ENGINEERING
TOMORROW

Design Guide

VLT® Decentral Drive FCD 302

drives.danfoss.com | VLT®

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® Decentral Drive FCD 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 a 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 guide is targeted at a worldwide audience. Therefore, wherever occurring, both SI and imperial units are shown.

1.2 Trademarks

- VLT® is a registered trademark of Danfoss A/S
- EtherNet/IP™ is a trademark of ODVA, Inc.
- Ethernet® is a registered trademark of Xerox Corporation.
- HIPERFACE® is a registered trademark of SICK STEGMANN GmbH.
- PROFIBUS® and PROFINET® are registered trademarks of PROFIBUS and PROFINET International (PI).
- Rittal® is a registered trademark of Rittal GmbH & Co. KG

1.3 Additional Resources

Other resources are available to understand advanced drive functions and programming.

- The *VLT® Decentral Drive FCD 302 Operating Guide* provides detailed information for the installation and commission of the drive.
- The *VLT® AutomationDrive FC 301/302 Programming Guide* provides detailed information on working with parameters and application examples.
- *Modbus RTU Operating Instructions* provides detailed information required for controlling, monitoring, and programming the drive via the built-in Modbus fieldbus
- The *VLT® PROFIBUS converter MCA 114 Operating Instructions*, *VLT® EtherNet/IP MCA 121 Installation Guide*, and *VLT® PROFINET MCA 120 Installation Guide*. The guides provide detailed information required for controlling, monitoring, and programming the drive via a fieldbus.
- *VLT® Encoder Option MCB 102 Installation Instructions*.
- *VLT® AutomationDrive FC 300, Resolver Option MCB 103 Installation Instructions*.
- *VLT® AutomationDrive FC 300, Safe PLC Interface Option MCB 108 Installation Instructions*.
- *VLT® Brake Resistor MCE 101 Design Guide*.
- *VLT® Frequency Converters Safe Torque Off Operating Guide*.
- Supplemental publications, drawings, EPLAN macros, and guides are available at www.danfoss.com.

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

1.4 Version History

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

Table 1: Document Version

Edition	Remarks
AJ267037025114, version 0601	New document structure. Editorial update.

2 Safety

2.1 Safety

When designing AC drives, some residual dangers cannot be avoided constructively. One example is the discharge time, which is very important to observe to avoid potential death or serious injury. For the Danfoss VLT® drives, the discharge time is from 4–40 minutes depending on the drive size.

For further information on safety precautions, refer to the product-specific operating guide.

2.2 Safety Symbols

The following symbols are used in Danfoss documentation and products.

DANGER

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

WARNING

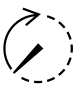
Indicates a hazardous situation which, if not avoided, could result in death or serious injury.

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).

	ISO warning symbol for general warnings
	ISO warning symbol for hot surfaces and burn hazard
	ISO warning symbol for high voltage and electric shock
	Symbol for indicating the required discharge time of the capacitors in the product.
	ISO action symbol for referring to the instructions

2.3 Safety Precautions

WARNING

IDENTIFYING HAZARDOUS SITUATIONS

Hazardous situations must be identified by the machine builder/integrator who is responsible for taking the necessary preventive means into consideration. Failure to identify hazardous situations can result in death or serious injury.

- Install extra monitoring and protective devices according to local and national safety regulations.

2.4 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, plants, 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 guides provided with the unit, especially the instructions given in the operating guide.
- Have a good knowledge of the generic and specialist standards applicable to the specific application.

3 Approvals and Certifications

3.1 Regulatory/Compliance Approvals for VLT® Decentral Drives FCD 302

This section provides a brief description of the various approvals and certifications that may be found on Danfoss VLT® Decentral Drive FCD 302. Not all listed approvals and certifications are valid for all drives, as they can be product-, application-, and country-specific.

The product label identifies which certifications apply to that individual drive. Specific certificates for VLT® Decentral Drive FCD 302 can be found on the Danfoss homepage VLT® Decentral Drive FCD 302 (danfoss.com).

NOTICE

IMPOSED LIMITATIONS ON THE OUTPUT FREQUENCY

The output frequency of the drive is limited to 590 Hz due to export control regulations. The software versions cannot be flashed.

3.2 Typical Product Approvals for VLT® Drives

The VLT® Decentral Drive product series complies with a wide scope of required standards and directives. Information on the specific product certifications can be found on the product label.

3.2.1 Directives Compliance

3.2.1.1 CE Mark

Figure 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)	2014/42/EU
ErP Directive	2009/125/EU
RoHS Directive(2)	2011/65/EU
Radio Equipment Directive(3)(2)	2014/53/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) Radio Equipment Directive is only required for interfaces supporting wireless communication.

3.2.1.2 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 75–1600 V DC voltage ranges.

3.2.1.3 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.

3.2.1.4 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.

3.2.1.5 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.

3.2.1.6 RoHS Directive

The Restriction of Hazardous Substances (RoHS) Directive is an EU directive that restricts the use of hazardous materials in the manufacturing of electronic and electrical products. Read more on Product compliance (danfoss.com).

3.2.1.7 Radio Equipment Directive

Devices that emit or receive radio waves as part of radio communication are required to comply with the Radio Equipment Directive. The drive itself does not contain a radio device, and hence compliance to the directive is not relevant. However, user interfaces containing active radio devices, such as the integrated control panel with wireless communication capabilities, comply with the directive.

3.3 CSA/cUL

c UL US LISTED

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.

3.4 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.

3.5 EAC

Figure 2: EAC Mark

The EurAsian Conformity (EAC) Mark indicates that the product conforms to all requirements and technical regulations applicable to the product per the EurAsian Customs Union, which is composed of the member states of the EurAsian Economic Union.

The EAC logo must be both on the product label and on the packaging label. All products used within the EAC area must be bought at Danfoss inside the EAC area.

3.6 UkrSEPRO

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Figure 3: UkrSEPRO Mark

The UkrSEPRO certificate indicates quality and safety of both products and services, in addition to manufacturing stability according to Ukrainian regulatory standards. The UkrSEPRO certificate is a required document to clear customs for any products coming into and out of the territory of Ukraine.

3.7 RCM Mark Compliance

Figure 4: 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.

3.8 Moroccan Conformity Mark

Figure 5: Moroccan Conformity Mark

The drive complies with relevant directives and their related standards for the Morocco market.

3.9 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.

4 Product Overview

4.1 VLT® Decentral Drive Systems

The VLT® Decentral Drive FCD 302 is a complete drive designed for decentral mounting. It can be mounted on the machine/wall close to the motor or directly on the motor.

All options are built into the unit, reducing the number of boxes to be mounted, connections, and terminations in the installation.

Benefits of the VLT® Decentral Drive FCD 302:

- Installation is flexible as the drive adapts to any brand of motor.
- Servicing is fast and easy due to the pluggable twin-part design.
- Smooth surface ensures easy cleaning of the drive.
- Cable savings are possible as a result of the integrated power and fieldbus-looping terminals.
- Integrated USB port ensures direct connection to a PC.
- The built-in smart logic controller reduces the need for PLC capacity.

4.2 Power Ratings

Table 3: Power Ratings for VLT® Decentral Drive FCD 302

Power rating [kW (hp)]	Type code	Hardware configuration
0.37–2.2 (0.5–3.0)	PK37/PK55/PK75/P1K1/P1K5/P2K2	Small unit, standalone mount
		Large unit, standalone mount
3.0 (4.0)	P3K0	Large unit, standalone mount

4.3 Weight and External Dimensions

Table 4: Drive Weight for VLT® Decentral Drive FCD 302

Power rating [kW (hp)]	Weight [kg (lb)]	Hardware configuration
0.37–2.2 (0.5–3.0)	9.8 (21.6)	Small unit, standalone mount
0.37–3.0 (0.5–4.0)	13.9 (30.6)	Large unit, standalone mount

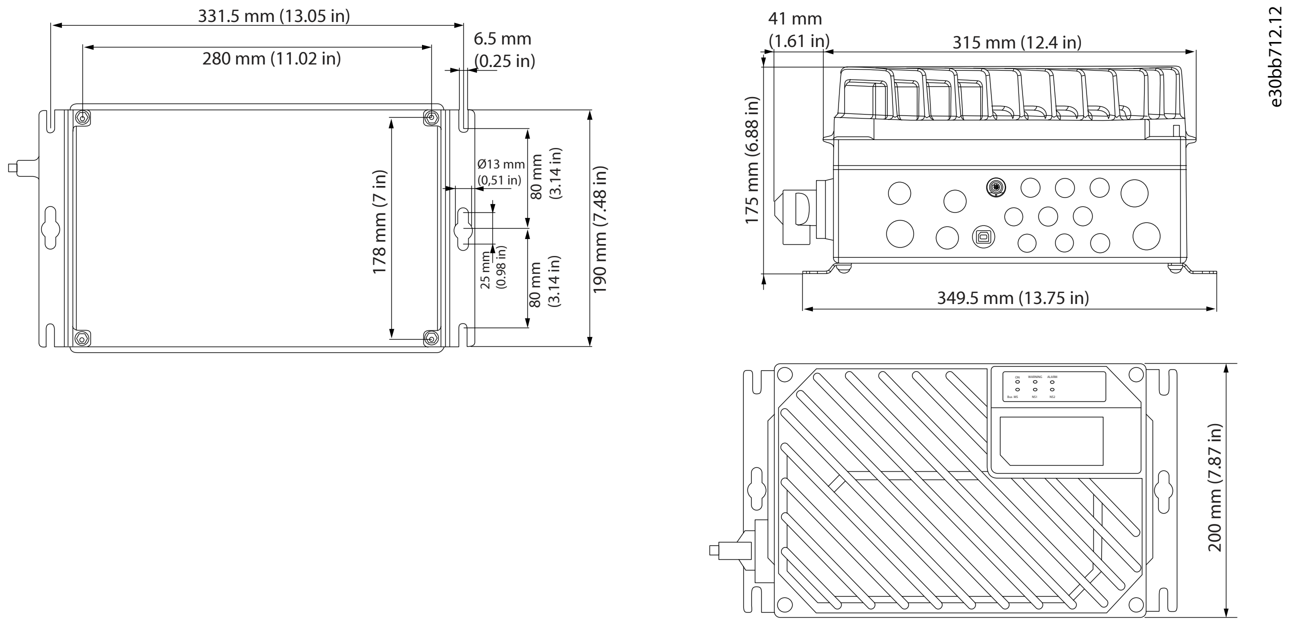


Figure 6: Dimensions FCD 302 0.37–2.2 kW (0.5–3.0 hp), Small Unit

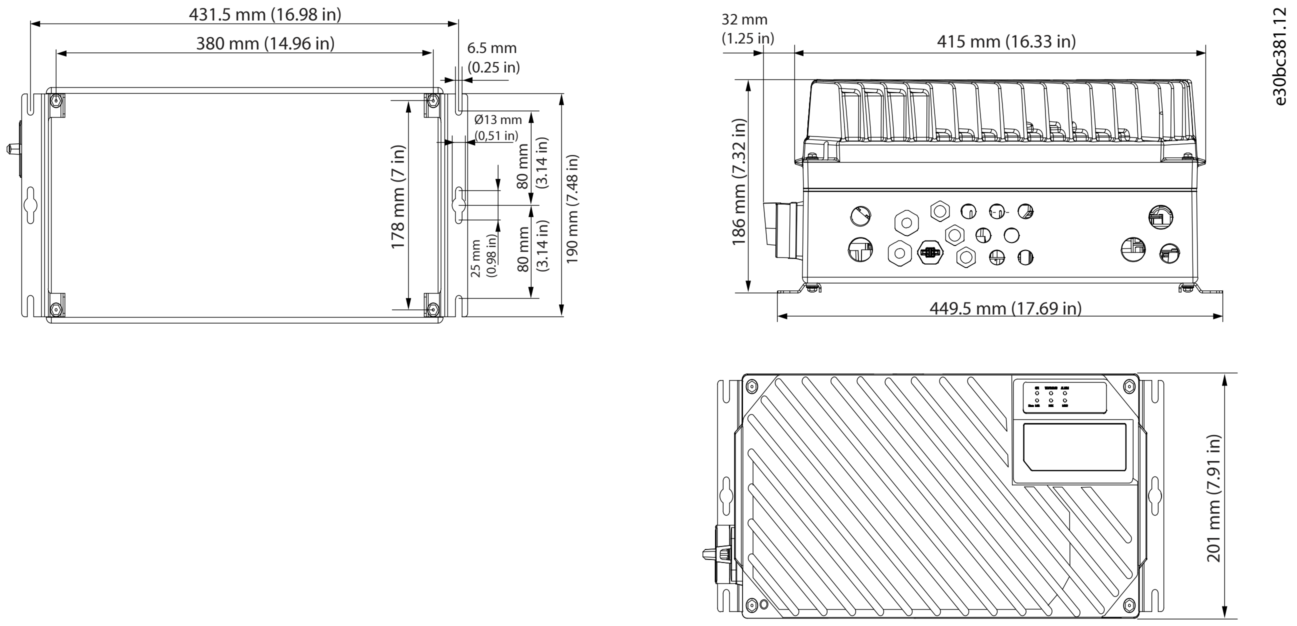


Figure 7: Dimensions FCD 302 0.37–3.0 kW (0.5–4.0 hp), Large Unit

5 Product Features

5.1 Automated Operational Features

5.1.1 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 optimization leads to reduced losses in the motor.

The AEO function can also be used in applications where a higher starting torque is required (for example, wastewater 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.

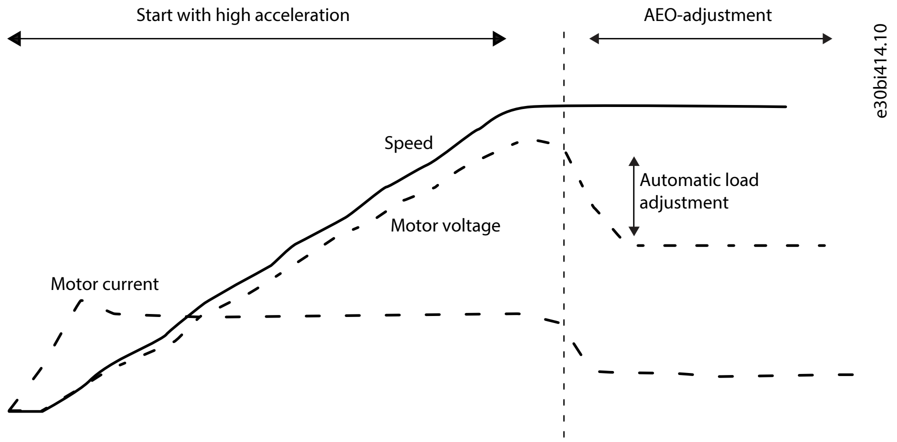


Figure 8: Automatic Energy Optimization

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

5.1.2 Short Circuit Protection

Motor (phase – phase)

The drive is protected against short circuits with current measurement in each of the 3 motor phases or in the DC-link. A short circuit between 2 output phases causes an overcurrent in the inverter. The inverter is turned off individually 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.

5.1.3 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 a 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 (permanent magnet motor) operation. If coasted at high RPM, the PM motor back EMF can potentially exceed the maximum voltage tolerance of the drive and cause damage. The drive is designed to prevent the occurrence of back EMF. 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***.
  - 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.

When possible, the control unit may attempt to correct the ramp (parameter ***2–17 Overvoltage Control***). The inverter turns off when a certain voltage level is reached to protect the transistors and the DC-link capacitors.

See parameter ***2–10 Brake Function*** and parameter ***2–17 Overvoltage Control*** to select the method used for controlling the DC-link voltage level.

NOTICE

Overvoltage control (OVC) cannot be activated when running a permanent magnet motor, that is, for parameter ***1–10 Motor Construction*** set to ***[1] PM non-salient SPM***.

5.1.4 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.

5.1.5 Imbalance of Supply Voltage Detection

Operation under severe supply voltage 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 supply voltage imbalance occurs (parameter ***14-12 Function at Mains Imbalance***).

5.1.6 Service Switch on the Output

Switching on the output between the motor and the drive is allowed. No damage to the drive can occur by switching on the output. However, fault messages can appear.

5.1.7 Overload Protection

The drive offers several safety features to avoid serious application damage.

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 that the drive can provide.

Electronic thermal relay (ETR)

ETR is an electronic feature that simulates a bimetal relay based on internal measurements. For more information, see 5.2.2 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.

5.1.8 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 PM VVC+ control (parameter ***30-22 Locked Rotor Detection***).

5.1.9 Protection and Monitoring

- Electronic motor thermal protection against overload.
- Temperature monitoring of the heat sink ensures that the drive trips if the temperature reaches a predefined level.
- The drive is protected against short circuits on motor terminals U, V, W.
- If a mains phase is missing, the drive trips or issues a warning (depending on the load).
- Monitoring of the DC-link voltage ensures that the drive trips if the DC-link voltage is too low or too high.
- The drive constantly checks for critical levels of internal temperature, load current, high voltage on the DC-link, and low motor speeds. As a response to a critical level, the drive can adjust the switching frequency and/or change the switching pattern to ensure the performance of the drive

5.1.10 Protection Mode

Once a hardware limit on motor current or DC-link voltage is exceeded, the drive enters protection mode. Protection mode means a change of the PWM modulation strategy and a low switching frequency to minimize losses. This continues 10 s after the last fault and increases the reliability and the robustness of the drive while re-establishing full control of the motor.

In hoist applications, protection mode is not usable because the drive is unable to leave this mode again. Therefore, it extends the time before activating the brake – which is not recommended. In hoisting applications, the protection mode can be disabled in the parameter settings so the drive trips immediately if 1 of the hardware limits is exceeded.

NOTICE

HOISTING APPLICATIONS

Disable protection mode in hoisting applications parameter ***14–26 Trip Delay at Inverter Fault*** = [*0*]

5.1.11 Automatic Derating

5.1.11.1 Overview of Automatic Derating

The drive constantly checks for critical levels:

- Critical 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 critical high internal temperatures and low motor speed, the drive can also force the PWM (Pulse Width Modulation) pattern to SFAVM (Stator Flux-oriented Asynchronous Vector Modulation).

NOTICE

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.

5.1.11.2 How Automatic Derating Works

The automatic derating is made up of contributions from separate functions that evaluate the need. Their interrelationship is shown in Figure 10.

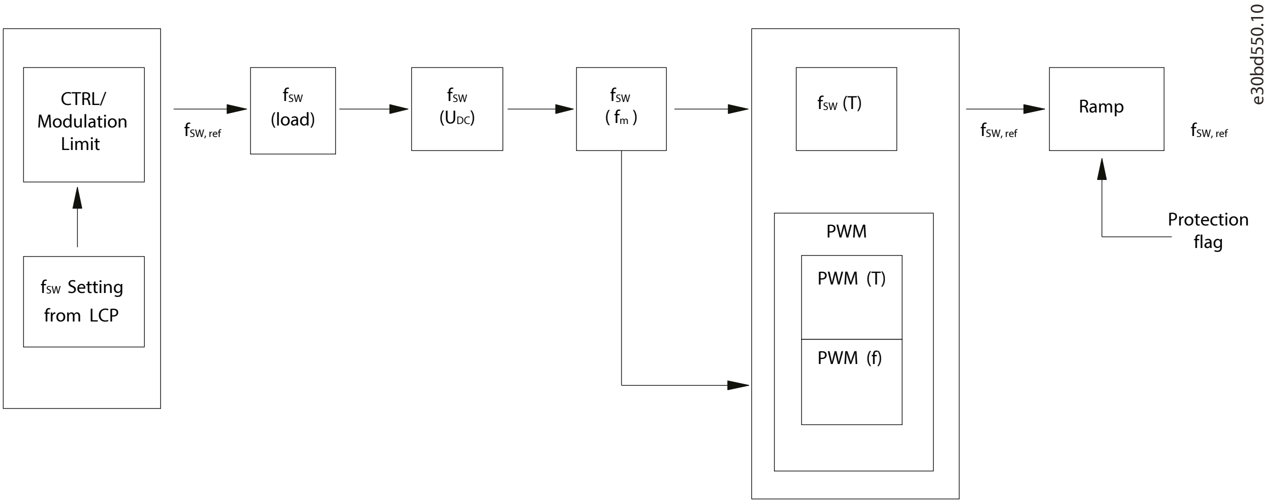


Figure 9: Automatic Derating Function Block

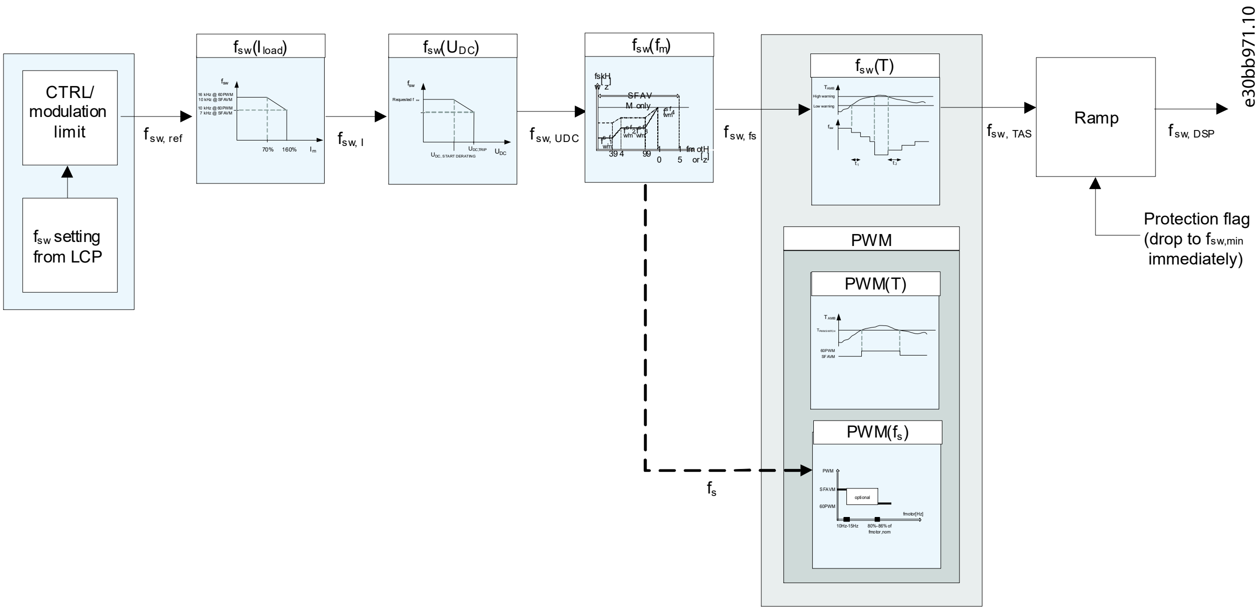
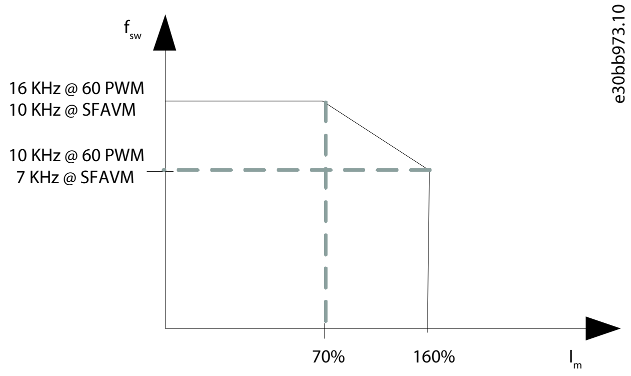


Figure 10: Interrelationship Between the Automatic Derating Contributions

The switching frequency is first derated due to motor current, followed by DC-link voltage, motor frequency, and then temperature. If multiple deratings occur on the same iteration, the resulting switching frequency would be the same as though only the most significant derating occurred by itself (the deratings are not cumulative). Each of these functions is presented in the following sections.

Table 5: Derating Functions

<table>
<tr><th>Background for derating</th><th>PWM - Functions that adjust the switching pattern</th><th>f_{sw} – Functions that derate the switching frequency</th></tr>
<tr><td>I_{load} ↑</td><td>No automatic derating</td><td>
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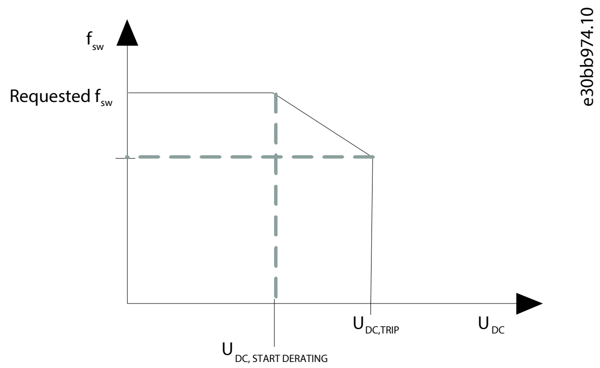
<tr><td>U_{dc} ↑</td><td>No automatic derating</td><td>
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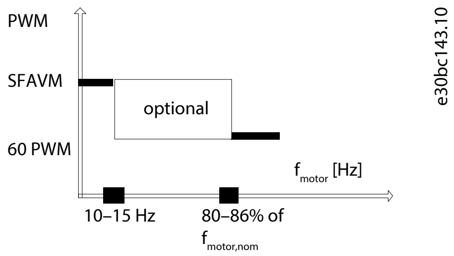
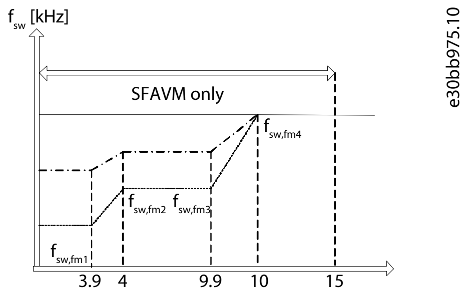
<tr><td>f_s</td><td>
</td><td>
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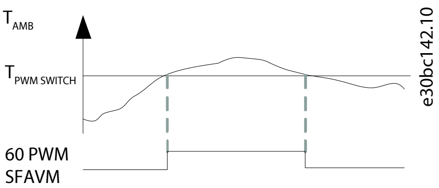
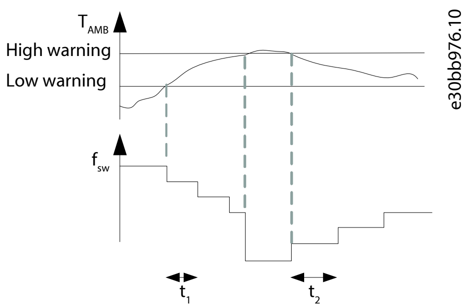
<tr><td>T ↑</td><td>
</td><td>
</td></tr>
</table>

5.1.11.3 High Internal Temperature

Derate the output current at high temperatures. This calculation takes place after the calculations for derating the switching frequency. The result is an attempt to lower the temperatures by first lowering the switching frequency, and then lowering the output current. Current derating only takes place if the unit is programmed to derate in overtemperature situations. If trip function is selected for overtemperature situations, the current derate factor is not lowered.

The switching frequency is derated based on both control card- and heat sink temperature. This function may sometimes be referred to as the temperature-adaptive switching frequency function (TAS).

NOTICE

In the example, 1 temperature affects the derating. In fact there are 2 limiting temperatures: control card temperature and heat sink temperature. Both have their own set of control temperatures.

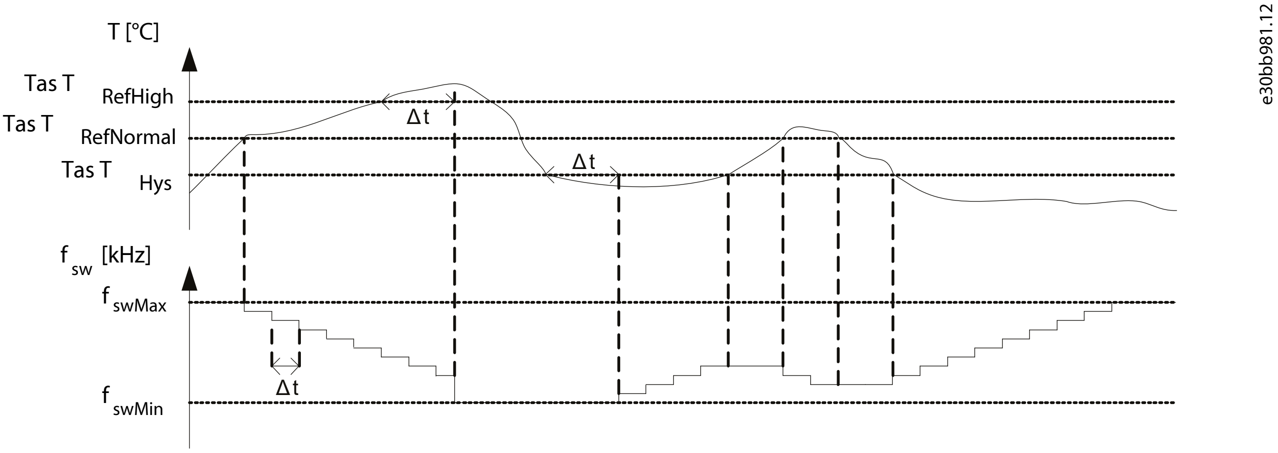


Figure 11: Switching Frequency Derating due to High Temperature

NOTICE

The value of dt depends on the temperature of the components. When the control card is too hot, dt is 10 s and when the heat sink is too hot, dt is 0 s (more critical)

The high warning can only be violated for a certain time before the drive trips.

