ENGINEERING TOMORROW

Design Guide

VLT® AutomationDrive FC 302 Enclosed Drives 90–710 kW

drives.danfoss.com

Contents

1 Introduction

1.1 Purpose of this Design Guide

This Design Guide is intended for qualified personnel, such as:

- Project and systems engineers.
- Design consultants.
- Application and product specialists.

The Design Guide provides technical information to understand the capabilities of the VLT® AutomationDrive FC 301/FC 302 for integration into motor control and monitoring systems. Its purpose is to provide design considerations and planning data for integration of the drive into a system. It caters for selection of drives and options for a diversity of applications and installations. Reviewing the detailed product information in the design stage enables developing a well-conceived system with optimal functionality and efficiency.

This manual is targeted at a worldwide audience. Therefore, wherever occurring, both SI and imperial units are shown.

1.2 Trademarks

VLT® is a registered trademark for Danfoss A/S.

1.3 Additional Resources

Various resources are available to understand advanced drive operation, programming, and directives compliance.

- The **Operating Guide** provides detailed information for the installation and start-up of the drive.
- The **Programming Guide** provides greater detail on how to work with parameters. It also contains application examples.
- The **VLT® Safe Torque Off Operating Guide** describes how to use Danfoss VLT® drives in functional safety applications. This manual is supplied with the drive when the Safe Torque Off option is present.
- The **VLT® Brake Resistor MCE 101 Design Guide** describes how to select the optimal brake resistor.
- Supplemental publications, drawings, and manuals are available at www.danfoss.com.

Optional equipment is available that may change some of the information described in these publications. Be sure to follow the instructions supplied with the options for specific requirements.

Contact a Danfoss supplier or visit www.danfoss.com for more information.

1.4 Document Version

The original language of this manual is English. This manual is regularly reviewed and updated. All suggestions for improvement are welcome.

Table 1: Document Version

Edition	Remarks
MG80K1xx	Initial release.

1.5 Conventions

- Numbered lists indicate procedures.
- Bulleted and dashed lists indicate listings of other information where the order of the information is not relevant.
- Bolded text indicates highlighting and section headings.
- Italicized text indicates the following:
  - Cross-reference.
  - Link.
  - Footnote.
  - Parameter name.
  - Parameter option.
  - Parameter group name.
  - Alarms/warnings.
- All dimensions in drawings are in metric values (imperial values in brackets).
- An asterisk (*) indicates the default setting of a parameter.

2 Safety

2.1 Safety

When installing or operating the AC drive, pay attention to the safety information provided in the Quick Installation Guide and the Operating Guide.

⚠ WARNING ⚠

LACK OF SAFETY AWARENESS

This document gives important information on how to prevent injury and damage to the equipment or the system. Ignoring them can lead to death, serious injury, or severe damage to the equipment.

- Make sure to fully understand the dangers and safety measures incurred in the application.

2.2 Safety Symbols

The following symbols are used in this manual:

⚠ DANGER ⚠

Indicates a hazardous situation which, if not avoided, will result in death or serious injury.

⚠ WARNING ⚠

Indicates a hazardous situation which, if not avoided, could result in death or serious injury.

⚠ CAUTION ⚠

Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.

NOTICE

Indicates information considered important, but not hazard-related (for example, messages relating to property damage).

2.3 Qualified Personnel

To allow trouble-free and safe operation of the unit, only qualified personnel with proven skills are allowed to transport, store, assemble, install, program, commission, maintain, and decommission this equipment.

Persons with proven skills:

- Are qualified electrical engineers, or persons who have received training from qualified electrical engineers and are suitably experienced to operate devices, systems, plant, and machinery in accordance with pertinent laws and regulations.
- Are familiar with the basic regulations concerning health and safety/accident prevention.
- Have read and understood the safety guidelines given in all manuals provided with the unit, especially the instructions given in the Operating Guide.
- Have good knowledge of the generic and specialist standards applicable to the specific application.

3 Approvals and Certifications

3.1 Regulatory/Compliance Approvals

This section provides a brief description of the various approvals and certifications that are on Danfoss VLT® AutomationDrive FC 302 Enclosed Drives.

NOTICE

IMPOSED LIMITATIONS ON THE OUTPUT FREQUENCY

From software version 6.72 onwards, the output frequency of the drive is limited to 590 Hz due to export control regulations. Software versions 6.xx also limit the maximum output frequency to 590 Hz, but these versions cannot be flashed, that is, neither downgraded nor upgraded.

3.2 Product Approvals and Certifications

The VLT® AutomationDrive FC 302 Enclosed Drive complies with the required standards and directives. This information can be found on the product nameplate, and on www.danfoss.com.

3.2.1 CE Mark

The drive complies with relevant directives and their related standards for the extended Single Market in the European Economic Area.

Table 2: EU directives applicable to drives

EU directive	Version
Low Voltage Directive	2014/35/EU
EMC Directive	2014/30/EU
Machinery Directive (1)	2006/42/EC
ErP Directive	2009/125/EU
RoHS Directive (2)	2011/65/EU

[1] *Machinery Directive conformance is only required for drives with an integrated safety function.*

[2] *For China RoHS, contact Danfoss application support to get the certificate.*

3.2.2 Low Voltage Directive

The aim of the Low Voltage Directive is to protect persons, domestic animals and property against dangers caused by the electrical equipment, when operating electrical equipment that is installed and maintained correctly, in its intended application. The directive applies to all electrical equipment in the 50–1000 V AC and the 75–1500 V DC voltage ranges.

3.2.3 EMC Directive

The purpose of the EMC (electromagnetic compatibility) Directive is to reduce electromagnetic interference and enhance immunity of electrical equipment and installations. The basic protection requirement of the EMC Directive states that devices that generate electromagnetic interference (EMI), or whose operation could be affected by EMI, must be designed to limit the generation of electromagnetic interference and shall have a suitable degree of immunity to EMI when properly installed, maintained, and used as intended. Electrical equipment devices used alone or as part of a system must bear the CE mark. Systems do not require the CE mark, but must comply with the basic protection requirements of the EMC Directive.

3.2.4 Machinery Directive

The aim of the Machinery Directive is to ensure personal safety and avoid property damage to mechanical equipment used in its intended application. The Machinery Directive applies to a machine consisting of an aggregate of interconnected components or devices of which at least 1 is capable of mechanical movement. Drives with an integrated functional safety function must comply with the Machinery Directive. Drives without a functional safety function do not fall under the Machinery Directive. If a drive is integrated into a machinery system, Danfoss can provide information on safety aspects relating to the drive. When drives are used in machines with at least 1 moving part, the machine manufacturer must provide a declaration stating compliance with all relevant statutes and safety measures.

3.2.5 ErP Directive

The ErP directive is the European Ecodesign Directive for energy-related products. The directive sets ecodesign requirements for energy-related products, including drives, and aims at reducing the energy consumption and environmental impact of products by establishing minimum energy-efficiency standards.

3.2.6 UL Listing

The Underwriters Laboratory (UL) mark indicates the safety of products and their environmental claims based on standardized testing. Drives of voltage 525–690 V are UL-certified for only 525–600 V. Enclosed drives are UL Listed as per UL 508A standard.

3.2.7 CSA/cUL

The CSA/cUL approval is for drives of voltage rated at 600 V or lower. Compliance with the relevant UL/CSA standard makes sure that safety design together with relevant information and markings, ensures that when the drive is installed and maintained according to the provided Operating/Installation Guide, the equipment meets the UL standards for electrical and thermal safety.This mark shows that the product complies with all required engineering specifications and testing. A certificate of compliance is provided on request.

3.2.8 RCM Mark Compliance

Illustration 1: RCM Mark

The RCM Mark label indicates compliance with the applicable technical standards for Electromagnetic Compatibility (EMC). An RCM Mark label is required for placing electrical and electronic devices on the market in Australia and New Zealand. The RCM Mark regulatory arrangements only deal with conducted and radiated emission. For drives, the emission limits specified in EN/IEC 61800-3 apply. A declaration of conformity can be provided on request.

3.2.9 TÜV

TÜV is a European safety organization which certifies the functional safety of the drive in accordance to EN/IEC 61800-5-2. The TÜV both tests products and monitors their production to ensure that companies stay compliant with their regulations.

3.3 Export Control Regulation

AC drives can be subject to regional and/or national export control regulations. Both the EU and USA have regulations for so-called dual-use products (products for both military and non-military use), which currently includes AC drives with a capacity to operate 600–2000 Hz. These products can still be sold, but it requires a set of measures, for example a license, or an end-user statement.

An ECCN number is used to classify all AC drives that are subject to export control regulations. The ECCN number is provided in the documentation accompanying the AC drive. If the AC drive is re-exported, it is the responsibility of the exporter to ensure compliance with the relevant export control regulations.

For further information, contact Danfoss Drives Global or the local sales office.

3.4 Enclosure Protection Rating

The VLT® drive series are available in various enclosure protection ratings to accommodate the needs of the application. Enclosure protection ratings are provided based on 2 international standards:

- UL type validates that the enclosures meet NEMA (National Electrical Manufacturers Association) standards. The construction and testing requirements for enclosures are provided in NEMA Standards Publication 250-2003 and UL 50, 11th edition.
- IP (Ingress Protection) ratings outlined by the IEC (International Electrotechnical Commission) in the rest of the world. The standard Danfoss VLT® drive series are available in various enclosure protections to meet the requirements of IP00 (Chassis), IP20 (Protected chassis), IP21 (NEMA Type 1), or IP54 (NEMA Type 12). In this manual, NEMA Type is written as Type, for example, IP21/Type 1.

4 VLT® Family Overview

4.1 VLT® Drives

Danfoss offers 3 types of AC drives in different-sized enclosures for a wide range of applications, with power ratings from 0.25–1200 kW (0.34–1350 hp).

Standalone drives (frequency converters)

The Danfoss standalone drives are so robust that they can be mounted outside of cabinets virtually anywhere, even right beside the motor. Equipped for the toughest of environment, they suit any application.

More uncompromising features:

- Enclosure sizes with protection ratings up to IP54/UL Type 12.
- Full EMC compliance according to international standards.
- Ruggedized and coated PCBs.
- Wide temperature range, operating from -25 to +40 °C (-13 to 104 °F) without derating.
- Motor cable lengths up to 150 m (492 ft) for shielded cables and 300 m (984 ft) for unshielded cables.

Enclosed drives

Danfoss enclosed drives are designed with the installer and operator in mind to save time on installation, commissioning, and maintenance. The enclosed drives are designed for full access from the front. After opening the cabinet door, all components can be reached without removing the drive, even when mounted side by side. Several cooling options, including back-channel cooling, provide optimum adaption to the installation location and application.

More time-saving features:

- An intuitive user interface with an award-winning local control panel (LCP) and common control platform that streamlines start-up and operating procedures.
- Robust design and advanced controls make Danfoss drives virtually maintenance free.

System modules

The compact design of the system modules makes them easy to fit even in small spaces. Integrated filters, input fuses, options, and accessories provide extra capabilities and protection without increasing the enclosure size.

More space-saving features:

- Built-in DC-link reactors for harmonic suppression eliminate the need for higher loss external AC line reactors.
- Optional built-in RFI filters are available throughout the power range.
- Regen terminals are available within the standard enclosures (for enclosure sizes D, E, and F).
- In addition to the many valuable features that the Danfoss drives offers as standard, there are several other control, monitoring, and power options available in pre-engineered factory configurations.

For more details on the enclosure types, the modularity, and the applications, see the product-specific Selection Guides on www.danfoss.com.

4.2 Power Drive System

4.2.1 System Overview

The term power drive system (PDS) is used by several standards. A PDS typically consists of a drive module, a motor, and their interconnections. It does not include driven load. For a general introduction explaining the basic elements of the PDS for an enclosed drive, refer to illustration 2.

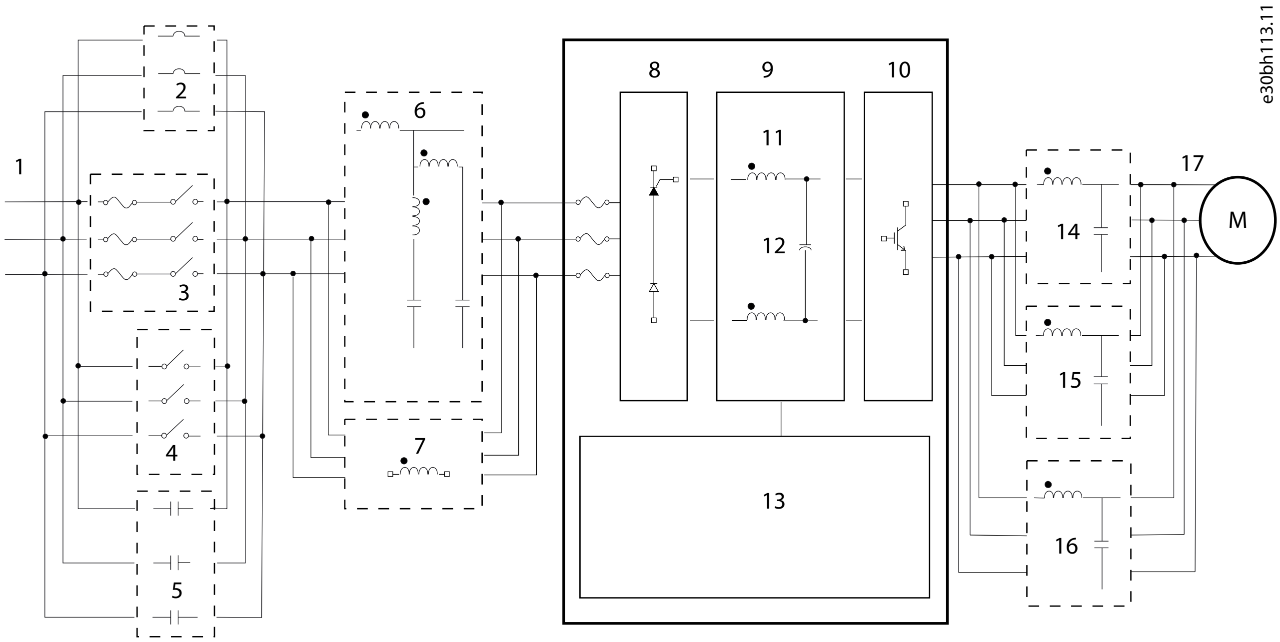


Illustration 2: Power Drive System for the Enclosed Drive

Table 3: Power Drive System for the Enclosed Drive Definitions

Item	Title	Functions
1	Mains input	Provides 3-phase AC mains power input to the drive module.
2	Molded-case circuit breaker (MCCB)	Input power option. Allows switching of input voltage. Includes circuit breaker, which trips at fault current or short circuit.
3	Fusible disconnect	Input power option. Allows switching of input voltage. Contains fuses, which clear the fault current or short circuit.
4	Non-fusible disconnect	Input power option. Allows switching of input voltage. Contains circuit breaker, which trips at fault current or short circuit.
5	Mains contactor	Input power option. Allows switching of input voltage. Enables remote connection or disconnection of input voltage.
6	Passive harmonic filter	Reduces input current harmonics below 5% or below 8%, depending on the selected filter.
7	Line reactor	Reduces rectifier current harmonics and stress, when connected to grid that has active filters.
8	Input rectifier section	Converts mains input AC voltage into DC voltage.
9	Intermediate DC bus section	Acts as a filter and stores energy in the form of DC voltage.

Item	Title	Functions
10	Inverter section	Converts the DC voltage into a variable, controlled PWM AC output voltage to the motor.
11	DC reactors	Filters the DC-link voltage. Reduces RMS current. Raises the power factor reflected back to the line. Reduces harmonics on the AC input.
12	Capacitor bank	Stores the DC power and provides ride-through protection for short power losses.
13	Control	Monitors input and motor current to provide efficient operation and control. Monitors the user interface and performs external commands. Provides status output and control. Includes the power card, fan power card (in E-sized drives only), and inrush card.
14	Sine-wave filter	Delivers sine current and reduces voltage spikes and dU/dt at the motor terminals.
15	dU/dt filter	Delivers reduced voltage spikes and dU/dt at the motor terminals.
16	Common mode filter	Reduces high-frequency bearing currents.
17	Motor output	Sends output to the motor being controlled.
Note: Dashed lines show customer-selected options.		

4.2.2 Overcurrent Protection

A correctly working drive limits the current it can draw from the supply. Still, Danfoss recommends using fuses and/or circuit breakers on the supply side to protect drive components in case a fault occurs in the drive.

Feeder circuits and branch circuits protection

To protect the installation against electrical and fire hazards, protect all branch circuits in an installation, switchgears, machines, and so on, against short circuits and overcurrent according to national/international regulations.

The feeder circuit includes all power conductors and components from the incoming feeder disconnect to the line side of the last branch short-circuit protection device (SCPD). The branch circuit includes all power conductors and components from the load side of the branch circuit SCPD to the controller load-side connections. Protect each branch circuit by its own disconnect and SCPD.

Short-circuit protection

To protect personnel and property if components break down in the drive, Danfoss recommends using the fuses/circuit breakers listed according to CE Compliance and UL Compliance.

Overcurrent protection

To limit threats to personnel and property damage, and to avoid fire hazards due to overheating of the cables in the installation, the drive provides overload protection. The drive is equipped with an internal overcurrent protection that can be used for upstream overload protection (UL applications excluded). Furthermore, fuses or circuit breakers can be used to provide the overcurrent protection in the installation. Always carry out overcurrent protection according to national regulations.

For more details and for selection of fuses and circuit breakers, refer to the Fuses, Circuit Breakers, and Switches section.

4.2.3 Passive Harmonic Filter

Passive harmonic filters are used to compensate for disturbances created from drives. They contribute with non-linear loads (such as diode rectifiers) that draw a non-sinusoidal current from the grid. Danfoss enclosed drives offer passive harmonic solutions via line reactors and passive harmonic filters (PHF). The passive harmonic filter is available as either a 5% or 8% current distortion option.

Passive solutions

Passive solutions consist of capacitors, inductors, or a combination of the 2 in different arrangements. More advanced passive solutions combine capacitors and inductors in trap arrangements specially tuned to eliminate harmonics starting from, for example, the 5th harmonic.

The simplest solution is to add inductors/reactors of typically 3–5% in front of the drive. This added inductance reduces the number of harmonic currents produced by the drive. The Danfoss enclosed drive offers a passive harmonic trap filter, which meets IEEE-519 Harmonic Limits standard.

The negative effect of harmonics is twofold

- Harmonic currents contribute to system losses (in cabling and transformer).
- Harmonic voltage distortion causes disturbance to and increase losses in other loads.

There are several ways of mitigating the harmonics caused by the 6-pulse rectifier in the drive. Selecting the right solution depends on several factors:

- The grid (background distortion, mains unbalance, resonance, and type of supply transformer/generator).
- Application (load profile, number of loads, and load size).
- Local/national requirements/regulations (for example IEEE 519, IEC, and ER G5/4).
- The total cost of ownership (for example initial cost, efficiency, and maintenance).

IEC standards are harmonized by various countries or supra-national organizations. All above-mentioned IEC standards are harmonized in the European Union with the prefix "EN". For example, the European EN 6100-3-2 is the same as IEC 61000-3-2. The situation is similar in Australia and New Zealand with the prefixed AS/NZS.

4.2.4 Line Reactors

A line reactor is an inductor which is wired in series between a power source and a load. Line reactors, also called input AC reactors, are used in motor drive applications. The main function of the line reactor is to limit the current. Line reactors also reduce the main harmonics, limit the inrush currents, and protect drives and motors. Line reactors help achieve an overall improvement of the true power factor and the quality of the input current waveform. Line reactors are classified by their percent impedance (denoted as percent IZ or %IZ), which is the voltage drop due to impedance at the rated current expressed as a percent of rated voltage. The most common line reactors have either 3% or 5% impedance.

In some situations, disturbances from the grid can damage the drive. To prevent disturbances, use a line reactor to ensure that only a minimum of impedance is in front of the drive. When calculating the impedance, also include the contribution from the supply transformer and the supply cables. In the following situations, add impedance (line reactor or transformer) in front of the drive:

- The installation site has switched power factor correction capacitors.
- The installation site has lightning strikes or voltage spikes.
- The installation site has power interruptions or voltage dips.
- The transformer kVA rating is too large compared to the drive kW rating.

Also, when planning load sharing applications, pay special attention to different enclosure size combinations and inrush concepts. For technical advice on load sharing applications, contact Danfoss application support.

4.2.5 Radio Frequency Interference (RFI)

Drives generate radio frequency interference (RFI) due to their variable-width current pulses. Drives and motor cables radiate these components and conduct them into the mains system.

RFI filters are used to reduce this interference on the mains. They provide noise immunity to protect devices against high-frequency conducted interference. They also reduce interference emitted to the mains cable or radiation from the mains cable. The filters are intended to limit interference to a specified level. Built-in filters are often standard equipment rated for specific immunity.

The VLT® AutomationDrive FC 302 Enclosed Drives can be ordered with different types of RFI filters. The following options are available in the type code:

- H2: No additional EMC filter. Fulfills EN 55011 Class A2 and EN/IEC 61800-3 Category 3.
- H4: Integrated EMC filter. Fulfills EN 55011 Class A1 and EN/IEC 61800-3 Category 2.

More details on RFI, the use of RFI filters, and EMC Compliance are in 10.4.5 EMC-compliant Installation.

RFI filter on IT grid

If the drive is supplied from an isolated mains source (IT mains, floating delta) or TT/TN-S mains with grounded leg (grounded delta), turn off the RFI filter.

When in the OFF position, the internal capacitors between the chassis (ground), the input RFI filter, and the DC-link are cut off. As the RFI switch is turned off, the drive does not meet optimum EMC performance.

By opening the RFI filter switch, the ground leakage currents are also reduced, but not the high-frequency leakage currents caused by the switching of the inverter. It is important to use isolation monitors that are suitable for use with power electronics (IEC 61557-8), for example, Deif type SIMQ, Bender type IRDH 275/375, ISO-685-D, or similar.

4.2.6 Frequency Inverter

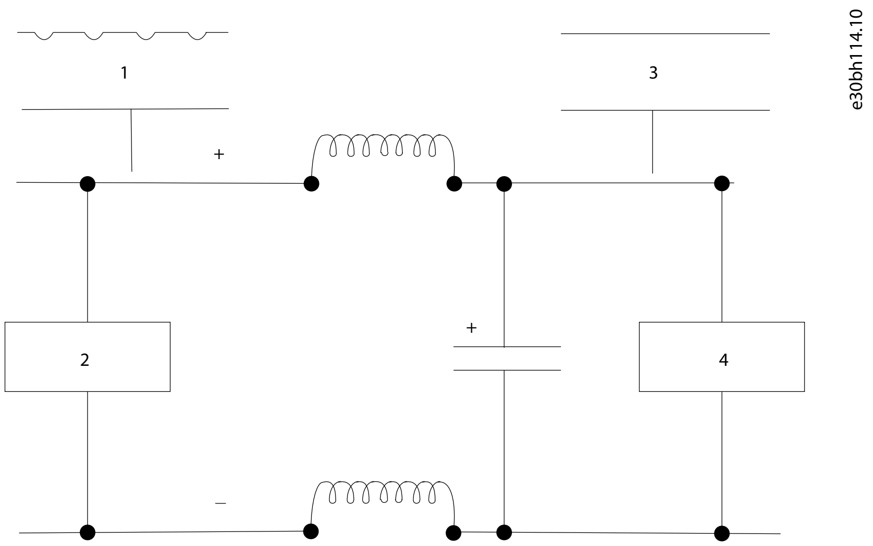
Today, mostly voltage-regulated drives are used for speed control in low-voltage grids. Their applications range from a few hundred watts to the lower megawatt range.

Most drives incorporate a basic drive module (BDM) based on a voltage-source PWM inverter with fast-switching power semiconductor devices such as insulated gate bipolar transistors (IGBT). The voltage generated by such an inverter incorporates a degree of high-frequency noise, which can lead to problems with electromagnetic compatibility (EMC). The rectifier also sends harmonic currents back to the network, which must be considered when designing a system.

Based on the system and process data, the designer must decide which technical solution fits the application. If high starting torque is needed, select drives with high overload capacity (HO). If high starting torque is not required, drives with normal overload (NO) are an alternative. The setup and the dimensioning of the system depend on the application (transmission, motor, output filter, and motor cable) and its environment (EMC filter, output filters, cables, mains, climate, and so on). Refer to the 4.2.1 System Overview when designing a system.

4.2.7 DC-link

The DC-link is a power storage facility for the output section of the inverter. The 2 major components of the DC-link section are capacitors and coils.



1	Direct current (AC ripple)	**2**	Rectifier
3	Direct current	**4**	Inverter

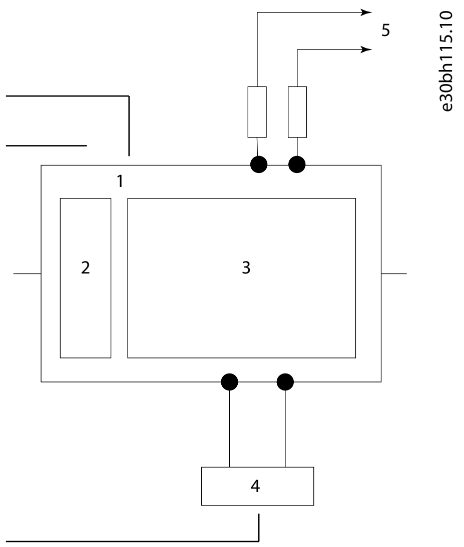
Illustration 3: Wiring Diagram of the DC-link

With Danfoss VLT® drives, the DC-link always uses DC coils, also known as DC line reactors or DC inductors. For cost considerations, most other drive manufacturers do not offer these DC line reactors as standard equipment. Danfoss regards these coils as essential for 2 main reasons:

- The ability to reduce mains harmonics by 48% for the 380–500-V drives and 60% for the 525–690-V drives at the specified grid conditions (R_{SCE}=120 for D9h/D10h and R_{SCE} = 75 for E5h/E6h).
- The ability to ride through a temporary power loss, thus avoiding numerous nuisance shutdowns.

The DC-link can have external terminals connected as shown in illustration 4. These terminals are not standard on all drive types. In these cases, add the terminals to the type code when ordering the drive.

- DC-link terminals (+,-) can be to supply the drive with a DC supply.
- When ordered, brake resistor terminals (R+, R-) include a built-in brake chopper. For more information on braking, see Section 9.10 Braking.



1 AC drive	**2** RFI
3 DC-link	**4** Brake resistor
5 DC-link (supply and load sharing)	

Illustration 4: DC-link with External Terminals

4.2.8 Brake Resistor

In applications where the motor is used as a brake, energy is generated in the motor and sent back into the drive. If the energy cannot be transported back to the motor, it increases the voltage in the drive DC line. In applications with frequent braking and/or high inertia loads, this increase can lead to an overvoltage trip in the drive and, finally, a shutdown.

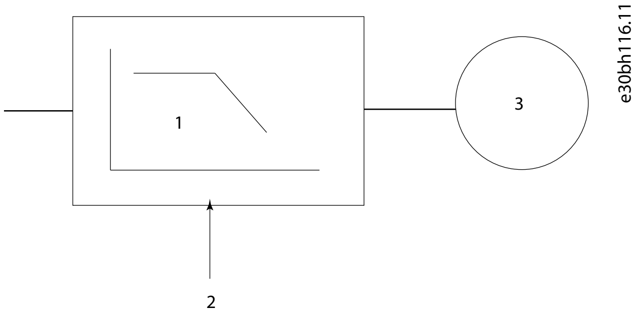
Brake resistors are used to dissipate the excess energy resulting from the regenerative braking. The resistor is selected based on its ohmic value, its power dissipation rate, and its physical size. Danfoss offers a wide variety of different resistors that are specially designed for Danfoss drives. For order numbers and more information on how to dimension brake resistors, refer to the VLT® Brake Resistor MCE 101 Design Guide.

4.2.9 Motor Side Filters (dU/dt, Sine–wave Filters, and Common-mode Filters)

The output voltage waveform of an inverter generates voltage spikes higher than the DC-link voltage of the drive at the motor terminals. These voltage spikes have a high rate of change in the voltage levels. The voltage level is measured in volt change per time unit. This measurement is the gradient of the voltage curve and is normally called dU/dt. When IGBTs are switching, values of the inverter can cause extra stress on the motor and motor cable insulation. The extra stress is not a problem on a short term basis, but over time (maybe 1–2 years) a high dU/dt can shorten motor life.

When designing a power drive system, verify that the dU/dt values of the motor can withstand the values coming from the inverter. Important factors are cable length and cable quality. Both long cables and short cables can challenge the motor.

If values are higher than allowed, use dU/dt filters to compensate.



1 dU/dt	**2** Output filters (dU/dt, sine-wave, and common-mode filters)
3 Motor	

Illustration 5: Motor-side Filters

dU/dt filters

These filters are differential mode filters which 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 winding.

Output filters are an alternative to line filters. An output filter is a coil and contrary to the line filters, the output filter has a built-in capacity. The output filter can cause undampened oscillations at the motor terminals, which increase the risk of double pulsing and overvoltages higher than twice the DC-link voltage. The dU/dt filters are low-pass LC filters with a well-defined cutoff frequency. Therefore, the ringing oscillations at the motor terminals are damped and there is a reduced risk of double pulsing and voltage peaks.

Sine–wave filters

VLT® Sine-wave Filter MCC 101 output filters are advanced differential-mode, 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. These actions reduce 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.

Common-mode filters

Danfoss common-mode HF filters are placed between the drive and the motor. They are nano crystalline cores that mitigate high-frequency noise in the motor cable (shielded or unshielded) and eliminate bearing currents and electro discharge machining (EDM) or bearing etching in the motor. Bearing currents caused by drives are also referred to as common-mode currents.

4.2.10 Cabling

When selecting cables, there are some important factors to consider to ensure that the cables match the requirements of the installation, for example:

- Power size and voltage range of the drive.
- Motor size and type.
- Are filters required on the input side with regards to EMC and harmonic mitigation?
- Are output filters required for motor overload protection and reduction of acoustic noise?
- Does the installation require parallel motor connection?
- Are brakes required, if yes, then what kind of brake?
- Environmental requirements, for example, need for derating.

For further information on cables, refer to the Specifications chapter.

4.2.11 Supported Motor Types

Today, the drive-controlled, 3-phase motor is a standard element in all automated applications. High-efficiency induction motors, but also motor designs such as permanent magnet motors, EC motors, and synchronous reluctance motors, need regulation with AC drives. Many motors cannot be operated directly from the 3-phase standard supply.

The Danfoss VLT® drives can control multiple motor technologies. The most advanced is the VLT® AutomationDrive FC 302. This drive is compatible with virtually all types of common AC motor technologies on the market:

- Induction motors (IM).
- Surface permanent magnet motors (SPM).
- Interior permanent magnet motors (IPM).
- Synchronous reluctance motors (SynRM).
- Permanent magnet assisted synchronous reluctance motors (PMaSynRM).

Induction motors, synchronous motors, and induction servo motors are all supported as standard without the need for extra software. The FC 302 can control the motors in either open loop or closed loop through its high precision motor control platform, VVC$^+$ or flux control.

Standard IEC line motors (IEC 60034-30-1)

The standard IEC 60034-30-1 of March 2014 replaces the standard 60034-30:2008, which has defined 3 efficiency levels for 3-phase induction motors. The updated standard IEC 60034-30-1 now includes the 4th efficiency level, IE4. Furthermore, 8-pole motors and an extended power range are now included in the standard.

Efficiency classes:

In the IEC 60034-30-1, the following efficiency classes are defined for induction motors:

- IE1 (Standard efficiency).
- IE2 (High efficiency).
- IE3 (Premium efficiency).
- IE4 (Super premium efficiency).

IE = Internation efficiency.

These motor types can all be operated with Danfoss VLT® drives.

More information on this topic can be found in the publication Motor Technologies for Higher Efficiency in Applications. This document can be downloaded from www.danfoss.com.

4.2.12 PDS Ecodesign

The international product standard IEC 61800-9 deals with the energy efficiency of drives and power drive systems (PDS). As shown in illustration 6, many power drive system components contribute to losses. Danfoss offers a tool for calculating the efficiency class and part load efficiency for Danfoss drives. See MyDrive® ecoSmart™

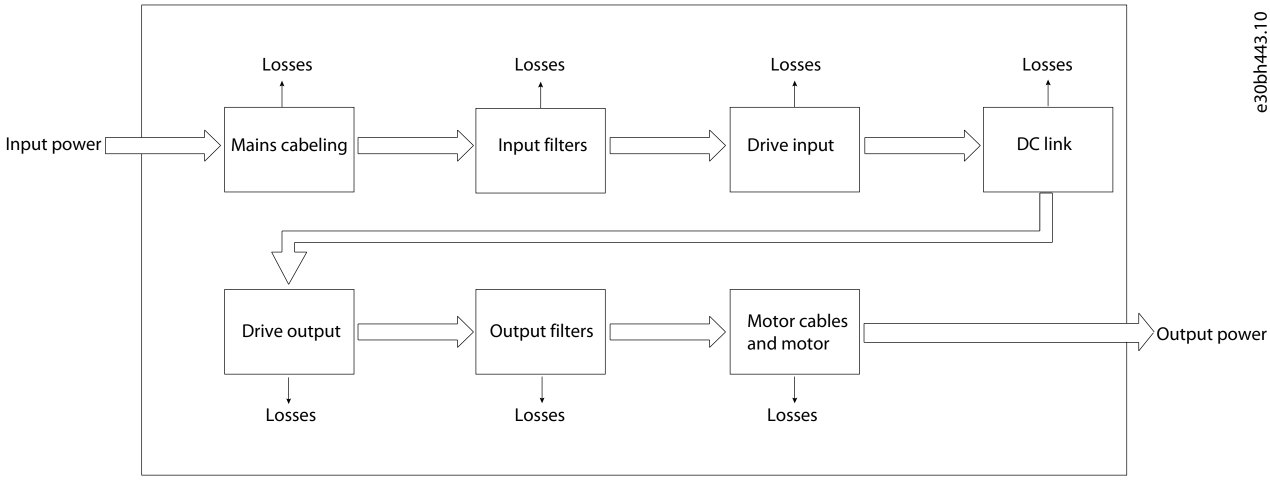


Illustration 6: Losses in a Power Drive System

4.2.12.1 Mains Cable Losses

Impedance in the cables creates energy losses in the ohmic part. For a 3-phase system with a star-point grounding, the power losses can be calculated by:

$P_{L,mains} = 3 * R * I_{L1}^2$

When using drives and motors, reactive power and harmonic currents included in the load also contribute to losses. The ratio between active and apparent power is called the power factor. A PDS with a power factor close to 1 results in the lowest losses in the mains. Using filters on the input side of the drive can influence this.

4.2.12.2 Motor and Motor Cable Losses

Motor cables introduce mainly ohmic losses. The longer the cables, the more resistance. In general, when correctly selected, the losses in cables shorter than 25 m (82 ft) are negligible. In single-wire cables with individual shielding, the current causes losses in the cable shielding. These losses are negligible when using 3-wire cables.

There are many different types of motors that can be operated with a drive. Therefore, a single answer on losses in motors cannot be given. In the standard IEC 61800-9-2:2017 annex D, a discussion on motor load and losses is available. A method to evaluate the losses generated in a drive motor is available in standards IEC 60034-2-1 and IEC TS 60034-2-4.

4.3 Functional Safety

4.3.1 Protection of Personnel and Equipment

Danfoss AC drives offer functional safety solutions for smart machine design. The VLT® AutomationDrive has Safe Torque Off (STO) built-in as standard. Along with other safety functions, STO enhances application safety. The drive-based functional safety offering complies with the requirements of international standards and requirements, including European Union Machinery Directive 2006/42/EC.

The STO function complies with ISO 13849-1-PL d and SIL2 according to IEC 61508/IEC 62061. With the VLT® Safety Option MCB 150 Series, this safety function can be extended to include SS1, SLS, SMS, safe jog mode, and more. The speed monitoring functions are available both with and without speed feedback.

4.3.2 VLT® Safety Option MCB 150 and MCB 151

The MCB 150 and MCB 151 can be integrated directly in the AC drive and is prepared for future connection to common safety bus systems. The module is certified according to ISO 13849-1 up to PL d and IEC 61508/IEC 62061 up to SIL 2, and provides SS1, SLS, and SMS functionality according to IEC 61800-5-2. The option can be used in low- and high-demand applications. SS1 offers ramp- and time-based functionality. SLS can be configured both with and without ramp-down on activation. SMS can be activated continously without having a safe input.

4.3.3 VLT® Safety Option MCB 152

The VLT® Safety Option MCB 152 operates the safety function of an AC drive via the PROFIsafe fieldbus combined with the VLT® PROFINET MCA 120 fieldbus option. Central and decentral drives at different machinery cells can easily be interconnected with the PROFIsafe safety fieldbus. The interconnection enables activation of the STO irrespectively of where a hazard occurs. The safety functions of the MCB 152 are implemented according to EN IEC 61800-5-2. Two configurable safe digital inputs are available for extension of safe I/Os.

The MCB 152 supports PROFIsafe functionality to activate integrated safety functions of the Danfoss from any PROFIsafe host up to Safety Integrity Level SIL 2 according to EN IEC 61508 and EN IEC 62061, Performance Level PL d, Category 3 according to EN ISO 13849-1.

4.3.4 Safety Functions

4.3.4.1 Safe Torque Off (STO)

STO is the required base for drive-based functional safety as defined per EN IEC 61800-5-2, as the STO function brings the drive safely to a no-torque state. STO is typically used for preventing an unexpected start-up (EN 1037) of machinery, or for an emergency stop fulfilling stop category 0 (EN 60204-1).

When STO is activated, it immediately switches off the drive output to the motor. Motor speed then coasts to a stop.

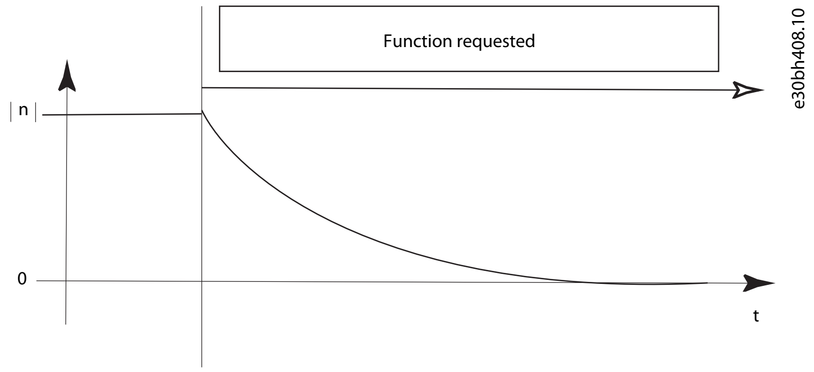


Illustration 7: Motor Speed Coasts to Stop After Activation of STO

4.3.4.2 Safe Stop 1 (SS1)

The Safe Stop 1 function stops the motor safely by using a controlled ramp stop and then activating the STO function. SS1 is typically used in applications like rolling mills where motion must be stopped in a controlled manner before switching to a no-torque state. In addition to a safe process stop, SS1 can be used to implement an emergency stop, fulfilling category 0 (EN 60204-1).

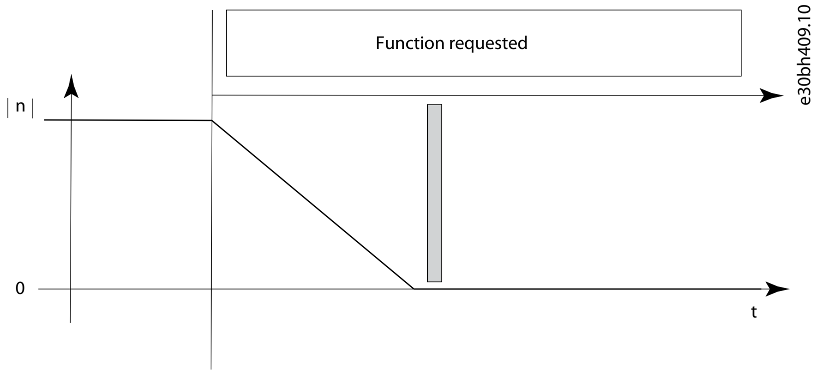


Illustration 8: Motor Speed Ramps Down to Standstill, SS1 then Activates STO

4.3.4.3 Safely Limited Speed (SLS)

The Safely Limited Speed function prevents motors from exceeding a defined speed limit. If the speed limit is exceeded, SLS activates the STO function, which stops the drive. The SLS safety function can be used in applications such as decanters, mixers, conveyors, or paper machines where excess speed can be hazardous during certain operations like maintenance or cleaning.

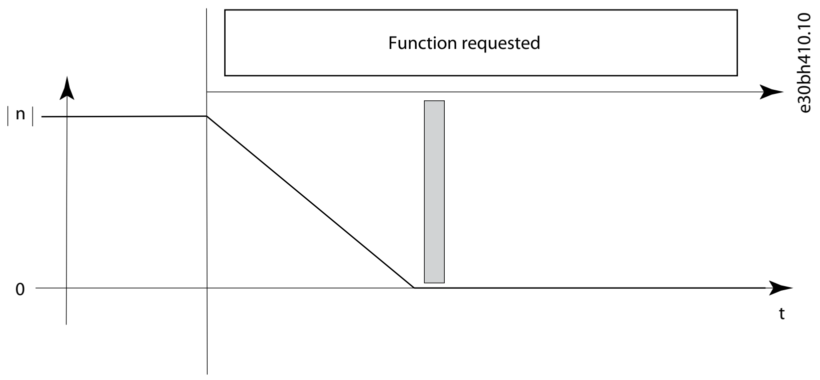


Illustration 9: SLS Monitoring Motor Speed

4.3.4.4 Safe Maximum Speed (SMS)

The SMS is a variant of the SLS safety function. It provides continuous protection against a motor exceeding a defined maximum speed limit. When SMS is used, it continuously monitors the motor speed. It is often used for centrifuges.

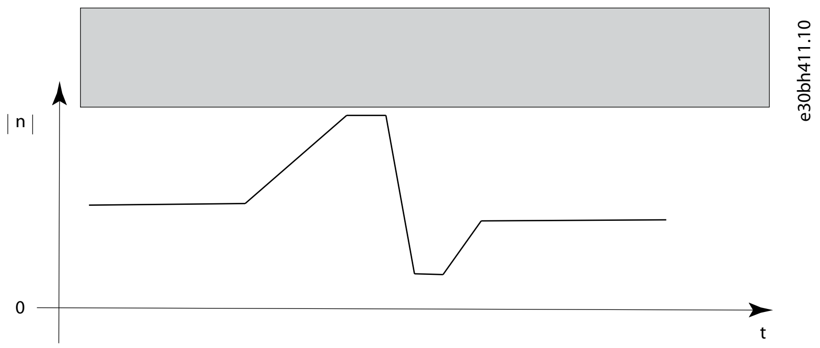


Illustration 10: SMS Ensuring that the Speed Limit is not Exceeded

4.3.4.5 PROFIsafe

As a software feature, PROFIsafe covers safety applications utilizing PROFIBUS and PROFINET in process and factory automation. The PROFIsafe protocol is suitable for both PROFIBUS and PROFINET networks without impacting the existing fieldbus standard. The protocol is also approved for wireless transmission channels such as Bluetooth and Wi-Fi.

4.4 Service and Maintenance Features

4.4.1 Service Log

The service log is a data logger extension (alarm data saved in drive memory and exportable to VLT® Motion Control Tool MCT 10). If certain alarms occur, the system saves a detailed log in 5 s increments.

Service technicians can analyze this information to troubleshoot and optimize the drive.

The drive saves up to 24 service log records in the flash memory. If the RTC (real-time clock) has been set in the drive, all errors and log files are date- and time-stamped.

The relevant service log file can then be analyzed as a scope in MCT 10. Danfoss specifies the channels. All scope functions such as Auto-scale and Diagnostics can be used. The HEX ad binary value can be shown, which also helps with the analysis.

Table 4: Alarms Triggering a Service Log Record

Alarm	Alarm log data	Parameter number
1	Time of trip (1 of the values): • Priority RTC (if available). • Priority operating time (if RTC is not available).	*Parameter 0-89 Date and Time Readout* or *parameter 15-32 Fault Log: Time*
2	Alarm code	*Parameter 15-30 Fault Log: Error Code*
3	Frequency	*Parameter 16-13 Frequency*
4	Speed (RPM)	*Parameter 16-17 Speed [RPM]*
5	Reference %	*Parameter 16-02 Reference %*
7	DC-link voltage	*Parameter 16-30 DC Link Voltage*
9	Motor phase U current	*Parameter 16-45 Motor Phase U Current*
10	Motor phase V current	*Parameter 16-46 Motor Phase V Current*
11	Motor phase W current	*Parameter 16-47 Motor Phase W Current*
12	Motor phase voltage	*Parameter 16-12 Motor Current*
15	Control word	*Parameter 16-00 Control Word*
16	Status word	*Parameter 16-03 Status Word*

Application-dependent trips/alarms such as Safe Torque Off (STO), do not trigger a service log record.

Sampling rate

There are 2 periods with different sampling rates:
- Slow samples: 20 samples at a rate of 250 ms resulting in 5 s of history before the trip.
- Fast samples: 50 samples at a rate of 5 ms resulting in 250 ms of detailed history before the trip.

4.4.2 Maintenance Functions

Danfoss VLT® drives feature preventive and condition-based monitoring functions.

4.4.2.1 Preventive Maintenance

Schedule maintenance based on a running hours counter. When planned maintenance occurs, the drive shows a message. Action flags can be transferred via fieldbus. *Parameter group 18-0* Maintenance Log* contains the last 10 preventive maintenance events. Maintenance log 0 is the latest log and maintenance log 9 is the oldest.

Parameters 18-00 to *18-03* show the maintenance item, the action, and the time of the occurrence.

The alarm log key gives access to both alarm log and maintenance log.

4.4.2.2 Condition-based Monitoring

The function uses the drive as a smart sensor for monitoring the condition of the motor and application. The VLT® AutomationDrive features licensed functions that enforce predictive maintenance actions, such as:

- Motor stator winding monitoring.
- Vibration monitoring.
- Load envelope monitoring.

Set various thresholds and determine the baseline with different methods according to relevant standards and guidelines such as the ISO 13373 standard for Condition Monitoring and Diagnostics of Machines or the VDMA 24582 guideline for condition monitoring.

The condition-based maintenance parameters are in *parameter group 45-** Condition Based Monitoring*.

4.4.2.2.1 Motor Stator Winding Monitoring

Motor winding failures lead to stop of operation and, thus, unwanted downtime. Motor winding failures start with a short circuit between 2 windings. Over time, the short circuit leads to a motor short circuit fault. By using the motor stator winding monitoring function, motor isolation faults are detected at an early stage, allowing maintenance of the motor before the winding fails entirely due to overheating.

- By analyzing the motor current signature, the drive detects motor winding damage at an early stage.
- The function does not require any external sensors.
- The drive sends a warning/alarm to the LCP or fieldbus.

4.4.2.2.2 Vibration Monitoring

The VLT® AutomationDrive FC 302 can be used with an external vibration transducer (velocity or acceleration type 4–20 mA) to monitor the vibration level in a motor or application. The available functions are baseline measurement, broadband trending, vibration during acceleration and deceleration, and transient vibration trending. The vibration monitoring is performed using standardized methods and threshold levels given in standards such as ISO 13373 for condition monitoring and diagnostics of machines or ISO 10816/20816 for measurement and classification of mechanical vibration. The advantage of performing this monitoring in the drive is the possibility of correlating data with the actual operating conditions such as steady state running/ramping, load condition, or speed.

- The function detects faults as:
  - Imbalance and eccentricity.
  - Looseness.
  - Misalignment.
  - Mechanical resonance.
- The function is not able to identify bearing wear-out in early stages.
- Drive correlates vibration with motor speed.

NOTICE

EVALUATING VIBRATION

The ISO 10816 standard provides guidance for evaluating vibration severity for machines operating within 10–200 Hz of frequency range. The standard shall be complied with before commissioning of vibration monitoring function.

4.4.2.2.3 Load Envelope

The VLT® AutomationDrive can determine a baseline load curve for the application. When wear-out occurs, the load curve moves and triggers a maintenance warning. The function is useful for fault detection in various applications with passive load:

- Fouling, sanding, broken impeller, or wear-out of pumps.
- Clogged filters and leakages in ventilation systems.
- Friction in machines.

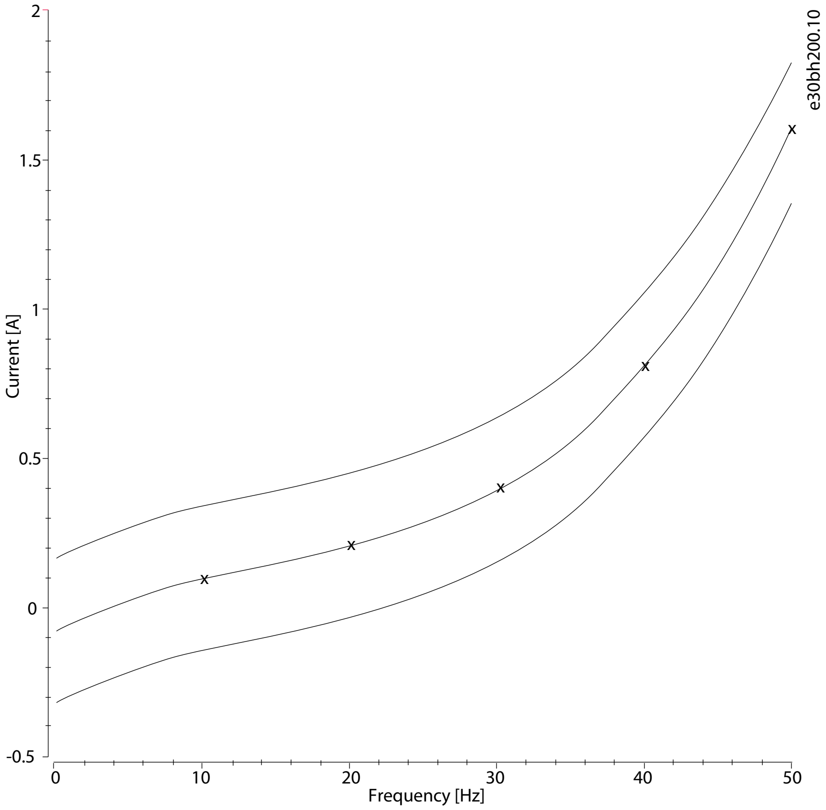


Illustration 11: Load Curve Example for Load Envelope Monitoring

5 Enclosed Drives with Power Options Overview

5.1 What is a VLT Enclosed Drive?

The VLT® AutomationDrive FC 302 Enclosed Drive is an IP21/54 (NEMA 1/12) enclosure surrounding either an IP20/Protected Chassis drive or IP00/Chassis drive to form the basis of the system. The following enclosed drive models are described in this Design Guide:

- D9h model: 90–132 kW (100–200 hp).
- D10h model: 160–315 kW (200–350 hp).
- E5h model: 315–560 kW (400–600 hp).
- E6h model: 450–710 kW (600–750 hp).

The VLT® AutomationDrive FC 302 Enclosed Drive is available with various power options, input filters, and output filters to create a factory-built, custom drive. Some options and filters result in extra cabinets attached to the left or right side of the drive cabinet. These optional cabinets are shown with dotted lines, while the drive cabinet is shaded.

NOTICE

OUTPUT FREQUENCY LIMIT

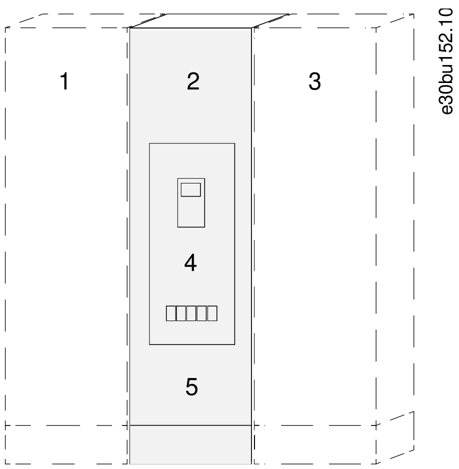
Due to export control regulations, the output frequency of an enclosed drive without sine-wave filter is limited to 590 Hz. Enclosed drives equipped with a sine-wave filter are limited to 60 Hz without derating. For demands exceeding 590 Hz, contact Danfoss.

NOTICE

RADIO INTERFERENCE

In a residential environment, this product can cause radio interference.

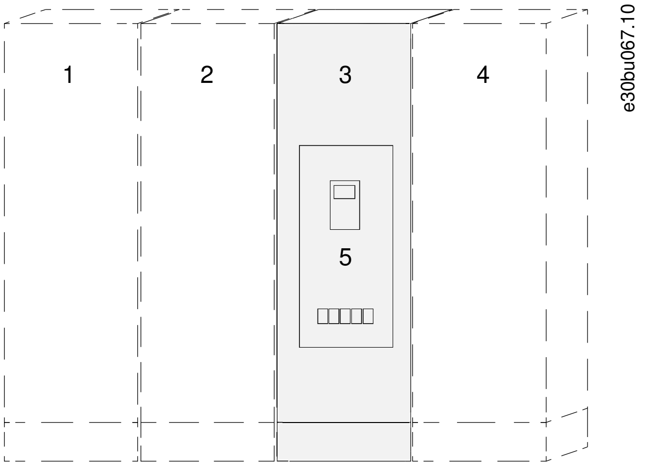
- Take supplementary mitigation measures.



1 Input filter cabinet (passive harmonic filter or line reactor)	**2** Drive cabinet
3 Sine-wave cabinet	**4** Control compartment
5 Input power options [1]	

[1] *The D9h enclosure does not require an input power options cabinet – the input power options are placed in the drive cabinet.*

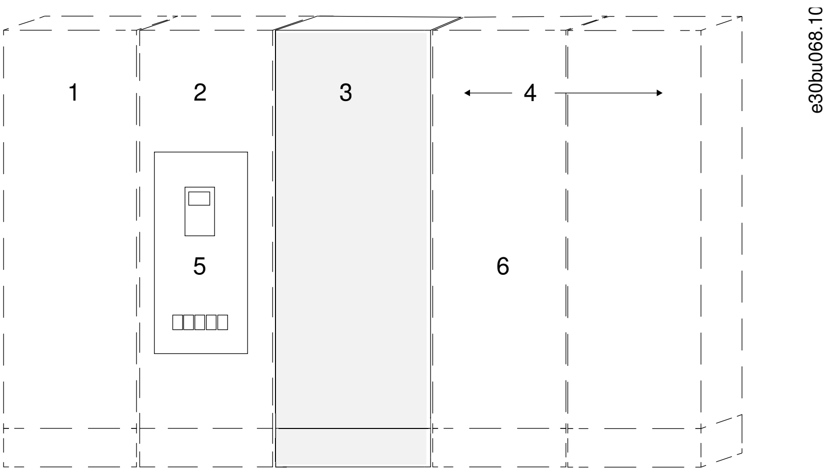
Illustration 12: Possible Configurations for a D9h Enclosed Drive



1 Input filter cabinet (passive harmonic filter or line reactor)	**2** Input power options cabinet [1]
3 Drive cabinet	**4** Sine-wave filter cabinet
5 Control compartment	

[1] *If more than 1 input power option is ordered, the D10h enclosed drive requires an input power options cabinet. Otherwise the single input power option is placed below the control compartment in the drive cabinet.*

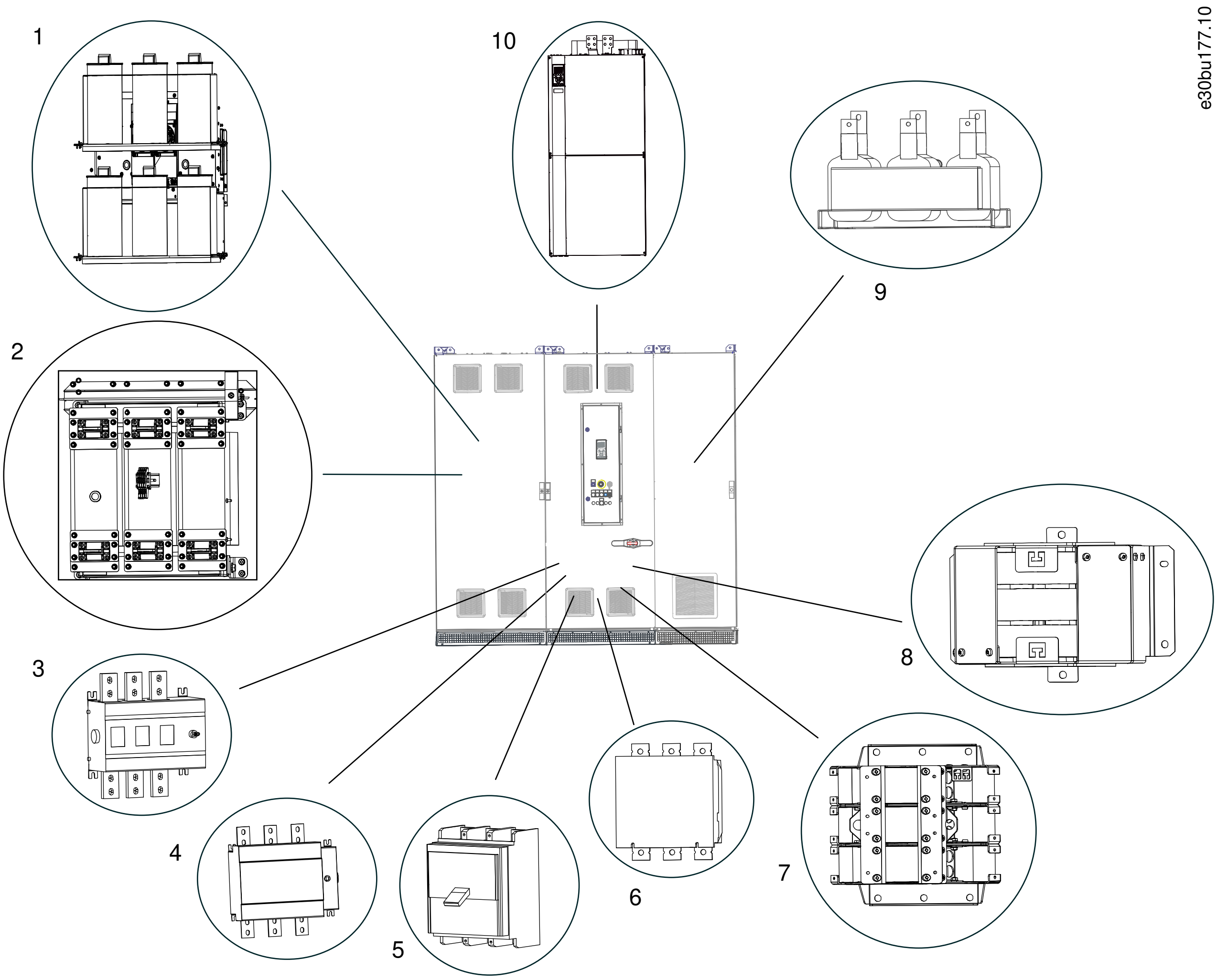
Illustration 13: Possible Configurations for a D10h Enclosed Drive



1 Input filter cabinet (passive harmonic filter or line reactor)	**2** Input power options cabinet
3 Drive cabinet	**4** Sine-wave filter cabinet
5 Control compartment	**6** dU/dt filter cabinet

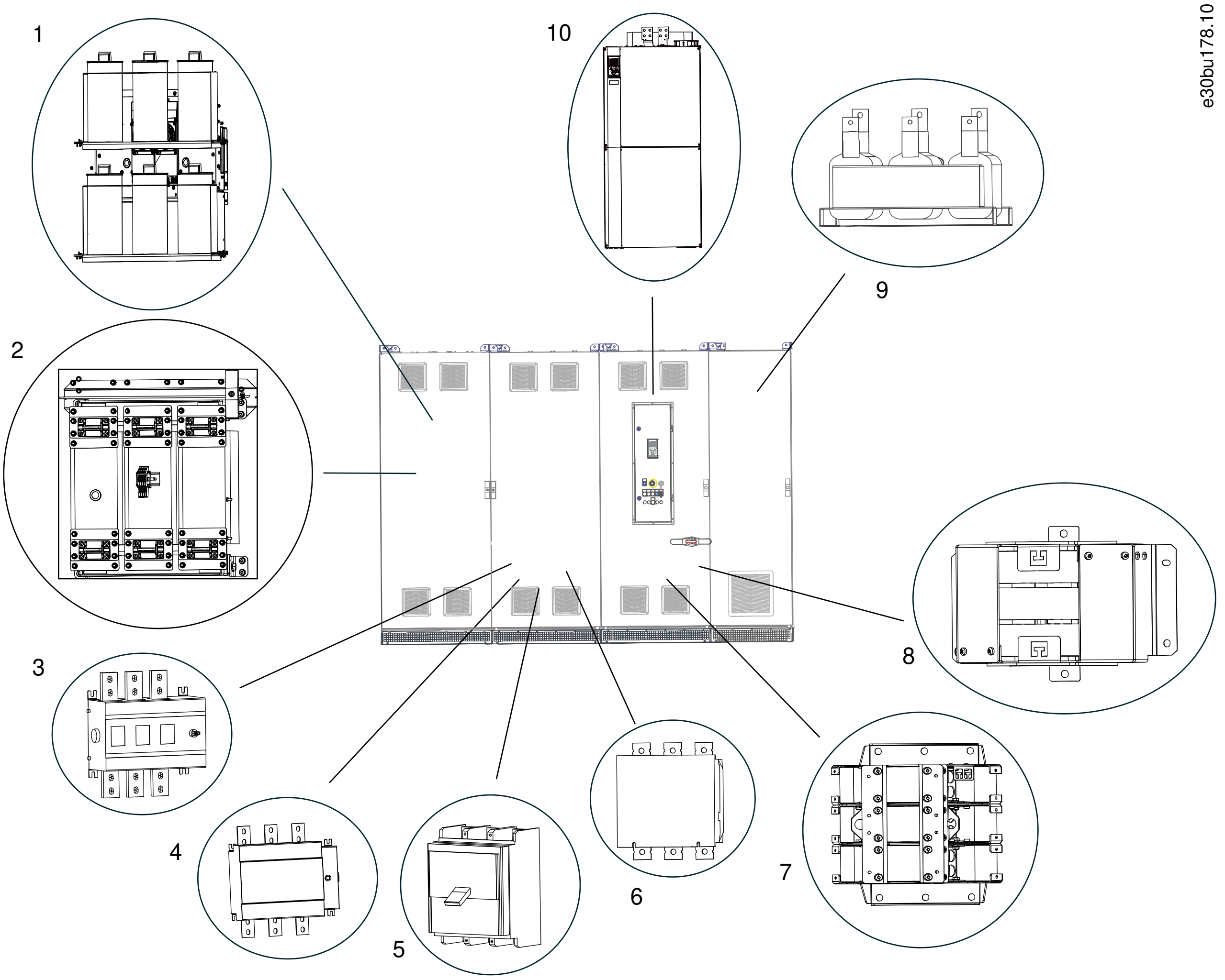
Illustration 14: Possible Configurations for an E5h or E6h Enclosed Drive

5.2 Location of Options within an Enclosed Drive



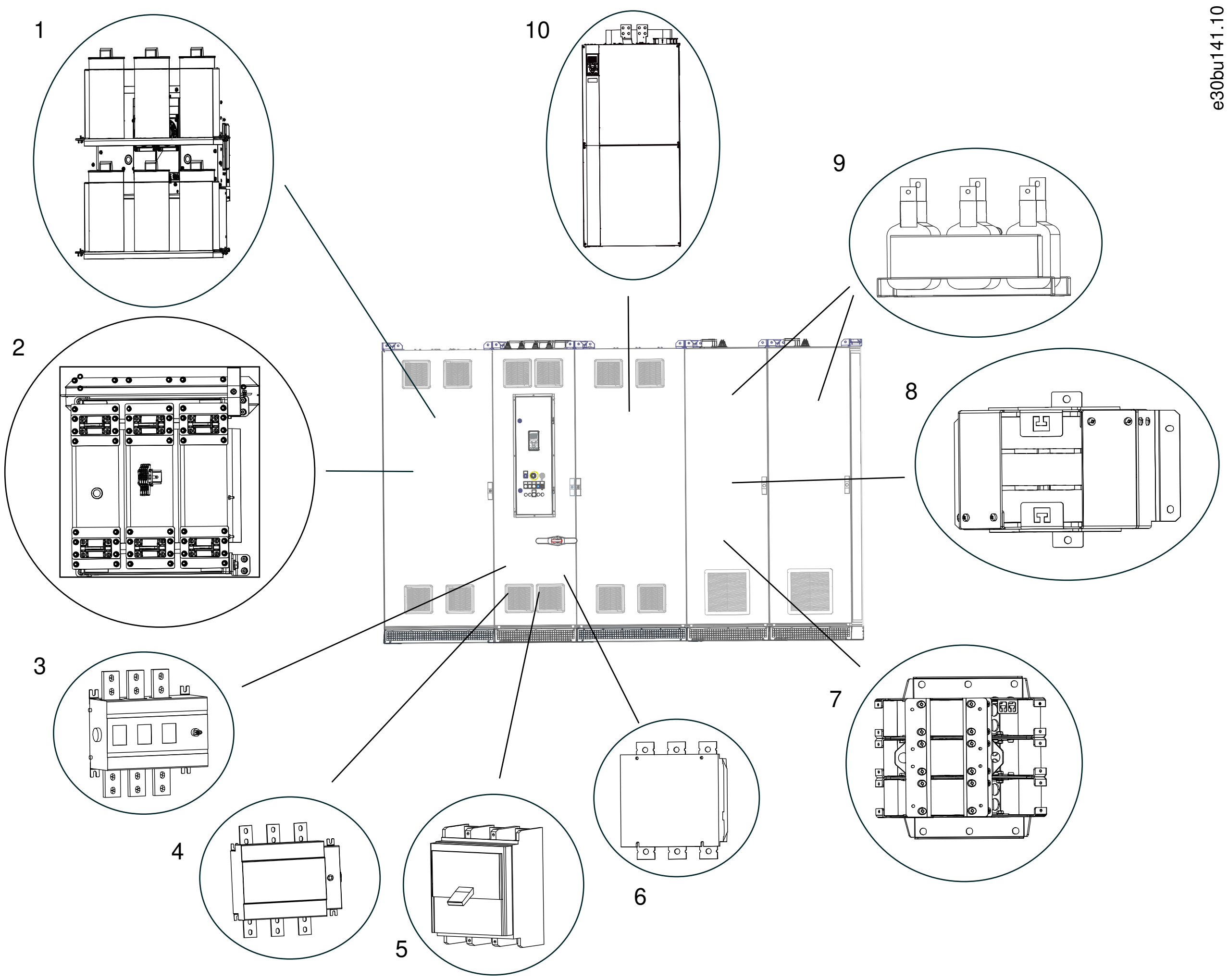
1	Passive harmonic filter (PHF)	**2**	Line reactor
3	Non-fusible disconnect	**4**	Fusible disconnect
5	Molded-case circuit breaker (MCCB)	**6**	Mains contactor
7	dU/dt filter	**8**	Common-mode filter
9	Sine-wave filter	**10**	Drive module (varies in power rating)

Illustration 15: Visual Representation of a D9h Enclosure and the Locations of Available Options



1	Passive harmonic filter (PHF)	2	Line reactor
3	Non-fusible disconnect	4	Fusible disconnect
5	Molded-case circuit breaker (MCCB)	6	Mains contactor
7	dU/dt filter	8	Common-mode filter
9	Sine-wave filter	10	Drive module (varies in power rating)

Illustration 16: Visual Representation of a D10h Enclosure and the Locations of Available Options



1	Passive harmonic filter (PHF)	**2**	Line reactor
3	Non-fusible disconnect	**4**	Fusible disconnect
5	Molded-case circuit breaker (MCCB)	**6**	Mains contactor
7	dU/dt filter	**8**	Common-mode filter
9	Sine-wave filter	**10**	Drive module (varies in power rating)

Illustration 17: Visual Representation of a E5h/E6h Enclosure and the Locations of Available Options

5.3 Power Ratings, Weight, and Dimensions

For detailed electrical specifications, including current ratings, see 7.1.1 Electrical Data, 380–500 V AC and 7.1.2 Electrical Data, 525–690 V AC.

