

Design Guide

# VLT® AutomationDrive FC 360

90–315 kW, Enclosure Sizes J8–J9



VLT®  
AutomationDrive



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# 1 Introduction

## 1.1 Purpose of the 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 drive for integration into motor control and monitoring systems. Its purpose is to provide design considerations and planning data for integration of the drive into a system. It caters for selection of drives and options for a diversity of applications and installations. Reviewing the detailed product information in the design stage enables developing a well-conceived system with optimal functionality and efficiency.

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

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## 1.2 Additional Resources

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

- The operating guide provides detailed information for the installation and start-up of the drive.
- The programming guide provides greater detail on working with parameters and many application examples.
- Instructions for operation with optional equipment.

Supplementary publications and manuals are available from Danfoss website [www.danfoss.com](http://www.danfoss.com).

## 1.3 Document Version

This guide is regularly reviewed and updated. All suggestions for improvement are welcome.

The original language of this manual is English.

Table 1: Document Version

Edition	Remarks
AJ435824192086, version 0101	First edition.

## 1.4 Approvals and Certifications

### 1.4.1 CE Mark

The CE mark (Conformité Européenne) indicates that the product manufacturer conforms to all applicable EU directives.

The EU directives applicable to the design and manufacture of drives are:

- The Low Voltage Directive.
- The EMC Directive.
- The Machinery Directive (for units with an integrated safety function).

The CE mark is intended to eliminate technical barriers to free trade between the EC and EFTA states inside the ECU. The CE mark does not regulate the quality of the product. Technical specifications cannot be deduced from the CE mark.

### 1.4.2 Low Voltage Directive

Drives are classified as electronic components and must be CE-labeled in accordance with the Low Voltage Directive. The directive applies to all electrical equipment in the 50–1000 V AC and the 75–1500 V DC voltage ranges.

The directive mandates that the equipment design must ensure the safety and health of people and livestock, and the preservation of material by ensuring the equipment is properly installed, maintained, and used as intended. Danfoss CE labels comply with the Low Voltage Directive, and Danfoss provides a declaration of conformity upon request.

### 1.4.3 EMC Directive

Electromagnetic compatibility (EMC) means that electromagnetic interference between pieces of equipment does not hinder their performance. The basic protection requirement of the EMC Directive 2014/30/EU 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.

A drive can be used as a standalone device or as part of a more complex installation. Devices in either of these cases must bear the CE mark. Systems do not have to be CE-marked but must comply with the basic protection requirements of the EMC directive.

## 2 Safety

### 2.1 Safety Symbols

The following symbols are used in Danfoss documentation.

#### 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).

The guide also includes ISO warning symbols related to hot surfaces and burn hazard, high voltage and electrical shock, and referring to the instructions.

	ISO warning symbol for hot surfaces and burn hazard
	ISO warning symbol for high voltage and electrical shock
	ISO action symbol for referring to the instructions

### 2.2 Qualified Personnel

Correct and reliable transport, storage, installation, operation, and maintenance are required for the trouble-free and safe operation of the drive. Only qualified personnel are allowed to install and operate this equipment.

Qualified personnel are defined as trained staff, who are authorized to install, commission, and maintain equipment, systems, and circuits in accordance with pertinent laws and regulations. Also, the qualified personnel must be familiar with the instructions and safety measures described in this manual.

## 2.3 Safety Precautions

### ! WARNING



#### HIGH VOLTAGE

Drives contain high voltage when connected to AC mains input, DC supply, load sharing, or permanent motors. Failure to use qualified personnel to install, start up, and maintain the drive can result in death or serious injury.

- Only qualified personnel must install, start up, and maintain the drive.
- Before performing any service or repair work, use an appropriate voltage measuring device to make sure that there is no remaining voltage on the drive.

### ! WARNING



#### UNINTENDED START

When the drive is connected to AC mains, DC supply, or load sharing, the motor may start at any time. Unintended start during programming, service, or repair work can result in death, serious injury, or property damage. Start the motor with an external switch, a fieldbus command, an input reference signal from the local control panel (LCP), via remote operation using MCT 10 software, or after a cleared fault condition.

- Disconnect the drive from the mains.
- Press *[Off/Reset]* on the LCP before programming parameters.
- Ensure that the drive is fully wired and assembled when it is connected to AC mains, DC supply, or load sharing.

### ! WARNING



#### DISCHARGE TIME (20 MINUTES)

The drive contains DC-link capacitors, which can remain charged even when the drive is not powered. High voltage can be present even when the warning LED indicator lights are off.

Failure to wait 20 minutes after power has been removed before performing service or repair work can result in death or serious injury.

- Stop the motor.
- Disconnect AC mains and remote DC-link power supplies, including battery back-ups, UPS, and DC-link connections to other drives.
- Disconnect or lock PM motor.
- Wait for the capacitors to discharge fully. The minimum waiting time is 20 minutes.
- Before performing any service or repair work, use an appropriate voltage measuring device to make sure that the capacitors are fully discharged.

**! WARNING**



**ELECTRICAL SHOCK HAZARD - LEAKAGE CURRENT HAZARD >3.5 MA**

Leakage currents exceed 3.5 mA. Failure to connect the drive properly to protective earth (PE) can result in death or serious injury.

- Ensure reinforced protective earthing conductor according to IEC 60364-5-54 cl. 543.7 or according to local safety regulations for high touch current equipment. The reinforced protective earthing of the drive can be done with:
  - a PE conductor with a cross-section of at least 10 mm<sup>2</sup> (8 AWG) Cu or 16 mm<sup>2</sup> (6 AWG) Al.
  - an extra PE conductor of the same cross-sectional area as the original PE conductor as specified by IEC 60364-5-54 with a minimum cross-sectional area of 2.5 mm<sup>2</sup> (14 AWG) (mechanically protected) or 4 mm<sup>2</sup> (12 AWG) (not mechanically protected).
  - a PE conductor completely enclosed with an enclosure or otherwise protected throughout its length against mechanical damage.
  - a PE conductor part of a multi-conductor power cable with a minimum PE conductor cross-section of 2.5 mm<sup>2</sup> (14 AWG) (permanently connected or pluggable by an industrial connector. The multi-conductor power cable shall be installed with an appropriate strain relief).
- NOTE: In IEC/EN 60364-5-54 cl. 543.7 and some application standards (for example IEC/EN 60204-1), the limit for requiring reinforced protective earthing conductor is 10 mA leakage current.

**! WARNING**



**EQUIPMENT HAZARD**

Contact with rotating shafts and electrical equipment can result in death or serious injury.

- Ensure that only trained and qualified personnel perform installation, start-up, and maintenance.
- Ensure that electrical work conforms to national and local electrical codes.
- Follow the procedures in this guide.

**! CAUTION**



**INTERNAL FAILURE HAZARD**

An internal failure in the drive can result in serious injury when the drive is not properly closed.

- Ensure that all safety covers are in place and securely fastened before applying power.

**NOTICE**

**HIGH ALTITUDES**

- For installation at altitudes above 2000 m (6562 ft), contact Danfoss regarding PELV.

## 3 Product Overview and Features

### 3.1 Power Ratings, Weights, and Dimensions

For enclosure sizes and power ratings of the drives, refer to the following table. For more dimensions, see the *chapter Exterior and Terminal Dimensions*.

Table 2: Power Ratings, Weights, and Dimensions, Enclosure Sizes J8–J9, 380–480 V

Enclosure size		J8	J9
IP		20	20
NEMA		Chassis	Chassis
Shipping dimensions [mm (in)]	Height	587 (23)	587 (23)
	Width	997 (39)	1170 (46)
	Depth	460 (18)	535 (21)
Drive dimensions [mm (in)]	Height	909 (36)	1122 (44)
	Width	250 (10)	350 (14)
	Depth	375 (15)	375 (15)
Maximum weight [kg (lb)]		98 (216)	164 (362)

### 3.2 Automated Operational Features

#### 3.2.1 Introduction

Automated operational features are active when the drive is operating. Most of them require no programming or setup. The drive has a range of built-in protection functions to protect itself and the motor when it runs.

For details of any setup required, in particular motor parameters, refer to the programming guide.

#### 3.2.2 Short-circuit Protection

##### Motor (phase-to-phase)

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

##### Mains side

A drive that works correctly limits the current it can draw from the supply. Still, it is recommended to use fuses and/or circuit breakers on the supply side as protection if there is component break-down inside the drive (1st fault).

#### NOTICE

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



### 3.2.3 Overvoltage Protection

#### Motor-generated overvoltage

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

- The load rotates the motor at constant output frequency from the drive, that is, the load generates energy.
- During deceleration (ramp-down) if the inertia moment is high, the friction is low, and the ramp-down time is too short for the energy to be dissipated as a loss throughout the drive system.
- Incorrect slip compensation setting causing higher DC-link voltage.
- Back EMF from PM motor operation. If coasted at a speed which is higher than nominal speed, the PM motor back EMF can potentially exceed the maximum voltage tolerance of the drive and cause damage. To help prevent this situation, the value of *parameter 4-19 Max Output Frequency* is automatically limited based on an internal calculation based on the value of *parameter 1-40 Back EMF at 1000 RPM*, *parameter 1-25 Motor Nominal Speed*, and *parameter 1-39 Motor Poles*.
- The overvoltage can be handled either using a brake function (*parameter 2-10 Brake Function*) and/or using overvoltage control (*parameter 2-17 Over-voltage Control*).

#### Brake functions

AC brake is an alternative to improving braking without using a brake resistor. This function controls an over-magnetization of the motor when the motor is acting as a generator. Increasing the electrical losses in the motor allows the OVC function to increase the braking torque without exceeding the overvoltage limit.

#### NOTICE

AC brake is not as effective as dynamic braking with a resistor.

#### Overvoltage control (OVC)

By automatically extending the ramp-down time, OVC reduces the risk of the drive tripping due to an overvoltage on the DC link.

#### NOTICE

Do not enable OVC in hoisting applications.

#### Ground fault

The drive provides low-impedance ground fault protection and high-impedance ground fault protection due to configuration of current transducer on the output phases. Depending on whether the LCP *parameter 0-06 GridType* is set to IT grid or not, different protection algorithms are executed.

Ground fault is detected during start-up stage and on-the-fly stage. After receiving the protection signals, the drive is coasted.

### 3.2.4 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 faster detection.

### 3.2.5 Supply Voltage Imbalance Detection

Operation under severe supply voltage imbalance reduces the lifetime of the motor and drive. If the motor is operated continuously near nominal load, conditions are considered severe. The default setting trips the drive if there is supply voltage imbalance.

A fast trip/warning option is available by utilizing LCP parameters (*parameter 14-17 Fast Mains Phase Loss Level* and *parameter 14-18 Fast Mains Phase Loss Min Power*) when a quick response to mains imbalance is expected.

### 3.2.6 Switching on the Output

Adding a switch to the output between the motor and the drive is allowed, however fault messages can appear.

### 3.2.7 Overload Protection

#### Power Limit

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

#### 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 4-12 Motor Speed Low Limit [Hz]* limits the minimum operating speed range of the drive.
- Maximum speed limit: *parameter 4-19 Max Output Frequency* limits 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. The characteristic is shown in the illustration in [3.3.4 Motor Thermal Protection](#).

#### Overvoltage

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.

### 3.2.8 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+/flux control (*parameter 30-22 Locked Rotor Protection*).

### 3.2.9 Automatic Derating

The drive constantly checks for the following critical levels:

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

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

**NOTICE**

The automatic derating is different when *parameter 14-55 Output Filter* is set to *[1] Sine-Wave Filter*.

### 3.2.10 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.

There is no need to select a V/Hz curve because the drive automatically adjusts motor voltage.

### 3.2.11 Automatic Switching Frequency Modulation

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

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

### 3.2.12 Automatic Derating for High Switching Frequency

The frequency range depends on power size and voltage rating. A switching frequency exceeding the maximum allowed range generates increased heat in the drive and requires the output current to be derated.

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

### 3.2.13 Power Fluctuation Performance

The drive withstands mains fluctuations such as:

- Transients.
- Momentary drop-outs.
- Short voltage drops.
- Surges.

The drive automatically compensates for input voltages  $\pm 10\%$  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.

### 3.2.14 Resonance Damping

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

### 3.2.15 Temperature-controlled Fans

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

### 3.2.16 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/EN 61800-3. Motor cables must be shielded and properly terminated to comply with the emission levels in EN 61800-3. For more information regarding EMC performance, see *chapter EMC Test Results*.

### 3.2.17 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.

## 3.3 Custom Application Features

### 3.3.1 Introduction

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

### 3.3.2 Automatic Motor Adaptation

Automatic motor adaptation (AMA) is an automated test procedure used to measure the electrical characteristics of the motor. AMA provides an accurate electronic model of the motor, allowing the drive to calculate optimal performance and efficiency. Running the AMA procedure also maximizes the automatic energy optimization feature of the drive. AMA is performed without the motor rotating and without uncoupling the load from the motor.

### 3.3.3 Process 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.

### 3.3.4 Motor Thermal Protection

To protect the application from serious damage, the drive offers several dedicated features.

#### Torque limit

The torque limit protects the motor from being overloaded independent of the speed. Torque limit is controlled in *parameter 4-16 Torque Limit Motor Mode* and *parameter 4-17 Torque Limit Generator Mode*. *Parameter 14-25 Trip Delay at Torque Limit* controls the time before the torque limit warning trips.

#### Current limit

*Parameter 4-18 Current Limit* controls the current limit, and *parameter 14-24 Trip Delay at Current Limit* controls the time before the current limit warning trips.

#### Minimum speed limit

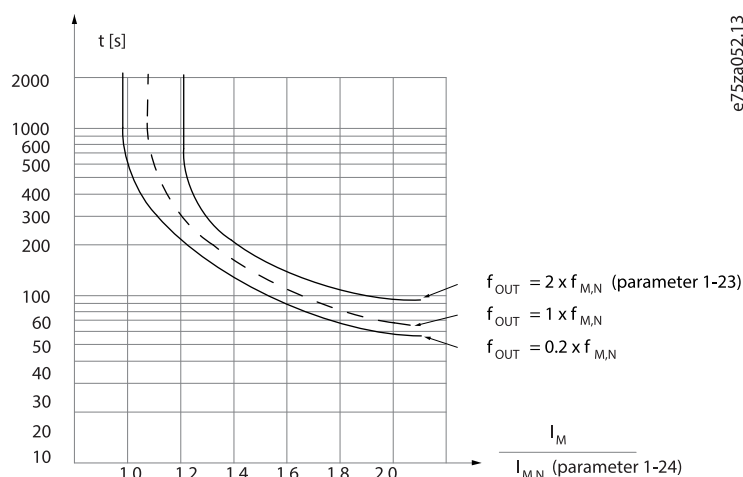
*Parameter 4-12 Motor Speed Low Limit [Hz]* sets the minimum output speed that the drive can provide.

## Maximum speed limit

**Parameter 4-14 Motor Speed High Limit [Hz]** or **parameter 4-19 Max Output Frequency** sets the maximum output speed that the drive can provide.

## ETR (electronic thermal relay)

The drive ETR function measures the actual current, speed, and time to calculate motor temperature. The function also protects the motor from being overheated (warning or trip). An external thermistor input is also available. ETR is an electronic feature that simulates a bimetal relay based on internal measurements. The characteristic is shown in [Figure 1](#).



**Figure 1: ETR**

The X-axis shows the ratio between  $I_{\text{motor}}$  and  $I_{\text{motor}}$  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**.

The motor ETR function is based on NEMA thermal relay function Class 10.

### NOTICE

The drive contains a software ETR function, which means that the drive has no information about what happens with the motor at different ambient temperatures and/or what happens at 1000 m above sea level. The software ETR function cannot fully replace a thermistor relay, because the thermistor relay includes a PTC sensor mounted on the motor, which is controlling the relay. However, the software ETR function is flexible and takes different parameters into account to get the required results. Besides the software ETR function, the drive has other protection features, for example, current limit and inverter thermal. In many situations, these features protect the drive and motor against overloads.

## 3.3.5 Mains Dropout

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

The drive can be configured (**parameter 14-10 Mains Failure**) to different types of behavior during mains dropout:

- Trip lock once the DC-link is exhausted.

- Coast with flying start whenever mains return (*parameter 1-73 Flying Start*).
- Kinetic back-up.
- Controlled ramp down.

### Flying start

This selection makes it possible to catch a motor that is spinning freely due to a mains dropout.

### Kinetic back-up

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

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

## 3.3.6 Automatic Restart

The drive can be programmed to restart the motor automatically after a minor trip, such as momentary power loss or fluctuation. This feature eliminates the need for manual resetting and enhances automated operation for remotely controlled systems. The number of restart attempts and the duration between attempts can be limited.

## 3.3.7 Full Torque at Reduced Speed

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

## 3.3.8 Frequency Bypass

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

## 3.3.9 Motor Preheat

To preheat a motor in a cold or damp environment, a small amount of DC current can be trickled continuously into the motor to protect it from condensation and cold starts. This function can eliminate the need for a space heater.

## 3.3.10 Programmable Setups

The drive has 2 setups that can be independently programmed. Using multi-setup, it is possible to switch between independently programmed functions activated by digital inputs or a serial command. Independent setups are used, for example, to change references, or for day/night or summer/winter operation, or to control multiple motors. The LCP shows the active setup. Setup data can be copied from drive to drive by downloading the information from the removable LCP.

## 3.3.11 Smart Logic Control (SLC)

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.

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

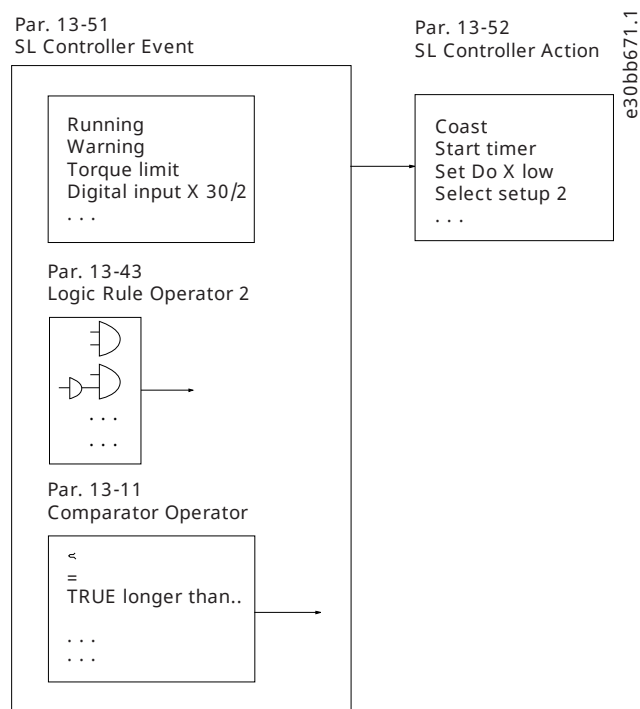


Figure 2: SLC Event and Action

Events and actions are each numbered and linked in pairs (states), which means that when event [0] is fulfilled (attains the value TRUE), action [0] is executed. After the 1st action is executed, the conditions of the next event are evaluated. If this event is evaluated as true, then the corresponding action is executed. 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 only evaluates event [0] during each scan interval. Only when event [0] is evaluated as true, the SLC executes action [0] and starts evaluating the next event. It is possible to program 1–20 events and actions. When the last event/action has been executed, the sequence starts over again from event [0]/action [0]. The following illustration shows an example with 4 event/actions:

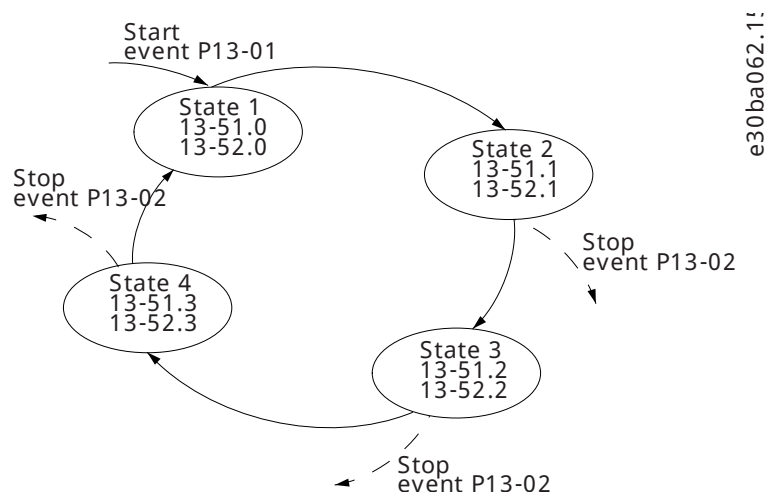


Figure 3: Order of Execution when 4 Events/Actions are Programmed

### Comparators

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

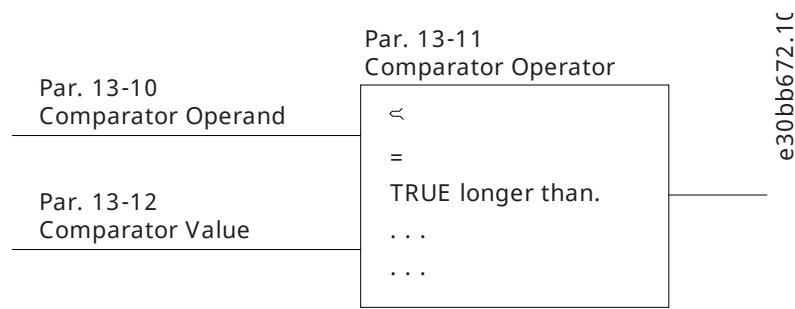


Figure 4: Comparators

### 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.

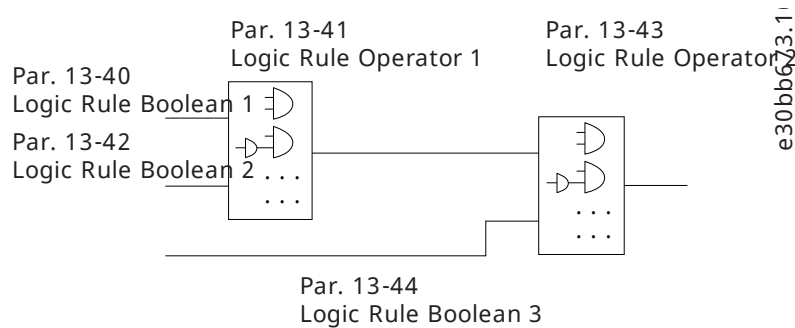


Figure 5: Logic Rules

## 3.4 Dynamic Braking

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

- **AC brake**  
The brake energy is distributed in the motor by changing the loss conditions in the motor (*parameter 2-10 Brake Function* = [2]). The AC brake function cannot be used in applications with high cycling frequency since this situation overheats the motor.
- **DC brake**  
An over-modulated DC current added to the AC current works as an eddy current brake (*parameter 2-02 DC Braking Time* ≠ 0 s).

## 3.5 Back-channel Cooling

### 3.5.1 Overview

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



### 3.5.2 Airflow for J8 & J9 Enclosures

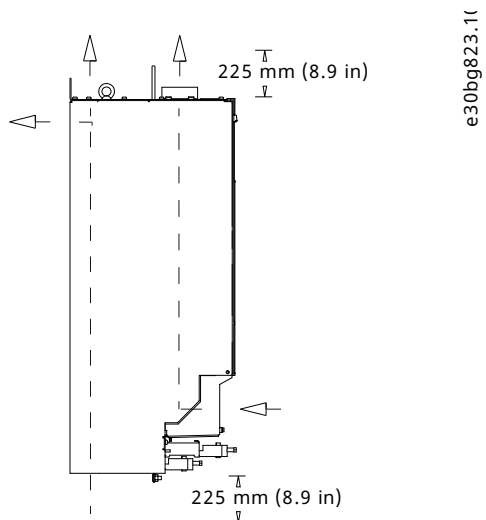


Figure 6: Standard Airflow Configuration for Enclosures J8 and J9

## 4 Options and Accessories Overview

### 4.1 Fieldbus Devices

#### 4.1.1 Overview

This chapter describes the fieldbus devices that are available with the drive. Using a fieldbus device reduces system cost, delivers faster and more efficient communication, and provides an easier user interface.

#### 4.1.2 VLT® PROFIBUS DP-V1 MCA 101

The VLT® PROFIBUS DP-V1 MCA 101 provides:

- 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 a GSD file.
- Acyclic parameterization using PROFIBUS DP-V1, PROFIdrive, or Danfoss FC profile state machines.

#### 4.1.3 VLT® PROFINET MCA 120

The VLT® PROFINET MCA 120 combines the highest performance with the highest degree of openness. The option is designed so that many of the features from the VLT® PROFIBUS MCA 101 can be reused, minimizing user effort to migrate PROFINET and securing the investment in a PLC program.

- Same PPO types as the VLT® PROFIBUS DP-V1 MCA 101 for easy migration to PROFINET.
- Built-in web server for remote diagnosis and reading out of basic drive parameters.
- Supports MRP.
- Implementation in accordance with Conformance Class B.

## 4.2 Functional Extensions

### 4.2.1 Overview

This chapter describes the functional extension options that are available with the drive.

#### 4.2.2 VLT® Encoder Input MCB 102

The VLT® Encoder Input MCB 102 option offers the possibility to connect various types of incremental and absolute encoders. The connected encoder can be used for closed loop speed control.