5.1.11.4 High Motor Load

The switching frequency is adjusted automatically according to the motor current. When a certain percentage of the nominal HO motor load is reached, the switching frequency is derated. This percentage is individual for each enclosure size and a value that is coded in the EEPROM along with the other points that limit the derating.

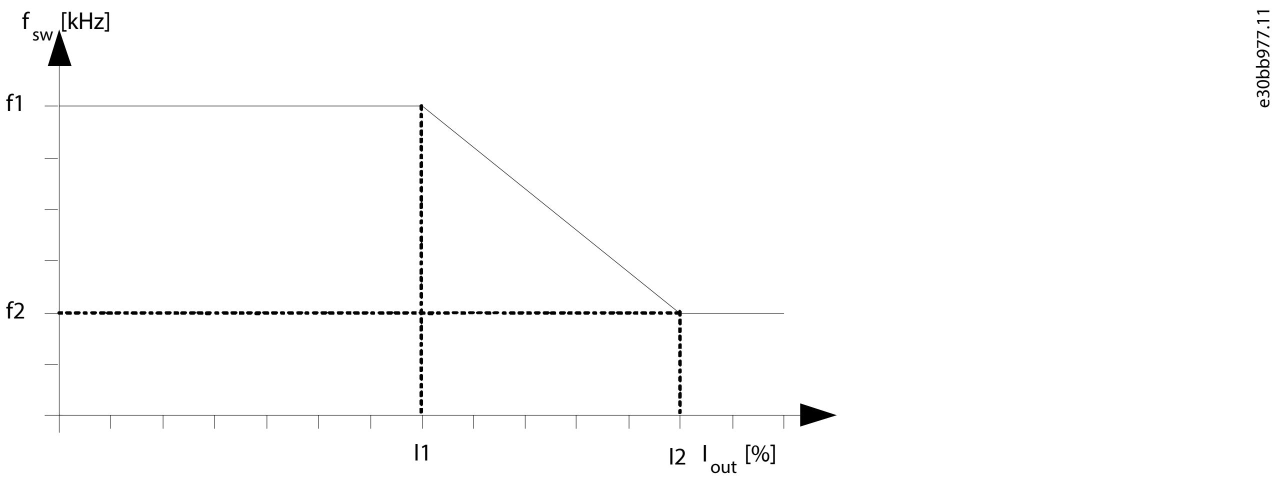


Figure 12: Derating of Switching Frequency According to Motor Load. f1, f2, I1, and I2 are Coded in EEPROM

In EEPROM, the limits depend on the modulation mode. In 60° AVM, f1 and f2 are higher than for SFAVM. I1 and I2 are independent of the modulation mode.

5.1.11.5 High Voltage on the DC-link

The switching frequency is adjusted automatically according to the voltage on the DC-link. When the DC-link reaches a certain magnitude, the switching frequency is derated. The points that limit the derating are individual for each enclosure size and are coded in the EEPROM.

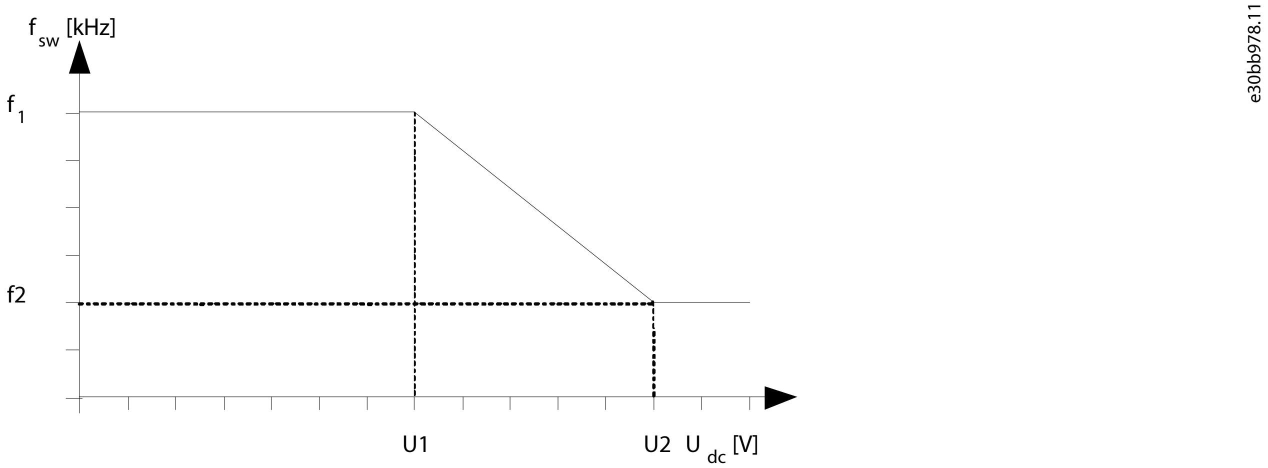


Figure 13: Derating of Switching Frequency According to Voltage on the DC-Link. f1, f2, U1, and U2 are Coded in EEPROM

In EEPROM, the limits depend on the modulation mode. In 60° AVM, f1 and f2 are higher than for SFAVM. U1 and U2 are independent of the modulation mode.

5.1.11.6 Low Motor Speed

The selection of PWM strategy depends on the stator frequency. To avoid that the same IGBT is running for too long (thermal consideration), $f_{m,switch1}$ is specified as the minimum stator frequency for 60° PWM. $f_{m,switch2}$ is specified as the maximum stator frequency for SFAVM to protect the drive. 60° PWM helps to reduce the inverter loss above $f_{m,switch1}$ as the switch loss is reduced by 1/3 by changing from SFAVM to 60° AVM.

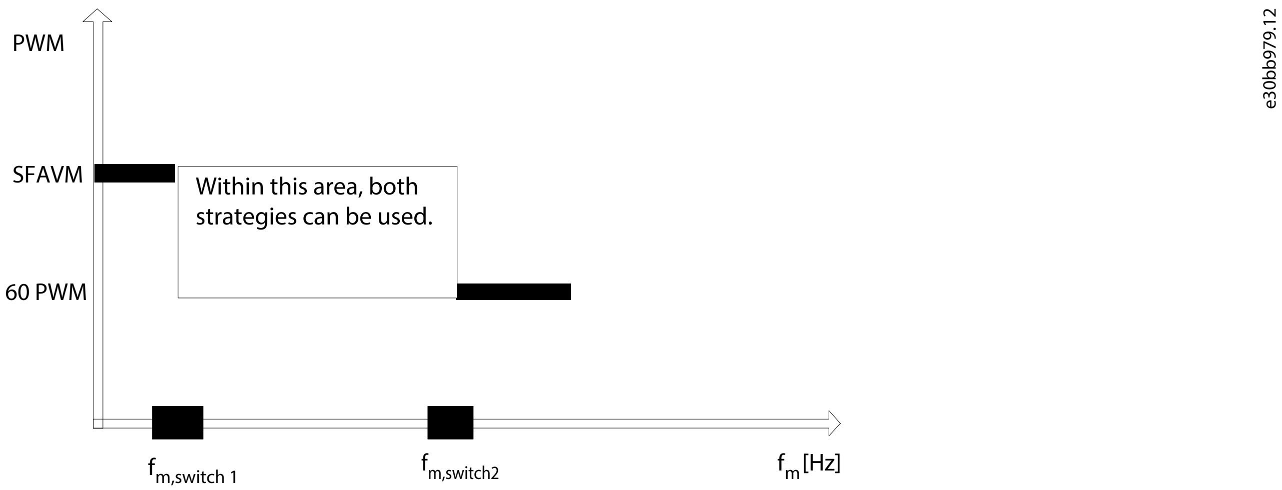


Figure 14: Selection of PWM Strategy

The shape of the average temperature is constant regardless of the stator frequency. The peak temperature, however, follows the shape of the output power for small stator frequencies and goes towards the average temperature for increasing stator frequency. This results in higher temperature variations for small stator frequencies. Which means that the expected lifetime of the component decreases for small stator frequencies if no compensation is used. Therefore, for low values of the stator frequency where the temperature variations are large, the switching frequency can be reduced to lower the peak temperature and by that the temperature variations.

For VT applications, the load current is relatively small for small stator frequencies and the temperature variations are thus not as large as for the CT applications. For this reason, also the load current is considered.

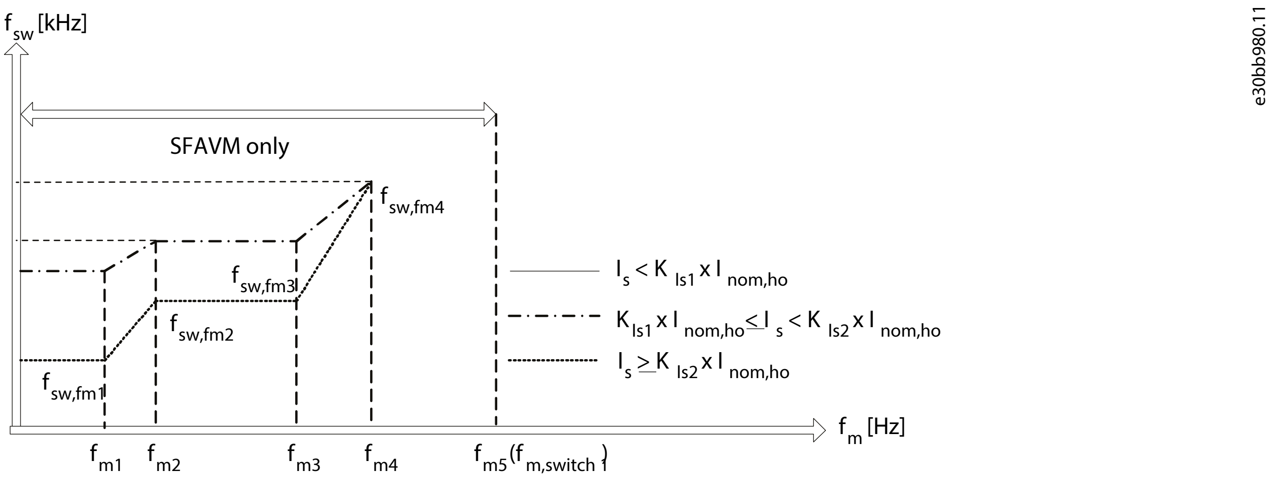


Figure 15: Switching Frequency (f_{sw}) Variation for Different Stator Frequencies (fm)

The points that limit the derating are individual for each enclosure size and are coded in the EEPROM.

NOTICE

The drive never derates the current automatically. Automatic derating refers to adaptation of the switching frequency and pattern.

For VT applications, the load current is considered before derating the switching frequency at low motor speed.

5.1.12 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.

5.1.13 Resonance Damping

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

5.1.14 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*.

5.1.15 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.

5.2 Custom Application Features

5.2.1 Overview of Custom Application Features

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

5.2.2 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.

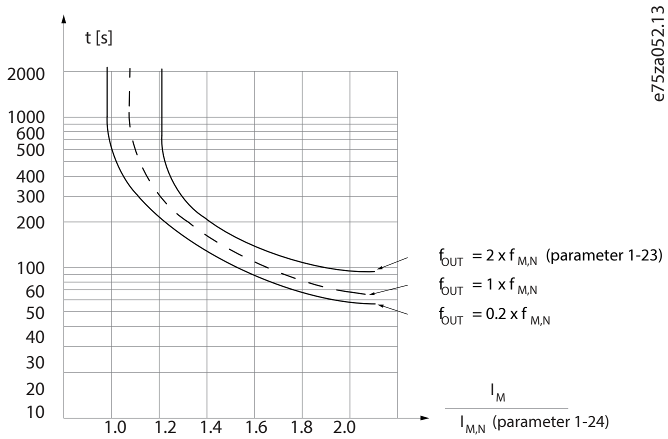


Figure 16: ETR Characteristics

The X-axis in Figure 16shows 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 setup instructions.

5.2.3 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.

5.2.4 Smart Logic Controller

5.2.4.1 Overview of the 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 Figure 17.

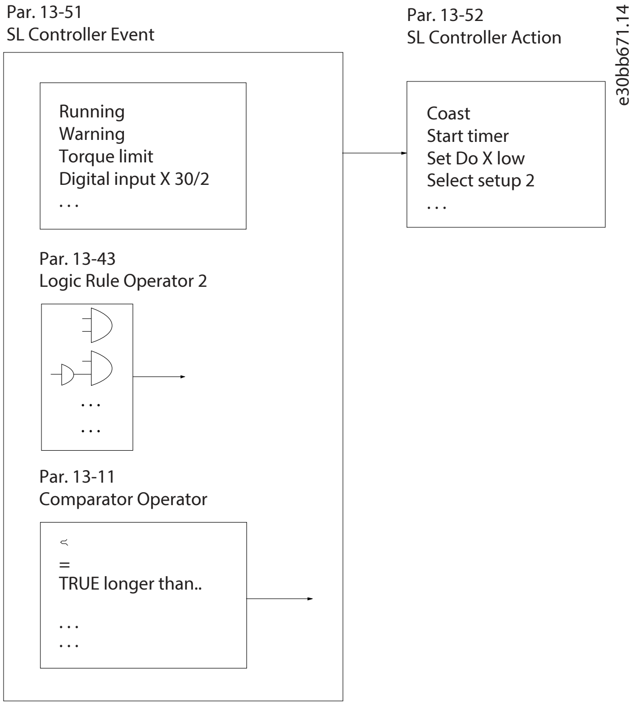


Figure 17: Current Control Status/Event and Action

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]) in 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 Figure 18 for an example with 3 events/actions:

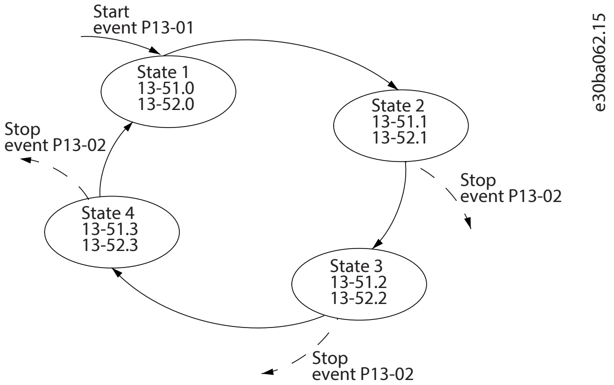


Figure 18: Example - Internal Current Control

5.2.4.2 Comparators

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

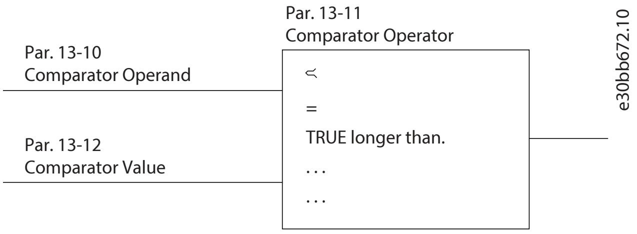


Figure 19: Comparators

5.2.4.3 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.

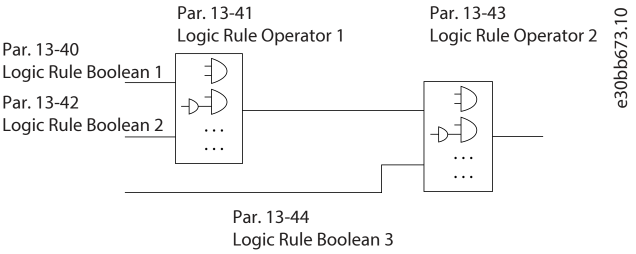


Figure 20: Logic Rules

5.2.5 Safe Torque Off

To run STO (safe torque off), extra wiring for the drive is required. See 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.

5.3 Braking

5.3.1 Brake Functions

Brake function is applied for braking the load on the motor shaft, either as dynamic brake or static brake.

5.3.2 Dynamic Brake Overview

Dynamic brake established by:

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***.

AC brake

- The brake energy is distributed in the motor by changing the loss conditions in the motor. The AC brake function cannot be used in applications with high cycling frequency since this overheats the motor, parameter ***2–10 Brake Function*** = [**2**] ***AC Brake***.

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.

5.3.3 Mechanical Brake Overview

A mechanical holding brake mounted directly on the motor shaft normally performs static braking. In some applications (usually synchronous permanent motors), the static holding torque holds the motor shaft. A PLC, a relay, or the drives digital output can control the holding brake.

NOTICE

A drive cannot provide Safe Torque Off control of a mechanical brake. A redundancy circuitry for the brake control must be included in the installation.

5.3.4 Hoist Mechanical Brake

The VLT® Decentral Drive FCD 302 features a mechanical brake control designed for hoisting applications. The hoist mechanical brake is activated in parameter ***1–72 Start Function*** via option [*6*] ***Hoist Mech. Brake Rel***. The main difference compared to the regular mechanical brake control, where a relay function monitoring the output current is used, is that the hoist mechanical brake function has direct control over the brake relay. This means that instead of setting a current for release of the brake, the torque is applied against the closed brake before release is defined. Because the torque is defined directly, the setup is more straightforward for hoisting applications. Set parameter ***2–28 Gain Boost Factor*** to obtain a quicker control when releasing the brake. The hoist mechanical brake strategy is based on a 3-step sequence, where motor control and brake release are synchronized to obtain the smoothest possible brake release.

3-step sequence

- Premagnetize the motor.
  - To ensure that there is a hold on the motor and to verify that it is mounted correctly, the motor is first premagnetized.
- Apply torque against the closed brake.
  - When the load is held by the mechanical brake, its size cannot be determined, only its direction. The moment the brake opens, the motor must take over the load. To facilitate the takeover, a user-defined torque, set in parameter ***2–26 Torque Ref***, is applied in the hoisting direction. This is used to restore the speed controller that finally takes over the load. To reduce wear on the gearbox due to backlash, the torque is acceled.
- Release the brake.
  - When the torque reaches the value set in parameter ***2–26 Torque Ref***, the brake is released. The value set in parameter ***2–25 Brake Release Time*** determines the delay before the load is released. To react as quickly as possible on the load-step that follows brake release, increase the proportional gain to boost the speed PID control.

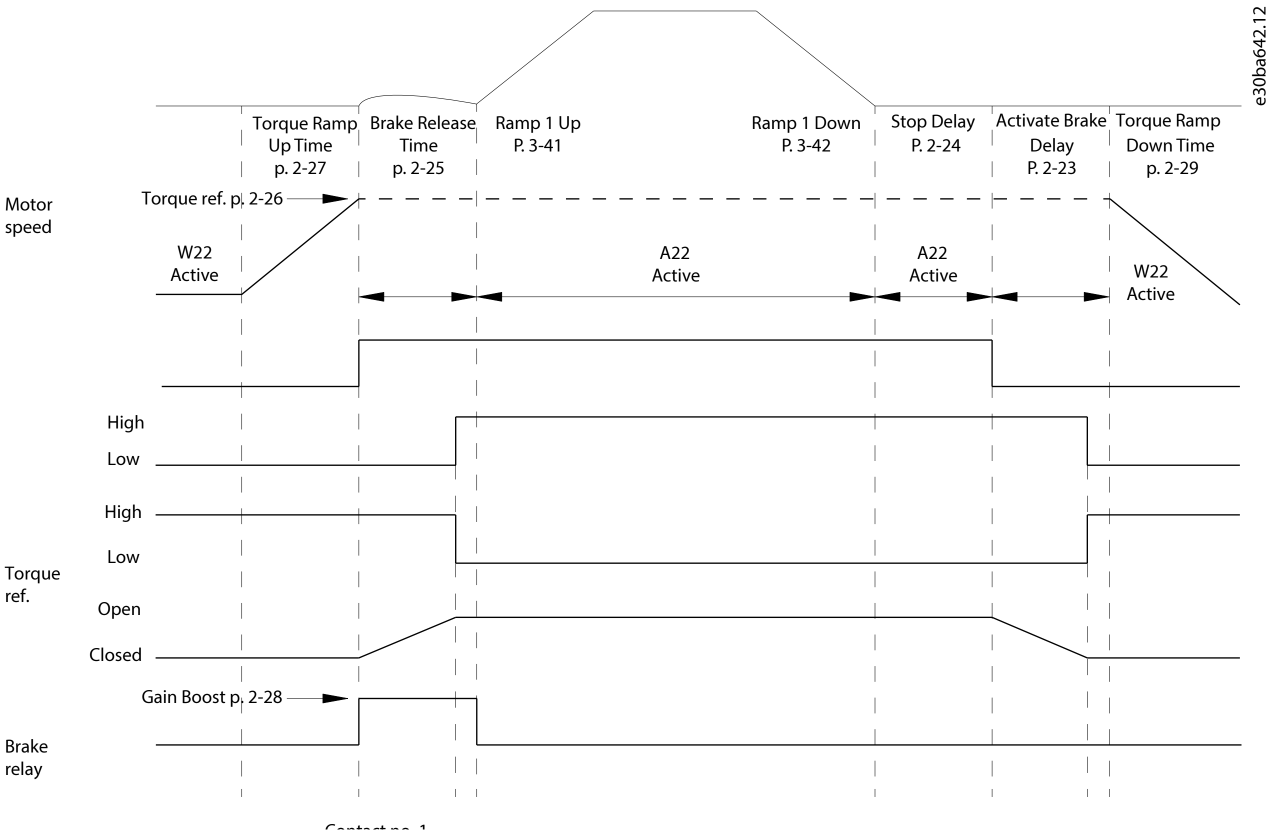


Figure 21: Brake Release Sequence for Hoist Mechanical Brake Control

1. Activate Brake Delay: The drive starts again from the mechanical brake-engaged position.
2. Stop Delay: When the time between successive starts is shorter than the setting in parameter ***2–24 Stop Delay***, the drive starts without applying the mechanical brake (for example, reversing).

Both relays 1 and 2 can be used to control the brake.

6 Options and Accessories Overview

6.1 Introduction to Options and Accessories

Danfoss offers a wide range of options and accessories for the VLT® Decentral Drive FCD 302.

This chapter provides an overview of the different hardware options and accessories.

6.2 VLT® Fieldbus Options

This topic gives an overview of currently available option cards related to fieldbus communication for the VLT® Decentral Drive FCD 302 series. The fieldbus solutions brochure can be downloaded from Options and Accessories (danfoss.com).

More detailed descriptions of the fieldbus option cards can be found in the installation guides, programming guides, and operating guides for the individual options. The guides can be downloaded from the Danfoss webpage, see 1.3 Additional Resources for more information.

Table 6: Fieldbus Options

Option name	Slot	Description
VLT® PROFIBUS DP MCA 101	A	Operating the drive via a fieldbus enables the reduction of system costs, faster and more efficient communication, and benefits from an easier user interface. • Wide compatibility, a high level of availability, support for all major PLC vendors, and compatibility with future versions. • Fast, efficient communication, transparent installation, advanced diagnosis and parameterization and auto-configuration of process data via GSD file. • Acyclic parameterization using PROFIBUS DP-V1, PROFIdrive, or Danfoss FC (MCA 101 only) profile state machines, PROFIBUS DP-V1, Master Class 1 and 2.
VLT® PROFINET MCA 120	A	PROFINET uniquely combines the highest performance with the highest degree of openness. The option is designed so that many of the features from the PROFIBUS can be reused, minimizing user effort to migrate PROFINET and securing the investment in a PLC program.
VLT® EtherNet/IP MCA 121	A	Ethernet is the future standard for communication at the factory floor. EtherNet/IP is based on the newest technology available for industrial use and handles even the most demanding requirements. EtherNet/IP™ extends commercial off-the-shelf Ethernet to the Common Industrial Protocol (CIP™) – the same upper-layer protocol and object model found in DeviceNet.

6.3 VLT® Functional Extensions

This topic gives an overview of currently available functional extension option cards for the VLT® Decentral Drive FCD 302 series.

The functional extension option cards documentation can be downloaded from Options and Accessories (danfoss.com).

More detailed descriptions of the functional extension option cards can be found in the installation guides, programming guides, and operating guides for the individual options. The guides can be downloaded from the Danfoss webpage, see 1.3 Additional Resources for more information.

Table 7: Functional Extensions for the VLT® Decentral Drive FCD 302

Option name	Slot	Description
VLT® Encoder Option MCB 102	B	A universal option for connecting encoder feedback from either an asynchronous or brushless servo (Permanent Magnet) motor or a process.
VLT® Resolver Input MCB 103	B	Supports resolver feedback from brushless servo motors, and feedback for flux vector-controlled induction motors in rough environments.
VLT® 24 V DC Supply Option MCB 107	D	Connects an external DC supply to keep the control section and any installed options active when mains power is down.
VLT® Safe PLC Interface Option MCB 108	B	Enables the connection of a dual-wire safety link between a Safe PLC and a single-pole 24 V DC input of the drive. The interface allows the Safe PLC to interrupt operation on the plus or minus link without interfering with the sense signal of the Safe PLC.

6.4 Brake Resistors

In certain applications, a breakdown of kinetic energy is required. In this drive, the energy is not fed back to the grid. Instead, the kinetic energy must be transformed to heat, and this is achieved by braking using a 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 drives DC-line. In applications with frequent braking and/or high inertia loads, this increase may 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 in respect to its ohmic value, its power dissipation rate, and its physical size. Danfoss brake resistors are available in several types, for internal or external installation to the drive. See 12.3.1 Accessories for further information.

For basic information on brake resistor selection, see 9.9.2.1 Selection of Brake Resistor.

7 Specifications

7.1 Electrical Data

Table 8: Shaft Output, Output Current, and Input Current

Mains supply 3x380–480 V AC							
Drive	PK37	PK55	PK75	P1K1	P1K5	P2K2	P3K0
Rated shaft output [kW]	0.37	0.55	0.75	1.1	1.5	2.2	3.0
Rated shaft output [hp]	0.5	0.75	1.0	1.5	2.0	3.0	4.0
Maximum input current							
Continuous (3x380–440 V) [A]	1.2	1.6	2.2	2.7	3.7	5.0	6.5
Intermittent (3x380–440 V) [A]	1.9	2.6	3.5	4.3	5.9	8.0	10.4
Continuous (3x441–480 V) [A]	1.0	1.4	1.9	2.7	3.1	4.3	5.7
Intermittent (3x441–480 V) [A]	1.6	2.2	3.0	4.3	5.0	6.9	9.1
Recommended maximum fuse size (non-UL)	gG-25						
Built-in circuit breaker (large unit)	CTI-25M code number: 047B3151						
Recommended circuit breaker Danfoss CTI-25M Code number:	FCD 302 Small and large unit. PK55/PK75/P1K1/P1K5/P2K2/P3K0. Power rating: 0.37–3.0 kW (0.5–4.0 hp).						
0.37, 0.55 kW	Code number: 047B3148						
0.75, 1.1 kW	Code number: 047B3149						
1.5, 2.2, 3.0 kW	Code number: 047B3151						
Recommended circuit breaker Danfoss CTI-45MB Code number:	FCD 302 Small unit.[1] PK55/PK75/P1K1/P1K5/P2K2 Power rating: 0.37–2.2 kW (0.5–3.0 hp)						
0.55, 0.75 kW	Code number: 047B3160						
1.1 kW	Code number: 047B3161						
1.5 kW	Code number: 047B3162						
2.2 kW	Code number: 047B3163						
Power loss at maximum load [W][2]	35	42	46	58	62	88	116
Efficiency[3]	0.93	0.95	0.96	0.96	0.97	0.97	0.97
Output current							
Continuous (3x380–440 V) [A]	1.3	1.8	2.4	3.0	4.1	5.2	7.2
Intermittent (3x380–440 V) [A]	2.1	2.9	3.8	4.8	6.6	8.3	11.5

Table 8: Shaft Output, Output Current, and Input Current - (continued)

Mains supply 3x380–480 V AC							
Continuous (3x441–480 V) [A]	1.2	1.6	2.1	3.0	3.4	4.8	6.3
Intermittent (3x441–480 V) [A]	1.9	2.6	3.4	4.8	5.4	7.7	10.1
Continuous kVA (400 V AC) [kVA]	0.9	1.3	1.7	2.1	2.8	3.9	5.0
Continuous kVA (460 V AC) [kVA]	0.9	1.3	1.7	2.4	2.7	3.8	5.0
Maximum cable size: Mains, motor, brake. [mm2 (AWG)]	Solid cable: 6 (10)						
Maximum cable size: Mains, motor, brake. [mm2 (AWG)]	Flexible cable: 4 (12)						

1) *Type CTI-45MB circuit breakers are not available for 3.0 kW (4.0 hp) units.*

2) *Applies to the dimensioning of drive cooling. If the switching frequency is higher than the default setting, the power losses may increase. LCP and typical control card power consumption are included. For power loss data according to EN 50598-2, refer to MyDrive® Energy (danfoss.com).*

3) *Efficiency is measured at nominal current. For energy efficiency class, see 7.4 Ambient Conditions. For part load losses, refer to MyDrive® Energy (danfoss.com).*

7.2 Mains Supply (L1, L2, L3)

Supply voltage(1), (2)	380–480 V/500–600 V ±10%
Supply frequency	50/60 Hz ±5%
Maximum imbalance temporary between mains phases	3.0% of rated supply voltage
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, L3 (power-ups)	Maximum 2 times per minute

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

2) *The unit is suitable for use on a circuit capable of delivering not more than 100000 RMS symmetrical Amperes, 240/500/600/690 V maximum.*

7.3 Motor Output and Motor Data

7.3.1 Motor Output (U, V, W)

Output voltage	0–100% of supply voltage
Output frequency	0–590 Hz(1)
Output frequency in flux mode	0–300 Hz
Switching on output	Unlimited
Ramp times	0.01–3600 s

1) *Dependent on voltage and power.*

7.3.2 Torque Characteristics

Starting torque (constant torque)	Maximum 160% for 60 s(1)
Starting torque	Maximum 180% up to 0.5 s(1)

Overload torque (constant torque)	Maximum 160% for 60 s(1)
Starting torque (variable torque)	Maximum 110% for 60 s(1)
Overload torque (variable torque)	Maximum 110% for 60 s(1)

1) Percentage relates to the nominal torque of the drive, dependent on power size.

