and thereby reduces expensive downtime and facility outages. Likewise, the display should have an integrated help function for the individual functions so that support is available to the commissioning technician or service technician at all times, especially for rarely used parameters, in order to eliminate operator errors as much as possible here as well.

For the optimal use of integrated diagnostic functions, it is very helpful to be able to display graphic plots ("scope function") in addition to alphanumeric data. In many cases this form of data display, such as ramp shapes and/or torque curves, makes troubleshooting easier.

Uniform concept

In water and wastewater treatment plants, a large number of Variable Frequency Drives are used in a wide variety of applications. The drives, which usually are mostly from the same manufacturer, differ primarily in their power ratings and therefore in their size and appearance. A uniform operator interface for the Variable Frequency Drives, with the same control panel over the entire power range, offers advantages for plant engineers and facility operators. The basic principle is that simplifying the operator interface makes commissioning and troubleshooting (if necessary) faster and more effective. Consequently, concepts based on plug-and-play control panels have proven their value in practice.

Integrated in the cabinet door

In many facilities in which Variable Frequency Drives are installed in cabinets, facility engineers should integrate the control panels in the cabinet doors to provide process visualisation. This is only possible with Variable Frequency Drives that have detachable control panels. With the control panel integrated in the cabinet door using a mounting frame, the Variable Frequency Drive can be controlled without opening the cabinet door and its operating state and process data can be read out.

Note: Ensure that the Variable Frequency Drive you plan to engineer into the system has the right operating concept. A design that provides the greatest possible ease of use for parameter configuration and programming is an advantage, since nowadays the functionality of the drive is not the only significant factor. Fast, easy user operation, preferably intuitive, is also important. This is the only way to reduce the effort, and thus the cost of familiarisation and the subsequent interaction times of employees responsible for working with Variable Frequency Drives.

Variable Frequency Drive parameters can also be configured and read out with the cabinet door closed.

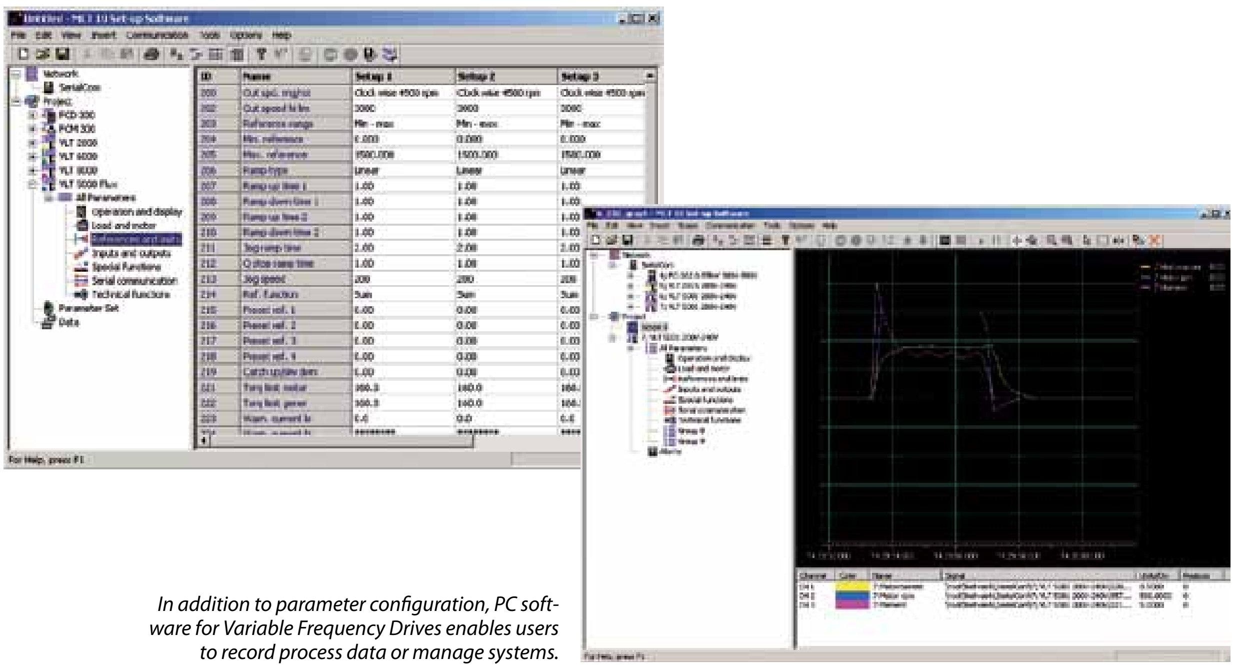
Practical aspects of control and parameter configuration with a PC