#### 4.2.3 VLT® Resolver Option MCB 103

The VLT® Resolver Option MCB 103 option enables connection of a resolver to provide speed feedback from the motor.

- Primary voltage:  $2-8 V_{rms}$ .
- Primary frequency: 2.0–15 kHz.
- Primary maximum current: 50 mA rms.
- Secondary input voltage:  $4 V_{rms}$ .
- Spring-loaded connection.

#### 4.2.4 VLT® 24 V DC Supply MCB 107

VLT® 24 V DC Supply MCB 107 connects an external DC supply to keep the control compartment and any installed option functioning during power failure. VLT® 24 V DC Supply MCB 107 also enables full operation of the LCP (including the parameter setting) and all installed options without connection to mains.

- Input voltage range: 24 V DC +/15% (maximum 37 V for 10 s)

- Maximum input current: 2.2 A
- Maximum cable length: 75 m (246 ft)
- Input capacitance load: < 10 uF
- Power up delay: < 0.6 s

#### 4.2.5 VLT® Sensor Input Option MCB 114

The VLT® Sensor Input Option MCB 114 protects the motor from being overheated by monitoring the temperature of motor bearings and windings.

- 3 self-detecting sensor inputs for 2 or 3-wire PT100/PT1000 sensors.

## 5 Specifications

### 5.1 Electrical Data

**Table 3: Electrical Data for Normal Overload, Mains Supply 3x380–480 V AC**

Drive	Q110	Q132	Q160	Q200	Q250	Q315
Enclosure size	J8	J8	J8	J9	J9	J9
<b>Normal overload=110% current during 60 s</b>						
Typical shaft output at 400 V [kW]	110	132	160	200	250	315
Typical shaft output at 460 V [hp]	150	200	250	300	350	450
<b>Output current (3-phase)</b>						
Continuous (at 400 V) [A]	212	260	315	395	480	588
Intermittent (60 s overload) (at 400 V) [A]	233	286	347	435	528	647
Continuous (at 460 V) [A]	190	240	302	361	443	535
Intermittent (60 s overload) (at 460 V) [A]	209	264	332	397	487	589
Continuous kVA (at 400 V) [kVA]	147	180	218	274	333	407
Continuous kVA (at 460 V) [kVA]	151	191	241	288	353	426
<b>Maximum input current</b>						
Continuous (at 400 V) [A]	204	251	304	381	463	567
Continuous (at 460 V) [A]	183	231	291	348	427	516
<b>Maximum number and size of cables per phase</b>						
Mains and motor [mm <sup>2</sup> (AWG)]	2x95 (2x3/0)			2x185 (2x350 mcm)		
Maximum external mains fuses [A]	315	350	400	550	630	800
Estimated power loss at 400 V [W]	2559	2954	3770	4116	5137	6674
Estimated power loss at 460 V [W]	2261	2724	3628	3569	4566	5714
Efficiency [%]	98					
Output frequency [Hz]	0–590					
Heat sink overtemperature trip [°C (°F)]	110 (230)					
Control card overtemperature trip [°C (°F)]	75 (167)			80 (176)		

**Table 4: Electrical Data for High Overload, Mains Supply 3x380–480 V AC**

Drive	H90K	H110	H132	H160	H200	H250
Enclosure size	J8	J8	J8	J9	J9	J9
<b>High overload=150% current during 60 s</b>						
Typical shaft output at 400 V [kW]	90	110	132	160	200	250
Typical shaft output at 460 V [hp]	125	150	200	250	300	350

Table 4: Electrical Data for High Overload, Mains Supply 3x380–480 V AC (continued)

Drive	H90K	H110	H132	H160	H200	H250
<b>Output current (3-phase)</b>						
Continuous (at 400 V) [A]	177	212	260	315	395	480
Intermittent (60 s overload) (at 400 V) [A]	266	318	390	473	593	720
Continuous (at 460 V) [A]	160	190	240	302	361	443
Intermittent (60 s overload) (at 460 V) [A]	240	285	360	453	542	665
Continuous kVA (at 400 V) [kVA]	123	147	180	218	274	333
Continuous kVA (at 460 V) [kVA]	127	151	191	241	288	353
<b>Maximum input current</b>						
Continuous (at 400 V) [A]	171	204	251	304	381	463
Continuous (at 460 V) [A]	154	183	231	291	348	427
<b>Maximum number and size of cables per phase</b>						
Mains and motor [mm <sup>2</sup> (AWG)]	2x95 (2x3/0)			2x185 (2x350 mcm)		
Maximum external mains fuses [A]	315	350	400	550	630	800
Estimated power loss at 400 V [W]	2031	2289	2923	3093	4039	5004
Estimated power loss at 460 V [W]	1828	2051	2089	2872	3575	4458
Efficiency [%]	98					
Output frequency [Hz]	0–590					
Heat sink overtemperature trip [°C (°F)]	110 (230)					
Control card overtemperature trip [°C (°F)]	75 (167)			80 (176)		

## 5.2 Mains Supply (L1, L2, L3)

Supply voltage	380–480 V ±10%
Supply frequency	50/60 Hz ±5%
Maximum imbalance temporary between mains phases	3.0% of rated supply voltage <sup>(1)</sup>
True power factor (λ)	≥0.9 nominal at rated load
Displacement power factor (cos Φ) near unity	>0.98
Switching on input supply L1, L2, L3 (power-ups)	Maximum 1 time/2 minute
Environment according to EN60664-1	Overvoltage category III/pollution degree 2

1) Calculations based on IEC61800-3.

Mains voltage low/mains voltage drop-out:

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

The drive is suitable for use on a circuit capable of delivering up to 100 kA short-circuit current rating (SCCR) at 480/600 V.

### 5.3 Motor Output (U, V, W)

Output voltage	0–100% of supply voltage
Output frequency in U/f mode (for AM motor)	0–500 Hz
Output frequency in VVC+ mode (for AM motor)	0–200 Hz
Output frequency in VVC+ mode (for PM motor)	0–400 Hz
Switching on output	Unlimited
Ramp times	0.01–3600 s

### 5.4 Torque Characteristics

Starting torque (constant torque)	Maximum 150% for 60 s <sup>(1)(2)</sup>
Overload torque (constant torque)	Maximum 150% for 60 s <sup>(1)(2)</sup>

1) Percentage relates to the nominal current of the drive.

2) Once every 10 minutes.

### 5.5 Ambient Conditions

J8/J9 enclosure size	IP20/Chassis
Vibration test (standard/ruggedized)	0.7 g
Relative humidity	5%–95% (IEC 721-3-3; Class 3K3 (non-condensing) during operation)
Aggressive environment (IEC 60068-2-43) H <sub>2</sub> S test	Class Kd
Aggressive gases (IEC 60721-3-3)	Class 3C3
Test method according to IEC 60068-2-43	H <sub>2</sub> S (10 days)
Ambient temperature (at SFAVM switching mode)	
- with derating	Maximum 55 °C (131 °F) <sup>(1)</sup>
- with full output power of typical EFF2 motors (up to 90% output current)	Maximum 50 °C (122 °F) <sup>(1)</sup>
- at full continuous FC output current	Maximum 45 °C (113 °F) <sup>(1)</sup>
Minimum ambient temperature during full-scale operation	-15 °C (5 °F)
Minimum ambient temperature at reduced performance	-20 °C (-4 °F)
Temperature during storage/transport	-25 to +65/70 °C (13 to 149/158 °F)

Maximum altitude above sea level without derating	1000 m (3281 ft)
Maximum altitude above sea level with derating	3000 m (9842 ft)
EMC standards	EN 61800-3
Energy efficiency class <sup>(2)</sup>	IE2

1) For more information on derating, see *chapter Derating*.

2) Determined according to EN 50598-2 at:

- Rated load.
- 90% rated frequency.
- Switching frequency factory setting.
- Switching pattern factory setting.

## 5.6 Cable Lengths and Cross-sections

Maximum motor cable length, shielded	150 m (492 ft)
Maximum motor cable length, unshielded	300 m (984 ft)
Maximum cross-section to motor and mains	See <i>chapter Electrical Data</i>
Maximum cross-section to control terminals, rigid wire	1.5 mm <sup>2</sup> /16 AWG (2x0.75 mm <sup>2</sup> )
Maximum cross-section to control terminals, flexible cable	1 mm <sup>2</sup> /18 AWG
Maximum cross-section to control terminals, cable with enclosed core	0.5 mm <sup>2</sup> /20 AWG
Minimum cross-section to control terminals	0.25 mm <sup>2</sup> /23 AWG

## 5.7 Digital Inputs

Programmable digital inputs	7
Terminal number	18, 19, 27, 29, 31, 32, 33 <sup>(1)</sup>
Logic	PNP or NPN
Voltage level	0–24 V DC
Voltage level, logic 0 PNP	< 5 V DC
Voltage level, logic 1 PNP	> 10 V DC
Voltage level, logic 0 NPN	> 19 V DC
Voltage level, logic 1 NPN	< 14 V DC
Maximum voltage on input	28 V DC
Pulse frequency range	4 Hz–32 kHz
(Duty cycle) minimum pulse width	4.5 ms
Input resistance, Ri	Approximately 4 kΩ

1) Terminals 27 and 29 can also be programmed as output.

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

## 5.8 Analog Inputs

Number of analog inputs	2
Terminal number	53, 54
Modes	Voltage or current
Mode select	Software
Voltage level	0–10 V
Input resistance, Ri	Approximately 10 kΩ
Maximum voltage	-15 V to +20 V
Current level	0/4 to 20 mA (scaleable)
Input resistance, Ri	Approximately 200 Ω
Maximum current	30 mA
Resolution for analog inputs	11 bit
Accuracy of analog inputs	Maximum error 0.5% of full-scale
Bandwidth	100 Hz

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

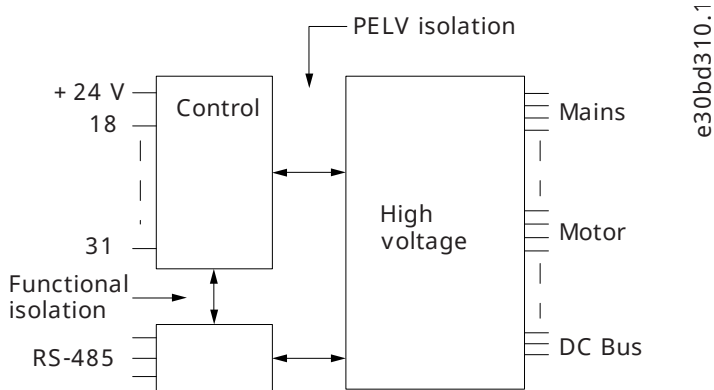


Figure 7: Analog Inputs

### NOTICE

#### HIGH ALTITUDES

- For installation at altitudes above 2000 m (6562 ft), contact Danfoss regarding PELV.

## 5.9 Pulse Inputs

Programmable pulse inputs	2
Terminal number pulse	29, 33
Maximum frequency at terminal 29, 33 (push-pull driven)	32 kHz



Maximum frequency at terminal 29, 33 (open collector)	5 kHz
Minimum frequency at terminal 29, 33	4 Hz
Voltage level	See the section on digital input
Maximum voltage on input	28 V DC
Input resistance, $R_i$	Approximately 4 k $\Omega$
Pulse input accuracy	Maximum error: 0.1% of full-scale

## 5.10 Digital Outputs

Programmable digital/pulse outputs	2
Terminal number	27, 29 <sup>(1)</sup>
Voltage level at digital/frequency outputs	0–24 V
Maximum output current (sink or source)	40 mA
Maximum load at frequency outputs	1 k $\Omega$
Maximum capacitive load at frequency outputs	10 nF
Minimum output frequency at frequency outputs	4 Hz
Maximum output frequency at frequency outputs	32 kHz
Accuracy of frequency outputs	Maximum error: 0.1% of full-scale
Resolution of frequency outputs	10 bit

1) Terminals 27 and 29 can also be programmed as inputs.

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

## 5.11 Analog Outputs

Number of programmable analog outputs	2
Terminal number	45, 42
Current range at analog outputs	0/4–20 mA
Maximum resistor load to common at analog outputs	500 $\Omega$
Accuracy on analog outputs	Maximum error: 0.8% of full-scale
Resolution on analog outputs	10 bit

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

## 5.12 Relay Outputs

Programmable relay outputs	2
Maximum cross-section to relay terminals	2.5 mm <sup>2</sup> (12 AWG)

Minimum cross-section to relay terminals	0.2 mm <sup>2</sup> (30 AWG)
Length of stripped wire	8 mm (0.3 in)
<b>Relay 01 terminal number</b>	1–3 (break), 1–2 (make)
Maximum terminal load (AC-1) <sup>(1)</sup> on 1–2 (NO) (Resistive load) <sup>(2)</sup>	400 V AC, 2 A
Maximum terminal load (AC-15) <sup>(1)</sup> on 1–2 (NO) (Inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1) <sup>(1)</sup> on 1–2 (NO) (Resistive load)	80 V DC, 2 A
Maximum terminal load (DC-13) <sup>(1)</sup> on 1–2 (NO) (Inductive load)	24 V DC, 0.1 A
Maximum terminal load (AC-1) <sup>(1)</sup> on 1–3 (NC) (Resistive load)	240 V AC, 2 A
Maximum terminal load (AC-15) <sup>(1)</sup> on 1–3 (NC) (Inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1) <sup>(1)</sup> on 1–3 (NC) (Resistive load)	50 V DC, 2 A
Maximum terminal load (DC-13) <sup>(1)</sup> on 1–3 (NC) (Inductive load)	24 V DC, 0.1 A
Minimum terminal load on 1–3 (NC), 1–2 (NO)	24 V DC 10 mA, 24 V AC 2 mA
Environment according to EN 60664-1	Overvoltage category III/pollution degree 2
<b>Relay 02 terminal number</b>	4–6 (break), 4–5 (make)
Maximum terminal load (AC-1) <sup>(1)</sup> on 4–5 (NO) (Resistive load) <sup>(2)</sup>	400 V AC, 2 A
Maximum terminal load (AC-15) <sup>(1)</sup> on 4–5 (NO) (Inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1) <sup>(1)</sup> on 4–5 (NO) (Resistive load)	80 V DC, 2 A
Maximum terminal load (DC-13) <sup>(1)</sup> on 4–5 (NO) (Inductive load)	24 V DC, 0.1 A
Maximum terminal load (AC-1) <sup>(1)</sup> on 4–6 (NC) (Resistive load)	240 V AC, 2 A
Maximum terminal load (AC-15) <sup>(1)</sup> on 4–6 (NC) (Inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1) <sup>(1)</sup> on 4–6 (NC) (Resistive load)	50 V DC, 2 A
Maximum terminal load (DC-13) <sup>(1)</sup> on 4–6 (NC) (Inductive load)	24 V DC, 0.1 A
Minimum terminal load on 4–6 (NC), 4–5 (NO)	24 V DC 10 mA, 24 V AC 2 mA
Environment according to EN 60664-1	Overvoltage category III/pollution degree 2

1) IEC 60947 part 4 and 5.

2) Overvoltage Category II.

The relay contacts are galvanically isolated from the rest of the circuit by reinforced isolation (PELV).

### 5.13 Control Card, RS485 Serial Communication

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

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

### 5.14 Control Card, 24 V DC Output

Terminal number	12
Maximum load	100 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.

### 5.15 Control Card, +10 V DC Output

Terminal number	50
Output voltage	10.5 V $\pm$ 0.5 V
Maximum load	15 mA

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

### 5.16 Control Characteristics

Resolution of output frequency at 0–500 Hz	$\pm$ 0.003 Hz
System response time (terminals 18, 19, 27, 29, 32, and 33)	$\leq$ 2 ms
Speed control range (open loop)	1:100 of synchronous speed
Speed accuracy (open loop)	$\pm$ 0.5% of nominal speed
Speed accuracy (close loop)	$\pm$ 0.1% of nominal speed

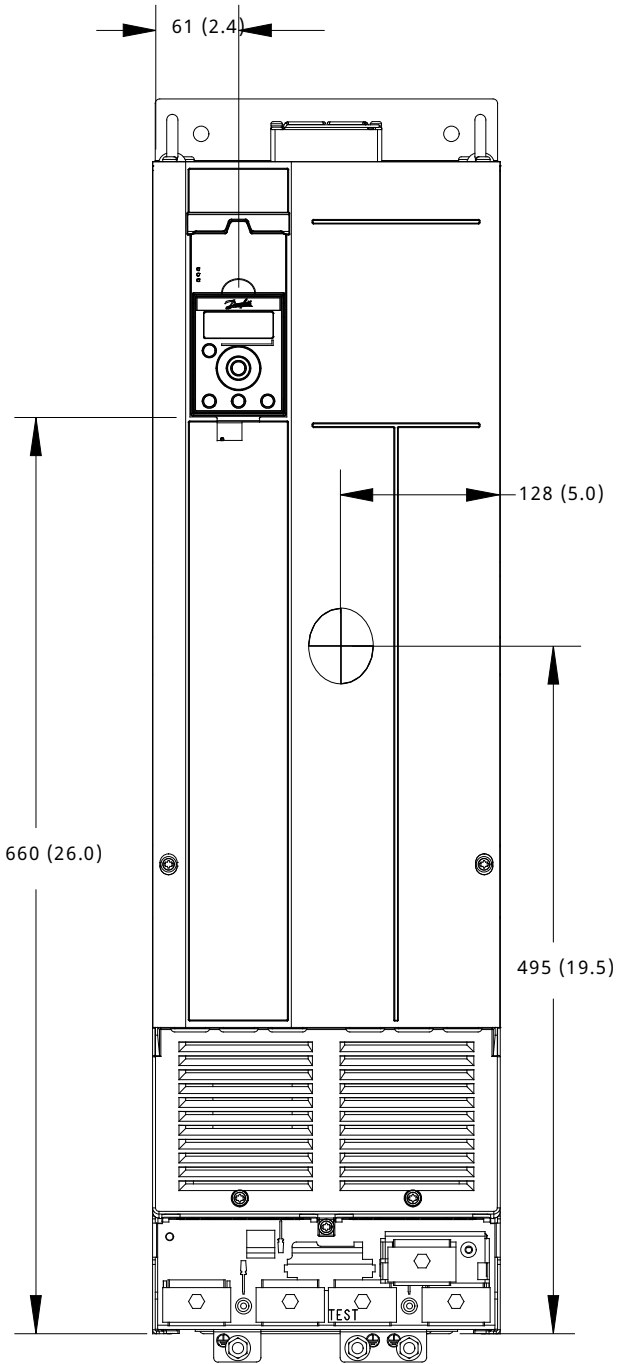
All control characteristics are based on a 4-pole asynchronous motor.