7.4 Ambient Conditions

Protection rating	IP66/Type 4X
Vibration test for units without circuit breaker	1.7 g RMS
Mount unit with integrated circuit breaker on a level, vibration proof, and torsionally rigid support structure	
Maximum relative humidity	5–95% (IEC 721-3-3); Class 3K3 (non-condensing) during operation
Ambient temperature(1)	Maximum 40 °C (75 °F) (24-hour average maximum 35 °C (95 °F))
Minimum ambient temperature during full-scale operation	0 °C (32 °F)
Minimum ambient temperature at reduced speed performance	-10 °C (14 °F)
Temperature during storage/transport	-25...65/70 °C (-13...149/158 °F)
Maximum altitude above sea level	1000 m (3280 ft)
Energy efficiency class(2)	IE2

1) For more information, see Mechanical Installation Consideration, section Derating in this guide.

2) Determined according to EN 50598-2 at: Rated load, 90% rated frequency, switching frequency factory setting and, switching pattern factory setting.

7.5 Cable Specifications

7.5.1 Motor Cable Length

Maximum length for shielded motor cable	10 m (32.8 ft)
Maximum length for unshielded motor cable(1)	10 m (32.8 ft)

1) Without fulfilling emission specifications.

7.5.2 Power Cable Cross-sections

Table 9: Maximum Cable Cross-section

Cable type	Mains [mm^2(AWG)]	Motor [mm^2(AWG)]	Brake [mm^2(AWG)]
Solid	6 (10)	6 (10)	6 (10)
Flexible	4 (12)	4 (12)	4 (12)

7.5.3 Control Cable Cross-sections

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	1.5 mm^2/16 AWG
Maximum cross-section to control terminals, flexible wire with cable end sleeves with collar	1.5 mm^2/16 AWG
Minimum cross-section to control terminals	0.25 mm^2/24 AWG

7.6 Control Input/Output and Control Data

7.6.1 Digital Inputs

Programmable digital inputs	4 (6)[(1)]
Terminal number	18, 19, 27[(1)], 29[(1)], 32, 33
Logic	PNP or NPN
Voltage level	0–24 V
Voltage level, logic 0 PNP	<5 V DC
Voltage level, logic 1 PNP	>10 V DC
Voltage level, logic 0 NPN	>19 V DC
Voltage level, logic 1 NPN	<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 27 and 29 can also be programmed as output.

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

7.6.2 STO Terminal 37

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

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

For further information about terminal 37 and Safe Torque Off, see the *Safe Torque Off Operating Guide*.

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. The return way can be created 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.

7.6.3 Analog Inputs

Number of analog inputs	2
Terminal number	53, 54
Modes	Voltage or current
Mode select	Switch S201 and switch S202
Voltage mode	Switch S201/S202 = OFF (U)
Voltage level	-10 V...+10 V (scalable)

Input resistance, R_i	Approximately 10 kΩ
Maximum voltage	±20 V
Current mode	Switch S201/S202 = ON (I)
Current level	0/4 mA 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	200 Hz

The analog inputs are galvanically isolated from the supply voltage (PELV) and other high voltage terminals, see Figure 22.

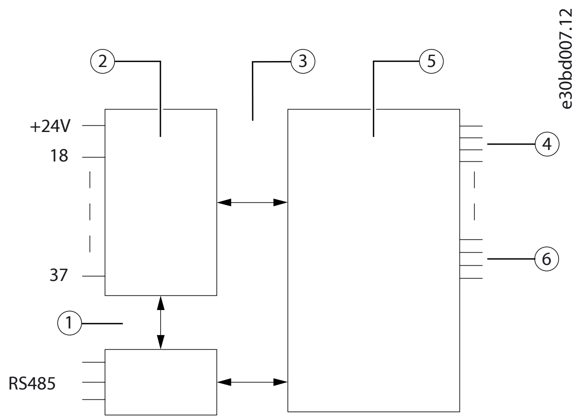


Figure 22: Analog Inputs

1	Functional isolation	**2**	Control
3	PELV isolation	**4**	Mains
5	High voltage	**6**	Motor

7.6.4 Pulse/Encoder Inputs

Programmable pulse/encoder inputs	2/1
Terminal number pulse/encoder	29, 33(1)/32(2), 33(2)
Maximum frequency at terminals 29, 32, 33	110 kHz (Push-pull driven)
Maximum frequency at terminals 29, 32, 33	5 kHz (Open collector)
Maximum frequency at terminals 29, 32, 33	4 Hz
Voltage level	See *Digital Inputs*.
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) Pulse inputs are 29 and 33.

2) Encoder inputs: 32=A, 33=B.

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

7.6.5 Digital Outputs

Programmable digital/pulse outputs	2
Terminal number	27, 29(1)
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) Terminals 27 and 29 can also be programmed as input.

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

7.6.6 Analog Output

Number of programmable outputs	1
Terminal number	42
Current range at analog output	0/4 mA 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.

7.6.7 Control Card 24 V DC Output

Terminal number	12, 13
Output voltage	24 V +1, -3 V
Maximum load	600 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.

7.6.8 Control Card +10 V DC Output

Terminal number(1)	50
Output voltage	10.5 V ±0.5 V
Maximum load	15 mA

1) The drive does not contain any mechanisms to limit 200 mA on terminal 50. Ensure not to draw more than 200 mA on the terminal.

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

7.6.9 Control Card RS-485 Serial Communication

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

The RS-485 serial communication circuit is galvanically isolated from the supply voltage (PELV).

7.6.10 Control Card USB Serial Communication

USB standard	1.1 (full speed)
USB plug	USB type B plug

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.

The USB ground connection is not galvanically isolated from protective earth. Use only an isolated laptop as PC connection to the USB connector on the drive.

7.6.11 Relay Outputs

Programmable relay outputs	2
Relay 01 terminal number	1–3 (break), 1–2 (make)
Maximum terminal load (AC-1)(1) on 1–3 (NC), 1–2 (NO) (resistive load)	240 V AC, 2 A
Maximum terminal load (AC-15)(1) (inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1)(1) on 1–2 (NO), 1–3 (NC) (resistive load)	48 V DC, 1 A
Maximum terminal load (DC-13)(1) (inductive load)	24 V DC, 0.1 A
Relay 02 terminal number	4–6 (break), 4–5 (make)
Maximum terminal load (AC-1)(1) on 4–5 (NO) (resistive load)(2), (3)	400 V AC, 2 A
Maximum terminal load (AC-15)(1) on 4–5 (NO) (inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1)(1) on 4–5 (NO) (resistive load)	80 V DC, 2 A
Maximum terminal load (DC-13)(1) on 4–5 (NO) (inductive load)	24 V DC, 0.1 A
Maximum terminal load (AC-1)(1) on 4–6 (NC) (resistive load)	240 V AC, 2 A
Maximum terminal load (AC-15)(1) on 4–6 (NC) (inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1)(1) on 4–6 (NC) (resistive load)	48 V DC, 1 A
Maximum terminal load (DC-13)(1) on 4–6 (NC) (inductive load)	24 V DC, 0.1 A
Minimum terminal load on 1–3 (NC), 1–2 (NO), 4–6 (NC), 4–5 (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.

7.6.12 Control Card Performance

Scan interval	1 ms

7.6.13 Control Characteristics

Resolution of output frequency at 0–590 Hz	±0.003 Hz
Repeat accuracy of precise start/stop (terminals 18, 19)	≤±0.1 ms
System response time (terminals 18, 19, 27, 29, 32, 33)	≤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 induction motor.

7.7 DC Voltage Levels

Table 10: FCD 302 DC Voltage Level

DC voltage level	380–480 V units (V DC)
Inverter undervoltage disable	373
Undervoltage warning	410
Inverter undervoltage re-enables (warning reset)	398
Overvoltage warning (without brake)	778
Dynamic brake turn-on	778
Inverter overvoltage re-enables (warning reset)	795
Overvoltage warning (with brake)	810
Overvoltage trip	820

Fuses

The unit is suitable for use on a circuit capable of delivering not more than 100000 RMS symmetrical Amperes, 500 V maximum.

Circuit breaker

The unit is suitable for use on a circuit capable of delivering not more than 10000 RMS symmetrical Amperes, 500 V maximum.

8 Mechanical Installation Consideration

8.1 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 condition 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 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.

8.2 Operating Environment

8.2.1 Humidity

The VLT® Decentral Drive FCD 302 meets the IEC/EN 60068-2-3 standard, EN 50178 9.4.2.2 at 50 °C (122 °F).

8.2.2 Aggressive Environments

The drive contains many mechanical and electronic components. All are to some extent vulnerable to environmental effects.

⚠ CAUTION

INSTALLATION ENVIRONMENTS

Failure to take necessary protective measures increases the risk of stoppages, potentially causing equipment damage and personnel injury.

- Do not install the drive in environments with airborne liquids, particles, or gases that may affect or damage the electronic components.

Degree of protection as per IEC 60529

In environments with high temperatures and humidity, corrosive gases such as sulphur, nitrogen, and chlorine compounds cause chemical processes on the drive components.

Such chemical reactions rapidly affect and damage the electronic components. In such environments, mount the equipment in a cabinet with fresh air ventilation, keeping aggressive gases away from the drive. An extra protection in such areas is a coating of the printed circuit boards, which can be ordered as an option.

Before installation

Check the ambient air for liquids, particles, and gases. This is done by observing existing installations in this environment. Typical indicators of harmful airborne liquids are water or oil on metal parts, or corrosion of metal parts.

Excessive dust particle levels are often found on installation cabinets and existing electrical installations. One indicator of aggressive airborne gases is the blackening of copper rails and cable ends on existing installations.

8.2.3 Vibration and Shock

The drive is tested according to the procedure based on the following standards.

The drive complies with requirements that exist for units mounted on the walls and floors of production premises, and in panels bolted to walls or floors.

- IEC/EN 60068-2-6: Vibration (sinusoidal) - 1970.

- IEC/EN 60068-2-64: Vibration, broad-band random.

8.2.4 Acoustic Noise

The acoustic noise from the drive comes from these sources:

- DC intermediate circuit coils.
- RFI filter choke.

VLT® Decentral Drive FCD 302 has no significant audible noise.

8.3 Maintenance Considerations

8.3.1 DrivePro® Preventive Maintenance

Generally, all technical equipment, including Danfoss AC drives, need a minimum level of preventive maintenance. To ensure trouble-free operation and long life of the drive, regular maintenance is recommended. Under specific conditions, the combination of stressful operation and environmental conditions work together to reduce the lifetime of the components significantly. These conditions can include, for example, extreme temperature, dust, high humidity, hours of use, corrosive environment, and loading.

For operation in stressful conditions, Danfoss offers the DrivePro® Preventive Maintenance service. DrivePro® services extend the lifetime and increase the performance of the product with scheduled maintenance including customized part replacements. DrivePro® services are tailored to the specific application and operating conditions. For more information, see DrivePro Services (danfoss.com)

To maintain optimal performance and longevity of a Danfoss drive, refer to the *Maintenance* chapter in the operating guide for a comprehensive maintenance/inspection schedule.

8.3.2 Service Access

When planning the installation, proper access for service and maintenance needs must be considered. In general, it is recommended to ensure:

- Access to power cabling and connectors.
- Access to control wiring.
- Access to clean the cooling channel and fan filters (if applicable).
- Access to the port to connect the drive to a PC.

8.4 Drive Placement

8.4.1 Standard Application

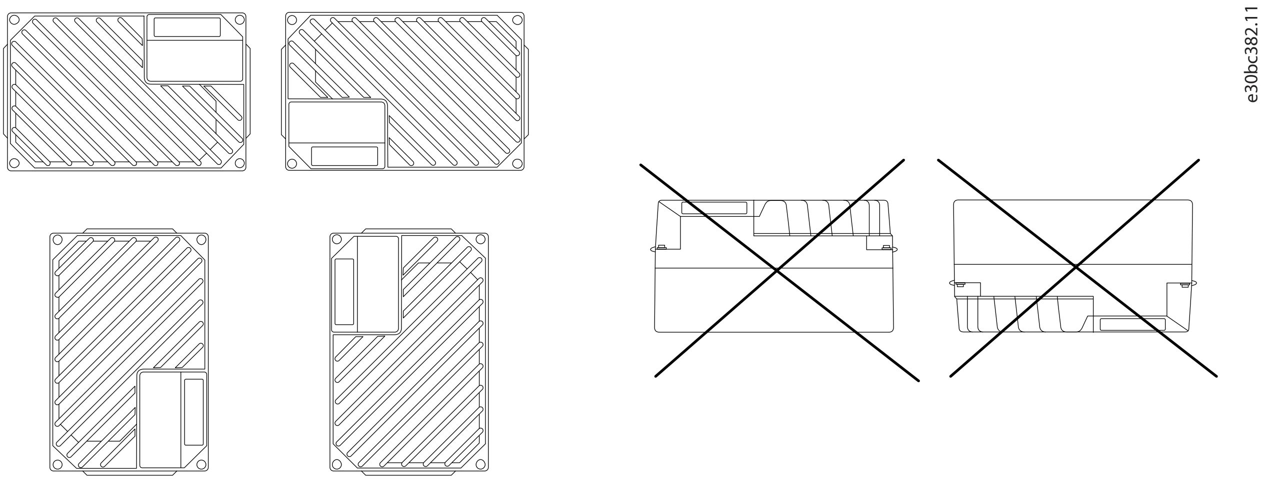


Figure 23: Allowed Mounting Positions for Standard Application

8.4.2 Hygienic Applications

Only VLT® Decentral Drive FCD 302 drives configured as hygienic enclosure designation, FCD 302 P XXX T4 W69, have the EHEDG (European Hygienic Engineering and Design Group) certification.

Mount the FCD 302 vertically on a wall or machine frame to ensure that liquids drain off the enclosure. To ensure optimal cleaning, use cable glands designed to meet hygienic application requirements, for example Rittal® HD 2410.110/120/130.

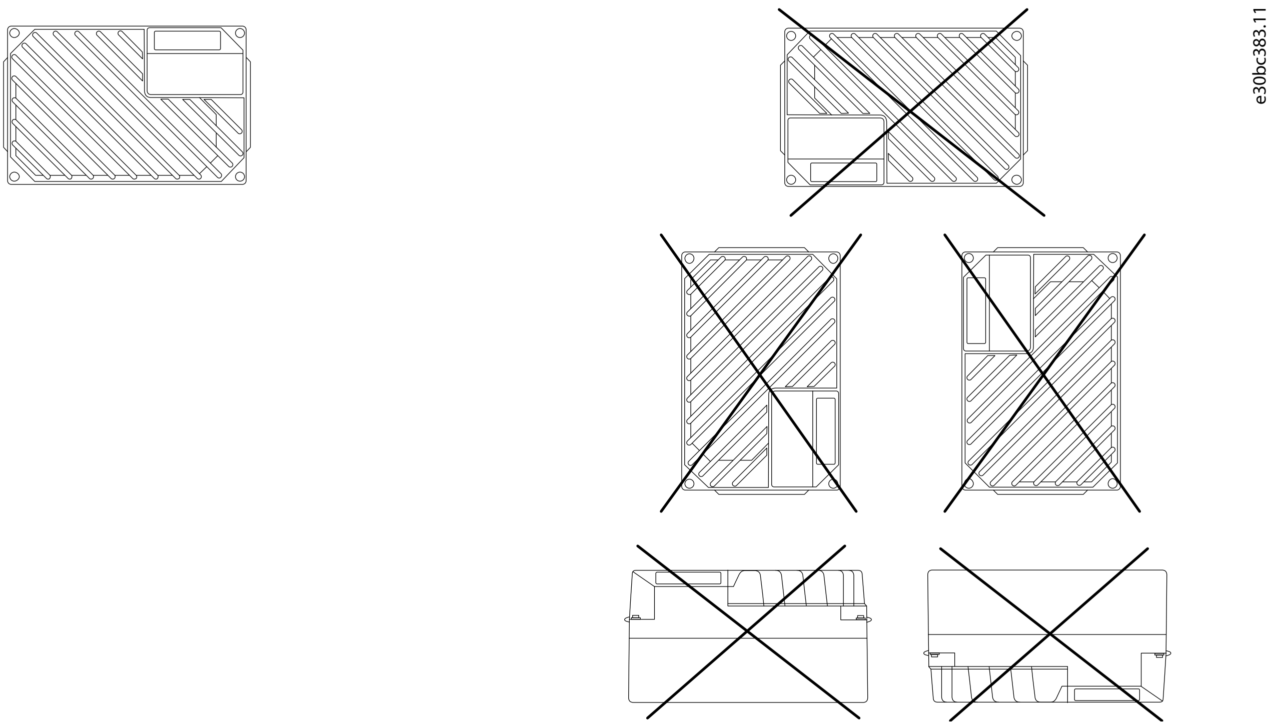


Figure 24: Allowed Mounting Positions for Hygienic Applications

8.5 Derating

8.5.1 Overview

Under some special conditions, where the operation of the drive is challenged, consider derating. In some conditions, derating must be done manually. In other conditions, the drive automatically performs a degree of derating when necessary. Derating is done to ensure the performance at critical stages where the alternative could be a trip.

Consider manual derating for:

- Air pressure – relevant for installation at altitudes above 1000 m (3280 ft).
- Motor speed – at continuous operation at low RPM in constant torque applications.
- Ambient temperature – relevant for ambient temperatures above 40 °C (104 °F).

Contact Danfoss for the Application Note for tables and elaboration. Only the case of running at low motor speeds is elaborated here.

8.5.2 Derating for Running at Low Speed

When a motor is connected to a drive, it is necessary to ensure that the cooling of the motor is adequate.

The level of heating depends on the load on the motor, the operating speed, and time.

Constant torque applications (CT mode)

A problem may occur at low RPM values in constant torque applications. In a constant torque application, a motor may overheat at low speeds due to less cooling air from the motor integral fan.

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. Another solution is to use a motor designed for this type of operation.

Alternatively, reduce the load level of the motor by selecting a larger motor. However, the design of the drive limits the motor size.

Variable (quadratic) torque applications (VT)

In VT applications such as centrifugal pumps and fans, there is no need for extra cooling or derating of the motor. This is because the torque is proportional to the square of the speed and the power is proportional to the cube of the speed.

8.5.3 Derating for Low Air Pressure

The cooling capability of air is decreased at lower air pressure.

Below 1000 m (3280 ft) altitude, derating is not necessary. But 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 Figure 25.

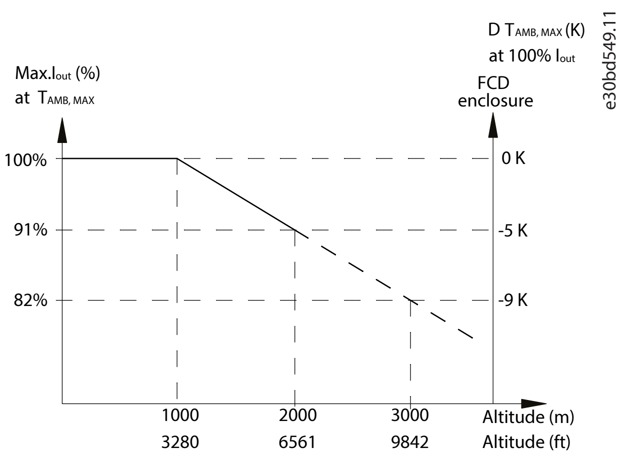


Figure 25: Derating of Output Current Versus Altitude at $T_{AMB, MAX}$

At altitudes above 2000 m (6561 ft), contact Danfoss regarding PELV.

An alternative is to lower the ambient temperature at high altitudes and by that ensuring 100% output current at high altitudes. As an example of how to read the graph, the situation at 2000 m (6561 ft) is elaborated for a 3.0 kW (4.0 hp) drive with $T_{AMB, MAX}$ = 40 °C (104 °F). At a temperature of 36 °C (96.8 °F) ($T_{AMB, MAX}$ - 3.3 K), 91% of the rated output current is available. At a temperature of 41.7 °C (107 °F), 100% of the rated output current is available.

8.5.4 Derating for Ambient Temperature and Switching Frequency

Graphs are presented individually for 60° AVM (Asynchronous Vector Modulation) and SFAVM (Stator Flux-oriented Asynchronous Vector Modulation). 60° AVM only switches 2/3 of the time whereas SFAVM switches throughout the whole period. The maximum switching frequency is 16 kHz for 60° AVM and 10 kHz for SFAVM.

Table 11: Discrete Switching Frequencies

Switching pattern	Discrete switching frequencies												
60° AVM	2	2.5	3	3.5	4	5	6	7	8	10	12	14	16
SFAVM	2	2.5	3	3.5	4	5	6	7	8	10	–	–	–

60° AVM - Pulse width modulation

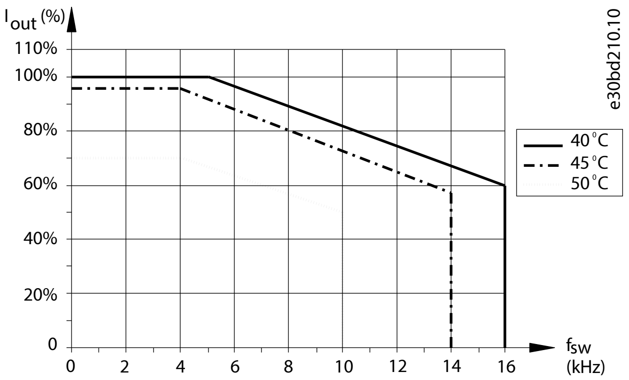


Figure 26: Derating of I_{out} for Different $T_{AMB, MAX}$ 0.37–0.55–0.75 kW

SFAVM - Stator frequency asynchronous vector modulation

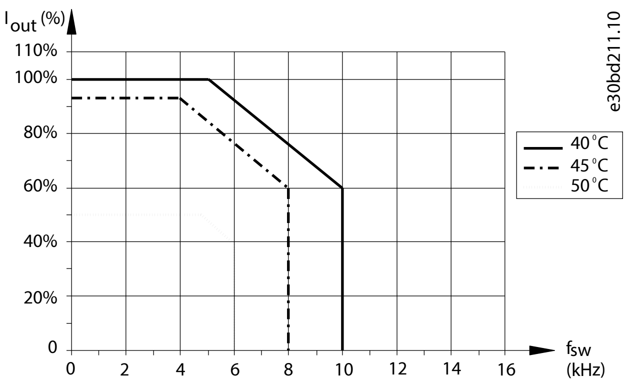


Figure 27: Derating of I_{out} for Different $T_{AMB, MAX}$ 0.37–0.55–0.75 kW

60° AVM - Pulse width modulation

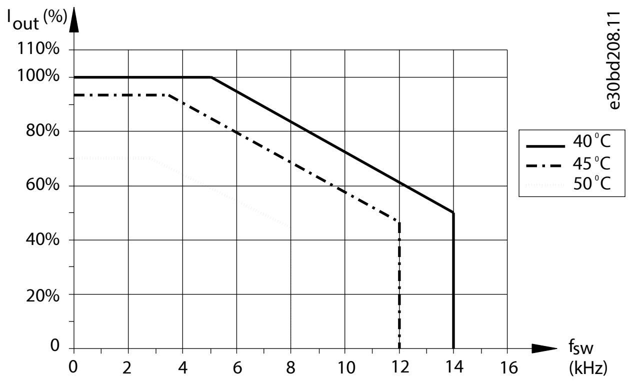


Figure 28: Derating of I_{out} for Different $T_{AMB, MAX}$ 1.1–1.5 kW

SFAVM - Stator frequency synchronous vector modulation

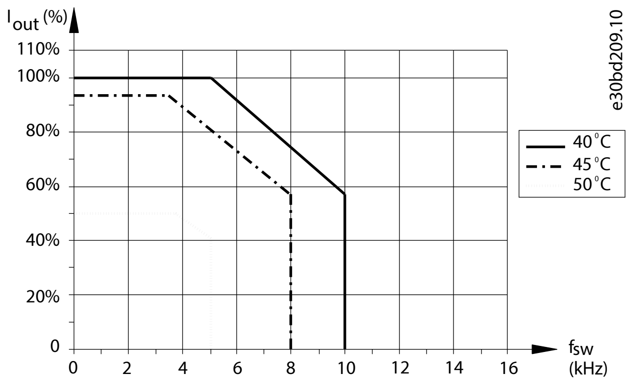


Figure 29: Derating of I_{out} for Different $T_{AMB, MAX}$ 1.1–1.5 kW

60° AVM - Pulse width modulation

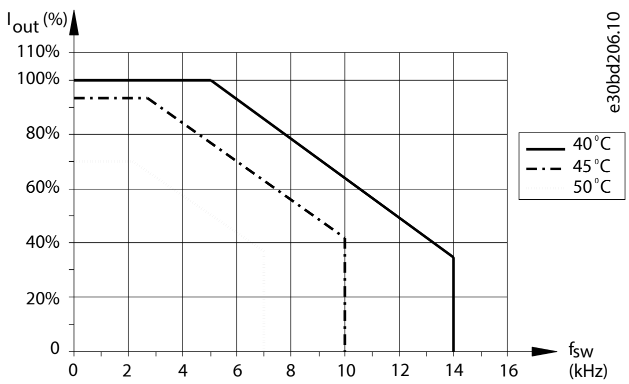


Figure 30: Derating of I_{out} for Different $T_{AMB, MAX}$ 2.2–3.0 kW

SFAVM - Stator frequency asynchronous vector modulation

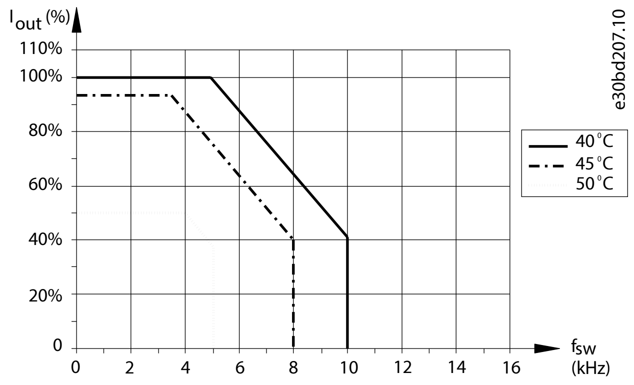


Figure 31: Derating of I_{out} for Different $T_{AMB, MAX}$ 2.2–3.0 kW

8.5.5 VT Applications

In Figure 32, the typical VT curve is below the maximum torque with derating and maximum torque with forced cooling at all speeds.

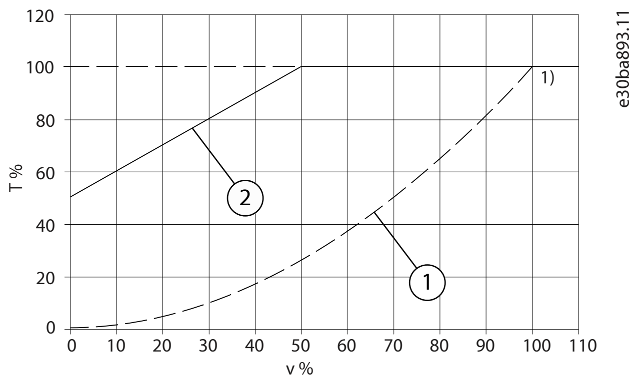


Figure 32: VT Applications - Maximum Load for a Standard Motor at 40 °C (104 °F)

1	Typical torque at VT load	**2**	Maximum torque

NOTICE

Oversynchronous speed operation results in a decrease of the available motor torque, inversely proportional to the increase in speed.

- Consider this in the design phase to avoid motor overload.

9 Electrical Installation Considerations

9.1 Safety Instructions

⚠ WARNING

INDUCED VOLTAGE

Induced voltage from output motor cables that run together can charge equipment capacitors, even with the equipment turned off and locked out. Failure to run output motor cables separately or to use shielded cables could result in death or serious injury.

- Run output motor cables separately or use shielded cables.
- Simultaneously lock out all the drives.

⚠ WARNING

SHOCK HAZARD

The unit can cause a DC current in the PE conductor. Failure to use a Type B residual current-operated protective device (RCD) may lead to the RCD not providing the intended protection and therefore may result in death or serious injury.

- When an RCD is used for protection against electric shock, only a Type B device is allowed on the supply side.

⚠ 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.

For electrical safety

According to the standard EN 61800-5-1, 1 or more of these conditions for the protective circuit must be true. The connection must be fixed.

- The protective earthing conductor must have a cross-sectional area of minimum 10 mm^2 (8 AWG) Cu or 16 mm^2 (6 AWG), OR
- There must be an automatic disconnection of the mains if the protective earthing conductor breaks, OR
- There must be a terminal for a 2nd protective earthing conductor in the same cross-sectional area as the 1st protective earthing conductor.

Cross-sectional area of the phase conductors (S) [mm^2 (AWG)]	The minimum cross-sectional area of the protective earthing conductor in question [mm^2(AWG)]
S≤16 (6)	S
16 (6)<S≤35 (2)	16 (6)
35 (2)<S	S/2

The values of the table are only valid if the protective earthing conductor is made of the same metal as the phase conductors. If not, the cross-sectional area of the protective earthing conductor must be determined in a manner that produces a conductance equivalent to that which results from the calculations in the table.