Extended options

In addition to operation using a control panel, modern Variable Frequency Drives usually support parameter configuration and data readout by a PC program. This software usually runs under Windows and supports several communication interfaces. It enables data exchange over a traditional RS 485 interface, a field bus (Profibus DPV1, Ethernet, etc.) or a USB interface.

A clearly structured user interface provides a quick overview of all the drives in a system. A good program also allows users to manage large systems with many drives. Parameter configuration is possible online and offline. Ideally, the program also allows documents to be integrated into the system. Among other things, this makes it possible to access system electrical diagrams or operating manuals from the program.

Remark: The VLT® MCT 10 program is a Windows-based engineering tool for easy system engineering, parameter configuration and programming of VLT® AQUA Drive units.



In addition to parameter configuration, PC software for Variable Frequency Drives enables users to record process data or manage systems.

Technical

Practical aspects of data exchange

Bus systems

Modern Variable Frequency Drives are intelligent, which enables them to handle many tasks in drive systems. Nevertheless, even now many devices operate with only four data points in a control system or under control of a PLC and act only as speed controllers. This means that operators do not make full use of the many useful functions and do not have access to stored system data. However, it is easy for users to exploit the full potential of Variable Frequency Drives by using a field bus link, such as Profibus, to integrate them in the control system. With just one hardware data point, this gives users full access to all parameters of the installed Variable Frequency Drives. Cabling and commissioning are simpler, which leads to cost savings from the installation phase onward. A large volume of data for effective facility management is available. Decoding of collective fault messages allows faults to be diagnosed, even remotely and the right fault correction actions to be initiated.

Better alarm management

Detailed alarm messages simplify the pin-pointing of possible fault causes and thereby provide effective support for remote facility monitoring. Remote maintenance using modems or the Internet allows state and/or fault messages to be displayed quickly, even with remote systems or system components.

Better facility management

The control room operator is able to monitor and adjust all Variable Frequency Drive settings remotely. Status data, such as the output frequency or power consumption, can be read out and processed at any time. Additional data for effective energy and peak load management is available without additional components.

Lower installation costs

It is not necessary to equip every Variable Frequency Drive with a display. The user or operator can access all relevant Variable Frequency Drive data via the control system.
Simplified wiring with two-wire connections.
Unused Variable Frequency Drive inputs and outputs can be used as I/O ports to integrate other components, such as sensors, filters and limit switches, into the control system.
No need for input and output components, since a single hardware data point is sufficient for controlling the Variable Frequency Drive.
Monitoring functions such as motor thermistor monitoring, dry pump protection, etc., as well as output and operating hours counters, are available without additional components.

Simplified commissioning

Parameter configuration is performed from the control room. All settings can be copied quickly and easily from one Variable Frequency Drive to another. A persistent backup copy of the settings can be stored in the display memory. Designers and commissioning staff can document the settings at the press of a button.

Remark: The RGO 100 Remote Guardian Option sets new standards for monitoring, maintenance and alarm processing for Variable Frequency Drives in one or more facilities. It supports typical tasks such as remote action, remote maintenance, alarm processing and data logging for system configuration and system monitoring.

Practical aspects of additional selection factors

Process controller

Modern Variable Frequency Drives are intelligent drive controllers. They can perform tasks and functions traditionally handled by PLCs. The implemented process controllers can also be used to build independent high-precision control loops. This facility is especially useful when retrofitting systems with insufficient PLC capacity or no PLC at all.
Active process parameter transducers (actual value transmitters for flow, pressure or level) can be powered from the Variable Frequency Drive's 24 V DC control voltage if it has sufficient power capacity.