### 5.17 Control Card Performance

Scan interval	1 ms
---------------	------

## 5.18 Exterior and Terminal Dimensions

### 5.18.1 J8 Exterior Dimensions



e30bv156.1f

Figure 8: Front View of J8

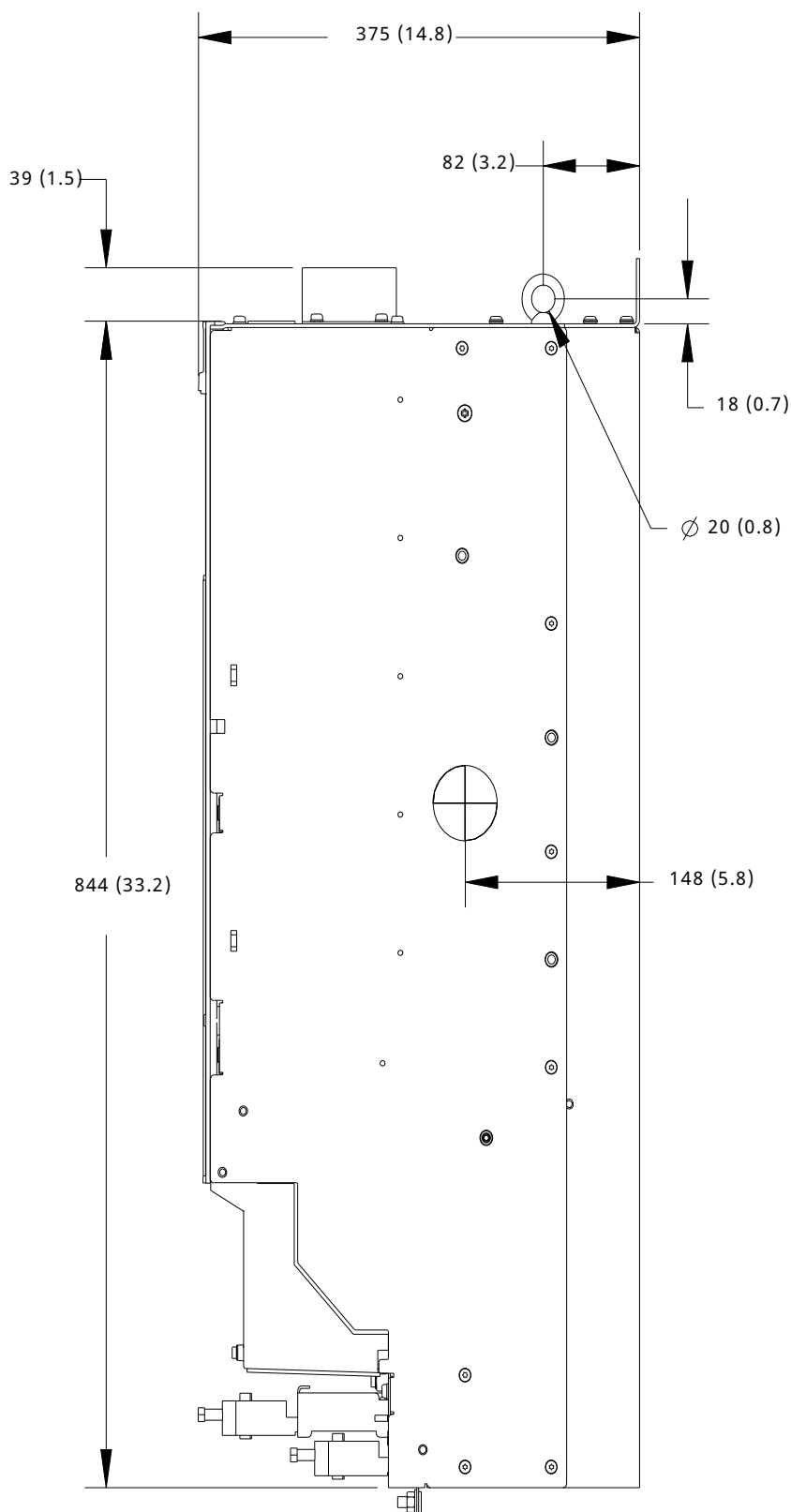


Figure 9: Side View of J8

e30bf802.10

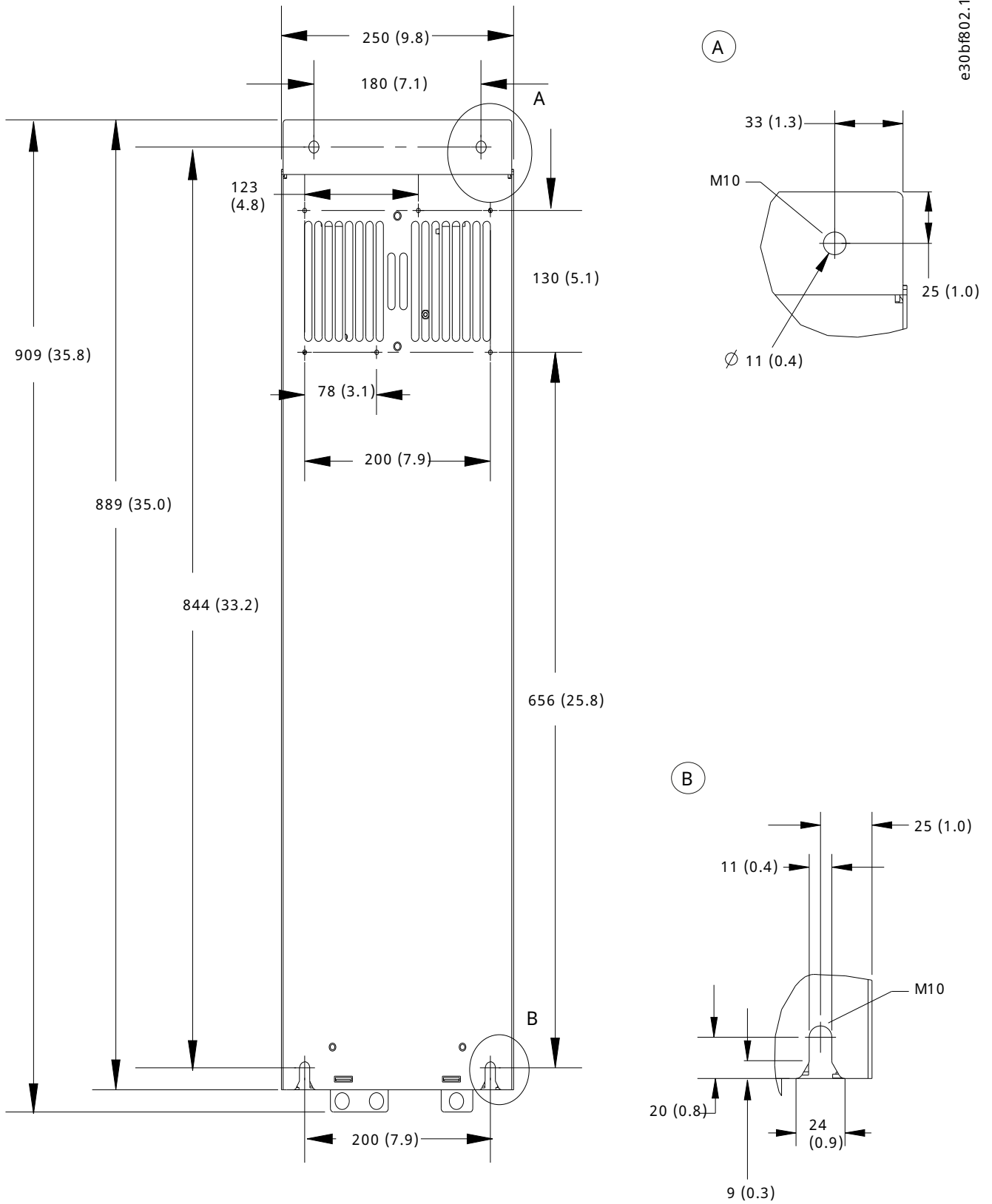
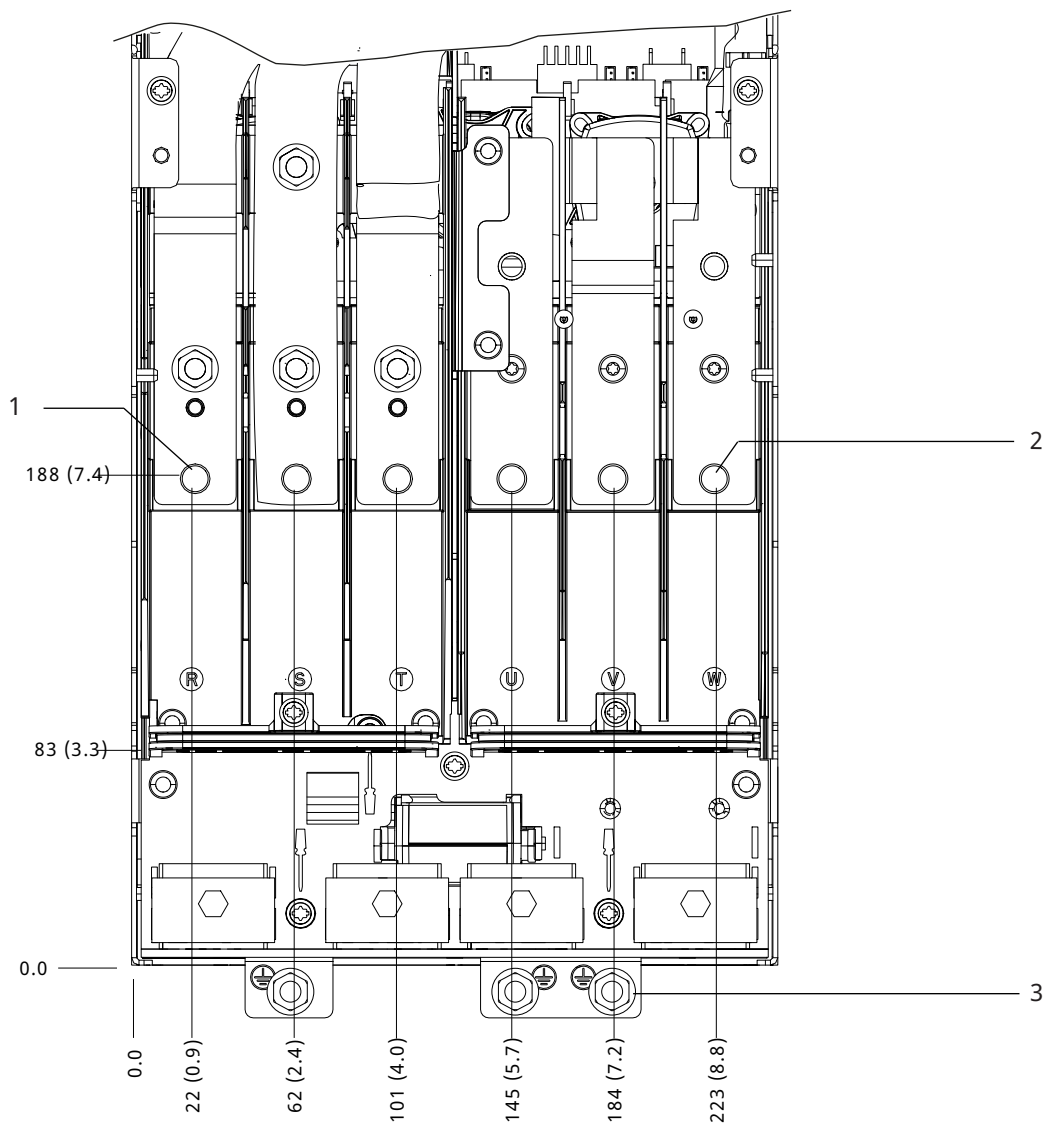


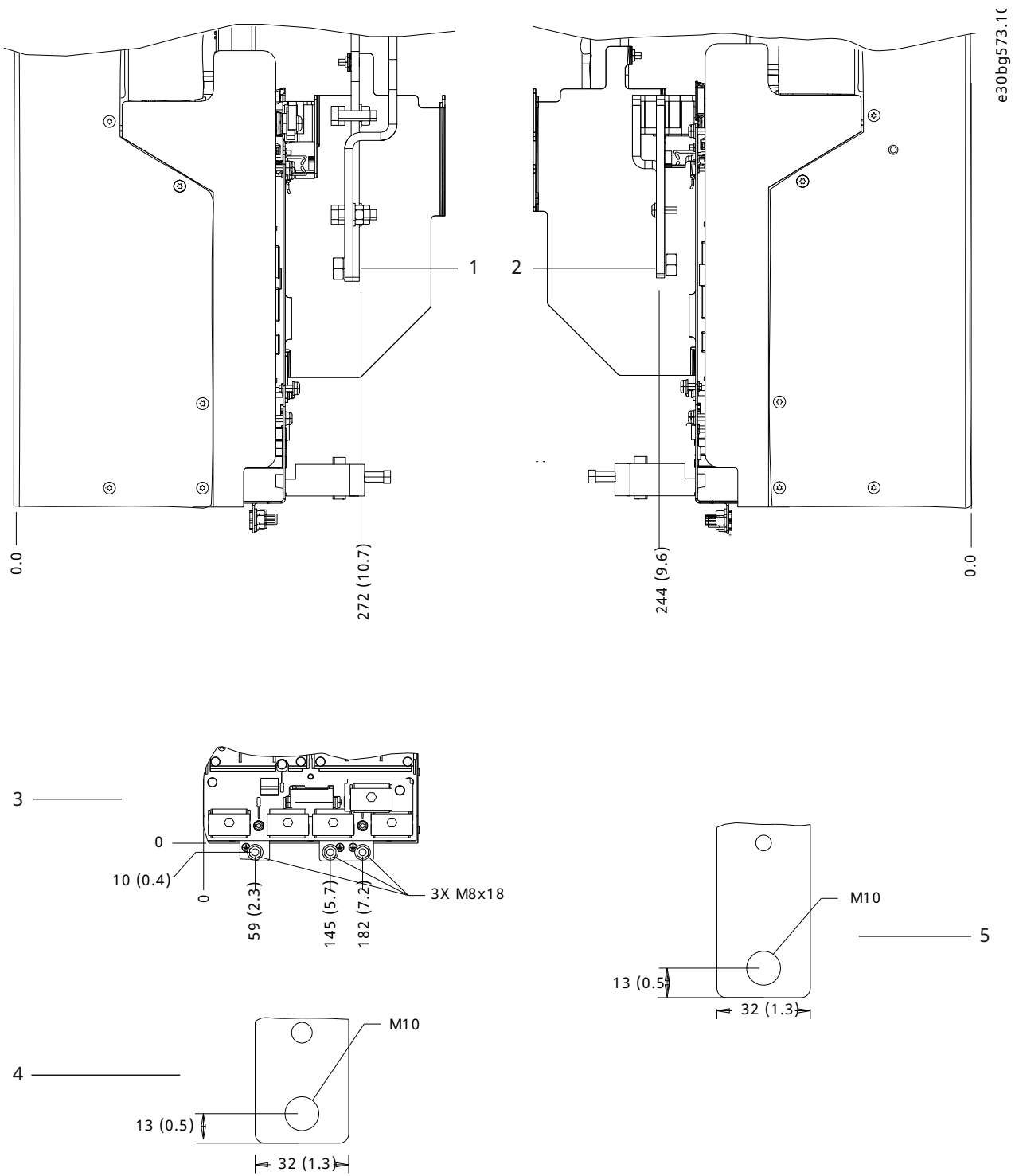
Figure 10: Back View of J8

### 5.18.2 J8 Terminal Dimensions



e30bg615.10

Figure 11: J8 Terminal Dimensions (Front View)



e30bg573.1c

Figure 12: J8 Terminal Dimensions (Side Views)

1	Mains terminals	2	Motor terminals
3	Ground terminals	4	Mains terminals
5	Motor terminals		



### 5.18.3 J9 Exterior Dimensions

e30bv157.10

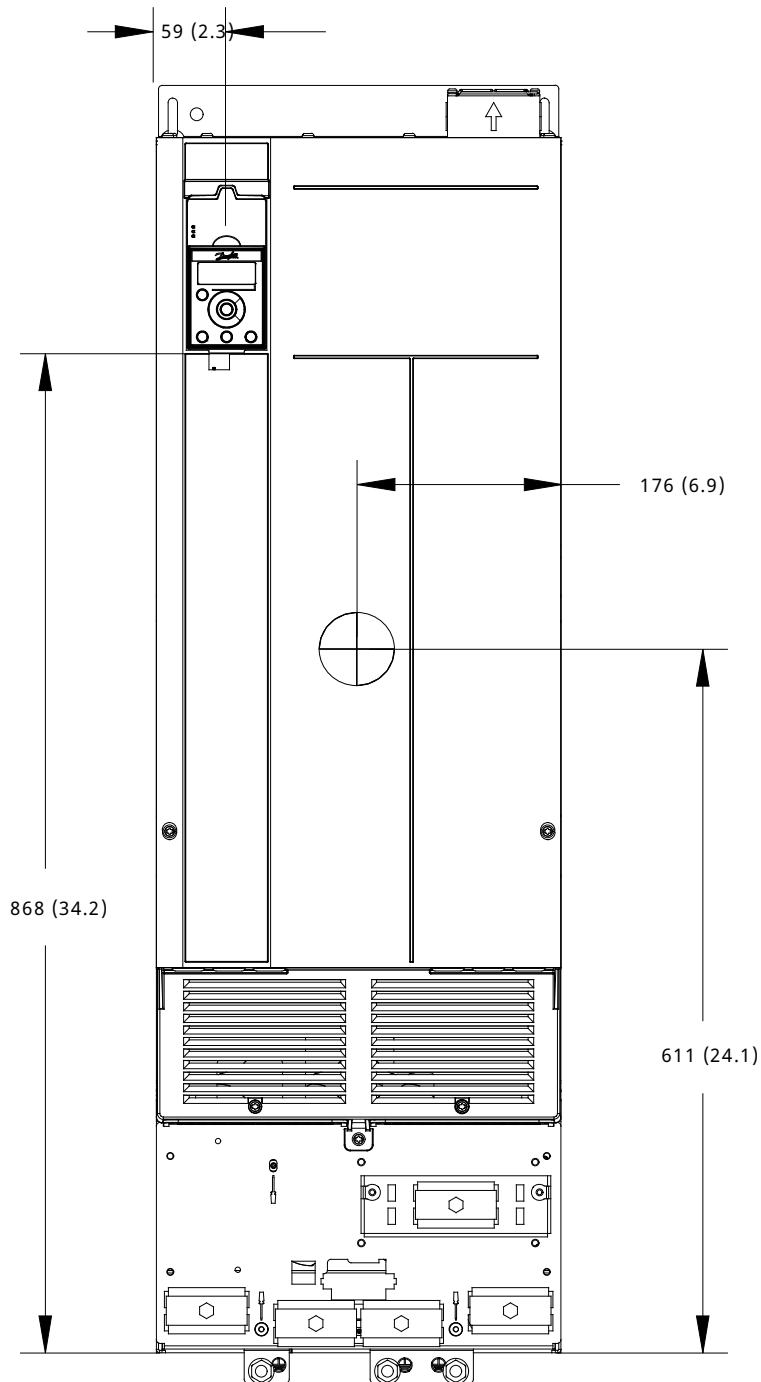


Figure 13: Front View of J9

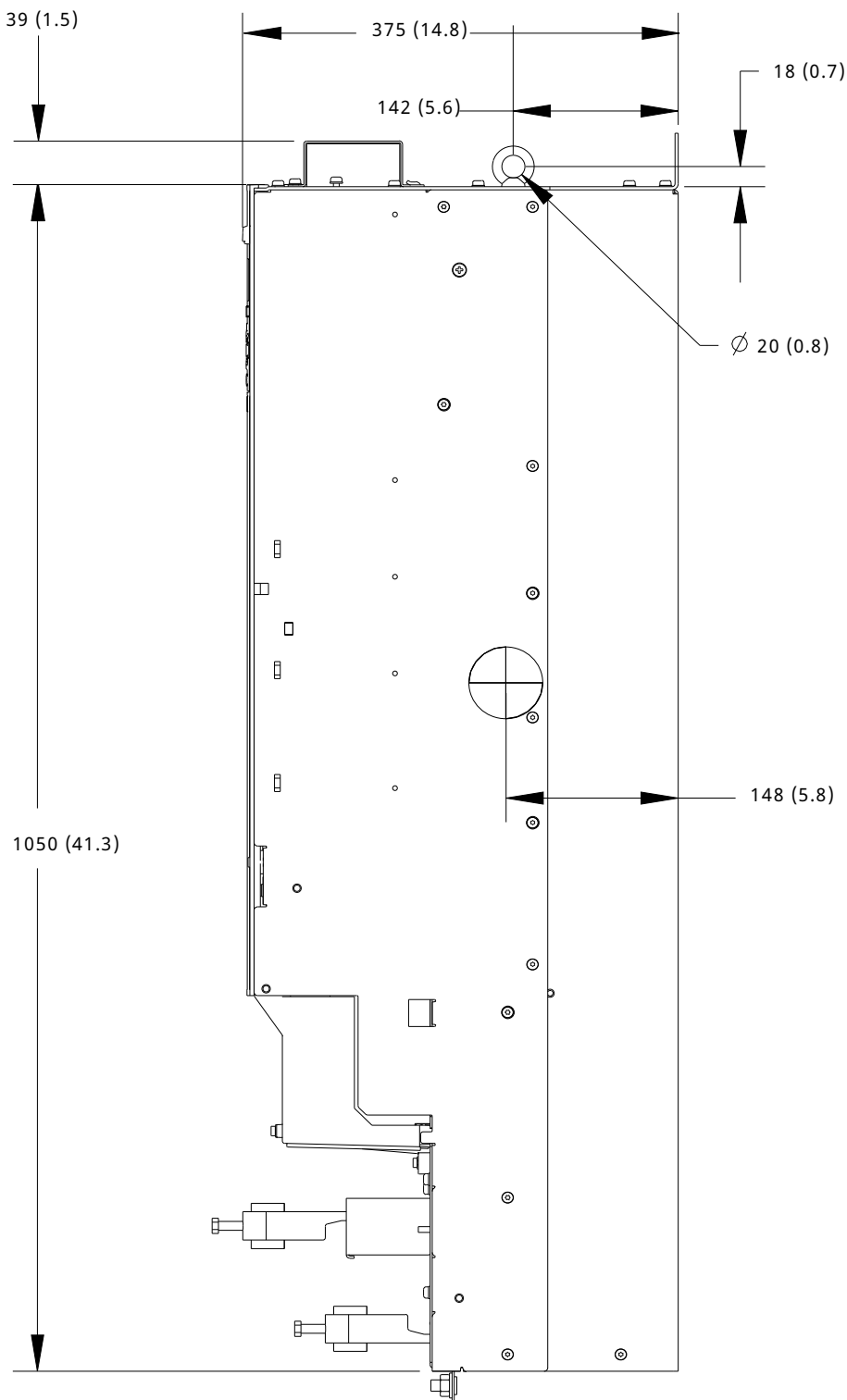


Figure 14: Side View of J9

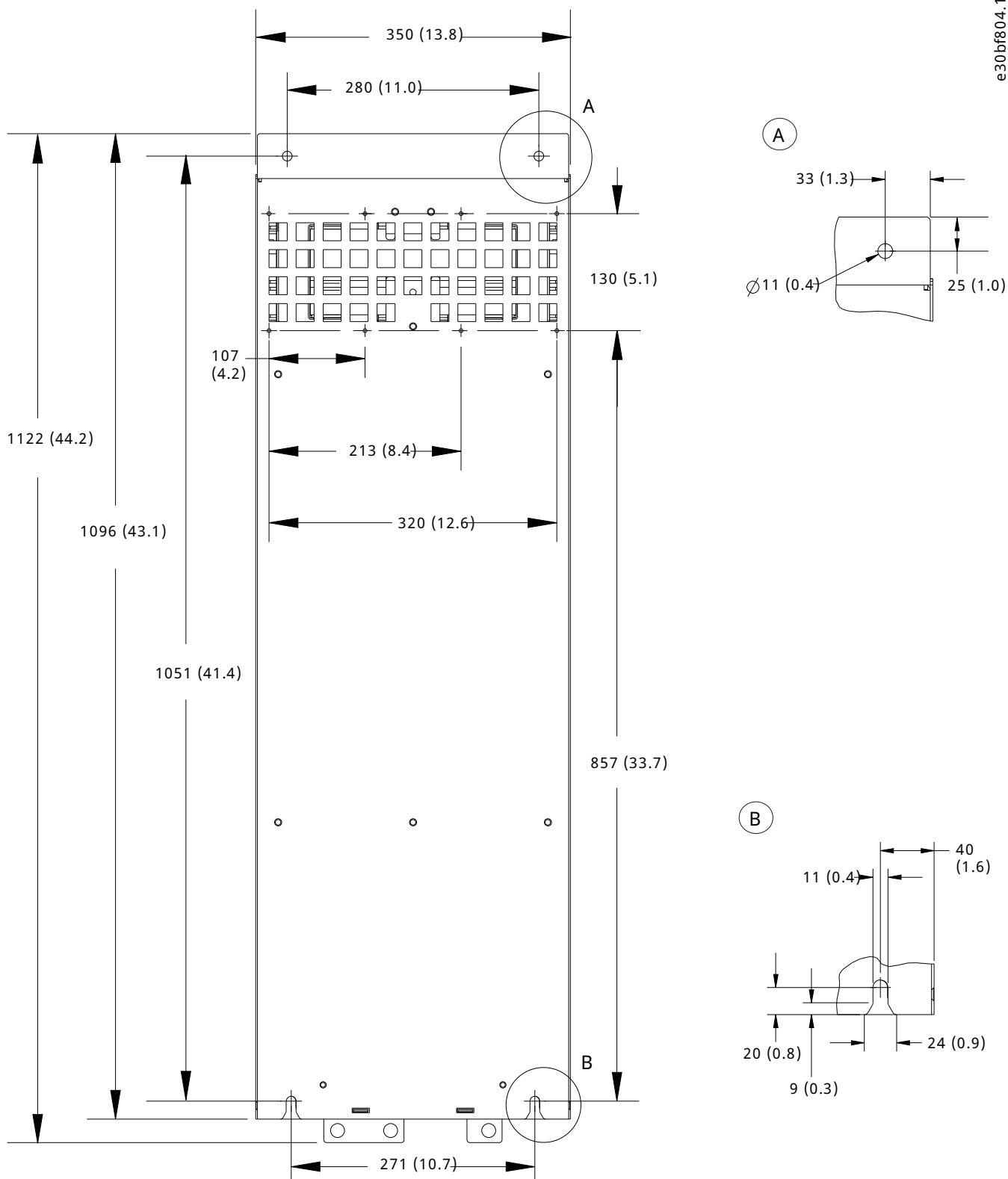


Figure 15: Back View of J9

5.18.4 J9 Terminal Dimensions

e30bg616.1c

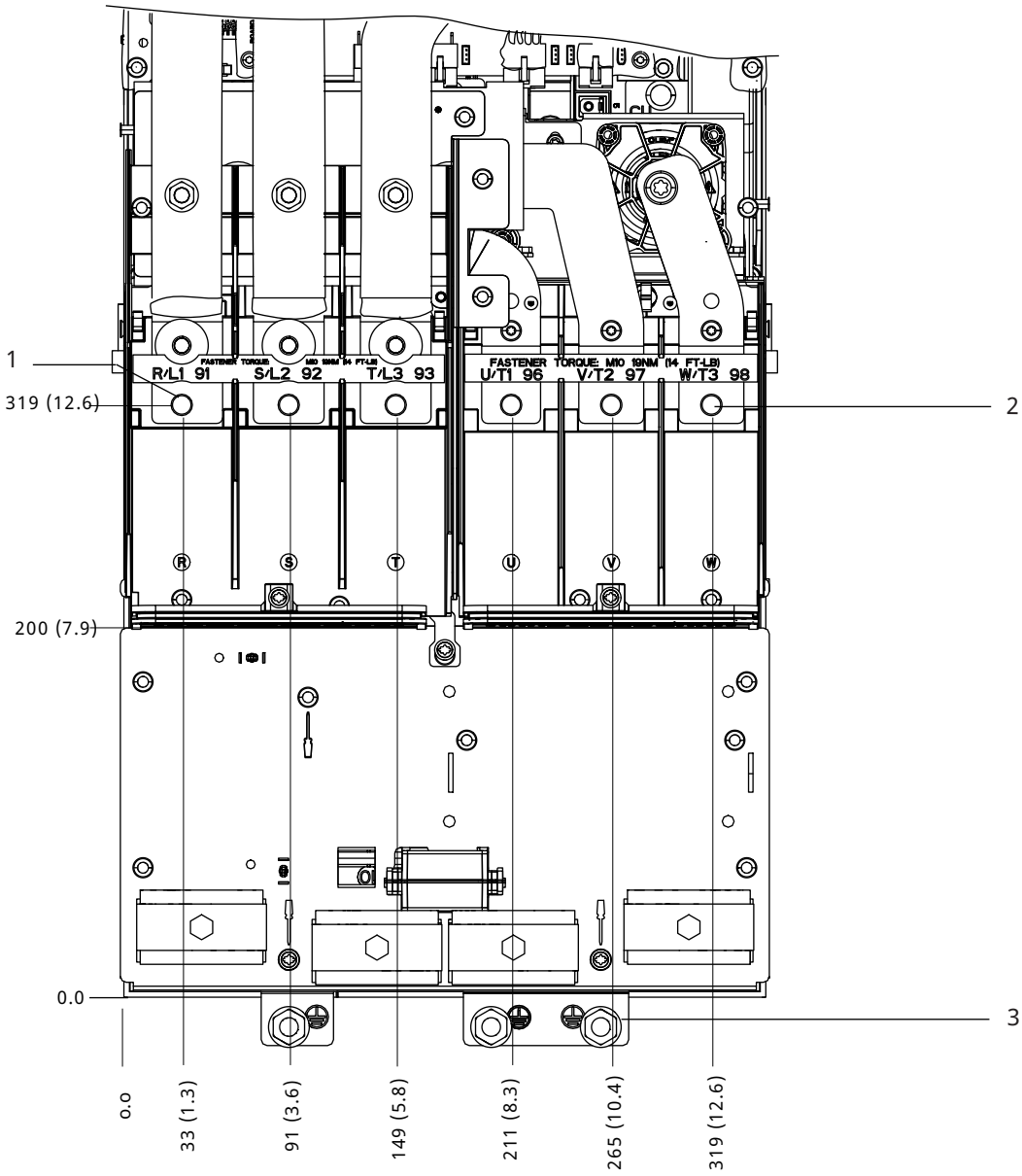
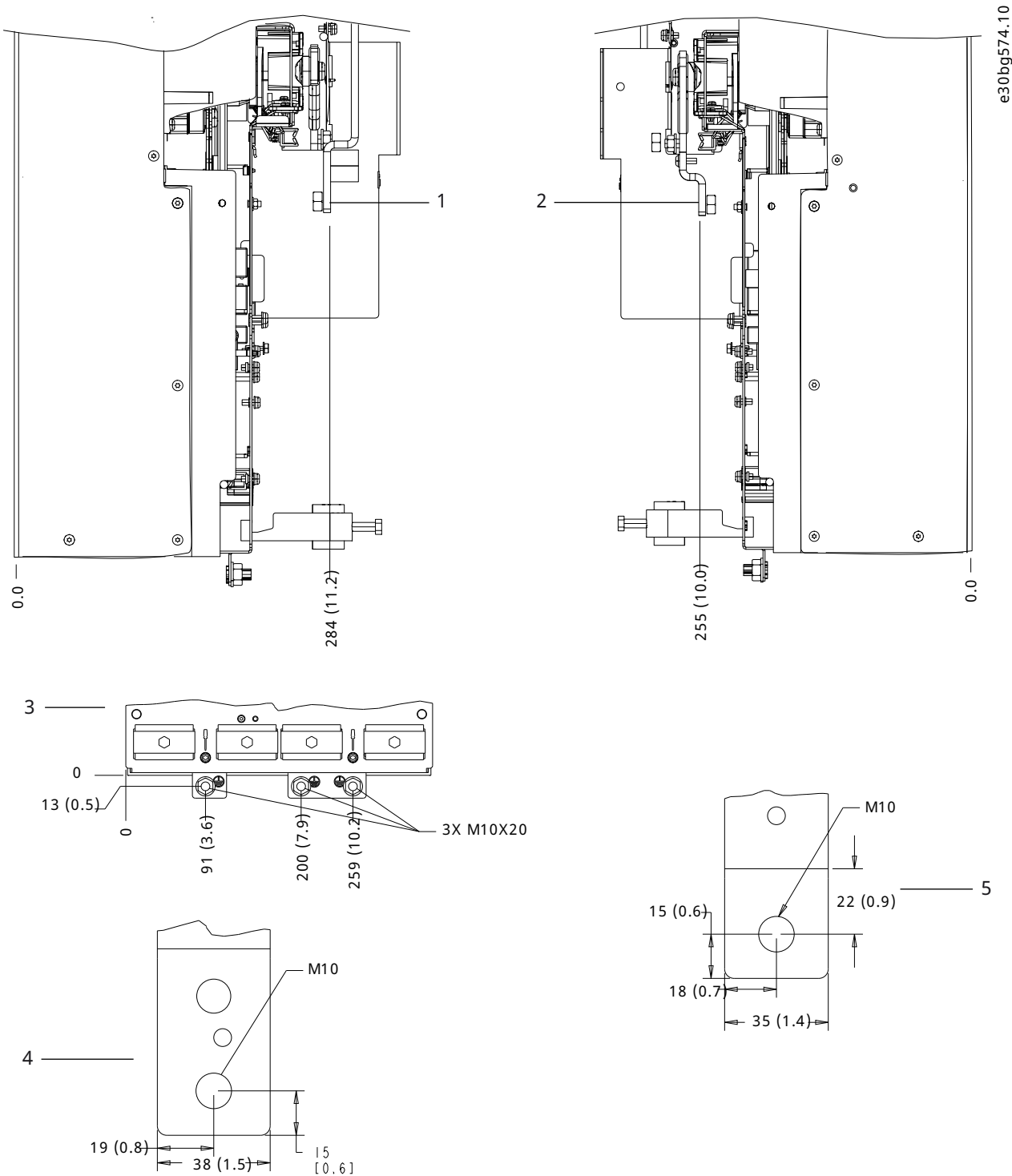


Figure 16: J9 Terminal Dimensions (Front View)

1	Mains terminals	2	Motor terminals
3	Ground terminals		



e30bg574.10

Figure 17: J9 Terminal Dimensions (Side Views)

1	Mains terminals	2	Motor terminals
3	Ground terminals	4	Mains terminals
5	Motor terminals		

## 6 Mechanical Installation Considerations

### 6.1 Storage

Store the drive in a dry location. Keep the equipment sealed in its packaging until installation. Refer to *chapter Ambient Conditions* for recommended ambient temperature.