Table 5: Power Ratings and Dimensions for D9h–D10h and E5h–E6h Enclosures (Standard Configurations)

Enclosed drive	D9h	D10h	E5h	E6h
Rated power at 380–500 V [kW (hp)] (1)	90–132 (125–200)	160–250 (250–350)	315–400 (450–550)	450–500 (600–650)
Rated power at 525–690 V [kW (hp)] (2)	90–132 (100–150)	160–315 (200–350)	355–560 (400–600)	630–710 (650–750)
Protection rating	IP21 (NEMA 1)/ IP54 (NEMA 12)	IP21 (NEMA 1)/IP54 (NEMA 12)	IP21 (NEMA 1)/IP54 (NEMA 12)	IP21 (NEMA 1)/IP54 (NEMA 12)
Drive cabinet	**D9h**	**D10h**	**E5h**	**E6h**
Height [mm (in)] (3)	2100 (82.7)	2100 (82.7)	2100 (82.7)	2100 (82.7)
Width [mm (in)] (4)	400 (15.8)	600 (23.6)	600 (23.6)	800 (31.5)
Depth [mm (in)]	600 (23.6)	600 (23.6)	600 (23.6)	600 (23.6)
Weight [kg (lb)] (4)	280 (617)	355 (783)	400 (882)	431 (950)
Input filter cabinet	**D9h**	**D10h**	**E5h**	**E6h**
Height [mm (in)] (3)	2100 (82.7)	2100 (82.7)	2100 (82.7)	2100 (82.7)
Width [mm (in)]	400 (15.8)	400 (15.8)/600 (23.6)	600 (23.6)	600 (23.6)/800 (31.5)
Depth [mm (in)]	600 (23.6)	600 (23.6)	600 (23.6)	600 (23.6)
Weight [kg (lb)]	410 (904)	410 (904)/530 (1168)	530 (1168)	530 (1168)/955 (2105)
Input power options cabinet	**D9h**	**D10h**	**E5h**	**E6h**
Height [mm (in)] (3)	–	2100 (82.7)	2100 (82.7)	2100 (82.7)
Width [mm (in)]	–	600 (23.6)	600 (23.6)	600 (23.6)
Depth [mm (in)]	–	600 (23.6)	600 (23.6)	600 (23.6)
Weight [kg (lb)]	–	380 (838)	380 (838)	380 (838)
Sine-wave filter cabinet	**D9h**	**D10h**	**E5h**	**E6h**
Height [mm (in)] (3)	2100 (82.7)	2100 (82.7)	2100 (82.7)	2100 (82.7)
Width [mm (in)]	600 (23.6)	600 (23.6)	1200 (47.2)	1200 (47.2)
Depth [mm (in)]	600 (23.6)	600 (23.6)	600 (23.6)	600 (23.6)
Weight [kg (lb)]				
dU/dt filter cabinet	**D9h**	**D10h**	**E5h**	**E6h**
Height [mm (in)] (3)	–	–	2100 (82.7)	2100 (82.7)
Width [mm (in)] (5)	–	–	400 (15.8)	400 (15.8)
Depth [mm (in)]	–	–	600 (23.6)	600 (23.6)
Weight [kg (lb)]	–	–	240 (529)	240 (529)
Top entry/exit cabinet	**D9h**	**D10h**	**E5h**	**E6h**
Height [mm (in)] (3)	2100 (82.7)	2100 (82.7)	2100 (82.7)	2100 (82.7)
Width [mm (in)] (5)	400 (15.8)	400 (15.8)	400 (15.8)	400 (15.8)
Depth [mm (in)]	600 (23.6)	600 (23.6)	600 (23.6)	600 (23.6)

Enclosed drive	D9h	D10h	E5h	E6h
Weight [kg (lb)]	164 (362)	164 (362)	164 (362)	164 (362)

[1] *All power ratings are taken at high overload. Output is measured at 400 V (kW) and 460 V (hp).*

[2] *All power ratings are taken at high overload. Output is measured at 690 V (kW) and 575 V (hp).*

[3] *Cabinet height includes standard 100 mm (3.9 in) pedestal. A 200 mm (7.9 in) or 400 mm (15.8 in) pedestal is optional.*

[4] *Without options.*

[5] *The E5h and E6h enclosures contain 2 sine-wave cabinets. The provided width is the total of both cabinets.*

6 VLT® AutomationDrive FC 302 Features

6.1 Automated Operational Features

Automated operational features are active when the drive is operating. Most of them require no programming or setup. The drive has a range of built-in protection functions to protect itself and the motor when it runs. For details of any required setup, in particular motor parameters, refer to the Programming Guide.

6.1.1 Short-circuit Protection

Motor (phase-to-phase)

The drive is protected against short circuits on the motor side by current measurements in each of the 3 motor phases. A short circuit between 2 output phases causes an overcurrent in the inverter. The inverter is turned off when the short circuit current exceeds the allowed value (*Alarm 16, Trip Lock*).

Mains side

A drive that works correctly limits the current it can draw from the supply. Still, it is recommended to use fuses and/or circuit breakers on the supply side as protection if there is a component breakdown inside the drive (1st fault). Mains side fuses are mandatory for UL compliance.

NOTICE

To ensure compliance with IEC 60364 for CE or NEC 2017 for UL, it is mandatory to use fuses and/or circuit breakers.

Brake resistor

The drive is protected from a short circuit in the brake resistor.

Load sharing

To protect the DC bus against short circuits and the drives from overload, install DC fuses in series with the load sharing terminals of all connected units.

6.1.2 Overvoltage Protection

Motor-generated overvoltage

The DC-link voltage is increased when the motor acts as a generator. This occurs in the following situations:

- The load drives the motor (at constant output frequency from the drive), that is, the load generates energy.
- During deceleration (ramp-down) if the moment inertia is high, the friction is low, and the ramp-down time is too short for the energy to be dissipated as a loss in the drive, the motor, and the installation.
- Incorrect slip compensation setting may cause higher DC-link voltage.
- Back EMF from PM motor operation. If coasted at high RPM, the PM motor back EMF may potentially exceed the maximum voltage tolerance of the drive and cause damage. To help prevent this, the value of *parameter 4-19 Max Output Frequency* is automatically limited based on an internal calculation. This calculation is based on the value of *parameter 1-40 Back EMF at 1000 RPM*, *parameter 1-25 Motor Nominal Speed*, and *parameter 1-39 Motor Poles*.

NOTICE

To avoid that the motor overspeeds (for example, due to excessive windmilling effects), equip the drive with a brake resistor.

The overvoltage can be handled either via using a brake function (*parameter 2-10 Brake Function*) and/or using overvoltage control (*parameter 2-17 Over-voltage Control*).

Brake functions

Connect a brake resistor to dissipate surplus brake energy. Connecting a brake resistor allows a higher DC-link voltage during braking. AC brake is an alternative to improve breaking without using a brake resistor. This function controls an overmagnetization of the motor when running regenerative, which can improve the OVC. Increasing the electrical losses in the motor allows the OVC function to increase the breaking torque without exceeding the overvoltage limit.

NOTICE

An AC brake is not as efficient as dynamic braking with a resistor and should not be used on frequently repeated braking applications as it may overheat the motor.

Overvoltage control (OVC)

OVC reduces the risk of the drive tripping due to an overvoltage on the DC link. This is managed by automatically extending the ramp-down time.

NOTICE

OVC can be activated for PM motors with control core, PM VVC^{+}, Flux open-loop control, and Flux closed-loop control.

NOTICE

LOSS OF HOIST CONTROL

Do not enable OVC in hoisting applications. If OVC is used with a hoist, the OVC will try to regulate the DC bus by spinning the motor faster, resulting in loss of hoisting control and/or damage to the hoist.

6.1.3 Missing Motor Phase Detection

The missing motor phase function (*parameter 4-58 Missing Motor Phase Function*) is enabled by default to avoid motor damage if a motor phase is missing. The default setting is 1000 ms, but it can be adjusted for a faster detection.

6.1.4 Mains Phase Imbalance Detection

Operation under severe mains imbalance conditions reduces the lifetime of the drive. Conditions are considered severe if the motor is operated continuously near nominal load. The default setting trips the drive if mains imbalance occurs (*parameter 14-12 Function at Mains Imbalance*).

6.1.5 Switching on the Output

Adding a switch to the output between the motor and the drive is allowed, however, fault messages can appear. Danfoss recommends not to use this feature for 525–690 V drives connected to an IT mains network.

6.1.6 Overload Protection

Torque limit

The torque limit feature protects the motor against overload, independent of the speed. Torque limit is controlled in *parameter 4-16 Torque Limit Motor Mode* and *parameter 4-17 Torque Limit Generator Mode*. The time before the torque limit warning trips is controlled in *parameter 14-25 Trip Delay at Torque Limit*.

Current limit

The current limit is controlled in *parameter 4-18 Current Limit*, and the time before the drive trips is controlled in *parameter 14-24 Trip Delay at Current Limit*.

Speed limit

Minimum speed limit: *Parameter 4-11 Motor Speed Low Limit [RPM]* or *parameter 4-12 Motor Speed Low Limit [Hz]* limit the minimum operating speed range of the drive. Maximum speed limit: *Parameter 4-13 Motor Speed High Limit [RPM]* or *parameter 4-19 Max Output Frequency* limit the maximum output speed the drive can provide.

Electronic thermal relay (ETR)

ETR is an electronic feature that simulates a bimetal relay based on internal measurements. See 6.2.2 Motor Thermal Protection.

Voltage limit

The inverter turns off to protect the transistors and the DC link capacitors when a certain hard-coded voltage level is reached.

Overtemperature

The drive has built-in temperature sensors and reacts immediately to critical values via hard-coded limits.

6.1.7 Locked Rotor Protection

There can be situations when the rotor is locked due to excessive load or other factors. The locked rotor cannot produce enough cooling, which in turn can overheat the motor winding. The drive is able to detect the locked rotor situation with open-loop PM flux control and PM VVC+ control (*parameter 30-22 Locked Rotor Detection*).

6.1.8 Automatic Derating

The drive constantly checks for the following critical levels:

- High temperature on the control card or heat sink.
- High motor load.
- High DC-link voltage.
- Low motor speed.

As a response to a critical level, the drive adjusts the switching frequency. For high internal temperatures and low motor speed, the drive can also force the PWM pattern to SFAVM.

NOTICE

DERATING WITH SINE-WAVE FILTER

The automatic derating is different when *parameter 14-55 Output Filter* is set to *[2] Sine-Wave Filter Fixed*.

- Refer to the Programming Guide for more information.

6.1.9 Automatic Energy Optimization

Automatic energy optimization (AEO) directs the drive to monitor the load on the motor continuously and adjust the output voltage to maximize efficiency. Under light load, the voltage is reduced and the motor current is minimized. The motor benefits from:

- Increased efficiency.
- Reduced heating.
- Quieter operation.

When using induction motors, the drive can optimize the energy efficiency of the motor in part load conditions by reducing the magnetization of the motor. This leads to reduced losses in the motor.

The updated AEO function features improved dynamics. This means that the AEO function can also be used in applications where a higher starting torque is required (for example, waste water pumps) or there are step load changes (such as conveyors). There is no need to select a V/Hz curve because the drive automatically adjusts motor voltage.

The AEO requires correct advanced motor data meaning that a complete automatic motor adaptation (AMA) has to be run.

6.1.10 Automatic Switching Frequency Modulation

The drive generates short electrical pulses to form an AC wave pattern. The switching frequency is the rate of these pulses. A low switching frequency (slow pulsing rate) causes audible noise in the motor, making a higher switching frequency preferable. A high switching frequency, however, generates heat in the drive that can limit the amount of current available to the motor.

Automatic switching frequency modulation regulates these conditions automatically to provide the highest switching frequency without overheating the drive. By providing a regulated high switching frequency, it quiets motor operating noise at slow speeds, when audible noise control is critical, and produces full output power to the motor when required.

6.1.11 Automatic Derating for High Switching Frequency

The drive is designed for continuous, full-load operation at switching frequencies between 1.5–2 kHz for 380–500 V, and 1–1.5 kHz for 525–690 V. The frequency range depends on power size and voltage rating. A switching frequency exceeding the maximum allowed range generates increased heat in the drive and requires the output current to be derated.

An automatic feature of the drive is load-dependent switching frequency control. This feature allows the motor to benefit from as high a switching frequency as the load allows.

6.1.12 Power Fluctuation Performance

The drive withstands mains fluctuations such as:

- Transients.
- Momentary dropouts.
- Short voltage drops.
- Surges.

The drive automatically compensates for input voltages ±10% from the nominal to provide full rated motor voltage and torque. With auto restart selected, the drive automatically powers up after a voltage trip. With flying start, the drive synchronizes to motor rotation before start.

6.1.13 Resonance Damping

Resonance damping eliminates the high-frequency motor resonance noise. Automatic or manually selected frequency damping is available.

6.1.14 Temperature-controlled Fans

Sensors in the drive regulate the operation of the internal cooling fans. Often, the cooling fans do not run during low load operation, or when in sleep mode or standby. These sensors reduce noise, increase efficiency, and extend the operating life of the fan.

6.1.15 EMC Compliance

Electromagnetic interference (EMI) and radio frequency interference (RFI) are disturbances that can affect an electrical circuit due to electromagnetic induction or radiation from an external source. The drive is designed to comply with the EMC product standard for drives IEC 61800-3 and the European standard EN 55011. Motor cables must be shielded and properly terminated to comply with the emission levels in EN 55011. For more information regarding EMC performance, see the EMC Test Results section.

6.1.16 Galvanic Isolation of Control Terminals

All control terminals and output relay terminals are galvanically isolated from mains power, which completely protects the controller circuitry from the input current. The output relay terminals require their own grounding. This isolation meets the stringent protective extra-low voltage (PELV) requirements for isolation.

The components that make up the galvanic isolation are:

- Supply, including signal isolation.
- Gate drive for the IGBTs, trigger transformers, and optocouplers.
- The output current Hall effect transducers.

6.2 Custom Application Features

Custom application functions are the most common features programmed in the drive for enhanced system performance. They require minimum programming or setup. See the Programming Guide for instructions on activating these functions.

6.2.1 Automatic Motor Adaptation (AMA)

Automatic motor adaptation (AMA) is an automated test procedure used to measure the electrical characteristics of the motor. AMA provides an accurate electronic model of the motor, allowing the drive to calculate optimal performance and efficiency. Running the

AMA procedure also maximizes the automatic energy optimization feature of the drive. AMA is performed without the motor rotating and without uncoupling the load from the motor.

6.2.2 Motor Thermal Protection

Motor thermal protection can be provided via:

- Direct temperature sensing using a
  - PTC- or KTY sensor in the motor windings and connected on a standard AI or DI.
  - PT100 or PT1000 in the motor windings and motor bearings, connected on VLT® Sensor Input Card MCB 114 and VLT® Programmable I/O MCB 115.
  - PTC thermistor input on VLT® PTC Thermistor Card MCB 112 (ATEX-approved).
- Mechanical thermal switch (Klixon type) on a DI.
- Built-in electronic relay (ETR).

ETR calculates motor temperature by measuring current, frequency, and operating time. The drive shows the thermal load on the motor in percentage and can issue a warning at a programmable overload setpoint. Programmable options at the overload allow the drive to stop the motor, reduce output, or ignore the condition. Even at low speeds, the drive meets I2t Class 20 electronic motor overload standards.

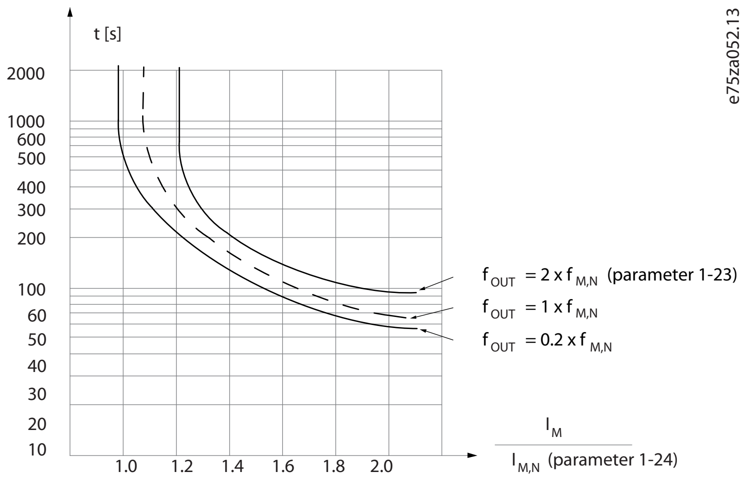


Illustration 18: ETR Characteristics

The X-axis shows the ratio between I_{motor} and I_{motor} nominal. The Y-axis shows the time in seconds before the ETR cuts off and trips the drive. The curves show the characteristic nominal speed at twice the nominal speed and at 0.2 x the nominal speed. At lower speed, the ETR cuts off at lower heat due to less cooling of the motor. In that way, the motor is protected from being overheated even at low speed. The ETR feature calculates the motor temperature based on actual current and speed. The calculated temperature is visible as a readout parameter in *parameter 16-18 Motor Thermal*. A special version of the ETR is also available for EX-e or EX-n motors in ATEX areas. This function makes it possible to enter a specific curve to protect the Ex-e motor. See the Programming Guide for set-up instructions.

6.2.3 Motor Thermal Protection for Ex-e Motors

The drive is equipped with an ATEX ETR thermal monitoring function for operation of Ex-e motors according to EN 60079-7. When combined with an ATEX-approved PTC monitoring device such as the VLT® PTC Thermistor Card MCB 112 or an external device, the installation does not require an individual approval from an approbated organization.

The ATEX ETR thermal monitoring function enables use of an Ex-e motor instead of a more expensive, larger, and heavier Ex-d motor. The function ensures that the drive limits motor current to prevent overheating.

Requirements related to the Ex-e motor

NOTICE

Install the drive outside the hazardous zone.

- Ensure that the Ex-e motor is approved for operation in hazardous zones (ATEX zone 1/21, ATEX zone 2/22) with drives. The motor must be certified for the specific hazardous zone.
- Install the Ex-e motor in zone 1/21 or 2/22 of the hazardous zone, according to motor approval.
- Ensure that the Ex-e motor is equipped with an ATEX-approved motor overload protection device. This device monitors the temperature in the motor windings. If there is a critical temperature level or a malfunction, the device switches off the motor.
  - The VLT® PTC Thermistor MCB 112 option provides ATEX-approved monitoring of motor temperature. It is a prerequisite that the drive is equipped with 3–6 PTC thermistors in series according to DIN 44081 or 44082.
  - Alternatively, an external ATEX-approved PTC protection device can be used.
- Sine-wave filter is required when the following apply:
  - Long cables (voltage peaks) or increased mains voltage produce voltages exceeding the maximum allowable voltage at motor terminals.
  - Minimum switching frequency of the drive does not meet the requirement stated by the motor manufacturer. The minimum switching frequency of the drive is shown as the default value in *parameter 14-01 Switching Frequency*.

Compatibility of motor and drive

For motors certified according to EN-60079-7, a data list including limits and rules is supplied by the motor manufacturer as a datasheet, or on the motor nameplate. During planning, installation, commissioning, operation, and service, follow the limits and rules supplied by the manufacturer for:

- Minimum switching frequency.
- Maximum current.
- Minimum motor frequency.
- Maximum motor frequency.

The requirements are indicated on the motor nameplate.

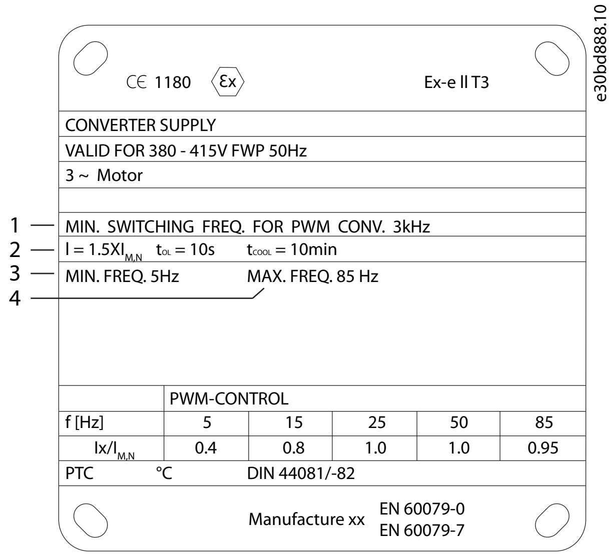


Illustration 19: Motor Nameplate showing Drive Requirements

When matching drive and motor, Danfoss specifies the following extra requirements to ensure adequate motor thermal protection:

- Do not exceed the maximum allowed ratio between drive size and motor size. The typical value is $I_{VLT,n} \leq 2 \times I_{m,n}$.
- Consider all voltage drops from drive to motor. If the motor runs with lower voltage than listed in the U/f characteristics, current can increase, triggering an alarm.

6.2.4 Mains Dropout

During a mains dropout, the drive keeps running until the DC-link voltage drops below the minimum stop level. The minimum stop level is typically 15% below the lowest rated supply voltage. The mains voltage before the dropout and the motor load determines how long it takes for the drive to coast.

Configure the mains dropout function of the drive in *parameter 14-10 Mains Failure*. The options are:

- Trip lock.
- Coast with flying start.
- Kinetic back-up.
- Controlled ramp-down.

Flying start

Flying start enables catching a motor that is spinning freely due to a mains dropout. This option is relevant for high-inertia applications, such as centrifuges and fans.

Kinetic back-up

This selection ensures that the drive runs as long as there is energy in the system. For short mains dropout, the operation is restored after mains return without bringing the application to a stop or losing control at any time. Several variants of kinetic back-up can be selected.

Configure the behavior of the drive at mains dropout in *parameter 14-10 Mains Failure* and *parameter 1-73 Flying Start*.

6.2.5 Built-in PID Controller

The built-in proportional, integral, derivative (PID) controller eliminates the need for auxiliary control devices. The PID controller maintains constant control of closed-loop systems where regulated pressure, flow, temperature, or other system requirements must be maintained.

The drive can use 2 feedback signals from 2 different devices, allowing the system to be regulated with different feedback requirements. The drive makes control decisions by comparing the 2 signals to optimize system performance.

6.2.6 Automatic Restart

The drive can be programmed to restart the motor automatically after a minor trip, such as momentary power loss or fluctuation.

This feature eliminates the need for manual resetting and enhances automated operation for remotely controlled systems. The number of restart attempts and the duration between attempts can be limited.

6.2.7 Flying Start

Flying start allows the drive to synchronize with an operating motor rotating at up to full speed in either direction. This prevents trips due to overcurrent draw. It minimizes mechanical stress to the system since the motor receives no abrupt change in speed when the drive starts.

6.2.8 Full Torque at Reduced Speed

The drive follows a variable V/Hz curve to provide full motor torque even at reduced speeds. Full output torque can coincide with the maximum designed operating speed of the motor. This drive differs from variable torque drives and constant torque drives. Variable torque drives provide reduced motor torque at low speed. Constant torque drives provide excess voltage, heat, and motor noise at less than full speed.

6.2.9 Frequency Bypass

In some applications, the system can have operational speeds that create a mechanical resonance. This mechanical resonance can generate excessive noise and possibly damage mechanical components in the system. The drive has 4 programmable bypass-frequency bandwidths (*parameters 4-60* to *4-63*). The bandwidths allow the motor to step over speeds that induce system resonance.

6.2.10 Motor Preheat

Instead of using a space heater, Danfoss provides motor preheat functionality. To preheat a motor in a cold or damp environment, a small amount of DC current can be trickled continuously into the motor to protect it from condensation and cold starts.

See *parameter 2-00 DC Hold Current* in the Programming Guide for more detail.

Another option is using the motor heater control, which is an option with the enclosed drive. A control relay terminal is extended to terminal block XDM, allowing the motor heater to be turned off/on automatically when the drive is powered on/off.

6.2.11 Programmable Set-ups

The drive has 4 set-ups that can be independently programmed. Using multi-setup, it is possible to switch between independently programmed functions activated by digital inputs or a serial command. Independent set-ups are used, for example, to change references, or for day/ night or summer/winter operation, or to control multiple motors. The LCP shows the active set-up.

Set-up data can be copied from drive to drive by downloading the information from the removable LCP, by using MCT 10, or by using a smart device if a VLT® Wireless Control Panel LCP 103 is installed.

6.2.12 Smart Logic Controller

Smart logic control (SLC) is a sequence of user-defined actions (see *parameter 13-52 SL Controller Action* [x]) executed by the SLC when the associated user-defined event (see *parameter 13-51 SL Controller Event* [x]) is evaluated as true by the SLC.

It is possible to create up to 4 independent sequences. Linking between sequences can be done by using logic rules. Use the SLC settings to activate, deactivate, and reset the smart logic control sequence. The logic functions and comparators are always running in the background, which opens for separate control of digital inputs and outputs. In MCT 10, it is possible to program the SLC sequences via the graphics plug-in.

The condition for an event can be a particular status or that the output from a logic rule or a comparator operand becomes true. That leads to an associated action as shown in the illustration 20.

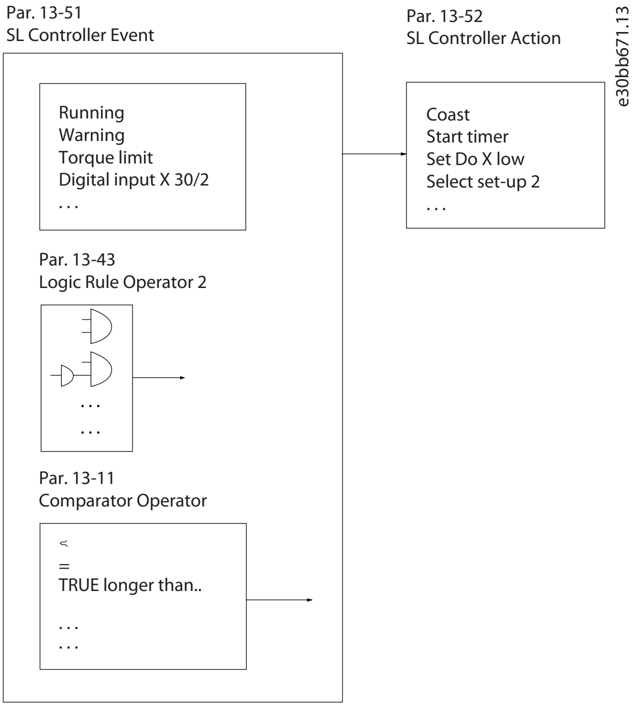


Illustration 20: Associated Action

Events and actions are each numbered and linked in pairs (states). This means that when event [0] is fulfilled (attains the value true), action [0] is executed. After this, the conditions of event [1] are evaluated and if evaluated true, action [1] is executed, and so on. Only 1 event is evaluated at any time. If an event is evaluated as false, nothing happens (in the SLC) during the current scan interval, and no other events are evaluated. When the SLC starts, it evaluates event [0] (and only event [0]) each scan interval. Only when event [0] is evaluated true, the SLC executes action [0] and starts evaluating event [1]. It is possible to program 1–20 events and actions per sequence.

When the last event/action has been executed, the sequence starts over again from event [0]/action [0]. See illustration 21 for an example with 3 events/actions:

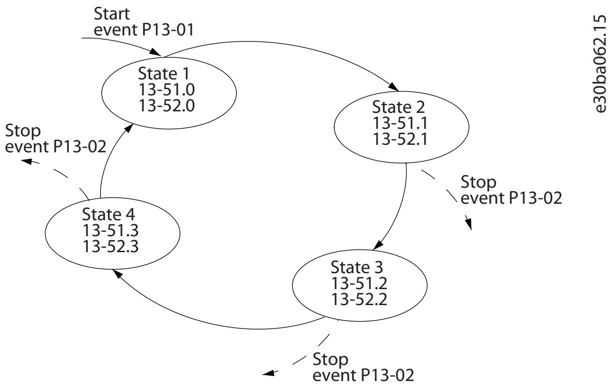


Illustration 21: Sequence with 4 Events/Actions

6.2.12.1 Comparators

Comparators are used for comparing continuous variables (for example, output frequency, output current, and analog input) to fixed preset values.

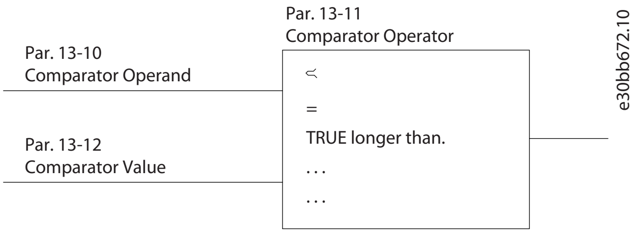


Illustration 22: Comparators

6.2.12.2 Logic Rules

Combine up to 3 boolean inputs (true/false inputs) from timers, comparators, digital inputs, status bits, and events using the logical operators and, or, and not.

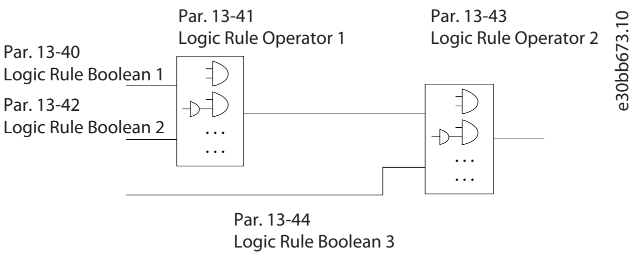


Illustration 23: Logic Rules

6.2.13 Safe Torque Off

To run STO, extra wiring for the drive is required. Refer to the VLT® Safe Torque Off Operating Guide for further information.

Liability conditions

The customer is responsible for ensuring that personnel know how to install and operate the Safe Torque Off function by:

- Reading and understanding the safety regulations concerning health, safety, and accident prevention.
- Understanding the generic and safety guidelines provided in the VLT® Safe Torque Off Operating Guide.
- Having a good knowledge of the generic and safety standards for the specific application.

6.3 Features for Specialized Applications

6.3.1 Torque Sharing/Droop

Use the droop function when load distribution between drives connected to the same load is required. For example, in multi-motor operation for anchor winches, cranes, and conveyors.

Many large winches, cranes, or conveyors have to be powered by 2 or more motors. If 1 fails, the others can handle the load (if the drives are sufficiently oversized). The motors are usually connected to 2 or more drives to ensure that the application runs smoothly. By using the droop function in the drive, it ensures, for example, that the winch motors create an equal torque at any speed and any load. Only 1 drive is thus required to control the winch.

Torque sharing

- More than 1 motor on the same shaft - need for torque sharing.
- Designed for flux open-loop control/closed-loop control.
- Stiffness is configured in *parameter 1-62 Slip Compensation* or *parameter 7-01 Speed PID Droop* (compensation).

Benefits:

- Single setup.
- No master/slave, all are programmed as master, no communication needed between masters.
- Less inertia in more small motors compared with 1 large motor.

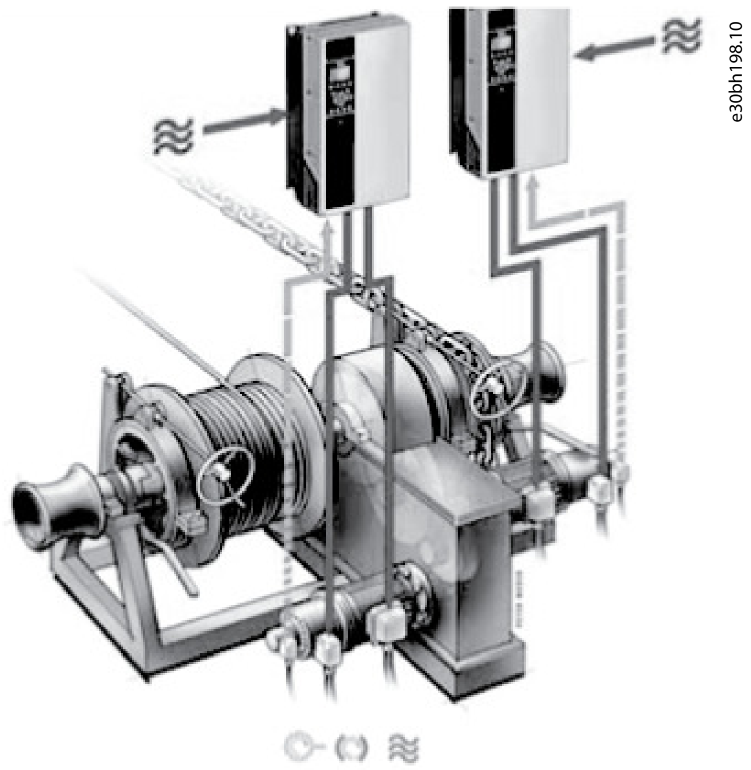


Illustration 24: Example of Torque Sharing

Commissioning of torque sharing drives

- Run drive in flux open-loop control/closed-loop control.
- Run drive in speed mode.
- Set negative value in *parameter 1-62 Slip Compensation*.
- Use same speed reference, start, and stop signals in all torque sharing drives.
- All torque sharing drives use the same parameters.

Example:

4-pole motor, nominal speed 1430 RPM ⇒ slip = 70 RPM at full load. If the reference is set to 1500 RPM and *parameter 1-62 Slip Compensation* is set to -50%, the motor runs 1465 RPM at full load.

- Torque sharing also work in overload situation.
- Torque sharing also works with different motors (not with same value in *parameter 1-62 Slip Compensation*). Use *parameter 7-01 Speed PID Droop* with the same values.

6.3.2 Power Limit Function

A power limit function limits the power distributed to the motor (power limit motor mode). Also, the power limit function can limit generative power fed back into the mains supply (AFE) or fed to a brake resistor (power limit generator mode). The power limit function is designed for flux open-loop control/closed-loop control and can be used for all motor types with flux control core (ASM-PM).

To activate the power limit, use a digital input or a fieldbus control word. To adjust the power limit level, use an analog input and/or fieldbus PCD channel.

Torque [Nm] = Power [W]/Speed [rad/sec]

The power limit function is activated and used in the following modes:

- Power limit always active (enabled).
- Power limit only when activated.
- Fixed power variable torque.
- Reduced power reduced speed (motor mode).

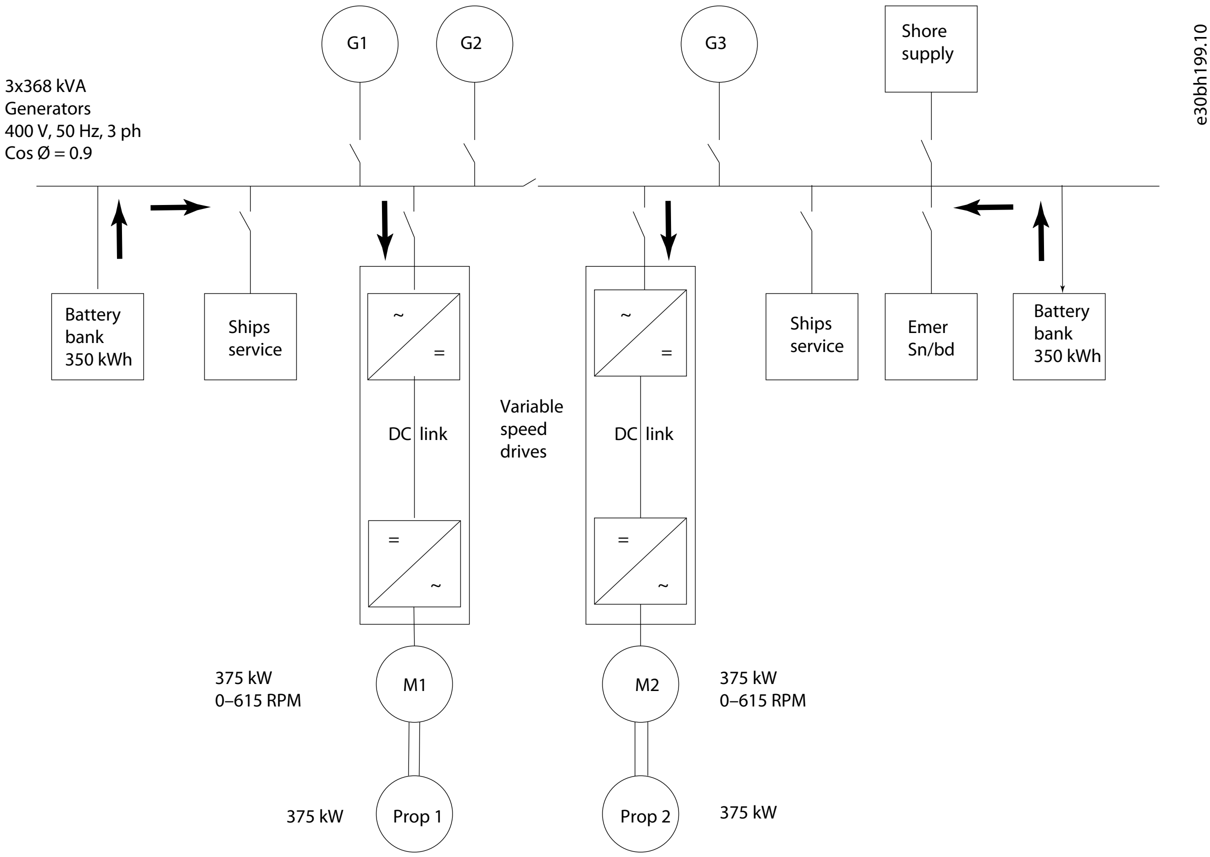


Illustration 25: Diagram of the Power Limit Function

The basic settings for the power that should be limited can be programmed via parameter settings. When power limit is active, *parameter 4-82 Power Limit Motor Mode* and *parameter 4-83 Power Limit Generator Mode* are used as limits. The drive then calculates the required torque levels to achieve a power limitation for motor/generator operation The motor speed is controlled so that the power limit values are not exceeded. When operating in power limit mode, the motor speed can deviate from the actual speed setpoint that is commanded.

One of the most common use cases for a power limit functionality is marine applications, such as winch and thruster applications, but the function can be used in all types of applications. On board a ship/vessel, the mains supply is always coming from a generator system. In many cases, several generators supply the total electrical load on the ship/vessel. If 1 of these generators fails/trips, the total power requirement cannot be fulfilled anymore. To insure availability fo critical parts of the application, a limited power consumption could keep the installation available and prevent the remaining generators from being instantly overloaded. The application can remain running when a power limit function is activated because the power is kept within the defined limits.

6.4 Dynamic Braking Overview

Dynamic braking slows the motor using 1 of the following methods:

- AC brake:
  - The brake energy is distributed in the motor by changing the loss conditions in the motor (*parameter 2-10 Brake Function = [2] AC Brake*). The AC brake function cannot be used in applications with high cycling frequency since this situation overheats the motor.
- DC brake:
  - An overmodulated DC current added to the AC current works as an eddy current brake (*parameter 2-02 DC Braking Time ≠ 0 s*).
- Resistor brake:
  - A brake IGBT keeps the overvoltage under a certain threshold by directing the brake energy from the motor to the connected brake resistor (*parameter 2-10 Brake Function = [1] Resistor Brake*). For more information on selecting a brake resistor, see the VLT® Brake Resistor MCE 101 Design Guide.

For drives equipped with the brake option, a brake IGBT along with terminals 81(R-) and 82(R+) are included for connecting an external brake resistor. The function of the brake IGBT is to limit the voltage in the DC link whenever the maximum voltage limit is exceeded. It limits the voltage by switching the externally mounted resistor across the DC bus to remove excess DC voltage present on the bus capacitors.

External brake resistor placement has the advantages of selecting the resistor based on application need, dissipating the energy outside of the control panel, and protecting the drive from overheating if the brake resistor is overloaded. The brake IGBT gate signal originates on the control card and is delivered to the brake IGBT via the power card and gatedrive card. Also, the power and control cards monitor the brake IGBT for a short circuit. The power card also monitors the brake resistor for overloads.

External brake resistor placement has the advantages of selecting the resistor based on application need, dissipating the energy outside of the control panel, and protecting the drive from overheating if the brake resistor is overloaded.

6.5 Back-channel Cooling Overview

A unique back-channel duct passes cooling air over the heat sinks with minimal air passing through the electronics area. There is an IP54/Type 12 seal between the back-channel cooling duct and the electronics area of the VLT® drive. This back-channel cooling allows 90% of the heat losses to be exhausted directly outside the enclosure when using 1 of the back-channel cooling kits. This design improves reliability and prolongs component life by dramatically reducing interior temperatures and contamination of the electronic components. Different back-channel cooling kits are available to redirect the airflow based on individual needs.

7 Specifications

7.1 Electrical Data

7.1.1 Electrical Data, 380–500 V AC

Table 6: Electrical Data, Mains Supply 3x380–500 V AC

FC 302	N90K		N110		N132	
High/normal overload High overload=150% or 160% torque for a duration of 60 s. Normal overload=110% torque for a duration of 60 s.	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**
Typical shaft output at 400 V [kW]	90	110	110	132	132	160
Typical shaft output at 460 V [hp]	125	150	150	200	200	250
Typical shaft output at 500 V [kW]	110	132	132	160	160	200
Enclosure size	D9h		D9h		D9h	
Output current (3-phase)						
Continuous (at 400 V) [A]	177	212	212	260	260	315
Intermittent (60 s overload) (at 400 V) [A]	266	233	318	286	390	347
Continuous (at 460/500 V) [A]	160	190	190	240	240	302
Intermittent (60 s overload) (at 460/500 V) [A]	240	209	285	264	360	332
Continuous kVA (at 400 V) [kVA]	123	147	147	180	180	218
Continuous kVA (at 460 V) [kVA]	127	151	151	191	191	241
Continuous kVA (at 500 V) [kVA]	139	165	165	208	208	262
Maximum input current						
Continuous (at 400 V) [A]	171	204	204	251	251	304
Continuous (at 460/500 V) [A]	154	183	183	231	231	291
Maximum number and size of cables per phase						
- Mains [mm^2 (AWG)]	2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)	
- Mains with disconnect [mm^2 (AWG)]	2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)	
- Mains with fusible disconnect [mm^2 (AWG)]	2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)	
- Mains with contactor [mm^2 (AWG)]	2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)	
- Motor [mm^2 (AWG)]	2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)	
Drive module power loss at 400 V [W] (1) (2) (3)	2031	2559	2289	2954	2923	3770
Drive module power loss at 460 V [W] (1) (2) (3)	1828	2261	2051	2724	2089	3628
Drive efficiency (2)	0.98		0.98		0.98	
Output frequency [Hz] (4)	0–590		0–590		0–590	

FC 302	N90K	N110	N132
Heat sink overtemperature trip [°C (°F)]	110 (230)	110 (230)	110 (230)
Control card overtemperature trip [°C (°F)]	75 (167)	75 (167)	75 (167)
PHF overtemperature trip [°C (°F)]	145 (293)	145 (293)	145 (293)
dU/dt filter overtemperature trip [°C (°F)]	150 (302)	150 (302)	150 (302)
Sine-wave filter overtemperature trip [°C (°F)]	150 (302)	150 (302)	150 (302)

[1] *Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the drive. Applies to dimensioning of drive cooling. If the switching frequency is higher than the default setting, the power losses can increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to . Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.*

[2] *Measured using 5 m (16.4 ft) shielded motor cables at rated load and rated frequency. Efficiency measured at nominal current. For energy efficiency class, see the Ambient Conditions section. For part load losses, see .*

[3] *See also Input Power Option Losses.*

[4] *If using an output filter, the output frequency is limited further. See* *7.4.1 Motor Output (U, V, W)*.

Table 7: Electrical Data, Mains Supply 3x380–500 V AC

FC 302	N160		N200		N250	
High/normal overload High overload=150% or 160% torque for a duration of 60 s. Normal overload=110% torque for a duration of 60 s.	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**
Typical shaft output at 400 V [kW]	160	200	200	250	250	315
Typical shaft output at 460 V [hp]	250	300	300	350	350	450
Typical shaft output at 500 V [kW]	200	250	250	315	315	355
Enclosure size	D10h		D10h		D10h	
Output current (3-phase)						
Continuous (at 400 V) [A]	315	395	395	480	480	588
Intermittent (60 s overload) (at 400 V) [A]	473	435	593	528	720	647
Continuous (at 460/500 V) [A]	302	361	361	443	443	535
Intermittent (60 s overload) (at 460/500 V) [A]	453	397	542	487	665	589
Continuous kVA (at 400 V) [kVA]	218	274	274	333	333	407
Continuous kVA (at 460 V) [kVA]	241	288	288	353	353	426
Continuous kVA (at 500 V) [kVA]	262	313	313	384	384	463
Maximum input current						
Continuous (at 400 V) [A]	304	381	381	463	463	567
Continuous (at 460/500 V) [A]	291	348	348	427	427	516
Maximum number and size of cables per phase						
- Mains [mm^2 (AWG)]	2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)	
- Mains with disconnect [mm^2 (AWG)]	2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)	

FC 302	N160		N200		N250	
- Mains with fusible disconnect [mm² (AWG)]	2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)	
- Mains with contactor [mm² (AWG)]	2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)	
- Mains [mm² (AWG)]	2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)	
Drive module power loss at 400 V [W] (1) (2) (3)	3093	4116	4039	5137	5005	6674
Drive module power loss at 460 V [W] (1) (2) (3)	2872	3569	3575	4566	4458	5714
Drive efficiency (2)	0.98		0.98		0.98	
Output frequency [Hz] (4)	0–590		0–590		0–590	
Heat sink overtemperature trip [°C (°F)]	110 (230)		110 (230)		110 (230)	
Control card overtemperature trip [°C (°F)]	80 (176)		80 (176)		80 (176)	
PHF overtemperature trip [°C (°F)]	145 (293)		145 (293)		145 (293)	
dU/dt filter overtemperature trip [°C (°F)]	150 (302)		150 (302)		150 (302)	
Sine-wave filter overtemperature trip [°C (°F)]	150 (302)		150 (302)		150 (302)	

[1] *Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the drive. Applies to dimensioning of drive cooling. If the switching frequency is higher than the default setting, the power losses can increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to . Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.*

[2] *Measured using 5 m (16.4 ft) shielded motor cables at rated load and rated frequency. Efficiency measured at nominal current. For energy efficiency class, see the Ambient Conditions section. For part load losses, see .*

[3] *See also Input Power Option Losses.*

[4] *If using an output filter, the output frequency is limited further. See 7.4.1 Motor Output (U, V, W).*

Table 8: Electrical Data, Mains Supply 3x380–500 V AC

FC 302	N315		N355		N400	
High/normal overload High overload=150% or 160% torque for a duration of 60 s. Normal overload=110% torque for a duration of 60 s.	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**
Typical shaft output at 400 V [kW]	315	355	355	400	400	450
Typical shaft output at 460 V [hp]	450	500	500	600	550	600
Typical shaft output at 500 V [kW]	355	400	400	500	500	530
Enclosure size	E5h		E5h		E5h	
Output current (3-phase)						
Continuous (at 400 V) [A]	600	658	658	745	695	800
Intermittent (60 s overload) (at 400 V) [A]	900	724	987	820	1043	880
Continuous (at 460/500 V) [A]	540	590	590	678	678	730
Intermittent (60 s overload) (at 460/500 V) [A]	810	649	885	746	1017	803
Continuous kVA (at 400 V) [kVA]	416	456	456	516	482	554

FC 302	N315		N355		N400	
Continuous kVA (at 460 V) [kVA]	430	470	470	540	540	582
Continuous kVA (at 500 V) [kVA]	468	511	511	587	587	632
Maximum input current						
Continuous (at 400 V) [A]	578	634	634	718	670	771
Continuous (at 460/500 V) [A]	520	569	569	653	653	704
Maximum number and size of cables per phase						
- Mains [mm^2 (AWG)]	4x127 (4x250 mcm)		4x127 (4x250 mcm)		4x127 (4x250 mcm)	
- Mains with disconnect [mm^2 (AWG)]	4x127 (4x250 mcm)		4x127 (4x250 mcm)		4x127 (4x250 mcm)	
- Mains with fusible disconnect [mm^2 (AWG)]	4x127 (4x250 mcm)		4x127 (4x250 mcm)		4x127 (4x250 mcm)	
- Mains with contactor [mm^2 (AWG)]	4x127 (4x250 mcm)		4x127 (4x250 mcm)		4x127 (4x250 mcm)	
- Motor [mm^2 (AWG)]	4x127 (4x250 mcm)		4x127 (4x250 mcm)		4x127 (4x250 mcm)	
Drive module power loss at 400 V [W] [(1) (2) (3)]	6178	6928	6851	8036	7297	8783
Drive module power loss at 460 V [W] [(1) (2) (3)]	5322	5910	5846	6933	7240	7969
Drive efficiency [(2)]	0.98		0.98		0.98	
Output frequency [Hz] [(4)]	0–590		0–590		0–590	
Heat sink overtemperature trip [°C (°F)]	110 (230)		110 (230)		110 (230)	
Control card overtemperature trip [°C (°F)]	80 (176)		80 (176)		80 (176)	
PHF overtemperature trip [°C (°F)]	145 (293)		145 (293)		145 (293)	
dU/dt filter overtemperature trip [°C (°F)]	150 (302)		150 (302)		150 (302)	
Sine-wave filter overtemperature trip [°C (°F)]	150 (302)		150 (302)		150 (302)	

[1] *Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the drive. Applies to dimensioning of drive cooling. If the switching frequency is higher than the default setting, the power losses can increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to . Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.*

[2] *Measured using 5 m (16.4 ft) shielded motor cables at rated load and rated frequency. Efficiency measured at nominal current. For energy efficiency class, see the Ambient Conditions section. For part load losses, see .*

[3] *See also Input Power Option Losses.*

[4] *If using an output filter, the output frequency is limited further. See 7.4.1 Motor Output (U, V, W).*

Table 9: Electrical Data, Mains Supply 3x380–500 V AC

FC 302	N450		N500	
High/normal overload High overload=150% or 160% torque for a duration of 60 s. Normal overload=110% torque for a duration of 60 s.	HO	NO	HO	NO
Typical shaft output at 400 V [kW]	450	500	500	560
Typical shaft output at 460 V [hp]	600	650	650	750

FC 302	N450		N500	
Typical shaft output at 500 V [kW]	530	560	560	630
Enclosure size	E6h		E6h	
Output current (3-phase)				
Continuous (at 400 V) [A]	800	880	880	990
Intermittent (60 s overload) (at 400 V) [A]	1200	968	1320	1089
Continuous (at 460/500 V) [A]	730	780	780	890
Intermittent (60 s overload) (at 460/500 V) [A]	1095	858	1170	979
Continuous kVA (at 400 V) [kVA]	554	610	610	686
Continuous kVA (at 460 V) [kVA]	582	621	621	709
Continuous kVA (at 500 V) [kVA]	632	675	675	771
Maximum input current				
Continuous (at 400 V) [A]	771	848	848	954
Continuous (at 460/500 V) [A]	704	752	752	858
Maximum number and size of cables per phase				
- Mains [mm^2 (AWG)]	4x185 (4x350 mcm)		4x185 (4x350 mcm)	
- Mains with disconnect [mm^2 (AWG)]	4x185 (4x350 mcm)		4x185 (4x350 mcm)	
- Mains with fusible disconnect [mm^2 (AWG)]	4x185 (4x350 mcm)		4x185 (4x350 mcm)	
- Mains with contactor [mm^2 (AWG)]	4x185 (4x350 mcm)		4x185 (4x350 mcm)	
- Motor [mm^2 (AWG)]	4x185 (4x350 mcm)		4x185 (4x350 mcm)	
Drive module power loss at 400 V [W] [(1) (2) (3)]	8352	9473	9449	11102
Estimated power loss at 460 V [W] [(1) (2) (3)]	7182	7809	7771	9236
Drive efficiency [(2)]	0.98		0.98	
Output frequency [Hz] [(4)]	0–590		0–590	
Heat sink overtemperature trip [°C (°F)]	110 (230)		100 (212)	
Control card overtemperature trip [°C (°F)]	80 (176)		80 (176)	
PHF overtemperature trip [°C (°F)]	150 (302)		150 (302)	
dU/dt filter overtemperature trip [°C (°F)]	150 (302)		150 (302)	
Sine-wave filter overtemperature trip [°C (°F)]	150 (302)		150 (302)	

[1] *Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the drive. Applies to dimensioning of drive cooling. If the switching frequency is higher than the default setting, the power losses can increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to . Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.*

[2] *Measured using 5 m (16.4 ft) shielded motor cables at rated load and rated frequency. Efficiency measured at nominal current. For energy efficiency class, see the Ambient Conditions section. For part load losses, see .*

[3] *See also Input Power Option Losses.*

[4] *If using an output filter, the output frequency is limited further. See 7.4.1 Motor Output (U, V, W).*

7.1.2 Electrical Data, 525–690 V AC

Table 10: Electrical Data, Mains Supply 3x525–690 V AC

FC 302	N90K		N110		N132		N160	
High/normal overload High overload=150% or 160% torque for a duration of 60 s. Normal overload=110% torque for a duration of 60 s.	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**
Typical shaft output at 550 V [kW]	75	90	90	110	110	132	132	160
Typical shaft output at 575 V [hp]	100	125	125	150	150	200	200	250
Typical shaft output at 690 V [kW]	90	110	110	132	132	160	160	200
Enclosure size	D9h		D9h		D9h		D10h	
Output current (3-phase)								
Continuous (at 550 V) [A]	113	137	137	162	162	201	201	253
Intermittent (60 s overload) (at 550 V) [A]	170	151	206	178	243	221	301	278
Continuous (at 575/690 V) [A]	108	131	131	155	155	192	192	242
Intermittent (60 s overload) (at 575/690 V) [A]	162	144	197	171	233	211	288	266
Continuous kVA (at 550 V) [kVA]	103	125	125	147	147	183	183	230
Continuous kVA (at 575 V) [kVA]	108	131	131	154	154	191	191	241
Continuous kVA (at 690 V) [kVA]	129	157	157	185	185	230	229	289
Maximum input current								
Continuous (at 525 V) [A]	109	132	132	156	156	193	193	244
Continuous (at 575/690 V) [A]	104	126	126	149	149	185	185	233
Maximum number and size of cables per phase								
- Mains [mm^2 (AWG)]	2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)		2x185 (2x350 mcm)	
- Mains with disconnect [mm^2 (AWG)]	2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)		2x185 (2x350 mcm)	
- Mains with fusible disconnect [mm^2 (AWG)]	2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)		2x185 (2x350 mcm)	
- Mains with contactor [mm^2 (AWG)]	2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)		2x185 (2x350 mcm)	
- Motor [mm^2 (AWG)]	2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)		2x95 (2x3/0 mcm)		2x185 (2x350 mcm)	
Drive module power loss at 600 V [W] (1) (2) (3)	1430	1740	1742	2101	2080	2649	2361	3074
Drive module power loss at 690 V [W] (1) (2) (3)	1480	1798	1800	2167	2159	2740	2446	3175
Drive efficiency (2)	0.98		0.98		0.98		0.98	
Output frequency [Hz] (4)	0–590		0–590		0–590		0–590	
Heat sink overtemperature trip [°C (°F)]	110 (230)		110 (230)		110 (230)		110 (230)	
Control card overtemperature trip [°C (°F)]	75 (167)		75 (167)		75 (167)		75 (167)	
PHF overtemperature trip [°C (°F)]	145 (293)		145 (293)		145 (293)		145 (293)	
dU/dt filter overtemperature trip [°C (°F)]	150 (302)		150 (302)		150 (302)		150 (302)	

FC 302	N90K	N110	N132	N160
Sine-wave filter overtemperature trip [°C (°F)]	150 (302)	150 (302)	150 (302)	150 (302)

[1] *Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the drive. Applies to dimensioning of drive cooling. If the switching frequency is higher than the default setting, the power losses can increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to . Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.*

[2] *Measured using 5 m (16.4 ft) shielded motor cables at rated load and rated frequency. Efficiency measured at nominal current. For energy efficiency class, see the Ambient Conditions section. For part load losses, see .*

[3] *See also Input Power Option Losses.*

[4] *If using an output filter, the output frequency is limited further. See 7.4.1 Motor Output (U, V, W).*

Table 11: Electrical Data, Mains Supply 3x525–690 V AC

FC 302	N200		N250		N315	
High/normal overload High overload=150% or 160% torque for a duration of 60 s. Normal overload=110% torque for a duration of 60 s.	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**
Typical shaft output at 550 V [kW]	160	200	200	250	250	315
Typical shaft output at 575 V [hp]	250	300	300	350	350	400
Typical shaft output at 690 V [kW]	200	250	250	315	315	400
Enclosure size	D10h		D10h		D10h	
Output current (3-phase)						
Continuous (at 550 V) [A]	395	303	303	360	360	418
Intermittent (60 s overload) (at 550 V) [A]	380	333	455	396	540	460
Continuous (at 575/690 V) [A]	242	290	290	344	344	400
Intermittent (60 s overload) (at 575/690 V) [A]	363	319	435	378	516	440
Continuous kVA (at 550 V) [kVA]	230	276	276	327	327	380
Continuous kVA (at 575 V) [kVA]	241	289	289	343	343	398
Continuous kVA (at 690 V) [kVA]	289	347	347	411	411	478
Maximum input current						
Continuous (at 525 V) [A]	244	292	292	347	347	403
Continuous (at 575/690 V) [A]	233	279	279	332	332	385
Maximum number and size of cables per phase						
- Mains [mm^2 (AWG)]	2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)	
- Mains with disconnect [mm^2 (AWG)]	2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)	
- Mains with fusible disconnect [mm^2 (AWG)]	2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)	
- Mains with contactor [mm^2 (AWG)]	2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)	
- Motor [mm^2 (AWG)]	2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)	

FC 302	N200		N250		N315	
Drive module power loss at 600 V [W] [(1) (2) (3)]	3012	3723	3642	4465	4146	5028
Drive module power loss at 690 V [W] [(1) (2) (3)]	3123	3851	3771	4614	4258	5155
Drive efficiency [(2)]	0.98		0.98		0.98	
Output frequency [Hz] [(4)]	0–590		0–590		0–590	
Heat sink overtemperature trip [°C (°F)]	110 (230)		110 (230)		110 (230)	
Control card overtemperature trip [°C (°F)]	80 (176)		80 (176)		80 (176)	
PHF overtemperature trip [°C (°F)]	150 (302)		150 (302)		150 (302)	
dU/dt filter overtemperature trip [°C (°F)]	150 (302)		150 (302)		150 (302)	
Sine-wave filter overtemperature trip [°C (°F)]	150 (302)		150 (302)		150 (302)	

[1] *Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the drive. Applies to dimensioning of drive cooling. If the switching frequency is higher than the default setting, the power losses can increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to . Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.*

[2] *Measured using 5 m (16.4 ft) shielded motor cables at rated load and rated frequency. Efficiency measured at nominal current. For energy efficiency class, see the Ambient Conditions section. For part load losses, see .*

[3] *See also Input Power Option Losses.*

[4] *If using an output filter, the output frequency is limited further. See 7.4.1 Motor Output (U, V, W).*

Table 12: Electrical Data, Mains Supply 3x525–690 V AC

FC 302	N355		N400		N500	
High/normal overload High overload=150% or 160% torque for a duration of 60 s. Normal overload=110% torque for a duration of 60 s.	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**
Typical shaft output at 550 V [kW]	315	355	355	400	400	450
Typical shaft output at 575 V [hp]	400	450	400	500	500	600
Typical shaft output at 690 V [kW]	355	450	400	500	500	560
Enclosure size	E5h		E5h		E5h	
Output current (3-phase)						
Continuous (at 550 V) [A]	395	470	429	523	523	596
Intermittent (60 s overload) (at 550 V) [A]	593	517	644	575	785	656
Continuous (at 575/690 V) [A]	380	450	410	500	500	570
Intermittent (60 s overload) (at 575/690 V) [A]	570	495	615	550	750	627
Continuous kVA (at 550 V) [kVA]	376	448	409	498	498	568
Continuous kVA (at 575 V) [kVA]	378	448	408	498	498	568
Continuous kVA (at 690 V) [kVA]	454	538	490	598	598	681
Maximum input current						
Continuous (at 525 V) [A]	381	453	413	504	504	574

FC 302	N355		N400		N500	
Continuous (at 575/690 V) [A]	366	434	395	482	482	549
Maximum number and size of cables per phase						
- Mains [mm^2 (AWG)]	4x127 (4x250 mcm)		4x127 (4x250 mcm)		4x127 (4x250 mcm)	
- Mains with disconnect [mm^2 (AWG)]	4x127 (4x250 mcm)		4x127 (4x250 mcm)		4x127 (4x250 mcm)	
- Mains with fusible disconnect [mm^2 (AWG)]	4x127 (4x250 mcm)		4x127 (4x250 mcm)		4x127 (4x250 mcm)	
- Mains with contactor [mm^2 (AWG)]	4x127 (4x250 mcm)		4x127 (4x250 mcm)		4x127 (4x250 mcm)	
- Motor [mm^2 (AWG)]	4x127 (4x250 mcm)		4x127 (4x250 mcm)		4x127 (4x250 mcm)	
Drive module power loss at 600 V [W] (1) (2) (3)	4989	6062	5419	6879	6833	8076
Drive module power loss at 690 V [W] (1) (2) (3)	4920	5939	5332	6715	6678	7852
Drive efficiency (2)	0.98		0.98		0.98	
Output frequency [Hz] (4)	0–590		0–590		0–590	
Heat sink overtemperature trip [°C (°F)]	110 (230)		110 (230)		110 (230)	
Control card overtemperature trip [°C (°F)]	80 (176)		80 (176)		80 (176)	
PHF overtemperature trip [°C (°F)]	150 (302)		150 (302)		150 (302)	
dU/dt filter overtemperature trip [°C (°F)]	150 (302)		150 (302)		150 (302)	
Sine-wave filter overtemperature trip [°C (°F)]	150 (302)		150 (302)		150 (302)	

[1] *Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the drive. Applies to dimensioning of drive cooling. If the switching frequency is higher than the default setting, the power losses can increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to . Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.*

[2] *Measured using 5 m (16.4 ft) shielded motor cables at rated load and rated frequency. Efficiency measured at nominal current. For energy efficiency class, see the Ambient Conditions section. For part load losses, see .*

[3] *See also Input Power Option Losses.*

[4] *If using an output filter, the output frequency is limited further. See 7.4.1 Motor Output (U, V, W).*

Table 13: Electrical Data, Mains Supply 3x525–690 V AC

FC 302	N560		N630		N710	
High/normal overload High overload=150% or 160% torque for a duration of 60 s. Normal overload=110% torque for a duration of 60 s.	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**
Typical shaft output at 550 V [kW]	450	500	500	560	560	670
Typical shaft output at 575 V [hp]	600	650	650	750	750	950
Typical shaft output at 690 V [kW]	560	630	630	710	710	800
Enclosure size	E5h		E6h		E6h	
Output current (3-phase)						
Continuous (at 550 V) [A]	596	630	659	763	763	889

FC 302	N560		N630		N710	
Intermittent (60 s overload) (at 550 V) [A]	894	693	989	839	1145	978
Continuous (at 575/690 V) [A]	570	630	630	730	730	850
Intermittent (60 s overload) (at 575/690 V) [A]	855	693	945	803	1095	935
Continuous kVA (at 550 V) [kVA]	568	600	628	727	727	847
Continuous kVA (at 575 V) [kVA]	568	627	627	727	727	847
Continuous kVA (at 690 V) [kVA]	681	753	753	872	872	1016
Maximum input current						
Continuous (at 550 V) [A]	574	607	635	735	735	857
Continuous (at 575/690 V) [A]	549	607	607	704	704	819
Maximum number and size of cables per phase						
- Mains [mm^2 (AWG)]	4x127 (4x250 mcm)		4x185 (4x350 mcm)		4x185 (4x350 mcm)	
- Mains with disconnect [mm^2 (AWG)]	4x127 (4x250 mcm)		4x185 (4x350 mcm)		4x185 (4x350 mcm)	
- Mains with fusible disconnect [mm^2 (AWG)]	4x127 (4x250 mcm)		4x185 (4x350 mcm)		4x185 (4x350 mcm)	
- Mains with contactor [mm^2 (AWG)]	4x127 (4x250 mcm)		4x185 (4x350 mcm)		4x185 (4x350 mcm)	
- Motor [mm^2 (AWG)]	4x127 (4x250 mcm)		4x185 (4x350 mcm)		4x185 (4x350 mcm)	
Drive module power loss at 600 V [W] *(1) (2) (3)*	8069	9208	8543	10346	10319	12723
Drive module power loss at 690 V [W] *(1) (2) (3)*	7848	8921	8363	10066	10060	12321
Drive efficiency *(2)*	0.98		0.98		0.98	
Output frequency [Hz] *(4)*	0–590		0–590		0–590	
Heat sink overtemperature trip [°C (°F)]	110 (230)		110 (230)		110 (230)	
Control card overtemperature trip [°C (°F)]	80 (176)		80 (176)		80 (176)	
PHF overtemperature trip [°C (°F)]	150 (302)		150 (302)		150 (302)	
dU/dt filter overtemperature trip [°C (°F)]	150 (302)		150 (302)		150 (302)	
Sine-wave filter overtemperature trip [°C (°F)]	150 (302)		150 (302)		150 (302)	

[1] *Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the drive. Applies to dimensioning of drive cooling. If the switching frequency is higher than the default setting, the power losses can increase. LCP and typical control card power consumptions are included. For power loss data according to EN 50598-2, refer to . Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.*

[2] *Measured using 5 m (16.4 ft) shielded motor cables at rated load and rated frequency. Efficiency measured at nominal current. For energy efficiency class, see the Ambient Conditions section. For part load losses, see .*

[3] *See also Input Power Option Losses.*

[4] *If using an output filter, the output frequency is limited further. See 7.4.1 Motor Output (U, V, W).*

7.2 Ambient Conditions

Environment

Enclosure	IP21/NEMA 1, IP54/NEMA 12

Vibration test	1.0 g
Maximum THDv	10%
Maximum relative humidity	5–93 (IEC 721-3-3); Class 3K3 (non-condensing) during operation
Aggressive environment (IEC 60068-2-43) H_2S test	Class Kd
Ambient temperature	Maximum 55° C (131° F) (24-hour average maximum 45 °C (113 °F)) [(1)]
Minimum ambient temperature during full-scale operation	0 °C (32 °F) [(1)]
Minimum ambient temperature at reduced speed performance	-10 °C (14 °F) [(1)]
Temperature during storage/transport	-25 to 65/70 °C (-13 to 149/158 °F)
Maximum altitude above sea level without derating	1000 m (3280 ft)
EMC standards, Emission	EN 61800-3
EMC standards, Immunity	EN 61800-3
Energy efficiency class [(2)]	IE2

[1] *For more information, see the Derating section.*

[2] *Determined according to EN 50598-2 at rated load, 90% rated frequency, switching frequency factory setting, and switching pattern factory setting.*

7.3 Mains Supply

The unit is suitable for use on a circuit capable of delivering not more than 65 kA short circuit current rating (SCCR) at 480/600 V.

Supply terminals	L1, L2, L3
Supply voltage [(1)]	380–480/500 V ±10%, 525–690 V ±10%
Supply frequency	50/60 Hz ±5%
Maximum imbalance temporary between mains phases	3.0% of rated supply voltage [(2)]
True power factor (λ)	≥0.9 nominal at rated load
Displacement power factor (cos Φ)	Near unity (>0.98)
Switching on the input supply L1, L2, and L3 (power-ups)	Maximum 1 time/2 minutes
Environment according to EN 60664-1	Overvoltage category III/pollution degree 2

[1] *Mains voltage low/mains drop-out: During low mains voltage or a mains drop-out, the drive continues until the DC-link voltage drops below the minimum stop level, which corresponds typically to 15% below the drive's lowest rated supply voltage. Power-up and full torque cannot be expected at mains voltage lower than 10% below the drive's lowest rated supply voltage.*

[2] *Calculations based on UL/IEC 61800-3.*

7.4 Motor Output and Motor Data

7.4.1 Motor Output (U, V, W)

Motor output (U, V, W)	
Output voltage	0–100% of supply voltage
Output frequency (without sine-wave filter)	0–590 Hz [(1)]
Output frequency (with sine-wave filter and no derating)	0–60 Hz without derating
Output frequency (with sine-wave filter and derating)	0–100 Hz
Output frequency in flux mode	0–300 Hz
Switching on output	Unlimited

Ramp times	0.01–3600 s

[1] *Dependent on voltage and power.*

7.4.2 Torque Characteristics

Torque characteristics	
Starting torque (constant torque)	Maximum 150% for 60 s once in 10 minutes [1]
Starting/overload torque (variable torque)	Maximum 110% up to 0.5 s once in 10 minutes [1]
Torque rise time in flux (for 5 kHz f_{sw})	1 ms
Torque rise time in VVC+ (independent of f_{sw})	10 ms

[1] *Percentage relates to the nominal torque.*

7.5 Motor and Control Cables

Motor and control cable lengths and cross-sections	
Maximum motor cable length, shielded	150 m (492 ft)
Maximum motor cable length, unshielded	300 m (984 ft)
Maximum cross-section to control terminals, flexible/rigid wire without cable end sleeves	1.5 mm^2/16 AWG
Maximum cross-section to control terminals, flexible wire with cable end sleeves	1 mm^2/18 AWG
Maximum cross-section to control terminals, flexible wire with cable end sleeves with collar	0.5 mm^2/20 AWG
Minimum cross-section to control terminals	0.25 mm^2/24 AWG

7.6 Control Input/Output and Control Data

7.6.1 Control Card, USB Serial Communication

USB standard	1.1 (full speed)
USB plug [1]	USB type B plug

[1] *Connection to the PC is carried out via a standard host/device USB cable.*

The USB connection is galvanically isolated from the supply voltage (PELV) and other high-voltage terminals; however, the USB ground connection is not galvanically isolated from ground. Use only an isolated laptop as PC connection to the USB connector on the drive.