The cross-sectional area of each protective earthing conductor that is not a part of the mains cable or the cable enclosure must be a minimum of:

- 25 mm^2 (14 AWG) if there is mechanical protection, AND
- 4 mm^2 (12 AWG) if there is no mechanical protection. With cord-connected equipment, ensure that the protective earthing conductor in the cord is the last conductor to be interrupted if the strain relief mechanism breaks.

Adhere to the local regulations on the minimum size of the protective earthing conductor.

Further instructions for electrical safety:

- Ground the drive in accordance with applicable standards and directives.
- Use a dedicated ground wire for input power, motor power, and control wiring.
- Do not ground 1 drive to another in a daisy-chain fashion.
- Keep the ground wire connections as short as possible.
- Follow the wiring requirements from the motor manufacturer.

For EMC-compliant installation

- Establish electrical contact between cable shield and drive enclosure by using metal grommets or by using the clamps provided on the equipment.
- Use high-strand wire to reduce burst transient.
- Do not use pigtails.

NOTICE

POTENTIAL EQUALIZATION

Risk of burst transient when the ground potential between the drive and the control system is different.

- Install equalizing cables between the system components. Recommended cable cross-section: 16 mm^2 (6 AWG).

Overcurrent protection:

- Extra protection equipment such as short-circuit protection or motor thermal protection between drive and motor are required for applications with multiple motors.
- Input fusing is required to provide short-circuit and overcurrent protection. If fuses are not factory-supplied, the installer must provide them. For more information see 9.6.2 Recommendations for Fuses and Circuit Breakers.

Wire type and ratings:

- All wiring must comply with local and national regulations regarding cross-section and ambient temperature requirements.
- Power connection wire recommendation: Minimum 75 °C (167 °F) rated copper wire.

9.2 Wiring Diagram

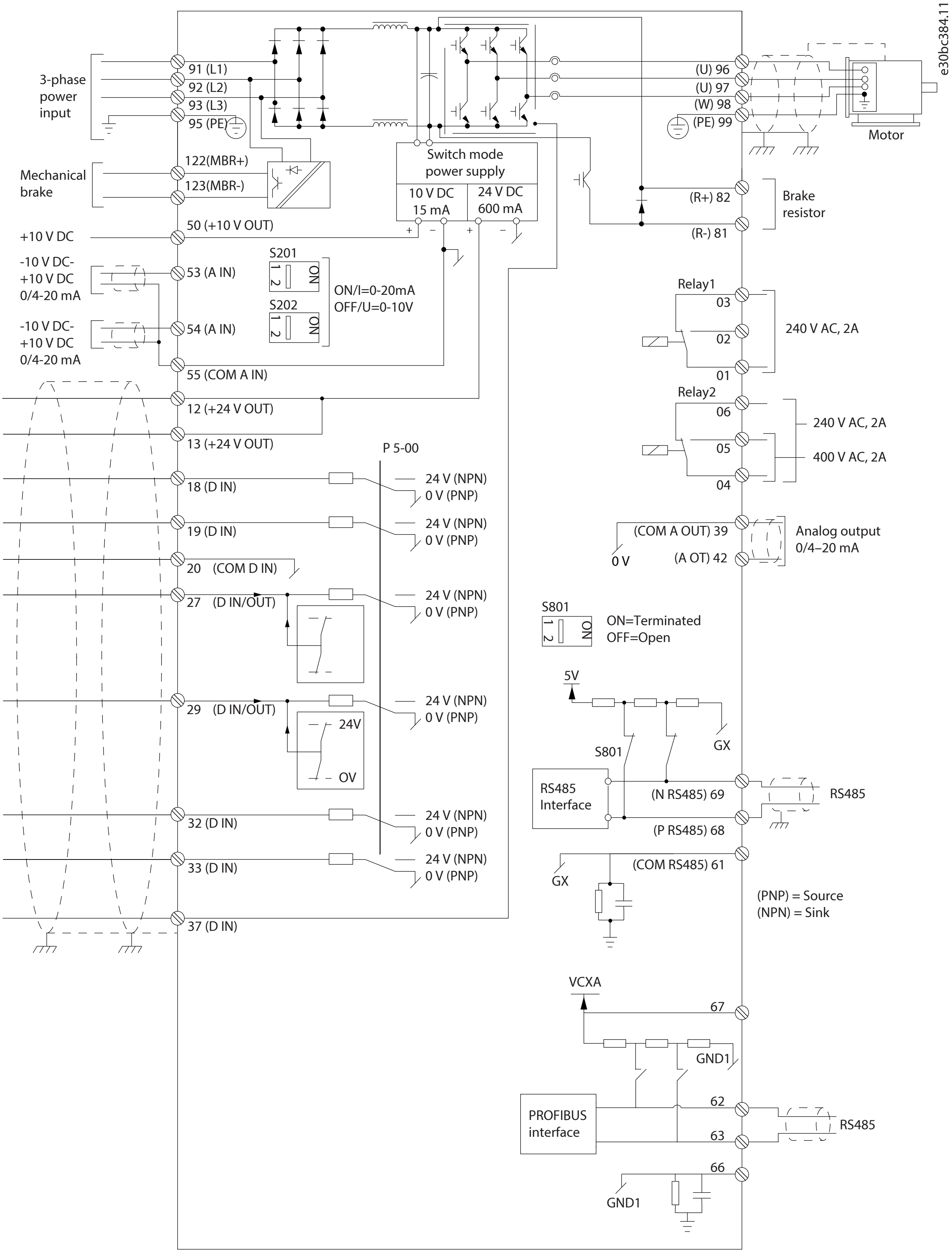


Figure 33: Basic Wiring Diagram

A	Analog	**D**	Digital
1	Terminal 37 is used for Safe Torque Off[1].	**2**	Relay 2 has no function when the drive has mechanical brake output

1) Refer to the VLT® Safe Torque Off Operating Guide

For information on EMC-compliant information, refer to 9.16 EMC Compliant Installation

9.3 Cables

9.3.1 EMC-correct Cables

To optimize EMC immunity of the control cables and emission from the motor cables, use braided shielded cables/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 (ZT) 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 is often stated as a percentage value.
- Shield type (braided or twisted).

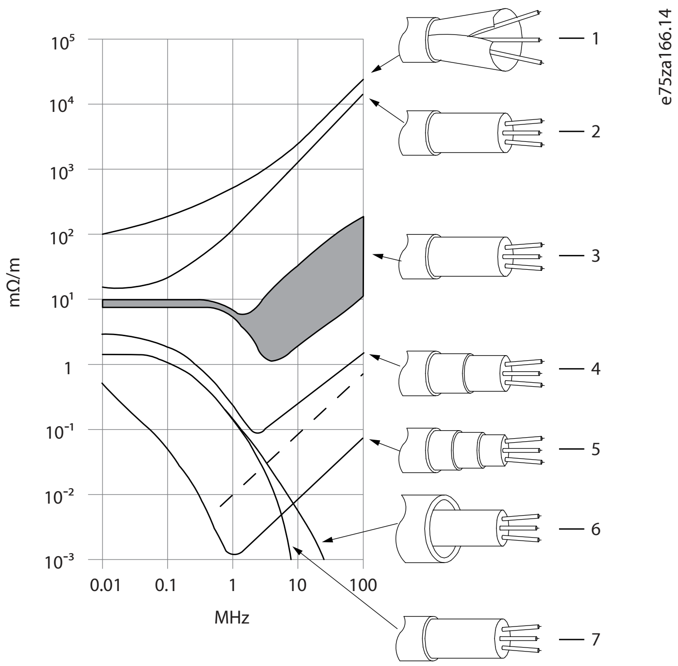


Figure 34: Transfer Impedance (Z_T)

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 a copper tube or steel tube.
7	Lead cable with 1.1 mm (0.04 in) wall thickness.		

9.3.2 Motor Cables

NOTICE

Shielded, armored cables are recommended to comply with EMC emission specifications.

For correct dimensioning of the motor cable, see 7.5.2 Power Cable Cross-sections and 7.5.1 Motor Cable Length.

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 motor contactor, the shield must be continued at the lowest possible HF impedance. Connect the motor cable shield to both the decoupling plate of the drive and to the metal housing of the motor.

Make the shield connections with the largest possible surface area (cable clamp). This is done by using the supplied installation devices in the drive. If it is necessary to split the shield to install a motor isolator or motor relay, the shield must be continued with the lowest possible HF impedance.

Cable length and cross-section

The drive has been tested with a given length of cable and a given cross-section of that cable. If the cross-section is increased, the cable capacitance - and thus the leakage current - may increase, and the cable length must be reduced correspondingly. Keep the motor cable as short as possible to reduce the noise level and leakage currents.

All types of 3-phase induction standard motors can be connected to the drive. Normally, small motors are star-connected (230/400 V, Y). Large motors are normally delta-connected (400/690 V, Δ). Refer to the motor nameplate for the correct connection mode and voltage.

For installation of mains and motor cables, refer to *VLT® Decentral Drive FCD 302 Operating Guide*.

Table 12: Motor Connection Terminals

	Terminal number				Description
	96	**97**	**98**	**99**	
Phases	U	V	W	PE (1)	Motor voltage 0–100% of mains voltage. 3 wires out of the motor.
	U1	V1	W1	PE (1)	Delta-connected.
	W2	U2	V2	PE (1)	6 wires out of the motor.
	U1	V1	W1	PE (1)	Star-connected U2, V2, W2. U2, V2, and W2 to be interconnected separately.

1) Protective ground connection.

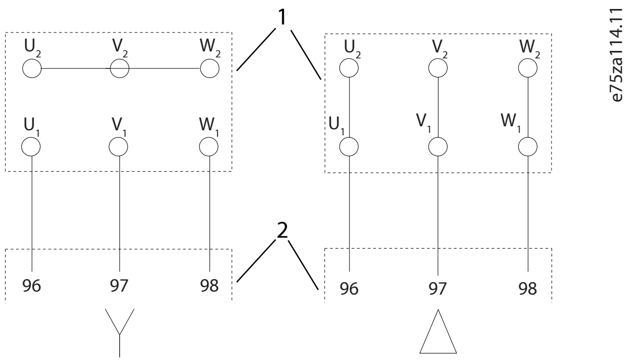


Figure 35: Star - Delta Grounding Connections

1	Motor	2	Drive

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

9.3.3 Equalizing Cable

As the shield of the communication cable must be connected to the ground by each drive/device, there is a risk of having a current in the communication cable. This might lead to communication problems as the equalizing current can interfere with the communication. To reduce currents in the shield of the communication cable, always apply a short grounding cable between units that are connected to the same communication cable. Danfoss recommend using minimum 16 mm2 (6 AWG) equalizing cable and install the equalizing cable parallel with the communication cable.

For good equalizing between VLT® Decentral Drive FCD 302 in a decentral installation, use the external equalizing terminal from Danfoss. See 12.3.1 Accessories stainless chassis kit, M16.

9.3.4 Mechanical Brake Cables

EMC (twisted cables/shielding)

To reduce the electrical noise from the wires between the mechanical brake and the drive, the wires must be twisted. For enhanced EMC performance, use a metal shield.

It is allowed to use twisted-pair cables, containing both the motor and brake cables.

9.3.5 Brake Resistor Cables

EMC (twisted cable/shielding)

To reduce the electrical noise from the wires between the brake resistor and the drive, the wires must be twisted.

For enhanced EMC performance, use a metal shield.

9.3.6 Cable Entry Holes

9.3.6.1 Cable Entries

Table 13: Specification of Cable Entries

Section	Gland specification
Motor side	1xM20, 1xM25
Control side	2xM20, 9xM16[1]
Mains side	2xM25

1) Also used for 4xM12/6xM12 sensor/actuator sockets.

9.3.6.2 Preparing Cable Entry Holes

The VLT® Decentral Drive FCD 302 is also available as a real NPT (national pipe thread) version.

- NPT1 for USA
- NPT2 for USA

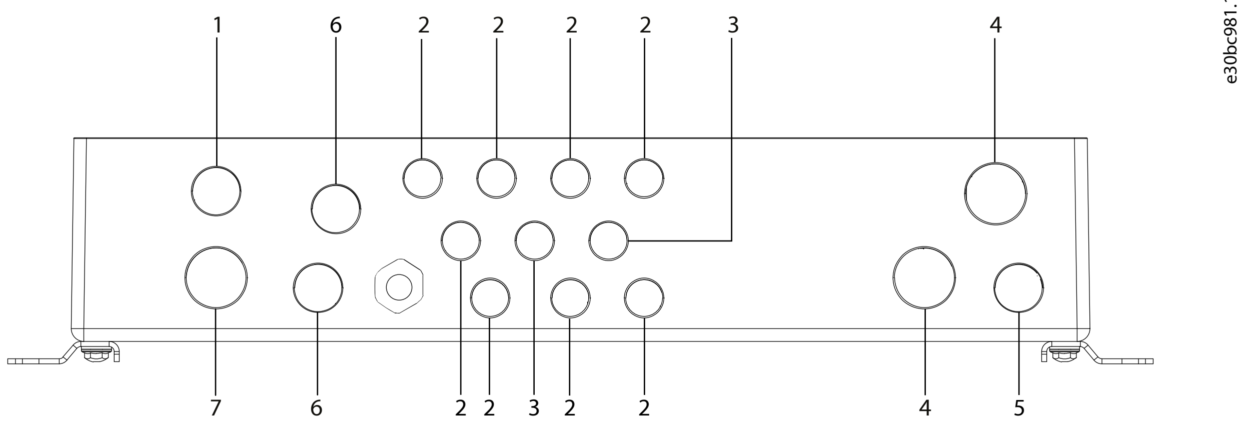


Figure 36: Cable Entry Holes - Large Unit, Standalone Mount

Table 14: Cable Entry Specification

Position number	Metric	NPT 1 for USA	NPT 2 for USA
1	Brake M20	1/2″ NPT	1/2″ NPT
2	8xM16	8xM16	3/8″ NPT(1)
3	2xM20	2xM20	1/2″ NPT
4	Mains cables M25	3/4″ NPT	3/4″ NPT
5	M20	M20	1/2″ NPT
6	24 V M20	1/2″ NPT	1/2″ NPT
7	Motor M25	3/4″ NPT	3/4″ NPT

1) Except the ground plug, which is M16.

9.4 Control Wiring and Terminals

9.4.1 Shielded Control Cables with Shielding Clamps

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).

Figure 37: Shielding Clamps at Both Ends

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

9.4.2 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).

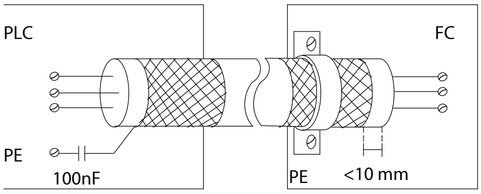


Figure 38: Connection with a 100 nF Capacitor

9.4.3 Avoid EMC Noise on Serial Communication

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

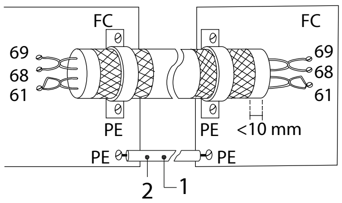


Figure 39: Twisted-pair Cables

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

Alternatively, the connection to terminal 61 can be omitted.

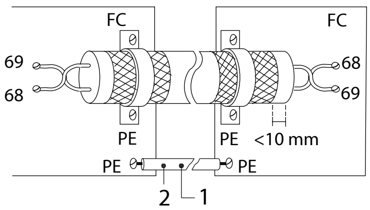


Figure 40: Twisted-pair Cables without Terminal 61

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

9.4.4 Input Polarity of Control Terminals

Long control cables and analog signals can in rare cases result in 50/60 Hz ground loops due to noise from mains supply cables. If this occurs, it can be necessary to break the shield or insert a 100 nF capacitor between shield and chassis. Connect the digital and analog inputs and outputs separately to the common inputs (terminal 20, 55, 39) to avoid ground currents from both groups affecting other groups. For example, switching on the digital input may disturb the analog input signal.

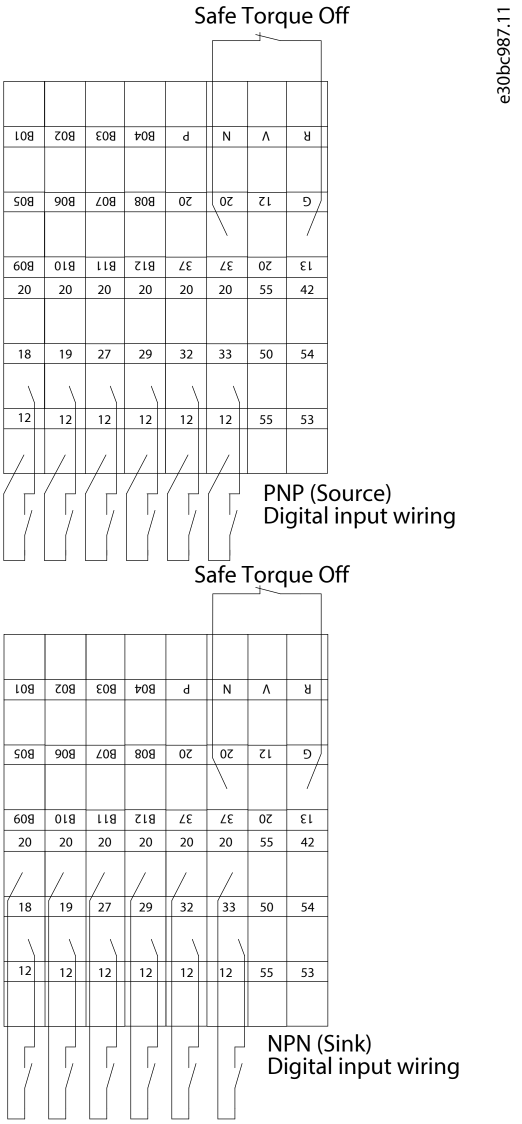


Figure 41: Input Polarity of Control Terminals

NOTICE

EMC EMISSION

To comply with EMC emission specifications, shielded cables and armored cables are recommended.

- See 9.14.1 EMC Test Results for more information if an unshielded/ unarmored cable is used.

9.5 Relays

9.5.1 Relay Output

The relay output with the terminals 01, 02, 03 and 04, 05, 06 has a capacity of maximum 240 V AC, 2 A. Minimum 24 V DC, 10 mA, or 24 V AC, 100 mA can be used for indicating status and warnings. The 2 relays are physically located on the installation card. The relays are programmable through parameter group ***5-4* Relays***. The relays are Form C, meaning each has 1 normally open contact and 1 normally closed contact on a single throw. The contacts of each relay are rated for a maximum load of 240 V AC at 2 amps

Relay 1

- Terminal 01: Common.

- Terminal 02: Normally open 240 V AC.
- Terminal 03: Normally closed 240 V AC.

Relay 2

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

Relay 1 and relay 2 are programmed in parameter ***5–40 Function Relay***, parameter ***5–41 On Delay, Relay***, and parameter ***5–42 Off Delay, Relay***.

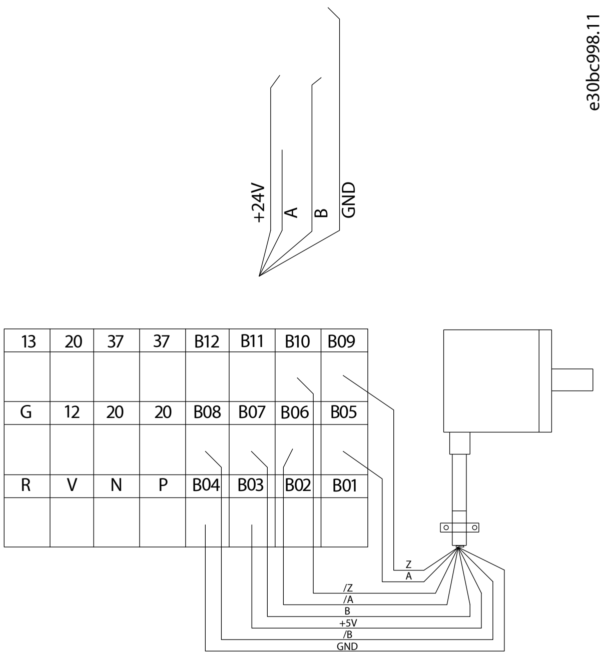


Figure 42: Relay Connection

9.5.2 Relay Connection

Set the relay output in parameter group ***5-4* Relays***.

For location of relay terminals, refer to *VLT® Decentral Drive FCD 302 Operating Guide*.

Table 15: Relay Settings

Number	Description
01-02	Make (normally open)
01-03	Break (normally closed)
04-05	Make (normally open)
04-06	Break (normally closed)

9.6 Fuses and Circuit Breakers

9.6.1 Recommended Protection on the Supply Side

Fuses ensure that possible damage to the drive is limited to damage inside the unit. Danfoss recommends fuses and/or circuit breakers on the supply side as protection.

NOTICE

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

NOTICE

Protect personnel and property against the consequence of component break-down internally in the drive.

Branch and circuit protection

To protect the installation against electrical and fire hazard, all branch circuits in an installation, switchgear, machines, and so forth, must be protected against short circuit and overcurrent. Protect the installation according to national/international regulations.

NOTICE

The recommendations given do not cover branch circuit protection for UL.

Short-circuit protection

Danfoss recommends using the fuses/circuit breakers mentioned in 9.6.2 Recommendations for Fuses and Circuit Breakers to protect service personnel and property if there is a component break-down in the drive.

9.6.2 Recommendations for Fuses and Circuit Breakers

⚠ CAUTION

MALFUNCTION

Failure to follow the recommendation may result in personnel risk and damage to the drive or other equipment.

The following sections list the recommended rated current. Danfoss recommends fuse type gG and Danfoss CB (Danfoss - CTI-25M) circuit breakers. Other types of circuit breakers may be used if they limit the energy into the drive to a level equal to or lower than the Danfoss CB types.

Follow the recommendations for fuses and circuit breakers to ensure that any damage to the drive is internal only.

For further information, see *Application Note Fuses and Circuit Breakers*.

9.6.3 CE Compliance (IEC 60364)

Use of fuses or circuit breakers is mandatory to comply with IEC 60364.

Danfoss recommends fuse size up to gG-25. This fuse size is suitable for use on a circuit capable of delivering 100000 A_{rms} (symmetrical), 480 V. With the proper fusing, the drive short-circuit current rating (SCCR) is 100000 A_{rms}.

9.6.4 UL Compliance (NEC 2009)

Fuses or circuit breakers are mandatory to comply with NEC 2009.

To meet UL/cUL requirements, use the pre-fuses in 7.7 DC Voltage Levels, and comply with the conditions listed in chapter *Specifications*.

The current and voltage ratings are also valid for UL.

9.6.5 UL/cUL Approved Pre-fuses

- American wire gauge. Maximum cable cross-section is the largest cable cross-section that can be attached to the terminals. Always observe national and local regulations.
- Use Type gG pre-fuses. To maintain UL/cUL, use pre-fuses of these types, see Table 16.
- Measured using a 10 m (32.8 ft) shielded/armored motor cable with a rated load and rated frequency.

9.6.6 Recommended Maximum Pre-fuse Size 25 A

Table 16: FCD 302 Pre-fuses Meeting UL/cUL Requirements

Brand	Fuse type(1)	UL file number	UL category (CCN code)(2)
Bussmann	FWH-	E91958	JFHR2
Bussmann	KTS-R	E4273	RK1/JDDZ
Bussmann	JKS-	E4273	J/JDDZ
Bussmann	JJS-	E4273	T/JDDZ
Bussmann	FNQ-R-	E4273	CC/JDDZ
Bussmann	KTK-R-	E4273	CC/JDDZ
Bussmann	LP-CC-	E4273	CC/JDDZ
SIBA	5017906-	E180276	RK1/JDDZ
Littelfuse	KLS-R	E81895	RK1/JDDZ
Ferraz Shawmut	ATM-R	E2137	CC/JDDZ
Ferraz Shawmut	A6K-R	E2137	RK1/JDDZ
Ferraz Shawmut	HSJ	E2137	J/HSJ

1) 5 A (0.37 kW (0.5 hp)), 7 A (0.55 kW (0.75 hp)), 9 A (0.75 kW (1.0 hp)), 12 A (1.1 kW (1.5 hp)), 15 A (1.5 kW (2.0 hp)), 20 A (2.2 kW (3.0 hp)), 25 A (3 kW (4.0 hp)).

2) The fuse types listed are the preferred and tested fuses. However, other suppliers or fuse types can be used as long as the UL category is equal to the fuse types listed in this table.

9.7 Disconnects and Contactors

The drive is available with 2 options:

- Service switch on the mains side or motor side.
- Built-in circuit breaker on the mains side, for 3.0 kW (4.0 hp) unit only.

Specify the requirement before ordering.

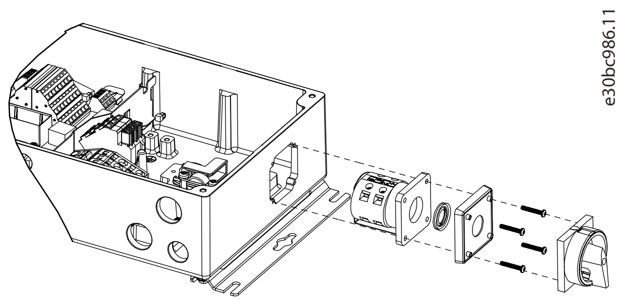


Figure 43: Location of Service Switch on the Mains Side, 3.0 kW (4.0 hp) Unit – IP66/Type 4X Indoor

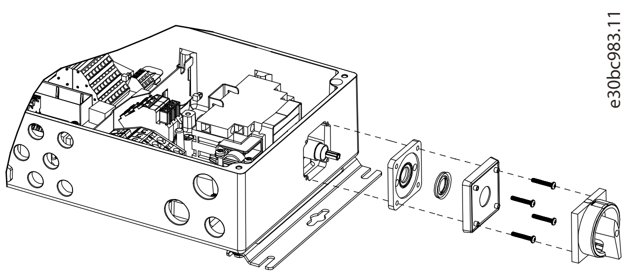


Figure 44: Location of Circuit Breaker on the Mains Side, 3.0 kW (4.0 hp) Unit

9.8 Motor

9.8.1 Motor Thermal Protection

The electronic thermal relay in the drive has received approval for single motor overload protection, when parameter ***1–90 Motor Thermal Protection*** is set for ETR Trip and parameter ***1–24 Motor Current*** is set to the rated motor current. See the motor nameplate.

9.8.2 Parallel Connection of Motors

The drive can control several parallel-connected motors. When using a 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. Circuit breakers are not suitable for protection device.

When motors are connected in parallel, parameter ***1-02 Flux Motor Feedback Source*** cannot be used, and parameter ***1-01 Motor Control Principle*** must be set to ***Special motor characteristics (U/f)***.

The total motor cable length specified in 7.5.1 Motor Cable Length is valid as long as the parallel cables are kept short. Short is defined as less than 10 m (32.8 ft) each.

9.8.3 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.

The motor insulation ratings listed in Table 17 are recommended. Use a dU/dt or sine-wave filter for motors with lower insulation ratings. For motor cable lengths, see cable specifications 7.5.1 Motor Cable Length.

Table 17: Motor Insulation Ratings

Nominal mains voltage	Motor insulation
$U_N \leq 420$	Standard U_{LL}=1300
420 V < $U_N \leq 500$	Reinforced U_{LL}=1600

9.8.4 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 a 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.

9.9 Braking

9.9.1 Mechanical Brake

9.9.1.1 Mechanical Brake Selection Guide

VLT® Decentral Drive FCD 302 can be configured with or without a brake (see position 18 in Table 53). If the inverter part is configured with brake, relay 1 can be configured for various applications, while relay 2 should be reserved only for the mechanical brake. Relay 2 is mounted inside the installation box, but in this configuration state it is not active.

The mechanical brake coil can be powered by a low voltage (of 24 V DC) or from mains line AC voltage. If the mechanical brake is a 24 V DC type, 1 of the 2 custom relays, relay 1, or a functional relay 2, can be used within the electrical specification (voltage, current, and so forth) or with external relays. If the drive is configured without brake, the internal electrical control signal for relay 2 is active.

If the brake is powered by mains supply, or a mains rectified DC voltage, it is recommended to order the FCD 302 with a mechanical brake. In this case, all the parameter settings for relay 2 now control the internal solid-state switch which gives the output voltage at the MBR(+) and MBR(-) terminals. In some motors, this mechanical brake can be of AC-type or DC-type. If the unit is AC-type, the mechanical brake has an internal diode D and the internal MOV, as described in Figure 45.