Periodic forming (capacitor charging) is not necessary during storage unless storage exceeds 12 months.

### 6.2 Lifting the Unit

Always lift the drive using the dedicated lifting eyes. To avoid bending the lifting holes, use a bar.

#### WARNING

##### RISK OF INJURY OR DEATH

Follow local safety regulations for lifting heavy weights. Failure to follow recommendations and local safety regulations can result in death or serious injury.

- Ensure that the lifting equipment is in proper working condition.
- See *chapter Product Overview and Features* for the weight of the different enclosure sizes.
- Maximum diameter for bar: 20 mm (0.8 in).
- The angle from the top of the drive to the lifting cable: 60° or greater.

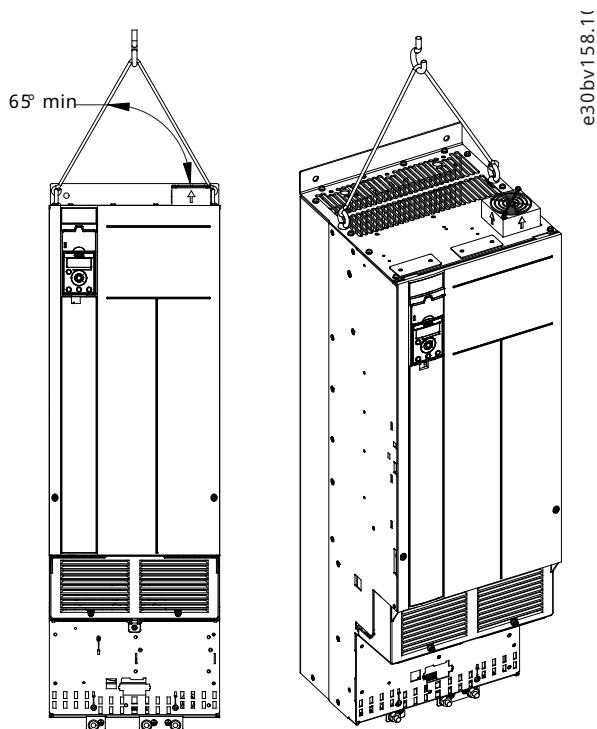


Figure 18: Recommended Lifting Method

## 6.3 Operating Environment

### 6.3.1 Operating Environment Overview

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

#### NOTICE

##### CONDENSATION

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

#### NOTICE

##### EXTREME AMBIENT CONDITIONS

Hot or cold temperatures compromise unit performance and longevity.

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

### 6.3.2 Gases

Aggressive gases, such as hydrogen sulphide, chlorine, or ammonia can damage the electrical and mechanical components. The unit uses conformal-coated circuit boards to reduce the effects of aggressive gases. For conformal coating class specifications and ratings, see *chapter Ambient Conditions*.

### 6.3.3 Dust

When installing the drive in dusty environments, pay attention to the following:

#### Periodic maintenance

When dust accumulates on electronic components, it acts as a layer of insulation. This layer reduces the cooling capacity of the components, and the components become warmer. The hotter environment decreases the life of the electronic components. Keep the heat sink and fans free from dust build-up.

#### Cooling fans

Fans provide airflow to cool the drive. When fans are exposed to dusty environments, the dust can damage the fan bearings and cause premature fan failure. Also, dust can accumulate on fan blades causing an imbalance which prevents the fans from properly cooling the unit.

## 6.4 Mounting Configurations

The following table lists the available mounting configurations for each enclosure size of the drive.

#### NOTICE

Improper mounting can result in overheating and reduced performance.

Table 5: Mounting Configurations

Enclosure size	Wall/cabinet mount	Pedestal mount (Standalone)
J8	X <sup>(1)</sup>	–
J9	X <sup>(1)</sup>	–

1) Can be wall-mounted, but Danfoss recommends that the drive is panel-mounted inside an enclosure due to its protection rating.

Mounting considerations:

- Locate the unit as near to the motor as possible. See the *chapter Cable Lengths and Cross-sections* for the maximum motor cable length.
- Ensure unit stability by mounting the unit to a solid surface.
- Ensure that the strength of the mounting location supports the unit weight.
- Ensure that there is enough space around the unit for proper cooling. Refer to the *chapter Back Channel Cooling*.
- Ensure enough access to open the door.
- Ensure cable entry from the bottom.

## 6.5 Cooling

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

The drive utilizes a back-channel cooling concept that removes heat sink cooling air. The heat sink cooling air carries approximately 90% of the heat out of the back channel of the drive. Redirect the back-channel air from the panel or room by using:

- **Duct cooling**  
Back-channel cooling kits are available to direct the heat sink cooling air out of the panel when IP20/Chassis drives are installed in Rittal enclosures. Use of these kits reduces the heat in the panel and smaller door fans can be specified.
- **Back-wall cooling**  
Installing top and base covers to the unit allows the back-channel cooling air to be ventilated out of the room.

Secure the necessary airflow over the heat sink.

Table 6: J8–J9 Airflow Rate

Enclosure size	Door fan/top fan [m <sup>3</sup> /hr (cfm)]	Heat sink fan [m <sup>3</sup> /hr (cfm)]
J8	102 (60)	420 (250)
J9	204 (120)	840 (500)

## 6.6 Derating

### 6.6.1 Overview of Derating

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



## Manual derating

When the following conditions are present, Danfoss recommends selecting a drive 1 power size higher (for example H132 instead of H110):

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

## Automatic derating

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

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

### 6.6.2 Derating for Low-Speed Operation

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

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

#### Constant torque applications

A problem can occur at low RPM values in constant torque applications. In a constant torque application, a motor can overheat at low speeds because less cooling air is being provided by the fan within the motor.

If the motor is run continuously at an RPM value lower than half of the rated value, the motor must be supplied with extra air cooling. If extra air cooling cannot be provided, a motor designed for low RPM/constant torque applications can be used instead.

#### Variable (quadratic) torque applications

Extra cooling or derating of the motor is not required in variable torque applications where the torque is proportional to the square of the speed, and the power is proportional to the cube of the speed. Centrifugal pumps and fans are common variable torque applications.

### 6.6.3 Derating for Altitude

The cooling capability of air is decreased at lower air pressure. No derating is necessary at or below 1000 m (3281 ft). Above 1000 m (3281 ft), the ambient temperature ( $T_{AMB}$ ) or maximum output current ( $I_{MAX}$ ) should be derated. Refer to [Figure 19](#) which shows that at 41.7 °C (107 °F), 100% of the rated output current is available. At 45 °C (113 °F) ( $T_{AMB, MAX-3K}$ ), 91% of the rated output current is available.

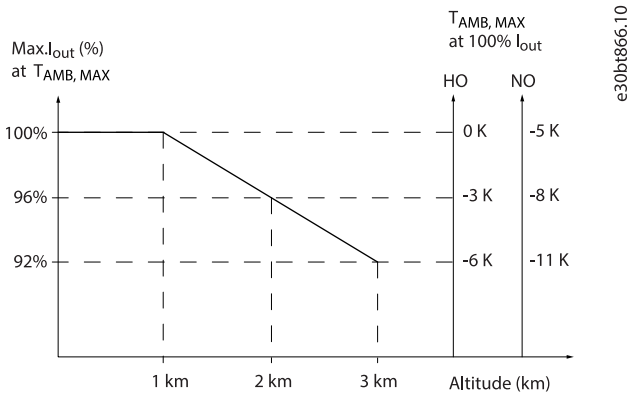


Figure 19: Derating of Output Current Based on Altitude at  $T_{AMB, MAX}$

### 6.6.4 Derating for Ambient Temperature and Switching Frequency

**NOTICE**

**FACTORY DERATING**

Danfoss drives are already derated for operational temperature (55 °C (131 °F)  $T_{AMB, MAX}$  and 50 °C (122 °F)  $T_{AMB, AVG}$ ).

Use the graphs in the following table to determine if the output current must be derated based on switching frequency and ambient temperature. When referring to the graphs,  $I_{out}$  indicates the percentage of rated output current, and  $f_{sw}$  indicates the switching frequency.

Table 7: Derating Tables for Drives Rated 380–480 V

Enclosure size	Switching pattern	High overload HO, 150%	Normal overload NO, 110%
J8-J9	60 AVM	<p>Graph showing <math>I_{out}</math> [%] vs <math>f_{sw}</math> [kHz] for High overload HO, 150%. The y-axis ranges from 60 to 110, and the x-axis from 0 to 9. Three curves are shown for ambient temperatures: 50 °C (122 °F), 55 °C (131 °F), and 55 °C (131 °F). The curves show a constant current until 3 kHz, then a linear decrease.</p>	<p>Graph showing <math>I_{out}</math> [%] vs <math>f_{sw}</math> [kHz] for Normal overload NO, 110%. The y-axis ranges from 50 to 110, and the x-axis from 0 to 9. Three curves are shown for ambient temperatures: 45 °C (113 °F), 50 °C (122 °F), and 55 °C (131 °F). The curves show a constant current until 3 kHz, then a linear decrease.</p>
	SFAVM	<p>Graph showing <math>I_{out}</math> [%] vs <math>f_{sw}</math> [kHz] for High overload HO, 150%. The y-axis ranges from 60 to 110, and the x-axis from 0 to 6. Three curves are shown for ambient temperatures: 45 °C (113 °F), 50 °C (122 °F), and 55 °C (131 °F). The curves show a constant current until 3 kHz, then a linear decrease.</p>	<p>Graph showing <math>I_{out}</math> [%] vs <math>f_{sw}</math> [kHz] for Normal overload NO, 110%. The y-axis ranges from 50 to 110, and the x-axis from 0 to 6. Three curves are shown for ambient temperatures: 40 °C (104 °F), 45 °C (113 °F), 50 °C (122 °F), and 55 °C (131 °F). The curves show a constant current until 3 kHz, then a linear decrease.</p>

## 7 Electrical Installation Considerations

### 7.1 Safety Instructions

See the *chapter Safety* for general safety instructions.

#### WARNING

##### INDUCED VOLTAGE

Induced voltage from output motor cables from different drives that are run together can charge equipment capacitors even with the equipment turned off and locked out. Failure to run output motor cables separately or 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 drive can cause a DC current in the ground conductor and thus result in death or serious injury. Failure to follow the recommendation means that the RCD cannot provide the intended protection.

- When a residual current-operated protective device (RCD) is used for protection against electrical shock, only an RCD of Type B is allowed on the supply side.

### Overcurrent protection

- Extra protective equipment such as short circuit protection or motor thermal protection between drive and motor is 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. See maximum fuse ratings in the *chapter 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.

See the *chapter Cable Lengths and Cross-sections* for recommended wire sizes and types.

#### CAUTION

##### PROPERTY DAMAGE

Protection against motor overload is not included in the default setting. To add this function, set **parameter 1-90 Motor Thermal Protection** to **[ETR trip]** or **[ETR warning]**. For the North American market, the ETR function provides class 20 motor overload protection in accordance with NEC. Failure to set **parameter 1-90 Motor Thermal Protection** to **[ETR trip]** or **[ETR warning]** means that motor overload protection is not provided and, if the motor overheats, property damage can occur.

## 7.2 Wiring Diagram

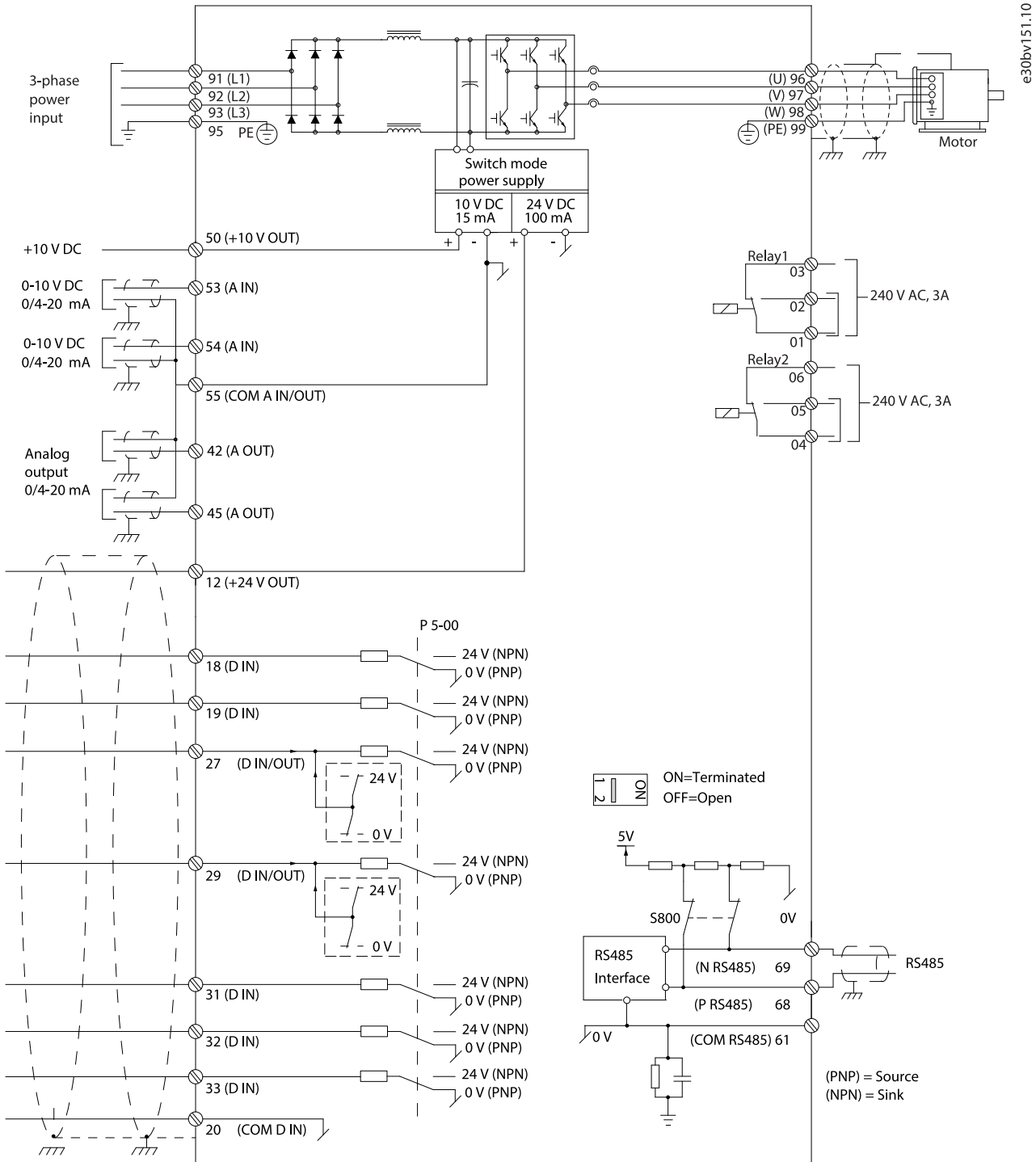


Figure 20: Wiring Diagram

## 7.3 Power Connections

### NOTICE

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

The power cable connections are located as shown in the following illustration. See *chapter Specifications* for correct dimensioning of motor cable cross-section and length.

For protection of the drive, use the recommended fuses unless the unit has built-in fuses. Recommended fuses are listed in [7.5 Fuses and Circuit Breakers](#). Ensure that proper fusing complies with local regulations.

The connection of mains is fitted to the mains switch if included.

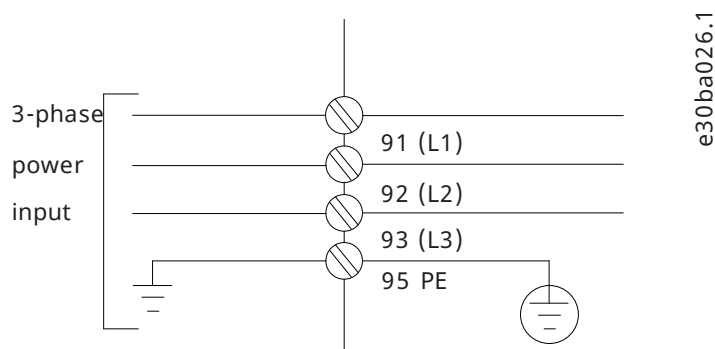


Figure 21: Power Cable Connections

### NOTICE

The motor cable must be shielded/armored. If an unshielded/unarmored cable is used, some EMC requirements are not complied with. Use a shielded/armored motor cable to comply with EMC emission specifications. For more information, see *chapter EMC-compliant Installation*.

### Shielding of cables

Avoid installation with twisted shield ends (pigtailed). They spoil the shielding effect at higher frequencies. If it is necessary to break the shield to install a motor isolator or contactor, continue the shield at the lowest possible HF impedance.

Connect the motor cable shield to both the decoupling plate of the drive and the metal housing of the motor.

Make the shield connections with the largest possible surface area (cable clamp) by using the installation devices within the drive.

### Cable length and cross-section

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

### Switching frequency

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

Table 8: Motor Cable Connection

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

1) Protected ground connection.

### NOTICE

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

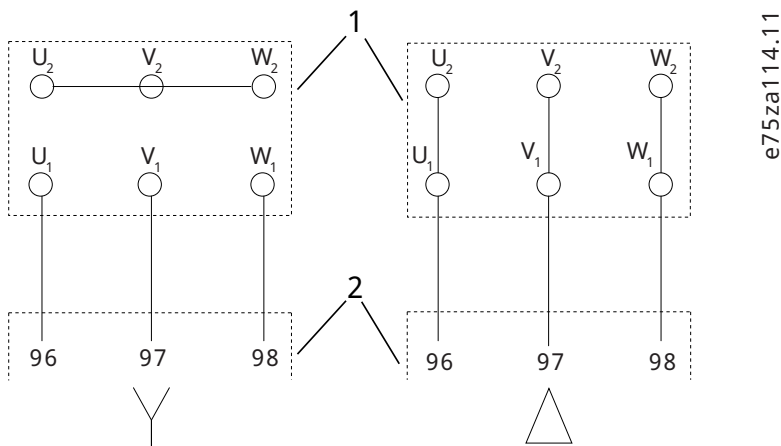


Figure 22: Motor Cable Connection

## 7.4 Control Wiring and Terminals

### 7.4.1 Correct Grounding of Control Cables

Control cables must be shielded and the shield must be connected with a cable clamp at both ends to the metal cabinet of the unit.

For correct grounding of control cables, see [Figure 23](#).

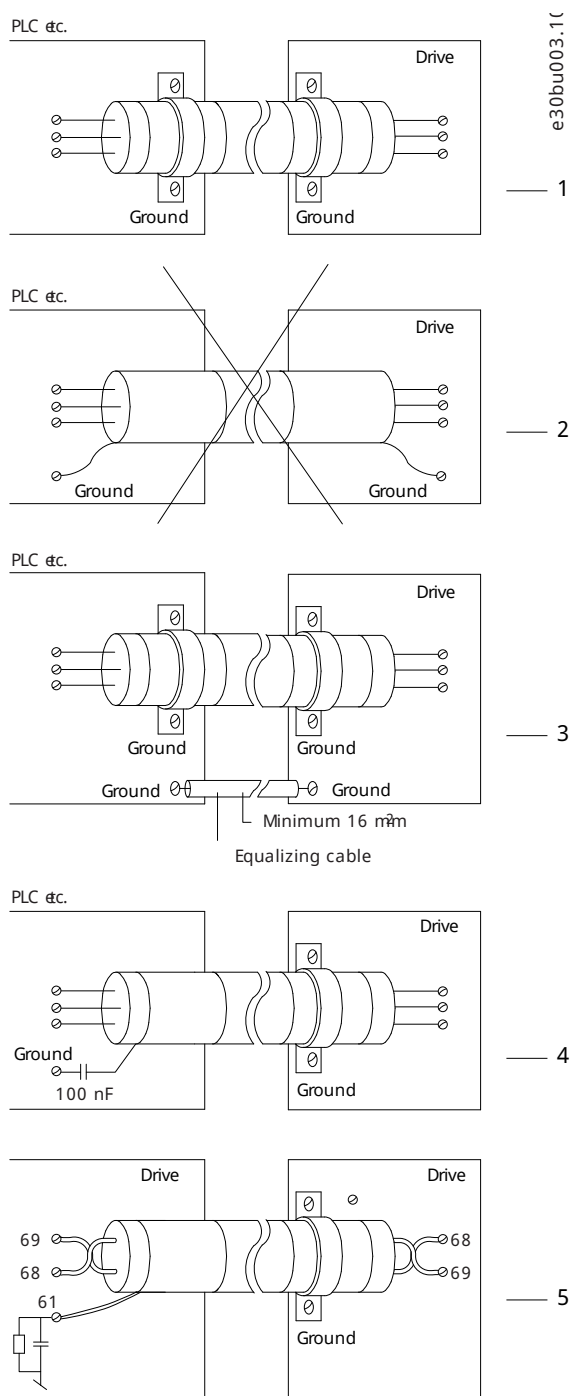


Figure 23: Grounding Examples

- |  |   |
|--|---|
| <p>1 Control cables and serial communication cables must be fitted with cable clamps at both ends to ensure the best possible electrical contact.</p> <p>3 If the ground potential between the drive and the PLC is different, electric noise can occur that disturbs the entire system. Fit an equalizing cable next to the control cable. Minimum cable cross-section: 16 mm<sup>2</sup> (6 AWG).</p> <p>5 When using cables for serial communication, eliminate low-frequency noise currents between 2 drives by connecting 1 end of the shield to terminal 61. This terminal is connected to ground via an internal RC link. Use twisted-pair cables for reducing the differential mode interference between the conductors.</p> | <p>2 Do not use twisted cable ends (pigtailed). They increase the shield impedance at high frequencies.</p> <p>4 If long control cables are used, 50/60 Hz ground loops are possible. Connect 1 end of the shield to ground via a 100 nF capacitor (keeping leads short).</p> |
|--|---|

### 7.4.2 Control Cable Routing

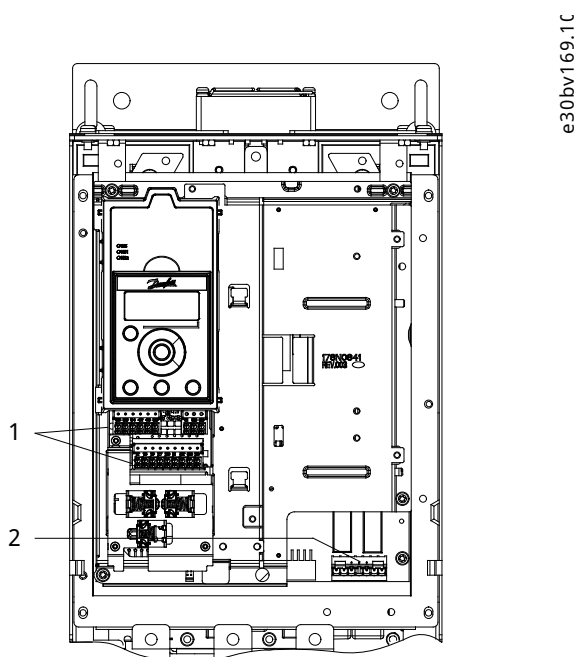
Tie down and route all control wires. Remember to connect the shields in a proper way to ensure optimum electrical immunity.