7.6.2 STO Terminal XD2.19 (Terminal XD2.19 is Fixed PNP Logic)

STO Terminal XD2.19 [1] [2]	
Voltage level	0–24 V DC
Voltage level, logic 0 PNP	<4 V DC
Voltage level, logic 1 PNP	>20 V DC
Maximum voltage on input	28 V DC

Typical input current at 24 V	50 mA rms
Typical input current at 20 V	60 mA rms
Input capacitance	400 nF

[1] *For more information about Terminal XD2.19 (Terminal 37 on the drive module) and Safe Torque Off, see the VLT® FC Series - Safe Torque Off Operating Guide.*

[2] *When using a contactor with a DC coil inside with STO, it is important to make a return way for the current from the coil when turning it off. This can be done by using a freewheel diode (or, alternatively, a 30 V or 50 V MOV for quicker response time) across the coil. Typical contactors can be bought with this diode.*

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

7.6.3 Control Card, 24 V DC Output

Terminal number	XD2.10, XD2.11
Output voltage	24 V +1, -3 V
Maximum load	200 mA

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

7.6.4 Control Card, 10 V DC Output

Terminal number	XD2.6
Output voltage	10.5 V ±0.5 V
Maximum load	15 mA

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

7.6.5 Digital Outputs

Programmable digital/pulse outputs	2
Terminal number [1]	XD2.14, XD2.15
Voltage level at digital/frequency output	0–24 V
Maximum output current (sink or source)	40 mA
Maximum load at frequency output	1 kΩ
Maximum 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	Maximum error: 0.1% of full scale
Resolution of frequency outputs	12 bit

[1] *Can also be programmed as input.*

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

7.6.6 Digital Inputs

Programmable digital inputs	4 (6)
Terminal number [1]	XD2.12, XD2.13, XD2.14, XD2.15, XD2.16, XD2.17
Logic	PNP or NPN
Voltage level	0–24 V DC
Voltage level, logic 0 PNP	<5 V DC
Voltage level, logic 1 PNP	>10 V DC
Voltage level, logic 0 NPN [2]	>19 V DC
Voltage level, logic 1 NPN [2]	<14 V DC
Maximum voltage on input	28 V DC
Pulse frequency range	0–110 kHz
(Duty cycle) minimum pulse width	4.5 ms
Input resistance, R_i	Approximately 4 kΩ

1 *Terminals XD2.14 and XD2.15 can also be programmed as output.*

2 *Except STO input terminal XD2.19.*

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

7.6.7 Pulse/Encoder Inputs

Programmable pulse/encoder inputs	2/1
Terminal number (pulse inputs)	XD2.15 [1], XD2.17
Terminal number (encoder inputs) [2]	XD2.16, XD2.17
Maximum frequency at terminals XD2.15, XD2.16, XD2.17 (push-pull driven)	110 kHz
Maximum frequency at terminals XD2.15, XD2.16, XD2.17 (open collector)	5 kHz
Maximum frequency at terminals XD2.15, XD2.16, XD2.17	4 kHz
Voltage level	See *Control Input/Output and Control Data*.
Maximum voltage on input	28 V DC
Input resistance, R_i	Approximately 4 kΩ
Pulse input accuracy (0.1–1 kHz)	Maximum error: 0.1% of full scale
Encoder input accuracy (1–11 kHz)	Maximum error: 0.05% of full scale

1 *FC 302 only.*

2 *Encoder inputs: XD2.16=A, XD2.17=B.*

The pulse and encoder inputs (terminals XD2.15, XD2.16, XD2.17) are galvanically isolated from the supply voltage (PELV) and other high-voltage terminals.

7.6.8 Control Characteristics

Resolution of output frequency at 0–590 Hz	±0.003 Hz
Repeat accuracy of precise start/stop (terminals XD2.12, XD2.13)	≤±0.1 ms
System response time (terminals XD2.12, XD2.13, XD2.14, XD2.15, XD2.16, XD2.17)	≤2 ms

Speed control range (open loop)	1:100 of synchronous speed
Speed control range (closed loop)	1:1000 of synchronous speed
Speed accuracy (open loop)	30–4000 RPM: Error ±8 RPM
Speed accuracy (closed loop), depending on resolution of feedback device	0–6000 RPM: Error ±0.15 RPM
Torque control accuracy (speed feedback)	Maximum error ±5% of rated torque

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

7.6.9 Relay Outputs

Programmable relay outputs	2
Relay 01 terminal number [(1)]	21–23 (break), 21–22 (make)
Maximum terminal load (AC-1) on 21–23 (NC), 21–22 (NO) (resistive load) [(2) (3)]	240 V AC, 2 A
Maximum terminal load (AC-15) (inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1) on 21–22 (NO), 21–23 (NC) (resistive load)	60 V DC, 1 A
Maximum terminal load (DC-13) (inductive load)	24 V DC, 0.1 A
Relay 02 (FC 302 only) terminal number [(1)]	24–26 (break), 24–25 (make)
Maximum terminal load (AC-1) on 24–25 (NO) (resistive load) [(2) (3)]	400 V AC, 2 A
Maximum terminal load (AC-15) on 24–25 (NO) (inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1) on 24–25 (NO) (resistive load)	80 V DC, 2 A
Maximum terminal load (DC-13) on 24–25 (NO) (inductive load)	24 V DC, 0.1 A
Maximum terminal load (AC-1) on 24–26 (NC) (resistive load)	240 V AC, 2 A
Maximum terminal load (AC-15) on 24–26 (NC) (inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1) on 24–26 (NC) (resistive load)	50 V DC, 2 A
Maximum terminal load (DC-13) on 24–26 (NC) (inductive load)	24 V DC, 0.1 A
Minimum terminal load on 21–23 (NC), 21–22 (NO), 24–26 (NC), 24–25 (NO)	24 V DC 10 mA, 24 V AC 20 mA
Environment according to EN 60664-1	Overvoltage category III/pollution degree 2

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

[2] *Overvoltage category II.*

[3] *UL applications 300 V AC 2 A.*

7.6.10 Analog Output

Number of programmable outputs	1
Terminal number	XD2.5
Current range at analog output	0/4 to 20 mA
Maximum load GND - analog output less than	500 Ω
Accuracy on analog output	Maximum error: 0.5% of full scale
Resolution of analog output	12 bit

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

7.6.11 Control Card, RS485 Serial Communication

Terminal number	XD2.2 (P,TX+, RX+), XD2.3 (N,TX-, RX-)
Terminal number XD2.1	Common for terminals XD2.2 and XD2.3

The RS485 serial communication circuit is galvanically isolated from the supply voltage (PELV).

7.6.12 Control Card Performance

Scan interval	1 ms

7.6.13 Analog Inputs

Number of analog inputs	2
Terminal number	XD2.7, XD2.8
Modes	Voltage or current
Mode select	Switch S201 and switch S202
Voltage mode	Switch S201/switch S202 = OFF (U)
Voltage level	-10 V to +10 V (scaleable)
Input resistance, R_i	Approximately 10 kΩ
Maximum voltage	±20 V
Current mode	Switch S201/S202 = ON (I)
Current level	0/4 to 20 mA (scaleable)
Input resistance, R_i	Approximately 200 Ω
Maximum current	30 mA
Resolution for analog inputs	10 bit (+ sign)
Accuracy of analog inputs	Maximum error 0.5% of full scale
Bandwidth	100 Hz

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

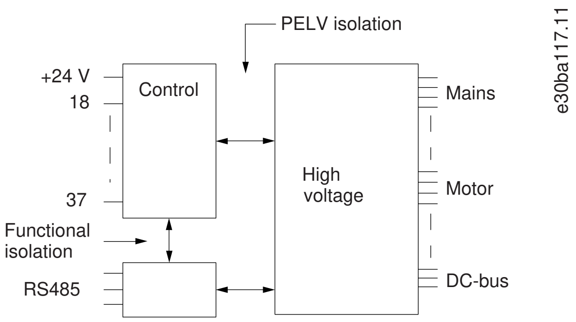


Illustration 26: PELV Isolation

7.7 Filter Specifications

7.7.1 Passive Harmonic Filter Specifications

Phase imbalance	Maximum of 3%
Voltage variation	+10%–15%
Nominal frequency	-2%, +2% (of 50 Hz or 60 Hz) when PHF is installed
Overload capability	150% for 60 s in a period of 10 minutes
Maximum inrush current, drive side	Maximum 5x$I_{nom\ drive}$
Maximum inrush current, PHF input side	Maximum 2x$I_{nom\ drive}$
Power derating	Same as drive

Table 14: Displacement Power Factor (Cos Phi)

Load [%]	Automatic capacitor control [p.u.] (1) (2)	Capacitor always connected [p.u.] (1)	Capacitor always open [p.u.] (1)
10	1.000	-0.790	1.000
25	-0.830	-0.830	0.990
50	-0.996	-0.996	0.950
75	0.997	0.997	0.930
100	0.986	0.986	0.920
160	0.980	0.980	0.910

[1] *Positive numbers indicate lagging reactive currents Negative numbers indicated leading currents.*

[2] *The capacitor connecting contactor switches at 20% load.*

7.7.2 Line Reactor Specifications

All line reactors are equipped with thermal switches and are looped to the enclosed drive for overtemperature protection. For more details, refer to the control compartment section. The line reactor configuration varies depending on the enclosure and voltage required.

Table 15: Line Reactor Configuration for D9h–D10h and E5h–E6h Enclosures, 380–500 V

Enclosure	Model	Impedance [%]
D9h	N90K	2.70
D9h	N110	3.22
D9h	N132	2.87
D10h	N160	3.47
D10h	N200	3.01
D10h	N250	3.65
E5h	N315	3.30
E5h	N355	3.62
E5h	N400	3.83

Enclosure	Model	Impedance [%]
E6h	N450	2.94
E6h	N500	3.23

Table 16: Line Reactor Configuration for D9h–D10h and E5h–E6h Enclosures, 525–690 V

Enclosure	Model	Impedance [%)
D9h	N90K	2.30
D9h	N110	2.78
D9h	N132	3.29
D10h	N160	2.92
D10h	N200	3.67
D10h	N250	3.08
D10h	N315	3.67
E5h	N355	2.89
E5h	N400	3.11
E5h	N500	3.55
E5h	N560	4.04
E6h	N710	3.19
E6h	N800	3.70

7.7.3 dU/dt Filter Specifications

Voltage rating	3x380–690 V
Motor frequency derating, 50 Hz	Nominal
Motor frequency derating, 60 Hz	Nominal
Motor frequency derating, 100 Hz	0.75 x nominal
Minimum switching frequency	No limit
Maximum switching frequency	Nominal switching frequency
Overload capacity	150% for 60 s, every 10 minutes.

7.7.4 Sine-wave Filter Specifications

Voltage rating	3x380–500 V and 525–690 V AC
Nominal current @ 50 Hz	212 A and 315 A for 380–500 V, 137 A and 222 A for 525–690 V [(1)]
Motor frequency with derating [(1)]	Up to 150 Hz
Motor frequency without derating	0–60 Hz
Minimum switching frequency	2 kHz for 380–500 V, 1.5 kHz for 525–690 V
Maximum switching frequency	Nominal switching frequency
Overvoltage category	OVC III as defined in IEC61800-5-1

Overload capacity	150% for 60 s every 10 minutes
Ambient temperature [°C (°F)] [(2)]	-15 (5) to +60 (140)
Storage temperature [°C (°F)]	-40 (-40) to +70 (158)
Transport temperature [°C (°F)]	-40 (-40) to +70 (158)
Altitude during operation	
	100% current (no derating) up to 1000 m (3280 ft)
	1% current derating for each 100 m (328 ft) above 1000 m (3280 ft)
	Maximum 4000 m (13123 ft) with 500 V AC
	Maximum 2000 m (6561 ft) with 690 V AC
Noise level	< 80 dB(A)

[1] *The current ratings for the E5h and E6h enclosures are achieved by filter paralleling.*

[2] *See illustration 28.*

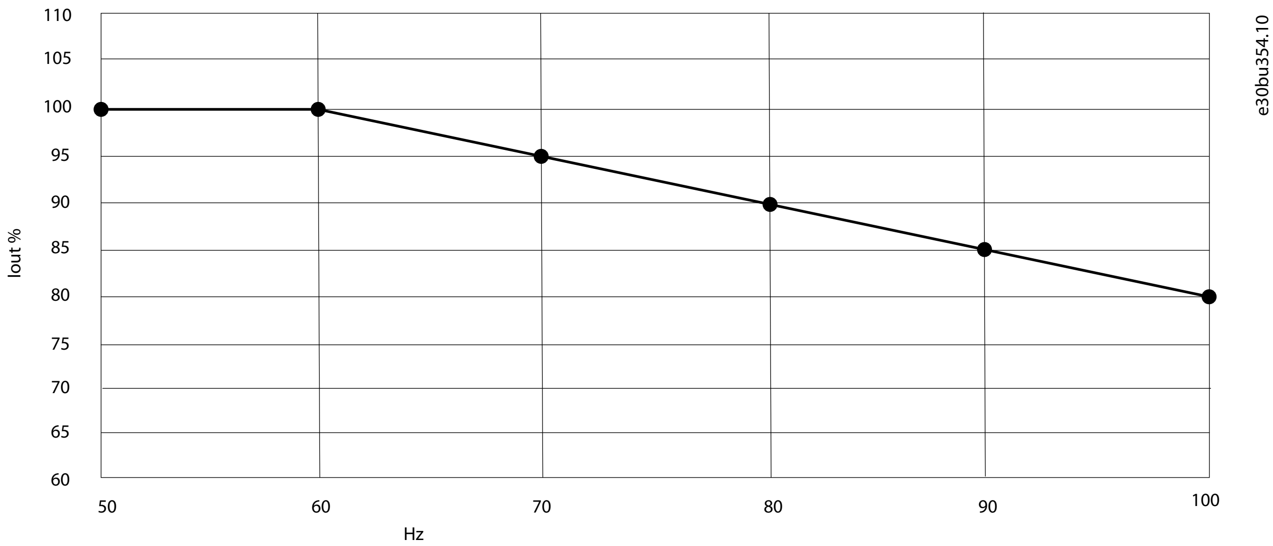


Illustration 27: Derating for Output Frequency While Using a Sine-wave Filter

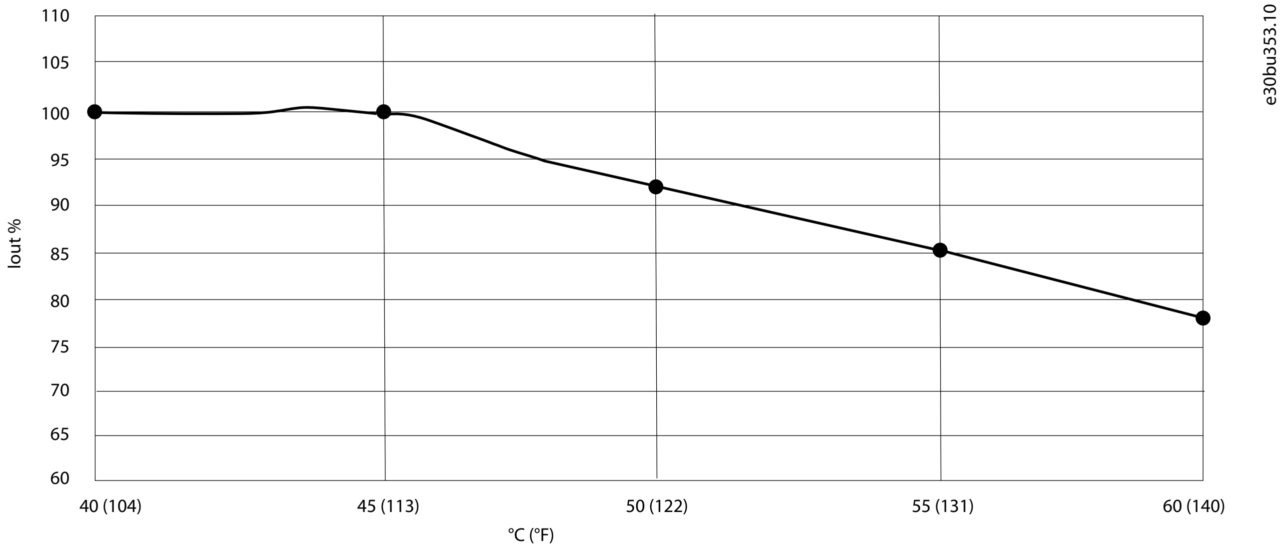


Illustration 28: Derating for Ambient Temperature While Using a Sine-wave Filter

7.8 Fastener Torque Ratings

Apply the correct torque when tightening fasteners in the locations that are listed in the table. Too low or too high torque when fastening an electrical connection results in a bad electrical connection. To ensure correct torque, use a torque wrench.

Table 17: Fastener Torque Ratings

Location	Bolt size	Torque [Nm (in-lb)]
Mains terminals	M10/M12	19 (168)/37 (335)
Motor terminals	M10/M12	19 (168)/37 (335)
Ground terminals	M8/M10	9.6 (84)/19.1 (169)
Brake terminals	M8	9.6 (84)
Relay terminals	–	0.5 (4)
Door/panel cover	M5	2.3 (20)
Cable entry plate	M5	2.3 (20)
Serial communication cover	M5	2.3 (20)

8 Exterior and Terminal Dimensions

8.1 Planning and Design Materials

Context:

Danfoss provides access to a consolidated product environment that can aid the system designer by providing the most current design/planning materials. The following materials are provided:

- Documents (manuals and fact sheets)
- Drawings (submittals, assembly/models, and wiring schematics)
- Software (configuration files)
- Case studies

Procedure

1. Open a browser and type www.Danfoss.com.
2. Select *Products*.
3. Select *AC drives*.
4. Select the product family (for example, VLT® AutomationDrive FC 301/302).

→ The browser opens the product family page, which provides links for the documents, drawings, and software of the various drives.

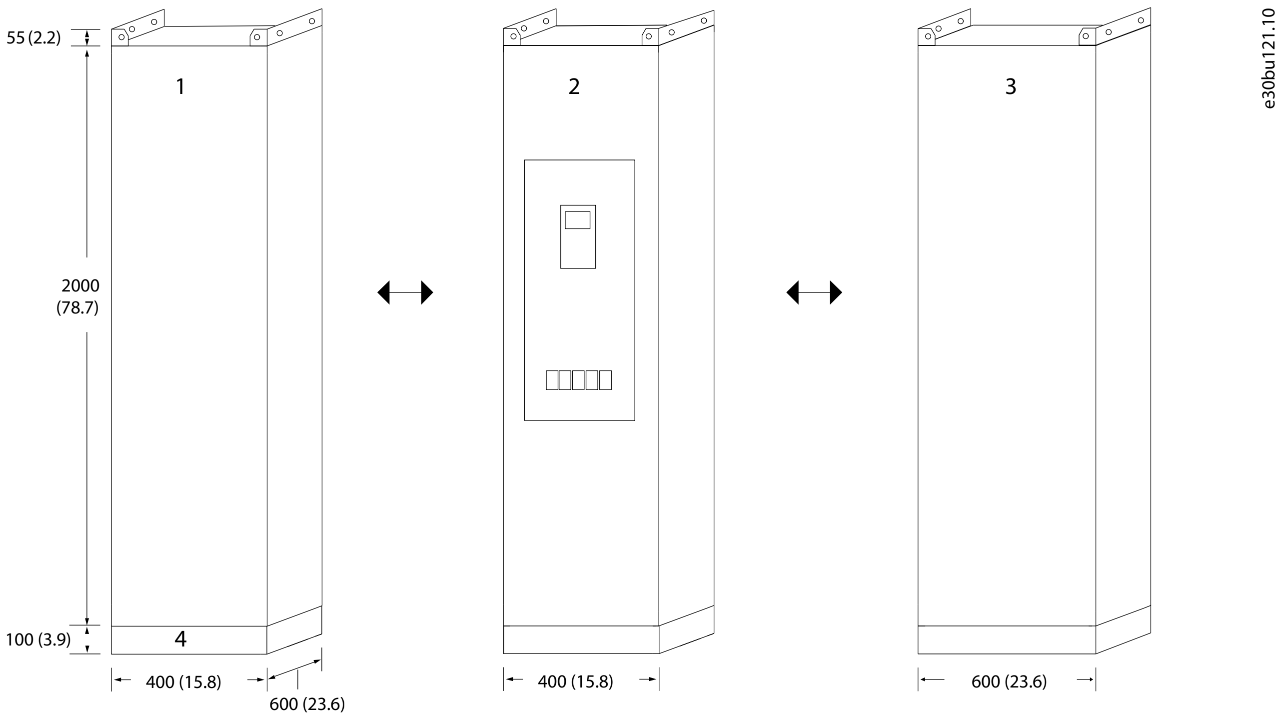
8.2 Exterior Dimensions

8.2.1 Pedestal Dimensions

The pedestal on which the enclosure sits is available in 3 different heights:

- 100 mm (3.9 in)
- 200 mm (7.9 in)
- 400 mm (15.8 in)

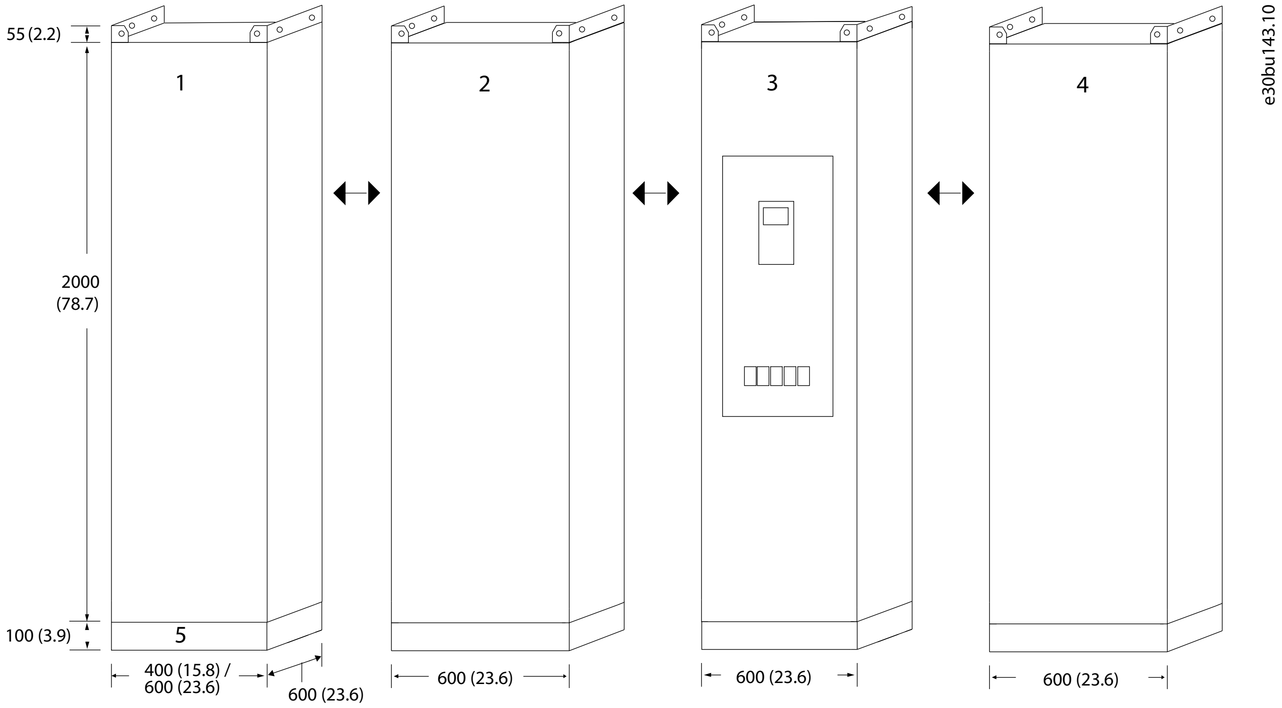
8.2.2 D9h Enclosed Drive Exterior Dimensions



1	Passive harmonic filter/line reactor cabinet	**2**	D9h drive cabinet
3	Sine-wave cabinet	**4**	Standard pedestal

Illustration 29: Dimensions for D9h Enclosure with Standard Pedestal

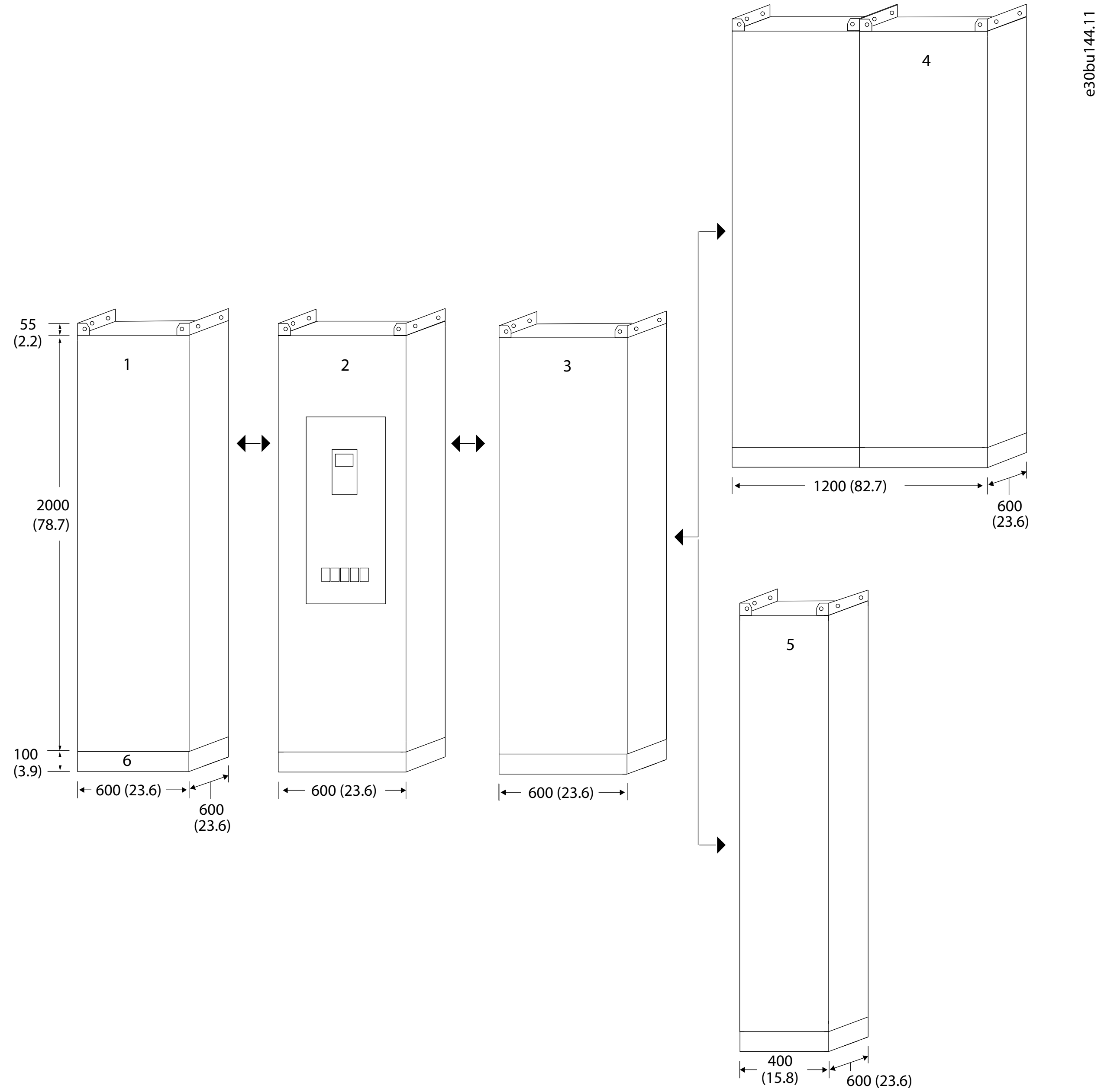
8.2.3 D10h Enclosed Drive Exterior Dimensions



1	Passive harmonic filter/line reactor cabinet	**2**	Options cabinet (provided when more than 1 input option is ordered)
3	D10h drive cabinet	**4**	Sine-wave cabinet
5	Standard pedestal		

Illustration 30: Dimensions for D10h Enclosure with Standard Pedestal

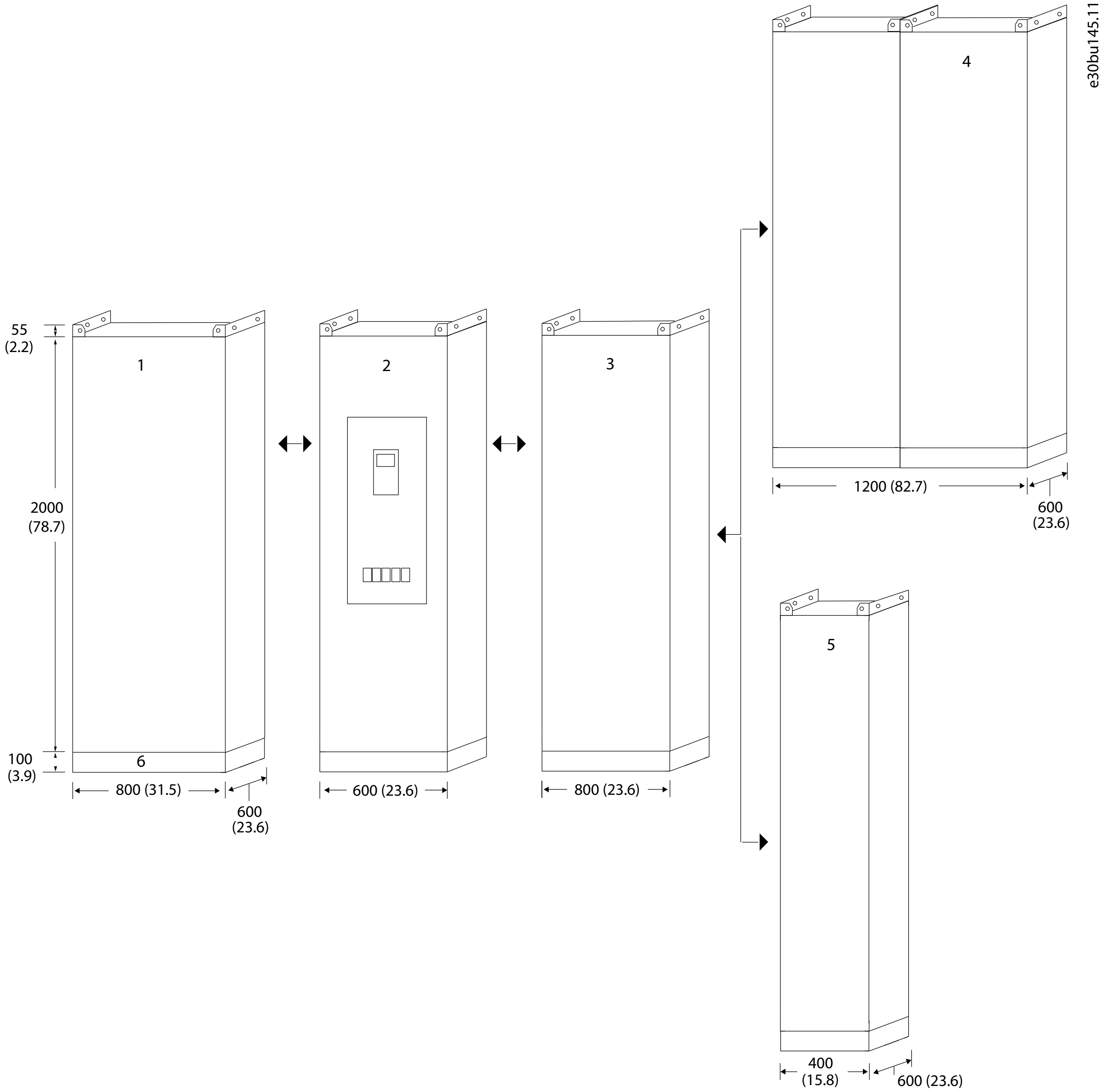
8.2.4 E5h Enclosed Drive Exterior Dimensions



1	Passive harmonic filter/line reactor cabinet	**2**	Options cabinet
3	E5h drive cabinet	**4**	Sine-wave cabinet
5	dU/dt cabinet	**6**	Standard pedestal

Illustration 31: Dimensions for E5h Enclosure with Standard Pedestal

8.2.5 E6h Enclosed Drive Exterior Dimensions



1	Passive harmonic filter/line reactor cabinet	**2**	Options cabinet
3	E6h drive cabinet	**4**	Sine-wave cabinet
5	dU/dt cabinet	**6**	Standard pedestal

Illustration 32: Dimensions for E6h Enclosure with Standard Pedestal

8.3 Cable Entry Dimensions

8.3.1 D9h Cable Entry Dimensions

Cable entry is indicated by the shaded box within the illustration.

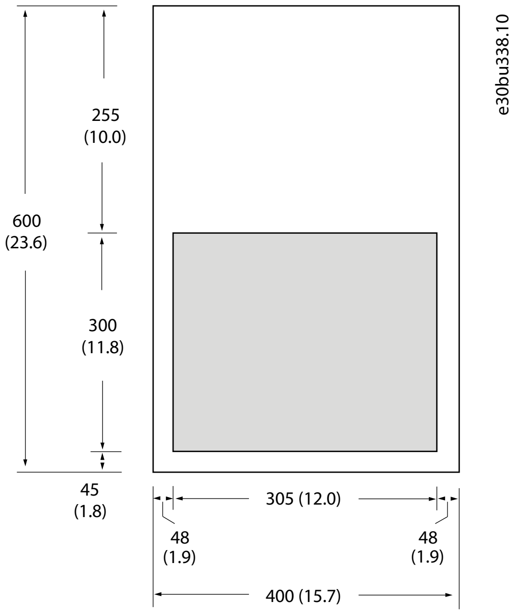


Illustration 33: Bottom Entry/Exit Cable Dimensions for 400 mm (15.7 in) Cabinet

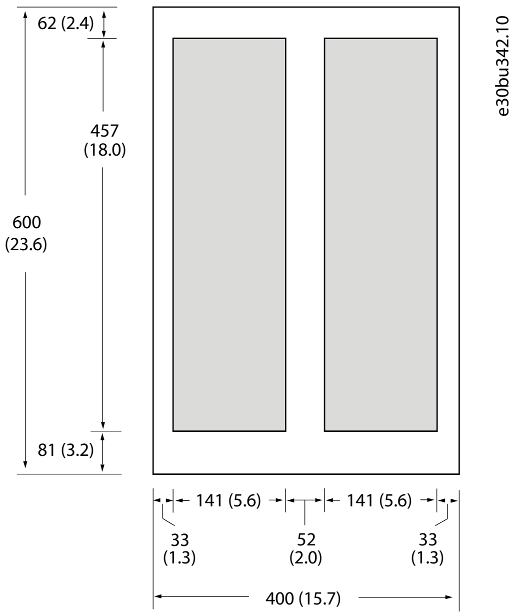


Illustration 34: Top Entry/Exit Cable Dimensions for 400 mm (15.7 in) Cabinet

8.3.2 D10h Cable Entry Dimensions

Cable entry is indicated by the shaded box within the illustration.

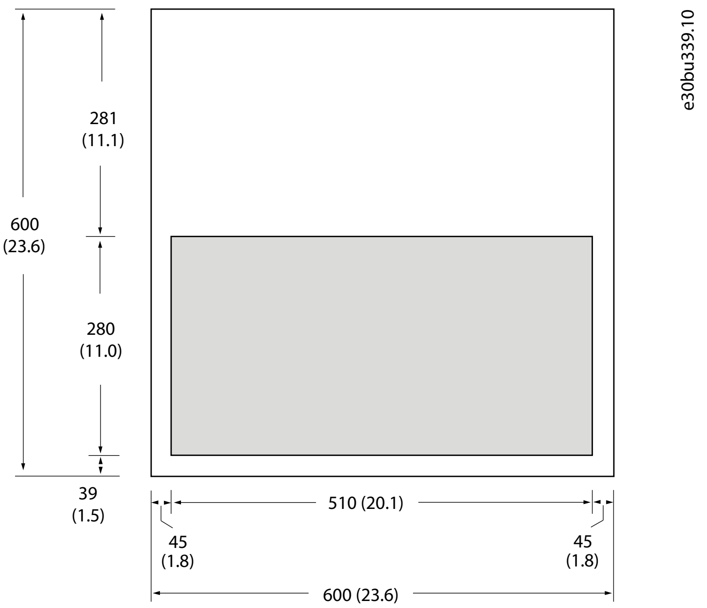


Illustration 35: Bottom Entry/Exit Cable Dimensions for 600 mm (23.6 in) Cabinet

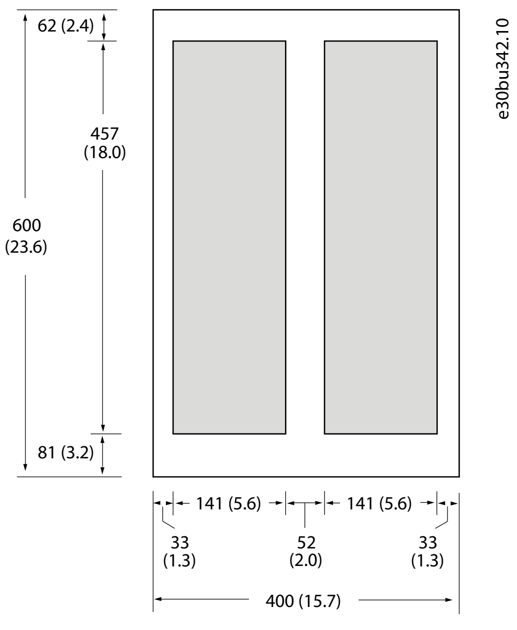


Illustration 36: Top Entry/Exit Cable Dimensions for 400 mm (15.7 in) Cabinet

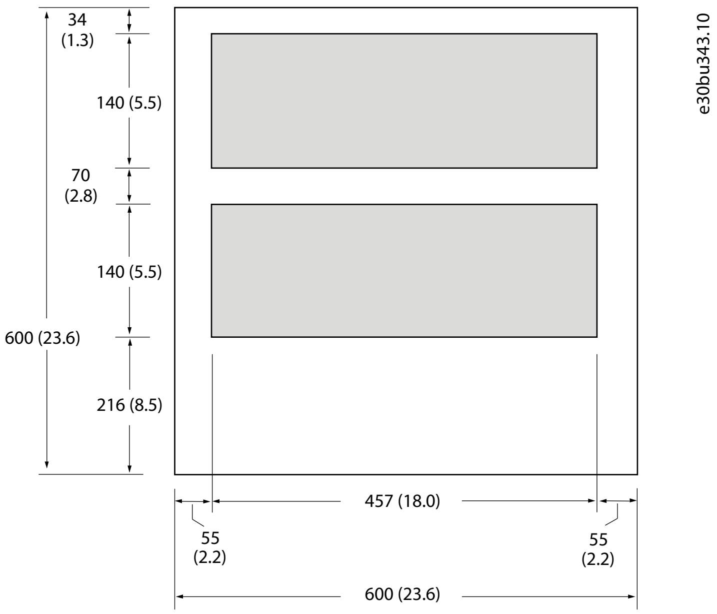


Illustration 37: Top Cable Entry Dimensions for 600 mm (23.6 in) Cabinet

8.3.3 E5h Cable Entry Dimensions

Cable entry is indicated by the shaded box within the illustration.

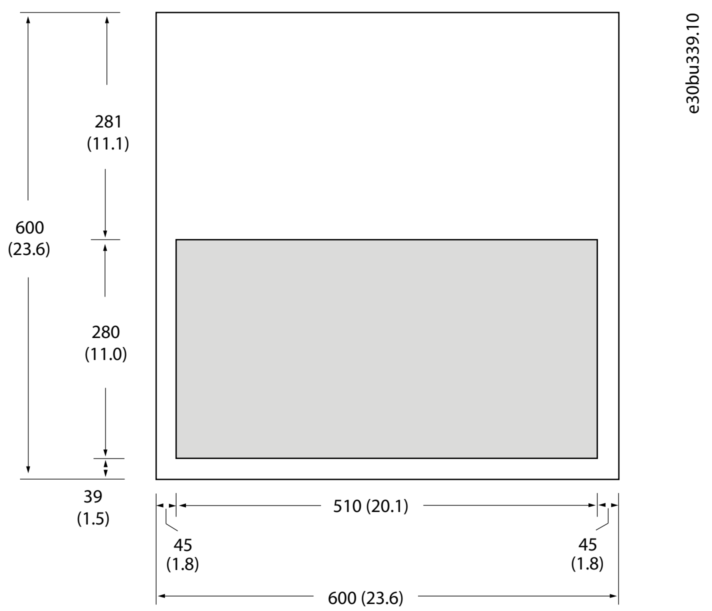


Illustration 38: Bottom Cable Entry Dimensions for 600 mm (23.6 in) Cabinet

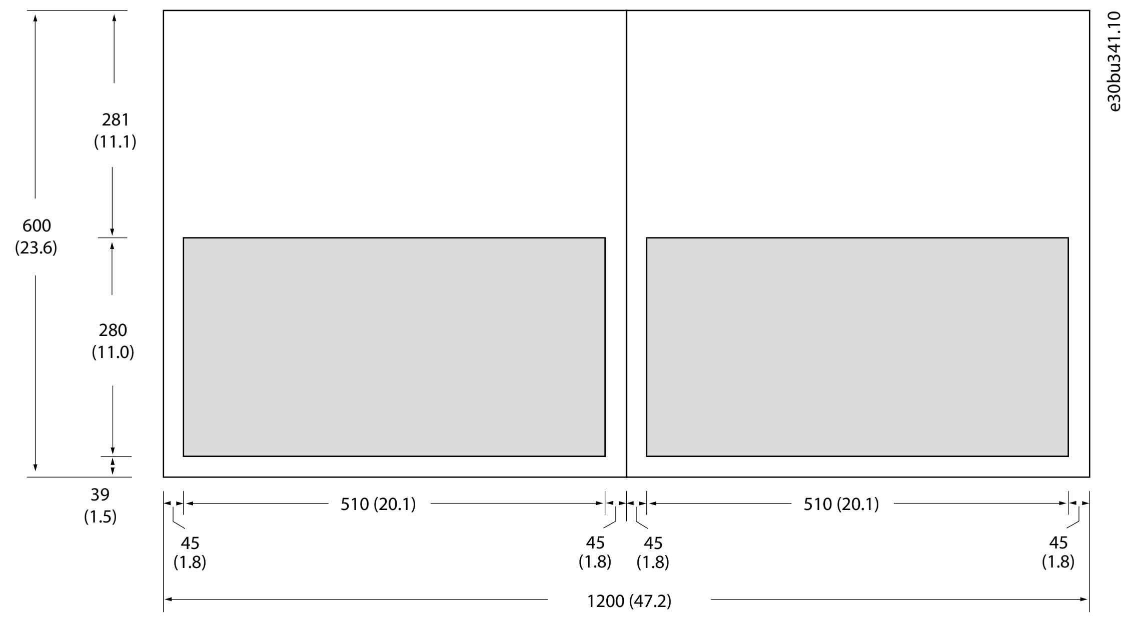


Illustration 39: Top/Bottom Cable Exit Dimensions for 1200 mm (47.2 in) Sine-wave Filter Cabinet

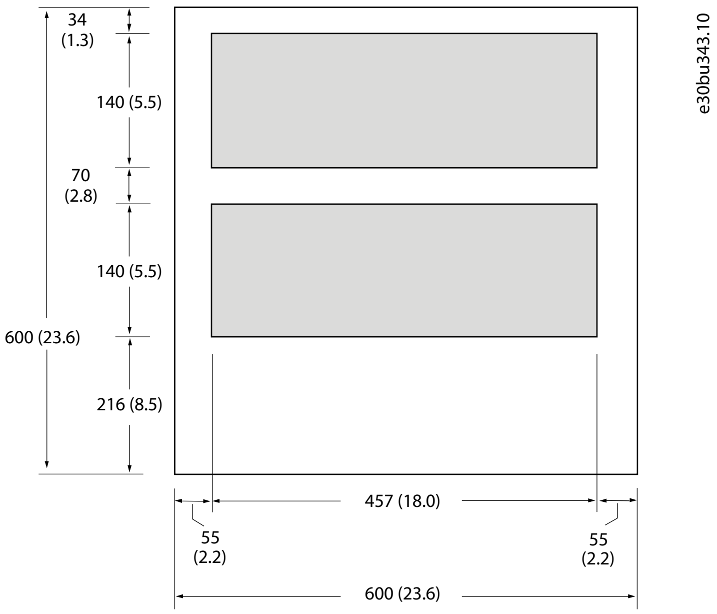


Illustration 40: Top Cable Entry Dimensions for 600 mm (23.6 in) Cabinet

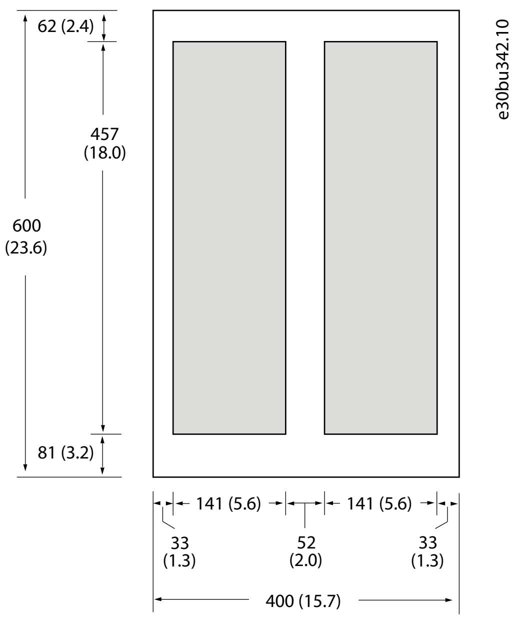


Illustration 41: Top Exit Cable Dimensions for 400 mm (15.7 in) Cabinet.

8.3.4 E6h Cable Entry Dimensions

Cable entry is indicated by the shaded box within the illustration.

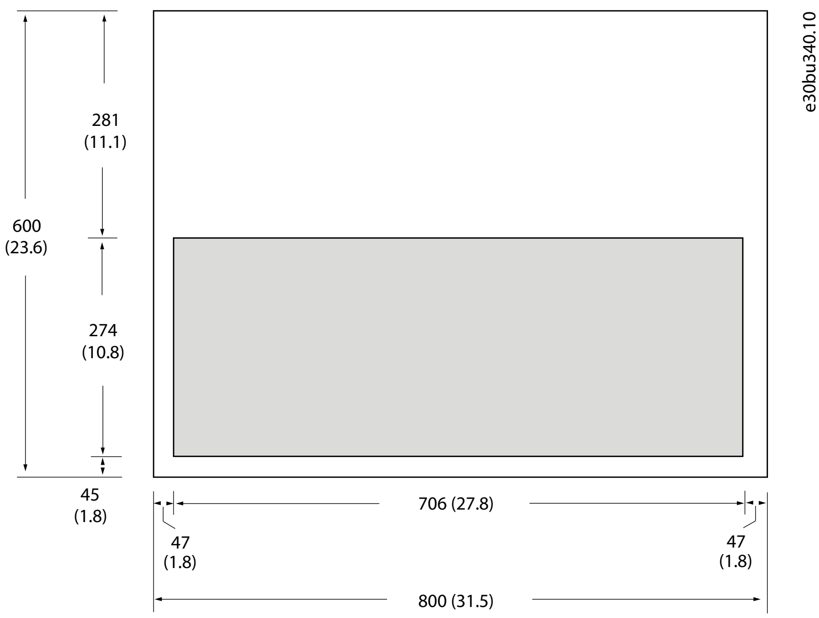


Illustration 42: Bottom Cable Entry Dimensions for 800 mm (31.5 in) Cabinet

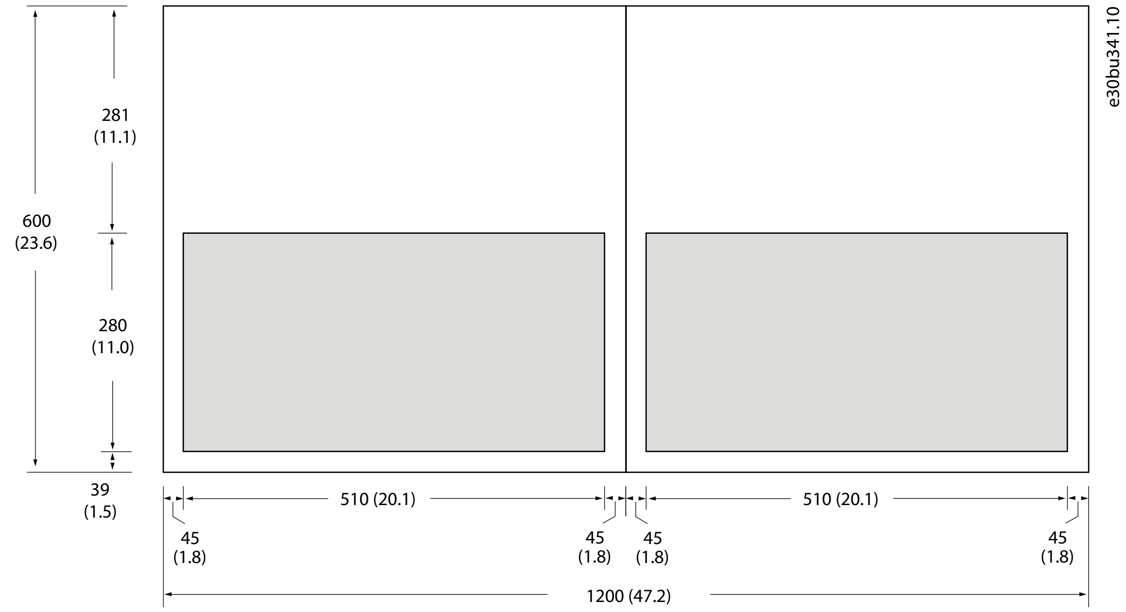


Illustration 43: Top/Bottom Cable Exit Dimensions for 1200 mm (47.2 in) Sine-wave Filter Cabinet

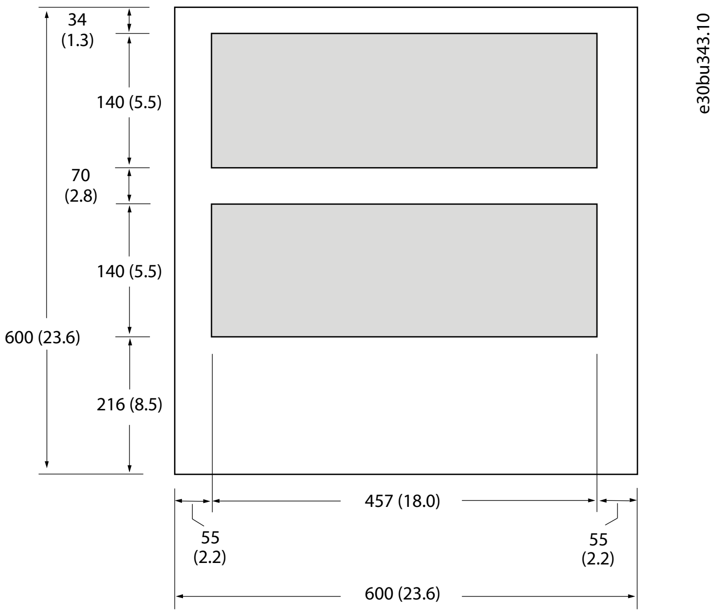


Illustration 44: Top Cable Entry Dimensions for 600 mm (23.6 in) Cabinet

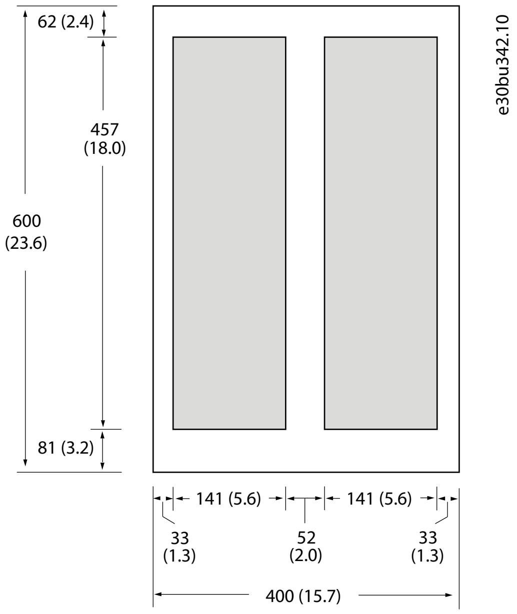


Illustration 45: Top Exit Cable Dimensions for 400 mm (15.7 in) Cabinet.

8.4 Terminal Dimensions

8.4.1 D9h Terminal Heights

For detailed terminal dimensions, refer to the submittal drawings. See 8.1 Planning and Design Materials.

Table 18: D9h Maximum Floor-to-Terminal Heights [mm (in)]

Pedestal	Mains (no options)	Mains contactor	Fusible disconnect	Non-fusible disconnect	Circuit breaker	dU/dt	Sine-wave
100 (3.9)	1313 (51.7)	776 (30.6)	456 (17.9)	480 (18.8)	478 (18.8)	300 (11.8)	854 (33.6)
200 (7.9)	1413 (55.6)	876 (34.5)	556 (21.9)	580 (22.8)	578 (22.8)	400 (15.7)	954 (37.5)
400 (15.8)	1613 (63.5)	1076 (42.4)	756 (29.7)	780 (30.7)	778 (30.6)	600 (23.6)	1154 (45.4)

8.4.2 D10h Terminal Heights

For detailed terminal dimensions, refer to the submittal drawings. See 8.1 Planning and Design Materials.

Table 19: D10h Maximum Floor-to-Terminal Heights [mm (in)]

Pedestal	Mains (no options)	Mains contactor	Fusible disconnect	Non-fusible disconnect	Circuit breaker	dU/dt	Sine-wave
100 (3.9)	1227 (48.3)	552 (21.7)	529 (20.8)	542 (21.3)	528 (20.8)	418 (16.4)	854 (33.6)
200 (7.9)	1327 (52.2)	652 (25.7)	629 (24.8)	642 (25.3)	628 (24.7)	518 (20.4)	954 (37.5)
400 (15.8)	1527 (60.1)	852 (33.6)	829 (32.7)	842 (33.2)	828 (32.6)	718 (28.3)	1154 (45.4)

8.4.3 E5h Terminal Heights

For detailed terminal dimensions, refer to the submittal drawings. See 8.1 Planning and Design Materials.

Table 20: E5h Maximum Floor-to-Terminal Heights [mm (in)]

Pedestal	Mains (no options)	Mains contactor	Fusible disconnect	Non-fusible disconnect	Circuit breaker	dU/dt	Sine-wave
100 (3.9)	569 (22.4)	1277 (50.3)	531 (20.9)	566 (22.3)	607 (19.9)	499 (19.6)	854 (33.6)
200 (7.9)	669 (26.3)	1377 (54.2)	631 (24.8)	666 (26.2)	707 (27.8)	599 (23.6)	954 (37.5)
400 (15.8)	869 (34.2)	1577 (62.1)	831 (32.7)	866 (34.1)	907 (35.7)	799 (31.5)	1153 (45.4)

8.4.4 E6h Terminal Heights

For detailed terminal dimensions, refer to the submittal drawings. See 8.1 Planning and Design Materials.

Table 21: E6h Maximum Floor-to-Terminal Heights [mm (in)]

Pedestal	Mains (no options)	Mains contactor	Fusible disconnect	Non-fusible disconnect	Circuit breaker	dU/dt	Sine-wave
100 (3.9)	569 (22.4)	1277 (50.3)	531 (20.9)	566 (22.3)	607 (19.9)	499 (19.6)	854 (33.6)
200 (7.9)	669 (26.3)	1377 (54.2)	631 (24.8)	666 (26.2)	707 (27.8)	599 (23.6)	954 (37.5)
400 (15.8)	869 (34.2)	1577 (62.1)	831 (32.7)	866 (34.1)	907 (35.7)	799 (31.5)	1154 (45.4)

9 Mechanical Installation Considerations

9.1 Storage

Store the drive in a dry location and keep the equipment sealed in its packaging until installation. Periodic forming (capacitor charging) is not necessary during storage unless storage exceeds 12 months.

If shelf life is longer than 4 years, a simple method, under no load conditions, can be used to check the conditions of the capacitors.

If the stable DC-link voltage is approximately equal to 1.41 x U_{mains}, the capacitors are OK. To check the DC-link voltage in the drive, either measure it or check the corresponding parameters in the display.

If the DC-link voltage is significantly smaller than 1.41 x U_{mains}, it takes time for the capacitors to recover. If the DC-link voltage stays at a low level and does not reach approximately 1.41 x U_{mains} , contact the local service agent.

9.2 Operating Environment

In environments with airborne liquids, particles, or corrosive gases, ensure that the IP/Type rating of the equipment matches the installation environment. For specifications regarding ambient conditions, see the Ambient Conditions section.

NOTICE

CONDENSATION

Moisture can condense on the electronic components and cause short circuits. Avoid installation in areas subject to frost. Install an optional space heater when the drive is colder than the ambient air. Operating in standby mode reduces the risk of condensation as long as the power dissipation keeps the circuitry free of moisture.

NOTICE

EXTREME AMBIENT CONDITIONS

Hot or cold temperatures compromise unit performance and longevity.

- Do not operate in environments where the ambient temperature exceeds 55 °C (131 °F).
- The drive can operate at temperatures down to -10 °C (14 °F). However, proper operation at rated load is only guaranteed at 0 °C (32 °F) or higher.
- If the temperature exceeds ambient temperature limits, extra air conditioning of the cabinet or installation site is required.

9.2.1 Gases

Aggressive gases, such as hydrogen sulfide, chlorine, or ammonia can damage electrical and mechanical components of a drive. Contamination of the cooling air can also cause the gradual decomposition of PCB tracks and door seals. Aggressive contaminants are often present in sewage treatment plants or swimming pools. A clear sign of an aggressive atmosphere is corroded copper.

In aggressive atmospheres, restricted IP enclosures are recommended along with conformal-coated circuit boards.

NOTICE

The drive comes standard with class 3C2 coating. On request, class 3C3 coating is available.

Table 22: Conformal Coating Class Ratings

Gas type	Unit	Class				
		3C1	3C2		3C3	
		–	Average value	Maximum value (1)	Average value	Maximum value (1)
Sea salt	n/a	None	Salt mist		Salt mist	
Sulfur oxide	mg/m^3	0.1	0.3	1.0	5.0	10
Hydrogen sulfide	mg/m^3	0.01	0.1	0.5	3.0	10
Chlorine	mg/m^3	0.0.1	0.1	0.03	0.3	1.0
Hydrogen chloride	mg/m^3	0.01	0.1	0.5	1.0	5.0
Hydrogen fluoride	mg/m^3	0.003	0.001	0.03	0.1	3.0
Ammonia	mg/m^3	0.3	1.0	3.0	10	35
Ozone	mg/m^3	0.01	0.05	0.1	0.1	0.3
Nitrogen	mg/m^3	0.1	0.5	1.0	3.0	9.0

[1] *Maximum values are transient peak values and are not to exceed 30 minutes per day.*

9.2.2 Dust

Installation of drives in environments with high dust exposure is often unavoidable. Consider the following when installing drives in such environments:

- Reduced cooling.
- Cooling fans.
- Filters.
- Periodic maintenance.

Reduced cooling

Dust forms deposits on the surface of the device and inside on the circuit boards and the electronic components. These deposits act as insulation layers and hamper heat transfer to the ambient air, reducing the cooling capacity. The components become warmer. This causes accelerated aging of the electronic components and the service life of the unit decreases. Dust deposits on the heat sink in the back of the unit also decrease the service life of the unit.

Cooling fans

The airflow for cooling the unit is produced by cooling fans, usually on the back of the unit. The fan rotors have small bearings into which dust can penetrate and act as an abrasive. This leads to bearing damage and fan failure.

Filters

High-power drives are equipped with cooling fans that expel hot air from the interior of the unit. Above a certain size, these fans are fitted with filter mats. These filters can quickly become clogged when used in dusty environments. Preventive measures are necessary under these conditions.

Periodic maintenance

Under the conditions described above, it is recommended to clean the drive during periodic maintenance. Remove dust from the heat sink and fans, and clean the filter mats.

9.2.3 Vibration and Shock

The drive has been tested according to the procedure based on the following standards:

- EN/IEC 60068-2-6.
- EN/IEC 60068-2-64.

These tests subject the unit to 0.7 g forces over the range of 18–1000 Hz random in 3 directions for 2 hours. All Danfoss VLT® drives comply with requirements that correspond to these conditions when the unit is wall or floor mounted and when the unit is mounted within panels bolted to walls or to floors.

9.2.4 Maintenance

Danfoss drive models up to 90 kW are maintenancefree. High-power drives (rated at 110 kW or higher) have built-in filter mats, which require periodic cleaning depending on the exposure to dust and contaminants. Maintenance intervals for the cooling fans (approximately 3 years) and capacitors (approximately 5 years) are recommended in most environments.

9.3 Installation Requirements

NOTICE

OVERHEATING

Improper mounting can result in overheating and reduced performance.

- Install the drive according to the installation and cooling requirements.

- Locate the unit as near to the motor as possible. For the maximum motor cable length, see 7.5 Motor and Control Cables.
- Ensure unit stability by mounting the unit to a solid surface.
- Ensure that the strength of the mounting location supports the unit weight.
- Ensure that there is enough space around the unit for proper cooling. Refer to 9.5 Enclosure Airflow.
- Ensure enough access to open the door.
- Ensure cable entry from the bottom.

9.4 Cooling Requirements

NOTICE

OVERHEATING

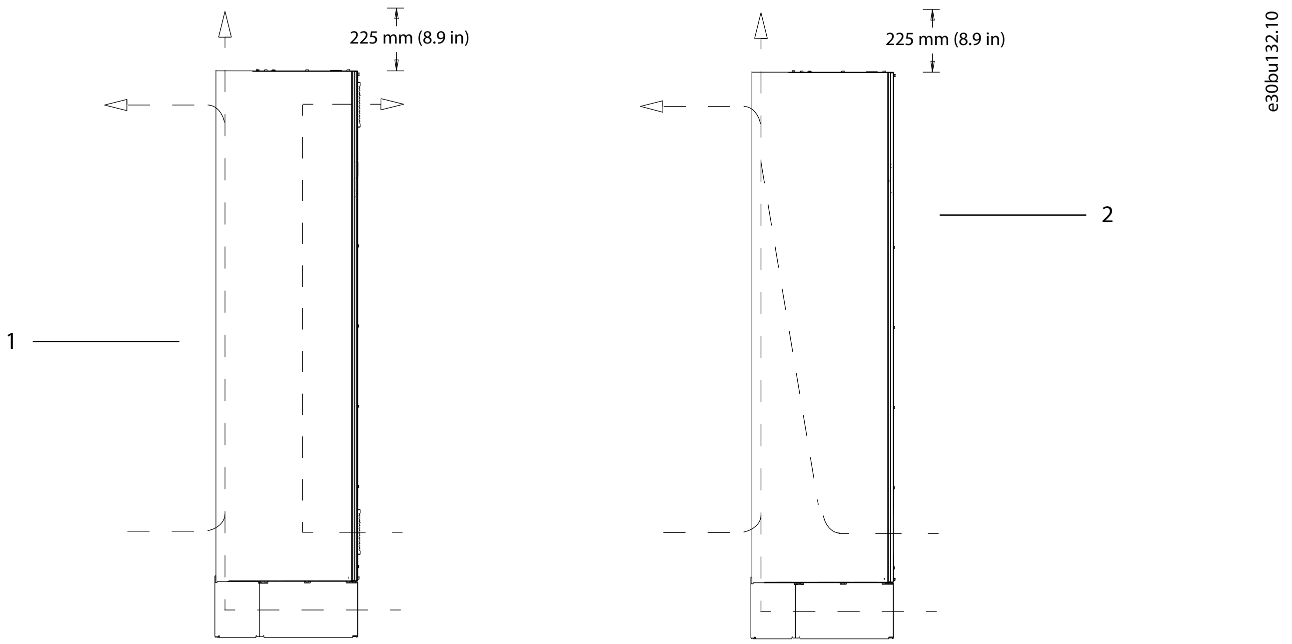
Improper mounting can result in overheating and reduced performance.

- Install the drive following the installation and cooling requirements.

- Ensure that top and bottom clearance for air cooling is provided. Clearance requirement: 225 mm (9 in).
- Provide sufficient airflow flow rate. See 9.6 Airflow Rates.
- Consider derating for temperatures starting between 45 °C (113 °F) and 50 °C (122 °F) and elevation 1000 m (3300 ft) above sea level.

The enclosed drive, excluding the input power options cabinet, utilizes a back-channel cooling concept that removes the air used to cool the heat sink. The heat sink cooling air carries approximately 90% of the heat out of the back channel of the drive. A back-channel cooling option allows the cooling air to be brought into and vented out of the room where the drive is installed.

9.5 Enclosure Airflow



1 Drive module cabinet	**2** PHF and sine-wave cabinets

Illustration 46: Enclosure Airflow in Sine-wave Filter, Passive Harmonic Filter, and Drive Cabinets

9.6 Airflow Rates

Table 23: Airflow Rates for D9h Enclosure

Cabinet	Back-channel fan [m³/hr (cfm)]	Drive module top fan [m³/hr (cfm)]	Cabinet door fan [m³/hr (cfm)]
PHF/line reactor	450 (265)	–	–
Drive	420 (250)	102 (60)	150 (90)
dU/dt	–	–	–
Sine-wave	900 (530)	–	–
Top entry/top exit	–	–	–

Table 24: Airflow Rates for D10h Enclosure

Cabinet	Back-channel fan [m³/hr (cfm)]	Drive module top fan [m³/hr (cfm)]	Cabinet door fan [m³/hr (cfm)]
PHF/line reactor	450 (265)	–	–
Input options	–	–	510 (310)
Drive	840 (500)	204 (120)	315 (185)
dU/dt	–	–	–
Sine-wave	900 (530)	–	–
Top entry/top exit	–	–	–

Table 25: Airflow Rates for E5h Enclosure

Cabinet	Back-channel fan [m³/hr (cfm)]	Drive module top fan [m³/hr (cfm)]	Cabinet door fan [m³/hr (cfm)]
PHF/line reactor	765 (450)	–	–
Input options	–	–	510 (310)
Drive	994 (585)	595 (350)	335 (200)
dU/dt	665 (392)	–	–
Sine-wave	2x900 (530)	–	–
Top entry/top exit	–	–	–

Table 26: Airflow Rates for E6h Enclosure

Cabinet	Back-channel fan [m³/hr (cfm)]	Drive module top fan [m³/hr (cfm)]	Cabinet door fan [m³/hr (cfm)]
PHF/line reactor	1285 (755)	–	–
Input options	–	–	510 (310)
Drive	1053–1206 (620–710)	629 (370)	430 (255)
dU/dt	665 (392)	–	–
Sine-wave	2x900 (530)	–	–
Top entry/top exit	–	–	–

9.7 Derating

9.7.1 Manual Versus Automatic Derating

Derating is a method used to reduce output current to avoid tripping the enclosed drive when high temperatures are reached within the enclosure. If certain extreme operating conditions are expected, a higher-powered drive can be selected to eliminate the need for derating. This is called manual derating. Otherwise, the drive automatically derates the output current to eliminate the excessive heat generated by extreme conditions.