Maintenance

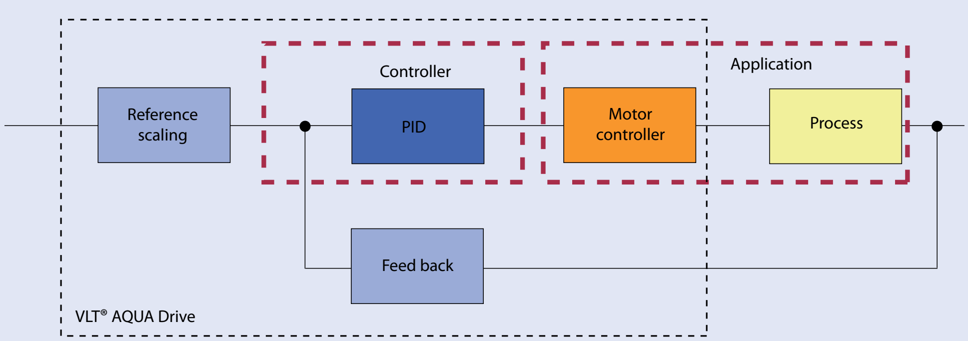
Most Variable Frequency Drives are virtually maintenance-free. High-power Variable Frequency Drives have built-in air filters which must be cleaned from time to time by the operator, depending on the dust exposure.
However, it must be noted that Variable Frequency Drive manufacturers specify maintenance intervals for the cooling fans (approximately 3 years) and capacitors (approximately 5 years) in their equipment.

Remark: Danfoss VLT® Variable Frequency Drive models up to 125 HP are maintenance-free. Models rated at 150 HP or more have air filters integrated in the cooling fans. They must be checked periodically and cleaned as necessary.

Storage

Like all electronic equipment, Variable Frequency Drives must be stored in a dry place. The manufacturer's specifications in this regard must be observed. Some manufacturers specify that the device must be formed periodically. For this purpose, the user must connect the device to a defined voltage for a certain period. This forming is necessary due to the aging of the capacitors in the device's DC link. The aging rate depends on the quality of the capacitors used in the device. Forming counters the aging process.

Remark: Due to the quality of the capacitors used and the flexible, order-specific manufacturing concept, this procedure is not necessary with VLT® AQUA Drive Variable Frequency Drives.



PID process controller block diagram

What VLT® is all about

Danfoss VLT Drives is the world leader among dedicated drives providers – and still gaining market share.

Environmentally responsible

VLT® products are manufactured with respect for the safety and well-being of people and the environment.

All activities are planned and performed taking into account the individual employee, the work environment and the external environment. Production takes place with a minimum of noise, smoke or other pollution and environmentally safe disposal of the products is pre-prepared.

UN Global Compact

Danfoss has signed the UN Global Compact on social and environmental responsibility and our companies act responsibly towards local societies.

EU Directives

All factories are certified according to ISO 14001 standard. All products fulfil the EU Directives for General Product Safety and the Machinery directive. Danfoss VLT Drives is, in all product series, implementing the EU Directive concerning Hazardous Substances in Electrical and Electrical Equipment (RoHS) and is designing all new product series according to the EU Directive on Waste Electrical and Electronic Equipment (WEEE).

Impact on energy savings

One year's energy savings from our annual production of VLT® drives will save the energy equivalent to the energy production from a major power plant. Better process control at the same time improves product quality and reduces waste and wear on equipment.

Dedicated to drives

Dedication has been a key word since 1968, when Danfoss introduced the world's first mass produced variable speed drive for AC motors – and named it VLT®.

Twenty five hundred employees develop, manufacture, sell and service drives and soft starters in more than one hundred countries, focused only on drives and soft starters.

Intelligent and innovative

Developers at Danfoss VLT Drives have fully adopted modular principles in development as well as design, production and configuration.

Tomorrow's features are developed in parallel using dedicated technology platforms. This allows the development of all elements to take place in parallel, at the same time reducing time to market and ensuring that customers always enjoy the benefits of the latest features.

Rely on the experts

We take responsibility for every element of our products. The fact that we develop and produce our own features, hardware, software, power modules, printed circuit boards, and accessories is your guarantee of reliable products.

Local backup – globally

VLT® motor controllers are operating in applications all over the world and Danfoss VLT Drives' experts located in more than 100 countries are ready to support our customers with application advice and service wherever they may be.

Danfoss VLT® Drives experts don't stop until the customer's drive challenges are solved.

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