- Isolate control wiring from high-power cables.
- When the drive is connected to a thermistor, ensure that the thermistor control wiring is shielded and reinforced/double insulated. A 24 V DC supply voltage is recommended.

#### Fieldbus connection

Connections are made to the relevant options on the control card. See the relevant fieldbus instruction. The cable must be tied down and routed along with other control wires inside the unit.

### 7.4.3 Control Terminals



e30bv169.1C

Figure 24: Control Terminal Locations



## 1 Control Terminals

## 2 Relays

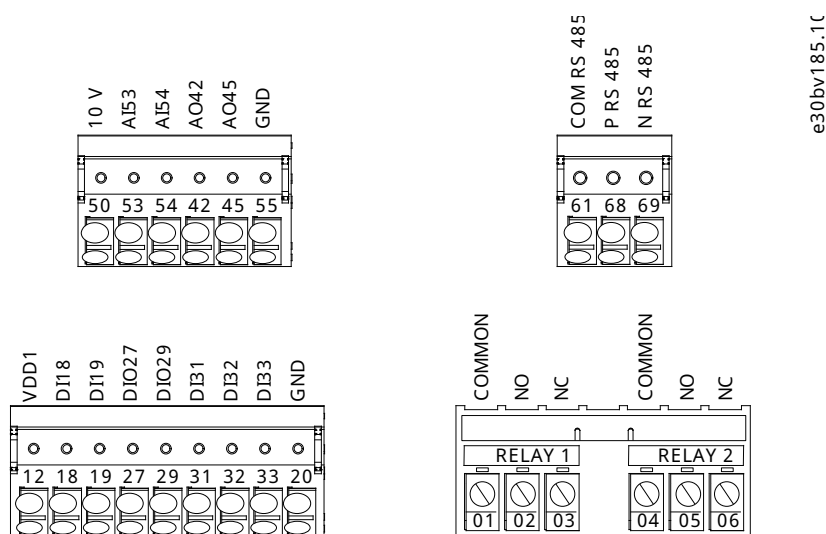


Figure 25: Terminal Numbers Located on the Connectors

Table 9: Terminal Descriptions

Terminal	Parameter	Default setting	Description
<b>Digital I/O, Pulse I/O, Encoder</b>			
12	–	+24 V DC	24 V DC supply voltage. Maximum output current is 100 mA for all 24 V loads.
18	<i>Parameter 5-10 Terminal 18 Digital Input</i>	<i>[8] Start</i>	Digital inputs.
19	<i>Parameter 5-11 Terminal 19 Digital Input</i>	<i>[10] Reversing</i>	
27	<i>Parameter 5-12 Terminal 27 Digital Input</i> <i>Parameter 5-30 Terminal 27 Digital Output</i>	DI <i>[2] Coast inverse</i> DO <i>[0] No operation</i>	
29	<i>Parameter 5-13 Terminal 29 Digital Input</i> <i>Parameter 5-31 Terminal 29 Digital Output</i>	DI <i>[14] Jog</i> DO <i>[0] No operation</i>	Selectable for either digital input, digital output, or pulse output. Default setting is digital input. Terminal 29 can be used for pulse input.
31	<i>Parameter 5-16 Terminal 31 Digital Input</i>	<i>[0] No operation</i>	Digital input.
32	<i>Parameter 5-14 Terminal 32 Digital Input</i>	<i>[0] No operation</i>	Digital input, 24 V encoder. Terminal 33 can be used for pulse input.
33	<i>Parameter 5-15 Terminal 33 Digital Input</i>	<i>[0] No operation</i>	

Table 9: Terminal Descriptions (continued)

Terminal	Parameter	Default setting	Description
20	–	–	Common for digital inputs and 0 V potential for 24 V supply.
<b>Analog inputs/outputs</b>			
50	–	+10 V DC	10 V DC analog supply voltage. 15 mA maximum commonly used for potentiometer or thermistor.
53	<i>Parameter group 6-1* Analog Input 1</i>	Reference	Analog input. Selectable for voltage or current.
54	<i>Parameter group 6-2* Analog Input 2</i>	Feedback	
42	<i>Parameter 6-91 Terminal 42 Analog Output</i>	<i>[0] No operation</i>	Programmable analog output. The analog signal is 0–20 mA or 4–20 mA at a maximum of 500 Ω. Can also be configured as digital outputs.
45	<i>Parameter 6-71 Terminal 45 Analog Output</i>	<i>[0] No operation</i>	
55	–	–	Common for analog input.
<b>Serial communication</b>			
61	–	–	Integrated RC-filter to connect cable shield if there are EMC problems.
68(+)	<i>Parameter group 8-3* FC Port Settings</i>	–	RS485 interface. A switch is provided on the control card for bus termination resistance.
69(-)	<i>Parameter group 8-3* FC Port Settings</i>	–	
<b>Relays</b>			
01, 02, 03	<i>Parameter 5-40 Function Relay [0]</i>	<i>[0] No operation</i>	Form C relay output. For AC or DC voltage and resistive or inductive loads.
04, 05, 06	<i>Parameter 5-40 Function Relay [1]</i>	<i>[0] No operation</i>	

## 7.5 Fuses and Circuit Breakers

Fuses ensure that possible damage to the drive is limited to damages inside the unit. To ensure compliance with EN 50178, use the recommended fuses as replacements. Use of fuses on the supply side is mandatory for IEC 60364 (CE) compliant installations.

Type aR fuses are recommended for enclosures J8–J9.

Table 10: J8–J9 Power/Semiconductor Fuse Sizes

Model	380–480 V
H90K/Q110	ar-315
H110/Q132	ar-350
H132/Q160	ar-400
H160/Q200	ar-500

Table 10: J8–J9 Power/Semiconductor Fuse Sizes (continued)

Model	380–480 V
H200/Q250	ar-630
H250/Q315	ar-800

Table 11: J8–J9 Power/Semiconductor Fuse Options, 380–480 V

Model	Fuse options						
	Bussman	Littelfuse	Littelfuse	Bussman	Siba	Ferraz-Shawmut	Ferraz-Shawmut (Europe)
H90K/Q110	170M2619	LA50QS300-4	L50S-300	FWH-300A	20 189 20.315	A50QS300-4	6,9URD31D08 A0315
H110/Q132	170M2620	LA50QS350-4	L50S-350	FWH-350A	20 189 20.350	A50QS350-4	6,9URD31D08 A0350
H132/Q160	170M2621	LA50QS400-4	L50S-400	FWH-400A	20 189 20.400	A50QS400-4	6,9URD31D08 A0400
H160/Q200	170M4015	LA50QS500-4	L50S-500	FWH-500A	20 189 20.550	A50QS500-4	6,9URD31D08 A0550
H200/Q250	170M4016	LA50QS600-4	L50S-600	FWH-600A	20 189 20.630	A50QS600-4	6,9URD31D08 A0630
H250/Q315	170M4017	LA50QS800-4	L50S-800	FWH-800A	20 189 20.800	A50QS800-4	6,9URD31D08 A0800

Table 12: J8–J9 Space Heater Fuse Recommendation

Bussmann	Rating
LPJ-21/2SP	2.5 A, 600 V

## NOTICE

### DISCONNECT SWITCH

All units ordered and supplied with a factory-installed disconnect switch require Class L branch circuit fusing to meet the 100 kA SCCR for the drive. If a circuit breaker is used, the SCCR rating is 42 kA. The input voltage and power rating of the drive determine the specific Class L fuse. The input voltage and power rating are found on the product nameplate.

## 7.6 Motor

### 7.6.1 Motor Rotation

Any 3-phase asynchronous standard motor can be used with a drive.

Table 13: Motor Cable Terminals Providing Clockwise Rotation (Factory Default)

Terminal	Function
96	U/T1
97	V/T2
98	W/T3
99	Ground

The direction of rotation can be changed by switching 2 phases in the motor cable, or by changing the setting of *parameter 4-10 Motor Speed Direction*.

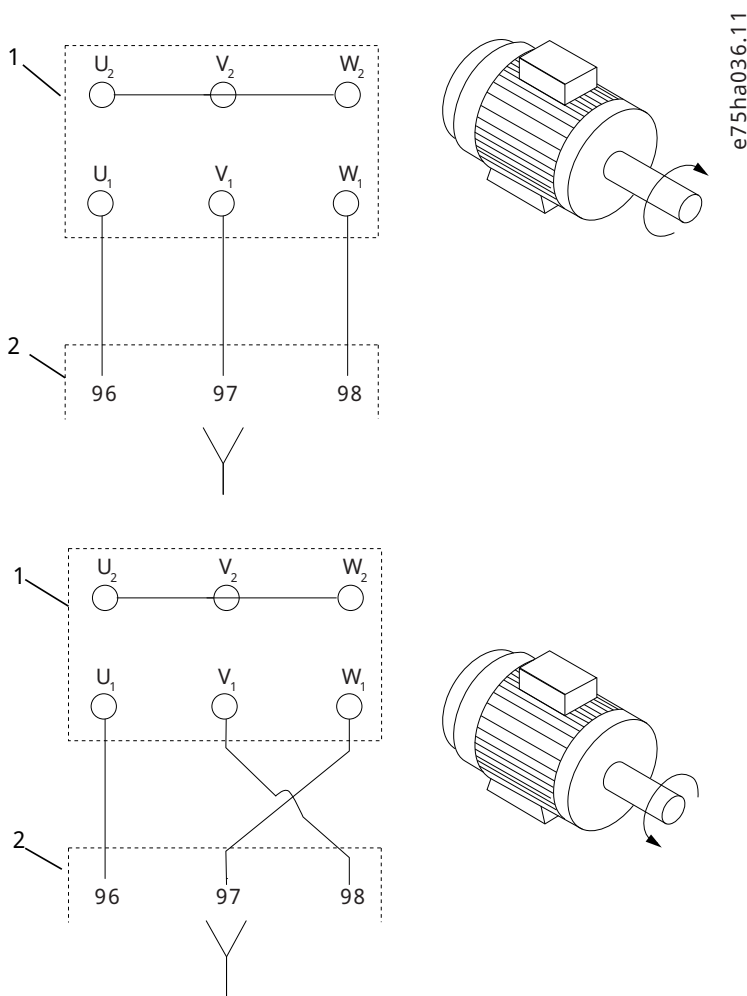


Figure 26: Changing Motor Rotation

### 7.6.2 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).

### 7.6.3 Parallel Connection of Motors

The drive can control several parallel-connected motors. For different configurations of parallel-connected motors, see [Figure 27](#).

When using parallel motor connection, observe the following points:

- Run applications with parallel motors in U/F mode (volts per hertz).
- VVC+ mode can be used in some applications.
- Total current consumption of motors must not exceed the rated output current IINV for the drive.
- Problems can occur at start and at low RPM if motor sizes are widely different because the relatively high ohmic resistance in the stator of a small motor demands a higher voltage at start and at low RPM.
- The electronic thermal relay (ETR) of the drive cannot be used as motor overload protection. Provide further motor overload protection by including thermistors in each motor winding or individual thermal relays.
- Recommended to run applications with parallel motors in U/F mode **parameter 1-01 Motor Control Principle[0] Asynchron**. Set the U/F graph in **parameter 1-55 U/f Characteristic - U** and **parameter 1-56 U/f Characteristic - F**.

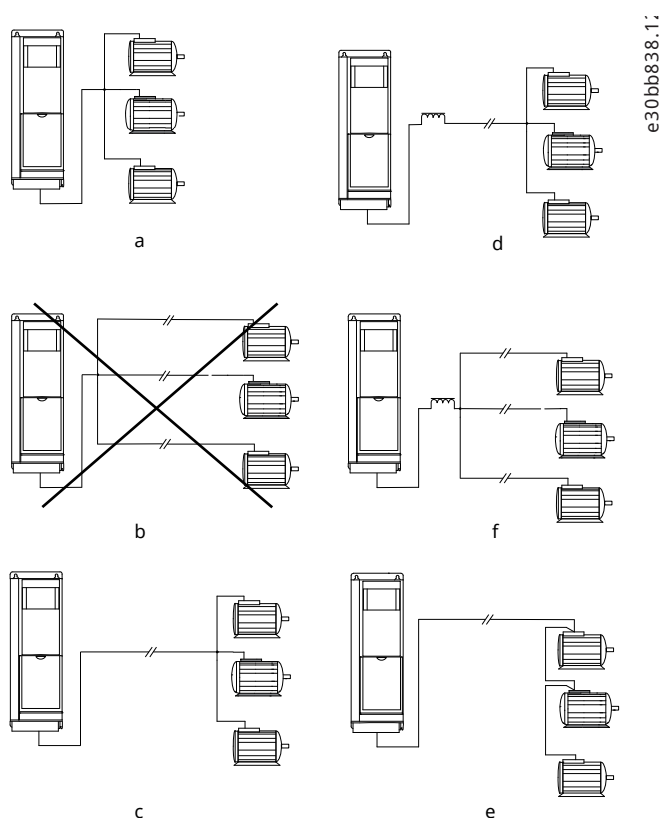


Figure 27: Different Parallel Connections of Motors

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

## 7.6.4 Motor Insulation

For motor cable lengths that are less than or equal to the maximum cable length listed in *chapter Cable Lengths and Cross-sections*, use the motor insulation ratings shown in the following table. If a motor has lower insulation rating, Danfoss recommends using a dU/dt or sine-wave filter.

**Table 14: Motor Insulation Ratings**

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

## 7.6.5 Motor Bearing Currents

To eliminate circulating bearing currents in all motors installed with the drive, install NDE (non-drive end) insulated bearings. To minimize DE (drive end) bearing and shaft currents, ensure proper grounding of the drive, motor, driven machine, and motor to the driven machine.

Standard mitigation strategies:

- Use an insulated bearing.
- Follow proper installation procedures.
  - Ensure that the motor and load motor are aligned.
  - 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. Use a shielded cable that has a 360° connection in the motor and the drive.
  - Ensure that the impedance from the drive to building ground is lower than the grounding impedance of the machine. This procedure 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 mains voltage is balanced to ground. This procedure can be difficult for IT, TT, TN-CS, or grounded leg systems.
- Use a dU/dt or sine-wave filter.

## 7.7 Residual Current Devices (RCD) and Insulation Resistance Monitor (IRM)

Use RCD relays, multiple protective earthing, or grounding as extra protection, provided they comply with local safety regulations.

If a ground fault appears, a DC current can 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. See *chapter Leakage Current* for more details.

## 7.8 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 high frequency switching 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.

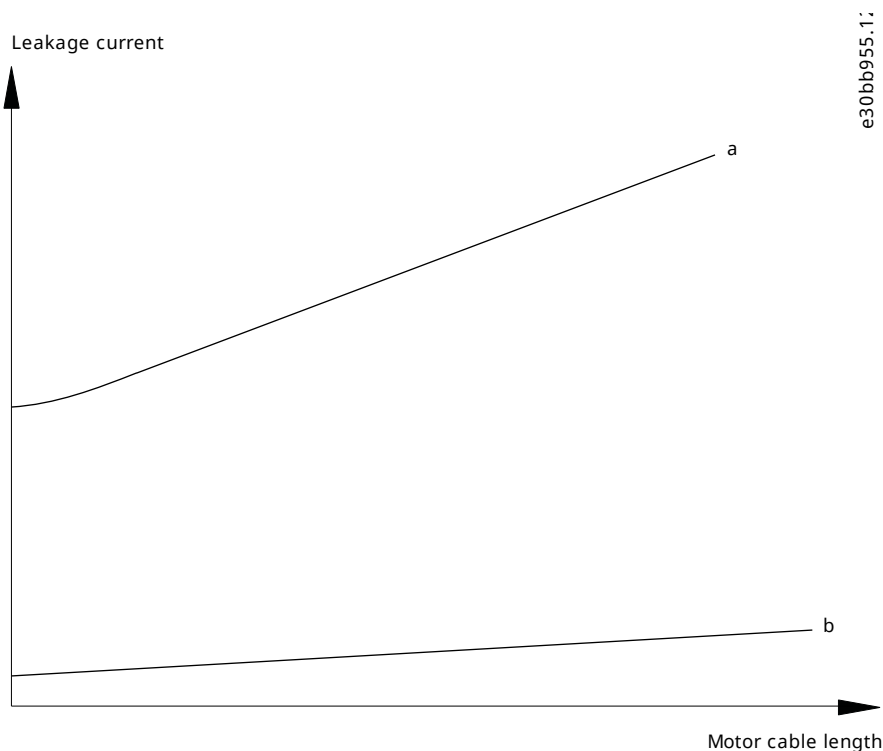


Figure 28: Motor Cable Length and Power Size Influence the Leakage Current. Power Size a > Power Size b.

The leakage current also depends on the line distortion.

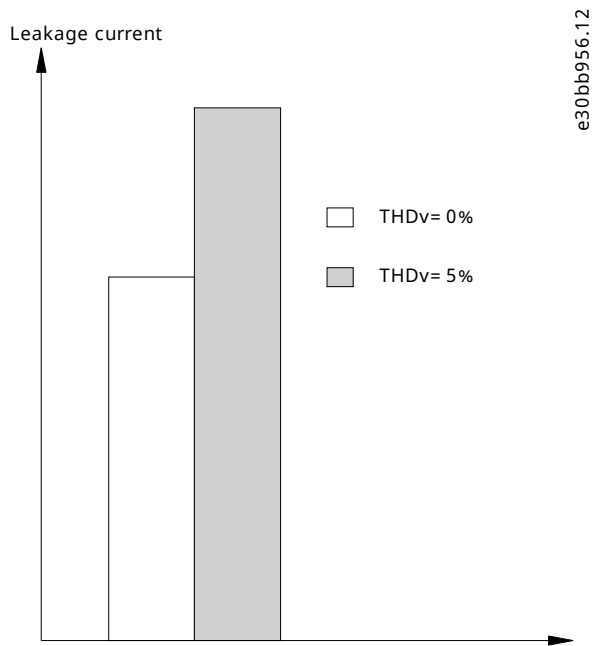


Figure 29: Line Distortion Influences Leakage Current

If the leakage current exceeds 3.5 mA, compliance with EN/IEC61800-5-1 (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<sup>2</sup> (8 AWG) cross-section.
- 2 separate ground wires both complying with the dimensioning rules.

See EN/IEC61800-5-1 and EN 50178 for further information.

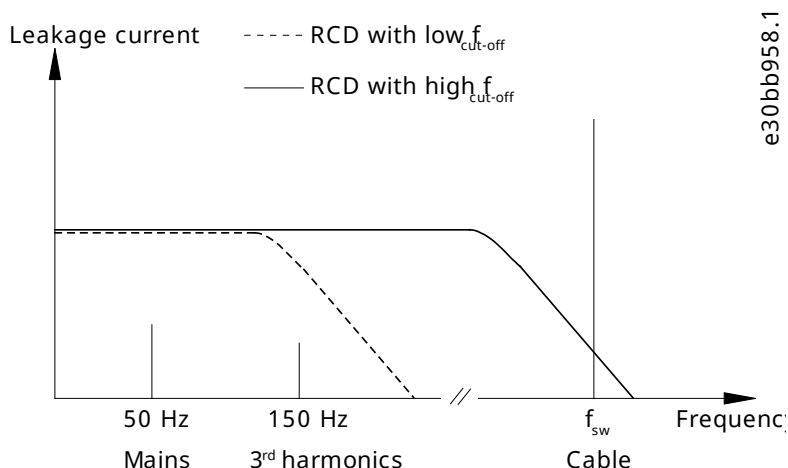
### Using RCDs

Where residual current devices (RCDs), also known as Ground Leakage Circuit Breakers, are used, comply with the following:

- Use RCDs of type B only as they can detect AC and DC currents.
- Use RCDs with a delay to prevent faults due to 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.

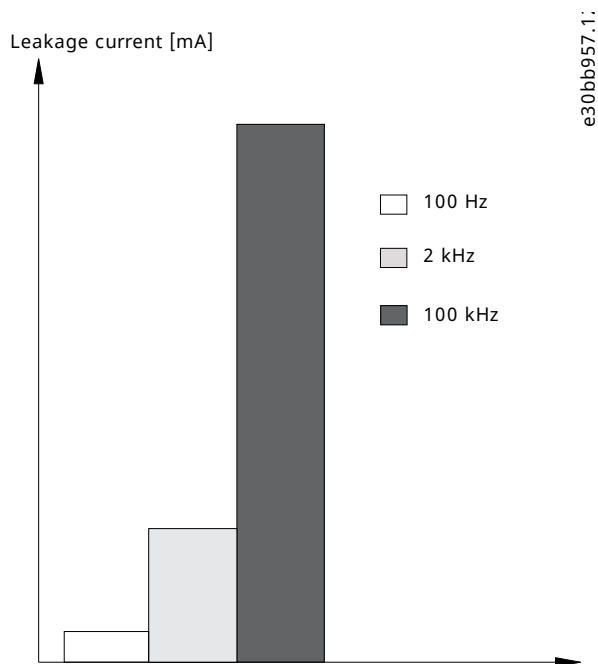




e30bb958.1

Figure 30: Main Contributions to Leakage Current

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



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Figure 31: Influence of the RCD Cut-off Frequency on Leakage Current

## 7.9 IT Mains

### Mains supplies isolated from ground

If the drive is supplied from an isolated mains source (IT mains, floating delta, or grounded delta) or TT/TN-S mains with grounded leg, the RFI switch is recommended to be turned off via **parameter 14-50 RFI Filter** on the drive and **parameter 14-50 RFI Filter** on the filter. For more detail, see IEC 364-3. In the off position, the filter capacitors between the chassis and the DC link are cut off to avoid damage to the DC link and to reduce the ground capacity currents, according to IEC 61800-3.

If optimum EMC performance is needed, or parallel motors are connected, or the motor cable length is above 25 m (82 ft), Danfoss recommends setting **parameter 14-50 RFI Filter** to [1] ON. Refer also to the Application Note, VLT on IT mains. It is important to use isolation monitors that are rated for use together with power electronics (IEC 61557-8).

## 7.10 Efficiency

### Efficiency of the drive ( $\eta_{VLT}$ )

The load on the drive has little effect on its efficiency. In general, the efficiency is the same at the rated motor frequency  $f_{M,N}$ , whether the motor supplies 100% of the rated shaft torque or only 75%, if there is part loads.

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 slightly when the switching frequency is set to a value of above 5 kHz. The efficiency is slightly reduced when 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 illustration. The factor in this graph must be multiplied by the specific efficiency factor listed in the specification tables in *chapter Electrical Data*.

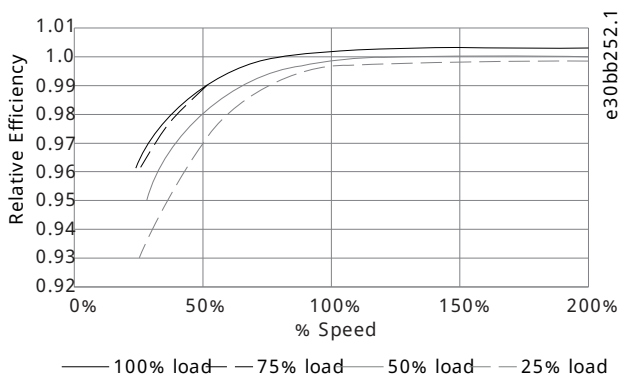


Figure 32: Typical Efficiency Curves

Example: Assume a 160 kW, 380–480/500 V AC drive at 25% load at 50% speed. The above illustration shows 0.97 - rated efficiency for a 160 kW drive is 0.98. The actual efficiency is then:  $0.97 \times 0.98 = 0.95$ .

### Efficiency of the motor ( $\eta_{MOTOR}$ )

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, both when the drive controls it and when it runs directly on the mains.

In small motors, the influence from the U/f characteristic on efficiency is marginal. However, in motors from 11 kW (15 hp) and up, the advantages are significant.

Typically the switching frequency does not affect the efficiency of small motors. Motors from 11 kW (15 hp) and up have their efficiency improved (1–2%) because the shape of the motor current sine-wave is almost perfect at high switching frequency.

### Efficiency of the system ( $\eta_{SYSTEM}$ )

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

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

## 7.11 Acoustic Noise

The acoustic noise from the drive comes from 3 sources:

- DC intermediate circuit coils.
- Internal fans.
- RFI filter choke.

The following table lists the typical acoustic noise values measured at a distance of 1 m (3.3 ft) from the unit.

Table 15: Acoustic Noise

Enclosure size	dBA at full fan speed
J8	73
J9	75

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

## 7.12 dU/dt Conditions

### NOTICE

To avoid the premature aging of motors that are not designed to be used with drives, such as those motors without phase insulation paper or other insulation reinforcement, Danfoss strongly recommends a dU/dt filter or a sine-wave filter fitted on the output of the drive. For further information about dU/dt and sine-wave filters, see the *Output Filters Design Guide*.