Manual derating

When the following conditions are present, Danfoss recommends selecting a drive 1 power size higher (for example P710 instead of P630):

- Low-speed – continuous operation at low RPM in constant torque applications.
- Low air pressure – operating at altitudes above 1000 m (3281 ft).
- High ambient temperature – operating at ambient temperatures of 10 °C (50 °F).
- High switching frequency.
- Long motor cables.
- Cables with a large cross-section.

Automatic derating

If the following operating conditions are found, the drive automatically changes switching frequency or switching pattern (PWM to SFAVM) to reduce excessive heat within the enclosure:

- High temperature on the control card or heat sink.
- High motor load or low motor speed.
- High DC-link voltage.

9.7.2 Derating for Low-speed Operation

When a motor is connected to a drive, it is necessary to ensure that the cooling of the motor is adequate. The level of cooling required depends on the following:

- Load on the motor.
- Operating speed.
- Length of operating time.

Constant torque applications (CT mode)

In a constant torque application, a motor may overheat at low speeds because the fan within the motor is providing less cooling air.

Therefore, if the motor is to be run continuously at an RPM value lower than half of the rated value, the motor must be supplied with extra air cooling. If extra air cooling is not available, use a motor designed for low RPM/constant torque applications, or select a larger motor to reduce the load level.

Variable (quadratic) torque applications (VT)

In variable torque applications where the torque is proportional to the square of the speed and the power is proportional to the cube of the speed, there is no need for extra cooling or derating of the motor. Common variable torque applications are centrifugal pumps and fans.

9.7.3 Derating for Ambient Temperature and Switching Frequency

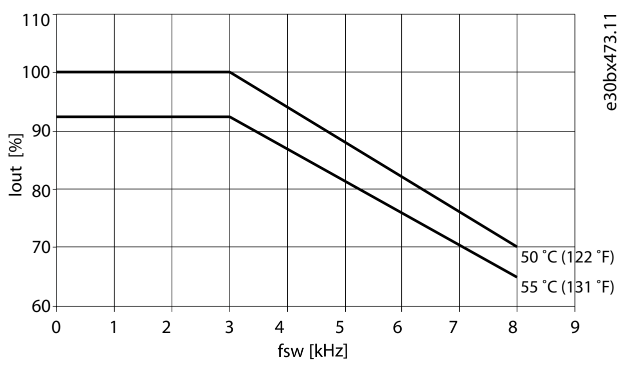
9.7.3.1 Ambient Temperature Range

The VLT® AutomationDrive FC 302 Enclosed Drives are designed to operate without the need for derating between -10 °C to 40/45 °C (14 °F to 104/113 °F). The enclosed drive can operate in ambient conditions up to 55 °C (131 °F), but the current must be derated. For more information regarding specific temperature ranges, see the Ambient Conditions section.

9.7.3.2 Enclosure Sizes D9h–D10h

Table 27: Derating for Ambient Temperature and Switching Frequency Using 60° AVM for D9h–D10h Drives Rated 380–500 V

High overload (HO), 150%



Normal overload (NO), 110%

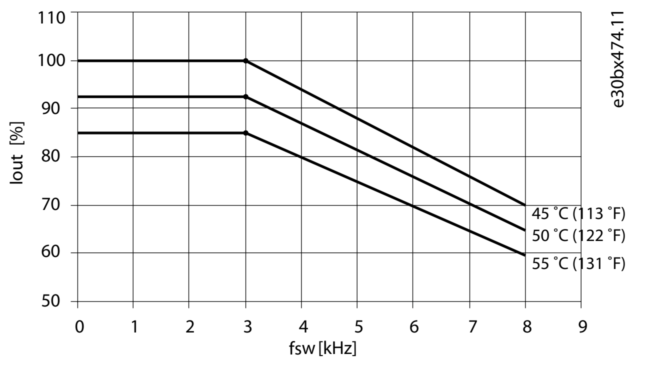
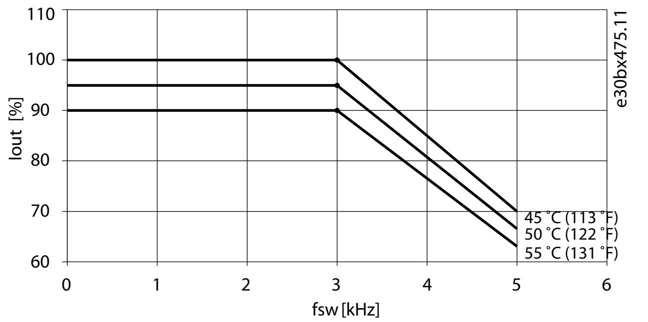


Table 28: Derating for Ambient Temperature and Switching Frequency Using SFAVM for D9h–D10h Drives Rated 380–500 V

High overload (HO), 150%



Normal overload (NO), 110%

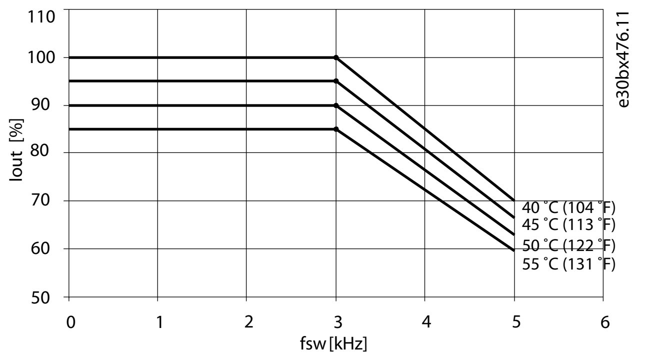
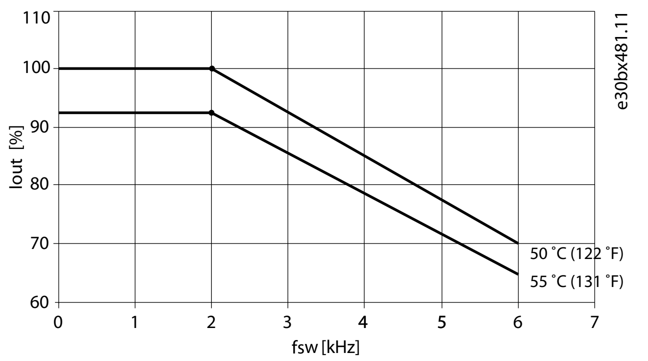


Table 29: Derating for Ambient Temperature and Switching Frequency Using 60° AVM for D9h–D10h Drives Rated 525–690 V

High overload (HO), 150%



Normal overload (NO), 110%

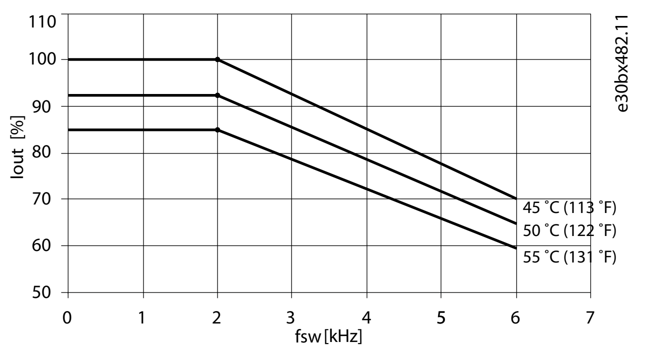
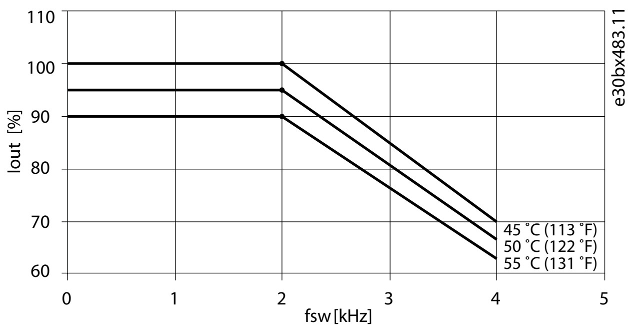
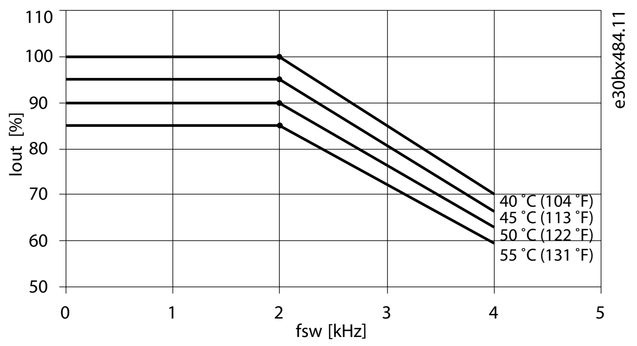


Table 30: Derating for Ambient Temperature and Switching Frequency Using SFAVM for D9h–D10h Drives Rated 525–690 V

High overload (HO), 150%	Normal overload (NO), 110%
	

9.7.3.3 Enclosure Sizes E5h–E6h

Table 31: Derating for Ambient Temperature and Switching Frequency Using 60° AVM for E5h–E6h Drives Rated 380–500 V

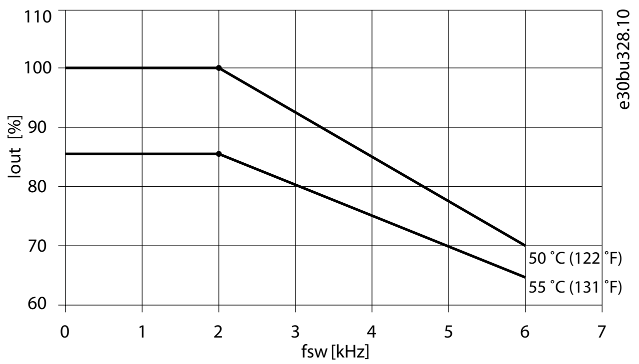
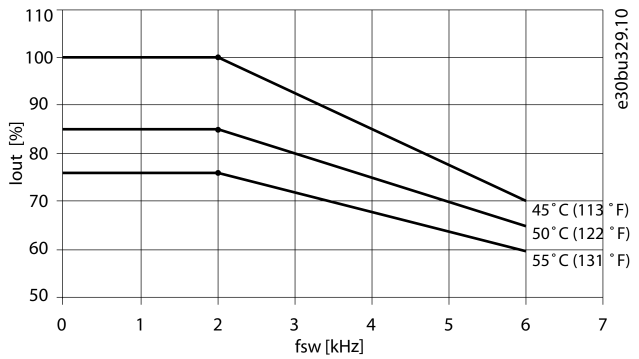
High overload (HO), 150%	Normal overload (NO), 110%
	

Table 32: Derating for Ambient Temperature and Switching Frequency Using SFAVM for E5h–E6h Drives Rated 380–500 V

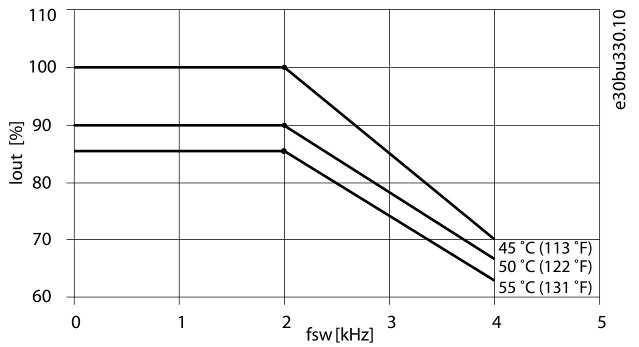
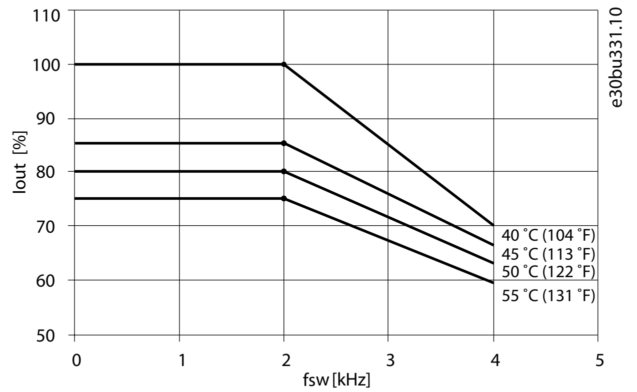
High overload (HO), 150%	Normal overload (NO), 110%
	

Table 33: Derating for Ambient Temperature and Switching Frequency Using 60° AVM for E5h–E6h Drives Rated 525–690 V

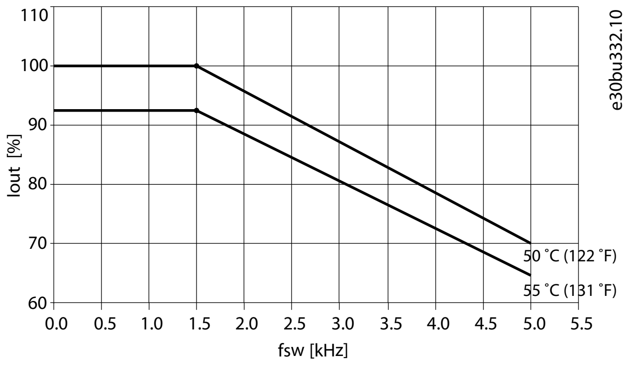
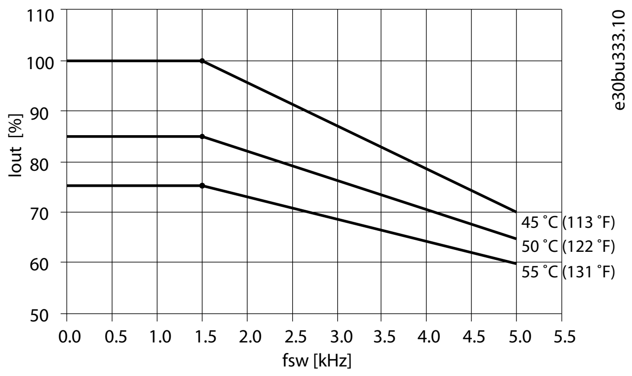
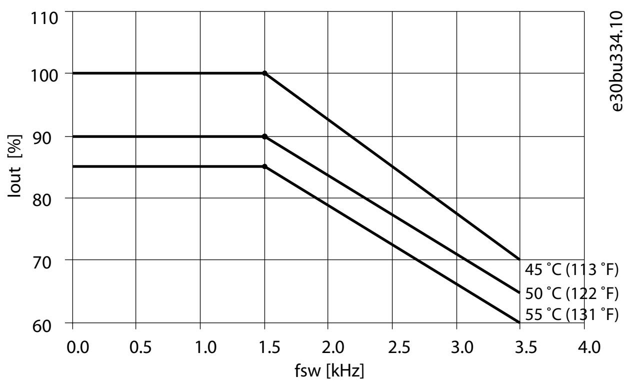
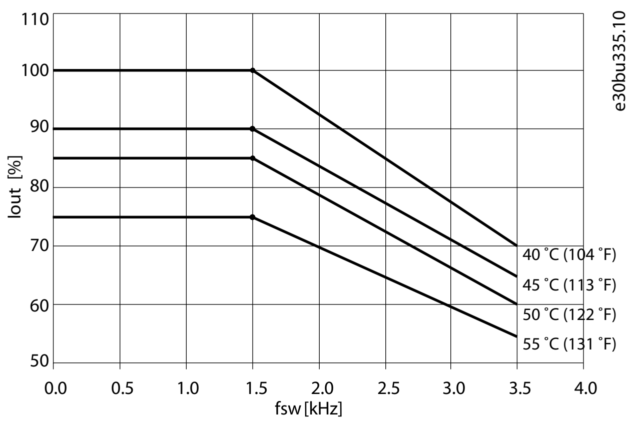
High overload (HO), 150%	Normal overload (NO), 110%
	

Table 34: Derating for Ambient Temperature and Switching Frequency Using SFAVM for E5h–E6h Drives Rated 525–690 V

High overload (HO), 150%	Normal overload (NO), 110%
	

9.7.4 Derating for Low Air Pressure

The cooling capability of air is decreased at lower air pressure. Below 1000 m (3280 ft) altitude, no derating is necessary. Above 1000 m (3280 ft), the ambient temperature (T_{AMB}) or maximum output current (I_{out}) should be derated in accordance with the diagram in illustration 63.

The illustration shows that at 41.7 °C (107 °F), 100% of the rated output current is available. At 45 °C (113 °F) ($T_{AMB,MAX}$-3 K), 91% of the rated output current is available.

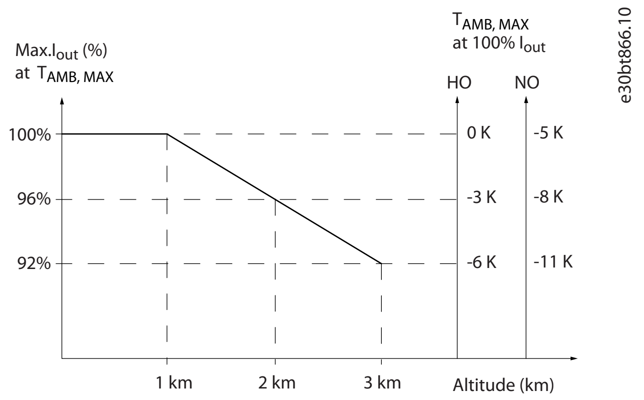


Illustration 63: Derating of Output Current Based on Altitude at $T_{AMB,MAX}$

9.8 Acoustic Noise

The acoustic noise from the drive comes from 3 sources:

- DC-link coils
- Internal fans
- RFI filter choke

Table 35: Acoustic Noise for Enclosures D9h–D10h and E5h–E6h

Enclosure size	50% fan speed [dBA] [(1)]	Full fan speed [dBA] [(1)]
D9h	–	73
D10h	–	75
E5h/E6h	–	80

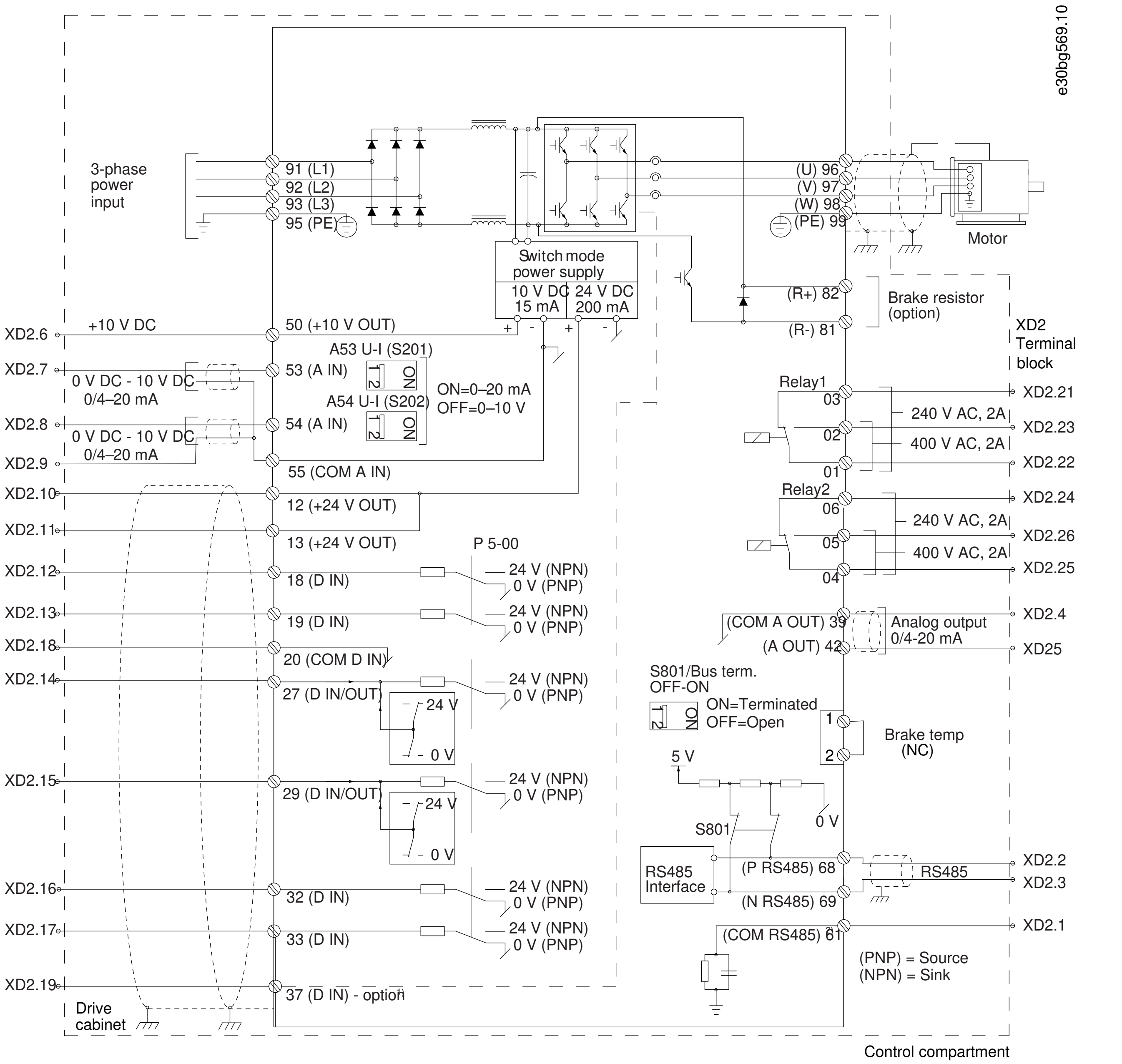
[1] *Values are measured 1 m (3.3 ft) from the unit.*

Test results were performed according to ISO 3744 for audible noise magnitude in a controlled environment. Noise tone has been quantified for engineering data record of hardware performance per ISO 1996-2 Annex D.

A new fan control algorithm for E1h-E4h enlosure sizes helps improve audible noise performance by allowing the operator to select different fan operation modes based on specific conditions. For more information, see *parameter 30-50 Heat Sink Fan Mode*.

10 Electrical Installation Considerations

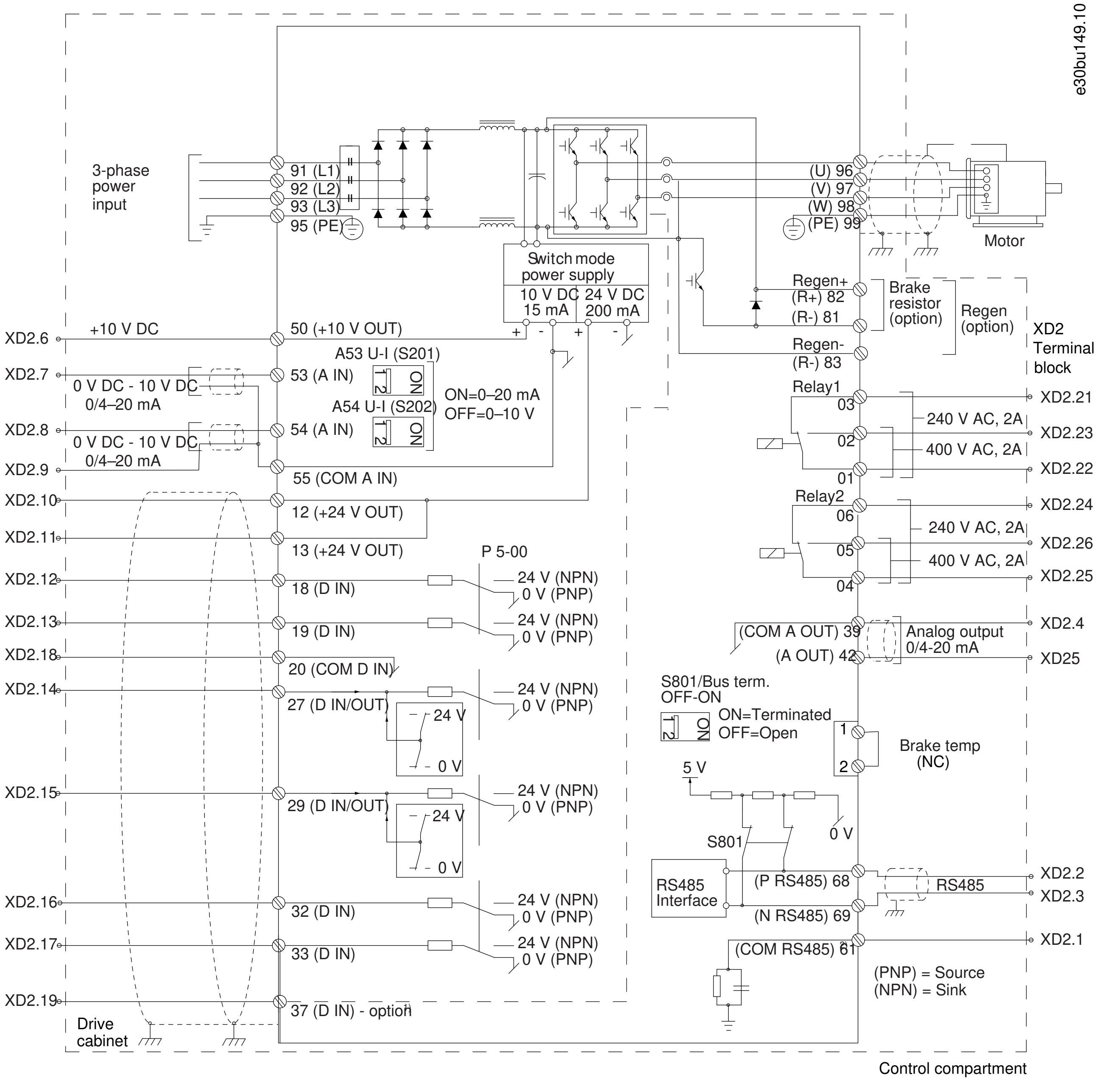
10.1 Wiring Overview for D9h and D10h Enclosed Drives



1	Terminal 37 (optional) is used for Safe Torque Off. Refer to the *VLT® FC Series - Safe Torque Off Operating Guide* for installation instructions.

Illustration 64: Basic Wiring Overview for Enclosures D9h and D10h

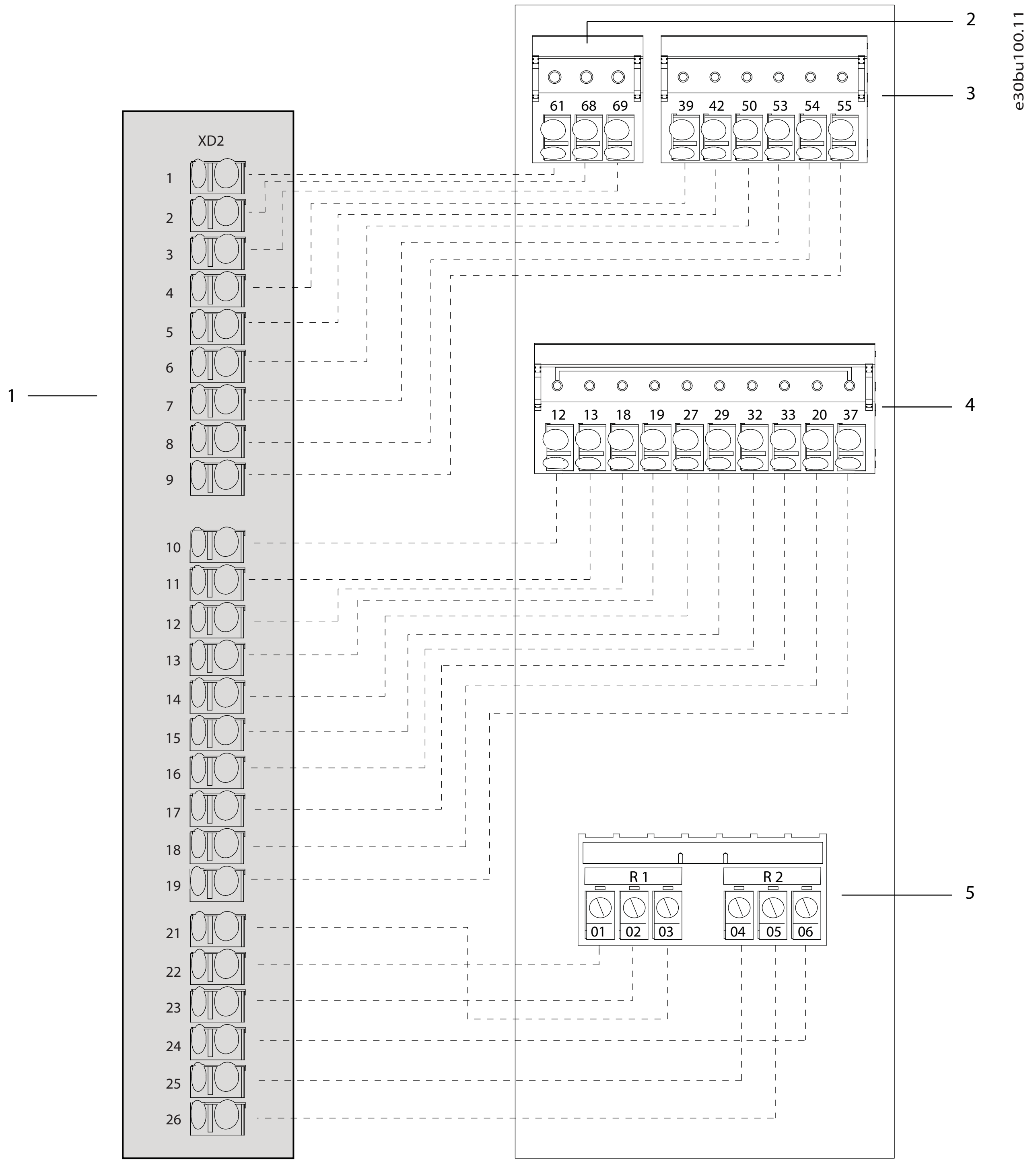
10.2 Wiring Overview for E5h and E6h Enclosed Drives



1	Terminal 37 (optional) is used for Safe Torque Off. Refer to the *VLT® FC Series - Safe Torque Off Operating Guide* for installation instructions.

Illustration 65: Basic Wiring Overview for Enclosures E5h and E6h

10.3 Control Terminal Wiring Diagram Cross-reference



1	User-accessible terminals (control compartment)	2	Serial communication terminals (drive module)
3	Analog input/output terminals (drive module)	4	Digital input/output terminals (drive module)

5 Relay terminals (drive module)	

Illustration 66: Serial Communication, Digital Input/Output, Analog Input/Output, and Relay Terminals Cross-reference

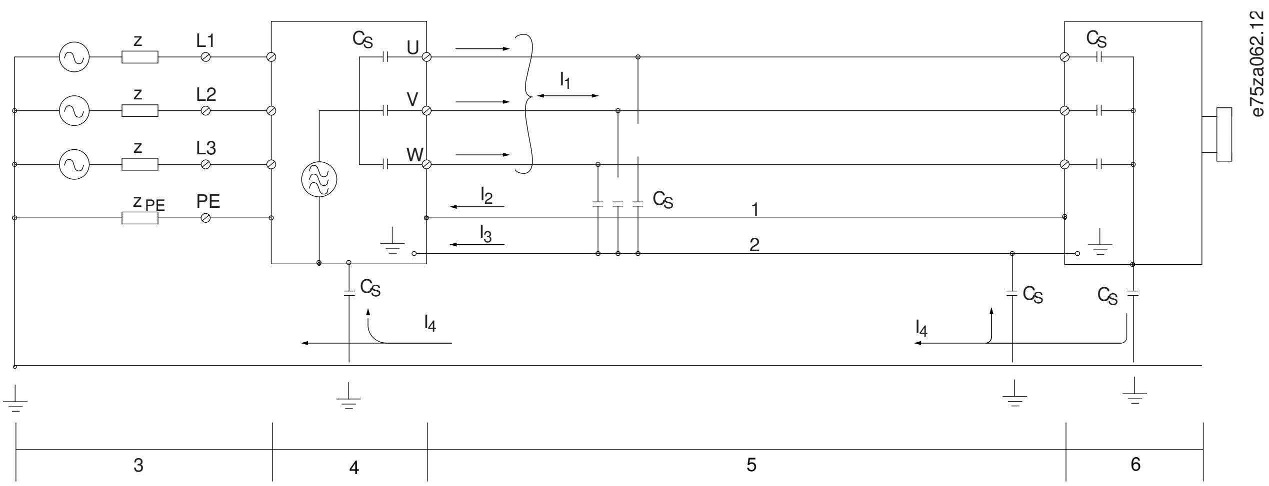
10.4 Electromagnetic Compatibility

Electrical devices both generate interference and are affected by interference from other generated sources. The electromagnetic compatibility (EMC) of these effects depends on the power and the harmonic characteristics of the devices. Uncontrolled interaction between electrical devices in a system can degrade compatibility and impair reliable operation. Interference takes the form of the following:

- Electrostatic discharges
- Rapid voltage fluctuations
- High-frequency interference

Electrical interference is most commonly found at frequencies in the range 150 kHz to 30 MHz. Airborne interference from the drive system in the range 30 MHz to 1 GHz is generated from the inverter, motor cable, and the motor.

Capacitive currents in the motor cable, coupled with a high dU/dt from the motor voltage, generate leakage currents. See illustration 67. Shielded motor cables have higher capacitance between the phase wires and the shield, and again between the shield and ground. This added cable capacitance, along with other parasitic capacitance and motor inductance, changes the electromagnetic emission signature produced by the unit. The change in electromagnetic emission signature occurs mainly in emissions less than 5 MHz. Most of the leakage current (I1) is carried back to the unit through the PE (I3), leaving only a small electromagnetic field (I4) from the shielded motor cable. The shield reduces the radiated interference but increases the low-frequency interference on the mains.



1 Ground wire	**2** Shield
3 AC mains supply	**4** Drive
5 Shielded motor cable	**6** Motor
C_S Possible shunt parasitic capacitance paths (varies with different installations)	**I_1** Common-mode leakage current
I_2 Shielded motor cable	**I_3** Safety ground (4th conductor in motor cables)

I_4 Unintended common-mode current	

Illustration 67: Electric Model Showing Possible Leakage Currents

10.4.1 EMC Test Results

The following test results have been obtained by using a system with a drive, a shielded control cable, a control box with potentiometer, a single motor, and shielded motor cable (Ölflex Classic 100 CY) at nominal switching frequency.

NOTICE

Conditions may change significantly for other setups.

NOTICE

Refer to illustration 78 for parallel motor cables.

Table 36: EMC Test Results (Emission) Maximum Motor Cable Length

RFI filter type		Conducted emission			Radiated emission		
		Cable length [m (ft)]			Cable length [m (ft)]		
Standards and require-ments	EN 55011/ CISPR 11	Class B	Class A, Group 1	Class A, Group 2	Class B	Class A, Group 1	Class A, Group 2
	EN/IEC 61800-3	Category C1	Category C2	Category C3	Category C1	Category C2	Category C3
H2							
FC 302	90–500 kW, 380–500 V	No	No	150 (492)	No	No	Yes
	55–710 kW, 525–690 V	No	No	150 (492)	No	No	Yes
H4							
FC 302	90–500 kW, 380–500 V	No	150 (492)	150 (492)	No	Yes	Yes
	55–710 kW, 525–690 V	–	–	–	–	–	–

10.4.2 Emission Requirements

According to the EMC product standard for AC drives, EN/IEC 61800-3:2004, the EMC requirements depend on the intended use of the drive. Four categories are defined in the EMC product standard. The definitions of the 4 categories together with the requirements for mains supply voltage conducted emissions are given in table 37.

Table 37: Emission Requirements

Category	Definition	Conducted emission requirement according to the limits given in EN 55011
C1	Drives installed in the 1st environment (home and office) with a supply voltage less than 1000 V.	Class B
C2	Drives installed in the 1st environment (home and office) with a supply voltage less than 1000 V, which are neither plug-in nor movable and are intended for installation and commissioning by a professional.	Class A Group 1
C3	Drives installed in the 2nd environment (industrial) with a supply voltage lower than 1000 V.	Class A Group 2
C4	Drives installed in the 2nd environment (industrial) with a supply voltage equal to or above 1000 V or rated current equal to or above 400 A or intended for use in complex systems.	No limit line. Make an EMC plan.

When the generic emission standards are used, the drives are required to comply with the limits in table 38.

Table 38: Emission Limit Classes

Environment	Generic standard	Conducted emission requirement according to the limits given in EN 55011
1st environment (home and office)	EN/IEC 61000-6-3 Emission standard for residential, commercial, and light industrial environments.	Class B
2nd environment (industrial environment)	EN/IEC 61000-6-4 Emission standard for industrial environments.	Class A Group 1

NOTICE

According to the EMC Directive, a system is defined as a combination of several types of equipment, finished products, and/or components combined, designed and/or put together by the same person (system manufacturer) intended to be placed on the market for distribution as a single functional unit for an end user and intended to be installed and operated together to perform a specific task. The EMC directive applies to products/systems and installations, but in case the installation is built up of CE marked products/systems the installation can also be considered compliant with the EMC directive. Installations shall not be CE marked.

According to the EMC Directive, Danfoss Drives as a manufacturer of product/systems is responsible for obtaining the essential requirements of the EMC directive and attaching the CE mark. For systems involving load sharing and other DC terminals, Danfoss Drives can only ensure compliance to EMC Directive when end users connect combinations of Danfoss Drives products as described in our technical documentation.

If any third-party products are connected to the load share or other DC terminals on the AC drives, Danfoss Drives cannot guarantee that the EMC requirements are fulfilled.

10.4.3 Immunity Requirements

The immunity requirements for drives depend on the environment in which they are installed. The requirements for the industrial environment are higher than the requirements for the home and office environment. All Danfoss VLT® drives comply with the requirements for the industrial environment and therefore also comply with the lower requirements for home and office environment with a large safety margin.

To document immunity against burst transient from electrical phenomena, the following immunity tests have been carried out on a system consisting of:

- A drive (with options if relevant).
- A shielded control cable.
- A control box with potentiometer, motor cable, and motor.

The tests were performed in accordance with the following basic standards:

- **EN 61000-4-2 (IEC 61000-4-2) Electrostatic discharges (ESD):** Simulation of electrostatic discharges from human beings.
- **EN 61000-4-3 (IEC 61000-4-3) Radiated immunity:** Amplitude modulated simulation of the effects of radar and radio communication equipment and mobile communications equipment.
- **EN 61000-4-4 (IEC 61000-4-4) Burst transients:** Simulation of interference brought about by switching a contactor, relay, or similar devices.
- **EN 61000-4-5 (IEC 61000-4-5) Surge transients:** Simulation of transients brought about by, for example, lightning that strikes near installations.
- **EN 61000-4-6 (IEC 61000-4-6) RF Common mode:** Simulation of the effect from radio-transmission equipment joined by connection cables.

The immunity requirements should follow product standard IEC 61800-3. See table 39.

Table 39: EMC Immunity, Voltage range: 200–240 V, 380–480 V

Basic standard	Burst IEC 61000-4-4	Surge IEC 61000-4-5	ESD IEC 61000-4-2	Radiated electro-magnetic field IEC 61000-4-3	RF common mode voltage IEC 61000-4-6
Acceptance criterion	B	B	B	A	A
Line	4 kV CM	2 kV/2 Ω DM 4 kV/12 Ω CM	–	–	10 V_{RMS}
Motor	4 kV CM	4 kV/2 Ω [(1)]	–	–	10 V_{RMS}
Brake	4 kV CM	4 kV/2 Ω [(1)]	–	–	10 V_{RMS}
Load sharing	4 kV CM	4 kV/2 Ω [(1)]	–	–	10 V_{RMS}
Control wires	2 kV CM	2 kV/2 Ω [(1)]	–	–	10 V_{RMS}
Standard bus	2 kV CM	2 kV/2 Ω [(1)]	–	–	10 V_{RMS}
Relay wires	2 kV CM	2 kV/2 Ω [(1)]	–	–	10 V_{RMS}
Application and Fieldbus options Application and network options	2 kV CM	2 kV/2 Ω [(1)]	–	–	10 V_{RMS}
LCP cable	2 kV CM	2 kV/2 Ω [(1)]	–	–	10 V_{RMS}
External 24 V DC	2 kV CM	0.5 kV/2 Ω DM 1 kV/12 Ω CM	–	–	10 V_{RMS}

Basic standard	Burst IEC 61000-4-4	Surge IEC 61000-4-5	ESD IEC 61000-4-2	Radiated electro-magnetic field IEC 61000-4-3	RF common mode voltage IEC 61000-4-6
Enclosure	–	–	8 kV AD 6 kV CD	10 V/m	–

[1] *Injection on cable shield.*

AD: Air Discharge

CD: Contact Discharge

CM: Common Mode

DM: Differential Mode

10.4.4 EMC Compatability

NOTICE

OPERATOR RESPONSIBILITY

According to the EN 61800-3 standard for variable-speed drive systems, the operator is responsible for ensuring EMC compliance. Manufacturers can offer solutions for operation conforming to the standard. Operators are responsible for applying these solutions and for paying the associated costs.

There are 2 options for ensuring electromagnetic compatibility:

- Eliminate or minimize interference at the source of emitted interference.
- Increase the immunity to interference in devices affected by its reception.

RFI filters

The goal is to obtain systems that operate stably without radio frequency interference between components. To achieve a high level of immunity, use drives with high-quality RFI filters.

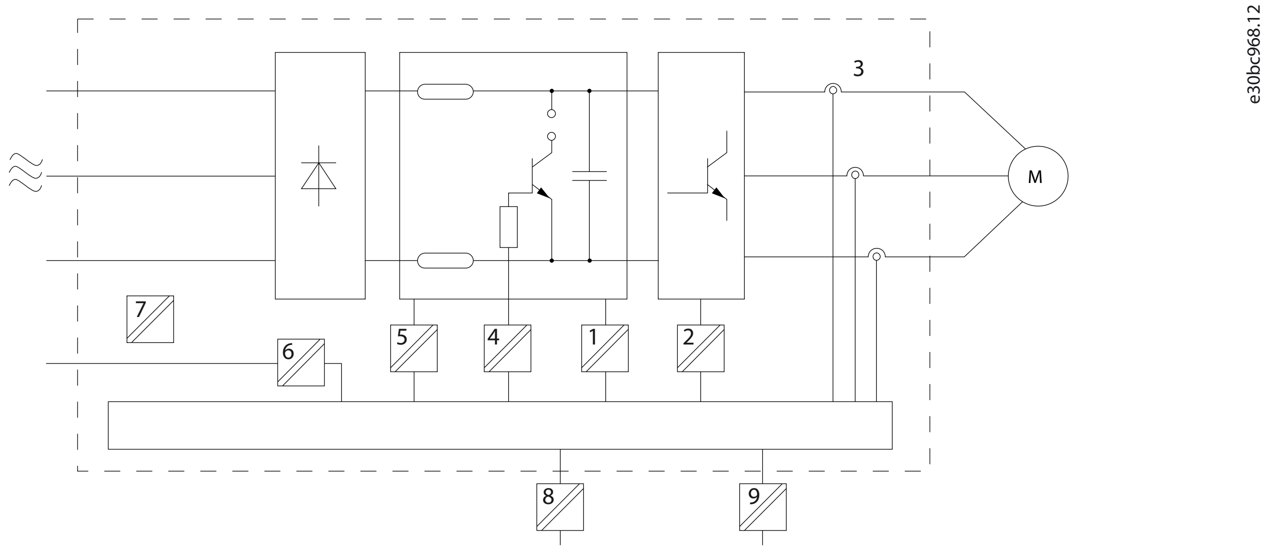
NOTICE

In a residential environment, this product can cause radio interference, in which case supplementary mitigation measures may be required.

PELV and galvanic isolation compliance

All control and relay terminals comply with PELV (excluding grounded Delta leg above 400 V). To obtain galvanic (ensured) isolation, fulfill requirements for higher isolation and provide the relevant creepage/clearance distances. These requirements are described in EN 61800-5.1.

Electrical isolation is provided as shown in illustration 68. The components described comply with both PELV and the galvanic isolation requirements.



1	Power supply (SMPS) including signal isolation of DC link	**2**	Gate drive for the IGBTs
3	Current transducers	**4**	Opto-coupler, brake module (optional)
5	Internal inrush, RFI, and temperature measurement circuits	**6**	Custom relays
7	Mechanical brake		

Illustration 68: Galvanic Isolation

10.4.5 EMC-compliant Installation

To obtain an EMC-compliant installation, be sure to follow all electrical installation instructions.

Also, remember to practice the following:

- When using relays, control cables, a signal interface, fieldbus, or brake, connect the shield to the enclosure at both ends. If the ground path has high impedance, is noisy, or is carrying current, break the shield connection on 1 end to avoid ground current loops.
- Convey the currents back to the unit using a metal mounting plate. Ensure good electrical contact from the mounting plate by securely fastening the mounting screws to the drive chassis.
- Use shielded cables for motor output cables. An alternative is unshielded motor cables within metal conduit.
- Ensure that motor and brake cables are as short as possible to reduce the interference level from the entire system.
- Avoid placing cables with a sensitive signal level alongside motor and brake cables.
- For communication and command/control lines, follow the particular communication protocol standards. For example, USB must use shielded cables, but RS485/ethernet can use shielded UTP or unshielded UTP cables.
- Ensure that all control terminal connections are rated protective extra low voltage (PELV).

NOTICE

TWISTED SHIELD ENDS (PIGTAILS)

Twisted shield ends increase the shield impedance at higher frequencies, which reduces the shield effect and increases the leakage current.

- Use integrated shield clamps instead of twisted shield ends.

NOTICE

SHIELDED CABLES

If shielded cables or metal conduits are not used, the unit and the installation do not meet regulatory limits on radio frequency (RF) emission levels.

NOTICE

EMC INTERFERENCE

Failure to isolate power, motor, and control cables can result in unintended behavior or reduced performance.

- Use shielded cables for motor and control wiring.
- Provide a minimum 200 mm (7.9 in) separation between mains input, motor cables, and control cables.

NOTICE

INSTALLATION AT HIGH ALTITUDE

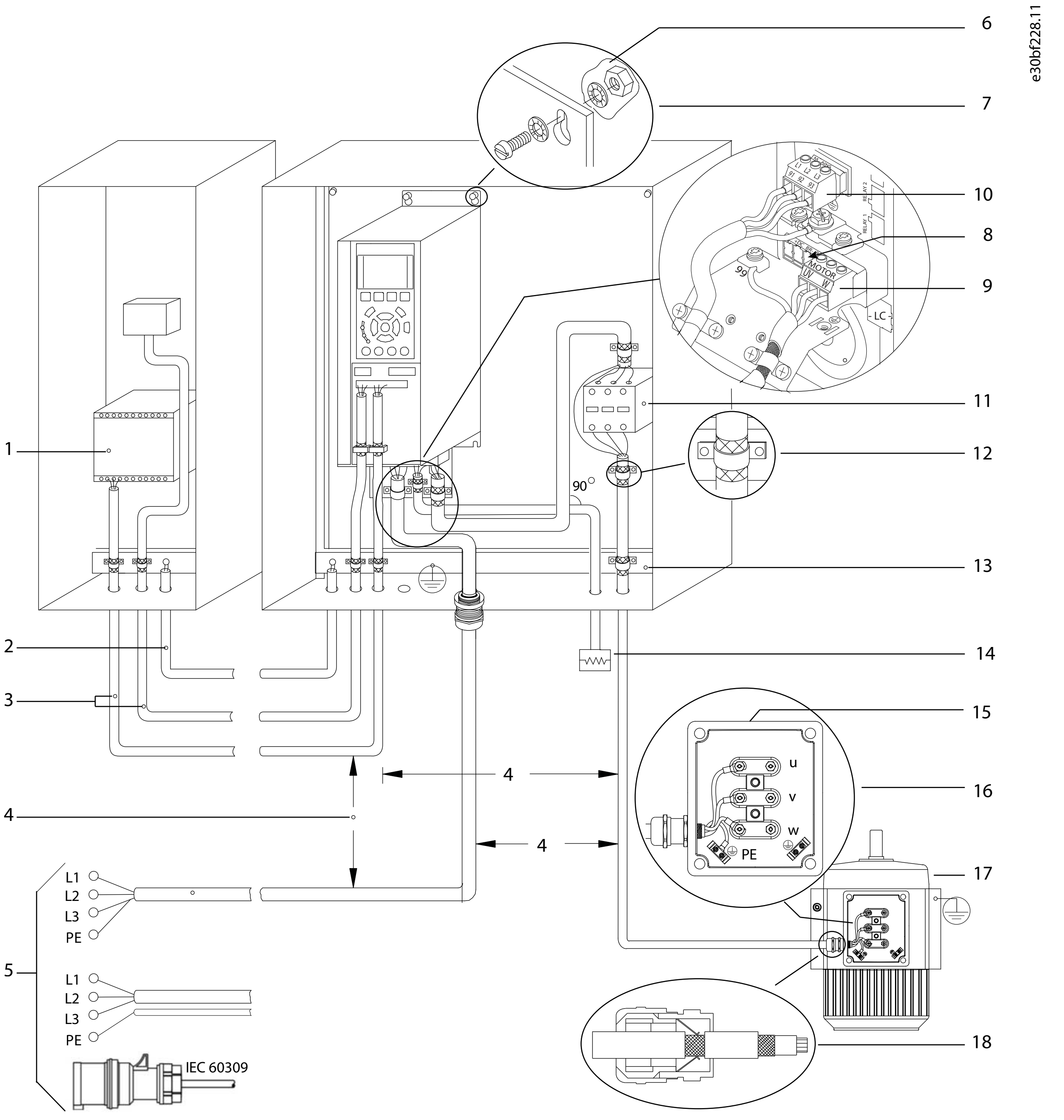
There is a risk for overvoltage. Isolation between components and critical parts could be insufficient and may not comply with PELV requirements.

- Use external protective devices or galvanic isolation. For installations above 2000 m (6500 ft) altitude, contact Danfoss regarding protective extra low voltage (PELV) compliance.

NOTICE

PROTECTIVE EXTRA LOW VOLTAGE (PELV) COMPLIANCE

Prevent electric shock by using PELV electrical supply and complying with local and national PELV regulations.



1	Programmable logic controller (PLC)	2	Minimum 16 mm^2 (6 AWG) equalizing cable
3	Control cables	4	Minimum 200 mm (7.9 in) between control cables, motor cables, and mains cables
5	Mains supply options, see IEC/EN 61800-5-1	6	Bare (unpainted) surface
7	Star washers	8	Brake cable (shielded) – not shown, but same gounding principle applies as for motor cable
9	Motor cable (shielded)		

11	Output contactor, and so on.	**10**	Mains cable (unshielded)
13	Common ground busbar. Follow local and national requirements for cabinet grounding.	**12**	Cable insulation stripped
15	Terminal box	**14**	Brake resistor
17	Motor	**16**	Connection to motor
		18	EMC cable gland

Illustration 69: Example of Proper EMC Installation

NOTICE

EMC INTERFERENCE

Use shielded cables for motor and control wiring, and separate cables for input power, motor wiring, and control wiring. Failure to isolate power, motor, and control cables can result in unintended behavior or reduced performance. Minimum 200 mm (7.9 in) clearance is required between power, motor, and control cables.

10.4.6 EMC-compliant Cables

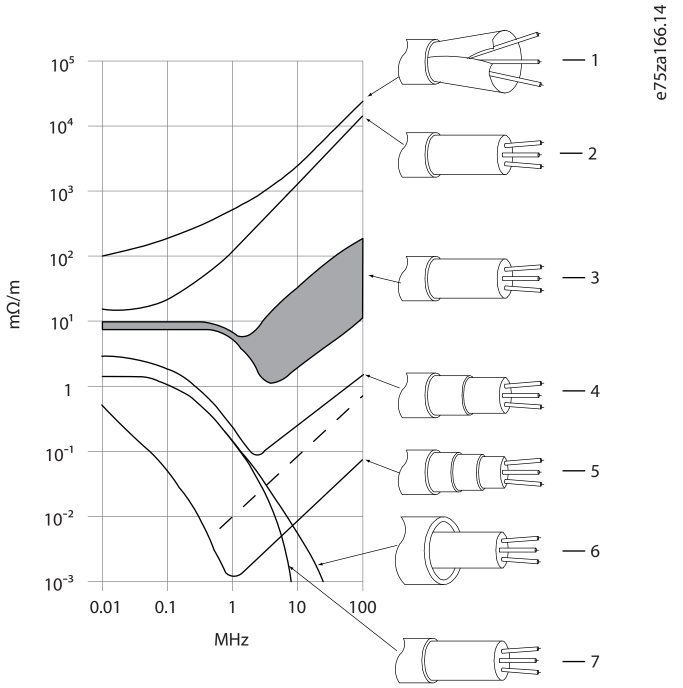
To optimize EMC immunity of the control cables and emission from the motor cables, use braided shielded/armored cables.

The ability of a cable to reduce the in- and outgoing radiation of electric noise depends on the transfer impedance (Z_T). The shield of a cable is normally designed to reduce the transfer of electric noise. However, a shield with a lower transfer impedance (Z_T) value is more effective than a shield with a higher transfer impedance (Z_T).

Cable manufacturers rarely state the transfer impedance (Z_T), but it is often possible to estimate transfer impedance (Z_T) by assessing the physical design of the cable.

Transfer impedance (Z_T) can be assessed based on the following factors:

- The conductibility of the shield material.
- The contact resistance between the individual shield conductors.
- The shield coverage, that is, the physical area of the cable covered by the shield - often stated as a percentage value.
- Shield type (braided or twisted).



1	Aluminum-clad with copper wire.	**2**	Twisted copper wire or armored steel wire cable.
3	Single-layer braided copper wire with varying percentage shield coverage. This is the typical reference cable.	**4**	Double-layer braided copper wire.
5	Twin layer of braided copper wire with a magnetic, shielded/armored intermediate layer.	**6**	Cable that runs in copper tube or steel tube.
7	Lead cable with 1.1 mm (0.04 in) wall thickness.		

Illustration 70: Transfer Impedance (Z_T)

10.5 Control Wiring and Terminals

Control terminals, with programmable functions, are provided for input commands such as run, stop, forward, reverse, and speed reference. Extra output terminals are provided to supply signals to run peripheral devices or for monitoring and reporting status.

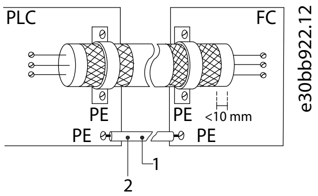
The control card logic can communicate via serial link with outside devices such as personal computers or programmable logic controllers (PLC).

The control card also provides 2 voltage supplies for use from the control terminals. The 24 V DC is used for switching functions such as start, stop, and forward/reverse. The 24 V DC supply can supply 200 mA of power, part of which can be used to power external encoders or other devices. A 10 V DC supply on terminal 50 is rated at 17 mA is also available for use with speed reference circuitry.

10.5.1 Shielded Control Cables

Usually, the preferred method is to secure control and serial communication cables with shielding clamps provided at both ends to ensure the best possible high frequency cable contact.

If the ground potential between the drive and the PLC is different, electric noise could disturb the entire system. Solve this problem by fitting an equalizing cable as close as possible to the control cable. Minimum cable cross-section: 16 mm^2 (6 AWG).



1 Minimum 16 mm^2 (6 AWG)	**2** Equalizing cable

Illustration 71: Shielding Clamps at Both Ends

10.5.1.1 50/60 Hz Ground Loops

With long control cables, ground loops may occur. To eliminate ground loops, connect 1 end of the shield to the ground with a 100 nF capacitor (keeping leads short).

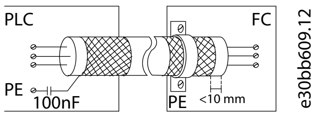
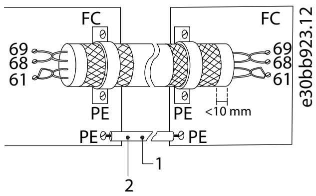


Illustration 72: Connection with a 100 nF Capacitor

10.5.1.2 Avoid EMC Noise on Serial Communication

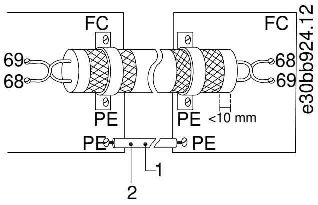
This terminal is connected to ground via an internal RC link. Use twisted-pair cables to reduce interference between conductors. The recommended method is shown in the following illustration.



1 Minimum 16 mm^2 (6 AWG)	**2** Equalizing cable

Illustration 73: Twisted-pair Cables

Alternatively, the connection to terminal 61 can be omitted.



1	Minimum 16 mm^2 (6 AWG)	**2**	Equalizing cable

Illustration 74: Twisted-pair Cables without Terminal 61

10.5.2 Control Terminals

Table 40: Serial Communication Terminals

XD2 terminal	Parameter	Default Setting	Description
1	–	–	Integrated RC-filter for cable shield. Used only for connecting the shield in case of EMC problems. .
2	*Parameter group 8-3* FC Port Settings*	–	RS485 interface. A switch (BUS TER.) is provided on the control card for bus termination resistance. See *Illustration 5.22*.
3	*Parameter group 8-3* FC Port Settings*	–	

Table 41: Digital Input/Output Terminal Descriptions

XD2 terminal	Parameter	Default setting	Description
10, 11	–	+24 V DC	24 V DC supply voltage for digital inputs and external transducers. Maximum output current 200 mA for all 24 V loads. .
12	*Parameter 5-10 Terminal 18 Digital Input*	*[8] Start*	Digital inputs.
13	*Parameter 5-11 Terminal 19 Digital Input*	*[10] Reversing*	
16	*Parameter 5-14 Terminal 32 Digital Input*	*[0] No operation*	
17	*Parameter 5-15 Terminal 33 Digital Input*	*[0] No operation*	
14	*Parameter 5-12 Terminal 27 Digital Input*	*[2] Coast inverse*	For digital input or output. Default setting is input.
15	*Parameter 5-13 Terminal 29 Digital Input*	*[14] JOG*	
18	–	–	Common for digital inputs and 0 V potential for 24 V supply.

XD2 terminal	Parameter	Default setting	Description
19	–	STO	When not using the optional STO feature, a jumper wire is required between terminal 10 (or 11) and terminal 19. This set-up allows the drive to operate with factory default programming values.

Table 42: Analog Input/Output Terminal Descriptions

XD2 terminal	Parameter	Default setting	Description
4	–	–	Common for analog output. .
5	*Parameter 6-50 Terminal 42 Output*	*[0] No operation*	Programmable analog output. 0–20 mA or 4–20 mA at a maximum of 500 Ω.
6	–	+10 V DC	10 V DC analog supply voltage for potentiometer or thermistor. 15 mA maximum.
7	*Parameter group 6-1* Analog Input 1*	Reference	Analog input. For voltage (V) or current (mA).
8	*Parameter group 6-2* Analog Input 2*	Feedback	
9	–	–	Common for analog input.

10.5.3 Relay Terminals

Table 43: Relay Terminal Descriptions

XD2 terminal	Parameter	Default setting	Description
21, 22, 23	*Parameter 5-40 Function Relay [0]*	*[0] No operation*	Form C relay outputs. For AC or DC voltage. .
24, 25, 26	*Parameter 5-40 Function Relay [1]*	*[0] No operation*	

10.5.4 Option Card Terminals

The option cards extend the functionality of drives and provide a high variety of interfaces to automation systems. When the option cards are specified in the type code, they are mounted in slots A, B, C, and D of the control card within the drive module. The option card wiring is routed to a terminal block within the control compartment. For more details, refer to the Installation/Operating Guide for the respective option card.

NOTICE

OPTION CARD INSTALLATION

If the option card is ordered along with the drive using the type code, the factory installs the option card and its wiring. If the option is ordered separately, the customer is responsible for installing the option card and the wiring extensions to the control compartment.

Table 44: Option A Terminal Connections for VLT® DeviceNet MCA 104, VLT® CANopen MCA 105, VLT® DeviceNet Converter MCA 194

Option card terminal	Corresponding terminal within the control compartment
1	XD2.40
2	XD2.41
3	XD2.42
4	XD2.43
5	XD2.44

Table 45: Option A Terminal Connections for VLT® PROFIBUS DP-V1 MCA 101, VLT® PROFIBUS Converter VLT 300 MCA 113, VLT® PROFIBUS Converter VLT 5000 MCA 114

Option card terminal	Corresponding terminal within the control compartment
67	XD2.40
66	XD2.41
63	XD2.42
62	XD2.43
CS	XD2.44

Table 46: Option A Terminal Connections for VLT® EtherNet/IP MCA 121, VLT® Modbus TCP MCA 122, VLT® POWERLINK MCA 123, VLT® EtherCAT MCA 124

Option card terminal	Corresponding terminal within the control compartment
Port 1	RJ45_1
Port 2	RJ45_2

Table 47: Option B Terminal Connections

Option card terminal	Corresponding terminal within the control compartment
1	XD2.46
2	XD2.47
3	XD2.48
4	XD2.49
5	XD2.50
6	XD2.51
7	XD2.52
8	XD2.53
9	XD2.54
10	XD2.55
11	XD2.56
12	XD2.57

Table 48: Option C0 Terminal Connections for VLT® Synchronizing Controller MCO 350

Option card terminal	Corresponding terminal within the control compartment
X55.1	XDW.1
X55.2	XDW.2
X55.3	XDW.3
X55.4	XDW.4
X55.5	XDW.5
X55.6	XDW.6
X55.7	XDW.7
X55.8	XDW.8
X55.9	XDW.9
X55.10	XDW.10
X55.11	XDW.11
X55.12	XDW.12
X56.1	XDW.13
X56.2	XDW.14
X56.3	XDW.15
X56.4	XDW.16
X56.5	XDW.17
X56.6	XDW.18
X56.7	XDW.19
X56.8	XDW.20
X56.9	XDW.21
X56.10	XDW.22
X56.11	XDW.23
X56.12	XDW.24
X57.1	XDW.27
X57.2	XDW.28
X57.3	XDW.29
X57.4	XDW.30
X57.5	XDW.31
X57.6	XDW.32
X57.7	XDW.33
X57.8	XDW.34
X57.9	XDW.35
X57.10	XDW.36

Option card terminal	Corresponding terminal within the control compartment
X58.1	XDW.25
X58.2	XDW.26
X59.1	XDW.37
X59.2	XDW.38
X59.3	XDW.39
X59.4	XDW.40
X59.5	XDW.41
X59.6	XDW.42
X59.7	XDW.43
X59.8	XDW.44

Table 49: Option C0 Terminal Connections for VLT® Positioning Controller MCO 351

Option card terminal	Corresponding terminal within the control compartment
X55.1	XDW.1
X55.2	XDW.2
X55.3	XDW.3
X55.4	XDW.4
X55.5	XDW.5
X55.6	XDW.6
X55.7	XDW.7
X55.8	XDW.8
X55.9	XDW.9
X55.10	XDW.10
X55.11	XDW.11
X55.12	XDW.12
X56.1	XDW.13
X56.2	XDW.14
X56.3	XDW.15
X56.4	XDW.16
X56.5	XDW.17
X56.6	XDW.18
X56.7	XDW.19
X56.8	XDW.20
X56.9	XDW.21
X56.10	XDW.22

Option card terminal	Corresponding terminal within the control compartment
X56.11	XDW.23
X56.12	XDW.24
X58.1	XDW.25
X58.2	XDW.26
X57.1	XDW.27
X57.2	XDW.28
X57.3	XDW.29
X57.4	XDW.30
X57.5	XDW.31
X57.6	XDW.32
X57.7	XDW.33
X57.8	XDW.34
X57.9	XDW.35
X57.10	XDW.36
X59.1	XDW.37
X59.2	XDW.38
X59.3	XDW.39
X59.4	XDW.40
X59.5	XDW.41
X59.6	XDW.42
X59.7	XDW.43
X59.8	XDW.44
X60.1	XDW.45
X60.2	XDW.46
X60.3	XDW.47
X60.4	XDW.48
X60.5	XDW.49
X62.2	XDW.50
X62.3	XDW.51
X62.4	XDW.52

Table 50: Option C1 Terminal Connections for VLT® Extended Relay Card MCB 113

Option card terminal	Corresponding terminal within the control compartment
X45.1	XDF.17
X45.2	XDF.18

Option card terminal	Corresponding terminal within the control compartment
X45.3	XDF.19
X45.4	XDF.20
X46.1	XDF.1
X46.2	XDF.2
X46.3	XDF.3
X46.4	XDF.4
X46.5	XDF.5
X46.6	XDF.6
X46.7	XDF.7
X46.8	XDF.8
X46.9	XDF.9
X46.10	XDF.10
X46.11	XDF.11
X46.12	XDF.12
X46.13	XDF.13
X46.14	XDF.14
X47.1	XDF.21
X47.2	XDF.22
X47.3	XDF.23
X47.4	XDF.24
X47.5	XDF.25
X47.6	XDF.26
X47.7	XDF.27
X47.8	XDF.28
X47.9	XDF.29
X47.10	XDF.30
X47.11	XDF.31
X47.12	XDF.32
X58.1	XDF.15
X58.2	XDF.16

Table 51: Option C1 Terminal Connections for VLT® Advanced Cascade Controller MCO 102

Option card terminal	Corresponding terminal within the control compartment
X67.1	XDF.21
X67.2	XDF.22

Option card terminal	Corresponding terminal within the control compartment
X67.3	XDF.23
X67.4	XDF.24
X67.5	XDF.25
X67.6	XDF.26
X67.7	XDF.27
X67.8	XDF.28
X67.9	XDF.29
X67.10	XDF.30
X67.11	XDF.31
X67.12	XDF.32
X66.1	XDF.1
X66.2	XDF.2
X66.3	XDF.3
X66.4	XDF.4
X66.5	XDF.5
X66.6	XDF.6
X66.7	XDF.7
X66.8	XDF.8
X66.9	XDF.9
X66.10	XDF.10
X66.11	XDF.11
X66.12	XDF.12
X66.13	XDF.13
X66.14	XDF.14
X58.1	XDF.15
X58.2	XDF.16

Table 52: Option D Terminal Connections

Option card terminal	Corresponding terminal within the control compartment
35	XD2.28
36	XD2.29

10.5.5 Personal Computer Connection

To control the drive from a PC, install the VLT® Motion Control Tool MCT 10. The PC is connected via a standard (host/device) USB cable, or via the RS485 interface. For more information on RS485, see the RS485 Installation and Set-up section in the VLT® AutomationDrive FC 302, 315–1200 kW Design Guide.

USB is a universal serial bus utilizing 4 shielded wires with ground pin 4 connected to the shield in the PC USB port. All standard PCs are manufactured without galvanic isolation in the USB port.

To prevent damage to the USB host controller through the shield of the USB cable, follow the ground recommendations described in the Operating Guide. When connecting the PC to the drive through a USB cable, Danfoss recommends using a USB isolator with galvanic isolation to protect the PC USB host controller from ground potential differences. It is also recommended not to use a PC power cable with a ground plug when the PC is connected to the drive through a USB cable. These recommendations reduce the ground potential difference, but does not eliminate all potential differences due to the ground and shield connected in the PC USB port.

10.6 Power Connections

10.6.1 Mains Connections

NOTICE

All cabling must comply with national and local regulations on cable cross-sections and ambient temperature. UL applications require 75 °C (167 °F) copper conductors. Non-UL applications can use 75 °C (167 °F) and 90 °C (194 °F) copper conductors.

NOTICE

The plug connector for power is pluggable on drives up to 7.5 kW (10 hp).

The power cable connections are located as shown in illustration 75. See the Electrical Data section for correct dimensioning or motor cable cross-section and length.

For protection of the drive, use the recommended fuses unless the unit has built-in fuses. Recommended fuses are listed in the Fuses, Circuit Breakers, and Switches section. Ensure that proper fusing complies with local regulations. The connection of mains is fitted to the mains switch, if included.

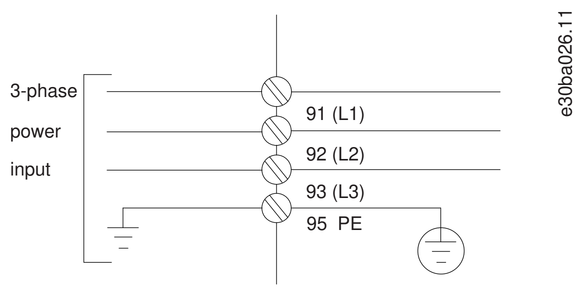


Illustration 75: Connection of Mains

Aluminum conductors

Terminals can accept aluminum conductors, but the conductor surface must be clean, and the oxidation must be removed and sealed by neutral, acid-free Vaseline grease before the conductor is connected. Furthermore, the terminal screw must be retightened after 2 days due to softness of the aluminum. It is crucial to keep the connection a gas tight joint, otherwise the aluminum surface oxidizes again.