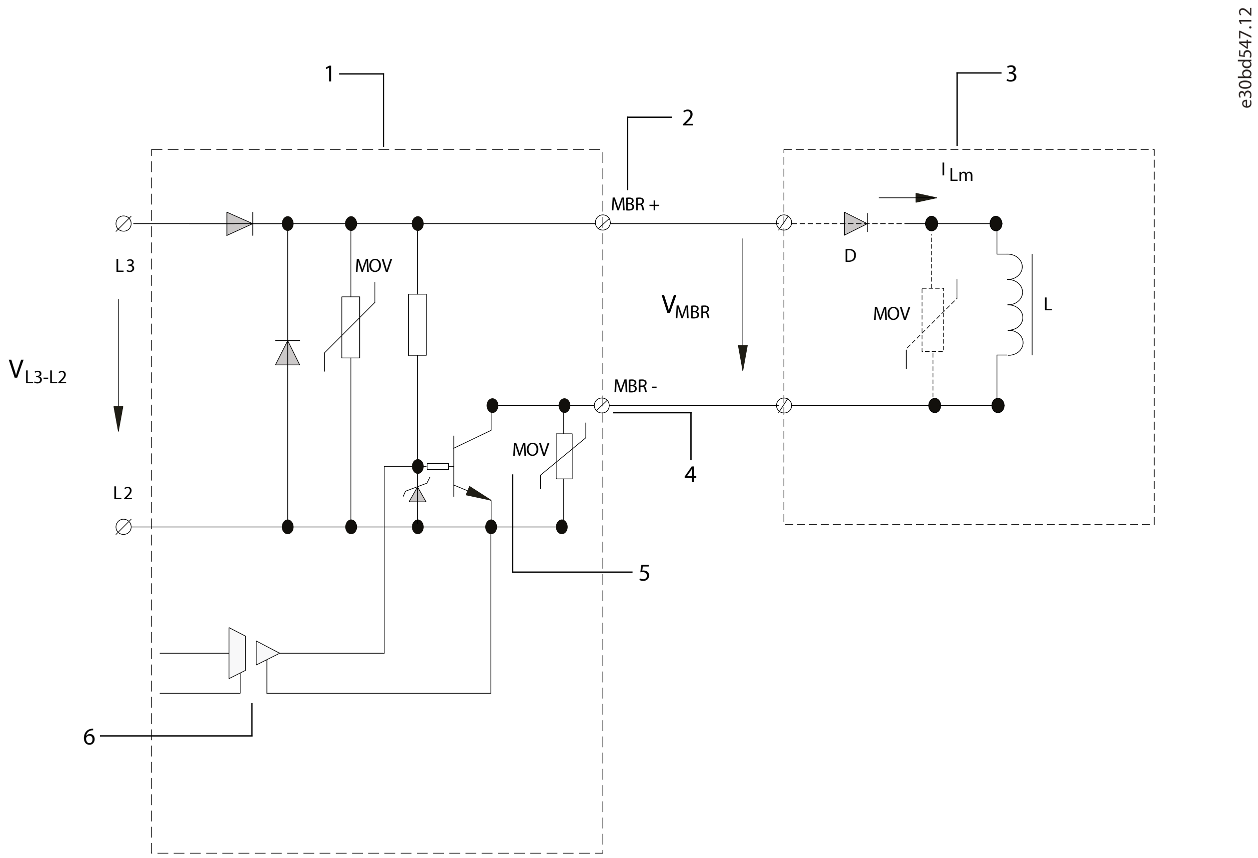


Figure 45: Electrical Diagram of Mechanical Brake

1	Inverter part	**2**	MBR+ terminal 122
3	Mechanical brake coil	**4**	MBR(-) terminal 123
5	Solid state switch	**6**	Galvanic isolated control circuit

The supply voltage is derived from the mains voltage between phases L2 and L3, which is passed through a single-pulse diode rectification.

The output voltage of a solid-state supply is not a constant value, but rather a pulsed voltage with an average level directly dependent on the mains voltage, as shown in Figure 46.

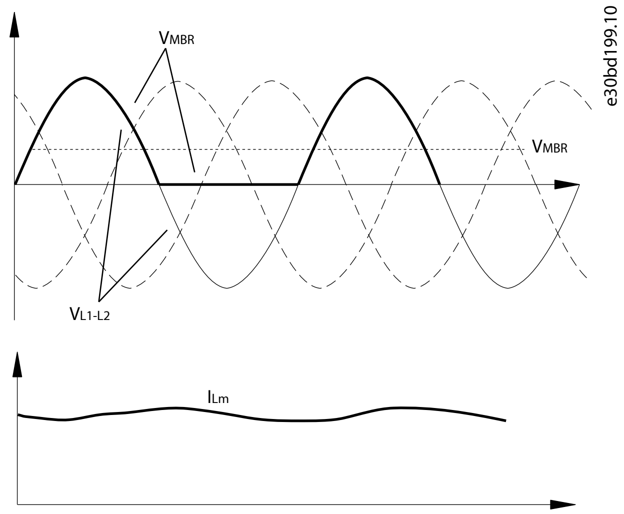


Figure 46: Instant Voltage V_{MBR} with its Average Level of V_{MBR}

V_{MBR}	Mechanical brake voltage	I_{LM}	Instant line voltage

This rectified voltage is applied to the mechanical brake inductor, with the smoothed current shape I_{Lm}.

The voltage shown in Figure 46 has the amplitude of the line voltage and an average voltage level calculated as:

$V_{MBR(DC)} = 0.45 \times V_{AC}$

Examples:

$V_{AC} = 400\ V_{rms} \Rightarrow V_{MBR} = 180\ V_{DC}$.

$V_{AC} = 480\ V_{rms} \Rightarrow V_{MBR} = 216\ V_{DC}$.

The average level of output voltage is directly determined by the amplitude of the line voltage measured between phases L1 and L2.

NOTICE

Maximum nominal voltage = 480 AC.

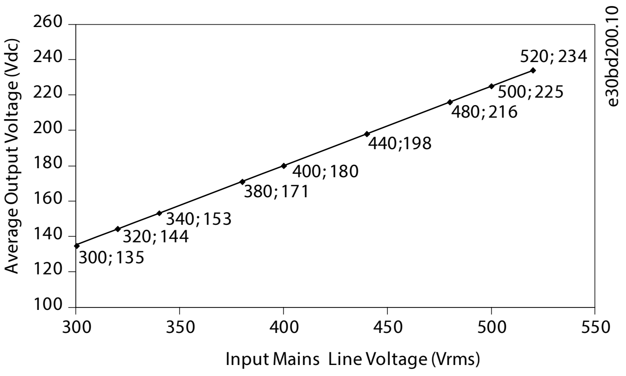


Figure 47: Average Output Voltage

It is possible to supply the mechanical brake in the motor with both DC and AC voltage. The output voltage is rectified by the internal diode inside the mechanical brake unit circuit. The average voltage applied to the brake coil remains at the same value.

9.9.1.2 Mechanical Brake Control

In hoisting applications, the ability to control the electromagnetic brake is essential. For controlling the brake, a relay output (relay 1 or relay 2/solid-state brake) or a programmed digital output (terminal 27 or 29) is required. Normally, this output must be closed for as long as the drive is unable to hold the motor, for example, because of excess load. For applications with an electromagnetic brake, select [***32***] ***mechanical brake control***in 1 of the following parameters:

- Parameter ***5-40 Function Relay*** (Array parameter).
- Parameter ***5-30 Terminal 27 Digital Output***.
- Parameter ***5-31 Terminal 29 Digital Output***.

When [***32***] ***mechanical brake control*** is selected, the mechanical brake relay stays closed during start until the output current is above a preset level. Select the preset level in parameter ***2-20 Release Brake Current***. During stop, the mechanical brake closes when the speed is below the level selected in parameter ***2-21 Activate Brake Speed [RPM]***. When the drive is brought into an alarm condition (that is, an overvoltage situation), or during STO (Safe Torque Off), the mechanical brake immediately cuts in.

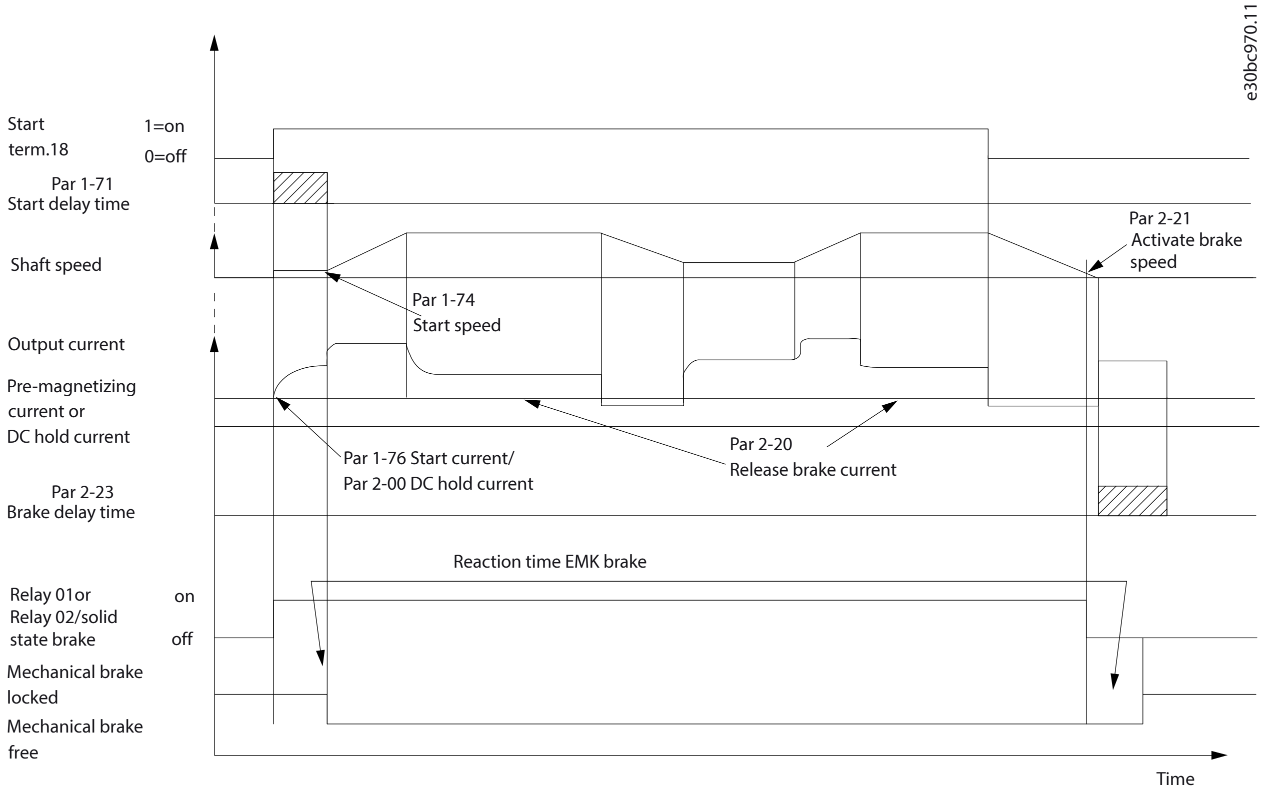


Figure 48: Mechanical Brake Control for Hoisting Applications

Step-by-step description

- To control the mechanical brake, use any relay output, digital output (terminal 27 or 29), or solid-state brake voltage output (terminals 122–123). Use a suitable contactor when required.
- Ensure that the output is switched off as long as the drive is unable to drive the motor. For example, due to the load being too heavy, or when the motor is not yet mounted.
- Select [***32***] ***mechanical brake control*** in parameter group ***5-4* Relays*** (or in parameter group ***5-3* Digital Outputs***) before connecting the mechanical brake.
- The brake is released when the motor current exceeds the preset value in parameter ***2-20 Release Brake Current***.
- The brake is engaged when the output frequency is lower than a preset limit. Set the limit in parameter ***2-21 Activate Brake Speed [RPM]*** or parameter ***2-22 Activate Brake Speed [Hz]*** and only if the drive carries out a stop command.

Recommendations: For vertical lifting or hoisting applications

NOTICE

Ensure that the load can be stopped in an emergency or a malfunction of a single part such as a contactor. When the drive enters alarm mode or an overvoltage situation, the mechanical brake cuts in.

For hoisting applications

NOTICE

Make sure that the torque limit settings do not exceed the current limit. Set torque limits in parameter ***4-16 Torque Limit Motor Mode*** and parameter ***4-17 Torque Limit Generator Mode***. Set current limit in parameter ***4-18 Current Limit***.

- Recommendation: Set parameter ***14-25 Trip Delay*** at ***Torque Limit*** to [*0*], parameter ***14-26 Trip Delay*** at ***Inverter Fault*** to [*0*], and parameter ***14-10 Mains Failure*** to [*3*] ***Coasting***.

9.9.1.3 Mechanical Hoist Brake

For an example of advanced mechanical brake control for hoisting applications, see 11.1 Application Examples.

9.9.2 Dynamic Brake

9.9.2.1 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*.

When the kinetic energy transferred to the resistor per braking period is unknown, calculate the average power using the cycle time and braking time. This is also referred to as the intermittent duty cycle. The resistor intermittent duty cycle is an indication of the duty cycle at which the resistor is active. See Figure 49 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).

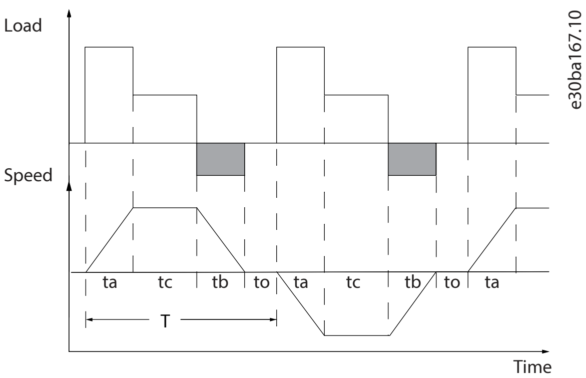


Figure 49: Dynamic Brake Cycle Time

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 used on dissipating excess heat.

Table 18: Braking at High Overload Torque Level

Type code	Cycle time	Braking duty cycle at 100% torque	Braking duty cycle at over torque (150/160%)
PK37–P3K0(1)	120 s	Continuous	40%

1) 3x380–480 V.

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:

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

Where:

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

The brake resistance depends on the DC-link voltage (U_{dc}). The brake function is settled in 4 areas of mains.

Table 19: Brake Limit Values

Size	Brake active	Warning before cutout	Cutout (trip)
FCD 302 3x380–480 V	778 V DC	810 V DC	820 V DC

NOTICE

Check that the brake resistor can handle a voltage of 820 V - unless brake resistors are used.

Danfoss recommends a brake resistance R_{rec} that can guarantee that the drive can brake at the highest brake power ($M_{br(\%)}$) of 160%.

Formula: $R_{rec}[\Omega] = \frac{U_{dc}^2 x 100}{P_{motor} x M_{br(\%)} x \eta_{VLT} x \eta_{motor}}$

η_{motor} is typically at 0.90

η_{VLT} is typically at 0.98

For 480 V drives, R_{rec} at 160% brake power.

Formula: $480V : R_{rec} = \frac{375300}{P_{motor}}[\Omega]$

⚠ WARNING

RISK OF FIRE

The brake resistors become 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.

NOTICE

The resistance in the brake resistor circuit should not exceed the limits recommended by Danfoss.

NOTICE

If a brake resistor with a higher ohmic value is selected, the 160% brake power may not be achieved. There is a risk that the drive cuts out for safety reasons.

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 for the drive. (The drive can control the contactor).

9.9.2.2 Brake Resistor

9.9.2.2.1 Brake Resistors 10 W

For drives equipped with the dynamic brake option, 1 brake IGBT along with terminals 81 (R-) and 82 (R+) is included in each inverter module for connecting a brake resistor/resistors.

An internal 10 W brake resistor can be mounted in the installation box (bottom part). This optional resistor is suitable for applications where braking IGBT is only active for short duty cycles, for example to avoid warning and trip events.

For internal brake resistors (10 W) use:

Brake resistor 1750 Ω 10 W/100%	For mounting inside installation box, below motor terminals.
Brake resistor 350 Ω 10 W/100%	For mounting inside installation box, below motor terminals.

9.9.2.2.2 Brake Resistor 40%

Placing the brake resistor externally has the advantages of selecting the resistor based on application need, dissipating the energy outside of the control panel. Furthermore it protects the drive from overheating if the brake resistor is overloaded.

Table 20: Brake Resistors 40%

Number	Function	
81 (optional function)	R-	Brake resistor terminals
82 (optional function)	R+	

- Use a shielded/armored connection cable to the brake resistor. Connect the shield to the metal cabinet of the drive and to the metal cabinet of the brake resistor with cable clamps.
- Dimension the cross-section of the brake cable to match the brake torque.

9.9.2.3 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. This limits the voltage from the DC link, which avoids a trip.

NOTICE

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

NOTICE

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 are 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.

9.10 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.

9.11 Leakage Current

9.11.1 Handling 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.

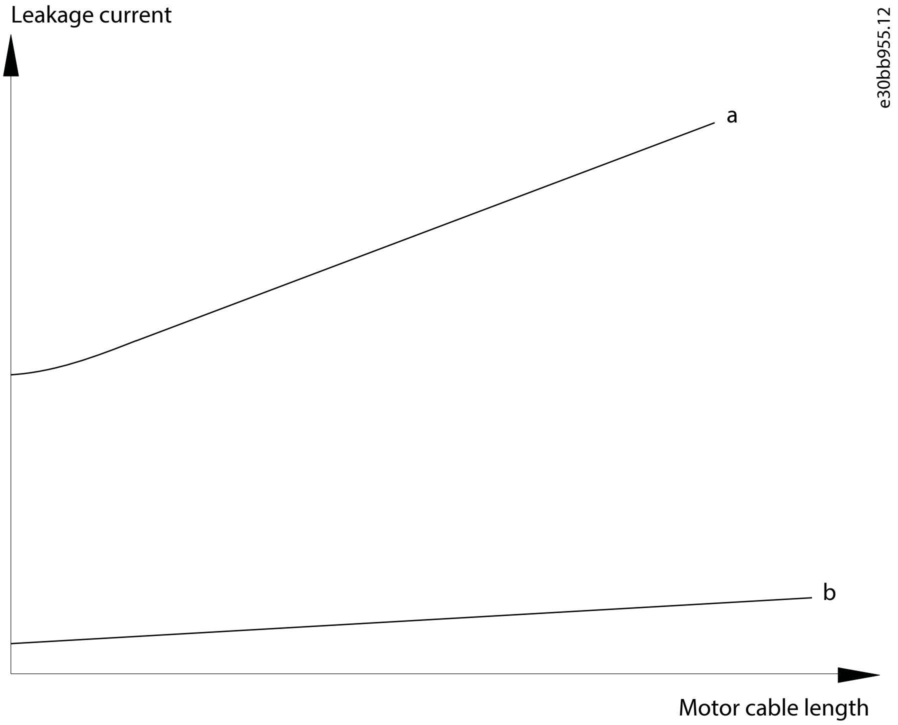


Figure 50: Influence of the Cable Length and Power Size on Leakage Current, Power Size a > Power Size b

The leakage current also depends on the line distortion.

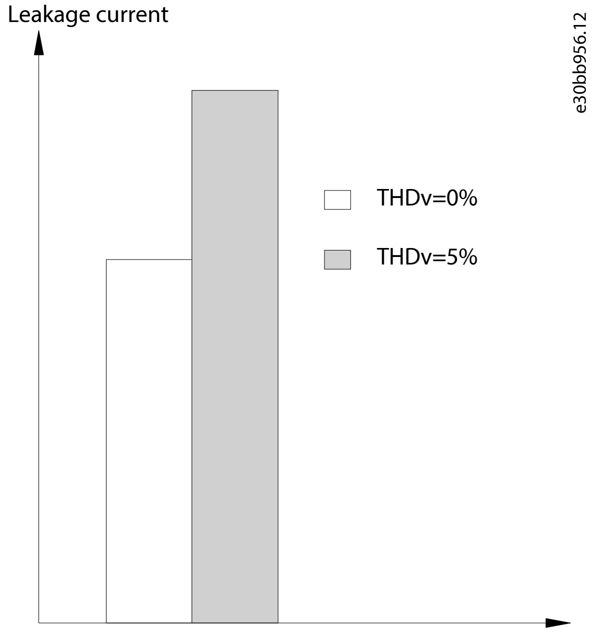


Figure 51: Influence of Line Distortion on Leakage Current

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.

9.11.2 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.

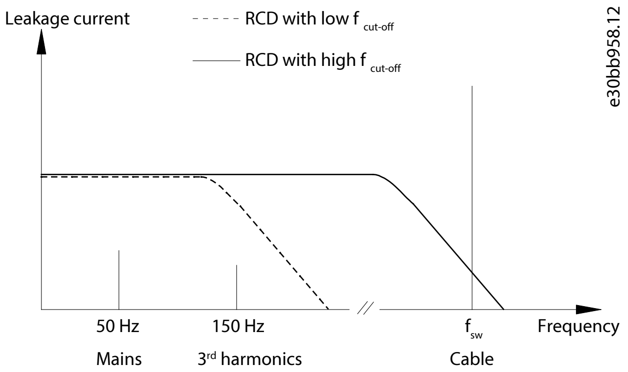


Figure 52: Mains Contributions to Leakage Current

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

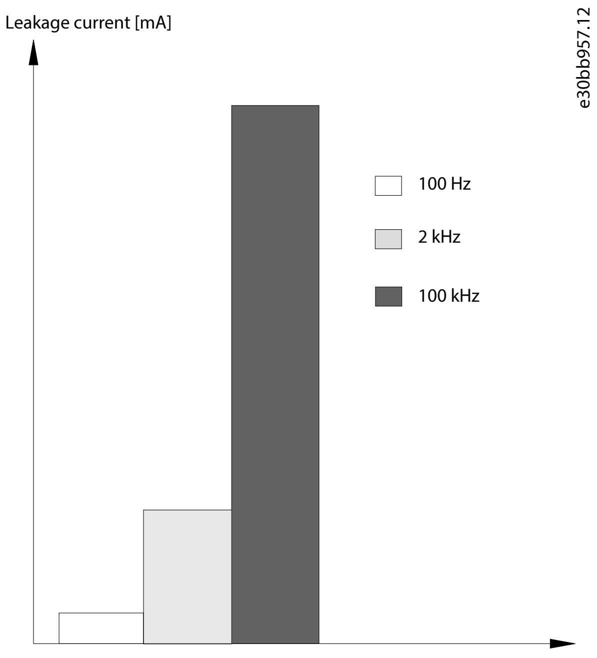


Figure 53: Influence of Cut-off Frequency of the RCD on what is Responded to/Measured

For more details, refer to the *RCD Application Note*.

9.12 Efficiency

Efficiency of the drive (n_{VLT})

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 following graph. Multiply the factor in this graph by the specific efficiency factor listed in Table 8:

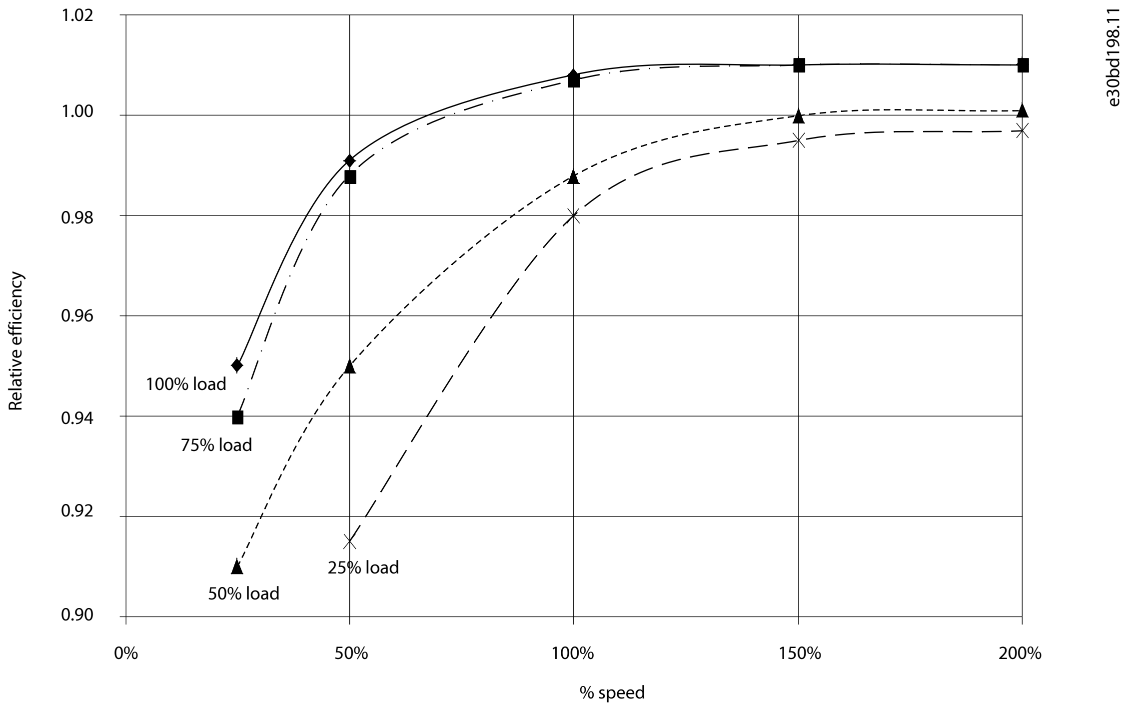


Figure 54: Typical Efficiency Curves

Example:

- Assume a 3.0 kW, 380–480 V AC at 75% load at 50% speed. The graph is showing 0.99 - the rated efficiency for a 3.0 kW, FCD 302 is 0.97.
- The calculated actual efficiency is: 0.99x0.97=0.96.

The MyDrive® Energy tool helps to calculate the efficiency, refer to MyDrive® Energy (danfoss.com).

Efficiency of the motor (ηMOTOR)

The efficiency of a motor connected to the drive depends on 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. This applies whether it is drive controlled or when it runs directly on mains.

In small motors, the influence from the U/f characteristic on efficiency is marginal.

In general, the switching frequency does not affect the efficiency of small motors. Motors with low internal impedance (for example, permanent magnet motors with a high-power factor) require a relatively high switching frequency to maintain the sine shape of the current. The resulting increase in switching losses can decrease the efficiency of the drive.

Efficiency of the system (ηSYSTEM)

To calculate the system efficiency, the efficiency of the drive (ηVLT) is multiplied by the efficiency of the motor (ηMOTOR):

- ηSYSTEM = ηVLT x ηMOTOR.

9.13 dU/dt

9.13.1 dU/dt Values for P0K37T4 and P0K55T4

Table 21: FCD 302 P0K37T4 and P0K55T4

Motor cable length [m (ft)]	Mains voltage [V_{rms}]	Rise time [μs]	Upeak [kV]	dU/dt [V/μs]
10 (32.8)	480	0.25	0.662	2118.40

9.13.2 dU/dt Values for P0K75T4

Table 22: FCD 302 P0K75T4

Motor cable length [m (ft)]	Mains voltage [V_{rms}]	Rise time [μs]	Upeak [kV]	dU/dt [V/μs]
10 (32.8)	480	0.22	0.66	2118.40

9.13.3 dU/dt Values for P1K1T4 and P1K5T4

Table 23: FCD 302 P1K1T4 and P1K5T4

Motor cable length [m (ft)]	Mains voltage [V_{rms}]	Rise time [μs]	Upeak [kV]	dU/dt [V/μs]
10 (32.8)	480	0.22	0.66	2400

9.13.4 dU/dt Values for P2K2T4

Table 24: FCD 302 P2K2T4

Motor cable length [m (ft)]	Mains voltage [V_{rms}]	Rise time [μs]	Upeak [kV]	dU/dt [V/μs]
10 (32.8)	480	0.142	0.685	3859.15

9.13.5 dU/dt Values for P3K0T4

Table 25: FCD 302 P3K0T4

Motor cable length [m (ft)]	Mains voltage [V_{rms}]	Rise time [μs]	Upeak [kV]	dU/dt [V/μs]
10 (32.8)	480	0.202	0.68	2693.07

9.14 Electromagnetic Compatibility (EMC)

9.14.1 EMC Test Results

The test results in Table 26 have been obtained using a system with a drive (with options if relevant):

- Shielded control cable.
- Control box with potentiometer.
- Motor.
- Motor shielded cable.

Table 26: EMC Test Results (Emission, Immunity)

RFI filter type		Conducted emission			Radiated emission	
Standards and requirements	EN 55011	Class B	Class A group 1	Class A group 2	Class B	Class A group 1
		Housing, trades, and light industries.	Industrial environment.	Industrial environment.	Housing, trades, and light industries.	Industrial environment.
	EN/IEC 61800-3	Category C1	Category C2	Category C3	Category C1	Category C2
		First environment. Home and office.	First environment. Home and office.	Second environment. Industrial.	First environment. Home and office.	First environment. Home and office.
H1						
VLT® FCD 302	0.37–3.0 kW (0.5–4.0 hp)	No	10 m (32.8 ft)	10 m (32.8 ft)	No	Yes

9.14.2 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 27.

Table 27: Emission Requirements

Category	Definition	Conducted emission requirement (1)
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 non-plug-in or non-movable. Installation and commissioning are intended 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.

1) According to the limits given in EN 55011.

When the generic emission standards are used, the drives are required to comply with the limits in Table 28.

Table 28: Emission Limit Classes

Environment	Generic standard	Conducted emission requirement [1]
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

1) According to the limits given in EN 55011.

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). The system is intended to be placed on the market for distribution as a single functional unit for an end user and 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. CE marking of installations is not a requirement.

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 with the EMC Directive when end users connect combinations of Danfoss Drives products as described in Danfoss 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.

9.14.3 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 the 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.

Follow product standard IEC 61800-3 for the immunity requirements. See Table 29.