When a transistor in the inverter bridge switches, the voltage across the motor increases by a dU/dt ratio depending on the motor cable (type, cross-section, length shielded or unshielded) and the inductance.

The natural induction causes an overshoot  $U_{PEAK}$  in the motor voltage before it stabilizes itself at a level depending on the voltage in the DC link. The rise time and the peak voltage  $U_{PEAK}$  affect the service life of the motor. In particular, motors without phase coil insulation are affected if the peak voltage is too high. Motor cable length affects the rise time and peak voltage. If the motor cable is short (a few meters), the rise time and peak voltage are lower. If the motor cable is long (100 m (328 ft)), the rise time and peak voltage are higher.

Peak voltage on the motor terminals is caused by the switching of the IGBTs. The drive complies with the demands of IEC 60034-25:2007 edition 2.0 regarding motors designed to be controlled by drives. The drive also complies with IEC 60034-17:2006 edition 4 regarding Norm motors controlled by drives.

### High-power range

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

Table 16: IEC dU/dt Test Results for J8–J9 with Unshielded Cables and No Output Filter, 380–480 V

Power size [kW (hp)]	Cable [m (ft)]	Mains voltage [V]	Rise time [ $\mu$ s]	Peak voltage [V]	dU/dt [V/ $\mu$ s]
90–160 (125–250)	30 (98)	500	0.71	1180	1339
	150 (492)	500	0.76	1423	1497
	300 (984)	500	0.91	1557	1370
200–315 (300–450)	30 (98)	500	1.10	1116	815
	150 (492)	500	2.53	1028	321
	300 (984)	500	1.29	835	517

Table 17: IEC dU/dt Test Results for J8–J9 with Shielded Cables and No Output Filter, 380–480 V

Power size [kW (hp)]	Cable [m (ft)]	Mains voltage [V]	Rise time [ $\mu$ s]	Peak voltage [V]	dU/dt [V/ $\mu$ s]
90–160 (125–250)	30 (98)	500	–	–	–
	150 (492)	500	0.66	1418	1725
	300 (984)	500	0.96	1530	1277
200–315 (300–450)	30 (98)	500	–	–	–
	150 (492)	500	0.56	1261	1820
	300 (984)	500	0.78	1278	1295

## 7.13 Electromagnetic Compatibility (EMC)

### 7.13.1 Overview

Electrical devices both generate interference and are affected by interference from other generated sources. The electromagnetic compatibility (EMC) of these effects depends on the power and the harmonic characteristics of the devices.

Uncontrolled interaction between electrical devices in a system can degrade compatibility and impair reliable operation. Interference takes the form of the following:

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

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

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

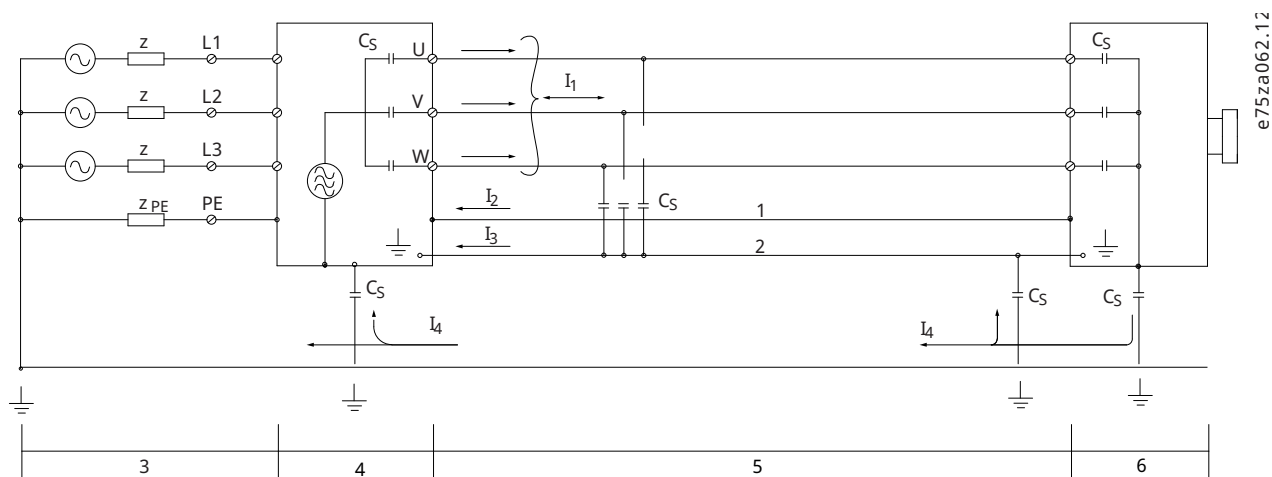


Figure 33: Electric Model Showing Possible Leakage Currents

1	Ground wire	2	Shield
3	AC mains supply	4	Drive
5	Shielded motor cable	6	Motor
Cs	Possible shunt parasitic capacitance paths (varies with different installations).	I <sub>1</sub>	Common-mode leakage current
I <sub>2</sub>	Shielded motor cable	I <sub>3</sub>	Safety ground (4th conductor in motor cables)
I <sub>4</sub>	Unintended common-mode current		

### 7.13.2 EMC Test Results

The following test results have been obtained using a drive (with options if relevant), a shielded control cable, a control box with potentiometer, a motor, and motor shielded cable.

Table 18: EMC Test Results (Emission)

RFI filter type		Conducted emission			Radiated emission		
		Class B Housing, trades, and light indus- tries	Class A group 1 Industrial en- vironment	Class A group 2 Industrial en- vironment	Class B Housing, trades, and light indus- tries	Class A group 1 Industrial en- vironment	Class A group 2 Industrial en- vironment
Standards and require- ments	EN 55011	Class B Housing, trades, and light indus- tries	Class A group 1 Industrial en- vironment	Class A group 2 Industrial en- vironment	Class B Housing, trades, and light indus- tries	Class A group 1 Industrial en- vironment	Class A group 2 Industrial en- vironment
	EN/IEC 61800-3	Category C1 Residential, commercial, or light indus- trial	Category C2 Commercial, or light indus- trial	Category C3 Industrial	Category C1 Residential, commercial, or light indus- trial	Category C2 Commercial, or light indus- trial	Category C3 Industrial
FC 360	90–315 kW 380–480 V	No	No	150 m (492 ft)	No	No	Yes

### 7.13.3 Emission Requirements

According to the EMC product standard for adjustable speed drives EN/IEC 61800-3, the EMC requirements depend on the environment in which the drive is installed. These environments along with the mains voltage supply requirements are defined in the following table.

The drives comply with EMC requirements described in IEC/EN 61800-3, category C3, for equipment having greater than 100 A per-phase current draw, installed in the 2nd environment. Compliance testing is performed with a 150 m (492 ft) shielded motor cable.

Table 19: Emission Requirements

Category (EN 61800-3)	Definition	Conducted emission (EN 55011)
C1	EUT of rated input voltage less than 1000 V, intended for use in a residential, commercial, or light industrial location.	Class B
C2	EUT of rated input voltage less than 1000 V, which is not a plug-in device or a movable device and not intended for use in a residential location.	Class A Group 1
C3	EUT of rated input voltage less than 1000 V, intended for use in an industrial location and not intended for use in a residential, commercial, or light industrial location.	Class A Group 2
C4	EUT of rated input voltage equal to or above 1000 V, or rated current equal to or above 400 A, or intended for use in complex systems in an industrial location. An EMC plan must be made.	–

The drives do not comply with generic emission standards. Extra methods, such as external filter, should be used for complying with generic emission standards.

Table 20: Generic Emission Standard Limits

Environment	Generic standard	Conducted emission requirement according to EN 55011 limits
First environment (home and office)	EN/IEC 61000-6-3 Emission standard for residential, commercial, and light industrial environments.	Class B
Second environment (industrial environment)	EN/IEC 61000-6-4 Emission standard for industrial environments.	Class A group 1

### 7.13.4 Immunity Requirements

The immunity requirements for drives depend on the installation environment. The requirements for the industrial environment are higher than the requirements for the home and office environment. All Danfoss drives comply with the requirements for both the industrial and the home/office environment.

To document immunity against burst transient, the following immunity tests have been performed on a drive (with options if relevant), a shielded control cable, and a control box with potentiometer, motor cable, and motor. The tests were performed in accordance with the following basic standards. For more details, see the following table.

- 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): Incoming electromagnetic field radiation, amplitude modulated simulation of the effects of radar, 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 lightning 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.

Table 21: EMC Immunity Form, Voltage Range: 380–480

Basic standard	Burst IEC 61000-4-4	Surge IEC 61000-4-5	ESD IEC 61000-4-2	Radiated electromagnetic field IEC 61000-4-3	RF common-mode voltage IEC 61000-4-6
Acceptance criterion	B	B	B	A	A
Line	4 kV CM	2 kV/2 Ω DM 4 kV/12 Ω CM	–	–	10 V <sub>RMS</sub>
Motor	4 kV CM	4 kV/2 Ω <sup>(1)</sup>	–	–	10 V <sub>RMS</sub>
Control wires	2 kV CM	2 kV/2 Ω <sup>(1)</sup>	–	–	10 V <sub>RMS</sub>
Standard bus	2 kV CM	2 kV/2 Ω <sup>(1)</sup>	–	–	10 V <sub>RMS</sub>
Relay wires	2 kV CM	2 kV/2 Ω <sup>(1)</sup>	–	–	10 V <sub>RMS</sub>
Application/field-bus options	2 kV CM	2 kV/2 Ω <sup>(1)</sup>	–	–	10 V <sub>RMS</sub>
LCP cable	2 kV CM	2 kV/2 Ω <sup>(1)</sup>	–	–	10 V <sub>RMS</sub>
External 24 V DC	2 kV CM	0.5 kV/2 Ω DM 1 kV/12 Ω CM	–	–	10 V <sub>RMS</sub>
Enclosure	–	–	8 kV AD 4 kV CD	10 V/m	–

1) Injection on cable shield.

AD: air discharge; CD: contact discharge; CM: common-mode; DM: differential mode.

### 7.13.5 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.

#### NOTICE

##### RADIO INTERFERENCE

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 drives control and relay terminals comply with PELV (excluding grounded Delta leg above 400 V).

Galvanic (ensured) isolation is obtained by fulfilling requirements for higher isolation and by providing the relevant creepage/clearance distances. These requirements are described in the EN 61800–5–1 standard.

Electrical isolation is provided as shown (see the following illustration). The components described comply with both PELV and the galvanic isolation requirements.

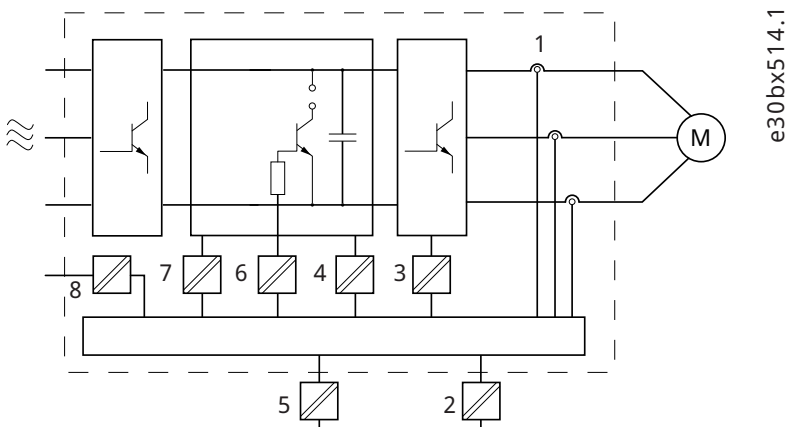


Figure 34: Galvanic Isolation

1	Current transducers	2	Galvanic isolation for the RS485 standard bus interface
3	Gate drive for the IGBTs	4	Supply (SMPS) including signal isolation of V DC, indicating the intermediate current voltage
5	Galvanic isolation for the 24 V backup option	6	Opto-coupler, brake module (optional)
7	Internal inrush, RFI, and temperature measurement circuits	8	Customer relays

### 7.13.6 EMC-compliant Installation

To obtain an EMC-compliant installation, follow the instructions provided in the operating guide. For an example of proper EMC installation, see the following illustration.



**NOTICE****TWISTED SHIELD ENDS (PIGTAILS)**

Twisted shield ends increase the shield impedance at higher frequencies, which reduces the shield effect and increases the leakage current. Avoid twisted shield ends by using integrated shield clamps.

- For use with relays, control cables, a signal interface, fieldbus, or brake, connect the shield to the enclosure at both ends. If the ground path has high impedance, is noisy, or is carrying current, break the shield connection on 1 end to avoid ground current loops.
- Convey the currents back to the unit using a metal mounting plate. Ensure good electrical contact from the mounting plate through the mounting screws to the drive chassis.
- Use shielded cables for motor output cables. An alternative is unshielded motor cables within metal conduit.

**NOTICE****SHIELDED CABLES**

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

- Ensure that motor and brake cables are as short as possible to reduce the interference level from the entire system.
- Avoid placing cables with a sensitive signal level alongside motor and brake cables.
- For communication and command/control lines, follow the particular communication protocol standards. For example, USB must use shielded cables, but RS485/ethernet can use shielded UTP or unshielded UTP cables.
- Ensure that all control terminal connections are PELV.

**NOTICE****EMC INTERFERENCE**

Use shielded cables for motor and control wiring. Make sure to separate mains input, motor, and control cables from one another. Failure to isolate these cables can result in unintended behavior or reduced performance. Minimum 200 mm (7.9 in) clearance between mains input, motor, and control cables are required.

**NOTICE****INSTALLATION AT HIGH ALTITUDE**

There is a risk of overvoltage. Isolation between components and critical parts could be insufficient and not comply with PELV requirements. Reduce the risk of overvoltage by using external protective devices or galvanic isolation.

- For installations above 2000 m (6500 ft) altitude, contact Danfoss regarding PELV compliance.

**NOTICE****PELV COMPLIANCE**

Prevent electric shock by using protective extra low voltage (PELV) electrical supply and complying with local and national PELV regulations.

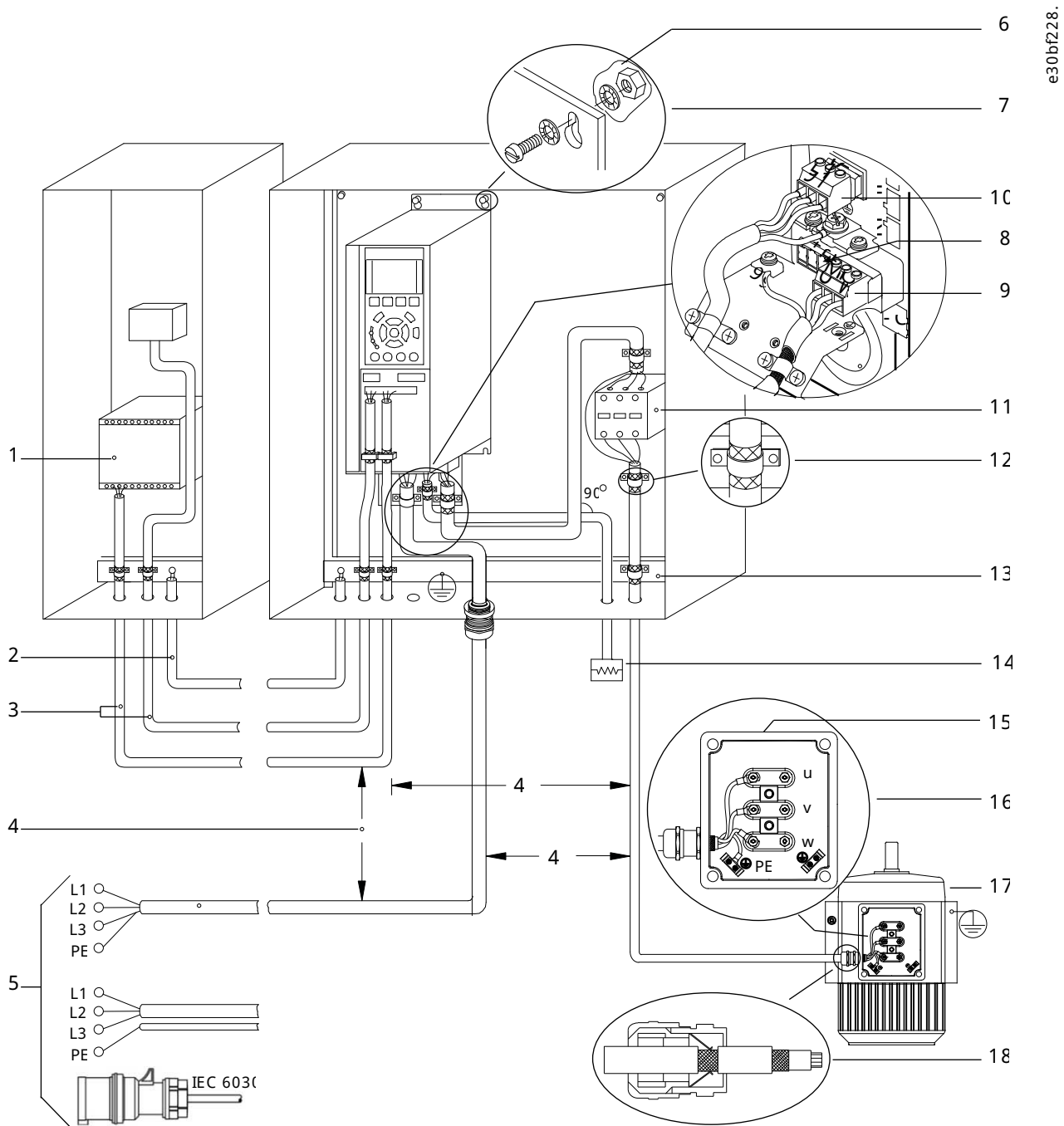


Figure 35: Example of Proper EMC Installation

1	PLC	2	Minimum 16 mm <sup>2</sup> (6 AWG) equalizing cable
3	Control cables	4	Minimum 200 mm (7.9 in) between control cables, motor cables, and mains cables.
5	Mains supply	6	Bare (unpainted) surface
7	Star washers	8	Brake cable (shielded)
9	Motor cable (shielded)	10	Main cable (shielded)
11	Output contactor	12	Cable insulation stripped

13	Common ground busbar. Follow local and national requirements for cabinet grounding.	14	Brake resistor
15	Metal box	16	Connection to motor
17	Motor	18	EMC cable gland

## 7.14 Harmonics

### 7.14.1 Harmonics Overview

Non-linear loads such as those found with 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 wiring and transformers that can affect other devices on the same power line.

### 7.14.2 Harmonic Analysis

Since harmonics increase heat losses, it is important to design systems with harmonics in mind to prevent overloading the transformer, inductors, and 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-wave currents at different frequencies, that is, different harmonic currents  $I_n$  with 50 Hz or 60 Hz as the basic frequency.

Table 22: 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 $n^{\text{th}}$ harmonic frequency.
$U_n$	Voltage at the $n^{\text{th}}$ harmonic frequency.
$n$	Harmonic order.

Table 23: Basic Currents and Harmonic Currents

	Basic current ( $I_1$ )	Harmonic current ( $I_n$ )		
Current	$I_1$	$I_5$	$I_7$	$I_{11}$
Frequency	50 Hz	250 Hz	350 Hz	550 Hz

Table 24: Harmonic Currents vs. RMS Input Current

Current	Harmonic current				
	$I_{\text{RMS}}$	$I_1$	$I_5$	$I_7$	$I_{11-49}$
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:

$$THDi = \frac{\sqrt{U_{25} + U_{27} + \dots + U_{2n}}}{U}$$

### 7.14.3 Effect of Harmonics in a Power Distribution System

In the following illustration, a transformer is connected on the primary side to a point of common coupling PCC1, on the medium voltage supply. The transformer has an impedance  $Z_{xfr}$  and feeds several loads. The point of common coupling where all loads are connected is PCC2. Each load connects through cables that have an impedance  $Z_1, Z_2, Z_3$ .

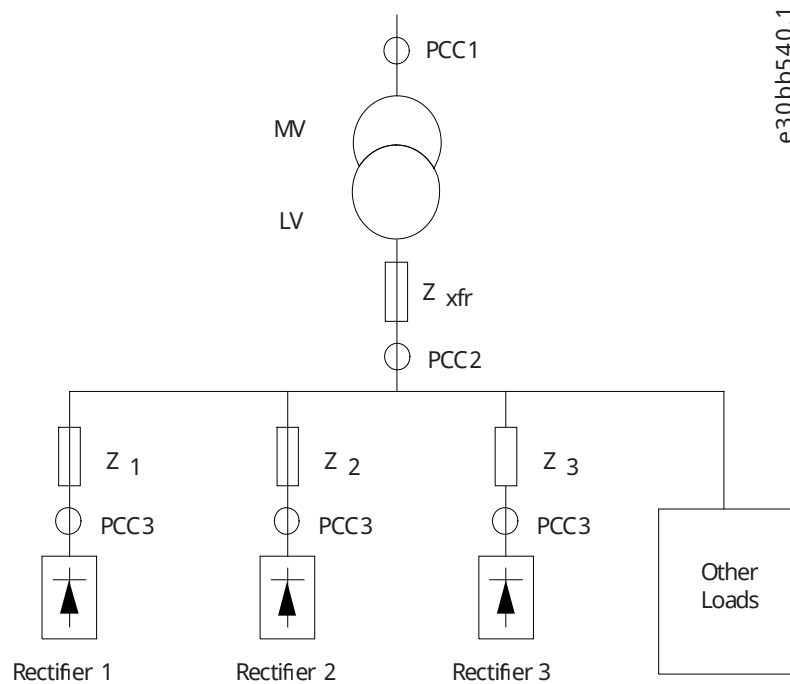


Figure 36: Small Distribution System

PCC	Point of common coupling	MV	Medium voltage
LV	Low voltage	$Z_{xfr}$	Transformer impedance
$Z_{\#}$	Modeling resistance and inductance in the wiring		

Harmonic currents drawn by non-linear loads cause distortion of the voltage because of the voltage drop on the impedances of the distribution system. Higher impedances result in higher levels of voltage distortion.

Current distortion relates to apparatus performance and it relates to the individual load. Voltage distortion relates to system performance. It is not possible to determine the voltage distortion in the PCC knowing only the harmonic performance of the load. To predict the distortion in the PCC, the configuration of the distribution system and relevant impedances must be known.

A commonly used term for describing the impedance of a grid is the short circuit ratio  $R_{sce}$ , where  $R_{sce}$  is defined as the ratio between the short circuit apparent power of the supply at the PCC ( $S_{sc}$ ) and the rated apparent power of the load.

$$(S_{equ})R_{sce} = \frac{S_{sc}}{S_{equ}}$$

where  $S_{sc} = \frac{U^2}{Z_{supply}}$  and  $S_{equ} = U \times I_{equ}$ .

#### Negative effects of harmonics

- Harmonic currents contribute to system losses (in cabling and transformer).

- Harmonic voltage distortion causes disturbance to other loads and increases losses in other loads.

#### 7.14.4 IEC Harmonic Standards

In most of Europe, the basis for the objective assessment of the quality of mains power is the Electromagnetic Compatibility of Devices Act (EMVG). Compliance with these regulations ensures that all devices and networks connected to electrical distribution systems fulfill their intended purpose without generating problems.

**Table 25: EN Design Standards for Mains Power Quality**

Standard	Definition
EN 61000-2-2, EN 61000-2-4, EN 50160	Define the mains voltage limits required for public and industrial power grids.
EN 61000-3-2, EN 61000-3-12	Regulate mains interference generated by connected devices in lower current products.
EN 50178	Monitors electronic equipment for use in power installations.

There are 2 European standards that address harmonics in the frequency range from 0 Hz to 9 kHz:

##### **EN 61000–2–2 (Compatibility Levels for Low-Frequency Conducted Disturbances and Signaling in Public Low-Voltage Power Supply Systems)**

The EN 61000–2–2 standard states the requirements for compatibility levels for PCC (point of common coupling) of low-voltage AC systems on a public supply network. Limits are specified only for harmonic voltage and total harmonic distortion of the voltage. EN 61000–2–2 does not define limits for harmonic currents. In situations where the total harmonic distortion  $THD(V)=8\%$ , PCC limits are identical to those limits specified in the EN 61000–2–4 Class 2.

##### **EN 61000–2–4 (Compatibility Levels for Low-Frequency Conducted Disturbances and Signaling in Industrial Plants)**

The EN 61000–2–4 standard states the requirements for compatibility levels in industrial and private networks. The standard further defines the following 3 classes of electromagnetic environments:

- Class 1 relates to compatibility levels that are less than the public supply network, which affects equipment sensitive to disturbances (lab equipment, some automation equipment, and certain protection devices).
- Class 2 relates to compatibility levels that are equal to the public supply network. The class applies to PCCs on the public supply network and to IPCs (internal points of coupling) on industrial or other private supply networks. Any equipment designed for operation on a public supply network is allowed in this class.
- Class 3 relates to compatibility levels greater than the public supply network. This class applies only to IPCs in industrial environments. Use this class where the following equipment is found:
  - Large drives.
  - Welding machines.
  - Large motors starting frequently.
  - Loads that change quickly.

Typically, a class cannot be defined ahead of time without considering the intended equipment and processes to be used in the environment. Drives observe the limits of Class 3 under typical supply system conditions ( $R_{SC}>10$  or  $V_{k\text{ Line}}<10\%$ ).