NOTICE

The motor cable must be shielded/armored. If an unshielded/unarmored cable is used, some EMC requirements are not complied with. Use a shielded/armored motor cable to comply with EMC emission specifications.

For more information on EMC, see 10.4.5 EMC-compliant Installation.

Shielding of cables

Avoid installation with twisted shield ends (pigtails). They spoil the shielding effect at higher frequencies. If it is necessary to break the shield to install a motor isolator or contactor, continue the shield at the lowest possible HF impedance. Connect the motor cable shield to both the decoupling plate of the drive and the metal housing of the motor. Make the shield connections with the largest possible surface area (cable clamp) by using the installation devices within the drive.

Cable length and cross-section

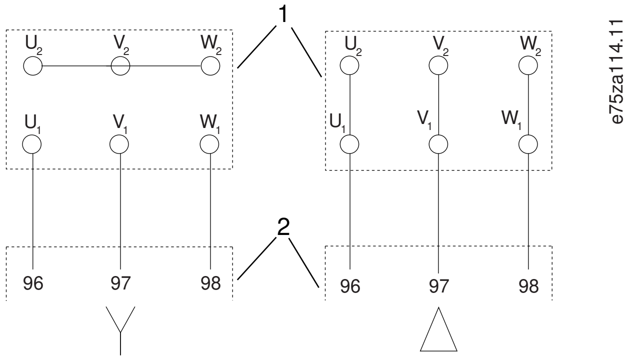
The drive has been EMC tested with a given length of cable. Keep the motor cable as short as possible to reduce noise level and leakage currents.

Switching frequency

When drives are used with sine-wave filters to reduce the acoustic noise from a motor, set the switching frequency according to the instructions in *parameter 14-01 Switching Frequency*.

NOTICE

In motors without phase insulation, paper, or other insulation reinforcement suitable for operation with voltage supply, use a sine-wave filter on the output of the drive.



1 Motor	**2** Drive

Illustration 76: Motor Cable Connection

10.6.2 IT Grid Connection

Mains supply isolated from ground

If the drive is supplied from an isolated mains source (IT mains, floating delta, or grounded delta) or TT/TN-S mains with grounded leg, the RFI switch is recommended to be turned off via *parameter 14-50 RFI Filter* on the drive and *parameter 14-50 RFI Filter* on the filter. For more detail, see IEC 364-3. In the off position, the filter capacitors between the chassis and the DC link are cut off to avoid damage to the DC link and to reduce the ground capacity currents, according to IEC 61800-3. If optimum EMC performance is needed, or parallel motors are connected, or the motor cable length is above 25 m (82 ft), Danfoss recommends setting *parameter 14-50 RFI Filter* to *[1] On*. Refer also to the Application Note, VLT on IT grid. It is important to use isolation monitors that are rated for use together with power electronics (IEC 61557-8).

Danfoss does not recommend using an output contactor for 525–690 V drives connected to an IT mains network.

10.6.3 DC Bus Connection

Terminals	Function
88, 89	DC bus

10.6.4 Brake Cable Connection

The connection cable to the brake resistor must be shielded and the maximum length from the drive to the DC bar is limited to 25 m (82 ft).

- Use cable clamps to connect the shield to the conductive backplate on the drive and to the metal cabinet of the brake resistor.
- Size the brake cable cross-section to match the brake torque.

Terminals	Function
81, 82	Brake resistor terminals

See the VLT® Brake Resistor MCE 101 Design Guide for more details.

NOTICE

If a short circuit in the brake module occurs, prevent excessive power dissipation in the brake resistor by using a mains switch or contactor to disconnect the mains from the drive.

10.6.5 Grounding

To obtain electromagnetic compatibility (EMC), consider the following basic issues when installing a drive.

- Safety grounding: Note that the drive has a high leakage current and must be grounded appropriately for safety reasons. Apply local safety regulations.
- High-frequency grounding: Keep the ground wire connections as short as possible.

Connect the different ground systems at the lowest possible conductor impedance. The lowest possible conductor impedance is obtained by keeping the conductor as short as possible and by using the greatest possible surface area. The metal cabinets of the different devices are mounted on the cabinet rear plate using the lowest possible HF impedance. This avoids having different HF voltages for the individual devices and avoids the risk of radio interference currents running in connection cables that may be used between the devices. The radio interference has been reduced. To obtain a low HF impedance, use the fastening bolts of the devices as HF connection to the rear plate. It is necessary to remove insulating paint or similar from the fastening points.

10.6.6 Safety Ground Connection

WARNING

LEAKAGE CURRENT HAZARD

Leakage currents exceed 3.5 mA. Failure to ground the drive properly can result in death or serious injury.

- Ensure the correct grounding of the equipment by a certified electrical installer.

The drive has a high leakage current and must be grounded appropriately for safety reasons according to IEC 61800-5-1.

10.7 Fuses, Circuit Breakers, and Switches

Fuses and circuit breakers ensure that possible damage to the drive is limited to damages inside the unit. Danfoss recommends fuses on the supply side as protection. For further information, see *Application Note Fuses and Circuit Breakers*.

NOTICE

Use of fuses on the supply side is mandatory for IEC 60364 (CE) and NEC 2009 (UL) compliant installations.

Danfoss provides the following mains options for the enclosed drive:

- Panel fuses
- Fusible disconnect
- Non-fusible disconnect
- Contactor
- Molded-case circuit breaker (MCCB)

10.7.1 Panel Fuses

Panel fuses are an option for upstream protection, and can be ordered as either a UL class fuse for UL variant or a gG fuse for IEC variant.

Table 53: Panel Fuses for VLT® AutomationDrive FC 302 Enclosed Drive Models N90K–N250, 380–500 V

	N90K	N110	N132	N160	N200	N250
IEC (Type gG)	250 A/500 V	315 A/500 V	355 A/500 V	425 A/500 V	630 A/500 V	630 A/500 V
Mersen P/N	NH1GG50V250	NH2GG50V315	NH2GG50V355	NH3GG50V425	NH3AGG50V630	NH3AGG50V630
UL (Class J/L/T)	300 A/600 V	350 A/600 V	400 A/600 V	500 A/600 V	600 A/600 V	750 A/600 V
Mersen P/N	A4J300	A4J350	A4J400	A4J500	A4J600	AABY750

Table 54: Panel Fuses for VLT® AutomationDrive FC 302 Enclosed Drive Models N315–N500, 380–500 V

	N315	N355	N400	N450	N500
IEC (Type gG)	800 A/500 V	1000 A/500 V	1000 A/500 V	1000 A/500 V	1250 A/500 V
Mersen P/N	NH4GG50V800	NH4GG50V1000	NH4GG50V1000	NH4GG50V1000	NH4GG50V1250
UL (Class J/L/T)	800 A/600 V	1000 A/600 V	1000 A/600 V	1100 A/600 V	1200 A/600 V
Mersen P/N	A4BY800	A4BY1000	A4BY1000	A4BY1100	A4BY1200

Table 55: Panel Fuses for VLT® AutomationDrive FC 302 Enclosed Drive Models N90K–N250, 525–690 V

	N90K	N110	N132	N160	N200	N250
IEC (Type gG)	250 A/690 V	250 A/690 V	250 A/690 V	315 A/690 V	355 A/690 V	425 A/690 V
Mersen P/N	NH2GG69V250	NH2GG69V250	NH2GG69V250	NH2GG69V315	NH3GG69V355	NH3GG69V425
UL (Class J/L/T)	175 A/600 V	200 A/600 V	250 A/600 V	350 A/600 V	400 A/600 V	500 A/600 V
Mersen P/N	A4J175	A4J200	A4J250	A4J350	A4J400	A4J500

Table 56: Panel Fuses for VLT® AutomationDrive FC 302 Enclosed Drive Models N315–N560, 525–690 V

	N315	N355	N400	N500	N560
IEC (Type gG)	500 A/690 V	500 A/500 V	630 A/500 V	800 A/500 V	800 A/500 V
Mersen P/N	NH3GG69V500	NH3GG69V500	NH4GG69V630	NH4GG69V800	NH4GG69V800
UL (Class J/L/T)	600 A/600 V	600 A/600 V	650 A/600 V	750 A/600 V	800 A/600 V
Mersen P/N	A4J600	A4J600	A4BY650	A4BY750	A4BY800

Table 57: Panel Fuses for VLT® AutomationDrive FC 302 Enclosed Drive Models N630–N710, 525–690 V

	N630	N710
IEC (Type gG)	1000 A/690 V	1000 A/690 V
ABB P/N	OFAA4AGG1000	OFAA4AGG1000
UL (Class J/L/T)	1000 A/600 V	1100 A/600 V
Mersen P/N	A4BY1000	A4BY1100

10.7.2 Contactor Switches

The mains contactor is an option. All units ordered and supplied with a factory-installed contactor require a Class L/J branch circuit fusing to meet the 65 kA SCCR for the drive system.

This option makes it possible to connect or disconnect the drive from the mains by using a control switch on the control compartment door or an external switch. The external switch must be wired to terminals XD0. See 10.1 Wiring Overview for D9h and D10h Enclosed Drives and 10.2 Wiring Overview for E5h and E6h Enclosed Drives. The mains contactor is supplied with 2 sets of auxiliary switches (1 normally open and 1 normally closed). These switches are on the sides of the contactor. By default, the NO auxiliary switch is wired at the factory and used by the system.

Auxiliary switch specifications

Rated operation current @ 230 V	6 A
Rated operation current @ 380 V	4 A
Rated operation current @ 500 V	1.5 A
Conventional thermal current, Ith	10 A
Rated voltage	500 V AC
Rated impulse withstand voltage	600 V AC

Table 58: Mains Contactor Switches for VLT® AutomationDrive FC 302 Enclosed Drive Models N90K–N250, 380–500 V

	N90K	N110	N132	N160	N200	N250
IEC	185 A/1000 V	185 A/1000 V	185 A/1000 V	400 A/1000 V	580 A/1000 V	500 A/1000 V
Eaton P/N	XTCE400M22A	XTCE400M22A	XTCE400M22A	XTCE400M22A	XTCE400M22A	XTCE500M22A
UL	185 A/1000 V	185 A/1000 V	185 A/1000 V	400 A/1000 V	400 A/1000 V	580 A/1000 V
Eaton P/N	XTCE400M22A	XTCE400M22A	XTCE400M22A	XTCE400M22A	XTCE580N22A	XTCE580N22A

Table 59: Mains Contactor Switches for VLT® AutomationDrive FC 302 Enclosed Drive Models N315–N500, 380–500 V

	N315	N355	N400	N450	N500
IEC	580 A/1000 V	580 A/1000 V	580 A/1000 V	820 A/1000 V	820 A/1000 V
Eaton P/N	XTCE580N22A	XTCE580N22A	XTCE580N22A	XTCE820N22A	XTCE820N22A
UL	820 A/1000 V	820 A/1000 V	820 A/1000 V	1000 A/1000 V	1000 A/1000 V
Eaton P/N	XTCE820N22A	XTCE820N22A	XTCE820N22A	XTCEC10N22A	XTCEC10N22A

Table 60: Mains Contactor Switches for VLT® AutomationDrive FC 302 Enclosed Drive Models N90K–N250, 525–690 V

	N90K	N110	N132	N160	N200	N250
IEC	185 A/1000 V	185 A/1000 V	185 A/1000 V	400 A/1000 V	400 A/1000 V	400 A/1000 V
Eaton P/N	XTCE400H22A	XTCE400H22A	XTCE400H22A	XTCE400M22A	XTCE400M22A	XTCE400M22A
UL	185 A/1000 V	185 A/1000 V	185 A/1000 V	400 A/1000 V	400 A/1000 V	400 A/1000 V
Eaton P/N	XTCE400H22A	XTCE400H22A	XTCE400H22A	XTCE400M22A	XTCE400M22A	XTCE400M22A

Table 61: Mains Contactor Switches for VLT® AutomationDrive FC 302 Enclosed Drive Models N315–N560, 525–690 V

	N315	N355	N400	N500	N560
IEC	400 A/1000 V	580 A/1000 V	580 A/1000 V	580 A/1000 V	580 A/1000 V
Eaton P/N	XTCE400M22A	XTCE580N22A	XTCE580N22A	XTCE580N22A	XTCE580N22A
UL	400 A/1000 V	580 A/1000 V	580 A/1000 V	580 A/1000 V	580 A/1000 V
Eaton P/N	XTCE400M22A	XTCE580N22A	XTCE580N22A	XTCE580N22A	XTCE580N22A

Table 62: Mains Contactor Switches for VLT® AutomationDrive FC 302 Enclosed Drive Models N630–N710, 525–690 V

	N630	N710
IEC	580 A/1000 V	820 A/1000 V

	N630	N710
Eaton P/N	XTCE580N22A	XTCE820N22A
UL	820 A/1000 V	1000 A/1000 V
Eaton P/N	XTCE820N22A	XTCEC10N22A

10.7.3 Fusible Disconnect Switches

The fusible disconnector switch is an option that safely isolates the drive from the mains with a fuse switch mounted below the drive module. All units ordered and supplied with a factory-installed fusible disconnect switch have a fuse built in to the switch. The fuse has been sized to meet 65kA SCCR for the system. The input voltage and power rating of the drive determines the specific class or gG fuse. The input voltage and power rating are found on the name plate and in the type code.

Table 63: Fusible Disconnect Switches for VLT® AutomationDrive FC 302 Enclosed Drive Models N90K–N250, 380–500 V

	N90K	N110	N132	N160	N200	N250
IEC	400 A/690 V	400 A/690 V	400 A/690 V	630 A/690 V	630 A/690 V	630 A/690 V
ABB P/N	OS400D30P	OS400D30P	OS400D30P	OS630D30P	OS630D30P	OS630D30P
UL	400 A/600 V	400 A/600 V	400 A/600 V	600 A/600 V	600 A/600 V	800 A/600 V
ABB P/N	OS400J30	OS400J30	OS400J30	OS600J30	OS600J30	OS800L30

Table 64: Fusible Disconnect Switches for VLT® AutomationDrive FC 302 Enclosed Drive Models N315–N500, 380–500 V

	N315	N355	N400	N450	N500
IEC	1250 A/690 V	1250 A/690 V	1250 A/690 V	1250 A/690 V	1250 A/690 V
ABB P/N	OS1250D30P	OS1250D30P	OS1250D30P	OS1250D30P	OS1250D30P
UL	800 A/600 V	1200 A/600 V	1200 A/600 V	1200 A/600 V	1200 A/600 V
ABB P/N	OS800L30	OS1200L30	OS1200L30	OS1200L30	OS1200L30

Table 65: Fusible Disconnect Switches for VLT® AutomationDrive FC 302 Enclosed Drive Models N90K–N250, 525–690 V

	N90K	N110	N132	N160	N200	N250
IEC	400 A/690 V	400 A/690 V	400 A/690 V	630 A/690 V	630 A/690 V	630 A/690 V
ABB P/N	OS400D30P	OS400D30P	OS400D30P	OS630D30P	OS630D30P	OS630D30P
UL	400 A/600 V	400 A/600 V	400 A/600 V	400 A/600 V	400 A/600 V	600 A/600 V
ABB P/N	OS400J30	OS400J30	OS400J30	OS400J30	OS400J30	OS600J30

Table 66: Fusible Disconnect Switches for VLT® AutomationDrive FC 302 Enclosed Drive Models N315–N560, 525–690 V

	N315	N355	N400	N500	N560
IEC	630 A/690 V	630 A/690 V	1250 A/690 V	1250 A/690 V	1250 A/690 V
ABB P/N	OS630D30P	OS630D30P	OS1250D30P	OS1250D30P	OS1250D30P
UL	600 A/600 V	600 A/600 V	800 A/600 V	800 A/600 V	800 A/600 V

	N315	N355	N400	N500	N560
ABB P/N	OS600J30	OS600J30	OS800L30	OS800L30	OS800L30

Table 67: Fusible Disconnect Switches for VLT® AutomationDrive FC 302 Enclosed Drive Models N630–N710, 525–690 V

	N630	N710
IEC	1250 A/690 V	1250 A/690 V
ABB P/N	OS1250D30P	OS1250D30P
UL	1200 A/600 V	1200 A/600 V
ABB P/N	OS1200L30	OS1200L30

10.7.4 Non-fusible Disconnect Switches

The non-fusible disconnector switch is an option. All units ordered and supplied with a factory-installed, non-fusible disconnect switch require a UL Class fuse to meet 65kA SCCR for the drive system.

Table 68: Non-fusible Disconnect Switches for VLT® AutomationDrive FC 302 Enclosed Drive Models N90K–N250, 380–500 V

	N90K	N110	N132	N160	N200	N250
IEC	400 A/600 V	400 A/600 V	400 A/600 V	630 A/600 V	630 A/600 V	630 A/600 V
ABB P/N	OT400E30	OT400E30	OT400E30	OT630E30	OT630E30	OT630E30
UL	400 A/690 V	400 A/690 V	400 A/690 V	600 A/690 V	600 A/690 V	800 A/690 V
ABB P/N	OT400U30	OT400U30	OT400U30	OT600U30	OT600U30	OT800U30

Table 69: Non-fusible Disconnect Switches for VLT® AutomationDrive FC 302 Enclosed Drive Models N315–N500, 380–500 V

	N315	N355	N400	N450	N500
IEC	1000 A/600 V	1000 A/600 V	1250 A/600 V	1250 A/600 V	1250 A/600 V
ABB P/N	OT1000E30	OT1000E30	OT1250E30	OT1250E30	OT1250E30
UL	800 A/690 V	1200 A/690 V	1200 A/690 V	1200 A/690 V	1200 A/690 V
ABB P/N	OT800U30	OT1200U30	OT1200U30	OT1200U30	OT1200U30

Table 70: Non-fusible Disconnect Switches for VLT® AutomationDrive FC 302 Enclosed Drive Models N90K–N250, 525–690 V

	N90K	N110	N132	N160	N200	N250
IEC	400 A/600 V	400 A/600 V	400 A/600 V	630 A/600 V	630 A/600 V	630 A/600 V
ABB P/N	OT400E30	OT400E30	OT400E30	OT630E30	OT630E30	OT630E30
UL	400 A/690 V	400 A/690 V	400 A/690 V	600 A/690 V	600 A/690 V	600 A/690 V
ABB P/N	OT400U30	OT400U30	OT400U30	OT600U30	OT600U30	OT600U30

Table 71: Non-fusible Disconnect Switches for VLT® AutomationDrive FC 302 Enclosed Drive Models N315–N560, 525–690 V

	N315	N355	N400	N500	N560
IEC	630 A/600 V	630 A/600 V	630 A/600 V	1000 A/600 V	1000 A/600 V
ABB P/N	OT630E30	OT630E30	OT630E30	OT1000E30	OT1000E30
UL	600 A/690 V	600 A/690 V	600 A/690 V	800 A/690 V	800 A/690 V
ABB P/N	OT600U30	OT600U30	OT600U30	OT800U30	OT800U30

Table 72: Non-fusible Disconnect Switches for VLT® AutomationDrive FC 302 Enclosed Drive Models N630–N710, 525–690 V

	N630	N710
IEC	1250 A/600 V	1250 A/600 V
ABB P/N	OT1250E30	OT1250E30
UL	1200 A/690 V	1200 A/690 V
ABB P/N	OT1200U30	OT1200U30

10.7.5 Molded-case Circuit Breakers

The molded-case circuit breaker (MCCB) is an option that combines a temperature sensitive device with a current sensitive electromagnetic device to protect the drive.

Table 73: MCCB Part Numbers for VLT® AutomationDrive FC 302 Enclosed Drive Models N90K–N250, 380–500 V

	N90K	N110	N132	N160	N200	N250
IEC	400 A/600 V	400 A/600 V	400 A/600 V	800 A/600 V	800 A/600 V	800 A/600 V
ABB P/N	T5L400T	T5L400T	T5L400T	T6L800T	T6L800T	T6L800T
UL	400 A/690 V	400 A/690 V	400 A/690 V	600 A/690 V	600 A/690 V	800 A/690 V
ABB P/N	T5L400TW	T5L400TW	T5L400TW	T6L600TW	T6L600TW	T6L800TW

Table 74: MCCB Part Numbers for VLT® AutomationDrive FC 302 Enclosed Drive Models N315–N500, 380–500 V

	N315	N355	N400	N450	N500
IEC	1000 A/690 V	1250 A/690 V	1250 A/690 V	1250 A/690 V	1600 A/690 V
ABB P/N	T71000LSPR231 DS-LS	T71250LSPR231 DS-LS	T71250LSPR231 DS-LS	T71250LSPR231 DS-LS	T71600LSPR231 DS-LS
UL	1200 A/600 V	1200 A/600 V	1200 A/600 V	1600 A/600 V	1600 A/600 V
ABB P/N	T7L1200PR231/P	T7L1200PR231/P	T7LQ1200PR231/P	T8V1600PR231/P	T8V1600PR231/P

Table 75: MCCB Part Numbers for VLT® AutomationDrive FC 302 Enclosed Drive Models N90K–N250, 525–690 V

	N90K	N110	N132	N160	N200	N250
IEC	400 A/690 V	400 A/690 V	400 A/690 V	630 A/690 V	630 A/690 V	630 A/690 V

	N90K	N110	N132	N160	N200	N250
ABB P/N	T5L400T	T5L400T	T5L400T	T6L630T	T6L630T	T6L630T
UL	400 A/600 V	400 A/600 V	400 A/600 V	600 A/600 V	600 A/600 V	600 A/600 V
ABB P/N	T5L400TW	T5L400TW	T5L400TW	T6L600TW	T6L600TW	T6L600TW

Table 76: MCCB Part Numbers for VLT® AutomationDrive FC 302 Enclosed Drive Models N315–N560, 525–690 V

	N315	N355	N400	N500	N560
IEC	600 A/690 V	1000 A/690 V	1000 A/690 V	1000 A/690 V	1000 A/690 V
ABB P/N	T6L630T	T7L1000LSPR23 1 DS-LS	T7L1000LSPR23 1 DS-LS	T7L1000LSPR23 1 DS-LS	T7L1000LSPR23 1 DS-LS
UL	600 A/600 V	1000 A/600 V	1000 A/600 V	1200 A/600 V	1200 A/600 V
ABB P/N	T6LQ600TW	T7L1000PR231/P	T7L1000PR231/P	T7L1200PR231/ P	T7L1200PR231/ P

Table 77: MCCB Part Numbers for VLT® AutomationDrive FC 302 Enclosed Drive Models N630–N710, 525–690 V

	N630	N710
IEC	1250 A/690 V	1250 A/690 V
ABB P/N	T7L1250LSPR23 1 DS-LS	T7L1250LSPR23 1 DS-LS
UL	1200 A/600 V	1200 A/600 V
ABB P/N	T7L1200PR231/ P	T7L1200PR231/ P

10.8 Relays

Relay 1

- Terminal 01: Common.
- Terminal 02: Normally open 240 V.
- Terminal 03: Normally closed 240 V.

Relay 2 (not FC 301/FC 302)

- Terminal 04: Common.
- Terminal 05: Normally open 400 V.
- Terminal 06: Normally closed 240 V.

More relay outputs are available by using the VLT® Relay Option Module MCB 105.

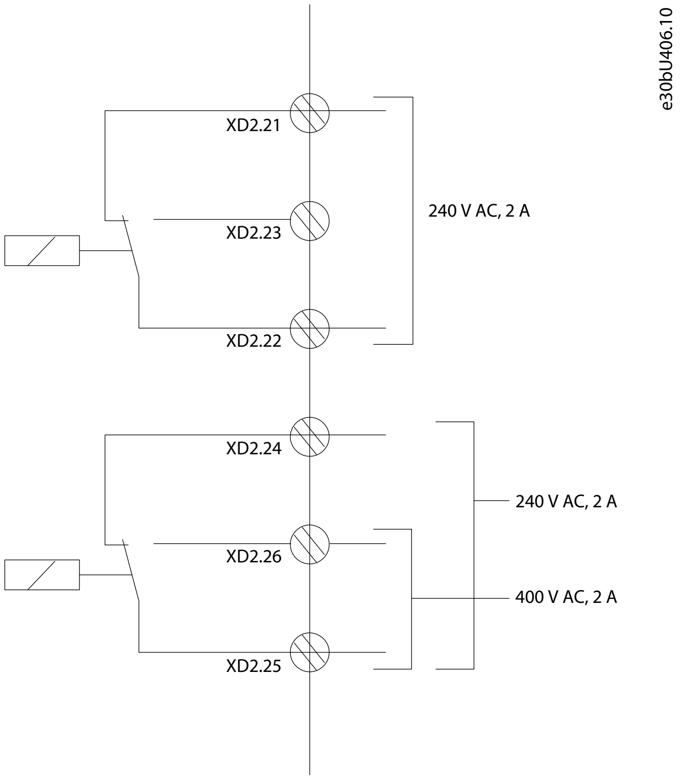


Illustration 77: Relay Output Wiring Diagram

To set the relay output, see *parameter group 5-4* Relays*.

Table 78: Description of Relays

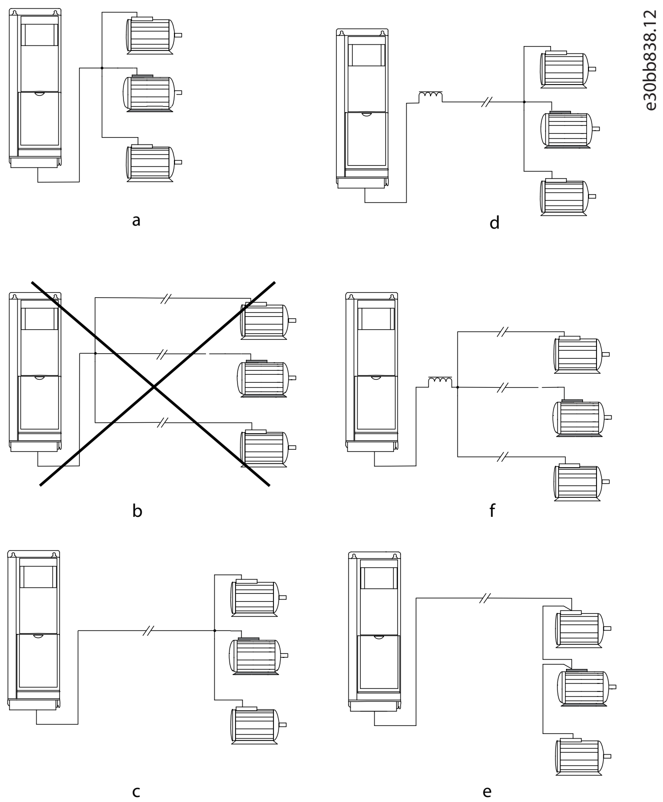
Control compartment terminals	Drive module terminals	Function
XD.22–XD.23	01-02	Make (normally open)
XD.21-XD.23	01-03	Break (normally closed)
XD.25-XD.26	04-05	Make (normally open)
XD.24-XD.26	04-06	Break (normally closed)

10.9 Motor

10.9.1 Parallel Connection of Motors

The drive can control several parallel-connected motors. When using parallel motor connection, observe the following:

- Recommended to run applications with parallel motors in U/F mode *parameter 1-01 Motor Control Principle* [0]. Set the U/F graph in *parameter 1-55 U/f Characteristic - U* and *parameter 1-56 U/f Characteristic - F*.
- VCC^{+} mode may be used in some applications.
- The total current consumption of the motors must not exceed the rated output current I_{INV} for the drive.
- If motor sizes are widely different in winding resistance, starting problems may occur due to too low motor voltage at low speed.
- The electronic thermal relay (ETR) of the drive cannot be used as motor overload protection for the individual motor. Provide further motor overload protection by including thermistors in each motor winding or individual thermal relays.



A Installations with cables connected in a common joint as shown in A and B are only recommended for short cable lengths.	**B** Be aware of the maximum motor cable length specified in the Electrical Data section.
C The total motor cable length specified in the Electrical Data section is valid as long as the parallel cables are kept short, less than 10 m (32 ft) each.	**D** Consider voltage drop across the motor cables.
E Consider voltage drop across the motor cables.	**F** The total motor cable length specified in the Electrical Data section is valid as long as the parallel cables are kept short, less than 10 m (32 ft) each.

Illustration 78: Different Parallel Connections of Motors

10.9.2 Motor Thermal Protection

The electronic thermal relay in the drive has received UL approval for single motor overload protection.

For motor thermal protection, it is also possible to use the VLT® PTC Thermistor Card MCB 112 option card. This card provides ATEX certification to protect motors in explosion hazardous areas Zone 1/21 and Zone 2/22. Combining ATEX ETR with the use of MCB 112 enables control of an Ex-e or EX-n motor in explosion hazardous ares.

Consult the Programming Guide for details on how to set up the drive for safe operation of Ex-e or Ex-n motors.

10.9.3 Motor Insulation

Modern motors for use with drives have a high degree of insulation to account for new generation high-efficiency IGBTs with high dU/dt. For retrofit in old motors, confirm the motor insulation or mitigate with dU/dt filter or, if necessary, a sine-wave filter.

For motor cable lengths less than or equal to the maximum cable length listed in the Electrical Data section, the motor insulation ratings listed in table 79 are recommended. If a motor has lower insulation rating, use a dU/dt or sine-wave filter.

Table 79: Motor Insulation Ratings

Nominal mains voltage [V]	Motor insulation [V]
$U_N \leq 420$	Standard U_{LL}=1300
420 V < $U_N \leq 500$	Reinforced U_{LL}=1600
500 V < $U_N \leq 600$	Reinforced U_{LL}=1800
600 V < $U_N \leq 690$	Reinforced U_{LL}=2000

10.9.4 Motor Bearing Currents

To minimize DE (Drive End) bearing and shaft currents, ground the drive, motor, driven machine, and motor to the driven machine properly. For more information, refer to the *Minimizing Bearing Failures in AC Drive Systems User Guide*.

Standard mitigation strategies

- Use an insulated bearing.
- Apply rigorous installation procedures:
  - Ensure that the motor and load motor are aligned.
  - Strictly follow the EMC Installation guideline.
  - Reinforce the PE so the high-frequency impedance is lower in the PE than the input power leads.
  - Provide a good high-frequency connection between the motor and the drive for instance by shielded cable which has a 360° connection in the motor and the drive.
  - Make sure that the impedance from the drive to the building ground is lower than the grounding impedance of the machine. This can be difficult for pumps.
  - Make a direct ground connection between the motor and load motor.
- Lower the IGBT switching frequency.
- Modify the inverter waveform, 60° AVM vs. SFAVM.
- Install a shaft grounding system or use an isolating coupling.
- Apply conductive lubrication.
- Use minimum speed settings if possible.
- Try to ensure that the line voltage is balanced to ground. This can be difficult for IT, TT, TN-CS, or Grounded leg systems.

10.10 Braking

10.10.1 Selection of Brake Resistor

To handle higher demands by regenerative braking, a brake resistor is necessary. Using a brake resistor ensures that the energy is absorbed in the brake resistor and not in the drive. For more information, see the VLT® Brake Resistor MCE 101 Design Guide.

If the amount of kinetic energy transferred to the resistor in each braking period is not known, the average power can be calculated based on the cycle time and braking time, also called intermittent duty cycle. The resistor intermittent duty cycle is an indication of the duty cycle at which the resistor is active. See illustration 79 for a typical braking cycle.

NOTICE

Motor suppliers often use S5 when stating the allowed load, which is an expression of intermittent duty cycle.

The intermittent duty cycle for the resistor is calculated as follows:

Duty cycle=t_b/T

T=cycle time in s.

t_b is the braking time in s (of the cycle time).

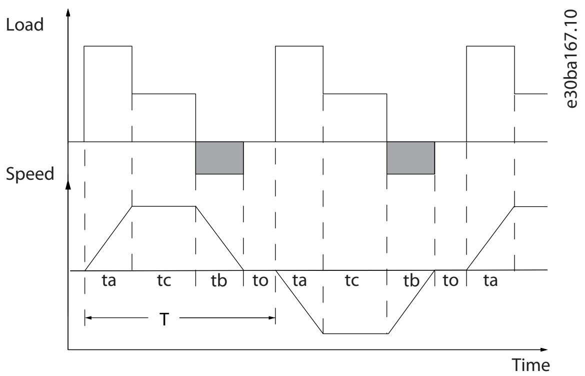


Illustration 79: Typical Braking Cycle

Brake resistors have a duty cycle of 5%, 10%, and 40%. If a 10% duty cycle is applied, the brake resistors are able to absorb brake power for 10% of the cycle time. The remaining 90% of the cycle time is spent on dissipating excess heat.

Table 80: Braking at High Overload Torque Level

	Cycle time (s)	Braking duty cycle at 100% torque	Braking duty cycle at overtorque (150/160%)
200–240 V			
PK25–P11K	120	Continuous	40%
P15K–P37K	300	10%	10%
380–500 V			
PK37–P75K	120	Continuous	40%
P90K–P160	600	Continuous	10%
P200–P800	600	40%	10%
525–600 V			
PK75–P75K	120	Continuous	40%
525–690 V			
P37K–400	600	40%	10%
P500–P560	600	40% (1)	10% (2)
P630–P1M0	600	40%	10%

[1] *500 kW at 86% braking torque/560 kW at 76% brake power.*

[2] *500 kW at 130% braking torque/560 kW at 115% brake power.*

NOTICE

Ensure that the resistor is designed to handle the required braking time.

The maximum allowed load on the brake resistor is stated as a peak power at a given intermittent duty cycle and can be calculated as:

$$R_{br}\ [\Omega] = \frac{U_{dc}^2}{P_{peak}}$$

where

$P_{peak} = P_{motor} \times M_{br}\ [\%] \times \eta_{motor} \times \eta_{VLT} [W]$

$P_{peak} = P_{motor} \times M_{br}\ [\%] \times \eta_{motor} \times \eta_{DRIVE} [W]$

The brake resistance depends on the DC-link voltage (U_{dc}).

Table 81: DC-link Voltage (UDC), FC 301/FC 302

Size [V]	Brake active [V DC]	High-voltage warning [V DC]	Overvoltage alarm [V DC]
FC 301, 3x200–240 V [1]	365	405	410
FC 301, 3x200–240 V [2]	390	405	410
FC 302, 3x200–240 V	390	405	410
FC 301, 3x380–480 [1]	728	810	820
FC 301, 3x380–480 V [2]	778	810	820
FC 302, 3x380–500 V [3]	810	840	855
FC 302, 3x380–500 V [4]	810	828	855
FC 302, 3x525–600 V [3]	943	965	975
FC 302, 3x525–300 V [4]	1099	1109	1130
FC 302, 3x525–690 V	1099	1109	1130

[1] *Enclosure size A.*

[2] *Enclosure sizes B, C*

[3] *Enclosure sizes A, B, C*

[4] *Enclosure sizes D, E, F*

NOTICE

Check that the brake resistor can handle a voltage of 4 V, or 1130 V. Danfoss brake resistors are rated for use on all Danfoss drives.

Danfoss recommends a brake resistance $R_{rec,}$ that can guarantee that the drive can brake at the highest brake power ($M_{br(\%)}$) of 150%. The formula can be written as:

$$200\,V\colon R_{\text{rec}} = \frac{107780}{P_{\text{motor}}}[\Omega]$$

$$500\,V\colon R_{\text{rec}} = \frac{464923}{P_{\text{motor}}}[\Omega]$$

$$600\,V\colon R_{\text{rec}} = \frac{630137}{P_{\text{motor}}}[\Omega]$$

$$690\,V\colon R_{\text{rec}} = \frac{832664}{P_{\text{motor}}}[\Omega]$$

NOTICE

The brake resistor circuit resistance selected should not be lower than what Danfoss recommends respecting the current limits.

NOTICE

If a higher value is selected, the brake energy is reduced accordingly to a value below 150%.

NOTICE

If a short circuit occurs in the brake transistor, power dissipation in the brake resistor is only prevented by using a mains switch or contactor to disconnect the mains from the drive. Alternatively, use a switch in the brake circuit. Uninterrupted power dissipation in the brake resistor can cause overheating, damage, or fire.

⚠ WARNING ⚠

RISK OF FIRE

The brake resistors get hot during braking. Failure to place the brake resistor in a secure area can result in property damage and/or serious injury.

- Ensure that the brake resistor is placed in a secure environment to avoid fire risk.
- Do no touch the brake resistor during or after braking to avoid serious burns.

10.10.2 Control with Brake Function

A relay/digital output can be used to protect the brake resistor against overloading or overheating by generating a fault in the drive. If the brake IGBT is overloaded or overheated, the relay/digital output signal from the drive to the brake turns off the brake IGBT. The relay/digital output signal does not protect against a short circuit in the brake IGBT or a ground fault in the brake module or wiring. If a short circuit occurs in the brake IGBT, Danfoss recommends a means to disconnect the brake.

Furthermore, the brake enables reading out the momentary power and the average power of the latest 120 s. The brake can monitor the power energizing and make sure that it does not exceed the limit selected in the brake monitor function. Consult the Operating Guide for more details.

NOTICE

Monitoring the brake power is not a safety function. A thermal switch connected to an external contactor is required for that purpose. The brake resistor circuit is not ground-leakage protected.

Overvoltage control (OVC) can be selected as an alternative brake function in parameters for overvoltage control. This function is active for all units and ensures that if the DC-link voltage increases, the output frequency also increases to limit the voltage from the DC link, which avoids a trip.

NOTICE

OVC cannot be activated when running a PM motor, while parameters for motor construction is set to PM non-salient SPM.

NOTICE

MORE REQUIREMENTS FOR BRAKING APPLICATIONS

When the motor brakes the machinery, the DC-link voltage of the drive increases. The effect of the increase equals an increase of the motor supply voltage of up to 20%. Consider this voltage increase when specifying the motor insulation requirements if the motor will be braking a large part of its operational time. **Example:** Motor insulation requirement for a 400 V AC mains voltage application must be selected as if the drive were supplied with 480 V.

10.11 Residual Current Device

Use RCD relays, multiple protective earthing, or grounding as extra protection to comply with local safety regulations. If a ground fault appears, a DC content may develop in the faulty current. If RCD relays are used, local regulations must be observed. Relays must be suitable for protection of 3-phase equipment with a bridge rectifier and for a brief discharge on power-up using RCDs.

10.12 Leakage Current

Follow national and local codes regarding protective earthing of equipment where leakage current exceeds 3.5 mA.

Drive technology implies high frequency switching at high power. This generates a leakage current in the ground connection.

The ground leakage current is made up of several contributions and depends on various system configurations, including:

- RFI filtering.
- Motor cable length.
- Motor cable shielding.
- Drive power.

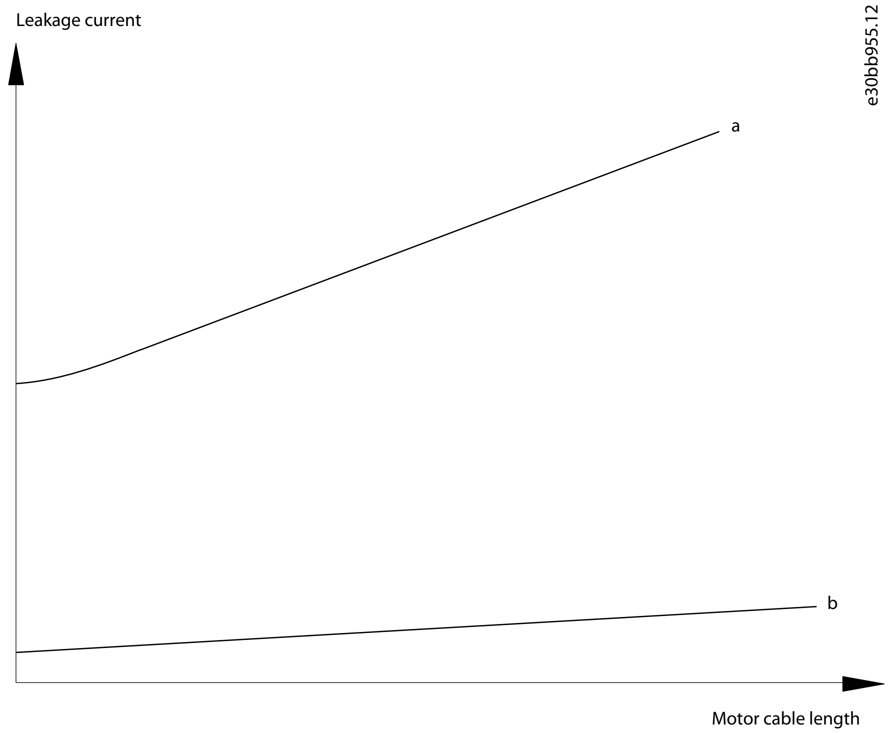


Illustration 80: Influence of the Cable Length and Power Size on Leakage Current

The leakage current also depends on the line distortion.

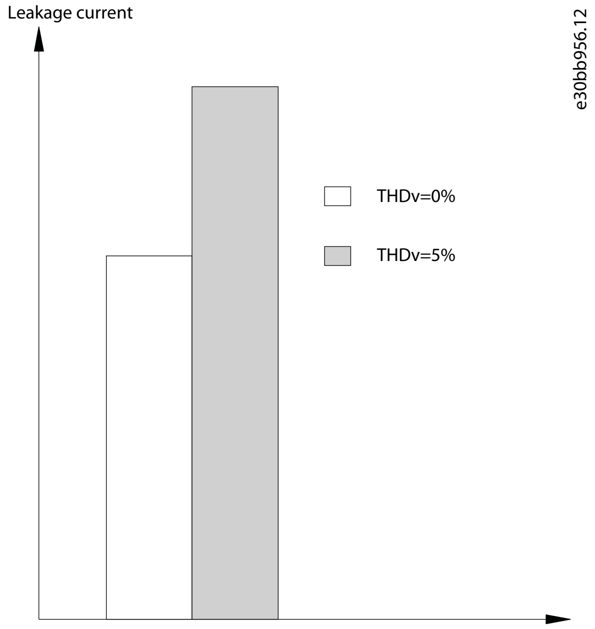


Illustration 81: Influence of Line Distortion on Leakage Current

If the leakage current exceeds 3.5 mA, compliance with EN/IEC 61800-5-1 (power drive system product standard) requires special care.

Reinforce grounding with the following protective earth connection requirements:

- Ground wire (terminal 95) of at least 10 mm^2 (8 AWG) cross-section.
- 2 separate ground wires both complying with the dimensioning rules.

See EN/IEC 61800-5-1 and EN 50178 for further information.

10.12.1 Using a Residual Current Device (RCD)

Where residual current devices (RCDs), also known as earth leakage circuit breakers (ELCBs), are used, comply with the following:

- Use RCDs of type B only, which are capable of detecting AC and DC currents.
- Use RCDs with an inrush delay to prevent faults caused by transient ground currents.
- Dimension RCDs according to the system configuration and environmental considerations.

The leakage current includes several frequencies originating from both the mains frequency and the switching frequency. Whether the switching frequency is detected depends on the type of RCD used.

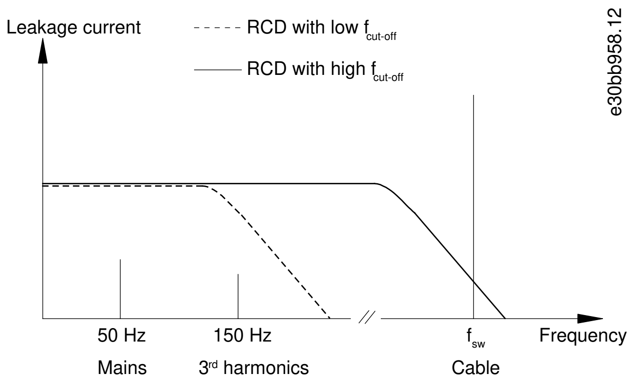


Illustration 82: Mains Contributions to Leakage Current

The amount of leakage current detected by the RCD depends on the cut-off frequency of the RCD.

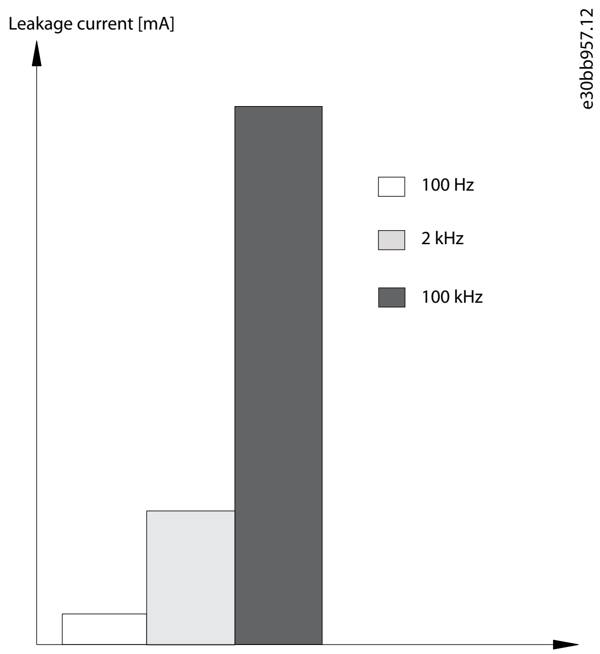


Illustration 83: Influence of Cut-off Frequency of the RCD on what is Responded to/Measured

For more details, refer to the RCD Application Note.

10.13 Efficiency

Efficiency of the drive (n)

The load on the drive has little effect on its efficiency. In general, the efficiency is the same at the rated motor frequency $f_{M,N,}$ even if the motor supplies 100% of the rated shaft torque or only 75%, for example if there are part loads. This also means that the efficiency of the drive does not change even if other U/f characteristics are selected. However, the U/f characteristics influence the efficiency of the motor. The efficiency declines a little when the switching frequency is set to a value of above 5 kHz. The efficiency is also slightly reduced if the mains voltage is 480 V, or if the motor cable is longer than 30 m (98 ft).

Drive efficiency calculation

Calculate the efficiency of the drive at different speeds and loads based on the graph in illustration 84. Multiply the factor in this graph by the specific efficiency factor listed for the drive in the Electrical Data section:

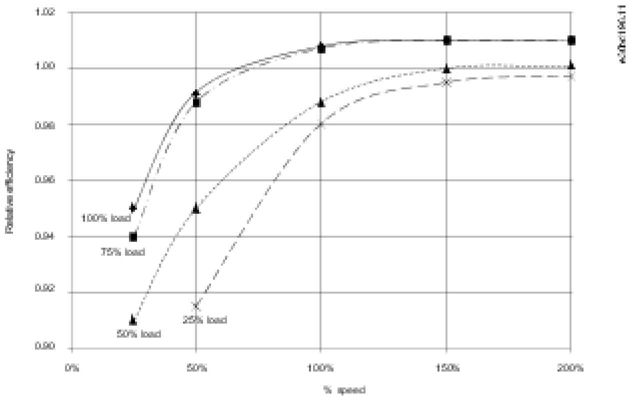


Illustration 84: Typical Efficiency Curves

Example: Assume a 160 kW, 380–480/500 V AC drive at 25% load at 50% speed. The graph shows 0.97 - the rated efficiency for a 160 kW drive is 0.98. The actual efficiency is then: 0.97x0.98=0.95.

Efficiency of the motor (η)

The efficiency of a motor connected to the drive depends on the magnetizing level. In general, the efficiency is as good as with mains operation. The efficiency of the motor depends on the type of motor. In the range of 75–100% of the rated torque, the efficiency of the motor is practically constant, both when the drive runs the motor and when it runs directly on mains. In small motors, the influence from the U/f characteristic on efficiency is marginal. However, in motors from 11 kW (15 hp) and up, the advantages are significant. Typically, the switching frequency does not affect the efficiency of small motors. Motors from 11 kW (15 hp) and up have their efficiency improved (1–2%) because the shape of the motor current sine-wave is almost perfect at high switching frequency.

Efficiency of the system (η)

To calculate the system efficiency, the efficiency of the drive (η_{VLT}) is multiplied by the efficiency of the motor (η_{MOTOR}):

$\eta_{SYSTEM} = \eta_{VLT} \times \eta_{MOTOR}$

10.14 dU/dt Conditions

To avoid damage to motors without phase insulation paper or other insulation reinforcement designed for operation of the drive, install a dU/dt filter or an LC filter on the output of the drive.

When a transistor in the inverter bridge switches, the voltage across the motor increases by a dU/dt ratio depending on:

- Motor inductance.
- Motor cable (type, cross-section, length, shielded, unshielded).

The natural induction causes an overshoot voltage peak in the motor voltage before it stabilizes. The level depends on the voltage in the DC link. Switching on the IGBTs causes peak voltage on the motor terminals. The rise time and the peak voltage affect the service life of the motor. If the peak voltage is too high, motors without phase coil insulation can be adversely affected over time. With short motor cables (a few meters), the rise time and peak voltage are lower. The rise time and peak voltage increase with cable length.

The power sizes in the dU/dt test result tables comply with the requirements of IEC 60034-17:2006 edition 4 regarding normal motors controlled by drives, IEC 60034-25:2007 edition 2.0 regarding motors designed to be controlled by drives, and NEMA MG 1-1998 Part 31.4.4.2 for inverter fed motors. The power sizes in the dU/dt test results tables do not comply with NEMA MG 1-1998 Part 30.2.2.8 for general purpose motors.

NOTICE

The measurements in the following tables done with a single power size and motor, but with several motor cable lengths, are for information only. Depending on the combination of drive, motor cable type, motor cable length, and motor, the values for U_{peak} and dU/dt can be higher at the motor terminal. Sometimes, the values exceed the limits given by the motor manufacturer.

- To avoid problems with too high dU/dt, use motor cables longer than 30–40 m (98–131 ft).
- If in doubt, use a dU/dt filter between the drive and the motor, or do a measurement in the actual installation.

10.14.1 dU/dt Test Results for Enclosures D9h/D10h

Test results for 380–500 V

Table 82: NEMA dU/dt Test Results for D9h–D10h with Unshielded Cables and No Output Filter, 380–500 V

Power size [kW (hp)]	Cable [m (ft)]	Mains voltage [V]	Rise time [µs]	Peak voltage [V]	dU/dt [V/µs]
90–132 (125–200)	30 (98)	500	0.26	1180	2109
	150 (492)	500	0.21	1423	3087
	300 (984)	500	0.56	1557	1032
160–250 (250–350)	30 (98)	500	0.63	1116	843
	150 (492)	500	0.80	1028	653
	300 (984)	500	0.71	835	651

Table 83: IEC dU/dt Test Results for D9h–D10h with Unshielded Cables and No Output Filter, 380–500 V

Power size [kW (hp)]	Cable [m (ft)]	Mains voltage [V]	Rise time [µs]	Peak voltage [V]	dU/dt [V/µs]
90–132 (125–200)	30 (98)	500	0.71	1180	1339
	150 (492)	500	0.76	1423	1497
	300 (984)	500	0.91	1557	1370
160–250 (250–350)	30 (98)	500	1.10	1116	815
	150 (492)	500	2.53	1028	321
	300 (984)	500	1.29	835	517

Table 84: NEMA dU/dt Test Results for D9h–D10h with Shielded Cables and No Output Filter, 380–500 V

Power size [kW (hp)]	Cable [m (ft)]	Mains voltage [V]	Rise time [µs]	Peak voltage [V]	dU/dt [V/µs]
90–132 (125–200)	30 (98)	500	–	–	–
	150 (492)	500	0.28	1418	2105
	300 (984)	500	0.21	1530	2450
160–250 (250–350)	30 (98)	500	–	–	–
	150 (492)	500	0.23	1261	2465
	300 (984)	500	0.96	1278	597

Table 85: IEC dU/dt Test Results for D9h–D10h with Shielded Cables and No Output Filter, 380–500 V

Power size [kW (hp)]	Cable [m (ft)]	Mains voltage [V]	Rise time [µs]	Peak voltage [V]	dU/dt [V/µs]
90–132 (125–200)	30 (98)	500	–	–	–
	150 (492)	500	0.66	1418	1725
	300 (984)	500	0.96	1530	1277
160–250 (250–350)	30 (98)	500	–	–	–
	150 (492)	500	0.56	1261	1820
	300 (984)	500	0.78	1278	1295

Test results for 525–690 V

NEMA does not provide dU/dt results for 690 V.

Table 86: IEC dU/dt Test Results for D9h–D10h with Unshielded Cables and No Output Filter, 525–690 V

Power size [kW (hp)]	Cable [m (ft)]	Mains voltage [V]	Rise time [µs]	Peak voltage [V]	dU/dt [V/µs]
55–132 (60–150)	30 (98)	690	–	–	–
	150 (492)	690	1.11	2135	1535
	300 (984)	690	1.28	2304	1433
160–315 (200–350)	30 (98)	690	–	–	–
	150 (492)	690	0.42	996	1885
	300 (984)	690	1.38	2163	1253

Table 87: IEC dU/dt Test Results for D9h–D10h with Shielded Cables and No Output Filter, 525–690 V

Power size [kW (hp)]	Cable [m (ft)]	Mains voltage [V]	Rise time [µs]	Peak voltage [V]	dU/dt [V/µs]
55–132 (60–150)	30 (98)	690	–	–	–
	150 (492)	690	1.03	2045	1590
	300 (984)	690	1.41	2132	1217
160–315 (200–350)	30 (98)	690	–	–	–
	150 (492)	690	1.00	2022	1617
	300 (984)	690	1.15	2097	1459

10.14.2 dU/dt Test Results for Enclosures E5h/E6h

Test results for 380–500 V

Table 88: NEMA dU/dt Test Results for E5h–E6h with Unshielded Cables and No Output Filter, 380–500 V

Power size [kW (hp)]	Cable [m (ft)]	Mains voltage [V]	Rise time [µs]	Peak voltage [V]	dU/dt [V/µs]
315–400 (450–550)	5 (16)	460	0.23	1038	2372
	30 (98)	460	0.72	1061	644
	150 (492)	460	0.46	1142	1160
	300 (984)	460	1.84	1244	283
450–500 (600–650)	5 (16)	460	0.42	1042	1295
	30 (98)	460	0.57	1200	820
	150 (492)	460	0.63	1110	844
	300 (984)	460	2.21	1175	239

Table 89: IEC dU/dt Test Results for E5h–E6h with Unshielded Cables and No Output Filter, 380–500 V

Power size [kW (hp)]	Cable [m (ft)]	Mains voltage [V]	Rise time [µs]	Peak voltage [V]	dU/dt [V/µs]
315–400 (450–550)	5 (16)	460	0.33	1038	2556
	30 (98)	460	1.27	1061	668
	150 (492)	460	0.84	1142	1094
	300 (984)	460	2.25	1244	443
450–500 (600–650)	5 (16)	460	0.53	1042	1569
	30 (98)	460	1.22	1200	1436
	150 (492)	460	0.90	1110	993
	300 (984)	460	2.29	1175	411

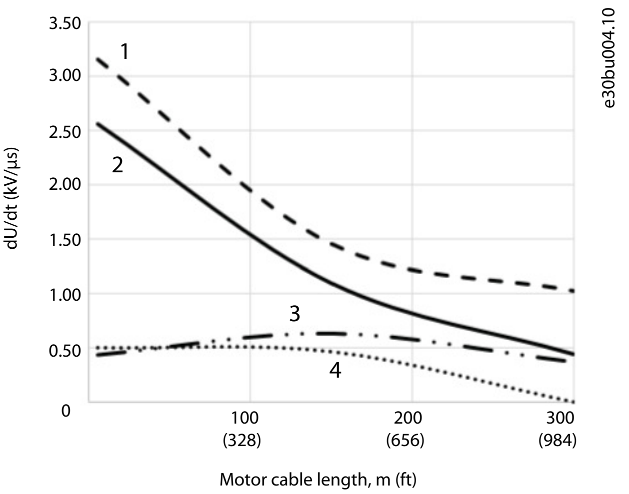
Table 90: NEMA dU/dt Test Results for E5h–E6h with Shielded Cables and No Output Filter, 380–500 V

Power size [kW (hp)]	Cable [m (ft)]	Mains voltage [V]	Rise time [µs]	Peak voltage [V]	dU/dt [V/µs]
315–400 (450–550)	5 (16)	460	0.17	1017	3176
	30 (98)	460	–	–	–
	150 (492)	460	0.41	1268	1311
450–500 (600–650)	5 (16)	460	0.17	1042	3126
	30 (98)	460	–	–	–
	150 (492)	460	0.22	1233	2356

Table 91: IEC dU/dt Test Results for E5h–E6h with Shielded Cables and No Output Filter, 380–500 V

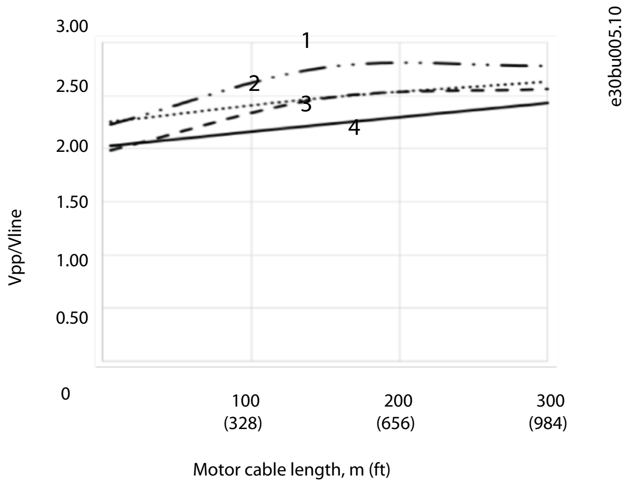
Power size [kW (hp)]	Cable [m (ft)]	Mains voltage [V]	Rise time [μs]	Peak voltage [V]	dU/dt [V/μs]
315–400 (450–550)	5 (16)	460	0.26	1017	3128
	30 (98)	460	–	–	–
	150 (492)	460	0.70	1268	1448
450–500 (600–650)	5 (16)	460	0.27	1042	3132
	30 (98)	460	–	–	–
	150 (492)	460	0.52	1233	1897

These illustrations show the typical rate of rise voltage and peak voltages at the motor terminals for both shielded and unshielded cables in various configurations. These values are true to steady state operation and at RMS input voltage range of the drive V_{line}. When the drive operates in braking mode, the intermediate DC-link voltage increases by 20%. This effect is similar to increasing the mains voltage by 20%. Consider this voltage increase when performing motor insulation analysis for braking applications.



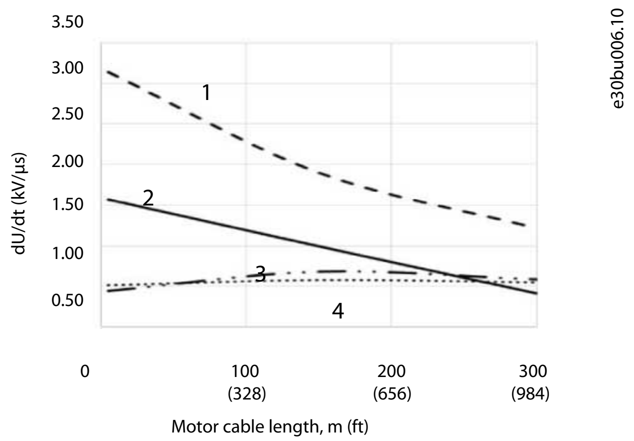
1	Unshielded cable with no filter	**2**	Shielded cable with no filter
3	Unshielded cable with dU/dt filter	**4**	Shielded cable with dU/dt filter

Illustration 85: dU/dt at Motor Terminals for Enclosures E5h, 380–500 V



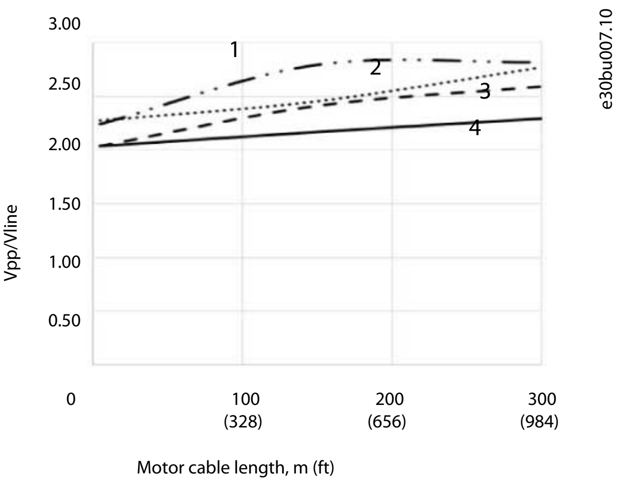
1	Unshielded cable with dU/dt filter	**2**	Shielded cable with dU/dt filter
3	Shielded cable with no filter	**4**	Unshielded cable with no filter

Illustration 86: Peak Voltages at Motor Terminals for Enclosures E5h, 380–500 V



1	Shielded cable with no filter	**2**	Unshielded cable with no filter
3	Unshielded cable with dU/dt filter	**4**	Shielded cable with dU/dt filter

Illustration 87: dU/dt at Motor Terminals for Enclosures E6h, 380–500 V



1	Unshielded cable with dU/dt filter	**2**	Shielded cable with dU/dt filter
3	Shielded cable with no filter	**4**	Unshielded cable with no filter

Illustration 88: Peak Voltages at Motor Terminals for Enclosures E6h, 380–500 V

Test results for 525–690 V

NEMA does not provide dU/dt results for 690 V.

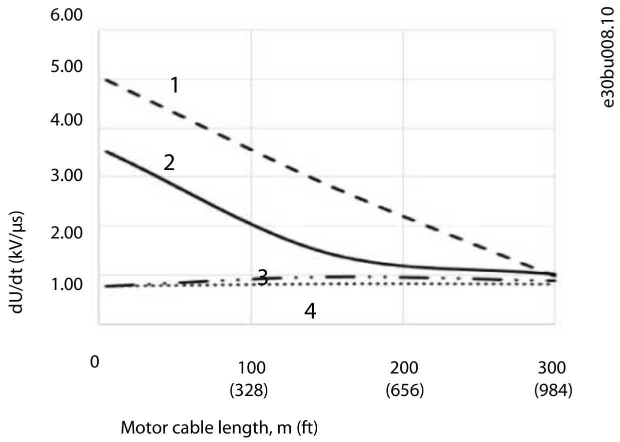
Table 92: IEC dU/dt Test Results for E5h/E6h with Unshielded Cables and No Output Filter, 525–690 V

Power size [kW (hp)]	Cable [m (ft)]	Mains voltage [V]	Rise time [µs]	Peak voltage [V]	dU/dt [V/µs]
355–560 (400–600)	30 (98)	690	0.37	1625	3494
	50 (164)	690	0.86	2030	1895
630–710 (650–750)	5 (16)	690	0.25	1212	3850
	20 (65)	690	0.33	1525	3712
	50 (164)	690	0.82	2040	1996

Table 93: IEC dU/dt Test Results for E5h/E6h with Shielded Cables and No Output Filter, 525–690 V

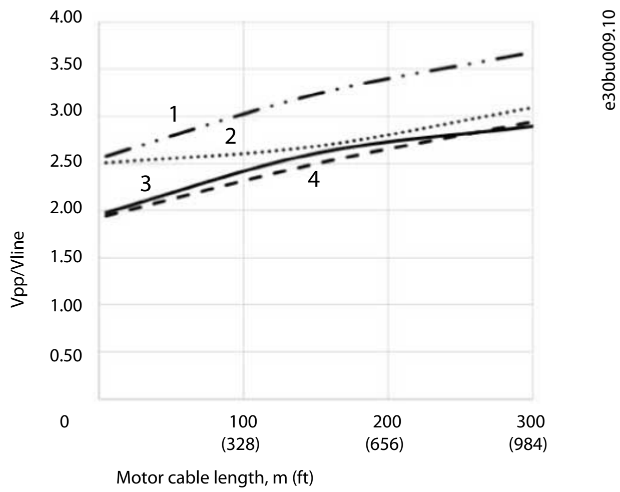
Power size [kW (hp)]	Cable [m (ft)]	Mains voltage [V]	Rise time [µs]	Peak voltage [V]	dU/dt [V/µs]
355–560 (400–600)	5 (16)	690	0.23	1450	5217
	48 (157)	690	0.38	1637	3400
	150 (492)	690	0.94	1762	1502
630–710 (650–750)	5 (16)	690	0.26	1262	3894
	48 (157)	690	0.46	1625	2826
	150 (492)	690	0.94	1710	1455

These illustrations show the typical rate of rise voltage and peak voltages at the motor terminals for both shielded and unshielded cables in various configurations. These values are true to steady state operation and at RMS input voltage range of the drive V_{line}. When the drive operates in braking mode, the intermediate DC-link voltage increases by 20%. This effect is similar to increasing the mains voltage by 20%. Consider this voltage increase when performing motor insulation analysis for braking applications.



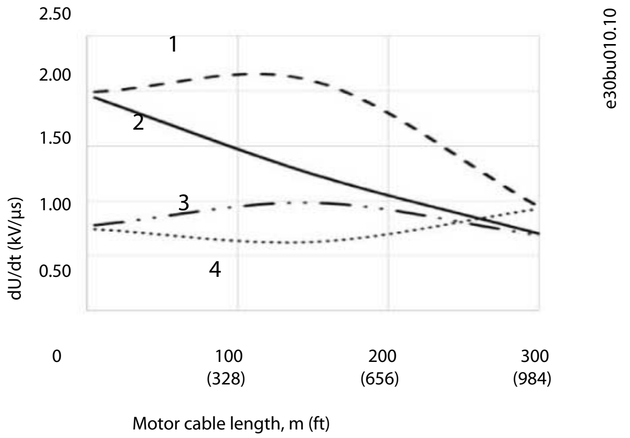
1 Unshielded cable with no filter	**2** Shielded cable with no filter
3 Unshielded cable with dU/dt filter	**4** Shielded cable with dU/dt filter

Illustration 89: dU/dt at Motor Terminals for Enclosures E5h, 525–690 V



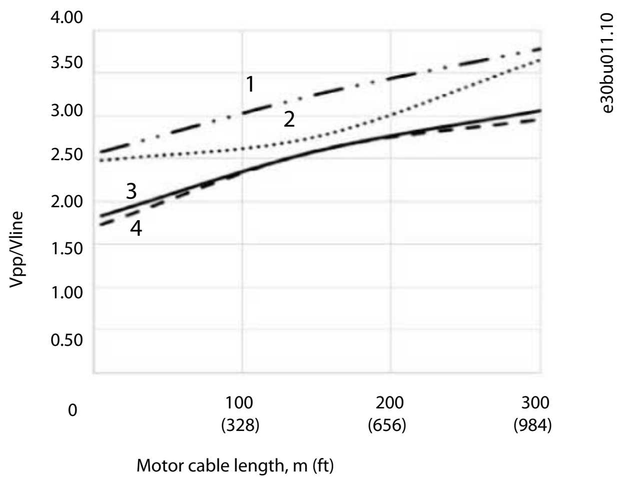
1 Unshielded cable with dU/dt filter	**2** Shielded cable with dU/dt filter
3 Shielded cable with no filter	**4** Unshielded cable with no filter

Illustration 90: Peak Voltages at Motor Terminals for Enclosures E5h, 525–690 V



1 Shielded cable with no filter	**2** Unshielded cable with no filter
3 Unshielded cable with dU/dt filter	**4** Shielded cable with dU/dt filter

Illustration 91: dU/dt at Motor Terminals for Enclosures E6h, 525–690 V



1 Unshielded cable with dU/dt filter	**2** Shielded cable with dU/dt filter
3 Shielded cable with no filter	**4** Unshielded cable with no filter

Illustration 92: Peak Voltages at Motor Terminals for Enclosures E6h, 525–690 V

10.15 Output Filters

10.15.1 Comparing Types of Output Filters

Danfoss offers 3 different output filters for the VLT® AutomationDrive FC 302 Enclosed Drive:

- Common-mode filter.
- dU/dt filter.
- Sine-wave filter.

To determine which filter is the best fit for a particular application, see table 94.