Table 29: 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(1)	2 kV/2 Ω DM(2) 4 kV/12 Ω CM(1)	–	–	10 V_{RMS}
Motor	4 kV CM(1)	4 kV/2 Ω(3)	–	–	10 V_{RMS}
Brake	4 kV CM(1)	4 kV/2 Ω(3)	–	–	10 V_{RMS}
Load sharing	4 kV CM(1)	4 kV/2 Ω(3)	–	–	10 V_{RMS}
Control wires	2 kV CM(1)	2 kV/2 Ω(3)	–	–	10 V_{RMS}
Standard bus	2 kV CM(1)	2 kV/2 Ω(3)	–	–	10 V_{RMS}
Relay wires	2 kV CM(1)	2 kV/2 Ω(3)	–	–	10 V_{RMS}
Application and fieldbus options	2 kV CM(1)	2 kV/2 Ω(3)	–	–	10 V_{RMS}
LCP cable	2 kV CM(1)	2 kV/2 Ω(3)	–	–	10 V_{RMS}
External 24 V DC	2 kV CM(1)	0.5 kV/2 Ω DM(2) 1 kV/12 Ω CM(1)	–	–	10 V_{RMS}
Enclosure	–	–	8 kV AD(4) 6 kV CD(5)	10 V/m	–

1) CM=Common-mode.

2) DM=Differential mode.

3) Injection on cable shield.

4) AD=Air discharge.

5) CD=Contact discharge.

9.14.4 EMC Compatibility

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.

NOTE: 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 Figure 55. The components described comply with both PELV and the galvanic isolation requirements.

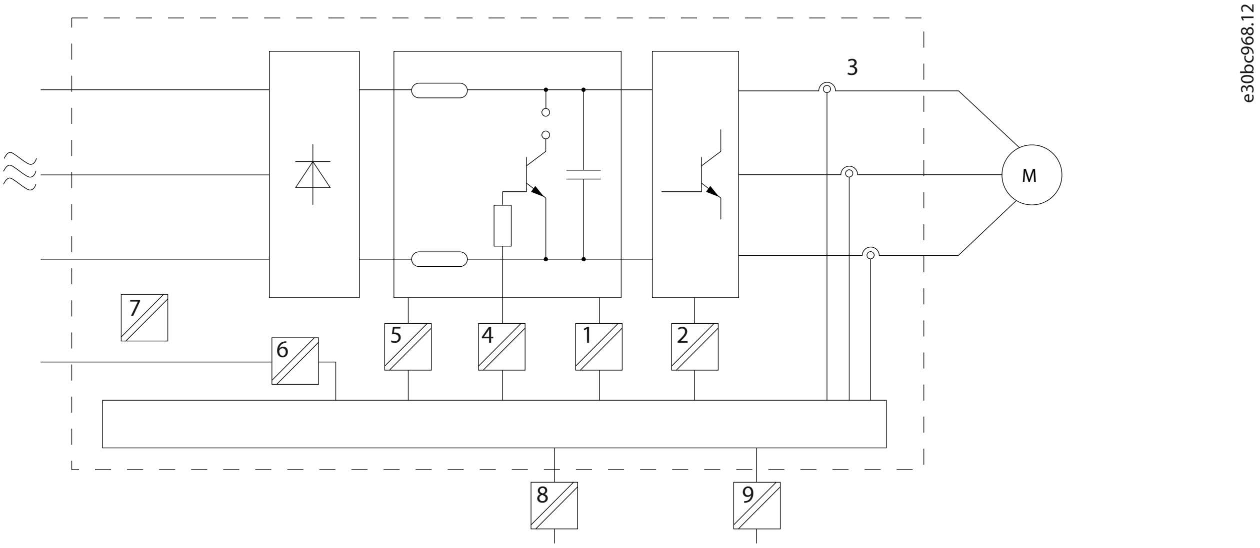


Figure 55: Galvanic Isolation

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	**8**	Functional galvanic isolation for the 24 V back-up option and for the RS-485 standard bus interface.
9	Functional galvanic isolation for the 24 V back-up option and for the RS-485 standard bus interface.		

9.15 Harmonics

9.15.1 Harmonics Overview

Non-linear loads, such as found in drives, do not draw current uniformly from the power line. This non-sinusoidal current has components which are multiples of the basic current frequency. These components are referred to as harmonics. It is important to control the total harmonic distortion on the mains supply. Although the harmonic currents do not directly affect electrical energy consumption, they generate heat in the wiring and transformers that can affect other devices on the same power line.

9.15.2 Harmonics Analysis

Since harmonics increase heat losses, it is important to consider harmonics when designing systems to avoid 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 30: 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 31: 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 32: 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:

$$\text{THDi} = \frac{\sqrt{I_5^2 + I_7^2 + \ldots . I_n^2}}{I}$$

9.16 EMC Compliant Installation

The following is a guideline to good engineering practice when installing drives. Follow these guidelines to comply with EN 61800-3 1st environment. If the installation is in EN 61800-3 2nd environment, for example, industrial networks or in an installation with its own transformer. Deviation from these guidelines is allowed but not recommended. For further information, refer to the chapter *Electromagnetic Compatibility (EMC)* in this guide.

Good engineering practice to ensure EMC compliant electrical installation:

- Use only braided shielded/armored motor cables and braided shielded/armored control cables. The shield must provide a minimum coverage of 80%. The shield material must be metal, not limited to but typically copper, aluminum, steel, or lead. There are no special requirements for the mains cable.
- Installations using rigid metal conduits are not required to use shielded cable, but the motor cable must be installed in a conduit separate from the control and mains cables. Full connection of the conduit from the drive to the motor is required. The EMC performance of flexible conduits varies a lot and information from the manufacturer must be obtained.

- Connect the shield/armor/conduit to the ground at both ends for motor cables and for control cables. Sometimes, it is not possible to connect the shield in both ends. If so, connect the shield at the drive.
- Avoid terminating the shield/armor with twisted ends (pigtails). It increases the high-frequency impedance of the shield, which reduces its effectiveness at high frequencies. Use low-impedance cable clamps or EMC cable glands instead.
- Avoid using unshielded/unarmored motor or control cables inside cabinets housing of the drives, whenever it can be avoided.
- Leave the shield as close to the connectors as possible.

Figure 56 shows an example of an EMC-compliant electrical installation of the VLT® Decentral Drive FCD 302. The drive is connected to a PLC, which is installed in a separate cabinet. Installations performed differently can achieve equivalent EMC performance if the preceding guidelines are followed.

If the installation is not carried out according to the guidelines, and if unshielded cables and control wires are used, then certain emission requirements are not fulfilled, although the immunity requirements are fulfilled. See chapter 9.14.1 EMC Test Results.

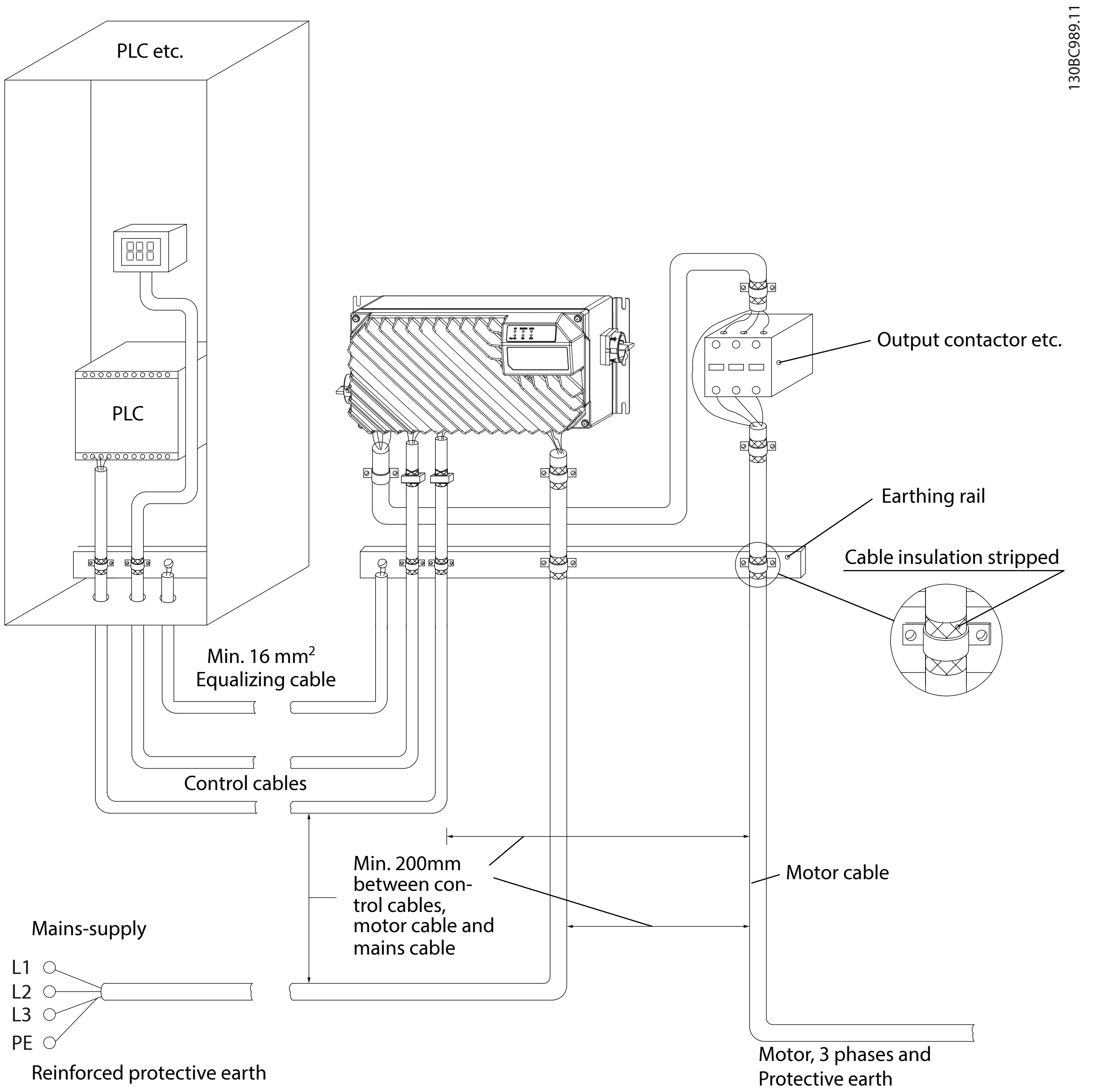


Figure 56: EMC-compliant Electrical Installation of the FCD 302 Drive

A minimum distance of 200 mm (7.87 in) is required between the fieldbus cable and the motor cable, and also between the fieldbus cable and the mains cable. If this cannot be achieved, use the optional PE grounding plug on the underside of the FCD 302 drive.

9.17 Connections

9.17.1 Power Connections Mains-side Dynamics

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.

For installation instructions and location of terminals, refer to *VLT® Decentral Drive FCD 302 Operating Guide*.

Connection of mains

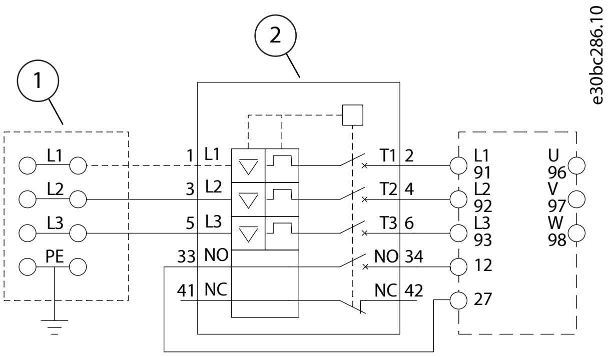


Figure 57: Circuit Breaker and Mains Disconnect. Large Unit, Standalone Mount Only

1	Looping terminals	**2**	Circuit breaker

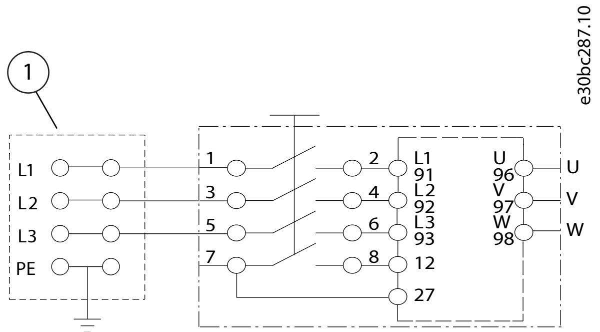


Figure 58: Service Switch at Mains with Looping Terminals. Large Unit, Standalone Mount Only

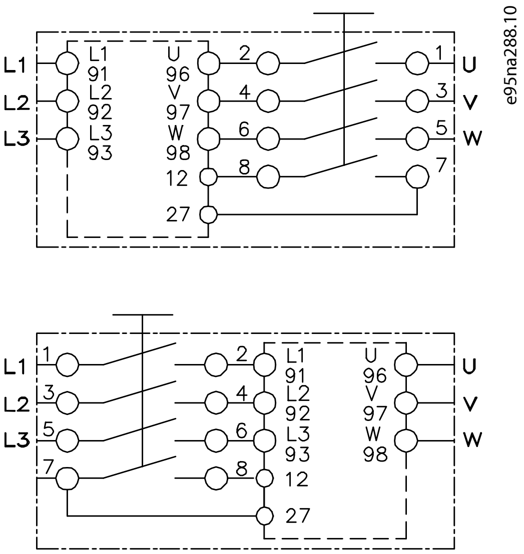


Figure 59: Motor and Connection of Mains with Service Switch

For both small and large units, the service switch is optional. The switch is shown mounted on the motor side. Alternatively, the switch can be on the mains side, or omitted.

For the large unit, the circuit breaker is optional. The large unit can be configured with either service switch or circuit breaker, not both. Figure 59 is not configurable in practice, but shows the respective positions of components only.

Usually, the power cables for mains are unshielded cables.

9.17.2 IT Grid Connection

Mains supply isolated from ground

NOTICE

RISK OF TRANSIENTS ON T5 DRIVES

If applying more than 440 V on T5 drives phase-to-phase voltage, there is not enough space between wires on the PCB. This situation may cause transients, which can damage the drive.

- Ensure that maximum 440 V is applied on T5 drives phase-to-phase voltage.

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.

9.17.3 Grounding Requirements

9.17.3.1 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.

9.17.3.2 Grounding

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

- Safety grounding: 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.

9.17.3.3 Electrical Grounding of the Installation Box

To obtain the electrical safety, always connect the safety ground on the dedicated connections inside the VLT® Decentral Drive FCD 302 installation box. See Figure 60.

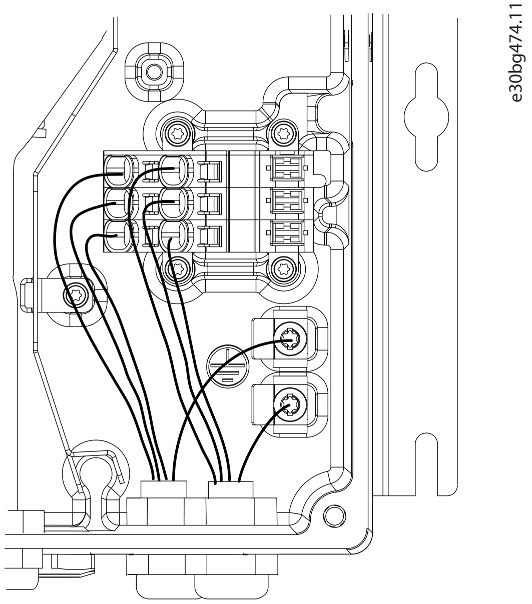


Figure 60: Electrical Safety Ground Connections

10 Basic Operating Principles

10.1 Introduction

This chapter provides an overview of the primary assemblies and circuitry of a Danfoss VLT® drive. It describes the internal electrical and signal processing functions. A description of the internal control structure is also included.

10.2 Drive Controls

A drive is an electronic controller that supplies a regulated amount of AC power to a 3-phase inductive motor. By supplying variable frequency and voltage to the motor, the drive varies the motor speed or maintains a constant speed as the load on the motor changes. Also, the drive can stop and start a motor without the mechanical stress associated with a line start.

In its basic form, the drive can be divided into 4 main areas:

- A rectifier consisting of SCRs or diodes that convert 3-phase AC voltage to pulsating DC voltage.
- A DC link consisting of inductors and their capacitor banks that stabilize the pulsating DC voltage.
- An inverter using IGBTs to convert the DC voltage to variable voltage and variable frequency AC.
- A control area consisting of software that runs the hardware to produce the variable voltage that controls and regulates the AC motor.

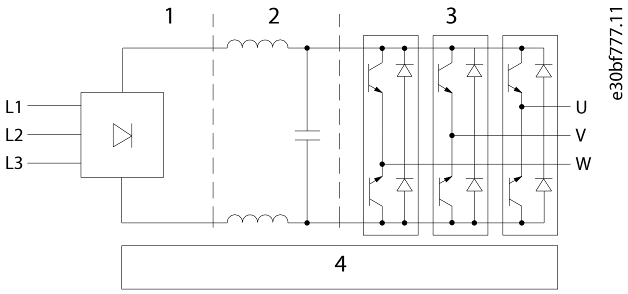


Figure 61: Internal Processing

1	Rectifier (SCR/diodes)	**2**	DC link (DC bus)
3	Inverter (IGBTs)	**4**	Control area

10.2.1 Control Principle

The control structure is a software process that controls the motor based on user-defined references, for example RPM, and whether feedback is used or not (closed loop/open loop). The operator defines the control by selecting the configuration mode.

The control structures are as follows:

- Open-loop control structure:
  - Speed (RPM).
  - Torque (Nm).
- Closed-loop control structure:
  - Speed (RPM).
  - Torque (Nm).
  - Process (user-defined units, for example, ft, rpm, psi, %, and bar).

User inputs/references

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 local (hand on).
- Remotely via analog/digital inputs and various serial interfaces (RS-485, USB, or an optional fieldbus). This method is referred to as remote (auto on) and is the default input setting. See more details in 10.2.2 Local (Hand On) and Remote (Auto On) Control.

10.2.2 Local (Hand On) and Remote (Auto On) Control

Active reference refers to the active input source. The active reference is configured via parameters. For more information, refer to the product-specific programming guide.

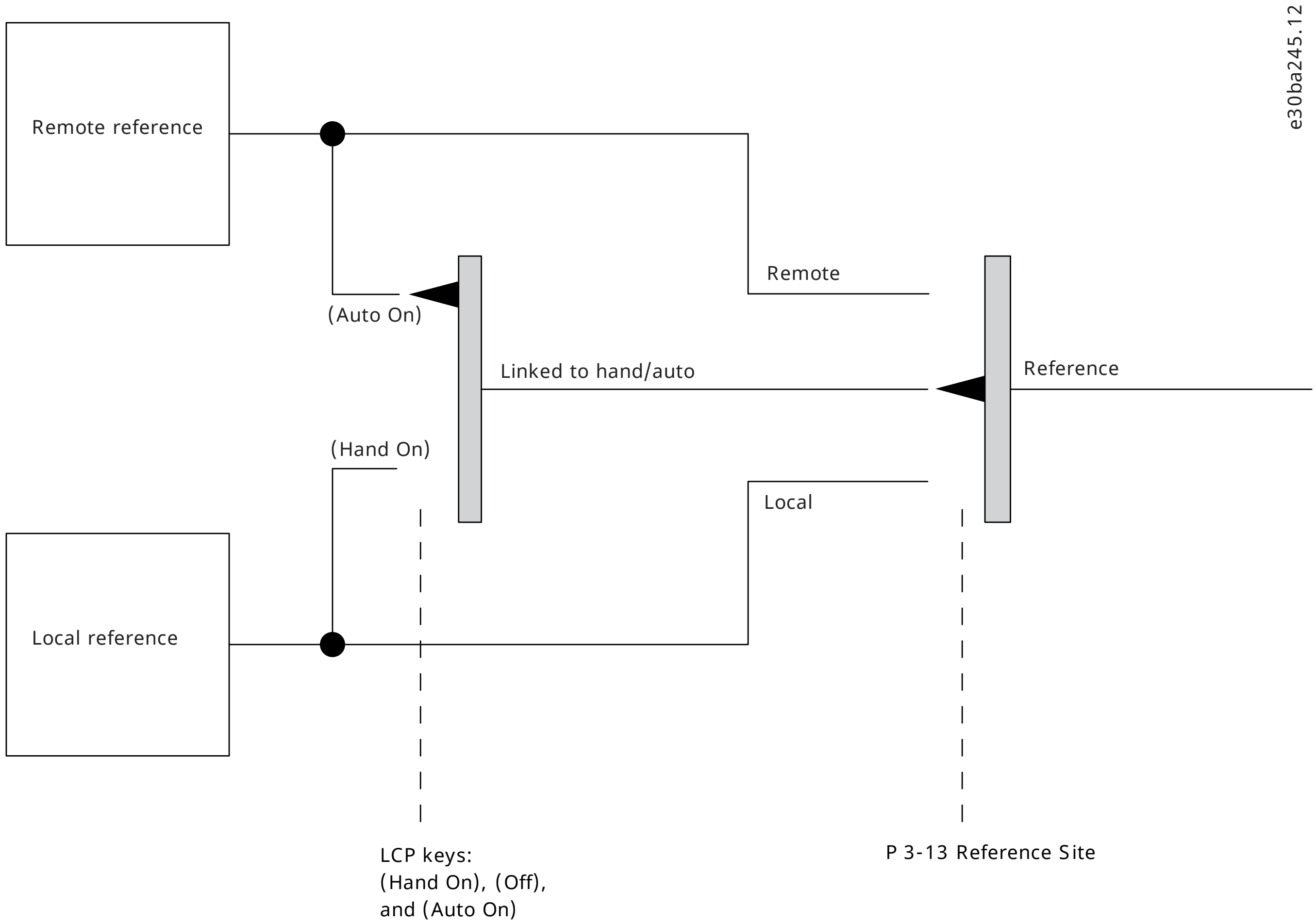


Figure 62: Selecting Active Reference

Remote handling of references applies to both open-loop and closed-loop operation. 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.

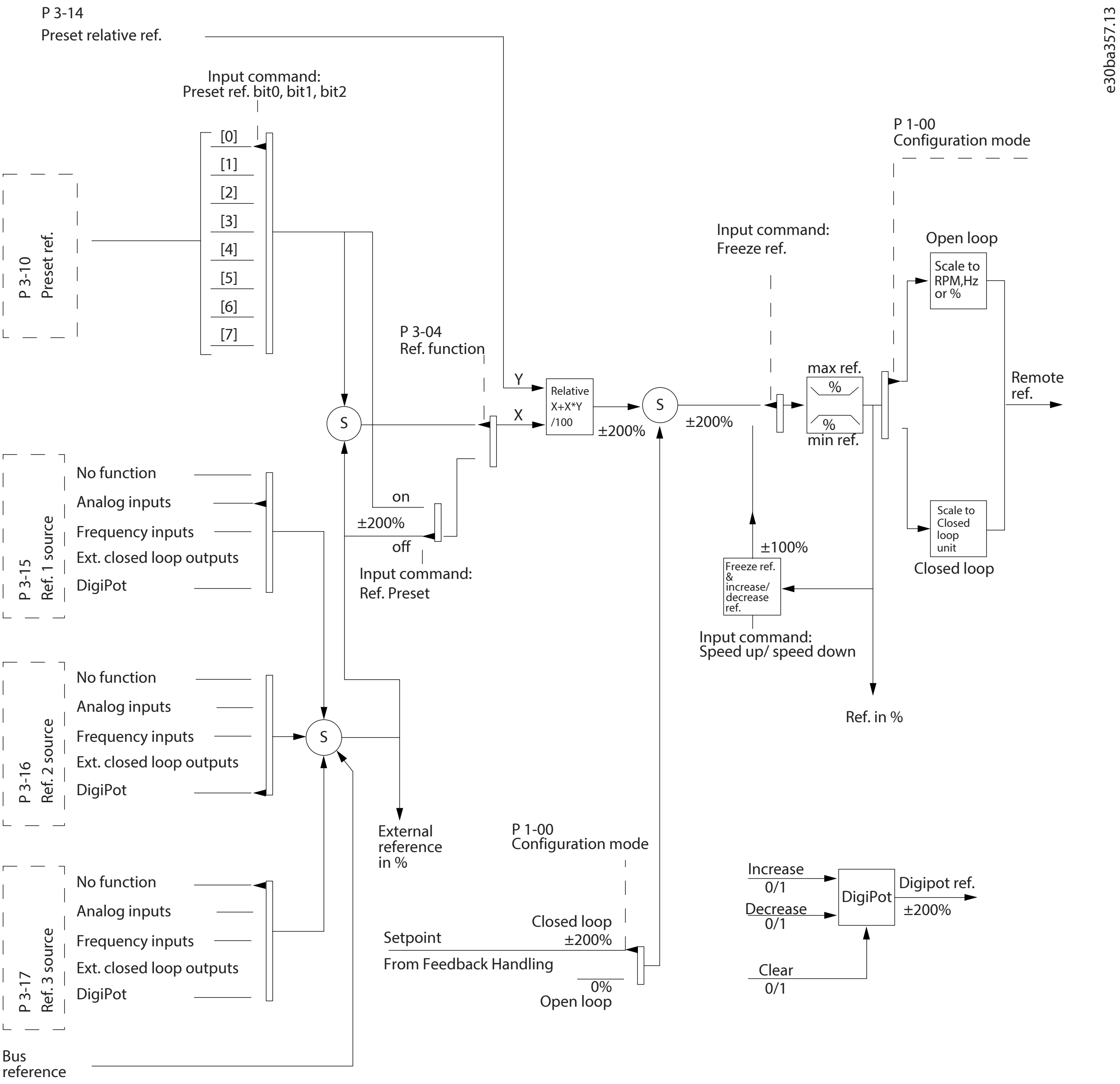


Figure 63: Remote Handling of Reference

10.3 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 Figure 64 and Figure 65.

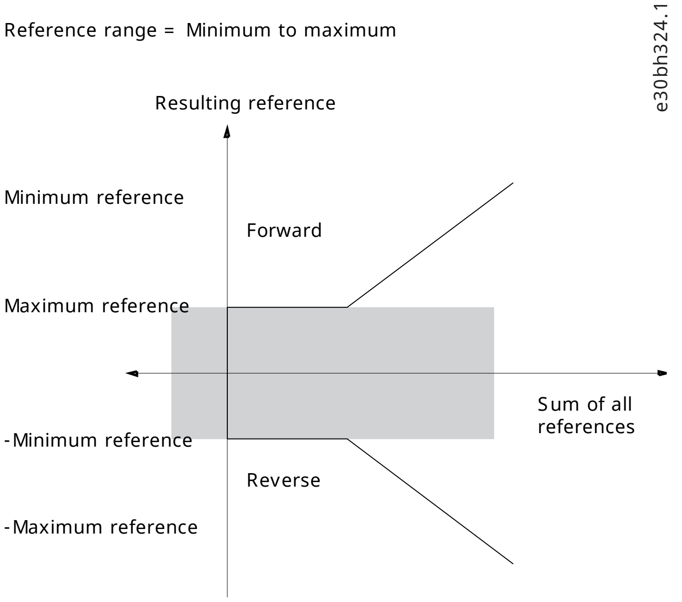


Figure 64: Sum of All References When the Reference Range is Set to 0

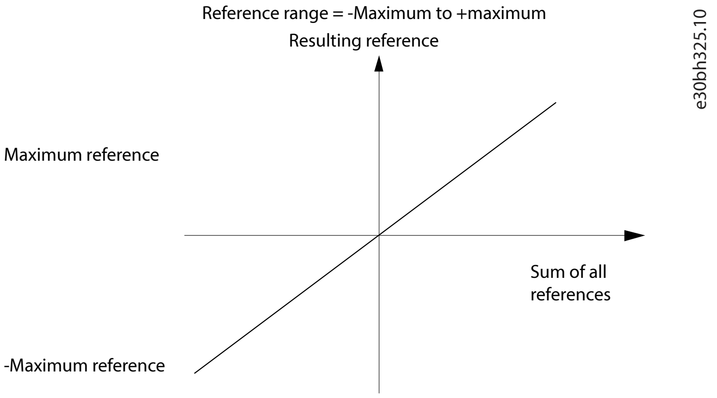


Figure 65: Sum of All References When the Reference Range is Set to 1

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 Figure 66.

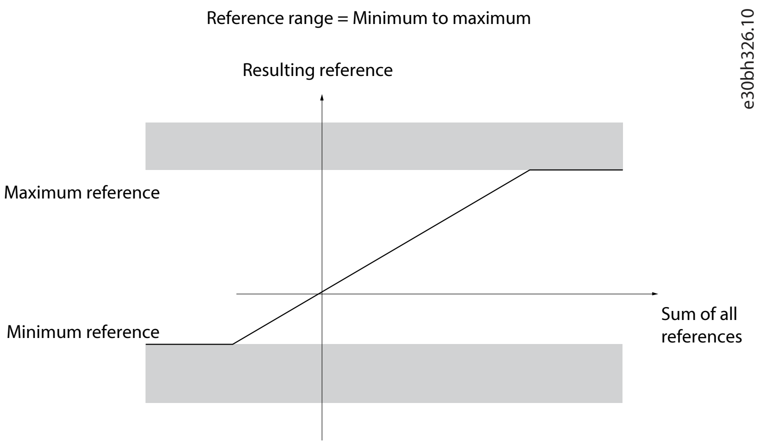


Figure 66: Sum of all References when Configuration Mode is set to Process

10.4 Control Principle

The drive rectifies the AC voltage from mains into DC voltage, after which the DC voltage is converted into an AC current with a variable amplitude and frequency.

The drive supplies the motor with variable voltage/current and frequency, standard induction motors, and non-salient permanent magnet motors.