Table 26: Compatibility Levels for Harmonics

Harmonic order (h)	Class 1 (V <sub>n</sub> %)	Class 2 (V <sub>n</sub> %)	Class 3 (V <sub>n</sub> %)
5	3	6	8
7	3	5	7
11	3	3.5	5
13	3	3	4.5
17	2	2	4
17 ≤ h ≤ 49	2.27 x (17/h) – 0.27	2.27 x (17/h) – 0.27	4.5 x (17/h) – 0.5

Table 27: Compatibility Levels for the Total Harmonic Voltage Distortion THDv

	Class 1	Class 2	Class 3
THDv	5%	8%	10%

### 7.14.5 Harmonic Compliance

Danfoss drives comply with the following standards:

- IEC61000-2-4.
- IEC61000-3-4.
- G5/4.

## 8 Basic Operating Principles of a Drive

### 8.1 Introduction

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

### 8.2 Description of Operation

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 the following 4 main areas:

#### Rectifier

The rectifier consists of SCRs or diodes that convert 3-phase AC voltage to pulsating DC voltage.

#### DC link (DC bus)

The DC link consists of inductors and capacitor banks that stabilize the pulsating DC voltage.

#### Inverter

The inverter uses IGBTs to convert the DC voltage to variable voltage and variable frequency AC.

#### Control

The control area consists of software that runs the hardware to produce the variable voltage that controls and regulates the AC motor.

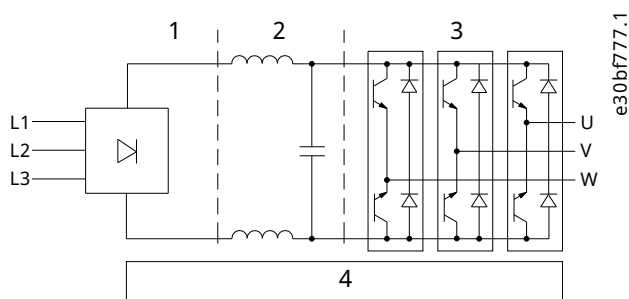


Figure 37: Internal Processing

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

### 8.3 Drive Controls

#### 8.3.1 Overview of Drive Controls

The following processes are used to control and regulate the motor:

- Reference handling.
- Feedback handling.
- User-defined control structure.
  - Open-loop/closed-loop mode.

- Motor control (speed, torque, or process).
- Control algorithms (VVC+, Flux Sensorless, and flux with motor feedback).

## 8.3.2 Reference Handling

### 8.3.2.1 Local and Remote Reference

#### Local reference

The local reference is active when the drive is operated with *[Hand On]* active. Adjust the reference via the *Up* key, *Down* key, *Right* key and the *[Back]* key.

#### Remote reference

The reference handling system for calculating the remote reference is shown in the [Figure 38](#).



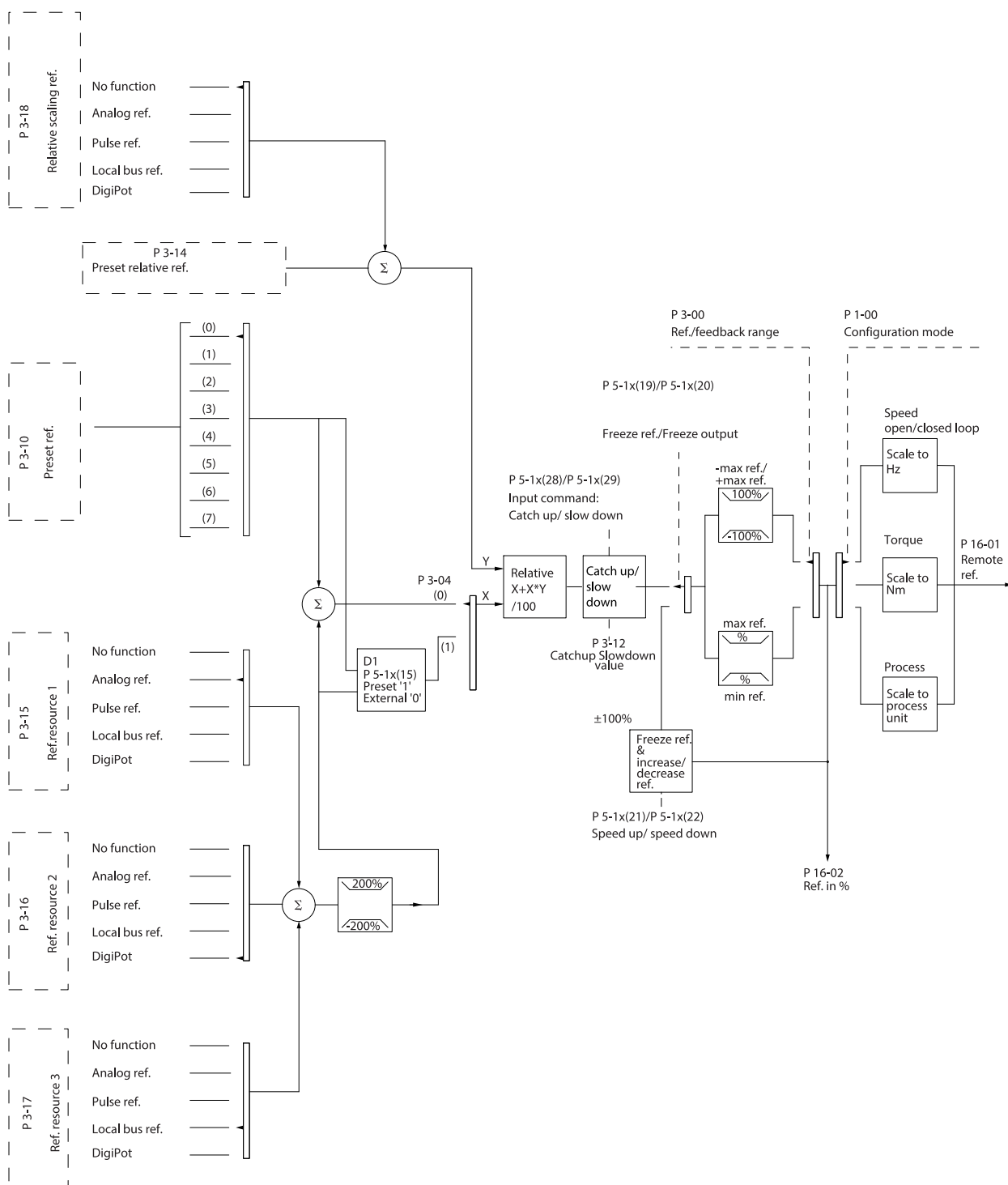


Figure 38: Remote Reference

The remote reference is calculated once in every scan interval and initially consists of 2 types of reference inputs:

1. X (the external reference): A sum (see **parameter 3-04 Reference Function**) of up to 4 externally selected references, comprising any combination (determined by the setting in **parameter 3-15 Reference 1 Source**, **parameter 3-16 Reference 2 Source**, and **parameter 3-17 Reference 3 Source**) of a fixed preset reference (**parameter 3-10 Preset Reference**), variable analog references, variable digital pulse references, and various fieldbus references in any unit the drive is monitoring ([Hz], [RPM], [Nm], and so on).
2. Y (the relative reference): A sum of 1 fixed preset reference (**parameter 3-14 Preset Relative Reference**) and 1 variable analog reference (**parameter 3-18 Relative Scaling Reference Resource**) in [%].

The 2 types of reference inputs are combined in the following formula:

$$\text{Remote reference} = X + X * Y / 100\%$$

If relative reference is not used, set **parameter 3-18 Relative Scaling Reference Resource** to [0] No function and **parameter 3-14 Preset Relative Reference** to 0%. The digital inputs on the drive can activate both the catch up/slow down function and the freeze reference function. The functions and parameters are described in the programming guide.

The scaling of analog references is described in **parameter group 6-1\* Analog Input 53** and **parameter group 6-2\* Analog Input 54**, and the scaling of digital pulse references is described in **parameter group 5-5\* Pulse Input**.

Reference limits and ranges are set in **parameter group 3-0\* Reference Limits**.

### 8.3.2.2 Reference Limits

**Parameter 3-00 Reference Range**, **parameter 3-02 Minimum Reference**, and **parameter 3-03 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 the following illustrations.

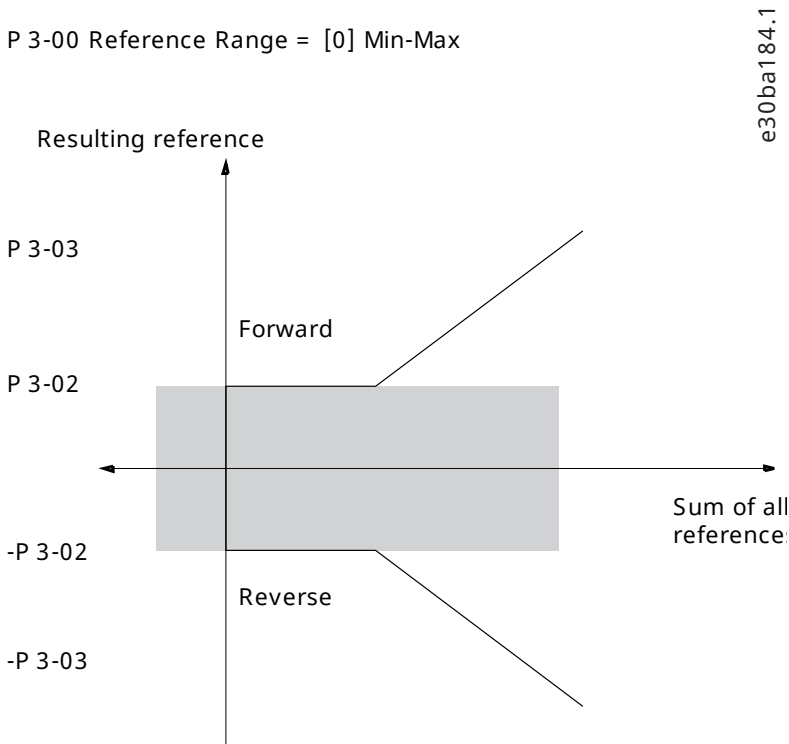


Figure 39: Sum of All References When Reference Range is Set to 0

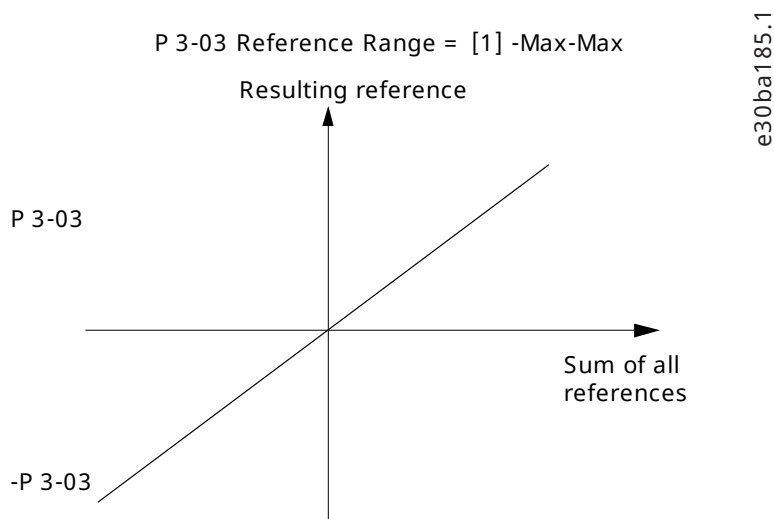


Figure 40: Sum of All References When Reference Range is Set to 1

The value of *parameter 3-02 Minimum Reference* cannot be set to less than 0, unless *parameter 1-00 Configuration Mode* is set to [3] Process. In that case, the following relations between the resulting reference (after clamping) and the sum of all references are as shown in [Figure 41](#).

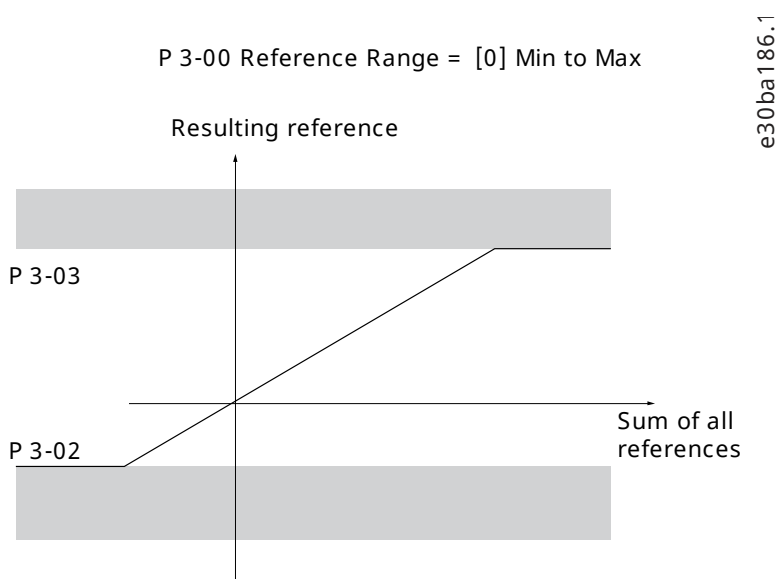


Figure 41: Sum of All References When Minimum Range is Set to a Minus Value

### 8.3.2.3 Scaling of Preset References and Bus References

Preset references are scaled according to the following rules:

- When *parameter 3-00 Reference Range* is set to [0] *Min-Max*, 0% reference equals 0 [unit] where unit can be any unit, for example RPM, m/s, and bar. 100% reference equals the maximum (absolute value of *parameter 3-03 Maximum Reference*, absolute value of *parameter 3-02 Minimum Reference*).
- When *parameter 3-00 Reference Range* is set to [1] *-Max+Max*, 0% reference equals 0 [unit], and 100% reference equals maximum reference.

Bus references are scaled according to the following rules:

- When *parameter 3-00 Reference Range* is set to [0] *Min–Max*, 0% reference equals minimum reference, and 100% reference equals maximum reference.
- When *parameter 3-00 Reference Range* is set to [1] *-Max–+Max*, -100% reference equals -maximum reference, and 100% reference equals maximum reference.

### 8.3.2.4 Scaling of Analog and Pulse References and Feedback

References and feedback are scaled from analog and pulse inputs in the same way. The only difference is that a reference above or below the specified minimum and maximum endpoints (P1 and P2 in the following illustration) are clamped while a feedback above or below is not.

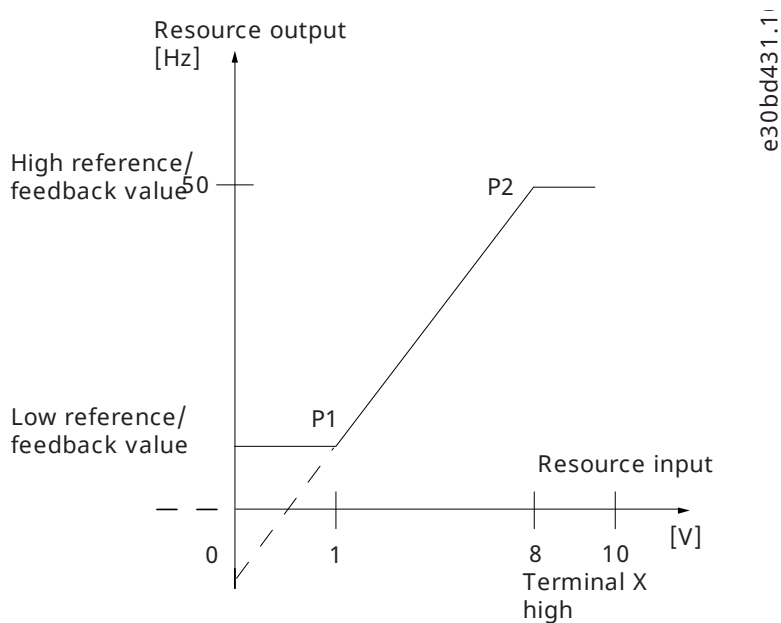


Figure 42: Minimum and Maximum Endpoints

The endpoints P1 and P2 are defined in the following table depending on choice of input.

Table 28: P1 and P2 Endpoints

Input	Analog 53 voltage mode	Analog 53 current mode	Analog 54 voltage mode	Analog 54 current mode	Pulse input 29	Pulse input 33
P1=(Minimum input value, minimum reference value)						
Minimum reference value	<i>Parameter 6-14 Terminal 53 Low Ref./Feedb. Value</i>	<i>Parameter 6-14 Terminal 53 Low Ref./Feedb. Value</i>	<i>Parameter 6-24 Terminal 54 Low Ref./Feedb. Value</i>	<i>Parameter 6-24 Terminal 54 Low Ref./Feedb. Value</i>	<i>Parameter 5-52 Term. 29 Low Ref./Feedb. Value</i>	<i>Parameter 5-57 Terminal 33 Low Ref./Feedb. Value</i>
Minimum input value	<i>Parameter 6-10 Terminal 53 Low Voltage [V]</i>	<i>Parameter 6-12 Terminal 53 Low Current [mA]</i>	<i>Parameter 6-20 Terminal 54 Low Voltage [V]</i>	<i>Parameter 6-22 Terminal 54 Low Current [mA]</i>	<i>Parameter 5-50 Terminal 29 Low Frequency [Hz]</i>	<i>Parameter 5-55 Terminal 33 Low Frequency [Hz]</i>
P2=(Maximum input value, maximum reference value)						

Table 28: P1 and P2 Endpoints (continued)

Input	Analog 53 voltage mode	Analog 53 current mode	Analog 54 voltage mode	Analog 54 current mode	Pulse input 29	Pulse input 33
Maximum reference value	<i>Parameter 6-15 Terminal 53 High Ref./Feedb. Value</i>	<i>Parameter 6-15 Terminal 53 High Ref./Feedb. Value</i>	<i>Parameter 6-25 Terminal 54 High Ref./Feedb. Value</i>	<i>Parameter 6-25 Terminal 54 High Ref./Feedb. Value</i>	<i>Parameter 5-53 Term. 29 High Ref./Feedb. Value</i>	<i>Parameter 5-58 Terminal 33 High Ref./Feedb. Value</i>
Maximum input value	<i>Parameter 6-11 Terminal 53 High Voltage [V]</i>	<i>Parameter 6-13 Terminal 53 High Current [mA]</i>	<i>Parameter 6-21 Terminal 54 High Voltage [V]</i>	<i>Parameter 6-23 Terminal 54 High Current [mA]</i>	<i>Parameter 5-51 Terminal 29 High Frequency [Hz]</i>	<i>Parameter 5-56 Terminal 33 High Frequency [Hz]</i>

### 8.3.2.5 Dead Band Around Zero

Sometimes, the reference (in rare cases also the feedback) should have a dead band around 0 to ensure that the machine is stopped when the reference is near 0.

To make the dead band active and to set the amount of dead band, do the following:

- Set either the minimum reference value or maximum reference value at 0. In other words, either P1 or P2 must be on the X-axis in [Figure 43](#).
- Ensure that both points defining the scaling graph are in the same quadrant.

P1 or P2 defines the size of the dead band as shown in [Figure 43](#).

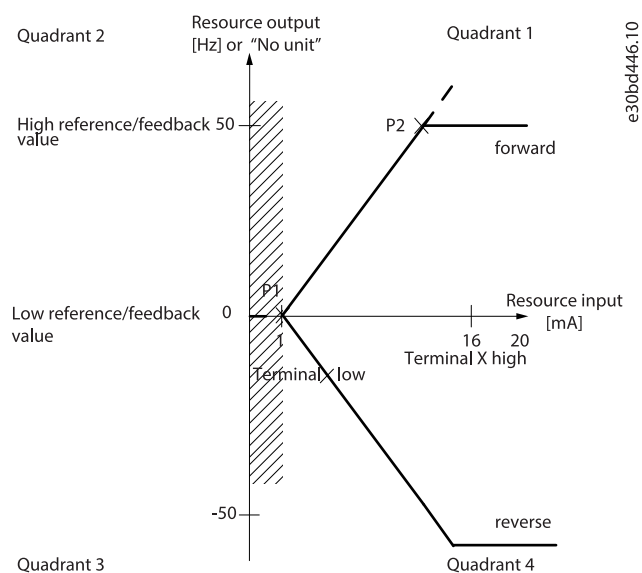


Figure 43: Size of Dead Band

#### Case 1: Positive reference with dead band, digital input to trigger reverse, part I

[Figure 44](#) shows how reference input with limits inside minimum to maximum limits clamps.

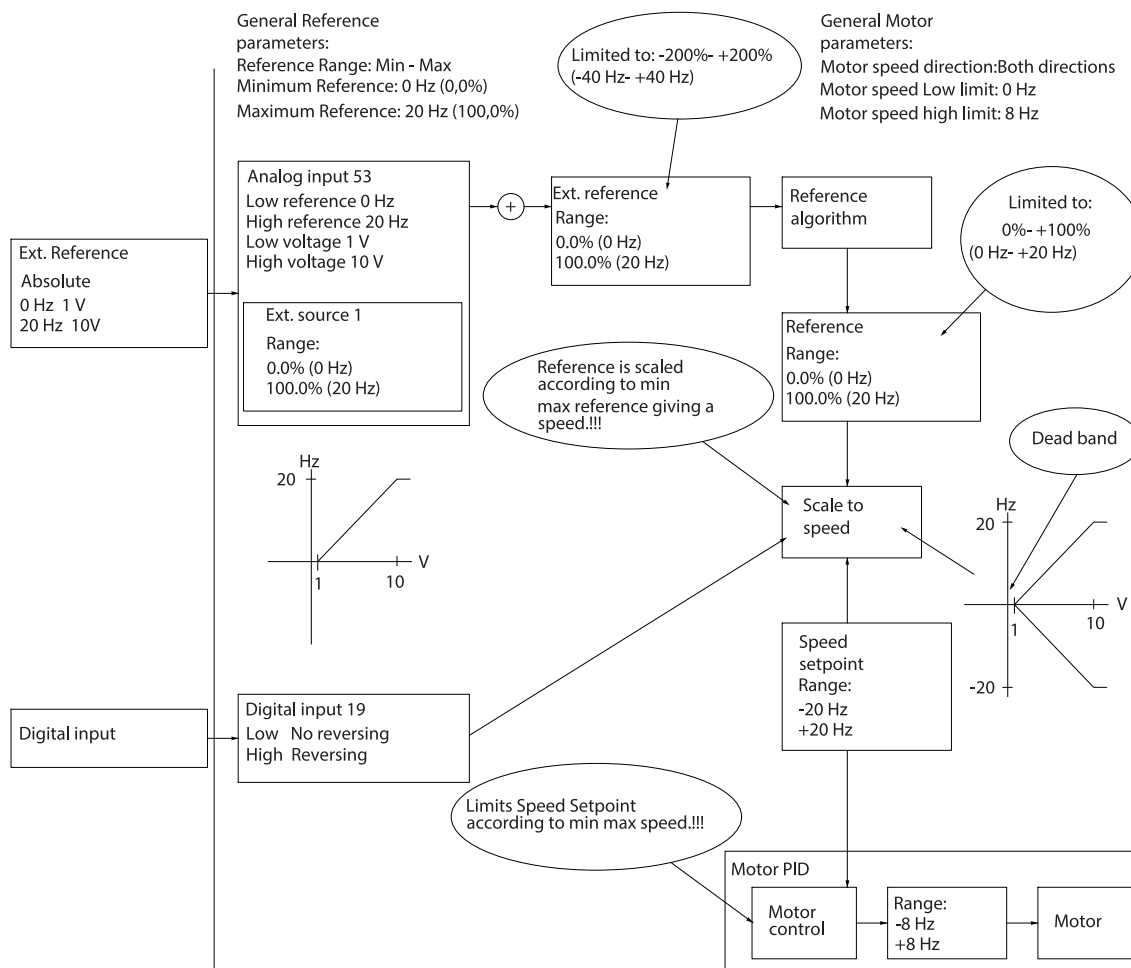
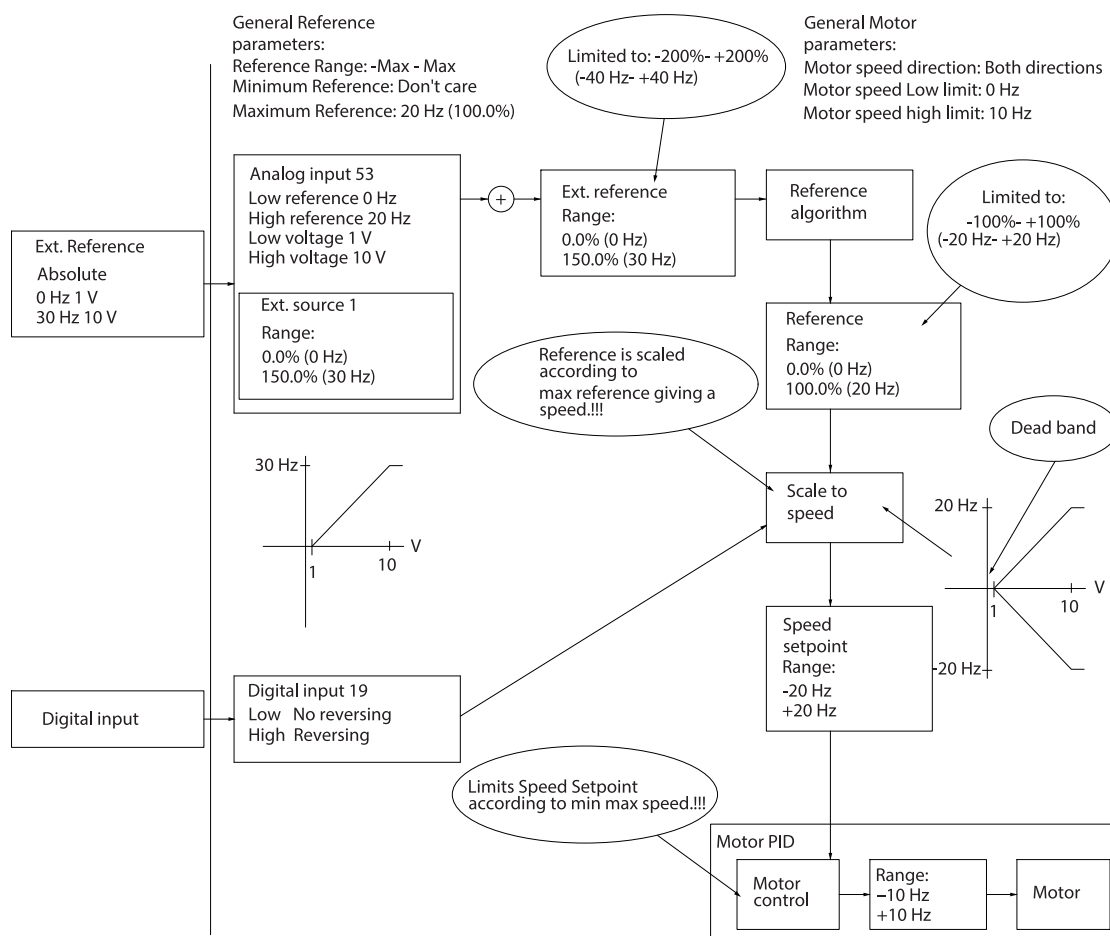


Figure 44: Clamping of Reference Input with Limits inside Minimum to Maximum

**Case 2: Positive reference with dead band, digital input to trigger reverse, part II**

Figure 45 shows how reference input with limits outside -maximum to +maximum limits clamps to the input low and high limits before adding to external reference, and how the external reference is clamped to -maximum to +maximum by the reference algorithm.