Table 94: Output Filter Comparison

Criteria	Common-mode filter	dU/dt filter	Sine-wave filter
Motor insulation stress	Does not reduce motor insulation stress.	Up to 150 m (492 ft) shielded/ unshielded cables. Complies with IEC 60034-17 [(1)]. Cable lengths longer than 150 m (492 ft) increase the risk of double pulsing.	Provides a sinusoidal phase-to-phase motor terminal voltage. Complies with EIC 60034-17 [(1)] and NEMA-MG1 requirements for general purpose motors with cables up to 1000 m (3280 ft).
Motor bearing stress	Reduces bearing currents caused by circulating currents.	Slightly reduced in high-power motors.	Partly reduces bearing stress by limiting common-mode high-frequency currents.
EMC performance	Reduces high-frequency emissions (above 1 MHz). Does not change the emission class and does not allow longer motor cables as specified for the drive's built-in RFI filter.	Eliminates motor cable ringing. Does not change the emission class and does not allow longer motor cables as specified for the drive's built-in RFI filter.	Eliminates motor cable ringing. Does not change the emission class and does not allow longer motor cables as specified for the drive's built-in RFI filter.
Maximum motor cable length	300 m (984 ft) for both shielded and unshielded cables.	With guaranteed EMC performance: 150 m (492 ft) shielded. Without guaranteed EMC performance: up to 150 m (492 ft) unshielded.	With guaranteed EMC performance: 150 m (492 ft) shielded and 300 m (984 ft) unshielded. Without guaranteed EMC performance: up to 1000 m (3280 ft).
Acoustic motor switching noise	Does not eliminate acoustic switching noise.	Does not eliminate acoustic switching noise.	Eliminates acoustic switching noise caused by magnetostriction from the motor.
Voltage drop	none	0.5%	4–10%

[1] *Not 690 V*

10.15.2 Protecting Motor Insulation

The output voltage of the drive is a series of trapezoidal pulses with a variable width (pulse width modulation) characterized by a pulse rise-time t_r. When a transistor in the inverter switches, the voltage across the motor terminal increases by a dU/dt ratio that depends on:

- the motor cable (type, cross-section, length, screened or unscreened, inductance and capacitance).
- the high frequency surge impendance of the motor.

Because of the impedance mismatch between the cable characteristic impedance and the motor surge impedance a wave reflection occurs, causing a ringing voltage overshoot at the motor terminals. Refer to illustration 93. The motor surge impedance decreases with the increase of motor size resulting in reduced mismatch with the cable impedance. The lower reflection coefficient (Γ) reduces the wave reflection and thereby the voltage overshoot. Typical values are given in table 95. In the case of parallel cables, the cable characteristic impedance is reduced, resulting in a higher reflection coefficient higher overshoot. For more information refer to IEC 61800-8.

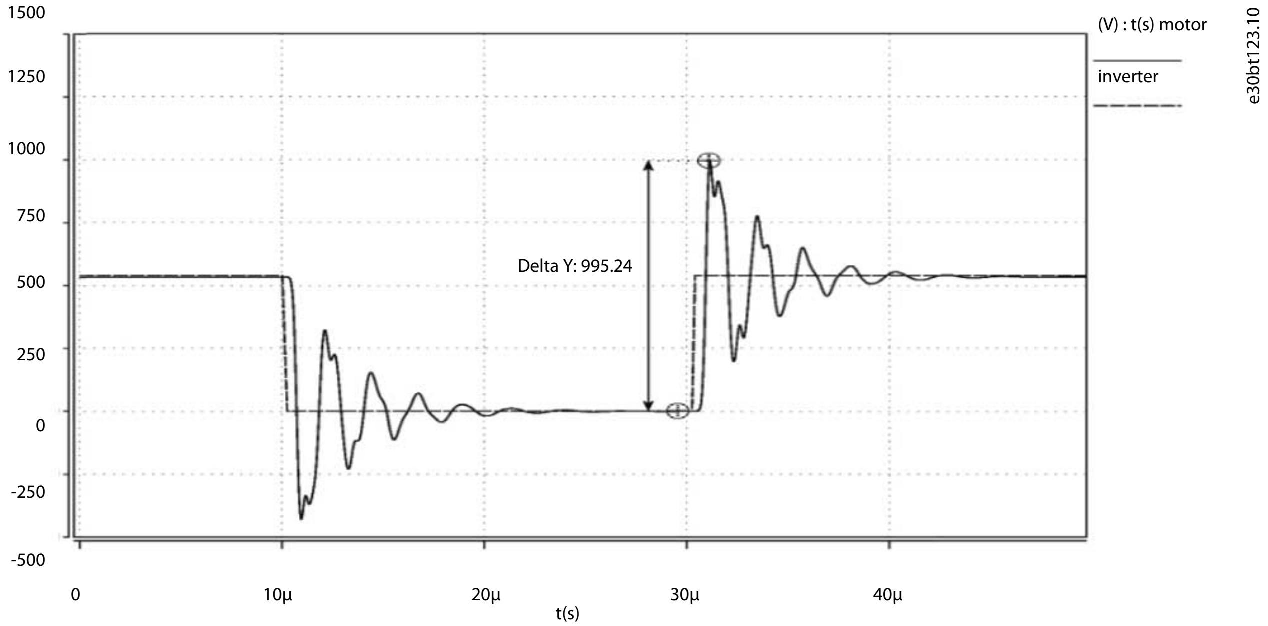


Illustration 93: Converter Output Voltage and Motor Terminal Voltage After 200 m (656 ft) of Cable

Typical values for the rise time and peak voltage U_{peak} are measured on the motor terminals between 2 phases. Two different definitions for the risetime t_r are used in practice. The international IEC standards define the rise-time as the time between 10% to 90% of the peak voltage U_{peak}. The US National Electrical Manufacturers Association (NEMA) defines the rise-time as the time between 10% and 90% of the final, settled voltage, that is equal to the DC-link voltage U_{DC}. See illustration 94 and illustration 95.

To obtain approximate values for cable lengths and voltages, use the following guidelines:

- Rise time increases with cable length.
- U_{peak} = DC-link voltage * (1 + Γ), where Γ represents the reflection coefficient.
- (IEC)

$$\mathrm{dU/dt} = \frac{0.8 * U_{\mathrm{peak}}}{t_r}$$

- (NEMA)

$$\mathrm{dU/dt} = \frac{0.8 * U_{\mathrm{peak}}}{t_r\ (\mathrm{NEMA})}$$

Table 95: Typical Values for Reflection Coefficients (IEC 61800-8)

Motor power [kW]	Zm [Ω]	Γ
<3.7	2000–5000	0.95
90	800	0.82
355	400	0.6

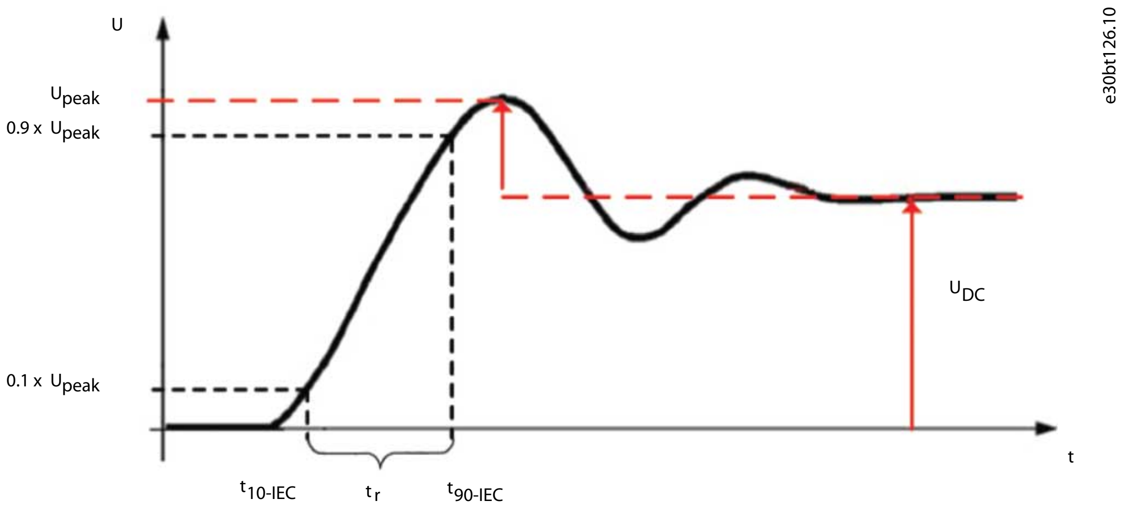


Illustration 94: IEC Definition of Risetime

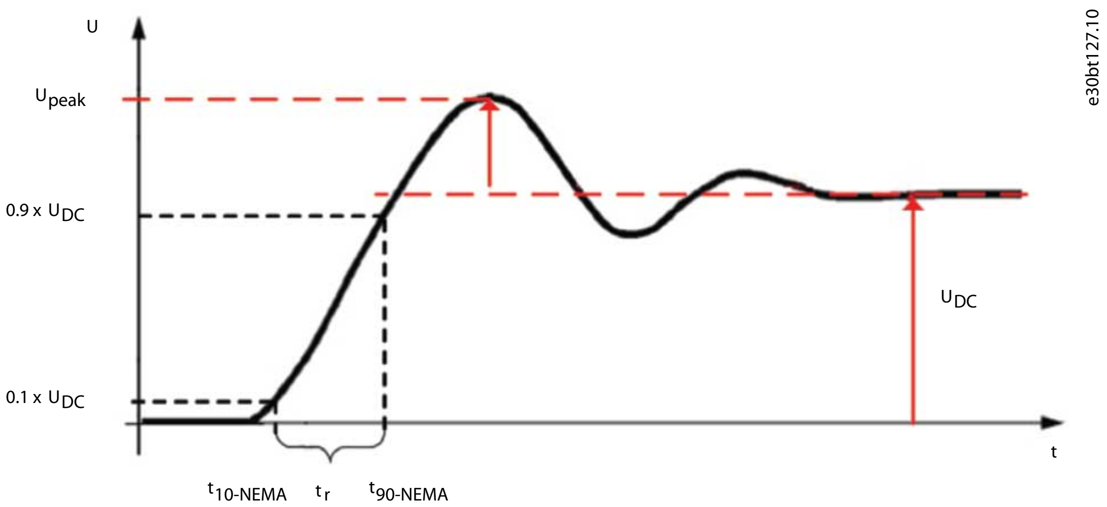


Illustration 95: NEMA Definition of Risetime

Various standards and technical specifications present limits of the admissible U_{peak} and tr for different motor types. Some of the most used limit lines are shown in illustration 96 and illustration 97.

- IEC 60034-17 – limit line for general purpose motors when fed by drives, 500 V motors.
- IEC 60034-25 – limit for converter rated motors: curve A is for 500 V motors and curve B is for 690 V motors.
- NEMA MG1 – Definite purpose inverter fed motors.

If, in an application, the resulting U_{peak} and t_r exceed the limits that apply for the motor used, use an output filter for protecting the motor insulation.

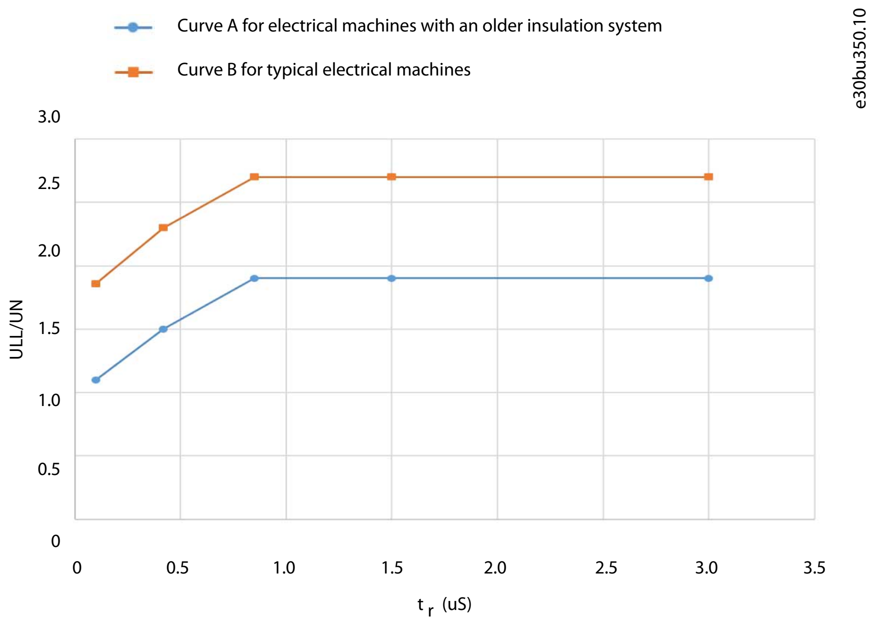


Illustration 96: IEC Limiting Curves of Impulse Voltage Between 2 Motor Phase Terminals

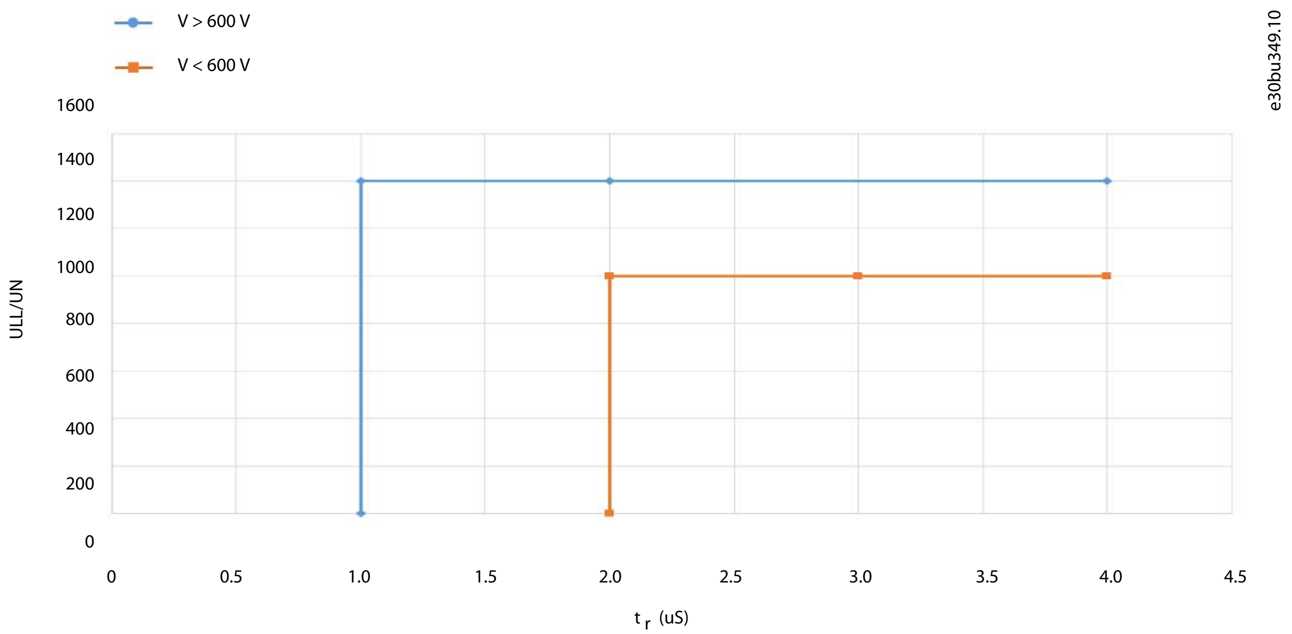


Illustration 97: NEMA Limiting Curves of Impulse Voltage Between 2 Motor Phase Terminals

10.15.3 Preventing Damage to Motor Bearings

Fast switching transistors in the drive combined with an inherent common-mode voltage (voltage between phases and ground) generate high-frequency bearing currents and shaft voltages. While bearing currents and shaft voltages can also occur in direct-on-line motors, these phenomena are accentuated when the motor is fed from a drive. Most bearing damage in motors fed by drives is caused by vibrations, misalignment, excessive axial or radial loading, improper lubrication, impurities in the grease. In some cases, bearing damage is caused by bearing currents and shaft voltages. The mechanism that causes bearing currents and shaft voltages is quite intricate and beyond the scope of this Design Guide. For more information, refer to the *Minimizing Bearing Failures in AC Drive Systems User Guide*.

Basically, 2 main mechanisms can be identified:

- Capacitive coupling: the voltage across the bearing is generated by parasitic capacitances in the motor.
- Inductive coupling: caused by circulating currents in the motor.

The grease film of a running bearing behaves like isolation. The voltage across the bearing can cause a breakdown of the grease film and produce a small electric discharge (a spark) between the bearing balls and the running track. This discharge produces a microscopic melting of the bearing ball and running track metal and in time it causes the premature wear-out of the bearing. This mechanism is called electrical discharge machining (EDM).

Common-mode filters are designed to reduce bearing damage. If using a dU/dt or sine-wave filter, Danfoss recommends using it with a common-mode filter. In addition to filters, the following methods can also be used to reduce bearing damage:

Provide a low-impedance return path.

- Follow EMC installation rules strictly. A good high frequency return path should be provided between motor and drive, for example by using shielded cables.
- Make sure that the motor is properly grounded and the grounding has a low-impedance for high frequency currents.
- Provide a good high-frequency ground connection between motor chassis and load.
- Use shaft grounding brushes.

Isolate the motor shaft from the load.

- Use isolated bearings (or at least one isolated bearing at the non-driving end NDE).
- Prevent shaft ground current by using isolated couplings.

Check mechanical components and tolerances.

- Make sure that the motor and load are properly aligned.
- Make sure the loading of the bearing (axial and radial) is within the specifications.
- Check the vibration level in the bearing.
- Check the grease in the bearing and make sure the bearing is correctly lubricated for the given operating conditions.

10.15.4 Reducing High Frequency Electromagnetic Noise in Motor Cables

When no filters are used, the ringing voltage overshoot that occurs at the motor terminals is the main high-frequency noise source. The correlation between the frequency of the voltage ringing at the motor terminals and the spectrum of the high-frequency conducted interference in the motor cable is shown in illustration 98. Besides this noise component, there are also other noise components such as:

- Common-mode voltage between phases and ground at the switching frequency and its harmonics – high amplitude but low frequency.
- High-frequency noise (above 10 MHz) caused by the switching of semiconductors - high frequency but low amplitude.

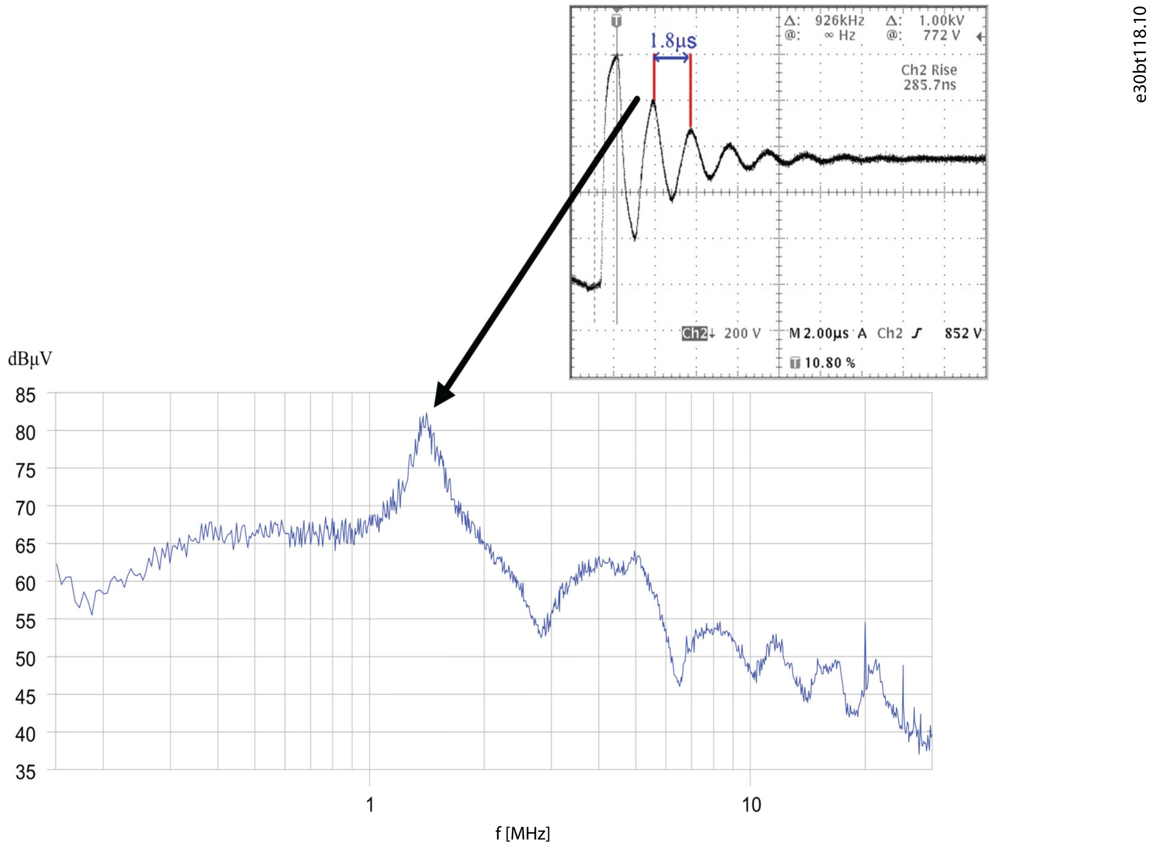


Illustration 98: Correlation Between the Frequency of the Ringing Voltage Overshoot and the Spectrum of Noise Emissions

When an output filter is installed, the following is achieved:

- In the case of dU/dt filters, the frequency of the ringing oscillation is reduced below 150 kHz.
- In the case of sine-wave filters, the ringing oscillation is eliminated and the motor is fed by a sinusoidal phase-to-phase voltage.

Remember that the other 2 noise components are still present. The use of unshielded motor cables is possible, but the layout of the installation should prevent noise coupling between the unshielded motor cable and the mains line or other sensitive cables (sensors, communication, and so on). The layout can be achieved by cable segregation and placement of the motor cable in a separate, continuous and grounded cable tray.

10.15.5 Reducing Motor Acoustic Noise

Motors generate acoustic noise from the following sources:

- Magnetic noise produced by the motor core through magnetostriction.
- Noise produced by the motor bearings.
- Noise produced by the motor ventilation.

When a motor is fed by a drive, the pulse width modulated (PWM) voltage applied to the motor introduces extra magnetic noise at the switching frequency and harmonics to the switching frequency (mainly the double of the switching frequency). To eliminate this additional switching noise, use a sine-wave filter. The sine-wave filter removes the pulse shaped voltage from the drive and provides a sinusoidal phase-to-phase voltage at the motor terminals.

10.15.6 Common-mode Filters

Common-mode filters are one of the mitigation measures to reduce bearing wear. However, they should not be used as the sole mitigation measure. Even when common-mode filters are used, the EMC-correct installation rules must be followed. These filters work by reducing the high-frequency common-mode currents that are associated with the electric discharges in the bearing. They also reduce the high-frequency emissions from the motor cable which can be used, for example, in applications with unshielded motor cables.

10.15.7 dU/dt Filters

The dU/dt filters consist of inductors and capacitors in a low-pass filter arrangement and their cut off frequency is above the nominal switching frequency of the drive. Compared to sine-wave filters they have lower L and C values, thus they are cheaper and smaller. With a dU/dt filter the voltage wave form is still pulse shaped but the current is sinusoidal – see the following illustrations. Features and benefits dU/dt filters reduce the voltage peaks and dU/dt of the pulses at the motor terminals. The dU/dt filters reduce dU/dt to approximately 500 V/µs. For specifications, see 7.7.3 dU/dt Filter Specifications.

The dU/dt filters offer the following advantages:

- Protects the motor against high dU/dt values and voltage peaks, hence prolongs motor life.
- Allows the use of motors that are not specifically designed for use with drives, such as found in retrofit applications.

Danfoss recommends using dU/dt filters in the following applications:

- Applications with frequent regenerative braking.
- Motors that are not rated for use with drives and not complying with IEC 600034-25.
- Motors placed in aggressive environments or running at high temperatures.
- Applications with risk of flash over.
- Installations using old motors (retrofit) or general purpose motors not complying with IEC 600034-17.
- Applications with motor cables less than 15 m (49 ft).
- 690 V applications.

The following section provides examples of voltage and current with and without a dU/dt filter.

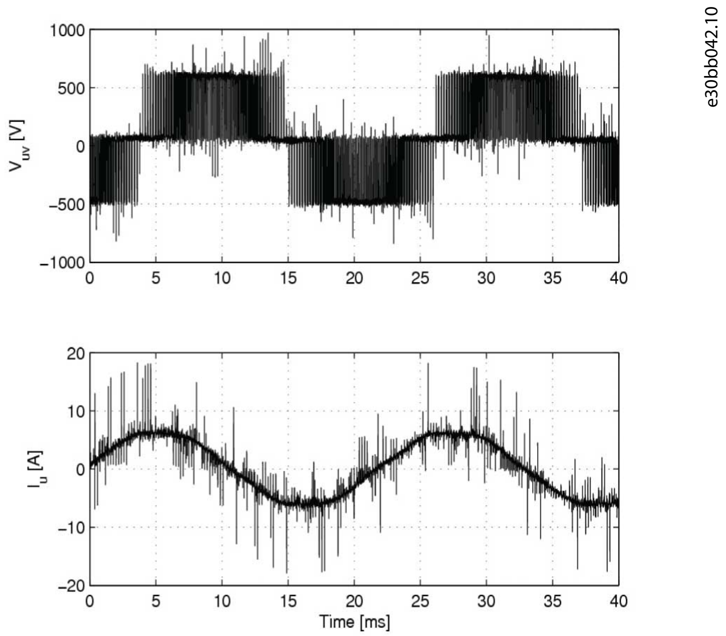


Illustration 99: Voltage and Current without a dU/dt Filter

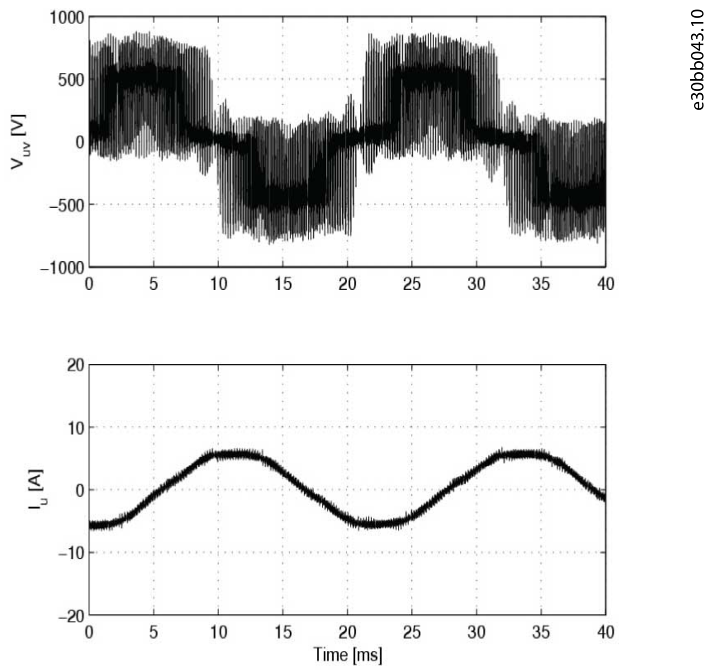


Illustration 100: Voltage and Current with a dU/dt Filter

The U_{peak} value depends on the U_{DC} from the LHD-P and as U_{DC} increases during motor braking (generative) U_{peak} can increase to values above the limits of IEC 60034-17 and thereby stress the motor insulation. Danfoss therefore recommends dU/dt filters in applications with frequent braking. As the cable length increases, the cable capacitance rises and the cable behaves like a low-pass filter. That means longer rise-time t_r for longer cables. Therefore it is recommended to use dU/dt filters only in applications with cable lengths up to 150 m (492 ft). Above 150 m (492 ft), dU/dt filters have no effect. If further reduction is needed, use a sine-wave filter.

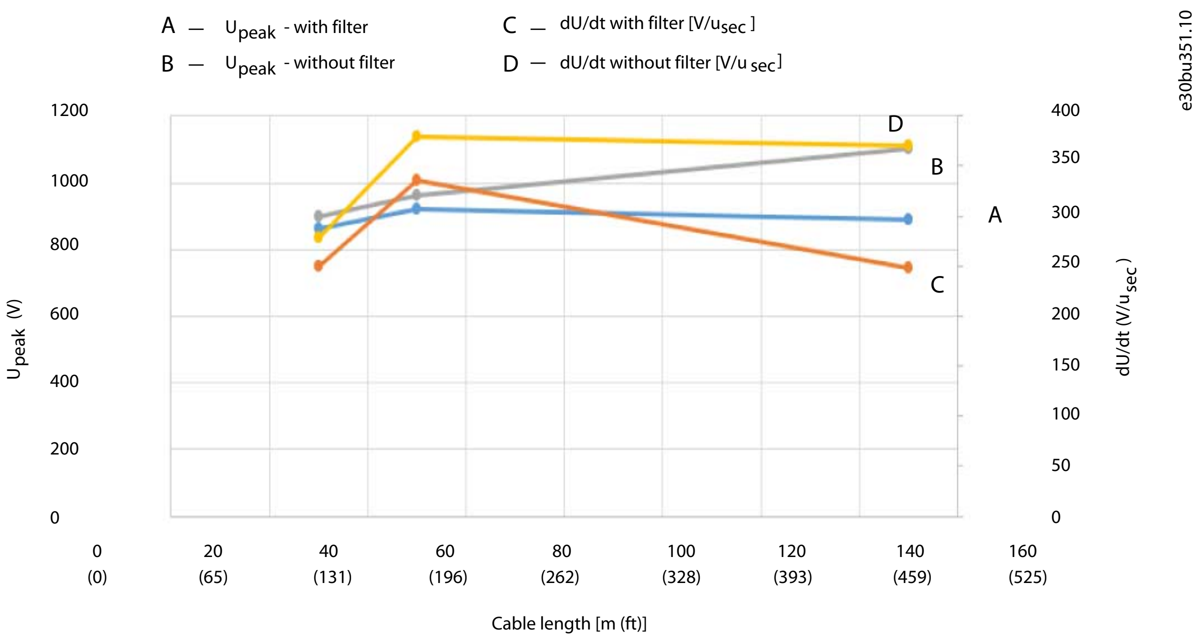


Illustration 101: 500 V with and without a dU/dt Filter

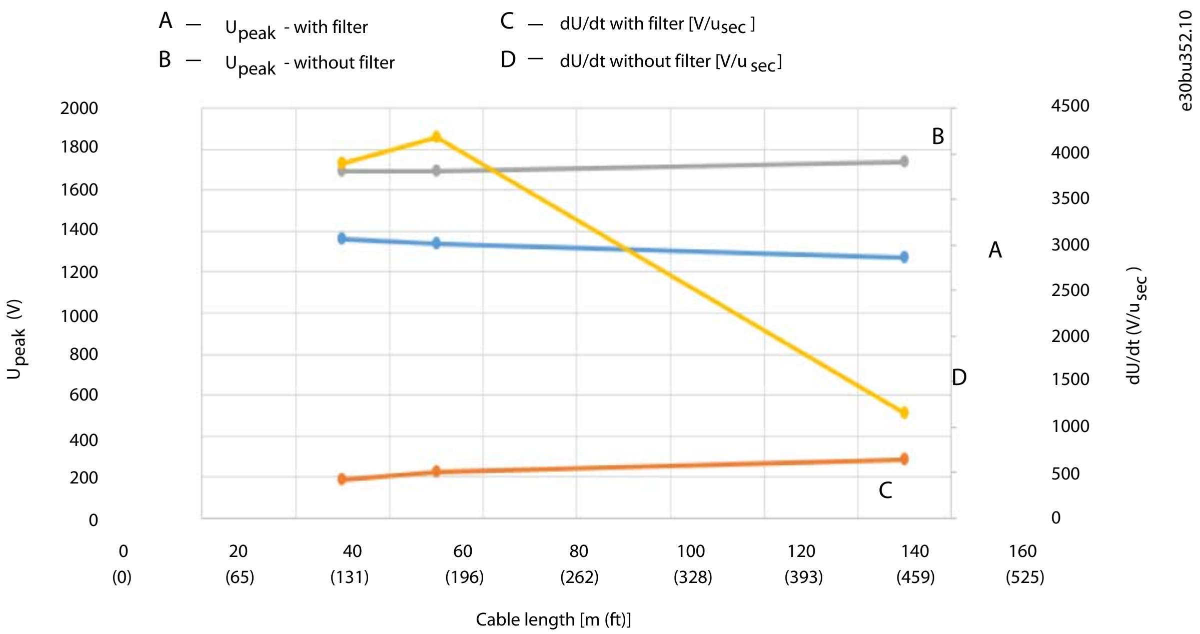


Illustration 102: 690 V with and without a dU/dt Filter

The U_{peak} and rise time behaves as a function of the motor cable length, as shown in illustration 101 and illustration 102. In installations with short motor cables, the rise time is short which causes high dU/dt values. The high dU/dt can cause a damaging high potential difference between the windings in the motor that can lead to breakdown of the insulation and flash-over. Danfoss recommends dU/dt filters in applications with motor cable lengths shorter than 15 m (49 ft).

Table 96: dU/dt Values for the N250 Model, 380–500 V

Cable length [m (ft)]	Mains voltage [V]	Rise time [us]	U_{peak} [KV]	dU/dt [V/us]
30 (98)	500	2.58	0.9	279.1
50 (164)	500	2.00	0.96	379.4
150 (492)	500	2.43	1.1	370.5

Table 97: dU/dt Values for the N315 Model, 525–690 V

Cable length [m (ft)]	Mains voltage [V]	Rise time [us]	U_{peak} [KV]	dU/dt [V/us]
30 (98)	690	2.58	1.36	420
50 (164)	690	2.09	1.34	500
150 (492)	690	1.79	1.27	640

10.15.8 Sine-wave Filters

Sine-wave filters consist of inductors and capacitors in a low-pass filter arrangement, and are designed to let only low frequencies pass. High frequencies are consequently shunted away, resulting in a sinusoidal phase to phase voltage waveform and sinusoidal current waveforms. With the sinusoidal waveforms, drive motors with reinforced insulation are no longer needed. The acoustic noise from the motor is also damped as a consequence of the sinusoidal wave condition. Also, the sine-wave filter reduces insulation stress and bearing currents in the motor, leading to prolonged motor lifetime and longer service intervals. Sine-wave filters allow longer motor cables. Since the filter does not act between motor phases and ground, it does not reduce leakage currents in the cables. For specifications, see . 7.7.4 Sine-wave Filter Specifications.

Danfoss recommends sine-wave filters for the following applications:

- Applications with frequent regenerative braking.
- Motors that are not rated for use with drives and not complying with IEC 600034-25.
- Motors placed in aggressive environments or running at high temperatures.
- Applications where the acoustic switching noise from the motor must be eliminated.
- Installations using old motors (retrofit) or general purpose motors not complying with IEC 600034-17.
- Applications with motor cables between 150–300 m (492–984 ft). The use of motor cables longer than 300 m (984 ft) depends on the specific application.
- Applications where there is a longer service interval for the motor.
- Step-up applications where the drive feeds a transformer.
- 690 V applications.

The following section provides examples of scenarios with and without a sine-wave filter.

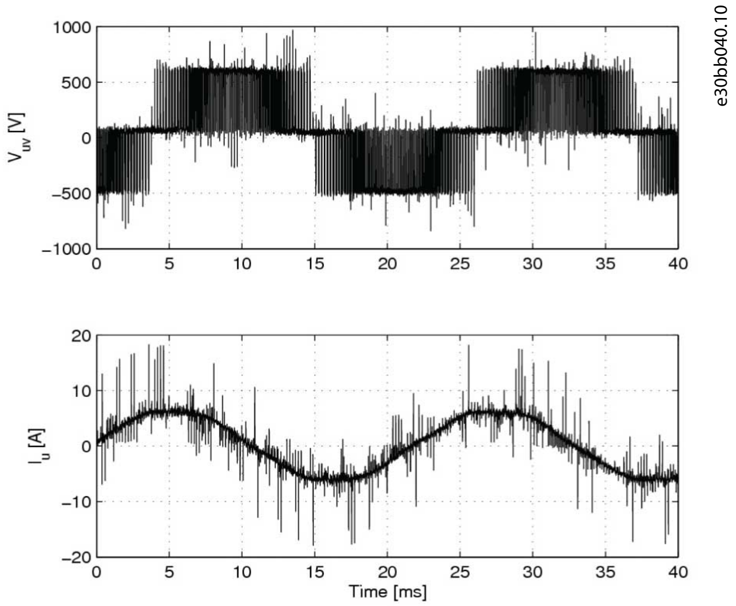


Illustration 103: Voltage and Current without a Sine-wave Filter

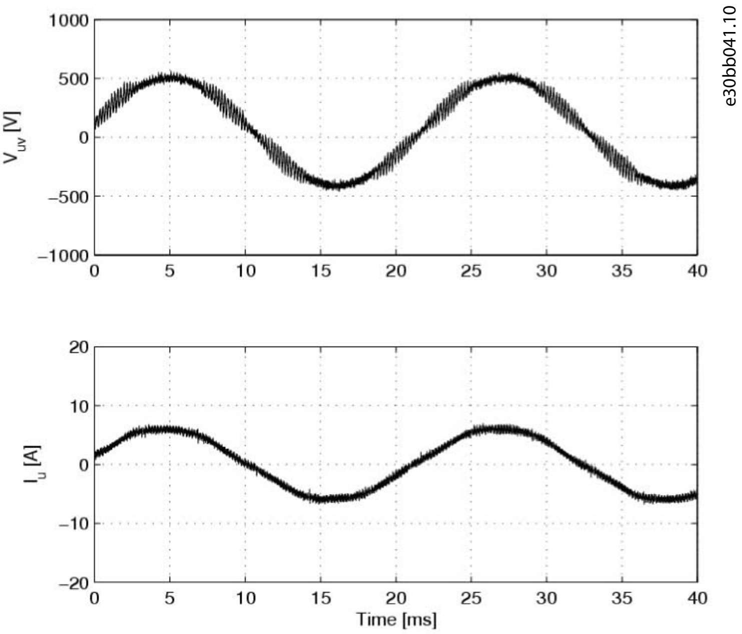


Illustration 104: Voltage and Current with a Sine-wave Filter

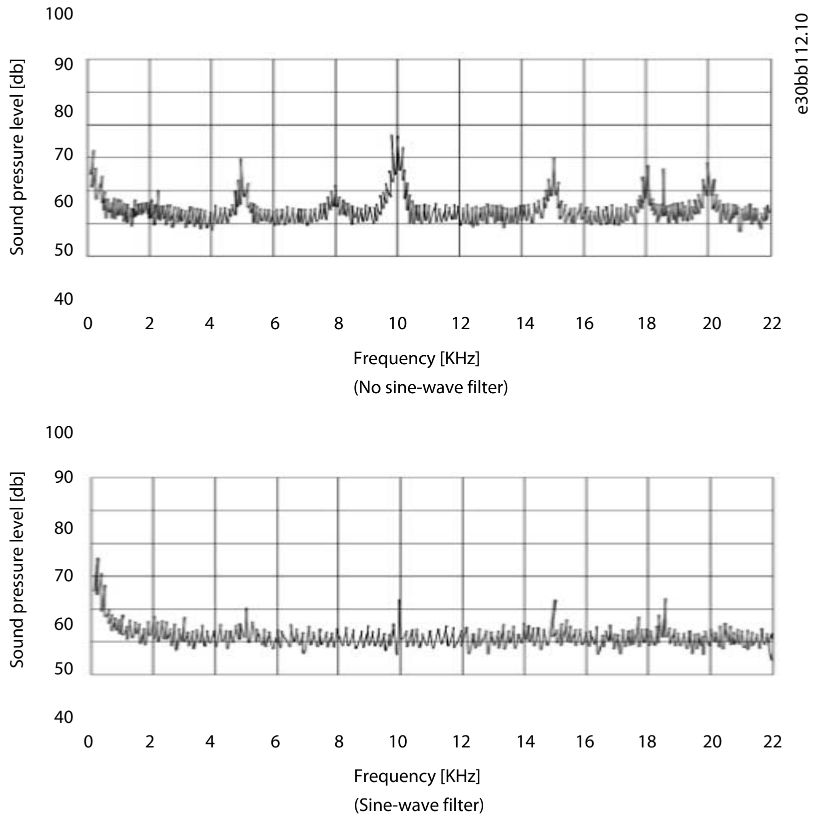


Illustration 105: Relative Motor Sound Pressure Level Measurements with and without a Sine-wave Filter

10.16 Harmonics Overview

10.16.1 Harmonics Analysis

Since harmonics increase heat losses, it is important to consider harmonics when designing systems to prevent overloading the transformer, the inductors, and the wiring. When necessary, perform an analysis of the system harmonics to determine equipment effects.

A non-sinusoidal current is transformed with a Fourier series analysis into sine-ware currents at different frequencies, that is, different harmonic currents I_N with 50 Hz or 60 Hz as the basic frequency.

Table 98: Harmonics-related Abbreviations

Abbreviation	Description
f_1	Basic frequency (50 Hz or 60 Hz)
I_1	Current at the basic frequency
U_1	Voltage at the basic frequency
I_n	Current at the n^{th} harmonic frequency
U_n	Voltage at the n^{th} harmonic frequency
n	Harmonic order

Table 99: Basic Currents and Harmonic Currents

	Basic current (I_1)	Harmonic current (I_n)		
Current	I_1	I_5	I_7	I_{11}
Frequency [Hz]	50	250	350	550

Table 100: Harmonic Currents versus RMS Input Current

Current	Harmonic current				
	I_{RMS}	I_1	I_5	I_7	I_{11-49}
Input current	1.0	0.9	0.5	0.2	<0.1

The voltage distortion on the mains supply voltage depends on the size of the harmonic currents multiplied by the mains impedance for the frequency in question. The total voltage distortion (THDi) is calculated based on the individual voltage harmonics using this formula:

$$\text{THDi} = \frac{\sqrt{I_5^2 + I_7^2 + \ldots\ldots I_n^2}}{I}$$

10.16.2 Harmonic Calculation

To determine the degree of voltage pollution on the grid and needed precaution, use the Danfoss MCT31 calculation software. The free VLT® Harmonic Calculation MCT 31 tool can be downloaded from www.danfoss.com. The software is built with a focus on user-friendliness and is limited to involve only system parameters that are normally accessible.

Also available is the online software tool Danfoss HCS, which can be found at www.danfoss-hcs.com.

10.16.3 Linear Loads

On a sinusoidal AC supply, a purely resistive load, such as an incandescent light bulb, draws a sinusoidal current in phase with the supply voltage. The power dissipated by the load is:

P = U * I

For reactive loads, such as an induction motor, the current is no longer in phase with the voltage, but lags the voltage creating a lagging true power factor with a value less than 1. In the case of capacitive loads, the current is in advance of the voltage, creating a leading true power factor with a value less than 1.

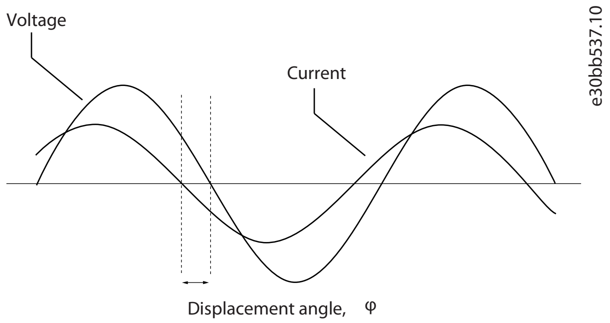


Illustration 106: Sinusoidal Current

In this case, the AC power has 3 components: real power (P), reactive power (Q), and apparent power (S). The apparent power is:

S = U * I,

where S = [kVA], P = [kW], and Q = [kVAR]

In the case of a perfectly sinusoidal waveform P, Q, and S can be expressed as vectors that form a triangle:

$S^2 = P^2 + Q^2$

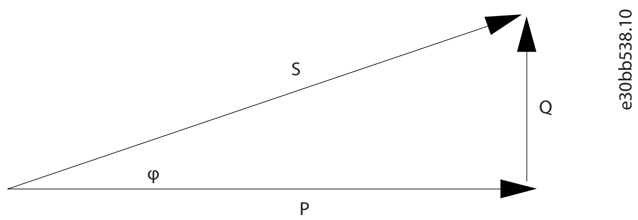


Illustration 107: Sinusoidal Current Expressed as Vectors

The displacement angle between current and voltage is φ. The displacement power factor is the ratio between the active power (P) and apparent power (S):

$$\mathrm{DPF} = \frac{P}{S} = \cos\Phi$$

10.16.4 Non-linear Loads

Non-linear loads (such as diode rectifiers) draw a non-sinusoidal current. The current drawn by a 6-pulse rectifier on a 3-phase supply is shown in illustration 108. A non-sinusoidal waveform can be decomposed in a sum of sinusoidal waveforms with periods equal to integer multiples of the fundamental waveform.

$f(t) = \Sigma a_h * \sin(h * \omega_1 * t)$

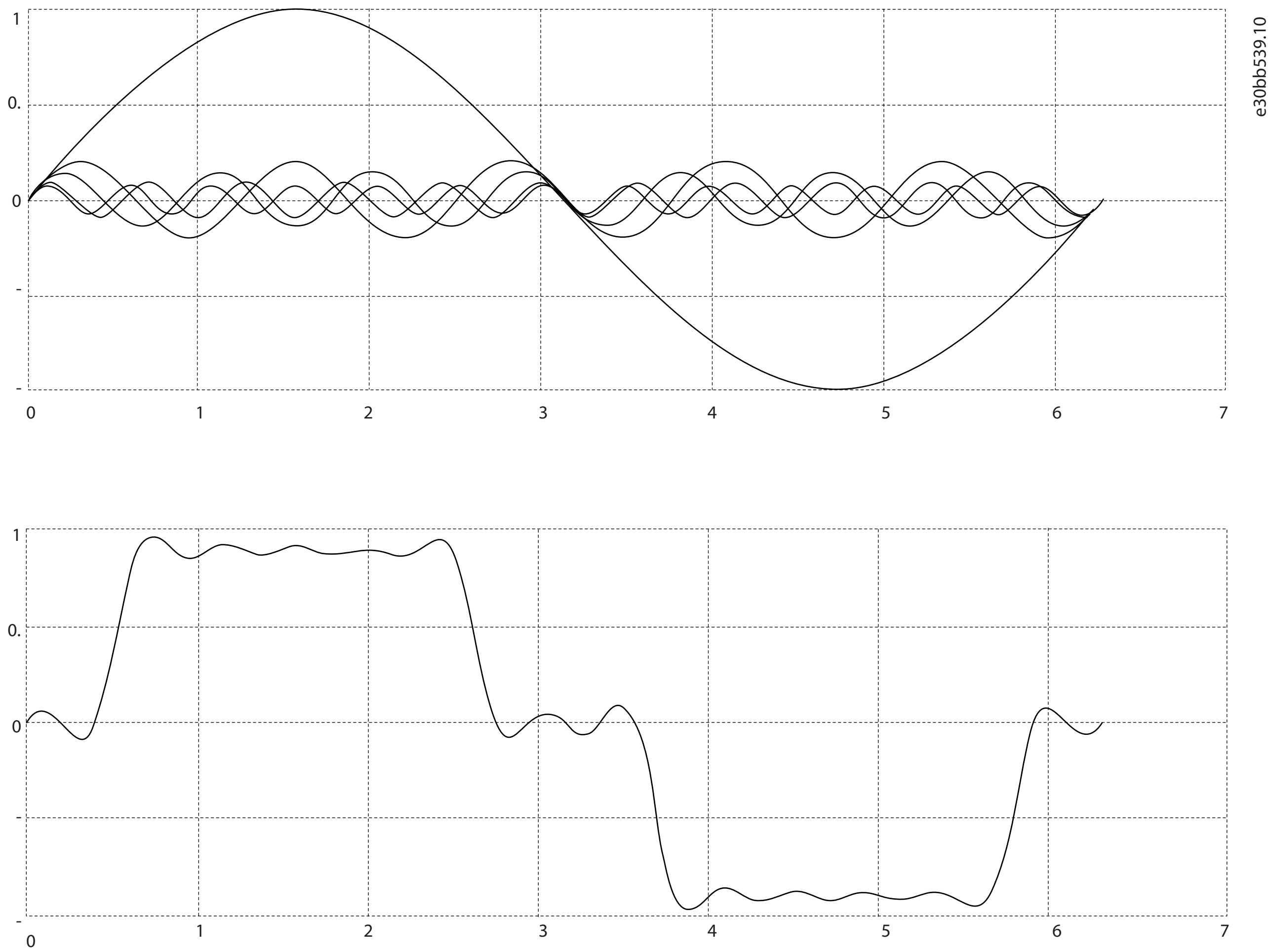


Illustration 108: Non-sinusoidal Current

The integer multiples of the fundamental frequency ω_1 are called harmonics. The RMS value of a non-sinusoidal waveform (current or voltage) is expressed as:

$$I_{\text{RMS}} = \sqrt{\sum_{h=1}^{h_{\max}} I_h^2}$$

The amount of harmonics in a waveform gives the distortion factor, or total harmonic distortion (THD), represented by the ratio of RMS of the harmonic content to the RMS value of the fundamental quantity, expressed as a percentage of the fundamental:

$$\text{THD} = \sqrt{\sum_{h=2}^{h_{\max}} \left(\frac{I_h}{I_1}\right)^2} * 100\,\%$$

Using the THD, the relationship between the RMS current IRMS and the fundamental current I1 can be expressed as:

$$I_{\text{RMS}} = I_1 * \sqrt{1 + \text{THD}^2}$$

The same applies for voltage. The true power factor PF (λ) is:

$$\text{PF} = \frac{P}{S}$$

In a linear system the true power factor is equal to the displacement power factor:

PF = DPF = cos (ϕ)

In non-linear systems the relationship between true power factor and displacement power factor is:

$$\mathrm{PF} = \frac{\mathrm{DPF}}{\sqrt{1+\mathrm{THD}^2}}$$

The power factor is decreased by reactive power and harmonic loads. Low power factor results in a high RMS current that produces higher losses in the supply cables and transformers. In the power quality context, the total demand distortion (TDD) term is often encountered. The TDD does not characterize the load, but it is a system parameter. TDD expresses the current harmonic distortion in percentage of the maximum demand current I_L.

$$\mathrm{TDD} = \sqrt{\sum_{h=2}^{h_{\max}} \left(\frac{I_h}{I_L}\right)^2} * 100\,\%$$

Another term often encountered in literature is the partial weighted harmonic distortion (PWHD). PWHD represents a weighted harmonic distortion that contains only the harmonics between the 14th and the 40th, as shown in the following definition.

$$\mathrm{PWHD} = \sqrt{\sum_{h=14}^{40} \left(\frac{I_h}{I_1}\right)^2} * 100\,\%$$

10.16.5 Effect of Harmonics in a Power Distribution System

In illustration 109, a transformer is connected on the primary side to a point of common coupling PCC1 on the medium voltage supply. The transformer has an impedance Z_{xfr} and feeds several loads. The point of common coupling where all loads are connected together is PCC2. Each load is connected through cables that have an impedance Z_1, Z_2, Z_3.

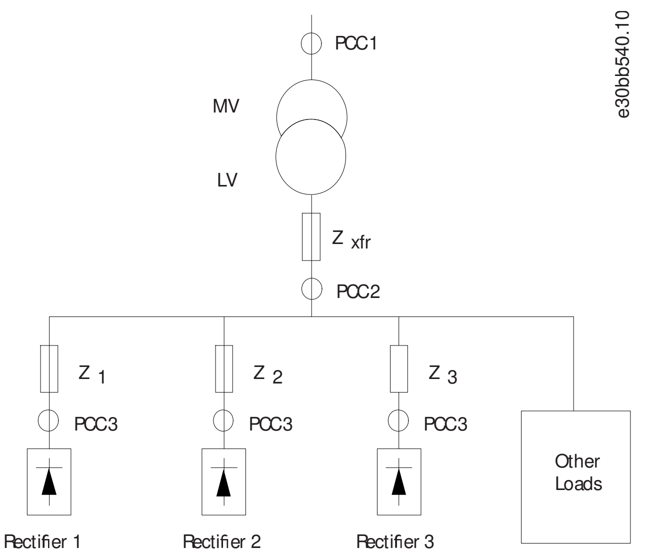


Illustration 109: Small Distribution System

Harmonic currents drawn by non-linear loads cause distortion of the voltage because of the voltage drop on the impedances of the distribution system. Higher impedances result in higher levels of voltage distortion.

Current distortion relates to apparatus performance and it relates to the individual load. Voltage distortion relates to system performance. It is not possible to determine the voltage distortion in the PCC knowing only the load's harmonic performance. To predict the distortion in the PCC, the configuration of the distribution system and relevant impedances must be known.

A commonly used term for describing the impedance of a grid is the short circuit ratio R_{sce}. R_{sce} is defined as the ratio between the short circuit apparent power of the supply at the PCC (S_{sc}) and the rated apparent power of the load (S_{equ}).

$$R_{\mathrm{sce}} = \frac{S_{\mathrm{ce}}}{S_{\mathrm{equ}}}$$

where

$$S_{\mathrm{sc}} = \frac{U^2}{Z_{\mathrm{supply}}} \text{ and } S_{\mathrm{equ}} = U * I_{\mathrm{equ}}$$

The negative effect of harmonics is twofold

- Harmonic currents contribute to system losses (in cabling, transformer).
- Harmonic voltage distortion causes disturbance to other loads and increase losses in other loads.

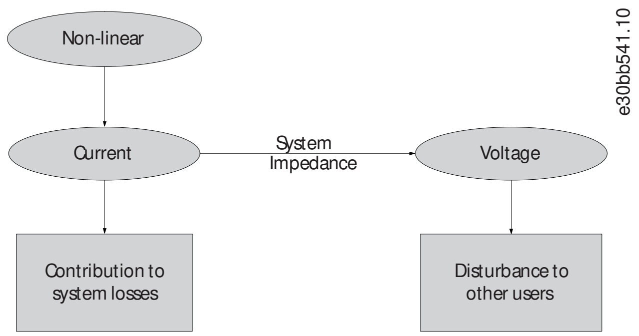


Illustration 110: Negative Effects of Harmonics

10.16.6 Operating Principle of an Enclosed Drive with a Passive Harmonic Filter

The VLT® AutomationDrive FC 302 Enclosed Drive with the optional passive harmonic filter (PHF) consists of a main inductor L0 and a 2-stage absorption circuit with the inductors L1/L2 and the capacitors C1/C2. The absorption circuit is specially tuned to eliminate harmonics starting with the 5th harmonic and is specific for the designed supply frequency. Consequently the circuit for 50 Hz has different parameters than the circuit for 60 Hz.

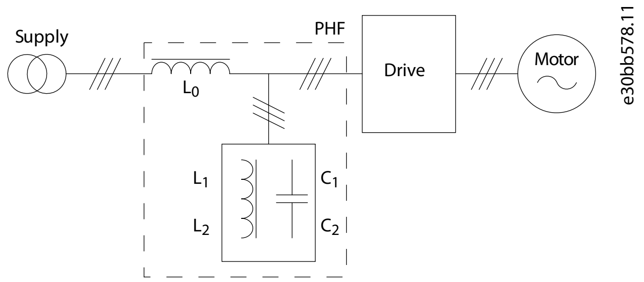


Illustration 111: Simplified Block Diagram of an Enclosed Drive with the PHF Option

There are 2 PHF options for the enclosed drive:

- PHF005 with 5% THDi (total current harmonic distortion).
- PHF008 with 8% THDi.

These options offer better performance than 12-pulse rectifiers (PHF008) and 18-pulse rectifiers (PHF005).The filter performance in terms of THDi varies as a function of the load. At nominal load the performance of the filter should be equal or better than 8% THDi for PHF008 and 5% THDi for PHF005.

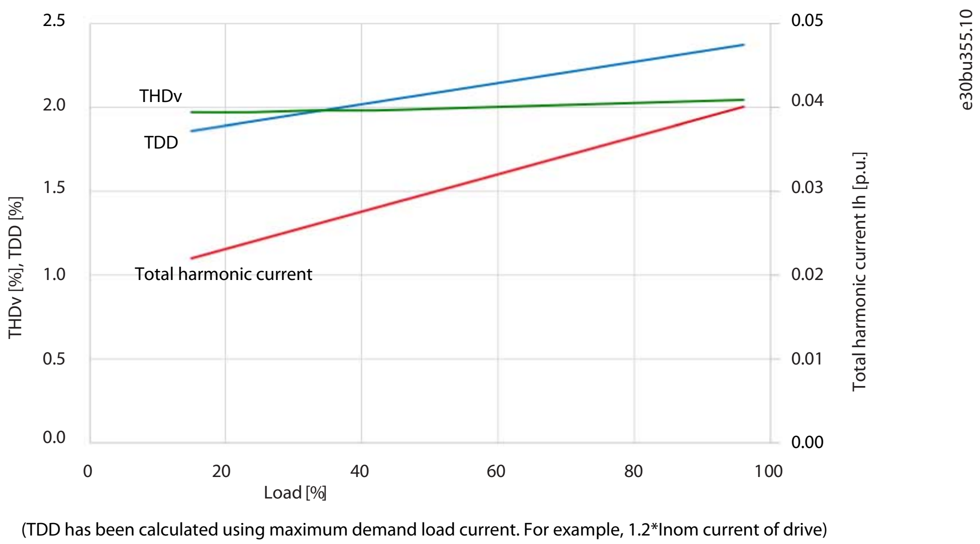


Illustration 112: Expected Variation of TDD, THDv, and Total Harmonic Current versus Load in an Enclosed Drive with the PHF Option

The design of the filters aims to achieve 8% respectively 5% THDi levels with a background distortion of THDv = 2%. Practical measurements on typical grid conditions in installations with drives show that often the performance of the filter is slightly better with a 2% background distortion. However, the complexity of the grid conditions and mix of specific harmonics cannot allow a general rule about the performance on a distorted grid. Therefore we have chosen to present worst-case performance deterioration characteristics with the background distortion.

The graphs in illustration 113 – illustration 114 are measured at a specific grid with a short circuit ratio Isc/IL <20. The Isc/IL is the ratio of the short-circuit available at the point of common coupling (PCC) to the maximum fundamental load current.

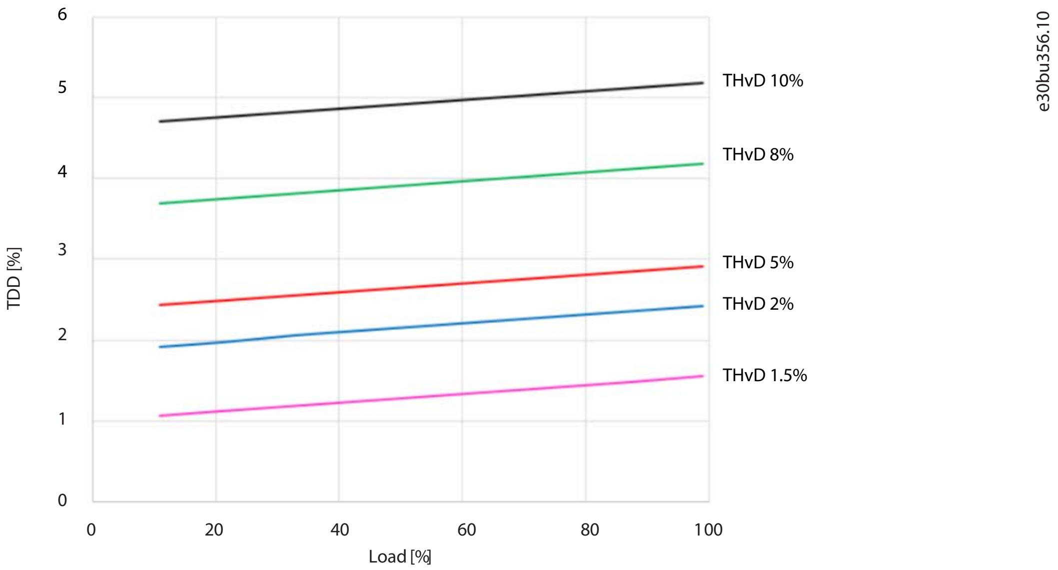


Illustration 113: TDD at Different Voltage Predistortion on an Enclosed Drive with the PHF Option

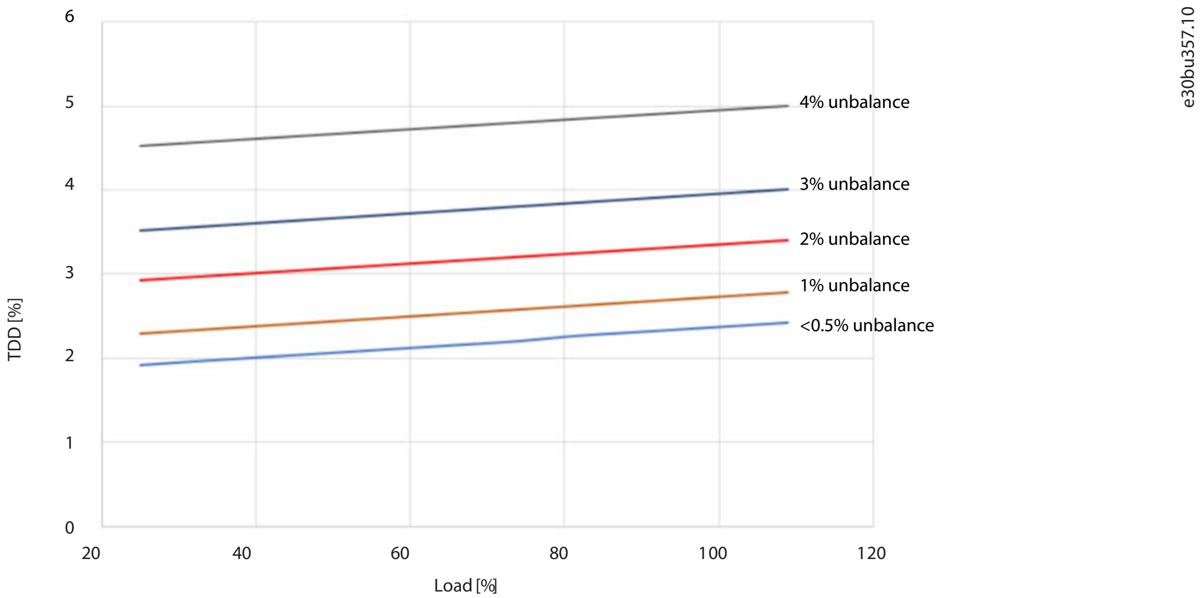


Illustration 114: TDD at Different Voltage Unbalance for the Enclosed Drive with PHF Option, 380–500 V

The filters have been tested and can operate at 8% and 10% THDv but the filter performance can no longer be guaranteed. The filter performance also deteriorates with the unbalance of the supply.

10.16.6.1 Power Factor

In no load conditions where the drive is in stand-by, the drive current is negligible and the main current drawn from the grid is the current through the capacitors in the passive harmonic filter. Therefore the power factor is close to 0 capacitive. Depending on the filter size, the capacitive current is approximately 25% of the filter nominal current. Typical values are 20–25%. The power factor increases with the load. Because of the higher value of the main inductor L0 in the PHF005, the power factor is slightly higher than in the PHF008. The graphs in illustration 115 – illustration 118 show typical values for the true power factor on PHF005 (500 V). The graphs were measured when the PHF capacitor contactor was closed.