The drive manages various motor control principles such as U/f special motor mode and VVC+. Short circuit behavior of the drive depends on the 3 current transducers in the motor phases.

The VLT® drives can run in open-loop and closed-loop application. Select the configuration mode when programming the drive.

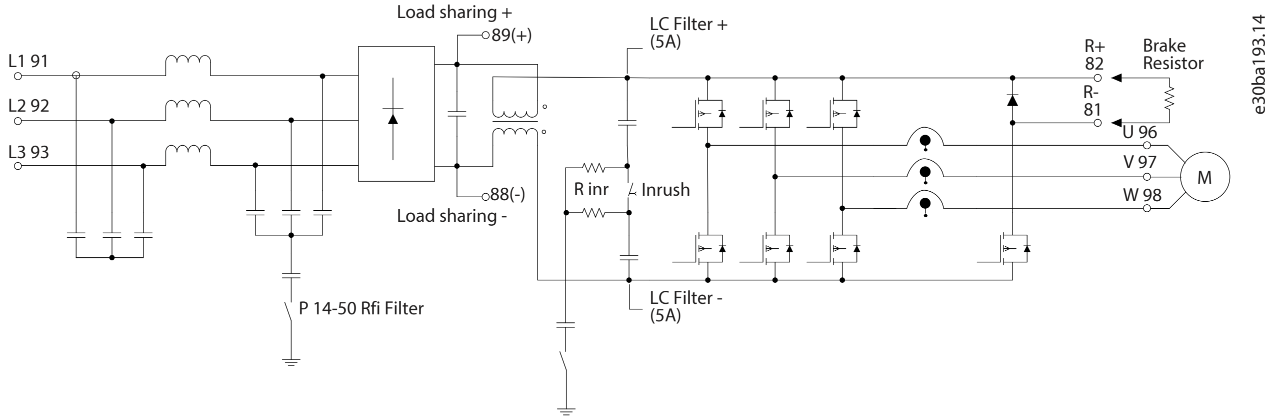


Figure 67: Control Structure Diagram

10.5 Control Structure Open Loop

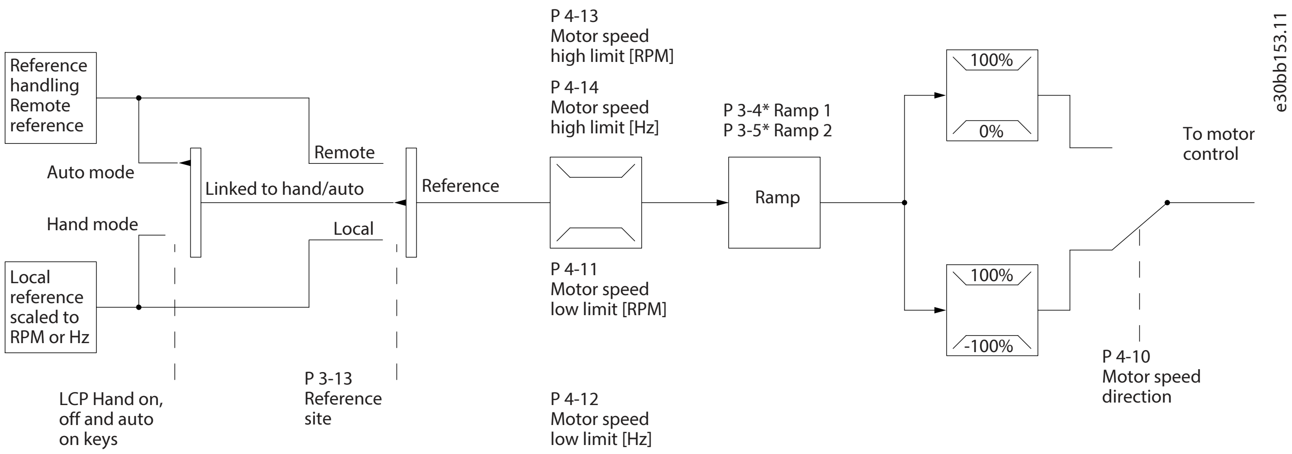


Figure 68: Open-loop Structure

In open-loop configurations, the resulting reference from the reference handling system or the local reference is received and fed through the ramp limitation and speed limitation before being sent to the motor control.

The output from the motor control is then limited by the maximum frequency limit.

10.6 Control Structure Closed Loop

The internal controller allows the drive to become a part of the controlled system. The drive receives a feedback signal from a sensor in the system. It then compares this feedback to a setpoint reference value and determines the error, if any, between these 2 signals. It then adjusts the speed of the motor to correct this error.

For example, consider a pump application where the speed of a pump is to be controlled to ensure a constant static pressure in a pipe. The static pressure value is supplied to the drive as the setpoint reference. A static pressure sensor measures the actual static pressure in the pipe and supplies this data to the drive as a feedback signal. If the feedback signal is greater than the setpoint reference, the drive slows the pump down to reduce the pressure. In a similar way, if the pipe pressure is lower than the setpoint reference, the drive automatically speeds the pump up to increase the pressure provided by the pump.

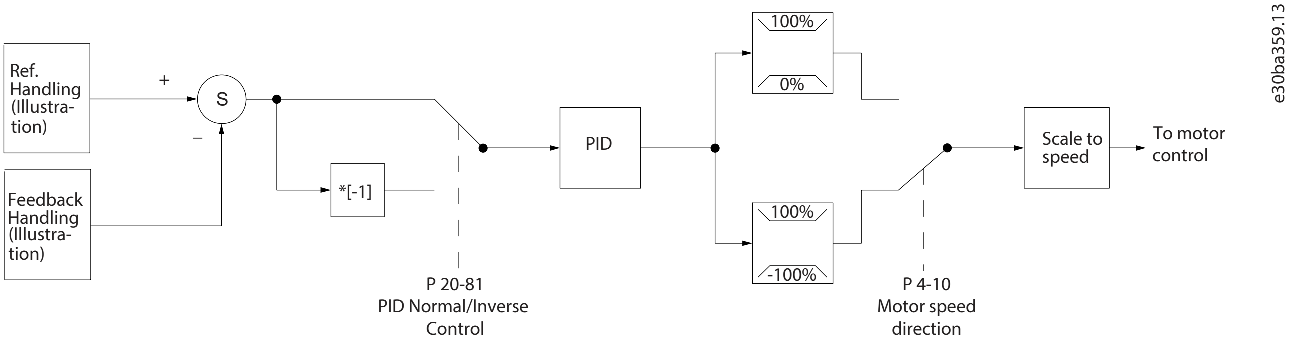


Figure 69: Control Structure Closed-loop

While the default values for the closed-loop controller of the drive often provide satisfactory performance, the control of the system can often be optimized by adjusting parameters. It is also possible to autotune the PI constants.

10.7 Control Structure in VVC+

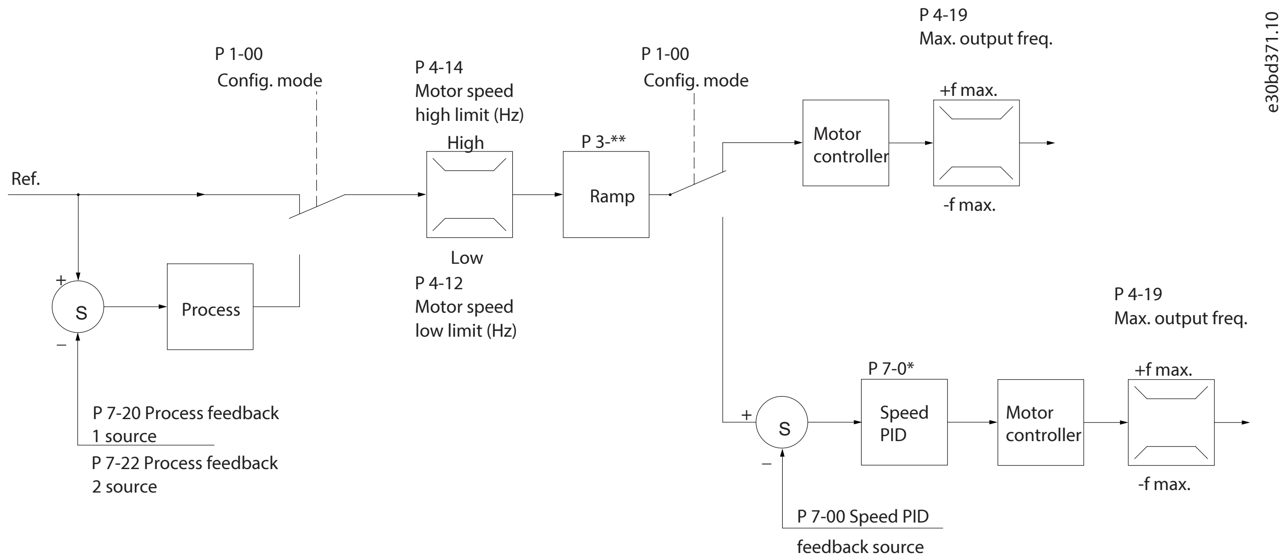


Figure 70: Control Structure in VVC+ Open-loop Configurations and Closed-loop Configurations

In the configuration shown in the above illustration, parameter ***1-01 Motor Control Principle*** is set to ***[1] VVC+*** and parameter ***1-00 Configuration Mode*** is set to ***[0] Speed open loop***. 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.

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 in parameter group ***7-0* Speed PID Ctrl***. 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 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 Basic I/O Configurations

11.1 Application Examples

The examples in this section are intended as a quick reference for common applications.

- Parameter settings are the regional default values unless otherwise indicated (selected in parameter ***0-03 Regional Settings***).
- 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.

11.2 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.

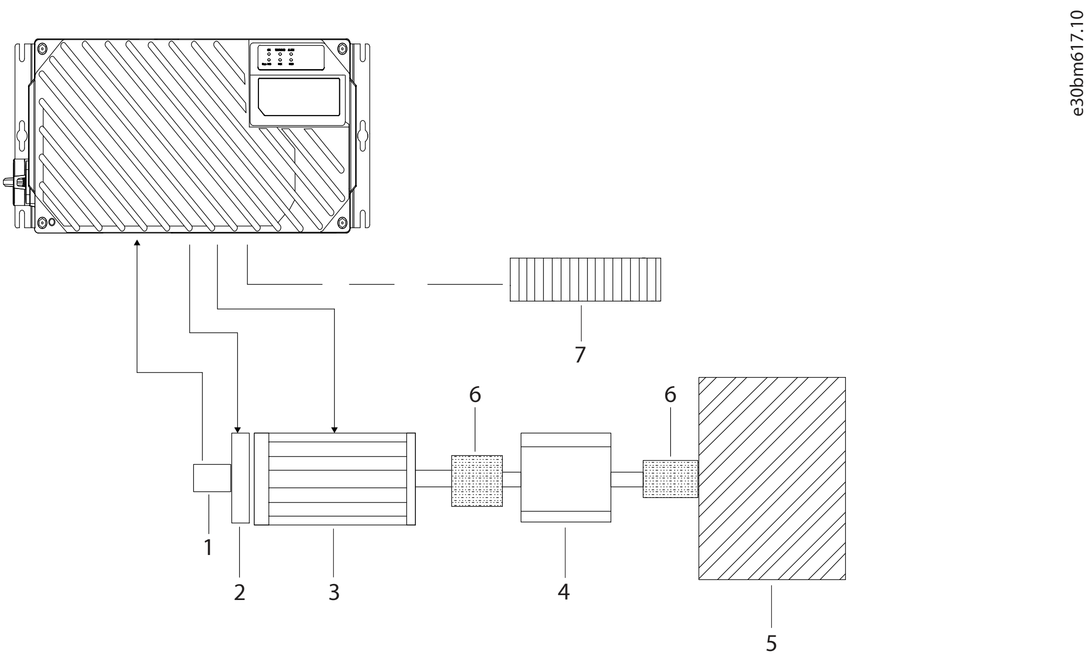
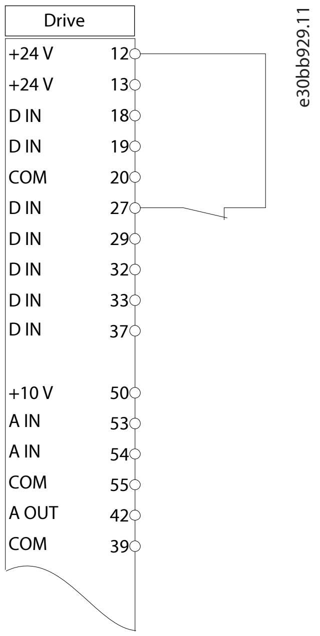


Figure 71: Basic Setup for Closed-loop Speed Control

1	Encoder	**2**	Mechanical brake
3	Motor	**4**	Gearbox
5	Load	**6**	Transmission
7	Brake resistor		

11.3 Wiring Configuration for Automatic Motor Adaptation (AMA)

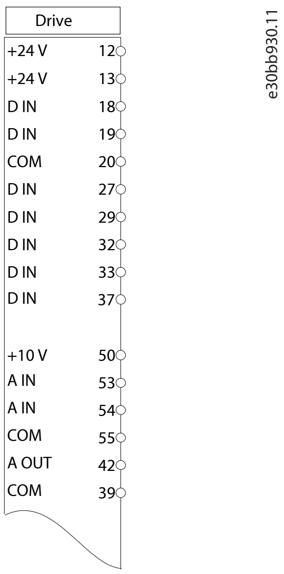
Table 33: Wiring Configuration for AMA with T27 Connected



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 the motor nameplate.	

11.4 Wiring Configuration for Automatic Motor Adaptation without T27

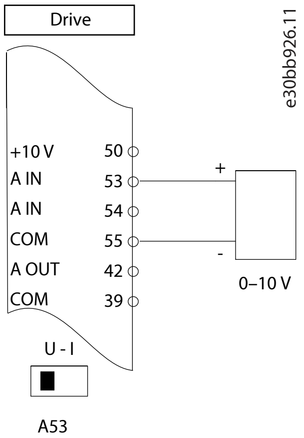
Table 34: AMA without T27 Connected



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: Parameter group ***1-2* Motor Data*** must be set according to the motor.	

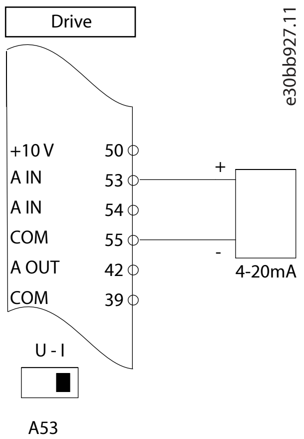
11.5 Wiring Configuration: Speed

Table 35: Analog Speed Reference (Voltage)



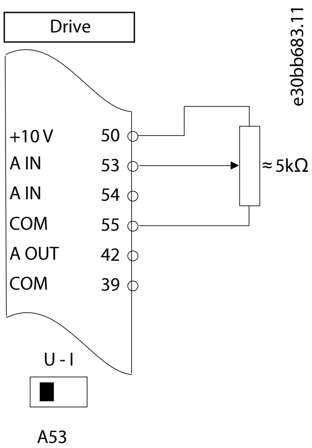
Parameters	
Function	**Setting**
Parameter ***6-10 Terminal 53 Low Voltage***	0.07 V*
Parameter ***6-11 Terminal 53 High Voltage***	10 V*
Parameter ***6-14 Terminal 53 Low Ref./ Feedb. value***	0 Hz
Parameter ***6-15 Terminal 53 High Ref./ Feedb. Value***	50 Hz
*=Default value	
Notes/comments: D IN 37 is an option.	

Table 36: Analog Speed Reference (Current)



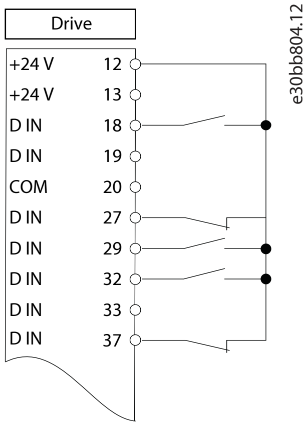
Parameters	
Function	**Setting**
Parameter ***6-12 Terminal 53 Low Current***	4 mA*
Parameter ***6-13 Terminal 53 High Current***	20 mA*
Parameter ***6-14 Terminal 53 Low Ref./ Feedb. value***	0 Hz
Parameter ***6-15 Terminal 53 High Ref./ Feedb. Value***	50 Hz
*=Default value	
Notes/comments: D IN 37 is an option.	

Table 37: 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.	

Table 38: 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***
	*=Default value	
	Notes/comments: D IN 37 is an option.	

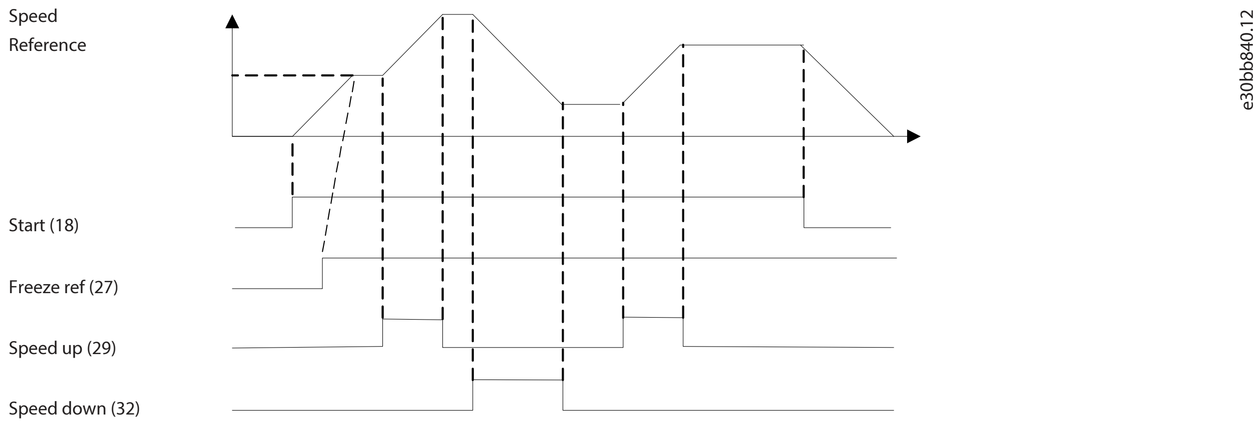
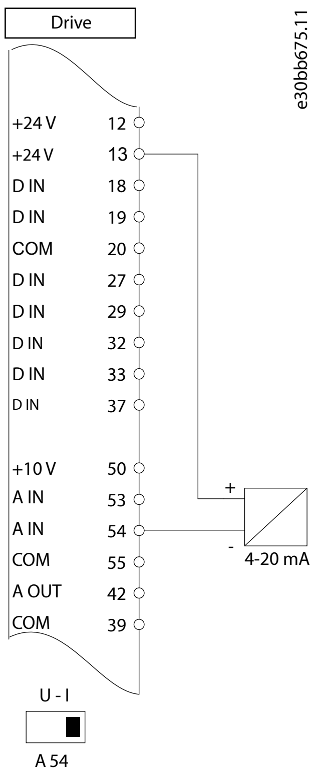


Figure 72: Speed Up/Down

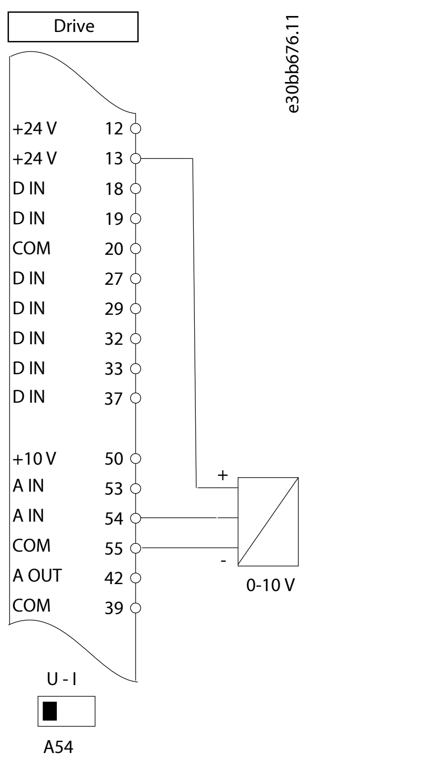
11.6 Wiring Configuration: Feedback

Table 39: Analog Current Feedback Transducer (2-wire)



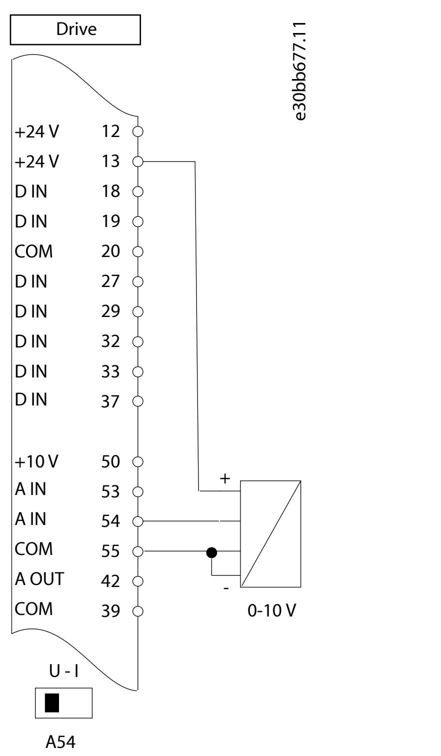
Parameters	
Function	**Setting**
Parameter ***6-22 Terminal 54 Low Current***	4 mA*
Parameter ***6-23 Terminal 54 High Current***	20 mA*
Parameter ***6-24 Terminal 54 Low Ref./ Feedb. value***	0*
Parameter ***6-25 Terminal 54 High Ref./ Feedb. Value***	50*
*=Default value	
Notes/comments: D IN 37 is an option.	

Table 40: 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.	

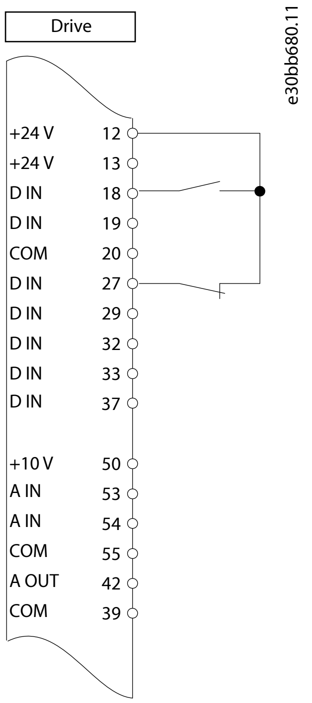
Table 41: Analog Voltage Feedback Transducer (4-wire)



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.	

11.7 Wiring Configuration: Run/Stop

Table 42: Run/Stop Command with External Interlock

<table>
<tr><th rowspan="5"></th><th colspan="2">Parameter</th></tr>
<tr><td>Function</td><td>Setting</td></tr>
<tr><td>Parameter 5-10 Terminal 18 Digital Input</td><td>[8] Start*</td></tr>
<tr><td>Parameter 5-12 Terminal 27 Digital Input</td><td>[7] External interlock</td></tr>
<tr><td colspan="2">*=Default value

Notes/comments:
D IN 37 is an option.</td></tr>
</table>

Table 43: Run/Stop Command without External Interlock

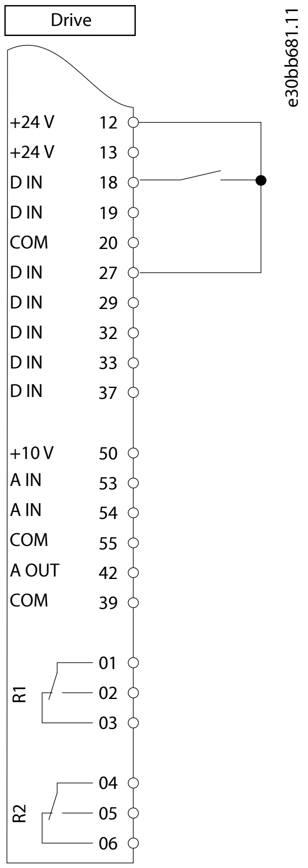
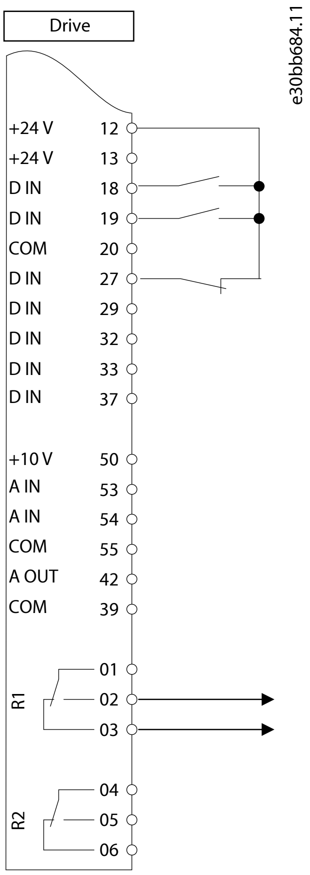
<table>
<tr><th></th><th colspan="2">Parameter</th></tr>
<tr><td rowspan="6">
</td><td>Function</td><td>Setting</td></tr>
<tr><td>Parameter 5-10 Terminal 18 Digital Input</td><td>[8] Start*</td></tr>
<tr><td>Parameter 5-12 Terminal 27 Digital Input</td><td>[7] External interlock</td></tr>
<tr><td colspan="2">*=Default value</td></tr>
<tr><td colspan="2">Notes/comments:
If parameter 5-12 Terminal 27 Digital Inputs is set to [0] No operation, a jumper wire to terminal 27 is not needed.
D IN 37 is an option.</td></tr>
</table>

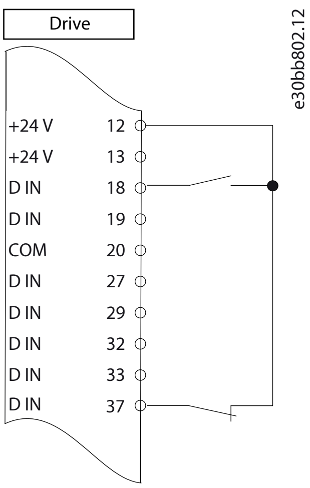
Table 44: Run Permissive



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.	

11.8 Wiring Configuration: Start/Stop

Table 45: 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 ***[0] No operation***, a jumper wire to terminal 27 is not needed. D IN 37 is an option.	

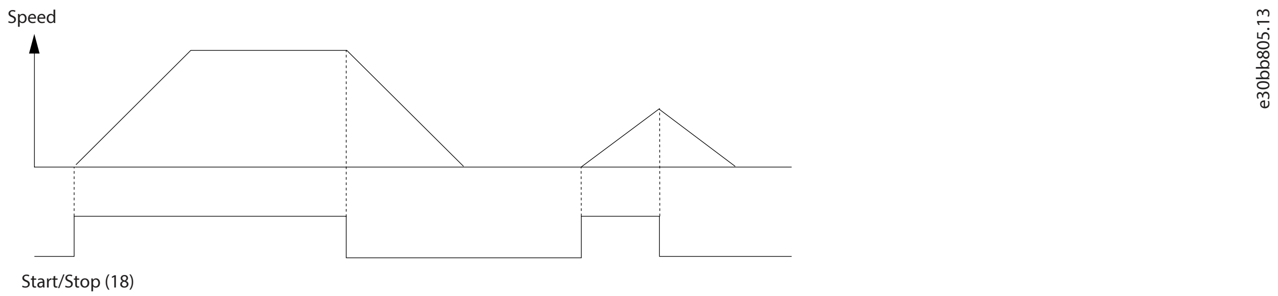
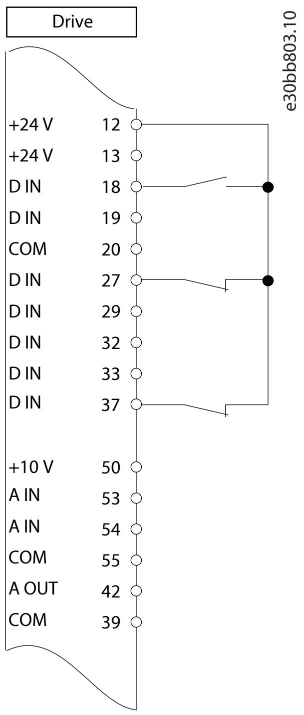


Figure 73: Start/Stop Command with Safe Torque Off

Table 46: 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 27 is not needed. D IN 37 is an option.	