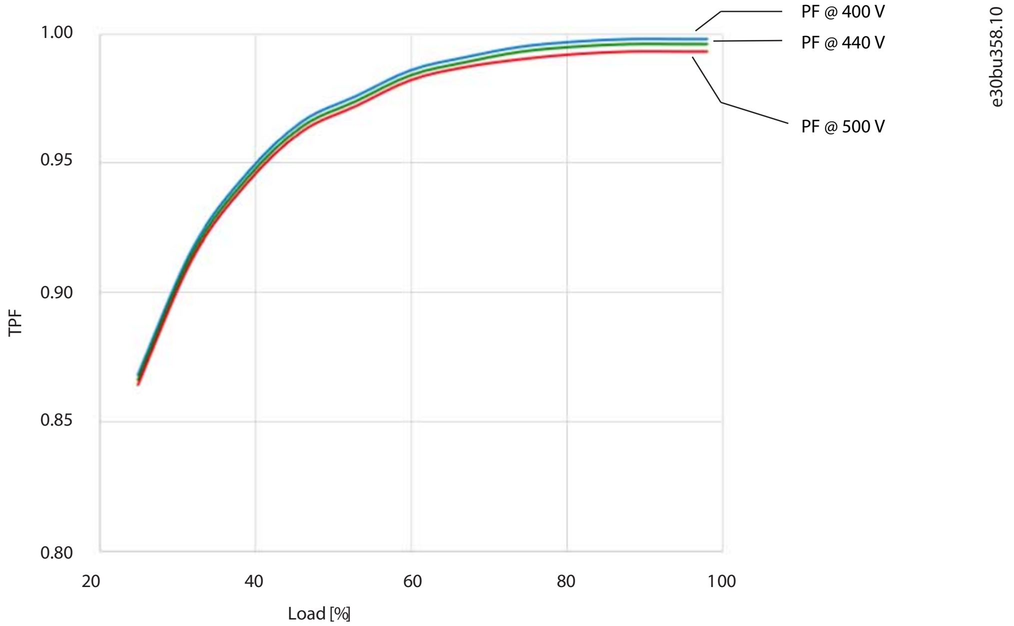


Illustration 115: True Power Factor Variation versus Load for the Enclosed Drive with PHF Option, 380–500 V

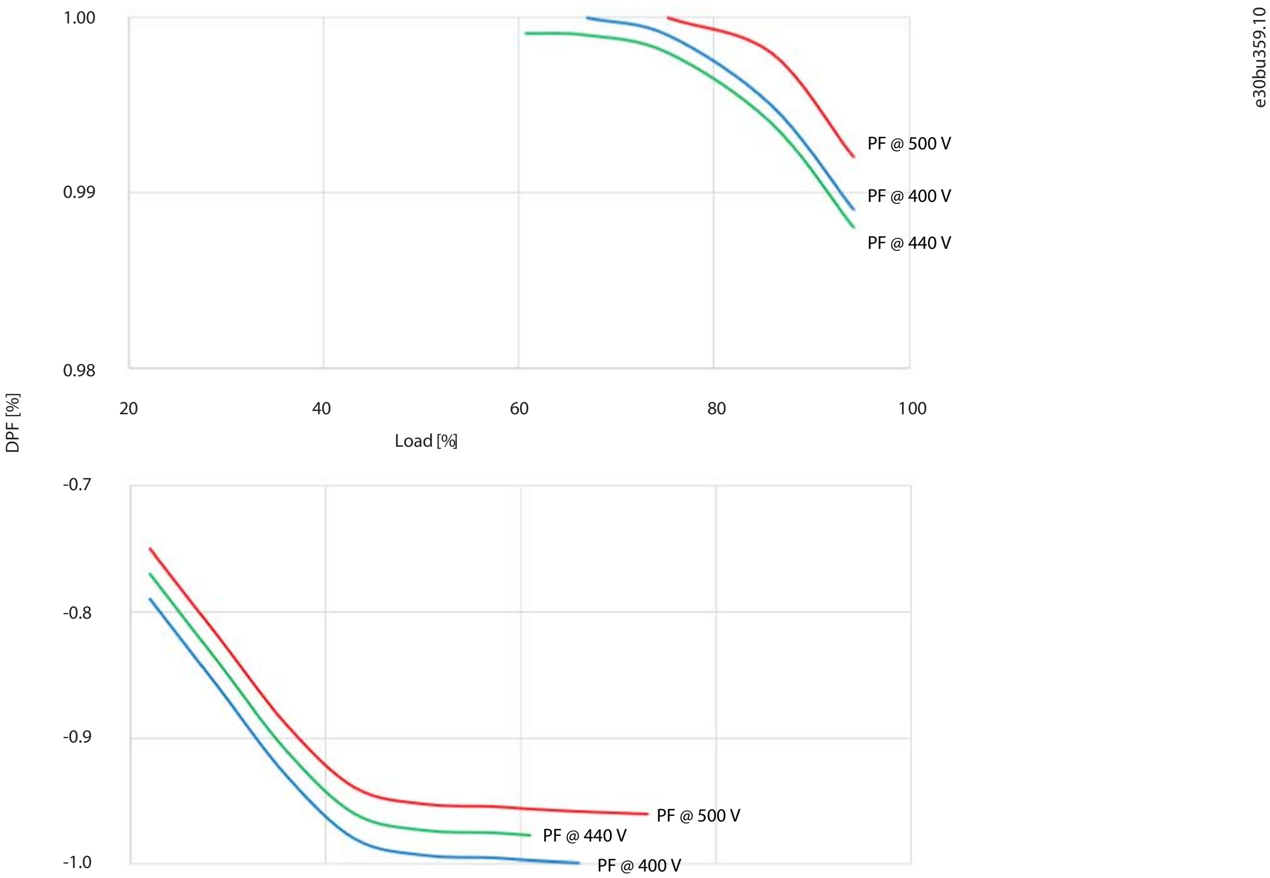


Illustration 116: Displacement Power Factor Variation versus Load for the Enclosed Drive with PHF Option, 380–500 V

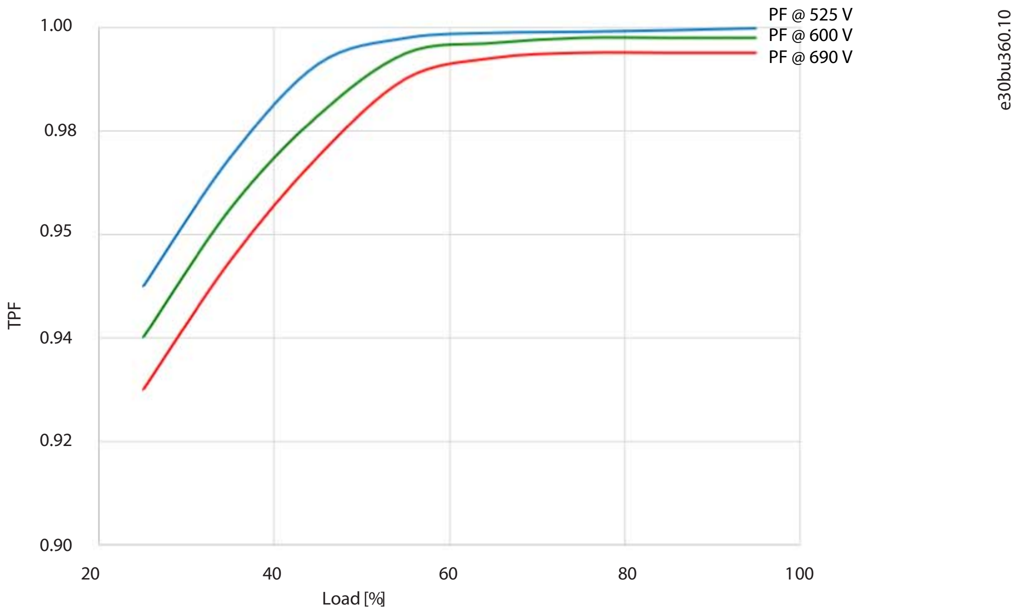


Illustration 117: True Power Factor Variation versus Load for the Enclosed Drive with PHF Option, 525–690 V

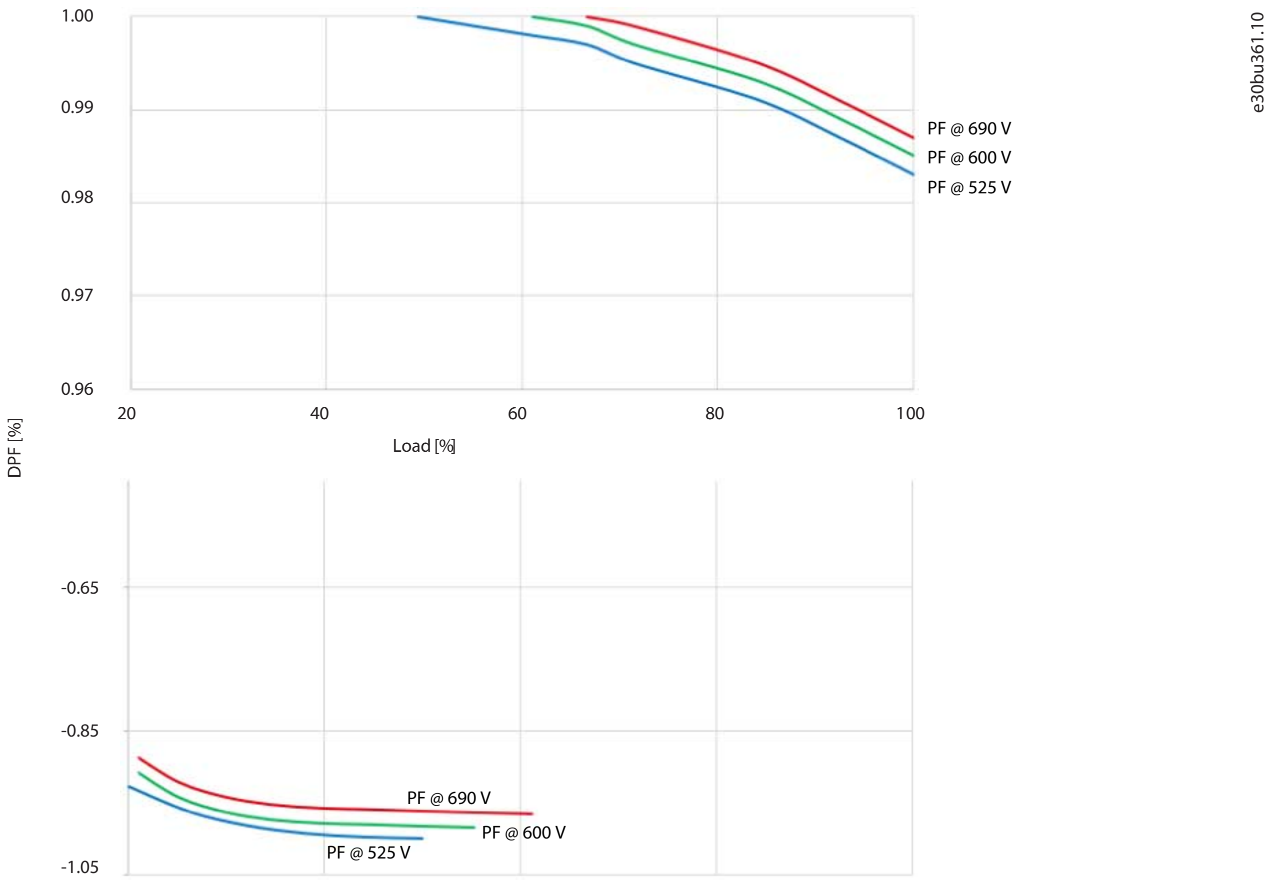


Illustration 118: Displacement Power Factor Variation versus Load for the Enclosed Drive with PHF Option, 525–690 V

10.16.6.2 Capacitor Disconnect

If the specific application requires a higher power factor at no-load and the reduction of the capacitive current in standby, a capacitor disconnect should be used. A contactor can disconnect the capacitor at loads below 20%. Do not connect capacitors at full load or disconnect at no load. It is very important to consider the capacitive current in the design of applications where the harmonic filter is supplied by a generator. The capacitive current can overexcite the generator in no-load and low-load condition. The overexcitation causes an increase of the voltage that can exceed the allowed voltage for the passive harmonic filter and the enclosed drive. Therefore a capacitor disconnect should always be used in generator applications and the design carefully considered.

10.16.6.3 Voltage Boost

In stand-by and under low conditions, the passive harmonic filter option boosts the input voltage with up to 5%, meaning that the voltage at the drive terminals is up to 5% higher than the voltage at the input of the filter. This feature should be considered at the design of the installation. Special care should be taken in 690 V applications, where the voltage tolerance of the drive is reduced to +5%, the boost voltage can, at low load and stand-by, be limited via the available capacitor disconnect.

10.16.6.4 DC-link Compensation

The VLT® FC series include a feature which ensures that the output voltage is independent of any voltage fluctuation in the DC-link, such as those caused by fast fluctuations in the mains supply voltage. In some cases, this dynamic compensation produces resonances in the DC-link and should be disabled. Typical cases include using a passive harmonic filter on supply grids with high short circuit ratio. Fluctuations can often be recognized by increased acoustical noise and in extreme cases by unintended tripping. To prevent resonances in the DC-link, Danfoss recommends disabling the DC-link compensation in *parameter 14-51 DC-link Compensation*.

Table 101: Parameter 14-51 DC-link Compensation

Option	Function
[0] Off	Disables DC-link compensation
[1] On	Enables DC-link compensation

10.16.7 Operating Principle of an Enclosed Drive with a Line Reactor

The VLT® AutomationDrive FC 302 Enclosed Drive with the optional line reactor consists of a single AC inductor, 2 or 3 inductors between supply and drive based on the power rating. Line reactors are being used due to their ability to provide the following benefits:

- Reduced harmonics, especially in applications using active filters.
- Protection against surges and interruptions, which prolongs the life of switching components.
- Withstands current under short circuit conditions.
- Protection for DC-link and front end components.

The line reactor option is specifically designed for optimizing active filter installations. When an active filter is placed in front of the drive, the drive side harmonics increase considerably since the active filter lowers of the impedance of the system. The reduction in impedance increases the current harmonics to higher value which increases the harmonic current requirement of the active filter. Therefore a higher rated active filter must be used. The increased current harmonics also negatively affects the DC-link. Danfoss recommends using line reactors when there is an active filter on the load side or in the PCC of the system.

Note that the impedance of the line reactor can go up to 3% of the base impedance which creates a voltage drop of 3% at 400 V for a 380–500 V system and 690 V for a 525–690 V system. Line reactors are designed to reduce the harmonics approximately 35% for a 380–500 V system and 40% for a 525–690 V system.

The THDi performance of the line reactor varies as a function of the load. At nominal load, the line reactor performance should be equal or better than 35% THDi for LR035 at 380–500 V and 40% THDi for LR040 at 525–690 V. At partial load, the THDi has higher values. Consequently, the negative effect of the harmonics at partial loads is lower than at full load.

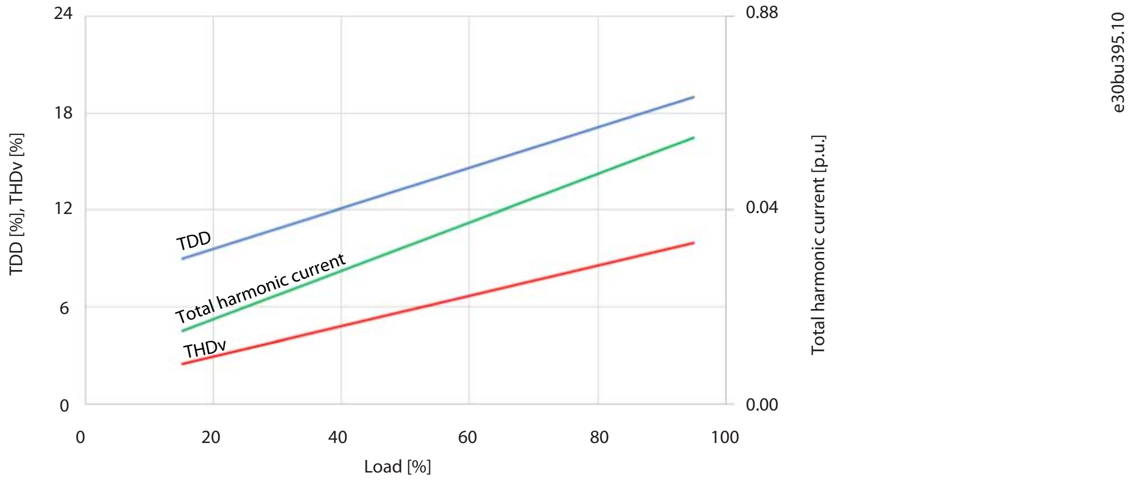


Illustration 119: Expected Variation of TDD, THDv, and Total Harmonic Current versus Load in an Enclosed Drive with the Line Reactor Option

The graph in illustration 112 is measured at a specific grid with a short circuit ratio Isc/IL <20. The Isc/IL is the ratio of the short circuit available at the point of common coupling (PCC) to the maximum fundamental load current.

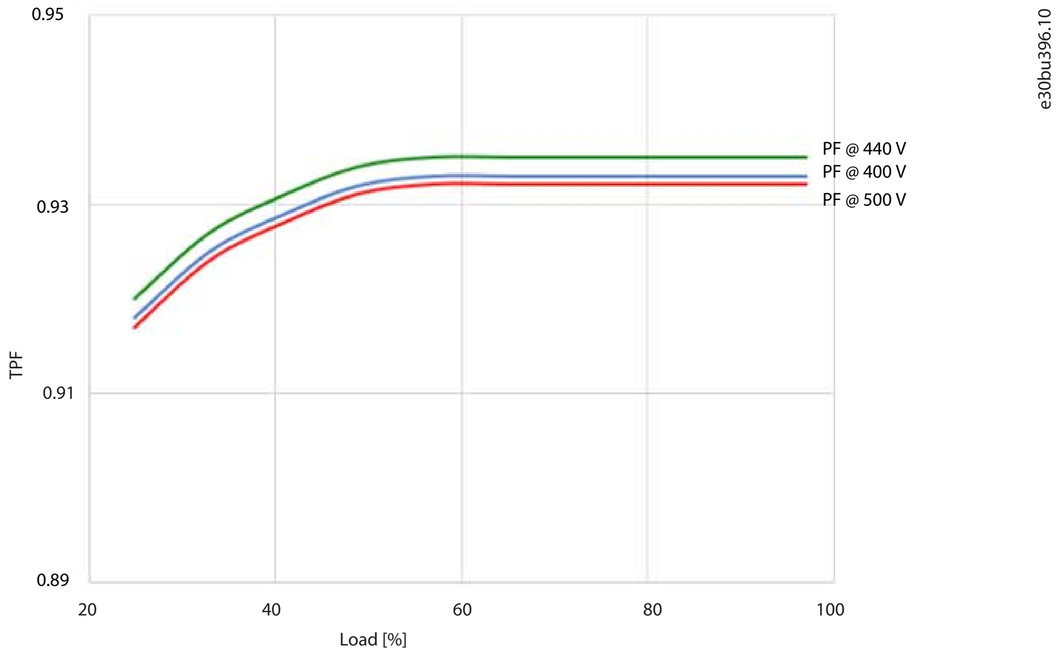


Illustration 120: True Power Factor Variation versus Load for an Enclosed Drive with Line Reactor, 380–500 V

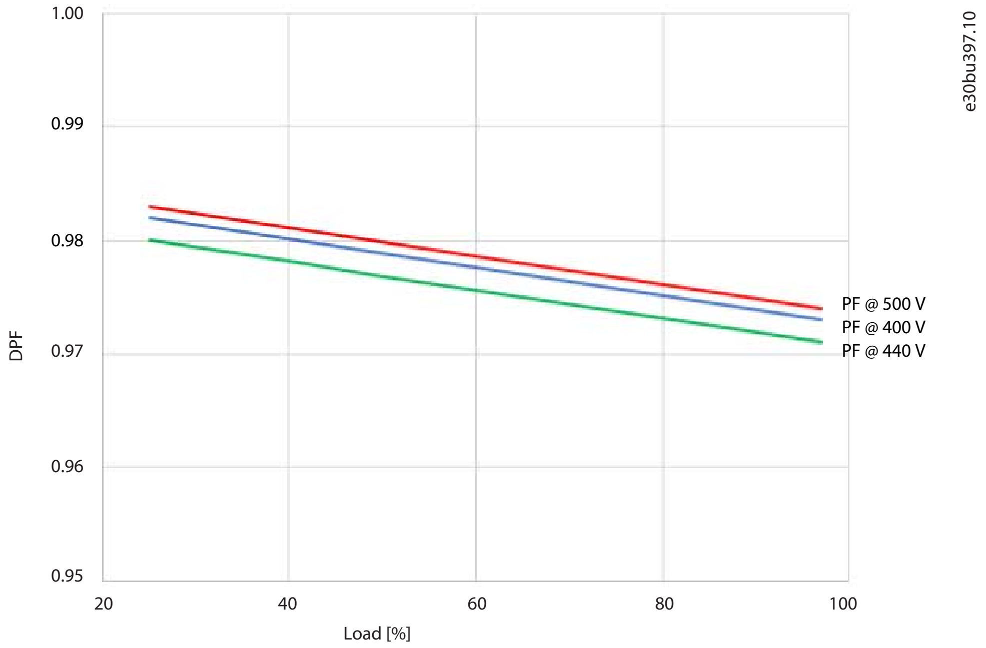


Illustration 121: Displacement Power Factor Variation versus Load for an Enclosed Drive with Line Reactor, 380–500 V

In no load conditions, such as when the drive is in stand-by mode, the drive current is negligible. The true power factor increases with the load, Power factor is close to 0.9 when the load is increased beyond 20% of full load. At full load, true power factor is close to 0.93. The following graphs in illustration 113 – illustration 114 show expected values of true power factor and displacement power factor for an eclosed drive with the line reactor option.

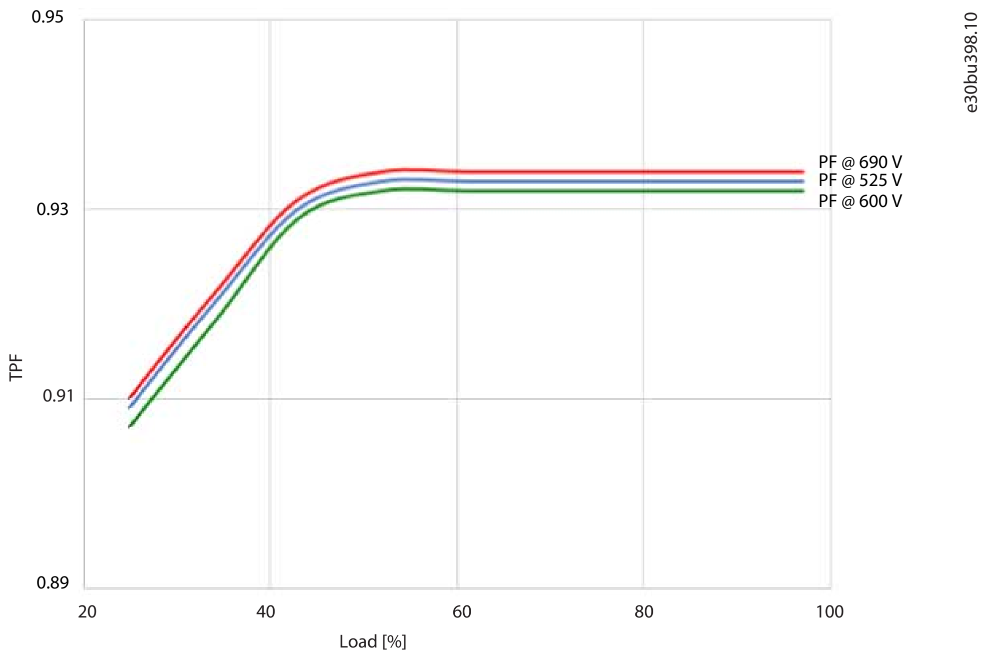


Illustration 122: True Power Factor Variation versus Load for an Enclosed Drive with Line Reactor, 525–690 V

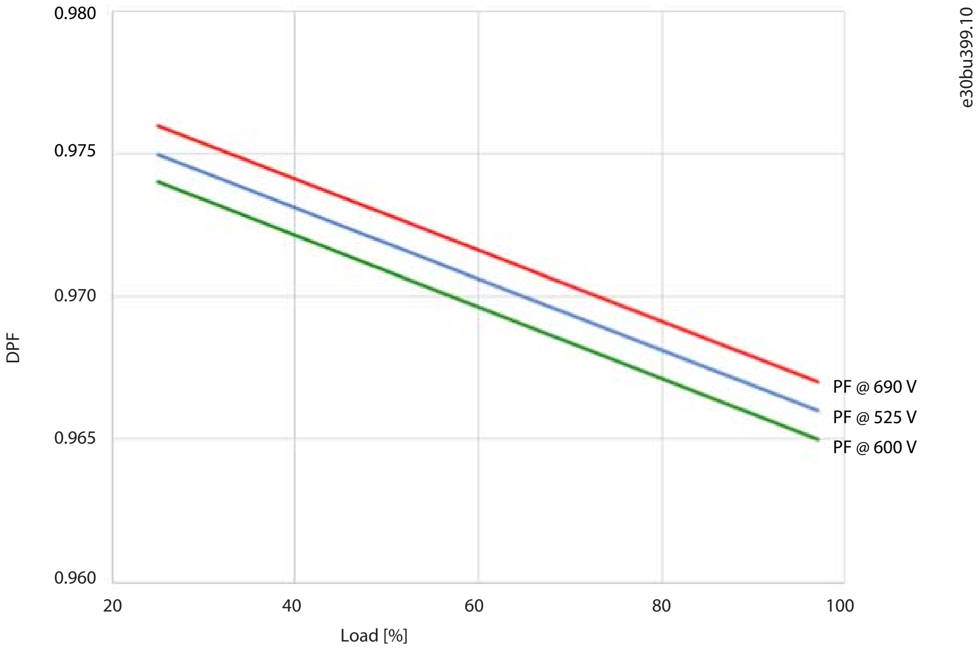


Illustration 123: Displacement Power Factor Variation versus Load for an Enclosed Drive with Line Reactor, 525–690 V

10.16.8 Harmonic Limitation Standards and Requirements

The requirements for harmonic limitation can be application specific or from standards that have to be observed.

The application specific requirements are related to a specific installation where there are technical reasons for limiting the harmonics. For example on a 250 kVA transformer with two 110 kW motors connected. One is connected direct on-line and the other one is supplied through a drive. If the direct on-line motor should also be supplied through a drive, the transformer will, in this case, be undersized. In order to retrofit, without changing the transformer, the harmonic distortion from the 2 drives has to be mitigated using the passive harmonic filter option.

There are various harmonic mitigation standards, regulations and recommendations. Different standards apply in different geographical areas and industries. The following encountered standards are discussed:

- IEC/EN 61000-3-2
- IEC/EN 61000-3-12
- IEC/EN 61000-3-4
- IEC/EN 61000-2-2
- IEC/EN 61000-2-4
- IEEE 519-2014
- G5/5

IEC 61000-3-2, Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)

The scope of IEC 61000-3-2 is equipment connected to the public low-voltage distribution system having an input current up to and including 16 A per phase. Four emission classes are defined: Class A through D. The Danfoss drives are in Class A. However, there are no limits for professional equipment with a total rated power greater than 1 kW.

IEC 61000-3-12, Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16 A and ≤75 A

The scope of IEC 61000-3-12 is equipment connected to the public low-voltage distribution system having an input current between 16 A and 75 A. The emission limits are currently only for 230/400 V 50 Hz systems. The emission limits that apply for drives are given in Table 4 in the standard. There are requirements for individual harmonics (5th, 7th, 11th, and 13th) and for THD and PWHD. VLT® AutomationDrive FC 302 complies comply with these limits without additional filtering.

IEC 61000-3-4, Limits, Limitation of emission of harmonic currents in low-voltage power supply systems for equipment with rated current greater than 16 A

IEC 61000-3-12 supersedes IEC 61000-3-4 for currents up to 75 A. Therefore the scope of IEC 61000-3-4 is equipment with rated current greater than 75 A connected to the public low-voltage distribution system. It has the status of technical report and should not be seen as an international standard. A 3-stage assessment procedure is described for the connection of equipment to the public supply and equipment above 75 A is limited to stage 3 connection based on the load's agreed power. The supply authority may accept the connection of the equipment on the basis of the agreed active power of the load's installation and local requirements of the supply authority apply. The manufacturer shall provide individual harmonics and the values for THD and PWHD.

IEC 61000-2-2 and IEC 61000-2-4 Compatibility levels for low-frequency conducted disturbances

IEC 61000-2-2 and IEC 61000-2-4 are standards that stipulate compatibility levels for low-frequency conducted disturbances in public low-voltage supply systems (IEC 61000-2-2) and industrial plants (IEC 61000-2-4). These low-frequency disturbances include but are not limited to harmonics. The values prescribed in these standards shall be taken into consideration when planning installations. In some situations, the harmonic compatibility levels cannot be observed in drive installations, and harmonic mitigation is needed.

IEEE 519, IEEE recommended practices and requirements for harmonic control in electrical power systems

IEEE 519 establishes goals for the design of electrical systems that include both linear and non-linear loads. Waveform distortion goals are established and the interface between sources and loads is described as point of common coupling (PCC). IEEE 519 is a system standard that aims the control of the voltage distortion at the PCC to a THD of 8% and limits the maximum individual frequency voltage harmonic to 5%. The development of harmonic current limits aims the limitation of harmonic injection from individual customers so they do not cause unacceptable voltage distortion levels to the overall harmonic distortion of the system voltage supplied by the utility.

The current distortion limits are given in Table 10.3 in the standard and depend on the ratio ISC/IL where ISC is the short circuit current at the utility PCC and IL is the maximum demand load current. The limits are given for individual harmonics up to the 35th and total demand distortion (TDD). Note that these limits apply at the PCC to the utility. While requiring individual loads to comply with these limits also ensures the compliance at the PCC, this is rarely the most economic solution, being unnecessarily expensive. The most effective way to meet the harmonic distortion requirements is to mitigate at the individual loads and measure at the PCC. However, if in a specific application it is required that the individual drive should comply with the IEEE 519 current distortion limits, the passive harmonic filter option can be used to meet these limits.

G5/4, Engineering recommendation, planning levels for harmonic voltage distortion and the connection of nonlinear equipment to transmission systems and distribution networks in the United Kingdom

G5/4 sets planning levels for harmonic voltage distortion to be used in the process of connecting non-linear equipment. A process for establishing individual customer emission limits based on these planning levels is described. G5/4 is a system level standard. For 400 V, the voltage THD planning level is 5% at the PCC. Limits for odd and even harmonics in 400 V systems are given in Table 2 in the standard. An assessment procedure for the connection of non-linear equipment is described. The procedure follows 3 stages, aiming to balance the level of detail required by the assessment process with the degree of risk that the connection of particular equipment will result in unacceptable voltage harmonic distortion. The passive harmonic filter option can be used to meet these limits.

10.16.9 IEC Harmonic Standards

In most of Europe, the basis for the objective assessment of the quality of mains power is the Electromagnetic Compatibility fo Devices Act (EMVG). Compliance with these regulations ensures that all devices and networks connected to electrical distribution systems fulfill their intended purpose without generating problems.

Table 102: EN Design Standards for Mains Power Quality

Standard	Definition
EN 61000-2-2, EN 61000-2-4, EN 50160	Define the mains voltage limits required for public and industrial power grids.
EN 61000-3-2, 61000-3-12	Regulate mains interference generated by connected devices in lower current products.
EN 50178	Monitors electronic equipment for use in power installations.

There are 2 European standards that address harmonics in the frequency range from 0 Hz to 9 kHz:

- EN 61000-2-2 Compatibility Levels for Low-Frequency Conducted Disturbances and Signaling in Public Low-Voltage Power Supply Systems.
- EN 61000-2-4 Compatibility Levels for Low-Frequency Conducted Disturbances and Signaling in Industrial Plants.

The EN 61000-2-2 standard states the requirements for compatibility levels for PCC (point of common coupling) of low voltage AC systems on a public supply network. Limits are specified only for harmonic voltage and total harmonic distortion of the voltage. EN 61000-2-2 does not define limits for harmonic currents. In situations where the total harmonic distortion THDv=8%, PCC limits are identical to those limits specified in the EN 61000-2-4 Class 2.

The EN 61000-2-4 standard states the requirements for compatibility levels in industrial and private networks. The standard further defines the following 3 classes of electromagnetic environments:

- Class 1 relates to compatibility levels that are less than the public supply network, which affects equipment sensitive to disturbances (lab equipment, some automation equipment, and certain protection devices).
- Class 2 relates to compatibility levels that are equal to the public supply network. The class applies to PCCs on the public supply network and to IPCs (internal points of coupling) on industrial or other private supply networks. Any equipment designed for operation on a public supply network allowed in this class.
- Class 3 relates to compatibility levels greater than the public supply network. This class applies only to IPCs in industrial environments. Use this class where the following equipment is found:
  - Large drives.
  - Welding machines.
  - Large motors starting frequently.
  - Loads that change quickly.

Typically, a class cannot be defined ahead of time without considering the intended equipment and processes to be used in the environment.

Table 103: Compatibility Levels for Harmonics

Harmonic order (h)	Class 1 (V_h%)	Class 2 (V_h%)	Class 3 (V_h%)
5	3	6	8
7	3	5	7
11	3	3.5	5
13	3	3	4.5
17	2	2	4
$17<h\leq 49$	2.27 x (17/h) - 0.27	2.27 x (17/h) - 0.27	4.5 x (17/h) - 0.5

Table 104: Compatibility Levels for the Total Harmonic Voltage Distortion THDv

	Class 1	Class 2	Class 3
THDv	5%	8%	10%

10.16.10 Harmonic Compliance

VLT® AutomationDrive FC 302 Enclosed Drives comply with the following standards:

- IEC 61000-2-4.
- IEC 61000-3-4.
- G5/5.
- IEEE519 - 2014.

11 Basic Operating Principles of a Drive

11.1 Drive Operation

Overview

An enclosed drive is an electronic controller that supplies a regulated amount of AC power to a 3-phase asynchronous motor. By supplying variable frequency and voltage to the motor, the drive controls the motor speed or torque. It also can maintain a constant speed as the load on the motor changes. The drive can stop and start a motor without the mechanical stress associated with a line start.

The enclosed drive offers additional functionality based on the selected options.

- If the sine-wave filter option is present, the system offers sinusoidal output current and reduced voltage spikes at the motor terminals.
- If the dU/dt filter option is present, the system offers reduced voltage spikes at the motor terminals due to long cables.
- If the passive harmonic filter (PHF) or line reactor is present, the system offers reduced input current harmonics.

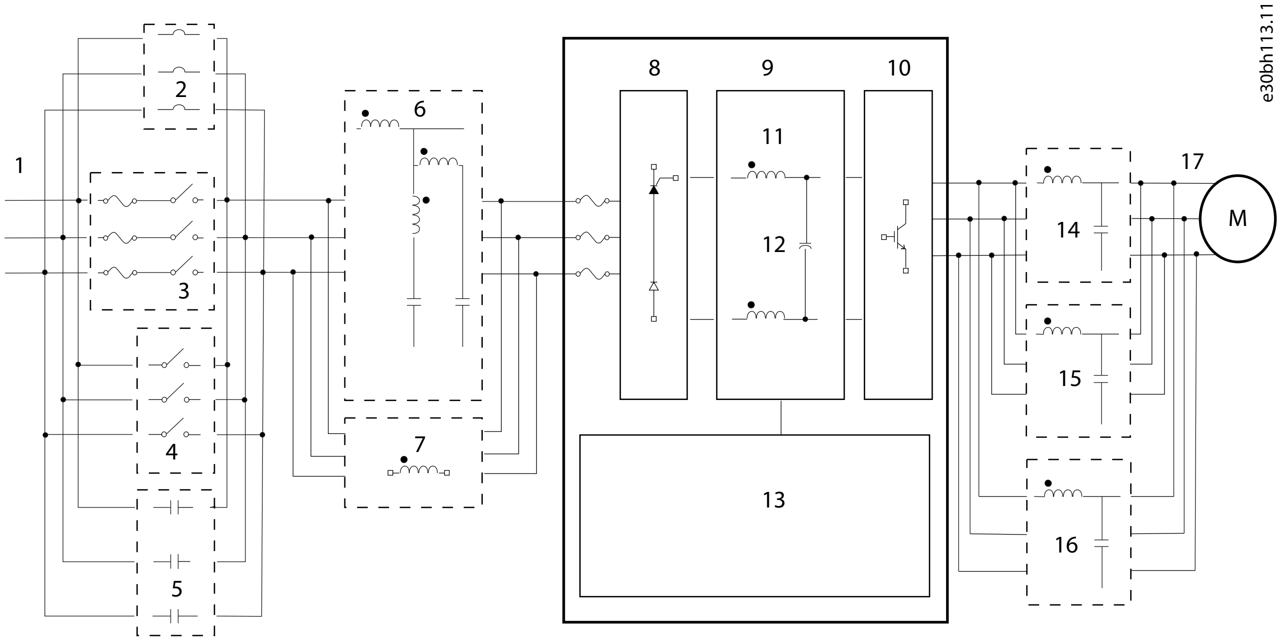


Illustration 124: Enclosed Drive Basic Block Diagram

Table 105: Enclosed Drive Block Diagram Definitions

Item	Title	Functions
1	Mains input	Provides 3-phase AC mains power input to the drive module.
2	Molded-case circuit breaker (MCCB)	Input power option. Allows switching of input voltage. Includes circuit breaker, which trips at fault current or short circuit.
3	Fusible disconnect	Input power option. Allows switching of input voltage. Contains fuses, which clear the fault current or short circuit.
4	Non-fusible disconnect	Input power option. Allows switching of input voltage. Contains circuit breaker, which trips at fault current or short circuit.

Item	Title	Functions
5	Mains contactor	Input power option. Allows switching of input voltage. Enables remote connection or disconnection of input voltage.
6	Passive harmonic filter	Reduces input current harmonics below 5% or below 8%, depending on the selected filter.
7	Line reactor	Reduces rectifier current harmonics and stress, when connected to grid that has active filters.
8	Input rectifier section	Converts mains input AC voltage into DC voltage.
9	Intermediate DC bus section	Acts as a filter and stores energy in the form of DC voltage.
10	Inverter section	Converts the DC voltage into a variable, controlled PWM AC output voltage to the motor.
11	DC reactors	Filters the DC-link voltage. Reduces RMS current. Raises the power factor reflected back to the line. Reduces harmonics on the AC input.
12	Capacitor bank	Stores the DC power and provides ride-through protection for short power losses.
13	Control	Monitors input and motor current to provide efficient operation and control. Monitors the user interface and performs external commands. Provides status output and control. Includes the power card, fan power card (in E-sized drives only), and inrush card.
14	Sine-wave filter	Delivers sine current and reduced voltage spikes and dU/dt at the motor terminals.
15	dU/dt filter	Delivers reduced voltage spikes and dU/dt at the motor terminals.
16	Common mode filter	Reduces high-frequency bearing currents.
17	Motor output	Sends output to the motor being controlled.
Note: Dashed lines represent customer-selected options.		

11.2 Drive Controls

The following processes are used to control and regulate the motor:

- User input (local and remote references).
- Feedback handling.
- User-defined control structure.
  - Open loop/closed-loop mode.
  - Motor control (speed, torque, or process).
- Control algorithms (VVC^{+}, flux sensorless, flux with motor feedback, and internal current control VVC^{+}).

11.3 User Inputs

The drive uses an input source (also called reference) to control and regulate the motor. The drive receives this input either:

- Manually via the LCP. This method is referred to as a local reference or (Hand On).
- Remotely via an analog/digital input and a serial interface (RS485, USB, or an optional fieldbus). This method is referred to as a remote reference or (Auto On). This method is the default input setting.

The term active reference refers to the active input source. The active reference is configured in *parameter 3-13 Reference Site*. For more information, see the product-specific Programming Guide.

11.4 Remote Reference Handling

Both open-loop and closed-loop operations use remote references. See illustration 125. Up to 8 internal preset references can be programmed into the drive. The active internal preset reference can be selected externally through digital control inputs or through the serial communication bus.

External references can also be supplied to the drive, most commonly through an analog control input. All reference sources and the bus references are added to produce the total external reference. The active reference can be selected from the following:

- External reference.
- Preset reference.
- Setpoint.
- Sum of the external reference, preset reference, and setpoint.

The active reference can be scaled. The scaled reference is calculated as follows:

$$\text{Reference} = X + X \times \left(\frac{Y}{100}\right)$$

X is the external reference, the preset reference, or the sum of these references, and Y is the internal preset relative reference I %. If Y, *parameter 3-14 Preset Relative Reference* is set to 0%, the scaling does not affect the reference.

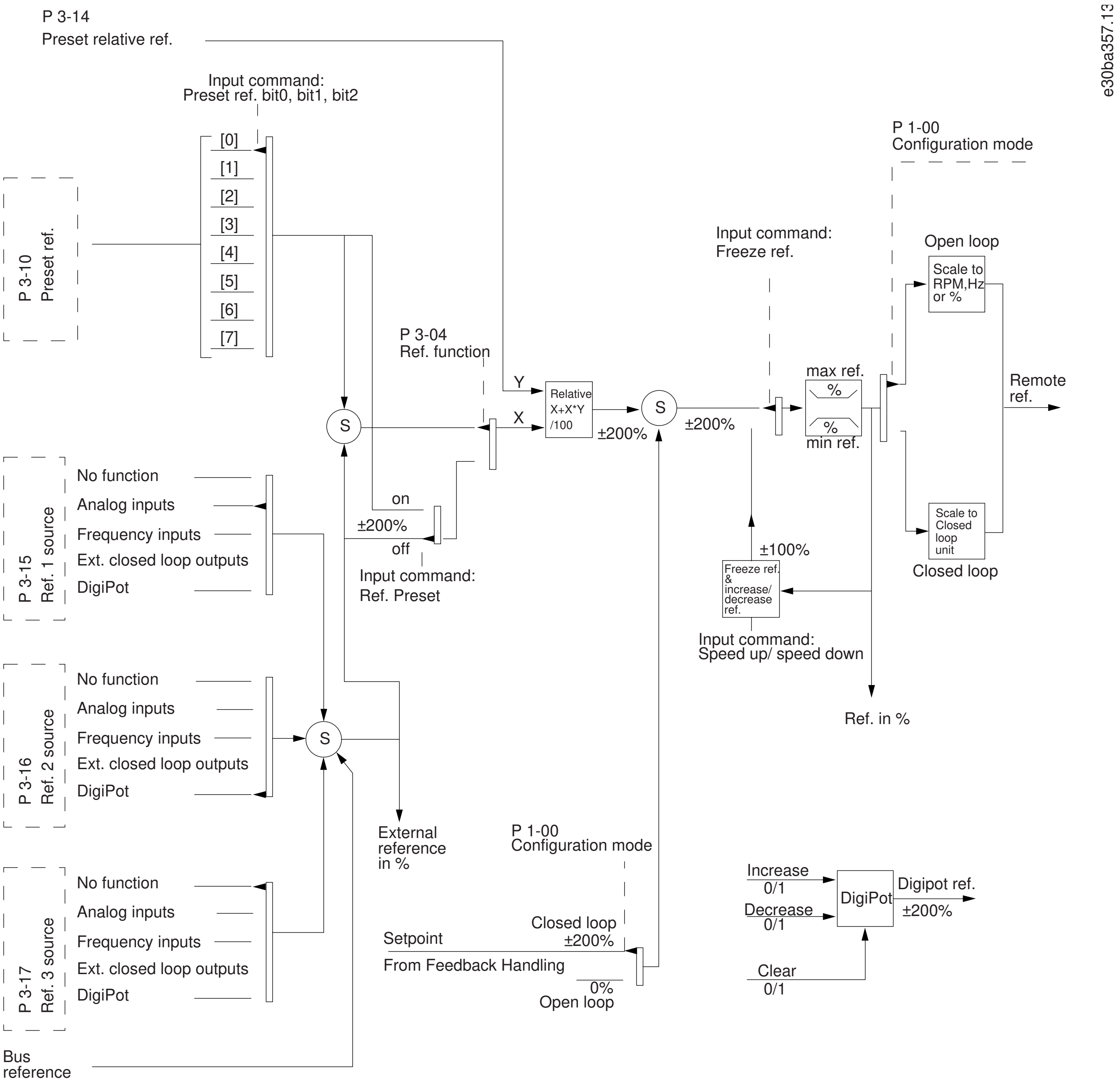


Illustration 125: Remote Reference Handling

11.5 Reference Limits

The reference range, minimum reference, and maximum reference define the allowed range of the sum of all references. The sum of all references is clamped when necessary. The relation between the resulting reference (after clamping) and the sum of all references are shown in illustration 126 and illustration 127.

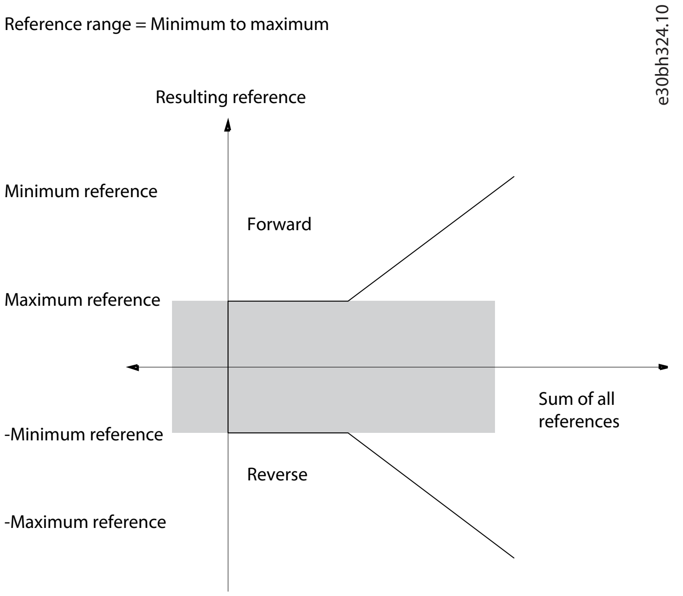


Illustration 126: Sum of All References When Reference Range is Set to 0

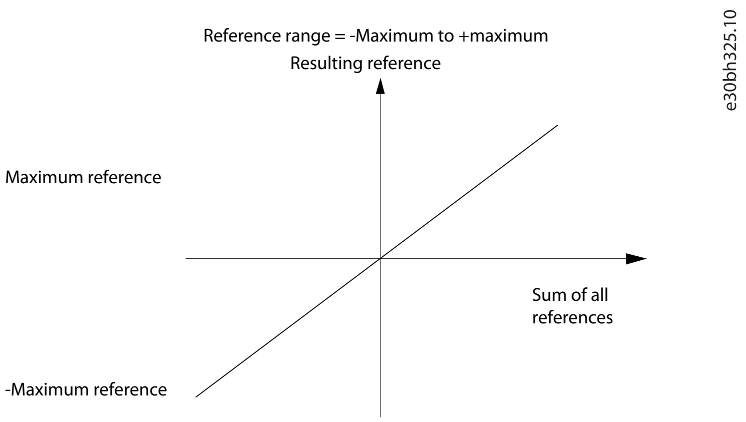


Illustration 127: Sum of All References When Reference Range is Set to 1

The minimum reference cannot be set to less than 0, unless the configuration mode is set to Process. In that case, the following relations between the resulting reference (after clamping) and the sum of all references are as shown in illustration 128.

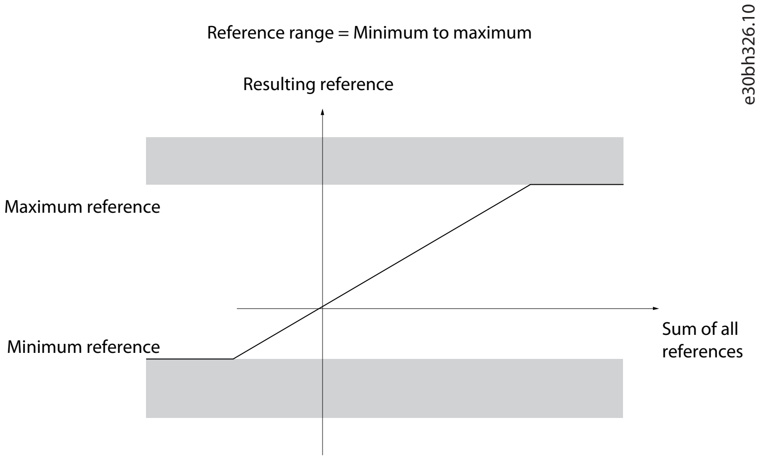


Illustration 128: Sum of all References when Configuration Mode is set to Process

11.6 Feedback Handling

Feedback handling can be configured to work with applications requiring advanced control, such as multiple setpoints and multiple types of feedback. Three types of control are common:

- Single zone (single setpoint). This control type is a basic feedback configuration. Setpoint 1 is added to any other reference (if any) and the feedback signal is selected.
- Multi-zone (single setpoint). This control type uses 2 or 3 feedback sensors but only 1 setpoint. The feedback can be added, subtracted, or averaged. In addition, the maximum or minimum value can be used. Setpoint 1 is used exclusively in this configuration.
- Multi-zone (setpoint/feedback). The setpoint/feedback pair with the largest difference controls the speed of the drive. The maximum value attempts to keep all zones at or below their respective setpoints, while the minimum value attempts to keep all zones at or above their respective setpoints.

Example:

A 2-zone, 2-setpoint application. Zone 1 setpoint is 15 bar, and the feedback is 5.5 bar. Zone 2 setpoint is 4.4 bar, and the feedback is 4.6 bar. If maximum is selected, the zone 2 setpoint and feedback are sent to the PID controller, since it has the smaller difference (feedback is higher than setpoint, resulting in a negative difference). If minimum is selected, the zone 1 setpoint and feedback is sent to the PID controller, since it has the larger difference (feedback is lower than setpoint, resulting in a positive difference).

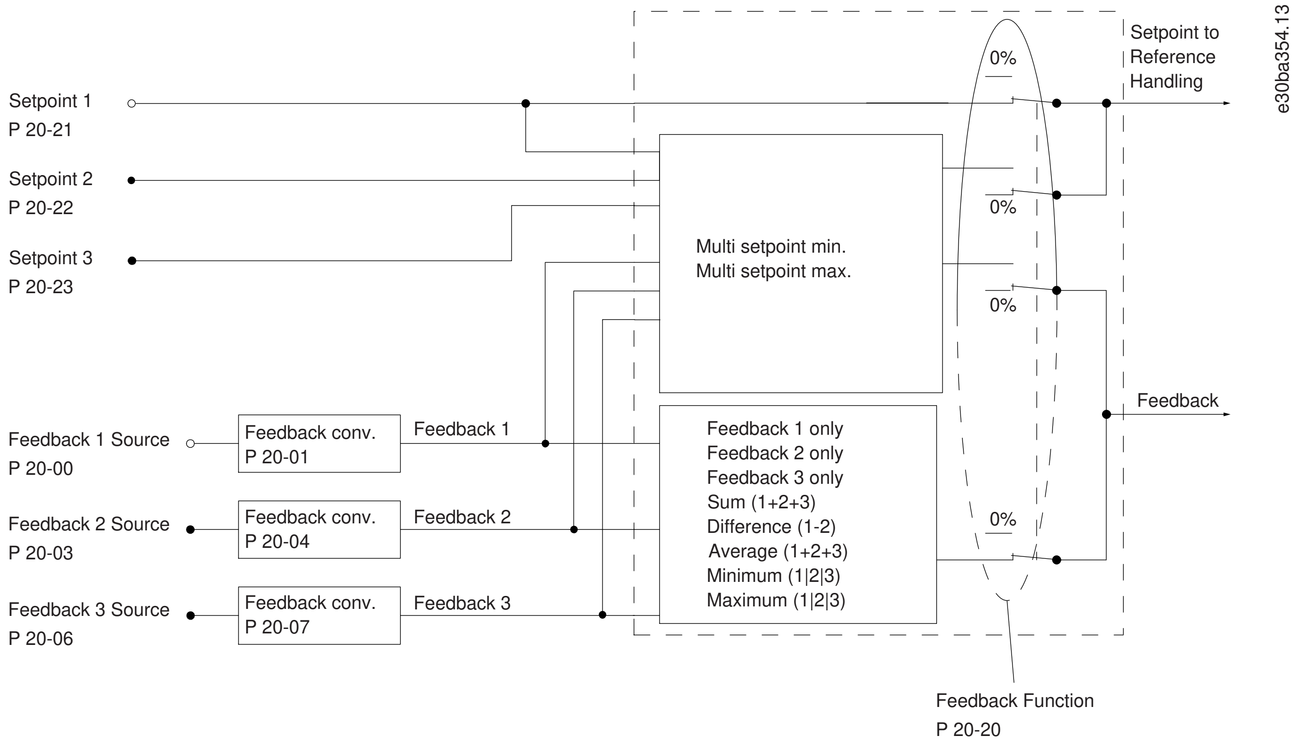


Illustration 129: Block Diagram of Feedback Signal Processing

Feedback conversion

In some applications, it is useful to convert the feedback signal. One example is using a pressure signal to provide flow feedback. Since the square root of pressure is proportional to flow, the square root of the pressure signal yields a value proportional to the flow.

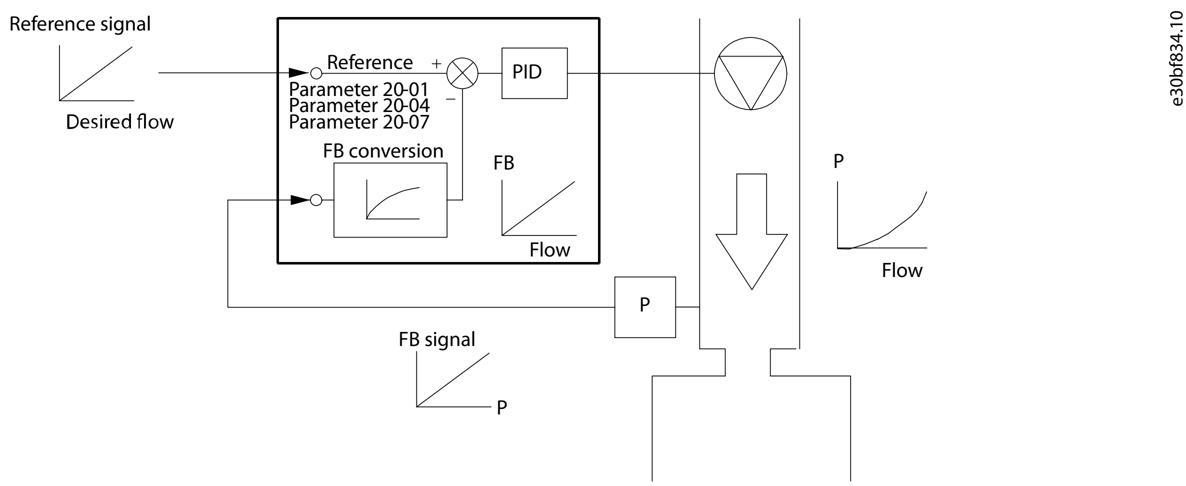


Illustration 130: Example of Feedback Conversion (Using Pressure Signal to Provide Flow Feedback)

11.7 Control Structure Overview

The control structure is a software process that controls the motor based on user-defined references (for example, RPM) and whether feedback is used/not used (closed loop/open loop). The operator defines the control in *parameter 1-00 Configuration Mode*. The control structures are as follows:

Open-loop

- Speed (RPM)
- Torque (Nm)

Closed-loop control structure

- Speed (RPM)
- Torque (Nm)
- Process (user-defined units, for example, feet, lpm, psi, %, bar)

11.7.1 Open-loop Control Structure

In open-loop mode, the drive uses 1 or more references (local or remote) to control the speed or torque of the motor. There are 2 types of open-loop control:

- Speed control. No feedback from the motor.
- Torque control. Used in VVC+ mode. The function is used in mechanically robust applications, but its accuracy is limited. Open-loop torque function works only in 1 speed direction. The torque is calculated based on current measurement within the drive. See the Basic I/O Configurations section.

In the configuration shown in illustration 131, the drive operates in open-loop mode. It receives input from either the LCP (hand-on mode) or via a remote signal (auto-on mode). The signal (speed reference) is received and conditioned with the following:

- Programmed minimum and maximum motor speed limits (in RPM and Hz).
- Ramp-up and ramp-down times.
- Motor rotation direction.

The reference is then passed on to control the motor.

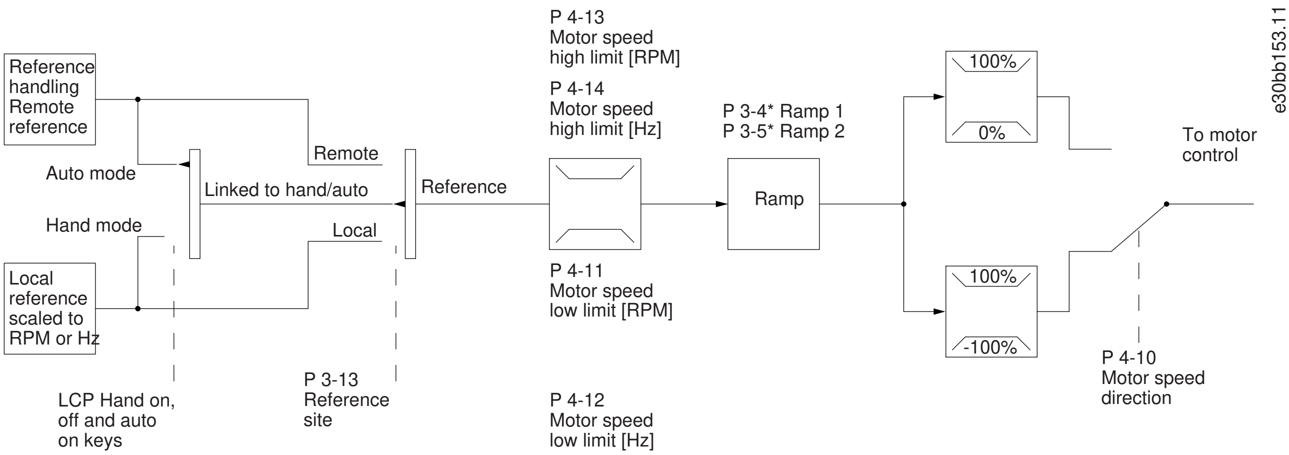


Illustration 131: Block Diagram of an Open-loop Control Structure

11.7.2 Closed-loop Control Structure

In closed-loop mode, the drive uses 1 or more references (local or remote) and feedback sensors to control the motor. The drive receives a feedback signal from a sensor in the system. It then compares this feedback to a setpoint reference value and determines if there is any discrepancy between these 2 signals. The drive then adjusts the speed of the motor to correct the discrepancy.

For example, consider a pump application in which the speed of the pump is controlled so that the static pressure in a pipe is constant (see illustration 132). The drive receives a feedback signal from a sensor in the system. It compares this feedback to a setpoint reference value and determines the discrepancy if any, between these 2 signals. It then adjusts the speed of the motor to compensate for the discrepancy. The static pressure setpoint is the reference signal to the drive. A static pressure sensor measures the actual static pressure in the pipe and provides this information to the drive as a feedback signal. If the feedback signal exceeds the setpoint reference, the drive ramps down to reduce the pressure. Similarly, if the pipe pressure is lower than the setpoint reference, the drive ramps up to increase the pump pressure.

There are 3 types of closed-loop control:

- Speed control. This type of control requires a speed PID feedback for an input. A properly optimized speed closed-loop control has higher accuracy than a speed open-loop control. Speed control is only used in the VLT® AutomationDrive FC 302.
- Torque control. Used in flux mode with encoder feedback, this control offers superior performance in all 4 quadrants and at all motor speeds. Torque control is only used in the VLT® AutomationDrive FC 302. The torque control function is used in applications where the torque on the motor output shaft is controlling the application as tension control. Torque setting is done by setting an analog, digital, or bus-controlled reference. When running torque control, it is recommended to make a full AMA procedure since the correct motor data is essential for optimal performance.
- Process control. Used to control application parameters that are measured by different sensors (pressure, temperature, and flow) and are affected by the connected motor through a pump or fan.

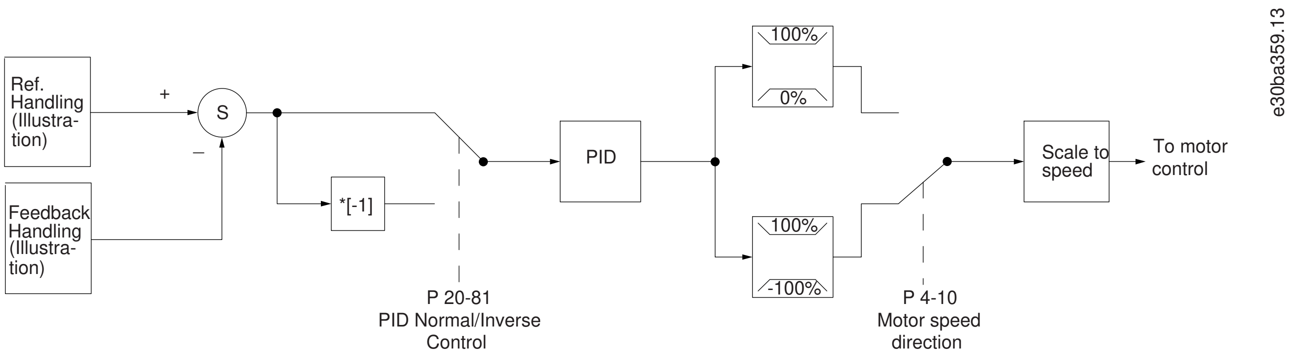


Illustration 132: Block Diagram of a Closed-loop Controller

Programmable features

While the default values for the drive in closed loop often provide satisfactory performance, system control can often be optimized by tuning the PID parameters. Auto tuning is provided for this optimization.

- Inverse regulation - motor speed increases when a feedback signal is high.
- Start-up frequency - lets the system quickly reach an operating status before the PID controller takes over.
- Built-in lowpass filter - reduces feedback signal noise.

11.8 Control Processing

See the Programming Guide for an overview of which control configuration is available for your application.

11.8.1 Control Structure in VVC+

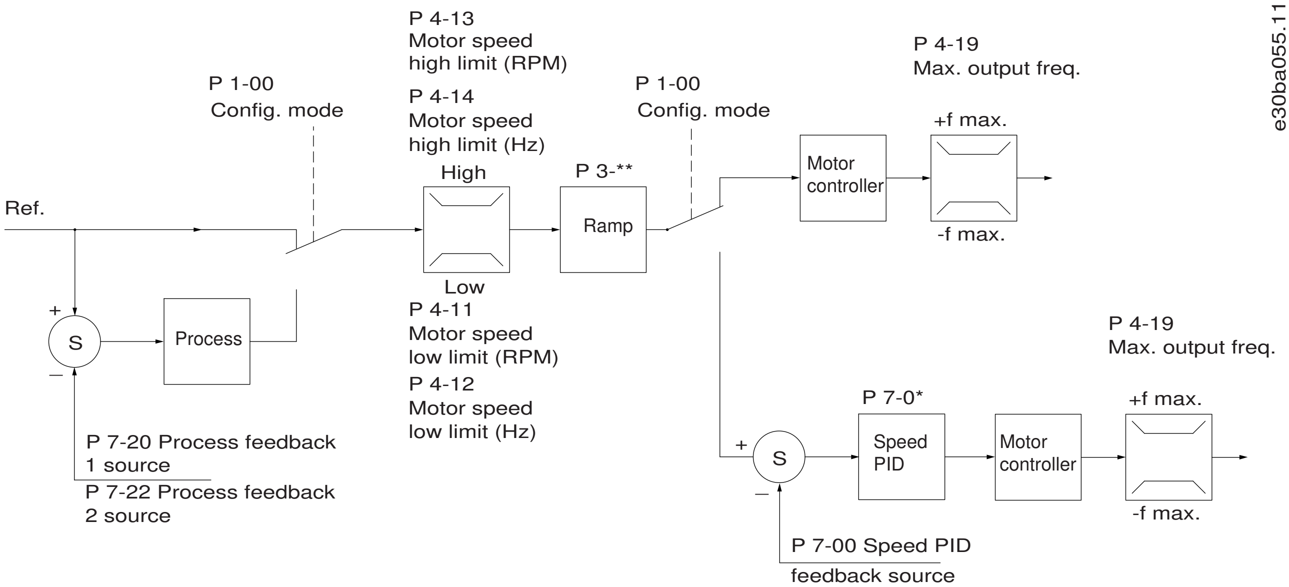


Illustration 133: Control Structure in VVC+ Open-loop and Closed-loop Configurations

In illustration 133, the resulting reference from the reference handling system is received and fed through the ramp limitation and speed limitation before being sent to the motor control. The output of the motor control is then limited by the maximum frequency limit.

Parameter 1-01 Motor Control Principle is set to *[1] VVC+* and *parameter 1-00 Configuration Mode is set to [0] Speed open loop. If parameter 1-00 Configuration Mode* is set to *[1] Speed closed loop*, the resulting reference is passed from the ramp limitation and speed limitation into a speed PID control. The speed PID control parameters are located in *parameter group 7-0* Speed PID Control*. The resulting reference from the speed PID control is sent to the motor control limited by the frequency limit.

Select *[3] Process* in *parameter 1-00 Configuration Mode* to use the process PID control for closed-loop control of, for example, speed or pressure in the controlled application. The process PID parameters are in *parameter groups 7-2* Process Ctrl. Feedb* and *7-3* Process PID Ctrl*.

11.8.2 Control Structure in Flux Sensorless

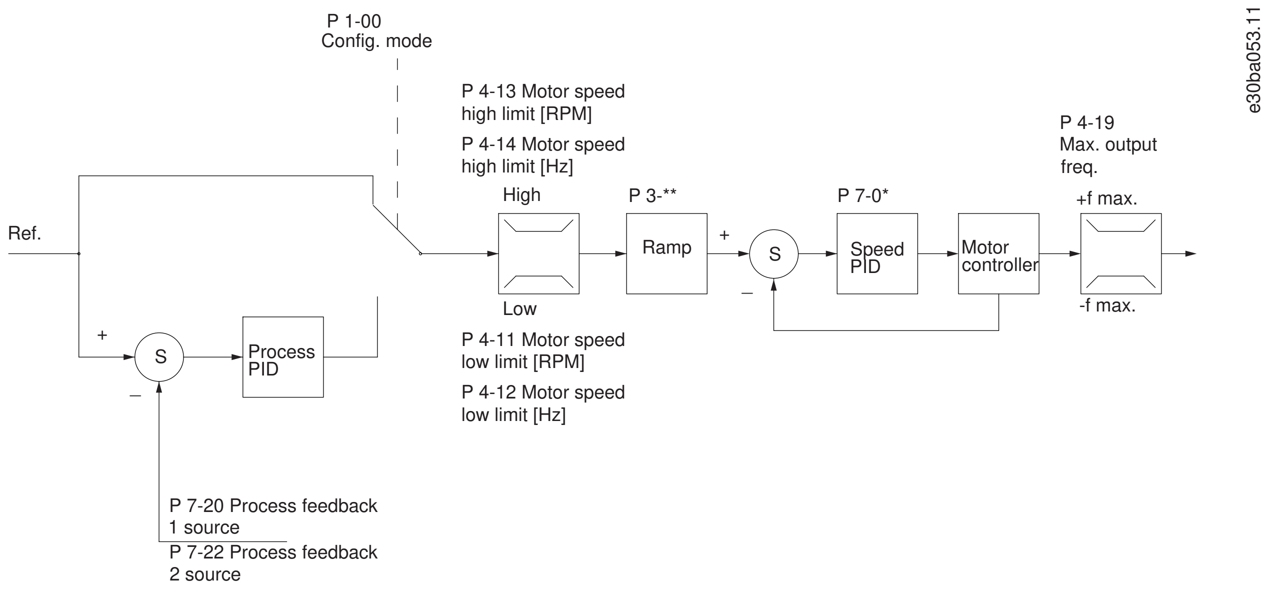


Illustration 134: Control Structure in Flux Sensorless Open-loop and Closed-loop Configurations

In illustration 134, the resulting reference from the reference handling system is fed through the ramp and speed limitations as determined by the parameter settings indicated.

Parameter 1-01 Motor Control Principle is set to *[2] Flux Sensorless* and *parameter 1-00 Configuration Mode* is set to *[0] Speed open loop*. An estimated speed feedback is generated to the speed PID to control the output frequency. The speed PID must be set with its P, I, and D parameters (*parameter group 7-0* Speed PID Control*).

Select *[3] Process* in *parameter 1-00 Configuration Mode* to use the process PID control for closed-loop control of the controlled application. The process PID parameters are found in *parameter groups 7-2* Process Ctrl. Feedb* and *7-3* Process PID Ctrl*.

11.8.3 Control Structure in Flux with Motor Feedback

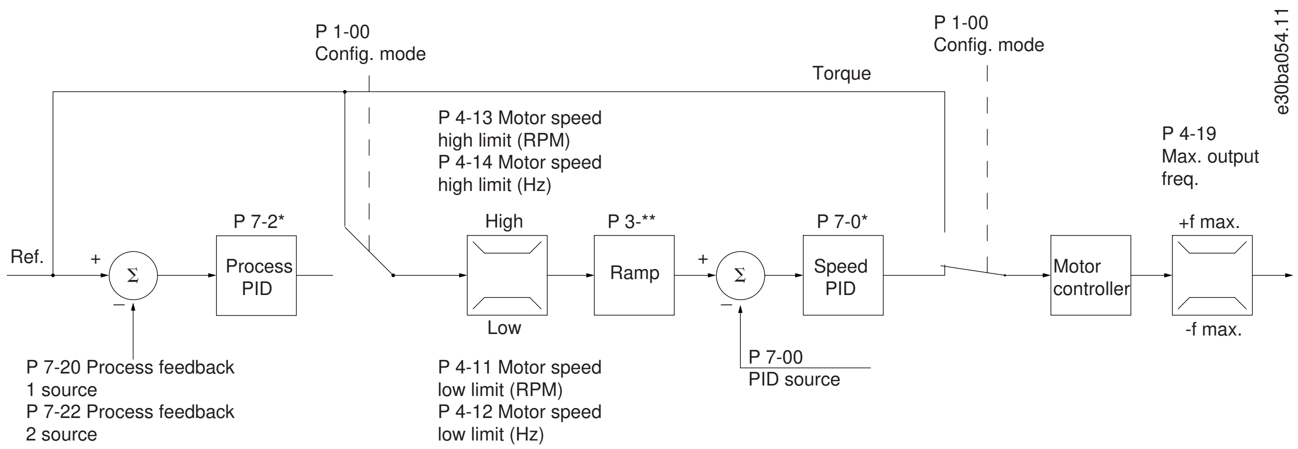


Illustration 135: Control Structure in Flux with Motor Feedback Configuration

In illustration 135, the motor control in this configuration relies on a feedback signal from an encoder or resolver mounted directly on the motor (set in *parameter 1-02 Flux Motor Feedback Source*). The resulting reference can be used as input for the speed PID control, or directly as a torque reference.

Parameter 1-01 Motor Control Principle is set to *[3] Flux w motor feedb* and *parameter 1-00 Configuration Mode* is set to *[1] Speed closed loop*. The speed PID control parameters are in *parameter group 7-0* Speed PID Control*.

Torque control can only be selected in the Flux with motor feedback (*parameter 1-01 Motor Control Principle*) configuration. When this mode has been selected, the reference uses the Nm unit. It requires no torque feedback, since the actual torque is calculated based on the current measurement of the drive.

Process PID control can be used for closed-loop control of speed or pressure in the controlled application. The process PID parameters are in *parameter groups 7-2* Process Ctrl. Feedb* and *7-3* Process PID Ctrl*.

11.8.4 Internal Current Control in VVC+ Mode

When the motor torque exceeds the torque limits set in *parameter 4-16 Torque Limit Motor Mode*, *parameter 4-17 Torque Limit Generator Mode*, and *parameter 4-18 Current Limit*, the integral current limit control is activated. When the drive is at the current limit during motor operation or regenerative operation, it tries to get below the preset torque limits as quickly as possible without losing control of the motor.

12 Wiring Configuration Examples

12.1 Application Examples

The examples in this section are intended as a quick reference for common applications.

- Parameter settings are the regional default values selected in *parameter 0-03 Regional Settings*, unless otherwise indicated.
- Parameters associated with the terminals and their settings are shown next to the drawings.
- Required switch settings for analog terminals A53 or A54 are also shown.

12.1.1 Programming a Closed-loop Drive System

A closed-loop drive system usually consists of:

- Motor.
- Drive.
- Encoder (as feedback system).
- Mechanical brake.
- Brake resistor (for dynamic braking).
- Transmission.
- Gear box.
- Load.

Applications demanding mechanical brake control typically need a brake resistor.

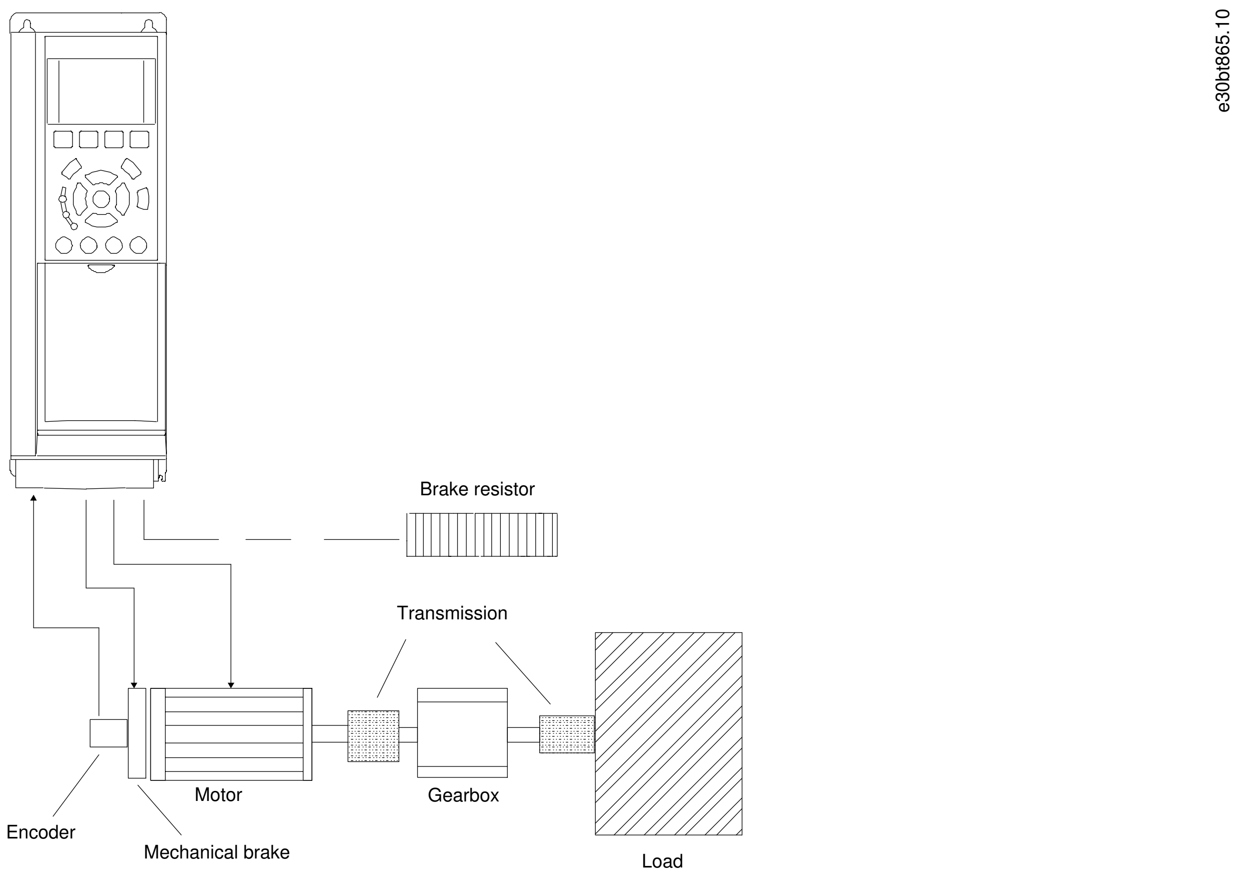
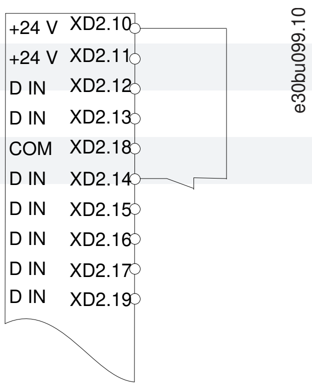


Illustration 136: Basic Set-up for Closed-loop Speed Control

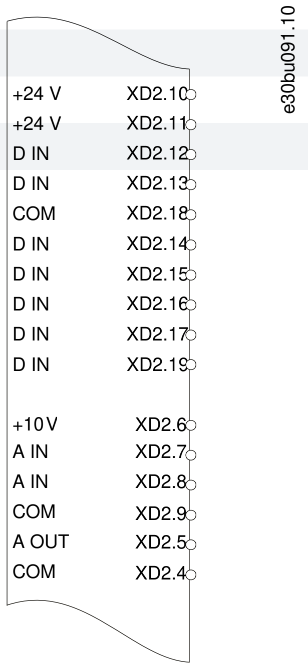
12.1.2 Wiring Configuration for Automatic Motor Adaptation (AMA)

Table 106: Wiring Configuration for AMA with T27 Connected

	Parameters	
	**Function**	**Setting**
	Parameter 1-29 Automatic Motor Adaptation (AMA)	*[1] Enable complete AMA*
	Parameter 5-12 Terminal 27 Digital Input	*[2]* Coast inverse*
	*=Default value	
	Notes/comments: Set *parameter group 1-2* Motor Data* according to motor nameplate. Terminal 27 in the parameter title corresponds to terminal XD2.14 in the control compartment.	

12.1.3 Wiring Configuration for Automatic Motor Adaptation (AMA) without T27

Table 107: Wiring Configuration for AMA without T27 Connected

	Parameters	
	**Function**	**Setting**
	Parameter 1-29 Automatic Motor Adaptation (AMA)	*[1] Enable complete AMA*
	Parameter 5-12 Terminal 27 Digital Input	*[0] No operation*
	*=Default value	
	Notes/comments: Set *parameter group 1-2* Motor Data* according to motor nameplate. Terminal 27 in the parameter title corresponds to terminal XD2.14 in the control compartment.	

12.1.4 Wiring Configuration: Speed

Table 108: Wiring Configuration for Analog Speed Reference (Voltage)

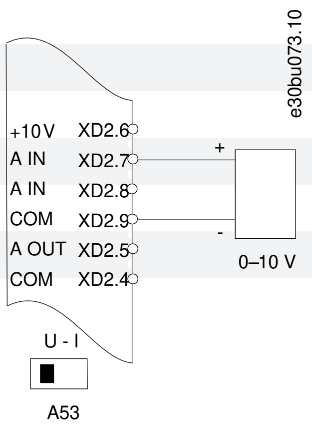
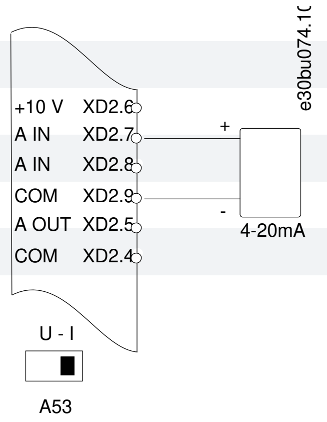
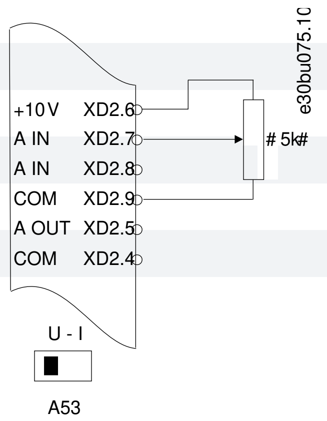
	Parameters	
	**Function**	**Setting**
	Parameter 6-10 Terminal 53 Low Voltage	0.07 V*
	Parameter 6-11 Terminal 53 High Voltage	10 V*
	Parameter 6-14 Terminal 53 Low Ref./Feedb. value	0 Hz
	Parameter 6-15 Terminal 53 High Ref./Feedb. Value	50 Hz
	*=Default value	
	Notes/comments: D IN 37 is an option. Terminal 53 in the parameter title corresponds to terminal XD2.7 in the control compartment.	

Table 109: Wiring Configuration for Analog Speed Reference (Current)



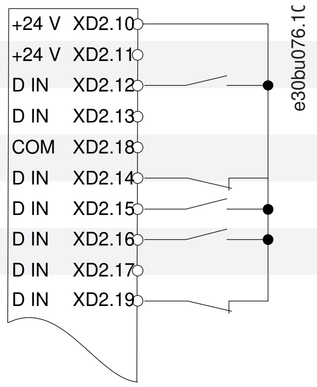
Parameters	
Function	**Setting**
Parameter 6-12 Terminal 53 Low Current	4 mA*
Parameter 6-13 Terminal 53 High Current	20 mA*
Parameter 6-14 Terminal 53 Low Ref./Feedb. value	0 Hz
Parameter 6-15 Terminal 53 High Ref./Feedb. Value	50 Hz
*=Default value	
Notes/comments: D IN 37 is an option. Terminal 53 in the parameter title corresponds to terminal XD2.7 in the control compartment.	

Table 110: Wiring Configuration for Speed Reference (Using a Manual Potentiometer)



Parameters	
Function	**Setting**
Parameter 6-10 Terminal 53 Low Voltage	0.07 V*
Parameter 6-11 Terminal 53 High Voltage	10 V*
Parameter 6-14 Terminal 53 Low Ref./Feedb. value	0 Hz
Parameter 6-15 Terminal 53 High Ref./Feedb. Value	50 Hz
*=Default value	
Notes/comments: D IN 37 is an option. Terminal 53 in the parameter title corresponds to terminal XD2.7 in the control compartment.	

Table 111: Wiring Configuration for Speed Up/Down

	Parameter	
	**Function**	**Setting**
	Parameter 5-10 Terminal 18 Digital Input	*[8] Start**
	Parameter 5-12 Terminal 27 Digital Input	*[19] Freeze Reference*
	Parameter 5-13 Terminal 29 Digital Input	*[21] Speed Up*
	Parameter 5-14 Terminal 32 Digital Input	*[22] Speed Down*
	*=Deafult value	
	Notes/comments: D IN 37 is an option. Terminal 18 in the parameter title corresponds to terminal XD2.12 in the control compartment. Terminal 27 in the parameter title corresponds to terminal XD2.14 in the control compartment. Terminal 29 in the parameter title corresponds to terminal XD2.15 in the control compartment. Terminal 32 in the parameter title corresponds to terminal XD2.16 in the control compartment.	

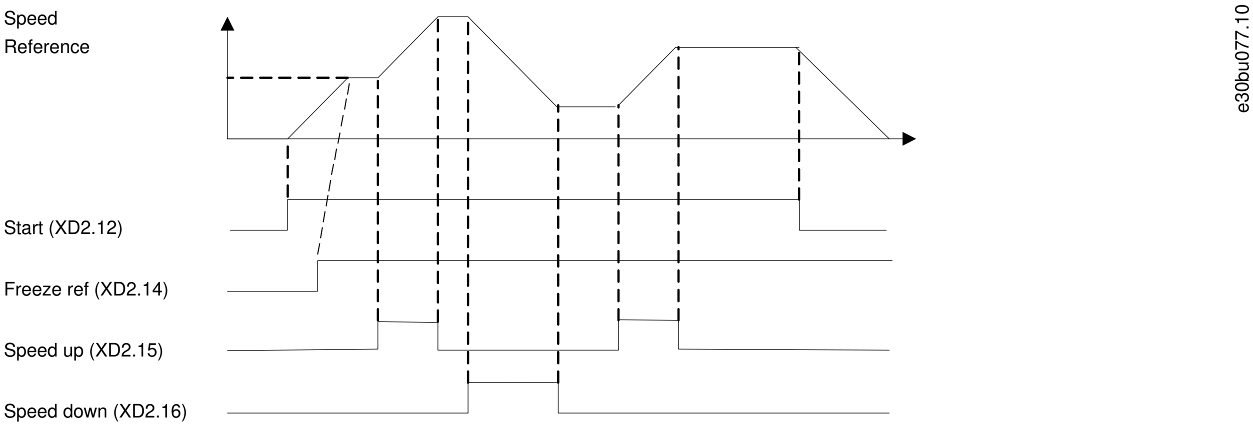


Illustration 137: Speed Up/Down

12.1.5 Wiring Configuration: Feedback

Table 112: Wiring Configuration for Analog Current Feedback Transducer (2-wire)

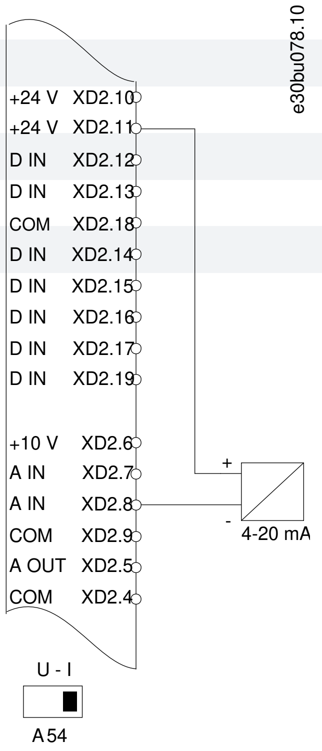
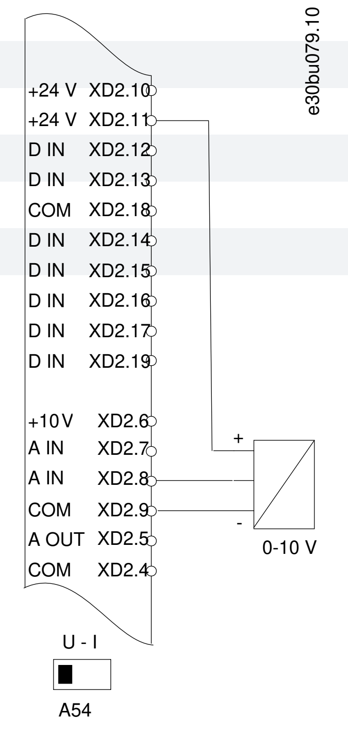
	Parameters	
	**Function**	**Setting**
	Parameter 6-22 Terminal 54 Low Current	4 mA*
	Parameter 6-23 Terminal 54 High Current	20 mA*
	Parameter 6-24 Terminal 54 Low Ref./Feedb. value	0*
	Parameter 6-25 Terminal 54 High Ref./Feedb. Value	50*
	*=Default value	
	Notes/comments: D IN 37 is an option. Terminal 54 in the parameter title corresponds to terminal XD2.8 in the control compartment.	

Table 113: Wiring Configuration for Analog Voltage Feedback Transducer (3-wire)



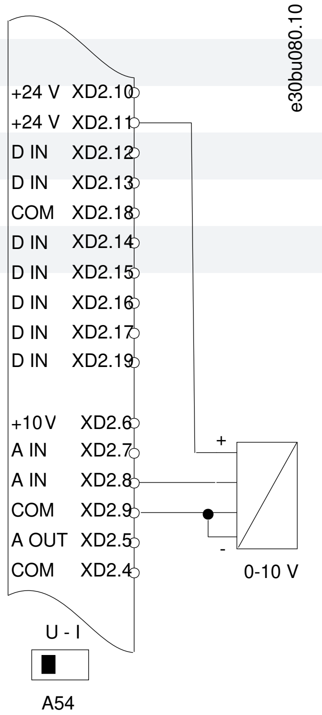
Parameters	
Function	**Setting**
Parameter 6-20 Terminal 54 Low Voltage	0.07 V*
Parameter 6-21 Terminal 54 High Voltage	10 V*
Parameter 6-24 Terminal 54 Low Ref./Feedb. value	0*
Parameter 6-25 Terminal 54 High Ref./Feedb. Value	50*
*=Default value	

Notes/comments:

D IN 37 is an option.

Terminal 54 in the parameter title corresponds to terminal XD2.8 in the control compartment.

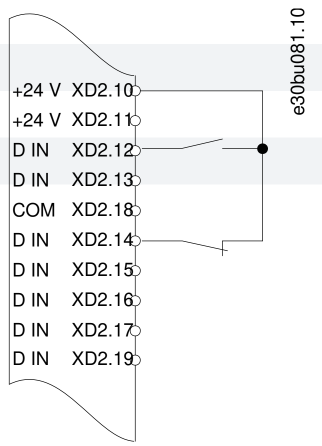
Table 114: Wiring Configuration for Analog Voltage Feedback Transducer (4-wire)



	Parameters	
	Function	**Setting**
	Parameter 6-20 Terminal 54 Low Voltage	0.07 V*
	Parameter 6-21 Terminal 54 High Voltage	10 V*
	Parameter 6-24 Terminal 54 Low Ref./Feedb. value	0*
	Parameter 6-25 Terminal 54 High Ref./Feedb. Value	50*
	*=Default value	
	Notes/comments: D IN 37 is an option. Terminal 54 in the parameter title corresponds to terminal XD2.8 in the control compartment.	

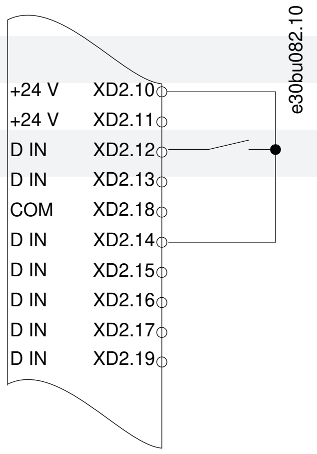
12.1.6 Wiring Configuration: Run/Stop

Table 115: Wiring Configuration for Run/Stop Command with External Interlock



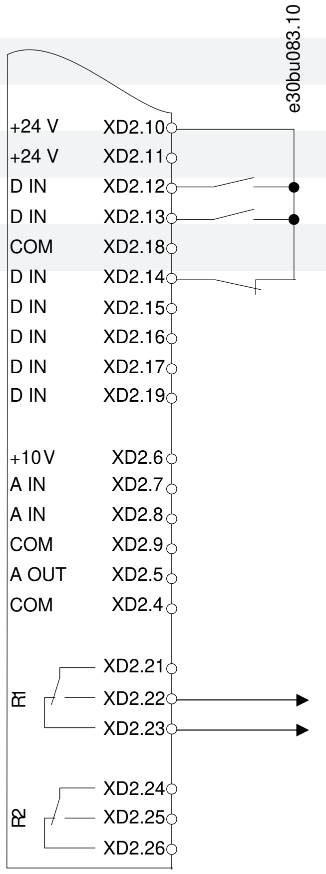
	Parameter	
	Function	**Setting**
	Parameter 5-10 Terminal 18 Digital Input	*[8] Start**
	Parameter 5-12 Terminal 27 Digital Input	*[7] External interlock*
	*=Default value	
	Notes/comments: D IN 37 is an option. Terminal 18 in the parameter title corresponds to terminal XD2.12 in the control compartment. Terminal 27 in the parameter title corresponds to terminal XD2.14 in the control compartment.	

Table 116: Wiring Configuration for Run/Stop Command without External Interlock



Parameter	
Function	**Setting**
Parameter 5-10 Terminal 18 Digital Input	*[8] Start**
Parameter 5-12 Terminal 27 Digital Input	*[7] External interlock*
*=Default value	
Notes/comments: If *parameter 5-12 Terminal 27 Digital Inputs* is set to *[0] No operation*, a jumper wire to terminal XD2.14 is not needed. D IN 37 is an option. Terminal 18 in the parameter title corresponds to terminal XD2.12 in the control compartment. Terminal 27 in the parameter title corresponds to terminal XD2.14 in the control compartment.	

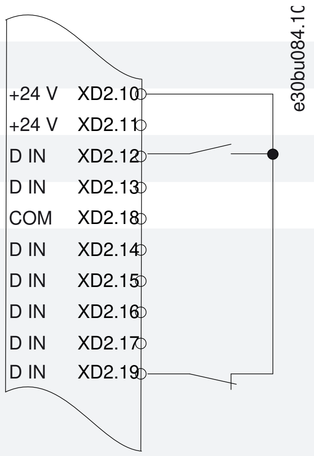
Table 117: Wiring Configuration for Run Permissive



Parameter	
Function	**Setting**
Parameter 5-10 Terminal 18 Digital Input	*[8] Start**
Parameter 5-11 Terminal 19 Digital Input	*[52] Run permissive*
Parameter 5-12 Terminal 27 Digital Input	*[7] External interlock*
Parameter 5-40 Function Relay	*[167] Start command act.*
*=Default value	
Notes/comments: D IN 37 is an option. Terminal 18 in the parameter title corresponds to terminal XD2.12 in the control compartment. Terminal 19 in the parameter title corresponds to terminal XD2.13 in the control compartment. Terminal 27 in the parameter title corresponds to terminal XD2.14 in the control compartment.	

12.1.7 Wiring Configuration: Start/Stop

Table 118: Wiring Configuration for Start/Stop Command with Safe Torque Off Option

	Parameter	
	**Function**	**Setting**
	Parameter 5-10 Terminal 18 Digital Input	*[Start]**
	Parameter 5-12 Terminal 27 Digital Input	*[0] No operation*
	Parameter 5-19 Terminal 37 Safe Stop	*[1] Safe Stop Alarm*
	*=Default value	
	Notes/comments: If *parameter 5-12 Terminal 27 Digital Input* is set to *[0] No operation*, a jumper wire to terminal XD2.14 is not needed. D IN 37 is an option. Terminal 18 in the parameter title corresponds to terminal XD2.12 in the control compartment. Terminal 27 in the parameter title corresponds to terminal XD2.14 in the control compartment. Terminal 37 in the parameter title corresponds to terminal XD2.19 in the control compartment.	

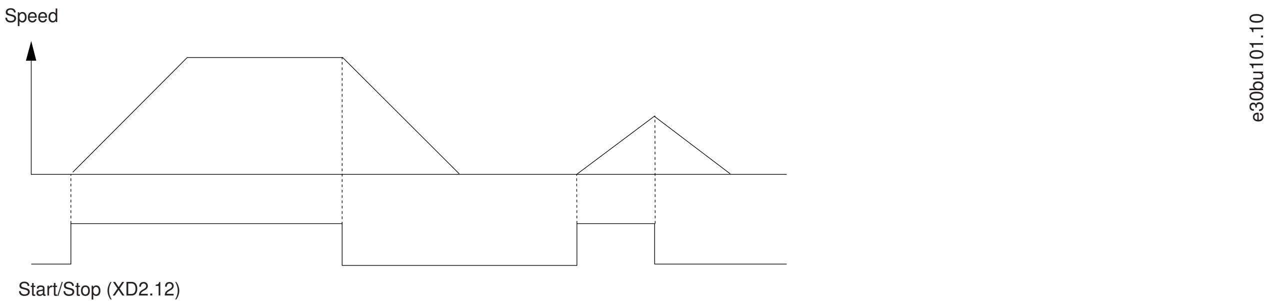
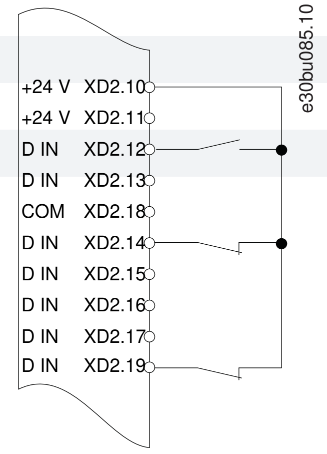


Illustration 138: Wiring Configuration for Start/Stop Command with Safe Torque Off

Table 119: Wiring Configuration for Pulse Start/Stop

	Parameter	
	**Function**	**Setting**
	Parameter 5-10 Terminal 18 Digital Input	*[9] Latched Start*
	Parameter 5-12 Terminal 27 Digital Input	*[6] Stop Inverse*
	*=Default value	
	Notes/comments: If *parameter 5-12 Terminal 27 Digital Input* is set *[0] No operation*, a jumper wire to terminal XD2.14 is not needed. D IN 37 is an option. Terminal 18 in the parameter title corresponds to terminal XD2.12 in the control compartment. Terminal 27 in the parameter title corresponds to terminal XD2.14 in the control compartment.	

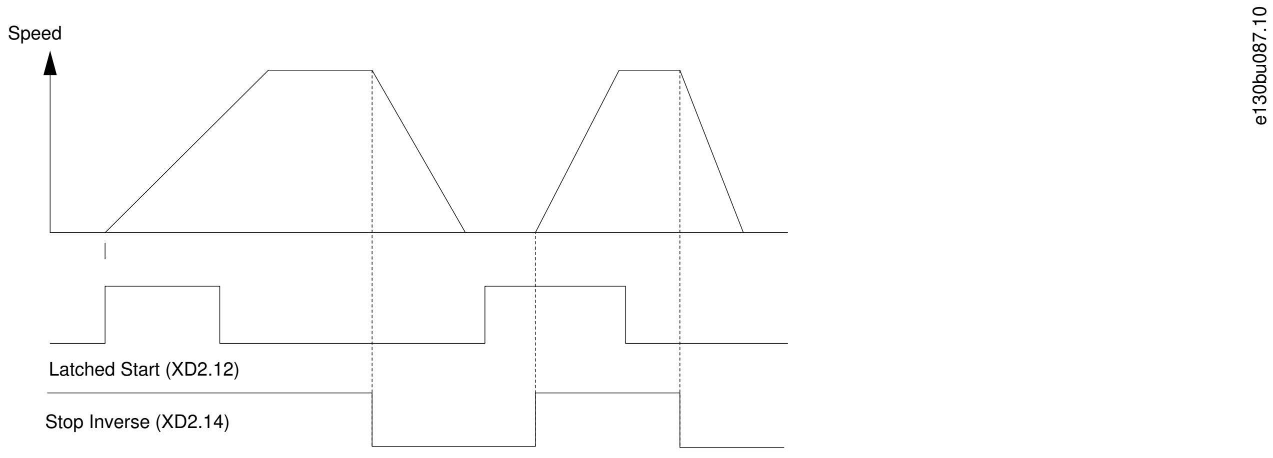
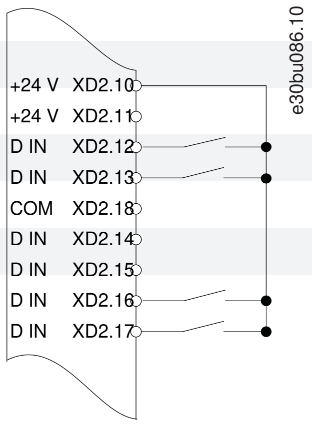


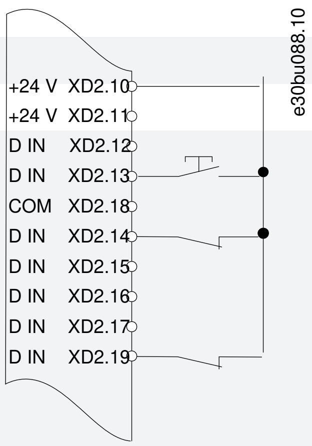
Illustration 139: Latched Start/Stop Inverse

Table 120: Wiring Configuration for Start/Stop with Reversing and 4 Preset Speeds

	Parameters	
	**Function**	**Setting**
	Parameter 5-10 Terminal 18 Digital Input	*[8] Start*
	Parameter 5-11 Terminal 19 Digital Input	*[10] Reversing**
	Parameter 5-12 Terminal 27 Digital Input	*[0] No operation*
	Parameter 5-14 Terminal 32 Digital Input	*[16] Preset ref bit 0*
	Parameter 5-15 Terminal 33 Digital Input	*[17] Preset ref bit 1*
	Parameter 3-10 Preset Reference	• Preset ref. 0 = 25% • Preset ref. 1 = 50% • Preset ref. 2 = 75% • Preset ref. 3 = 100%
	*=Default value	
	Notes/comments: D IN 37 is an option. Terminal 18 in the parameter title corresponds to terminal XD2.12 in the control compartment. Terminal 19 in the parameter title corresponds to terminal XD2.13 in the control compartment. Terminal 27 in the parameter title corresponds to terminal XD2.14 in the control compartment. Terminal 32 in the parameter title corresponds to terminal XD2.16 in the control compartment. Terminal 33 in the parameter title corresponds to terminal XD2.17 in the control compartment.	

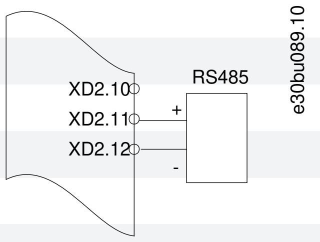
12.1.8 Wiring Configuration: External Alarm Reset

Table 121: Wiring Configuration for External Alarm Reset

	Parameter	
	**Function**	**Setting**
	Parameter 5-11 Terminal 19 Digital Input	*[1] Reset*
	*=Default value	
	Notes/comments: D IN 37 is an option. Terminal 19 in the parameter title corresponds to terminal XD2.13 in the control compartment.	

12.1.9 Wiring Configuration: RS485

Table 122: Wiring Configuration for RS485 Network Connection

	Parameter	
	**Function**	**Setting**
	Parameter 8-30 Protocol	FC*
	Parameter 8-31 Address	1*
	Parameter 8-32 Baud Rate	9600*
	*=Default value	
	Notes/comments: Select protocol, address, and baud rate in the above-mentioned parameters. D IN 37 is an option.	

12.1.10 Wiring Configuration: Motor Thermistor

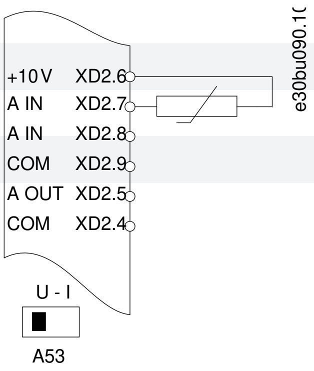
CAUTION

THERMISTOR INSULATION

Risk of personal injury or equipment damage.

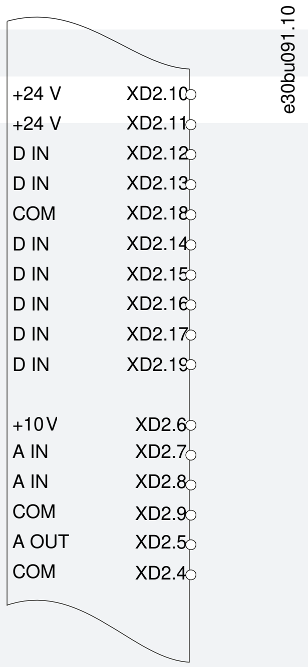
- Use only thermistors with reinforced or double insulation to meet PELV insulation requirements.

Table 123: Wiring Configuration for Motor Thermistor

	Parameters	
	**Function**	**Setting**
	Parameter 1-90 Motor Thermal Protection	*[2] Thermistor trip*
	Parameter 1-93 Thermistor Source	*[1] Analog input 53*
	* = Default value	
	If only a warning is required, set *parameter 1-90 Motor Thermal Protection* to *[1] Thermistor warning*. D IN 37 is an option. Input 53 in the parameter corresponds to terminal XD2.7 in the control compartment.	

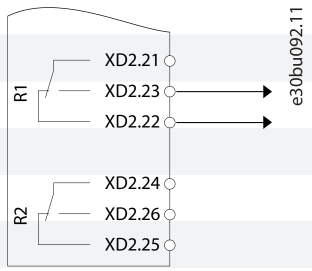
12.1.11 Wiring for Regeneration

Table 124: Wiring Configuration for Regeneration

	Parameters	
	**Function**	**Setting**
	Parameter 1-90 Motor Thermal Protection	100%*
	* = Default value	
	To disable regeneration, decrease *parameter 1-90 Motor Thermal Protection* to 0%. However, if the application uses motor brake power and regeneration is not enabled, the drive will trip.	

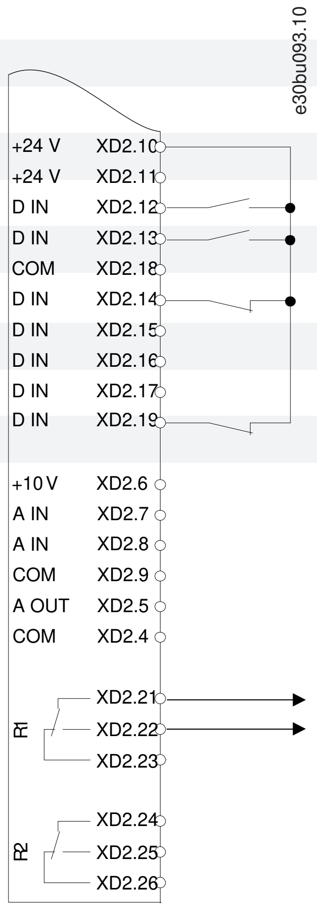
12.1.12 Wiring Configuration for a Relay Set-up with Smart Logic Control

Table 125: Wiring Configuration for a Relay with Smart Logic Control

	Parameters	
	**Function**	**Setting**
	Parameter 4-30 Motor Feedback Loss Function	*[1] Warning*
	Parameter 4-31 Motor Feedback Speed Error	100 RPM
	Parameter 4-32 Motor Feedback Loss Timeout	5 s
	Parameter 7-00 Speed PID Feedback Source	*[2] MCB 102*
	Parameter 17-11 Resolution (PPR)	1024*
	Parameter 13-00 SL Controller Mode	*[1] On*
	Parameter 13-01 Start Event	*[19] Warning*
	Parameter 13-02 Stop Event	*[44] Reset key*
	Parameter 13-10 Comparator Operand	*[21] Warning no.*
	Parameter 13-11 Comparator Operator	*[1] ≈ (equal)**
	Parameter 13-12 Comparator Value	90
	Parameter 13-51 SL Controller Event	*[22] Comparator 0*
	Parameter 13-52 SL Controller Action	*[32] Set digital out A low*
	Parameter 5-40 Function Relay	*[80] SL digital output A*
	*=Default value	
	Notes/comments: If the limit in the feedback monitor is exceeded, *warning 90, Feedback Mon.* is issued. The SLC monitors *warning 90, Feedback Mon.* and if the warning becomes true, relay 1 is triggered. External equipment may require service. However, if the feedback error goes below the limit again within 5 s and the warning disappears, press [Reset] on the LCP.	

12.1.13 Wiring Configuration: Mechanical Brake Control

Table 126: Wiring Configuration for Mechanical Brake Control

	Parameters	
	Function	**Setting**
	*Parameter 5-40 Function Relay*	*[32] Mech. brake ctrl.*
	Parameter 5-10 Terminal 18 Digital Input	*[8] Start**
	Parameter 5-11 Terminal 19 Digital Input	*[11] Start reversing*
	Parameter 1-71 Start Delay	0.2
	Parameter 1-72 Start Function	*[5] VVC+/ FLUX Clockwise*
	Parameter 1-76 Start Current	$I_{m,n}$
	Parameter 2-20 Release Brake Current	Application dependent
	Parameter 2-21 Activate Brake Speed [RPM]	Half of nominal slip of the motor
	* = Default value	
	Notes/comments: Terminal 18 in the parameter title corresponds to terminal XD2.12 in the control compartment. Terminal 19 in the parameter title corresponds to terminal XD2.13 in the control compartment.	

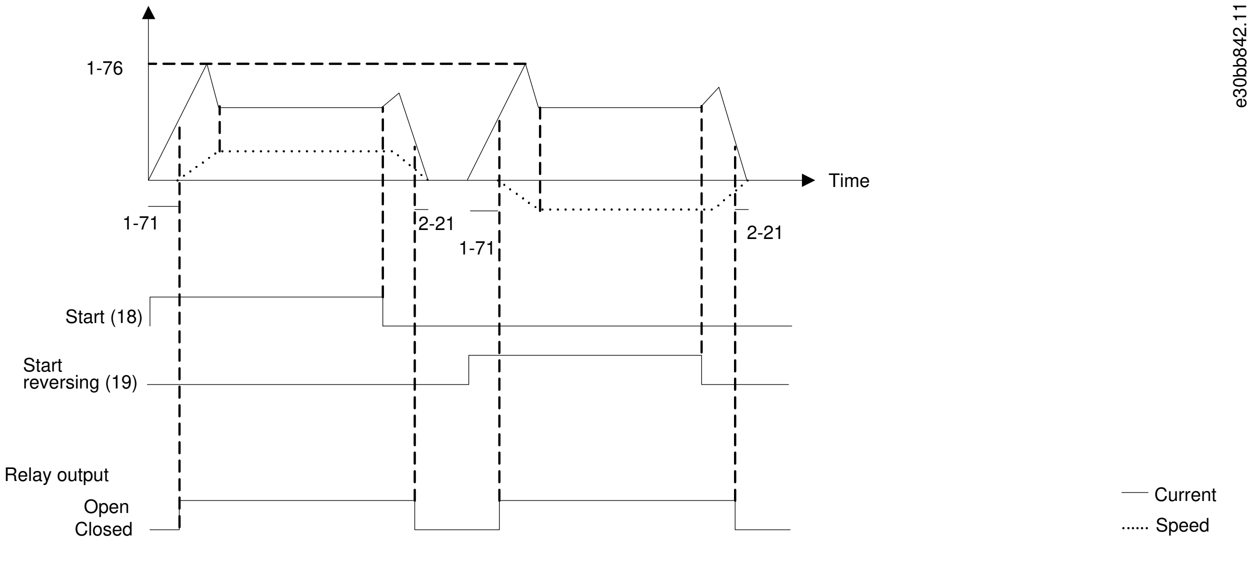


Illustration 140: Mechanical Brake Control

12.1.14 Wiring Configuration for the Encoder

The direction of the encoder, identified by looking into the shaft end, is determined by which order the pulses enter the drive.

- Clockwise (CW) direction means channel A is 90 electrical degrees before channel B.
- Counterclockwise (CCW) direction means channel B is 90 electrical degrees before A.

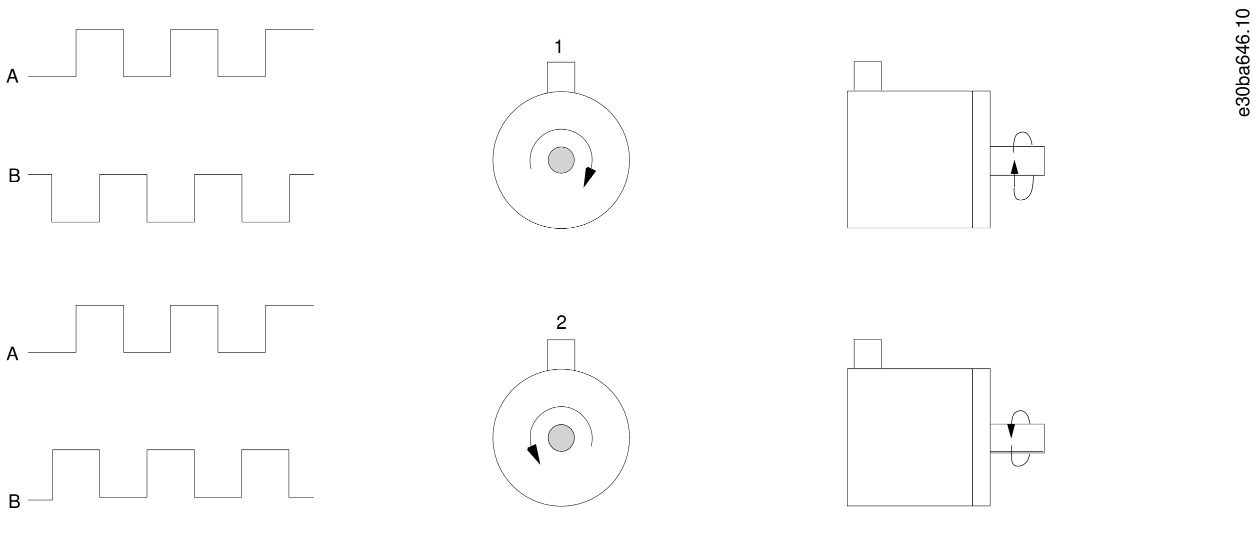


Illustration 141: Determining Encoder Direction

NOTICE

Maximum cable length is 5 m (16 ft.)

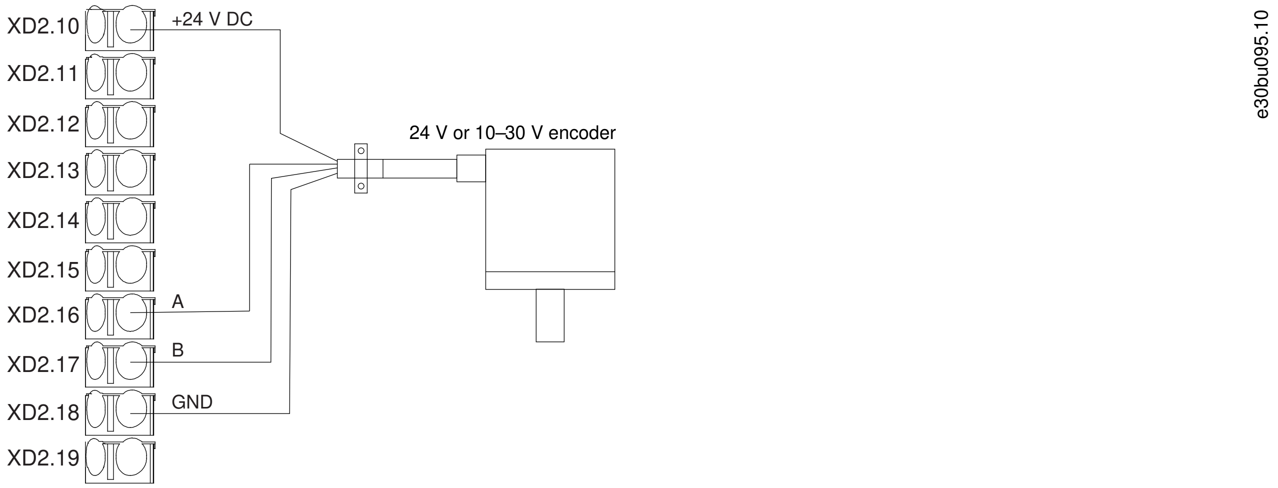


Illustration 142: Wire Configuration for the Encoder

12.1.15 Wiring Configuration for Torque and Stop Limit

In applications with an external electro-mechanical brake, such as hoisting applications, it is possible to stop the drive via a standard stop command and simultaneously activate the external electro-mechanical brake.

If a stop command is activated via terminal XD2.12 and the drive is not at the torque limit, the motor ramps down to 0 Hz. If the drive is at the torque limit and a stop command is activated, the system activates terminal XD2.15 output (programmed to *[27] Torque limit & stop*). The signal to terminal XD2.14 changes from logic 1 to logic 0 and the motor starts to coast. This process ensures that the hoist stops even if the drive itself cannot handle the required torque, for example due to excessive overload.

Example of programming a hoisting application

To program the stop and torque limit for the above example, perform the following connections:

- Connect to terminal XD2.12. Then set *parameter 5-10 Terminal 18 Digital Input* to *8 [Set]*.
- Connect terminal XD2.14 to terminal XD2.15. Then set the following parameters:
  - *Parameter 5-12 Terminal 27 Digital Input* to *[2] Coasting Stop, Inverse*.
  - *Parameter 5-02 Terminal 29 Mode* to *[1] Terminal 29 Mode Output*.
  - *Parameter 5-31 Terminal 29 Digital Output* to *[27] Torque limit & stop*.
- Connect to relay output 1 (XD2.21). Then set *parameter 5-40 Function Relay* to *[32] Mechanical Brake Control*.

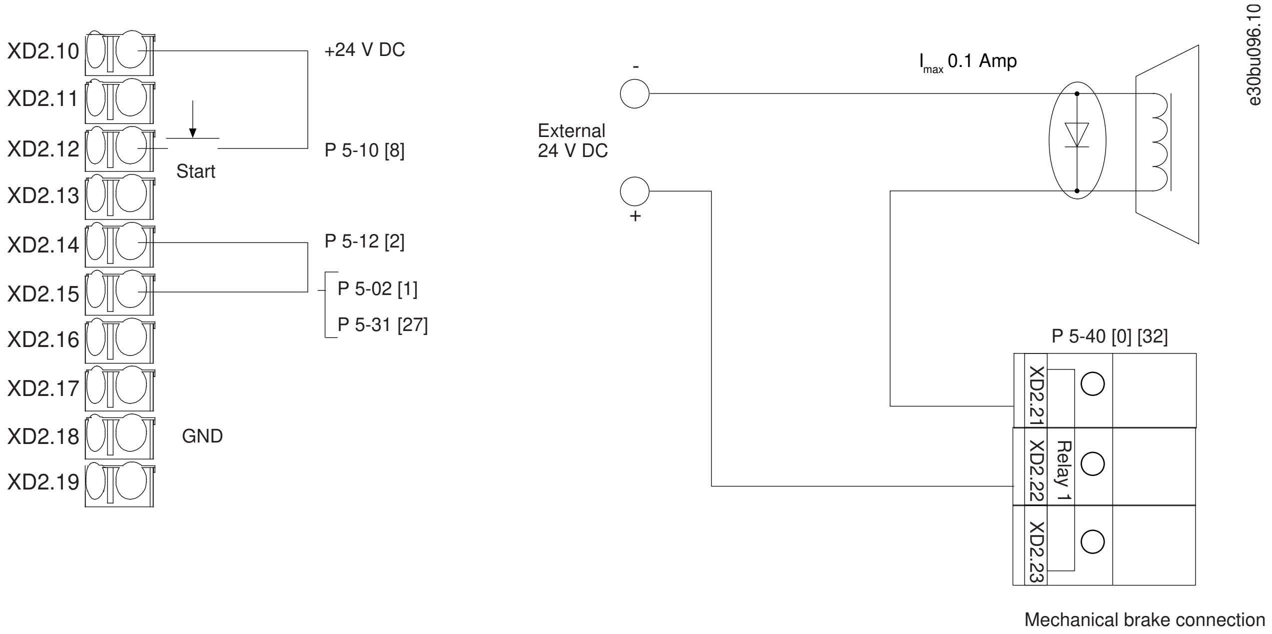


Illustration 143: Wire Configuration for Torque and Stop Limit

13 How to Order a Drive

13.1 Drive Configurator

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
P	L	V				T	4	I	9	0	K	C	1	X	M	X	D	X	X	1	X	A	X	L	2	1	X	X	X	X	X	X	X	X	2	X	X	X

e30bu326.10

Illustration 144: Type Code Example

Configure the right drive for the right application from the internet-based Drive Configurator and generate the type code string. The Drive Configurator automatically generates an 8-digit sales number to be delivered to the local sales office. Furthermore, it is possible to establish a project list with several products and send it to a Danfoss sales representative.

The Drive Configurator can be found on the global website: www.danfoss.com/drives.

13.1.1 Type Code

An example of the type code is:

PLV302T7I710C1BMXXXX7XAXL21XXXXXXXD2

The meaning of the characters in the string is in table 127 and table 128. In the example above, a brake IGBT, a 120 V internal auxiliary power supply, and an emergency switch off are built in.

Table 127: Ordering Type Code, Enclosures D9h–D10h and E5h–E6h

Description	Position	Possible options
Product group	1–3	PLV
Drive series	4–6	302: FC 302
Input filter	7	T: None
		P: Passive THDi=5%, 50 Hz
		H: Passive THDi=8%, 50 Hz
		L: Passive THDi=5%, 60 Hz
		U: Passive THDi=8%, 60 Hz
Mains voltage	8	5: 380–500 V
		7: 525–690 V
Standard	9	I: IEC
		U: UL
Power rating	10–12	90: (N90K) 90 kW/125 hp
		110: (N110) 110 kW/150 hp
		132: (N132) 132 kW/200 hp

Description	Position	Possible options
		160: (N160) 160 kW/250 hp
		200: (N200) 200 kW/315 hp
		250: (N250) 250 kW/355 hp
		315: (N315) 315 kW/400 hp
		355: (N355) 355 kW/450 hp
		400: (N400) 400 kW/550 hp
		450: (N450) 450 kW/600 hp
		500: (N500) 500 kW/650 hp
		560: (N560) 560 kW/750 hp
		630: (N630) 630 kW/900 hp
		710: (N710) 710 kW/1000 hp
PCB coating (drive module)	13	C: Coated
		R: Uncoated
Plinth	14	1: 100 mm (3.9 in)
		2: 200 mm (7.9 in)
		4: 400 mm (15.7 in)
		5: Marine
Brake	15	X: No brake IGBT
		B: Brake IGBT
Mains option	16–17	MX: No infeed option
		M1: Fusible disconnect
		M2: Non-fusible disconnect
		M3: Circuit breaker
		M4: Mains contactor
		M5: AC reactor
		M6: Fuses
		MA: Fusible disconnect + mains contactor
		MB: Non-fusible disconnect + mains contactor
		MC: AC reactor + fusible disconnect
		MD: AC reactor + fusible disconnect + mains contactor
		ME: AC reactor + non-fusible disconnect
		MF: AC reactor + circuit breaker

Description	Position	Possible options
		MG: AC reactor + mains contactor
		MH: AC reactor + fusible disconnect + mains contactor
Output filter	18	X: No filter
		D: dU/dt
		S: Sine-wave
		C: Common mode
		1: Common mode + dU/dt
		2: Common mode + sine-wave
Unused	19	X: None
Cable in-feed	20	X: Bottom
		T: Top
		L: Mains top, motor bottom
		M: Mains bottom, motor top
Auxiliary supply	21	1: 230 V AC External
		2: 230 V AC Internal
		4: 230 V AC Internal + 24 V DC Internal
		5: 230 V AC External + 24 V DC Internal
		6: 120 V AC External
		7: 120 V AC Internal
		8: 120 V AC Internal + 24 V DC Internal
		9: 120 V AC External + 24 V DC Internal
Back-channel cooling	22	X: In bottom/out top
		1: In back/out back
		C: In back/out top
		D: In bottom/out back
		N: No back channel cooling
Auxiliary functional options	23–24	AX: No auxiliary options
		A1: AC socket + cabinet light
		A2: Extended I/O terminals
		A3: Cabinet heater
		A4: Motor heater control

Description	Posi-tion	Possible options
		A5: Insulation monitor
		AA: AC socket + cabinet light + extended I/O terminals
		AB: AC socket + cabinet light + cabinet heater
		AC: AC socket + cabinet light + motor heater control
		AD: AC socket + cabinet light + insulation monitor
		AE: AC socket + cabinet light + extended I/O terminals + cabinet heater
		AF: AC socket + cabinet light + extended I/O terminals + motor heater control
		AG: AC socket + cabinet light + extended I/O terminals + insulation monitor
		AH: AC socket + cabinet light + extended I/O terminals + cabinet heater + motor heater control
		AI: AC socket + cabinet light + extended I/O terminals + cabinet heater + insulation monitor
		AJ: AC socket + cabinet light + extended I/O terminals + motor heater control + insulation monitor
		AK: AC socket + cabinet light + extended I/O terminals + cabinet heater + motor heater control + insulation monitor
		AL: AC socket + cabinet light + cabinet heater + motor heater control
		AM: AC socket + cabinet light + cabinet heater + insulation monitor
		AN: AC socket + cabinet light + cabinet heater + motor heater control + insulation monitor
		AO: AC socket + cabinet light + motor heater control + insulation monitor
		AP: Extended I/O terminals + cabinet heater
		AQ: Extended I/O terminals + motor heater control
		AR: Extended I/O terminals + insulation monitor
		AS: Extended I/O terminals + cabinet heater + motor heater control
		AT: Extended I/O terminals + cabinet heater + insulation monitor
		AU: Extended I/O terminals + cabinet heater + motor heater control + insulation monitor
		AV: Extended I/O terminals + motor heater control + insulation monitor
		AW: Cabinet heater + motor heater control
		A8: Cabinet heater + insulation monitor
		AY: Cabinet heater + motor heater control + insulation monitor
		AZ: Motor heater control + insulation monitor
User interface	25	L: LCP in door
		N: No LCP in door
Protection rating	26–27	21: IP21
		54: IP54
Door-mounted option	28–29	XX: No door-mounted option

Description	Position	Possible options
		D1: Signal lights + reset button
		D2: Emergency switch off with push button
		D4: STO/SS1 with emergency push button + SLS (TTL encoder)
		D5: STO/SS1 with emergency push button + SLS (HTL encoder)
		DA: Signal lights + reset button + emergency switch with push button
		DC: Signal lights + reset button + STO/SS1 with emergency push button + SLS (TTL encoder)
		DE: Signal lights + reset button + STO/SS1 with emergency push button + SLS (HTL encoder)

Table 128: Ordering Type Code, Options

Description	Position	Possible options
A option	30	X: No A option
		0: VLT® PROFIBUS DP-V1 MCA 101 (standard)
		4: VLT® DeviceNet MCA 104 (standard)
		6: VLT® CANopen MCA 105 (standard)
		G: VLT® LonWorks MCA 108
		J: VLT® BACnet MCA 109
		T: VLT® PROFIBUS Converter VLT 300 MCA 113
		U: VLT® PROFIBUS Converter VLT 5000 MCA 114
		L: VLT® PROFINET MCA 120
		N: VLT® EtherNet/IP MCA 121
		Q: VLT® Modbus TCP MCA 122
		Y: VLT® POWERLINK MCA 123
		8: VLT® EtherCAT MCA 124
		W: VLT® DeviceNet Converter MCA 194
B option	31	X: No B option
		0: VLT® Analog I/O MCB 109
		2: VLT® PTC Thermistor Card MCB 112
		4: VLT® Sensor Input MCB 114
		K: VLT® General Purpose I/O Option MCB 101
		P: VLT® Relay Option MCB 105
		Y: VLT® Extended Cascade Controller MCO 101
		R: VLT® Encoder Option MCB 102
		U: VLT® Resolver Option MCB 103
		Z: VLT® Safety PLC Interface MCB 108

Description	Position	Possible options
		6: VLT® Safe Option TTL MCB 150
		7: VLT® Safe Option HTL MCB 151
		S: VLT® Safety Option MCB 152
C0 option	32	X: No C0 option
		4:VLT® Motion Control MCO 305
C1 option	33	X: No C1 option
		5: VLT® Advanced Cascade Controller MCO 102
		R: VLT® Extended Relay Card MCB 113
C option software/E1 option	34	X: No C software option
		0: VLT® Synchronizing Controller MCO 350
		1: VLT® Positioning Controller MCO 351
		2: VLT® Center Winder MCO 352
		D: VLT® 24 V DC Supply MCB 107
D option	35	0: VLT® 24 V DC Supply MCB 107
		X: No D option
EMC filter	36	2: (H2) RFI class A2 (C3)
		4: (H4) RFI class A1 (C2)
		5: (H5) RFI marine

13.1.2 Language Packages

Drives are automatically delivered with a language package relevant to the region from which it is ordered. 4 regional language packages cover the following languages:

Table 129: Regional Language Packages

Language package 1	Language package 2	Language package 3	Language package 4
English	English	English	English
German	German	German	German
French	Chinese	Slovenian	Spanish
Danish	Korean	Bulgarian	English US
Spanish	Thai	Romanian	Brazilian Portuguese
Swedish	Traditional Chinese	Hungarian	Turkish
Italian	Bahasa Indonesian	Czech	Polish
Finnish		Russian	

To order drives with a different language package, contact the local sales office.

13.2 Ordering Numbers for Customer-Installed Options and Kits

13.2.1 Order Numbers for Options for Slot A

Table 130: Ordering Numbers for A Options

Description	Ordering number	
	Uncoated	Coated
VLT® PROFIBUS DP MCA 101	130B1100	130B1200
VLT® DeviceNet MCA 104	130B1102	130B1202
VLT® CANopen MCA 105	130B1103	130B1205
VLT® PROFIBUS Converter MCA 113	130B1245	–
VLT® PROFIBUS Converter MCA 114	–	130B1246
VLT® PROFINET MCA 120	130B1135	130B1235
VLT® EtherNet/IP MCA 121	130B1119	130B1219
VLT® Modbus TCP MCA 122	130B1196	130B1296
VLT® POWERLINK MCA 123	130B1489	130B1490
VLT® EtherCAT MCA 124	130B5546	130B5646
VLT® DeviceNet Converter MCA 194	–	130B5601

13.2.2 Order Numbers for Options for Slot B

Table 131: Ordering Numbers for B Options

Descriptions	Ordering number	
	Uncoated	Coated
VLT® General Purpose I/O MCB 101	130B1125	130B1212
VLT® Encoder Input MCB 102	130B1115	130B1203
VLT® Resolver Input MCB 103	130B1127	130B1227
VLT® Relay Option MCB 105	130B1110	130B1210
VLT® Safe PLC I/O MCB 108	130B1120	130B1220
VLT® PTC Thermistor Card MCB 112	–	130B1137
VLT® Programmable I/O MCB 115	–	130B1266
VLT® Safe option MCB 150	–	130B3280
VLT® Safe option MCB 151	–	130B3290
VLT® PROFIsafe MCB 152	130B1135	130B1235
VLT® Sensorless Safety MCB 159 (1)	Select VLT® Sensorless Safety MCB 159 as a C1 option in the configurator when ordering a new drive.	

[1] *MCB 159 is factory-mounted and must be ordered with VLT® Safety Option MCB 151.*

13.2.3 Order Numbers for Options for Slot C

Table 132: Ordering Numbers for C Options

Description	Ordering number	
	Uncoated	Coated
VLT® Motion Controller MCO 305	130B1134	130B1234
VLT® Synchronizing Controller MCO 350	130B1152	130B1252
VLT® Positioning Controller MCO 351	130B1153	120B1253
VLT® Extended Relay Card MCB 113	130B1164	130B1264
VLT® Mounting Kit for C Option, 40 mm, enclosure sizes A2/A3	130B7530	
VLT® Mounting Kit for C Option, 60 mm, enclosure sizes A2/A3	130B7531	
VLT® Mounting Kit for C Option, enclosure size A5	130B7532	
VLT® Mounting Kit for C Option, enclosure sizes B/C/D/E/F (except B3)	130B7533	
VLT® Mounting Kit for C Option, 40 mm, enclosure size B3	130B1413	
VLT® Mounting Kit for C Option, 60 mm, enclosure size B3	130B1414	

13.2.4 Order Numbers for Options for Slot D

Table 133: Order Numbers for D Options

Description	Order number	
	Uncoated	Coated
VLT® 24 V DC Supply MCB 107	130B1108	130B1208
VLT® Real-time Clock MCB 117	–	130B6544

13.2.5 Order Numbers for PC Software

Table 134: Order Numbers for VLT® Motion Control Tool MCT 10

Description	Order number
VLT® Motion Control Tool MCT 10, 1 license	130B1000
VLT® Motion Control Tool MCT 10, 5 licenses	130B1001
VLT® Motion Control Tool MCT 10, 10 licenses	130B1002
VLT® Motion Control Tool MCT 10, 25 licenses	130B1003
VLT® Motion Control Tool MCT 10, 50 licenses	130B1004
VLT® Motion Control Tool MCT 10, 100 licenses	130B1005
VLT® Motion Control Tool MCT 10, >100 licenses	130B1006

13.2.6 Ordering of Brake Resistors, VLT® AutomationDrive FC 302

Explanation of terms used in the tables for ordering brake resistors

Horizontal braking: Duty cycle 10% and maximum 120 s repetition rates according to the reference brake profile. Average power corresponds to 6%.

Vertical braking: Duty cycle 40% and maximum 120 s repetition rates according to the reference brake profile. Average power corresponds to 27%.

Cable cross-section: Recommended minimum value based on PVC-insulated copper cable, 30 °C (86 °F) ambient temperature with normal heat dissipation. All cabling must comply with national and local regulations on cable cross-sections and ambient temperature.

Thermal relay: Brake current setting of external thermal relay. All resistors have a built-in thermal relay switch N.C.

The IP54 is with 1000 mm (39.4 in) fixed, unshielded cable. Can be used for vertical and horizontal mounting. For horizontal mounting, derating is required.

IP21 and IP65 are with screw terminal for cable termination and can be used for horizontal and vertical mounting. For horizontal mounting, derating is required.

IP20 is with bolt connection for cable termination. Used for floor mounting.

IP65 is a flat-pack type brake resistor with fixed cable.

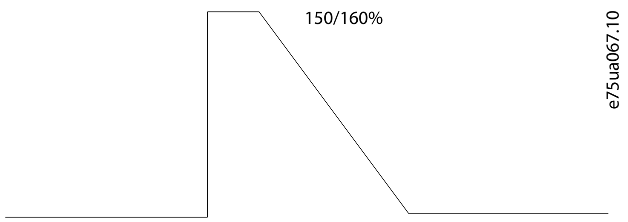


Illustration 145: Horizontal Loads

Illustration 146: Vertical Loads

13.2.6.1 Order Numbers for Brake Resistors, 380–500 V, Vertical Braking 40% Duty Cycle

Table 135: Ordering Numbers for Brake Resistors, 380–500 V, Vertical Braking 40% Duty Cycle

Drive data	Brake resistor data		Installation
		Danfoss part numbers	

Drive data			Brake resistor data						Installation	
P_m [kW (hp)]	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont}$ [kW]	Wire IP54	Screw terminal IP65	Screw terminal IP20	Bolt connection IP20	Cable cross-section [mm^2 (AWG)]	Thermo relay [A]
90 (125)	3.6	5.1	4.7	42	–	–	–	175u3221	50	95
110 (150)	3.0	4.2	3.7	52	–	–	–	175u3223	70	119
132 (200)	2.5	3.5	3.3	60	–	–	–	175u3225	2x35	135
160 (250)	2.0	2.9	2.7	78	–	–	–	175u3228	2x50	170
200 (300)	1.6	2.3	2.1	90	–	–	–	175u3230	2x70	207
250 (350)	1.2	1.8	1.7	–	–	–	–	–	–	–
315 (450)	1.2	1.5	1.3	–	–	–	–	–	–	–
355 (500)	1.1	1.3	1.2	–	–	–	–	–	–	–
400 (550)	0.9	1.1	1.1	–	–	–	–	–	–	–
450 (600)	0.9	1.0	2x1.9	–	–	–	–	–	–	–
500 (650)	0.9	0.9	2x1.7	–	–	–	–	–	–	–

13.2.6.2 Order Numbers for Brake Resistors, 380–500 V, Horizontal Braking 10% Duty Cycle

Table 136: Ordering Numbers for Brake Resistors, 380–500 V, Horizontal Braking 10% Duty Cycle

Drive data			Brake resistor data						Installation	
					Danfoss part numbers					
P_m [kW (hp)]	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont}$ [kW]	Wire IP54	Screw terminal IP65	Screw terminal IP20	Bolt connection IP20	Cable cross-section [mm^2 (AWG)]	Thermo relay [A]
90 (125)	3.6	5.1	4.7	9	–	–	–	175u3079	16	44
110 (150)	3.0	4.2	3.7	11	–	–	–	175u3083	25	55
132 (200)	2.5	3.5	3.3	13	–	–	–	175u3084	35	63

Drive data			Brake resistor data						Installation	
160 (250)	2.0	2.9	2.7	16	–	–	–	175u3088	50	77
200 (300)	1.6	2.3	2.1	20	–	–	–	175u3091	70	98
250 (350)	1.2	1.8	1.7	26	–	–	–	175u3093	2x35	124
315 (450)	1.2	1.5	1.3	32	–	–	–	175u3097	2x35	157
355 (500)	1.1	1.3	1.2	36	–	–	–	175u3098	2x50	173
400 (550)	0.9	1.1	1.1	42	–	–	–	175u3099	2x50	196
450 (600)	0.9	1.0	2x1.9	–	–	–	–	–	–	–
500 (650)	0.9	0.9	2x1.7	–	–	–	–	–	–	–

13.2.6.3 Order Numbers for Brake Resistors, 525–690 V, Vertical Braking 40% Duty Cycle

Table 137: Ordering Numbers for Brake Resistors, 525–690 V, Vertical Braking 40% Duty Cycle

Drive data			Brake resistor data						Installation	
					Danfoss part numbers					
P_m [kW (hp)]	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont}$ [kW]	Wire IP54	Screw terminal IP65	Screw terminal IP20	Bolt connection IP20	Cable cross-section [mm^2 (AWG)]	Thermo relay [A]
90 (100)	8.8	9.5	9.1	42	–	–	–	175u3214	35	68
110 (125)	6.6	7.8	7.4	52	–	–	–	175u3215	50	84
132 (150)	4.2	6.4	6.1	60	–	–	–	175u3218	70	99
160 (200)	4.2	5.3	5.0	78	–	–	–	175u3220	2x35	125
200 (250)	3.4	4.2	4.0	90	–	–	–	175u3222	2x35	150
250 (300)	2.3	3.4	3.2	–	–	–	–	–	–	–
315 (350)	2.3	2.7	2.5	–	–	–	–	–	–	–
355 (400)	2.0	2.4	2.3	–	–	–	–	–	–	–

Drive data			Brake resistor data						Installation	
400 (400)	1.9	2.1	2.0	–	–	–	–	–		–
500 (500)	1.5	1.7	1.6	–	–	–	–	–		–
560 (600)	1.4	1.5	1.4	–	–	–	–	–	–	–
630 (650)	1.2	1.3	2x2.6	–	–	–	–	–	–	–
710 (750)	1.1	1.2	2x2.2	–	–	–	–	–	–	–

13.2.6.4 Order Numbers for Brake Resistors, 525–690 V, Horizontal Braking 10% Duty Cycle

Table 138: Ordering Numbers for Brake Resistors, 525–690 V, Horizontal Braking 10% Duty Cycle

Drive data			Brake resistor data						Installation	
					Danfoss part numbers					
P_m [kW (hp)]	R_{min} [Ω]	$R_{br.nom}$ [Ω]	R_{rec} [Ω]	$P_{br.cont}$ [kW]	Wire IP54	Screw terminal IP65	Screw terminal IP20	Bolt connection IP20	Cable cross-section [mm^2 (AWG)]	Thermo relay [A]
90 (100)	8.8	9.5	9.1	9	–	–	–	175u3067	16	32
110 (125)	6.6	7.8	7.4	11	–	–	–	175u3072	16	39
132 (150)	4.2	6.4	6.1	13	–	–	–	175u3075	16	46
160 (200)	4.2	5.3	5.0	16	–	–	–	175u3078	25	57
200 (250)	3.4	4.2	4.0	20	–	–	–	175u3082	35	71
250 (300)	2.3	3.4	3.2	26	–	–	–	175u3085	50	90
315 (350)	2.3	2.7	2.5	32	–	–	–	175u3089	70	113
355 (400)	2.0	2.4	2.3	36	–	–	–	175u3090	2x35	125
400 (400)	1.9	2.1	2.0	42	–	–	–	175u3092	2x35	145
500 (500)	1.5	1.7	1.6	52	–	–	–	175u3094	2x50	180
560 (600)	1.4	1.5	1.4	60	–	–	–	175u3095	2x50	207

Drive data			Brake resistor data						Installation	
630 (650)	1.2	1.3	2x2.6	–	–	–	–	–	–	–
710 (750)	1.1	1.2	2x2.2	–	–	–	–	–	–	–

13.2.7 Spare Parts

Visit the VLT® Shop or the configurator for ordering spare parts available for a specific application on VLTshop.danfoss.com.

14 Appendix

14.1 Symbols and Abbreviations

60° AVM	Pulse width modulation
°C	Degrees Celsius
°F	Degrees Fahrenheit
AC	Alternating current
AEO	Automatic energy optimization
AWG	American wire gauge
AMA	Automatic motor adaptation
BDM	Basic drive module
CBM	Condition-based monitoring
CDM	Complete drive module
DC	Direct current
EMC	Electro-magnetic compatibility
ETR	Electronic thermal relay
$f_{M,N}$	Nominal motor frequency
I_{INV}	Rated inverter output current
I_{LIM}	Current limit
$I_{M,N}$	Nominal motor current
$I_{VLT,MAX}$	Maximum output current
$I_{VLT,N}$	Rated output current supplied by the drive
IMC	Integrated motion controller
IP	Ingress protection
LCP	Local control panel
MCT	Motion control tool
n_s	Synchronous motor speed
$P_{M,N}$	Nominal motor power
PDS	Power drive system
PELV	Protective extra low voltage
PCB	Printed circuit board

PM motor	Permanent magnet motor
PWM	Pulse width modulation
RPM	Revolutions per minute
Regen	Regenerative terminals
SFAVM	Stator frequency asynchron vector modulation
T_{LIM}	Torque limit
TAS	Temperature-adaptive switching frequency function
$U_{M,N}$	Nominal motor voltage

14.2 Required Parameter Settings for Drive Options

On performing a factory reset on the drive, all drive parameters revert to their factory default value. Several drive options have parameter settings that must be configured differently from the factory default values in order for the options to perform properly.

Table 139: Parameter Setting for the Active Filter Option (Typecode Character 7 = A)

Parameter	Change value to
Parameter 5-02 Terminal 29 Mode	*[1] Output*

Table 140: Parameter Settings for the Passive Filter Option (Typecode Character 7 = P/H/L/U)

Parameter	Change value to
Parameter 5-02 Terminal 29 Mode	*[1] Output*
Parameter 5-10 Terminal 18 Digital Input	*[51] External Interlock*
Parameter 5-31 Terminal 29 Digital Output	*[188] AHF Capacitor Connect*
Parameter 14-51 DC-link Compensation	*[0] Off*

Table 141: Parameter Settings for the dU/dt Filter Option (Typecode Character 18 = D/1)

Parameter	Change value to
Parameter 5-02 Terminal 29 Mode	*[1] Output*
Parameter 14-52 Fan Control	*[3] On 100%*

Table 142: Parameter Settings for the Sine-wave Filter Option (Typecode Character 18 = S/2)

Parameter	Change value to
Parameter 5-02 Terminal 29 Mode	*[1] Output*
Parameter 14-55 Output Filter	*[2] Sine-Wave Filter Fixed*

Table 143: Parameter Settings for the Indicator Light + Reset Button Option (Typecode Character 28–29 = D1/DA/DB/DC/DD/DE)

Parameter	Change value to
Parameter 5-40 Function Relay [1]	*[5] Running*
Parameter 5-40 Function Relay [2]	*[9] Alarm*
Parameter 5-11 Terminal 19 Digital Input	*[1] Reset*

Index

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