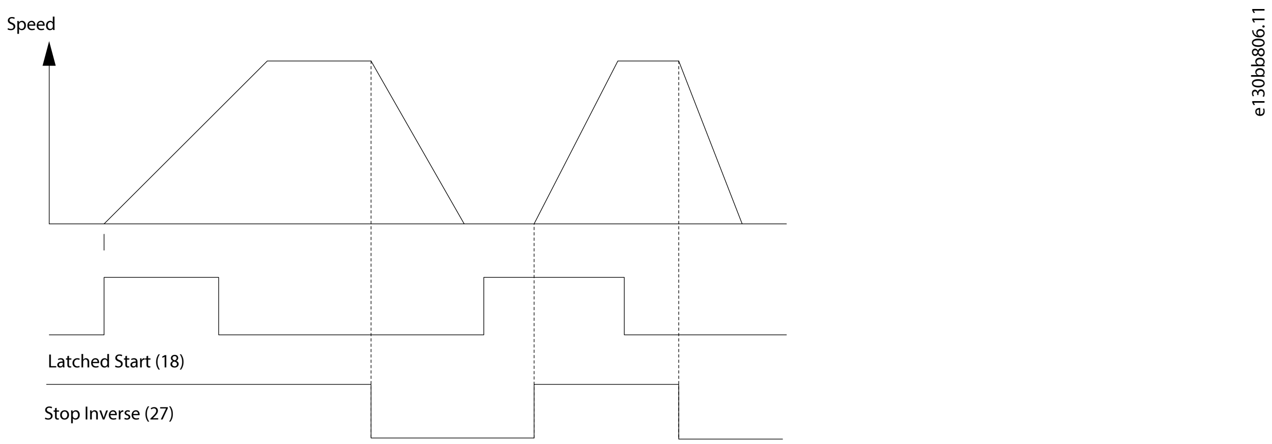
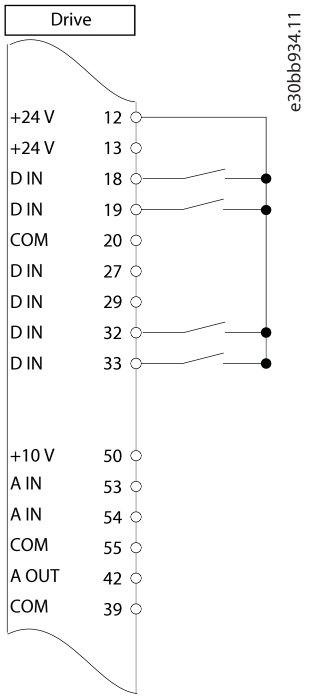


Figure 74: Latched Start/Stop Inverse

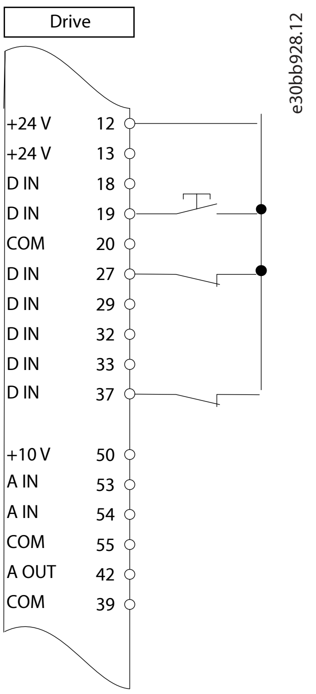
Table 47: Start/Stop with Reversing and 4 Preset Speeds



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.	

11.9 Wiring Configuration: External Alarm Reset

Table 48: 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.	

11.10 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.

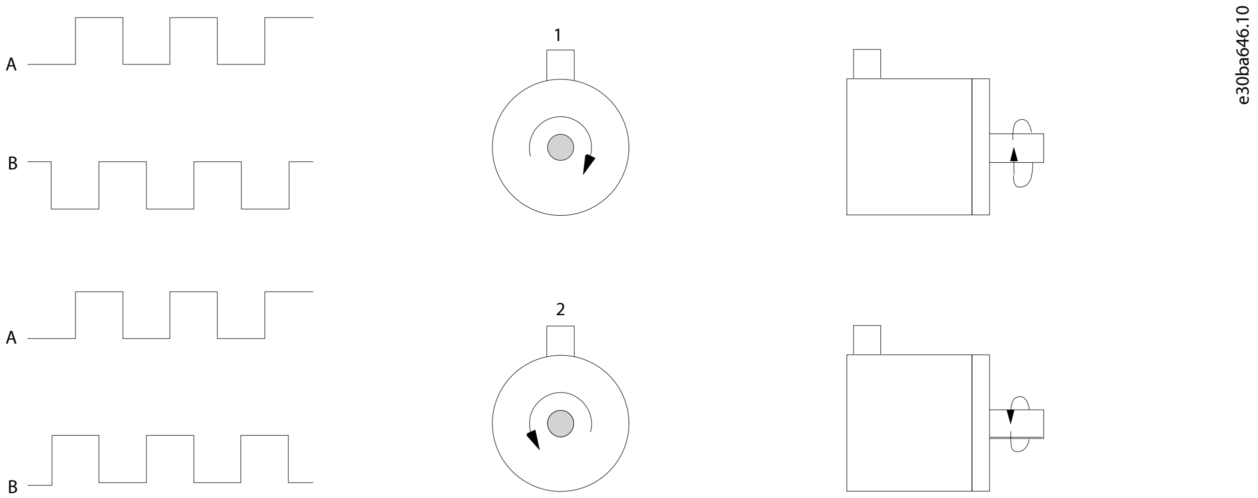


Figure 75: Determining Encoder Direction

NOTE: Maximum cable length is 5 m (16 ft.)

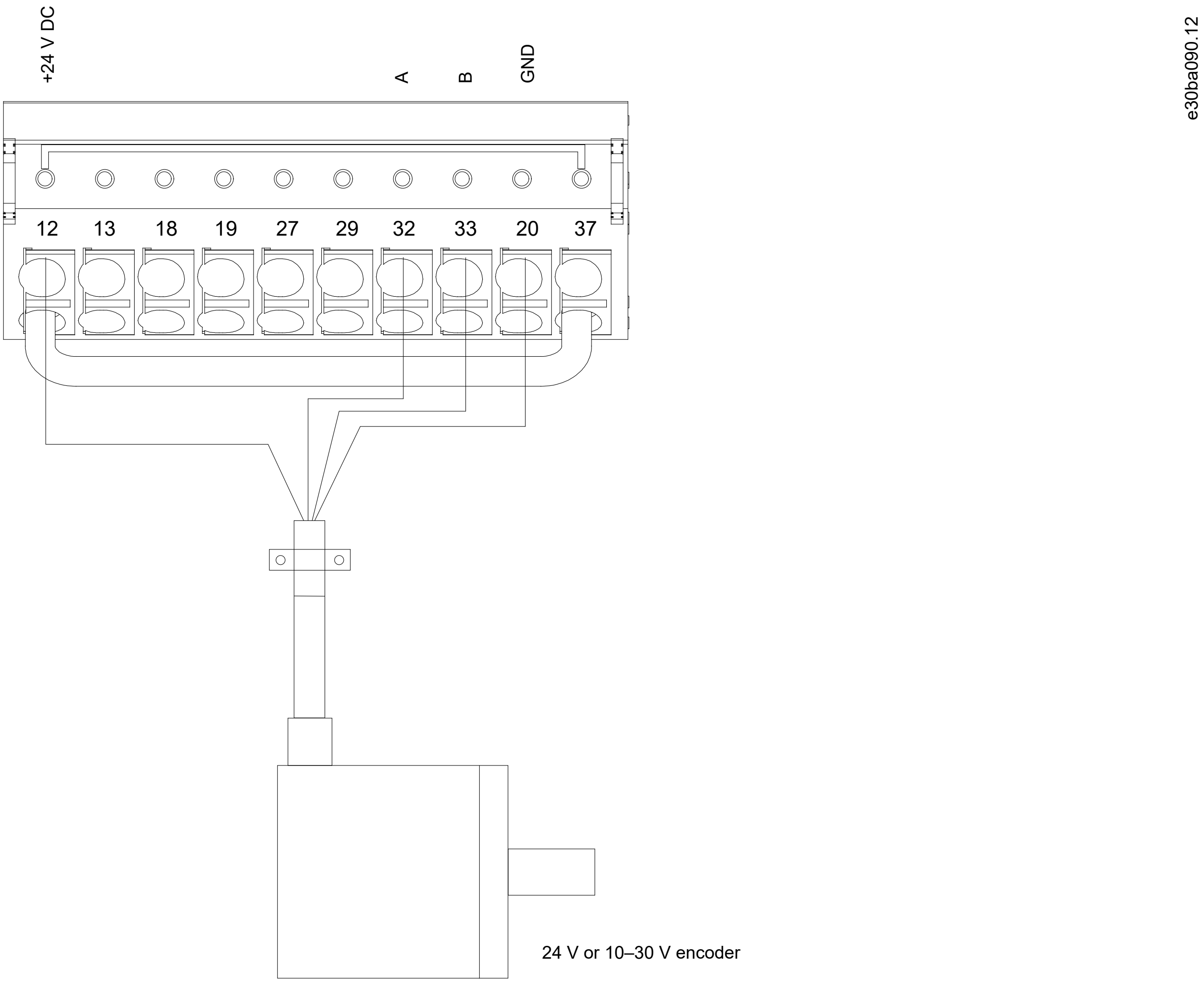
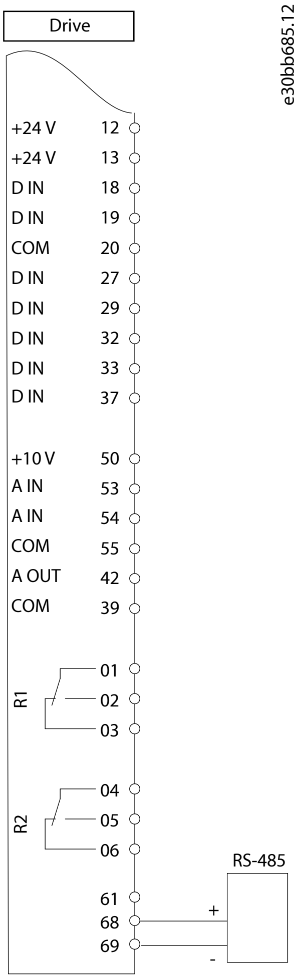


Figure 76: Wire Configuration for the Encoder

11.11 Wiring Configuration: RS-485

Table 49: RS-485 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.	

11.12 Wiring Configuration: Motor Thermistor

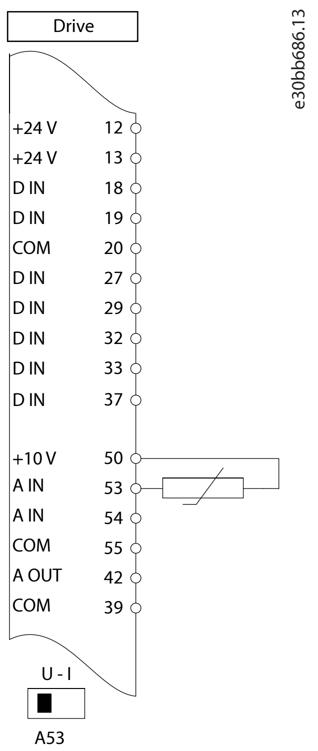
⚠ CAUTION

THERMISTOR INSULATION

Risk of personal injury or equipment damage.

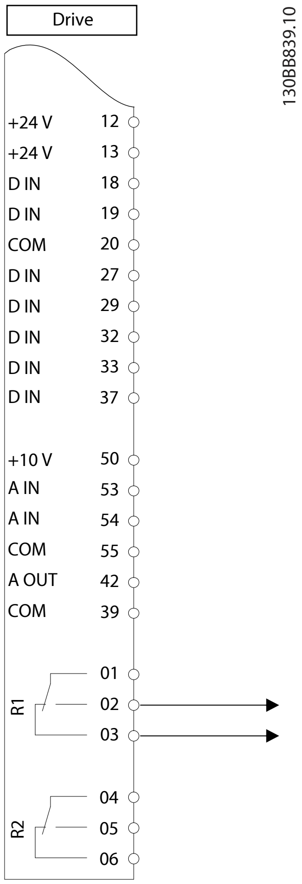
- To meet PELV insulation requirements, use only thermistors with reinforced or double insulation.

Table 50: 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.	

11.13 Wiring Configuration for a Relay Setup with Smart Logic Control

Table 51: Wiring Configuration for a Relay Setup with Smart Logic Control



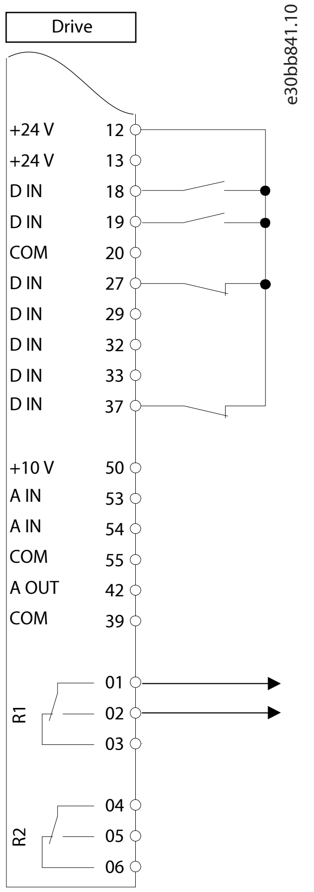
Parameters	
Function	**Setting**
Parameter ***4-30 Motor Feedback Loss Function***	***[1] Warning***
Parameter ***4-31 Motor Feedback Speed Error***	100 RPM
Parameter ***4-32 Motor Feedback Loss Timeout***	5 s
Parameter ***7-00 Speed PID Feedback Source***	***[2] MCB 102***
Parameter ***17-11 Resolution (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. If the feedback error goes below the limit again within 5 s, the drive continues and the warning disappears. Reset relay 1 by pressing [*Reset*] on the LCP.

11.14 Wiring Configuration: Mechanical Brake Control

Table 52: 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	
–	

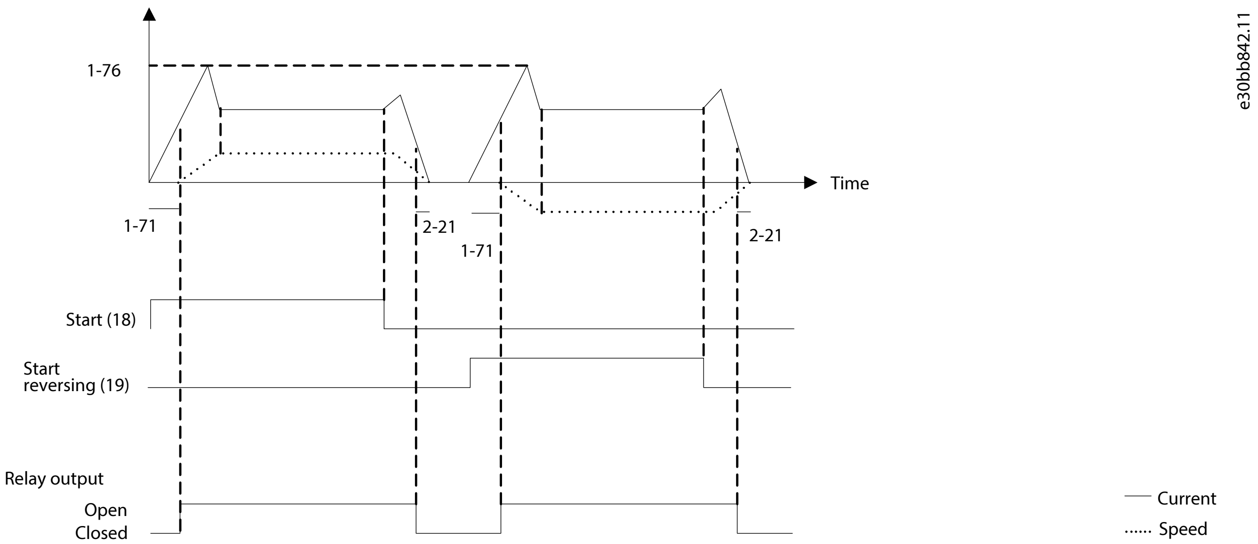


Figure 77: Mechanical Brake Control

12 How to Order a Drive

12.1 Drive Configurator

Position	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	39	39
	F	C	D	3	0	2	P				T	4				H	1											X	A		B		X	X	X	X	X	D	

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Figure 78: Type Code String (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 Configurators can be found on the global website: Drives Configurators (danfoss.com).

12.2 Type Code

Table 53: Ordering Type Code VLT® Decentral Drive FCD 302

Description	Position	Possible options
Product group	01–03	FCD: Decentral drive
Drive series	04–06	302: Advanced performance
Power size	07–10	PK37: 0.37 kW/0.5 hp PK55: 0.55 kW/0.75 hp PK75: 0.75 kW/1.0 hp P1K1: 1.1 kW/1.5 hp P1K5: 1.5 kW/2.0 hp P2K2: 2.2 kW/3.0 hp P3K0: 3.0 kW/4.0 hp (large unit, standalone mount only) PXXX: Installation box only (without power section)
Phases, mains voltage	11–12	T: 3-phase 4: 380–480 V AC
Enclosure	13–15	B66: Standard Black - IP66/Type 4X W66: Standard White - IP66/Type 4X W69: Hygienic White - IP66K/Type 4X
RFI filter	16–17	H1: RFI filter class A1/C2
Brake	18	X: No brake S: Brake chopper + mechanical brake supply
Hardware configuration	19	1: Complete product, small unit, standalone mount 3: Complete product, large unit, standalone mount X: Drive part, small unit (no installation box) Y: Drive part, large unit (no installation box) R: Installation box, small unit, standalone mount (no drive part) T: Installation box, large unit, standalone mount (no drive part)
Brackets	20	X: No brackets E: Flat brackets F: 40 mm brackets

Table 53: Ordering Type Code VLT® Decentral Drive FCD 302 - (continued)

Description	Position	Possible options
Threads	21	X: No installation box M: Metric threads
Switch option	22	X: No switch option E: Service switch on mains input F: Service switch on motor output L: Circuit breaker & mains disconnect, looping terminals (large unit only) K: Service switch on mains input with extra looping terminals (large unit only)
Display	23	X: No display connector (No installation box) C: With display connector
Sensor plugs	24	X: No sensor plugs E: Direct mount 4xM12: 4 digital inputs F: Direct mount 6xM12: 4 digital inputs, 2 relay outputs
Motor plug	25	X: No motor plug
Mains plug	26	X: No mains plug
Fieldbus plug	27	X: No fieldbus plug E: M12 Ethernet P: M12 PROFIBUS
Reserved	28	X: For future use
A option	29–30	AX: No A option A0: PROFIBUS DP AN: EtherNet/IP AL: PROFINET
B option	31–32	BX: No B option BR: Encoder option BU: Resolver option BZ: Safety PLC Interface
Reserved	33–37	XXXXX: For future use
D option	38–39	DX: No D option D0: 24 V DC backup input

NOTICE

OPTIONS CONTROL CARD

A and D options for FCD 302 are integrated into the control card.

- Do not use pluggable options for drives. Future retrofit requires exchange of the entire control card. B options are pluggable, using the same concept as for frequency converters.

12.3 Order Numbers for Options and Accessories

12.3.1 Accessories

Table 54: Ordering Numbers: Accessories

Accessories	Description	Ordering number
Mounting brackets extended	Mounting brackets extended	130B5771
Mounting brackets	Flat brackets	130B5772
LCP cable (New type)(1) 1 LCP plug (New Type) included	Preconfectioned cable to be used between inverter and LCP	134B1556
Brake resistor 1750 Ω 10 W/100%	For mounting inside installation box below motor terminals	130B5778
Brake resistor 350 Ω 10 W/100%	For mounting inside installation box below motor terminals	130B5780
VLT® Control Panel LCP 102	Graphical LCP for programming and read-out	130B1078
Venting membrane, goretex	Preventing condensation inside the enclosure	175N2116
Stainless chassis kit, M16	Stainless Steel	130B5833

1) LCP cable and LCP plug (New type) are available from November 2025.

12.3.2 Fieldbus Options

Table 55: Control Cards with Fieldbus Options

Item	Ordering number
Control card PROFIBUS	130B5781
Control card Ethernet	130B5788
Control card PROFINET	130B5794

12.3.3 Spare Parts

Table 56: Spare Parts

Spare parts	Description	Ordering number
Protection cover	Plastic protection cover for inverter part	130B5770
Gasket	Gasket between installation box and inverter part	130B5773
Accessory bag	Spare cable clamps and screws for shield termination	130B5774
Service switch	Spare switch for mains or motor disconnect	130B5775
LCP plug (New type)(1)	Spare plug for mounting in installation box	134B1557
Main termination board	For mounting in installation box	130B5779
M12 sensor plugs	Set of two M12 sensor plugs for mounting in cable gland hole	130B5411
Control card	Control card with 24 V backup	130B5783
Control card PROFIBUS	Control card PROFIBUS with 24 V backup	130B5781

Table 56: Spare Parts - (continued)

Spare parts	Description	Ordering number
Control card Ethernet	Control card Ethernet with 24 V backup	130B5788
Control card PROFINET	Control card PROFINET with 24 V backup	130B5794

1) LCP plug (New type) is available from November 2025.

The packaging contains:

- Accessories bag, supplied only with order of installation box.
  - 2 cable clamps.
  - Elevation bracket for cable clamp.
  - Screw 4 mm x 20 mm.
  - Thread forming 3.5 mm x 8 mm.
- Documentation.
  - The box contains 1 or 2 bags and 1 or more booklets, depending on the fitted options.

13 Appendix

13.1 Definitions

Coast

The motor shaft is in free mode. No torque on the motor.

$I_{VLT, MAX}$

Maximum output current.

$I_{VLT, N}$

Rated output current supplied by the drive.

$U_{VLT, MAX}$

Maximum output voltage.

Control command

Start and stop the connected motor with LCP and digital inputs.

Functions are divided into 2 groups.

Functions in group 1 have higher priority than functions in group 2.

Group 1	Reset, coast stop, reset and coast stop, quick stop, DC brake, stop, the [*OFF*] key.
Group 2	Start, pulse start, reversing, start reversing, jog, freeze output.

Motor running

Torque generated on the output shaft and speed from 0 RPM to maximum speed on the motor.

f_{JOG}

Motor frequency when the jog function is activated (via digital terminals or bus).

f_M

Motor frequency.

f_{MAX}

Maximum motor frequency.

f_{MIN}

Minimum motor frequency.

$f_{M, N}$

Rated motor frequency (nameplate data).

I_M

Motor current (actual).

$I_{M, N}$

Nominal motor current (nameplate data).

$n_{M, N}$

Nominal motor speed (nameplate data).

n_s

Synchronous motor speed. $n_S = \frac{2 \times \text{Parameter}1-23 \times 60s}{\text{Parameter}1-39}$

n_{slip}

Motor slip.

$P_{M,N}$

Rated motor power (nameplate data in kW or hp).

$T_{M,N}$

Rated torque (motor).

U_M

Instantaneous motor voltage.

$U_{M,N}$

Rated motor voltage (nameplate data).

Break-away torque

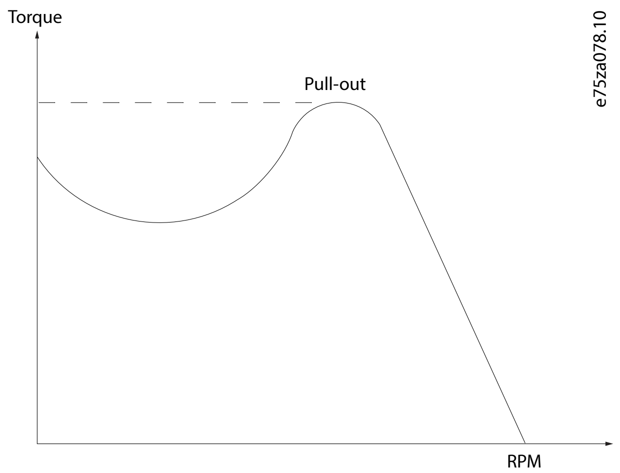

Figure 79: Break-away Torque

η_{VLT}

The efficiency of the drive is defined as the ratio between the power output and the power input.

Start-disable command

A start-disable command belonging to the control commands in group 1.

Stop command

A stop command belonging to the control commands in group 1.

Analog reference

A signal sent to the analog inputs 53 or 54 can be voltage or current.

Binary reference

A signal sent via the serial communication port.

Preset reference

A defined preset reference to be set from -100% to +100% of the reference range. Selection of 8 preset references via the digital terminals. Selection of 4 preset references via the bus.

Pulse reference

A pulse frequency signal sent to the digital inputs (terminal 29 or 33).

Ref_{MAX}

Determines the relationship between the reference input at 100% full-scale value (typically 10 V, 20 mA) and the resulting reference. The maximum reference value is set in parameter ***3-03 Maximum Reference***.

Ref_{MIN}

Determines the relationship between the reference input at 0% value (typically 0 V, 0 mA, 4 mA) and the resulting reference. The minimum reference value is set in parameter ***3-02 Minimum Reference***.

Analog inputs

The analog inputs are used for controlling various functions of the drive. There are 2 types of analog inputs:

- Current input, 0–20 mA, and 4–20 mA.
- Voltage input, -10 V DC to +10 V DC.

Analog outputs

The analog outputs can supply a signal of 0–20 mA, 4–20 mA.

Automatic motor adaptation, AMA

AMA algorithm determines the electrical parameters for the connected motor at standstill.

Brake resistor

The brake resistor is a module capable of absorbing the brake power generated in regenerative braking. This regenerative brake power increases the DC-link voltage and a brake chopper ensures that the power is sent to the brake resistor.

CT characteristics

Constant torque characteristics used for all applications such as conveyor belts, displacement pumps, and cranes.

Digital inputs

The digital inputs can be used for controlling various functions of the drive.

Digital outputs

The drive features 2 solid-state outputs that can supply a 24 V DC (maximum 40 mA) signal.

DSP

Digital signal processor.

ETR

Electronic thermal relay is a thermal load calculation based on present load and time. Its purpose is to estimate the motor temperature.

Initializing

If initializing is carried out the drive returns to the default setting, see parameter ***14–22 Operation Mode***.

Intermittent duty cycle

An intermittent duty rating refers to a sequence of duty cycles. Each cycle consists of an on-load and an off-load period. The operation can be either periodic duty or non-periodic duty.

LCP

The local control panel makes up a complete interface for control and programming of the drive. The control panel is detachable and can be installed up to 3 m (10 ft) from the drive, that is, in a front panel with the installation kit option.

lsb

Least significant bit.

msb

Most significant bit.

MCM

Short for mille circular mil, an American measuring unit for cable cross-section. 1 MCM = 0.5067 mm^2.

On-line/off-line parameters

Changes to on-line parameters are activated immediately after the data value is changed. To activate changes to offline parameters, press [*OK*].

Process PID

The PID control maintains the required speed, pressure, temperature, and so on, by adjusting the output frequency to match the varying load.

PCD

Process control data.

Power cycle

Switch off the mains until the display (LCP) is dark, then turn the power on again.

Pulse input/incremental encoder

An external, digital pulse transmitter used for feeding back information on motor speed. The encoder is used in applications where great accuracy in speed control is required.

RCD

Residual current device.

Setup

Save parameter settings in 4 setups. Change between the 4 parameter setups and edit 1 setup, while another setup is active.

SFAVM

Switching pattern called stator flux-oriented asynchronous vector modulation, parameter ***14-00 Switching Pattern***.

Slip compensation

The drive compensates for the motor slip by giving the frequency a supplement that follows the measured motor load keeping the motor speed almost constant.

SLC

The SLC (smart logic control) is a sequence of user-defined actions executed when the associated user-defined events are evaluated as true by the SLC. (For further information, refer to 5.2.4.1 Overview of the Smart Logic Controller).

STW

Status word

FC standard bus

Includes RS-485 bus with FC protocol or MC protocol, parameter ***8–30 Protocol***.

THD

Total harmonic distortion states the total contribution of harmonic.

Thermistor

A temperature-dependent resistor is placed where the temperature is to be monitored (drive or motor).

Trip

A state entered in fault situations, for example if the drive is subject to overvoltage or when it is protecting the motor, process, or mechanism. Restart is prevented until the cause of the fault has disappeared, and the trip state is canceled by activating reset or, sometimes, by being programmed to reset automatically. Do not use trip for personal safety.

Trip lock

The drive enters this state in fault situations to protect itself. The drive requires physical intervention, for example, when there is a short circuit on the output. A trip lock can only be canceled by disconnecting mains, removing the cause of the fault, and reconnecting the drive. Restart is prevented until the trip state is canceled by activating reset or, sometimes, by being programmed to reset automatically. Do not use the trip lock state for personal safety.

VT characteristics

Variable torque characteristics used for pumps and fans.

VVC+

If compared with standard voltage/frequency ratio control, Voltage Vector Control (VVC+) improves the dynamics and the stability, both when the speed reference is changed and in relation to the load torque.

60° AVM

60° asynchronous vector modulation, parameter ***14-00 Switching Pattern***.

Power factor

The power factor is the relation between I_1 and I_{RMS}.

$$\text{Power factor} = \frac{\sqrt{3} x U x I_1 \cos\phi}{\sqrt{3} x U x I_{RMS}}$$

The power factor for 3-phase control:

$$\text{Power factor} = \frac{I1 x \cos\phi 1}{I_{RMS}} = \frac{I_1}{I_{RMS}} \text{ since } \cos\phi 1 = 1$$

The power factor indicates to which extent the drive imposes a load on the mains supply. The lower the power factor, the higher the I_{RMS} for the same kW performance.

$$I_{RMS} = \sqrt{I_1^2 + I_5^2 + I_7^2 + .. + I_n^2}$$

In addition, a high power factor indicates that the different harmonic currents are low. The DC coils in the drives produce a high power factor, which minimizes the imposed load on the mains supply.

Target position

The final target position specified by positioning commands. The profile generator uses this position to calculate the speed profile.

Commanded position

The actual position reference calculated by the profile generator. The drive uses the commanded position as the setpoint for position PI.

Actual position

The actual position from an encoder, or a value that the motor control calculates in an open loop. The drive uses the actual position as feedback for position PI.

Position error

Position error is the difference between the actual position and the commanded position. The position error is the input for the position PI controller.

Position unit

The physical unit for position values.

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