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Figure 45: Clamping of Reference Input with Limits outside -Maximum to +Maximum

## 8.3.3 Control Structures

### 8.3.3.1 Control Principle

A drive rectifies AC voltage from mains into DC voltage. Then the DC voltage is converted into an AC current with a variable amplitude and frequency.

The motor is supplied with variable voltage/current and frequency, enabling variable speed control of 3-phased standard AC motors and permanent magnet synchronous motors.

### 8.3.3.2 Control Modes

The drive is capable of controlling either the speed or the torque on the motor shaft. Setting **parameter 1-00 Configuration Mode** determines the type of control.

#### Speed control

There are 2 types of speed control:

- Speed open-loop control, which does not require any feedback from the motor (sensorless).
- Speed closed-loop PID control, which requires a speed feedback to an input. A properly optimized speed closed-loop control has higher accuracy than a speed open-loop control.

Select which input to use as speed PID feedback in **parameter 7-00 Speed PID Feedback Source**.

#### Torque control

The torque control function is used in applications where the torque on the motor output shaft is controlling the application as tension control. Torque control can be either in VVV+ torque open loop in flux sensorless or in flux control closed loop. The best performance is with flux closed loop, especially near 0 speed. Torque control can be selected in **parameter 1-00 Configuration Mode**. Torque setting is done by setting an analog, digital, or bus controlled reference. When running torque control, it is recommended to run a full AMA procedure, because correct motor data is important in achieving optimal performance.

- Closed loop in VVC+ mode. This function is used in applications with low to medium dynamic variation of shaft, and offers excellent performance in all 4 quadrants and at all motor speeds. The speed feedback signal is mandatory. It is recommended to use MCB102 option card. Ensure that the encoder resolution is at least 1024 PPR, and the shield cable of the encoder is well grounded, because the accuracy of the speed feedback signal is important. Tune **parameter 7-06 Speed PID Lowpass Filter Time** to get the best speed feedback signal.
- Open loop in VVC+ mode. The function is used in mechanically robust applications, but the accuracy is limited. The open-loop torque function works for 2 directions. The torque is calculated based on the internal current measurement in the drive.

### Speed/torque reference

The reference to these controls can be either a single reference or the sum of various references including relatively scaled references. Handling of reference is explained in detail in the *chapter Reference Handling*.

## 8.3.4 Control Processing

### 8.3.4.1 Control Structure in VVC+

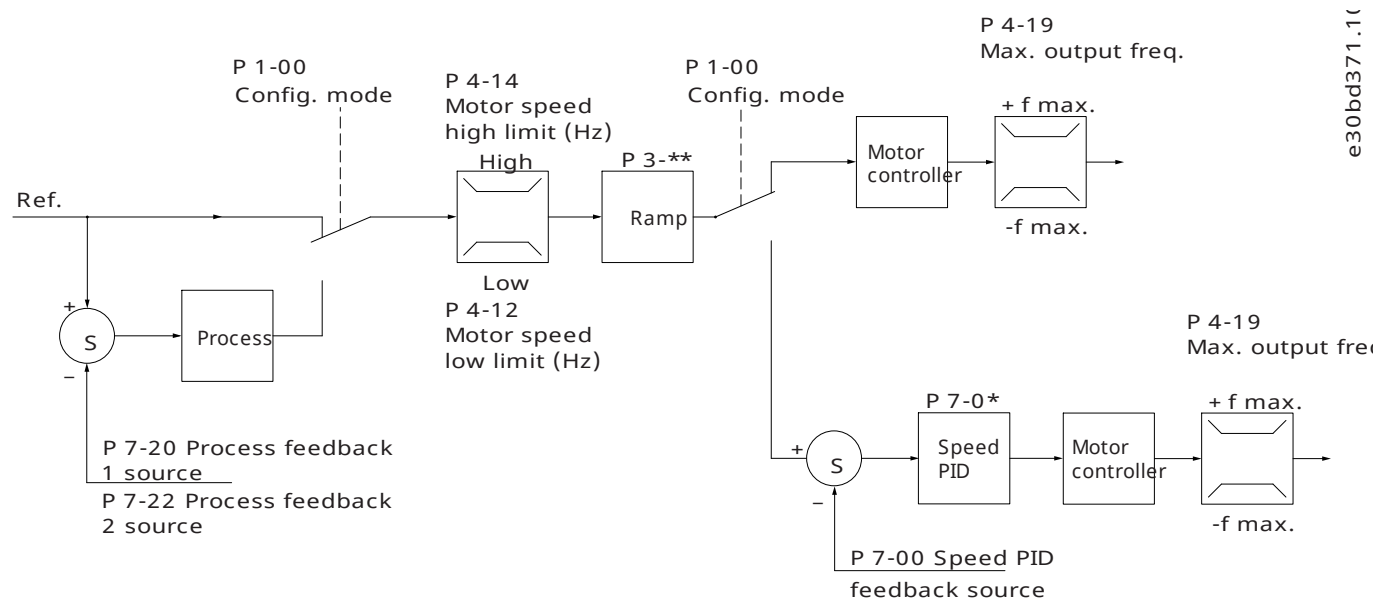


Figure 46: Control Structure in VVC+ Open-loop Configurations and Closed-loop Configurations

In the configuration shown in [Figure 46](#), **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.

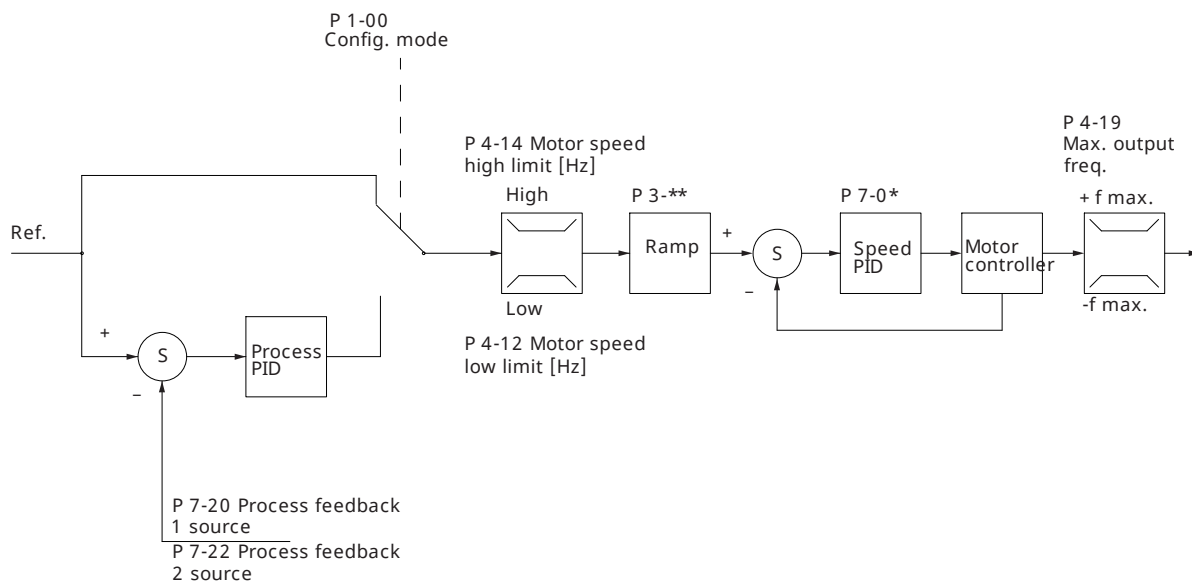
If **parameter 1-00 Configuration Mode** is set to [1] Speed closed loop, the resulting reference is passed from the ramp limitation and speed limitation into a Speed PID control. The Speed PID control parameters are in **parameter group 7-0\* Speed PID Ctrl**. The resulting reference from the Speed 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 **parameter groups 7-3\* Process PID Ctrl.**

### 8.3.4.2 Control Structure in Flux Sensorless

Control structure in Flux Sensorless open-loop and closed-loop configurations.



e30bv187.1

Figure 47: Control Structure in Flux Sensorless

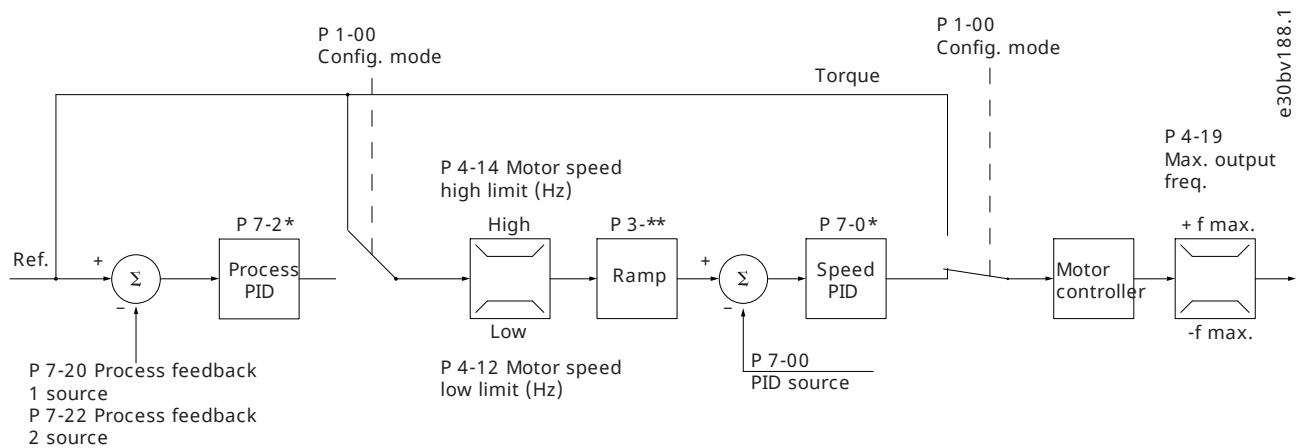
In the configuration shown, **parameter 1-01 Motor Control Principle** is set to **[2] Flux Sensorless** and **parameter 1-00 Configuration Mode** is set to **[0] Speed open loop**. The resulting reference from the reference handling system is fed through the ramp and speed limitations as determined by the parameter settings indicated.

An estimated speed feedback is generated to the speed PID to control the output frequency.

The speed PID must be set with its P, I, and D parameters (**parameter group 7-0\* Controllers**).

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 group 7-2\* Process Ctrl. Feedb** and **parameter group 7-3\* Process PID Ctrl.**

### 8.3.4.3 Control Structure in Flux with Motor Feedback



**Figure 48: Control Structure in Flux with Motor Feedback**

In the configuration shown, **parameter 1-01 Motor Control Principle** is set to **[3] Flux w/ motor feedb** and **parameter 1-00 Configuration Mode** is set to **[1] Speed closed loop**.

Select **[1] Speed closed loop** in **parameter 1-00 Configuration Mode** to use the resulting reference as an input for the Speed PID control. The Speed PID control parameters are in **parameter group 7-0\* Speed PID Ctrl**.

Select **[2] Torque** in **parameter 1-00 Configuration Mode** to use the resulting reference directly as a torque reference. Torque control can only be selected in the flux with motor feedback (**parameter 1-01 Motor Control Principle**) configuration. When this mode has been selected, the reference uses the Nm unit. It requires no torque feedback, since the actual torque is calculated based on the current measurement of the drive.

Select **[3] Process** in **parameter 1-00 Configuration Mode** to use the process PID control for closed-loop control of a process variable (for example, speed) in the controlled application.

## 9 RS485 Installation and Setup

### 9.1 Introduction

#### 9.1.1 Overview

RS485 is a 2-wire bus interface compatible with multi-drop network topology. The nodes can be connected as a bus or via drop cables from a common trunk line. A total of 32 nodes can be connected to 1 network segment.

Repeaters divide network segments, see [Figure 49](#).

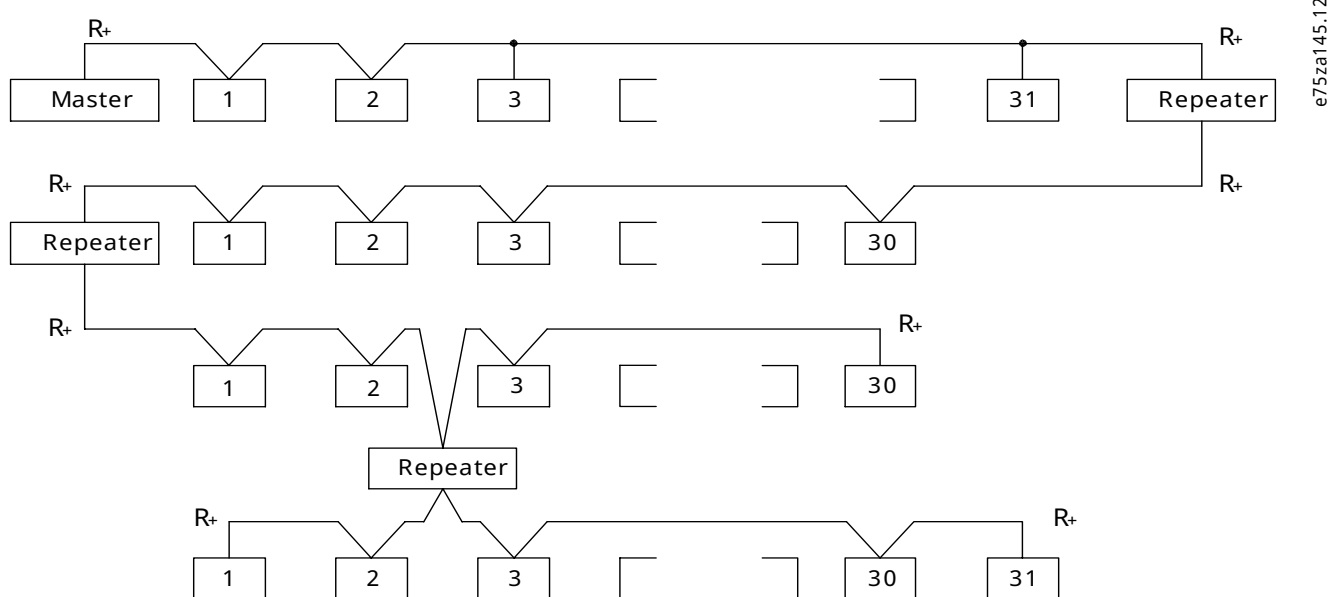


Figure 49: RS485 Bus Interface

#### NOTICE

Each repeater functions as a node within the segment in which it is installed. Each node connected within a given network must have a unique node address across all segments.

Terminate each segment at both ends, using either the termination switch (S801) of the drives or a biased termination resistor network. Always use shielded twisted pair (STP) cable for bus cabling and follow good common installation practice.

Low-impedance ground connection of the shield at every node is important, including at high frequencies. Thus, connect a large surface of the shield to ground, for example with a cable clamp or a conductive cable gland. Sometimes, it is necessary to apply potential-equalizing cables to maintain the same ground potential throughout the network, particularly in installations with long cables.

To prevent impedance mismatch, use the same type of cable throughout the entire network. When connecting a motor to the drive, always use shielded motor cable.

Table 29: Cable Specifications

Cable	Shielded twisted pair (STP)
Impedance [ $\Omega$ ]	120
Cable length [m (ft)]	Maximum 1200 (3937) (including drop lines). Maximum 500 (1640) station-to-station.

### 9.1.2 Network Connection

Connect the drive to the RS485 network as follows (see also [Figure 50](#)):

1. Connect signal wires to terminal 68 (P+) and terminal 69 (N-) on the main control board of the drive.
2. Connect the cable shield to the cable clamps.

#### NOTICE

To reduce noise between conductors, use shielded, twisted-pair cables.

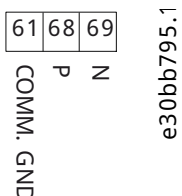


Figure 50: Network Connection

### 9.1.3 Hardware Setup

To terminate the RS485 bus, use the terminator switch on the main control board of the drive.

The factory setting for the switch is OFF.

### 9.1.4 Parameter Settings for Modbus Communication

Table 30: Modbus Communication Parameter Settings

Parameter	Function
<i>Parameter 8-30 Protocol</i>	Select the application protocol to run for the RS485 interface.
<i>Parameter 8-31 Address</i>	Set the node address. <div style="background-color: #005596; color: white; text-align: center; padding: 5px; margin-top: 10px;"><b>NOTICE</b></div> <p>The address range depends on the protocol selected in <i>parameter 8-30 Protocol</i>.</p>
<i>Parameter 8-32 Baud Rate</i>	Set the baud rate. <div style="background-color: #005596; color: white; text-align: center; padding: 5px; margin-top: 10px;"><b>NOTICE</b></div> <p>The default baud rate depends on the protocol selected in <i>parameter 8-30 Protocol</i>.</p>

Table 30: Modbus Communication Parameter Settings (continued)

Parameter	Function
<i>Parameter 8-33 Parity/Stop Bits</i>	Set the parity and number of stop bits. <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p style="text-align: center; margin: 0;"><b>NOTICE</b></p> <p style="margin: 0;">The default selection depends on the protocol selected in <i>parameter 8-30 Protocol</i>.</p> </div>
<i>Parameter 8-35 Minimum Response Delay</i>	Specify a minimum delay time between receiving a request and transmitting a response. This function is for overcoming modem turnaround delays.
<i>Parameter 8-36 Maximum Response Delay</i>	Specify a maximum delay time between transmitting a request and receiving a response.
<i>Parameter 8-37 Maximum Inter-char delay</i>	If transmission is interrupted, specify a maximum delay time between 2 received bytes to ensure timeout. <div style="border: 1px solid black; padding: 5px; margin-top: 10px;"> <p style="text-align: center; margin: 0;"><b>NOTICE</b></p> <p style="margin: 0;">The default selection depends on the protocol selected in <i>parameter 8-30 Protocol</i>.</p> </div>

### 9.1.5 EMC Precautions

To achieve interference-free operation of the RS485 network, Danfoss recommends the following EMC precautions.

#### NOTICE

Observe relevant national and local regulations, for example, regarding protective ground connection. To avoid coupling of high frequency noise between the cables, keep the RS485 communication cable away from motor and brake resistor cables. Normally, a distance of 200 mm (8 in) is sufficient. Maintain the greatest possible distance between the cables, especially where cables run in parallel over long distances. When crossing is unavoidable, the RS485 cable must cross motor and brake resistor cables at an angle of 90°.

## 9.2 FC Protocol

### 9.2.1 Overview

The FC protocol, also referred to as FC bus or standard bus, is the Danfoss standard fieldbus. It defines an access technique according to the master/follower principle for communications via a fieldbus.

One master and a maximum of 126 followers can be connected to the bus. The master selects the individual followers via an address character in the telegram. A follower itself can never transmit without first being requested to do so, and direct telegram transfer between the individual followers is not possible. Communications occur in the half duplex mode.

The master function cannot be transferred to another node (single-master system).

The physical layer is RS485, thus utilizing the RS485 port built into the drive. The FC protocol supports different telegram formats:

- A short format of 8 bytes for process data.
- A long format of 16 bytes that also includes a parameter channel.

- A format used for texts.

### 9.2.2 FC with Modbus RTU

The FC protocol provides access to the control word and bus reference of the drive.

The control word allows the Modbus master to control several important functions of the drive:

- Start.
- Stop of the drive in various ways:
  - Coast stop.
  - Quick stop.
  - DC brake stop.
  - Normal (ramp) stop.
- Reset after a fault trip.
- Run at various preset speeds.
- Run in reverse.
- Change of the active setup.
- Control of the 2 relays built into the drive.

The bus reference is commonly used for speed control. It is also possible to access the parameters, read their values, and where possible, write values to them. Accessing the parameters offers a range of control options, including controlling the setpoint of the drive when its internal PI controller is used.

## 9.3 FC Protocol Network Configuration

To enable the FC protocol for the drive, set the following parameters.

Table 31: Parameters to Enable the Protocol

Parameter	Setting
<i>Parameter 8-30 Protocol</i>	FC
<i>Parameter 8-31 Address</i>	1–126
<i>Parameter 8-32 Baud Rate</i>	2400–115200
<i>Parameter 8-33 Parity/Stop Bits</i>	Even parity, 1 stop bit (default)

## 9.4 FC Protocol Message Framing Structure

### 9.4.1 Content of a Character (byte)

Each character transferred begins with a start bit. Then 8 data bits are transferred, corresponding to a byte. Each character is secured via a parity bit. This bit is set at 1 when it reaches parity. Parity is when there is an equal number of 1s in the 8 data bits and the parity bit in total. A stop bit completes a character, consisting of 11 bits in all.

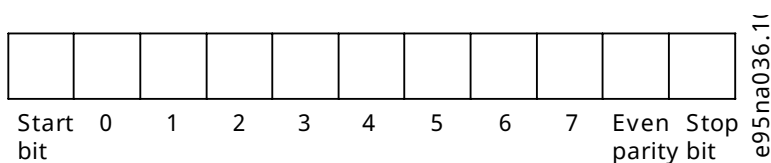


Figure 51: Content of a Character

## 9.4.2 Telegram Structure

Each telegram has the following structure:

- Start character (STX) = 02 hex.
- A byte denoting the telegram length (LGE).
- A byte denoting the drive address (ADR).

Several data bytes (variable, depending on the type of telegram) follow.

A data control byte (BCC) completes the telegram.



Figure 52: Telegram Structure

## 9.4.3 Telegram Length (LGE)

The telegram length is the number of data bytes plus the address byte ADR and the data control byte BCC.

Table 32: Length of Telegrams

4 data bytes	$LGE=4+1+1=6$ bytes
12 data bytes	$LGE=12+1+1=14$ bytes
Telegrams containing texts	$10^{(1)}+n$ bytes

1) 10 represents the fixed characters, while n is variable (depending on the length of the text).

## 9.4.4 Drive Address (ADR)

Address format 1–126

- Bit 7 = 1 (address format 1–126 active).
- Bit 0–6 = drive address 1–126.
- Bit 0–6 = 0 broadcast.

The follower returns the address byte unchanged to the master in the response telegram.

## 9.4.5 Data Control Byte (BCC)

The checksum is calculated as an XOR-function. Before the first byte in the telegram is received, the calculated checksum is 0.

## 9.4.6 The Data Field

The structure of data blocks depends on the type of telegram. There are 3 telegram types, and the type applies to both control telegrams (master=>follower) and response telegrams (follower=>master).

The 3 types of telegram are:

### Process block (PCD)

The PCD is made up of a data block of 4 bytes (2 words) and contains:

- Control word and reference value (from master to follower).
- Status word and present output frequency (from follower to master).

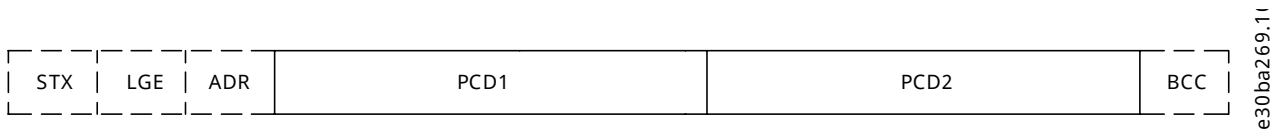


Figure 53: Process Block

### Parameter block

The parameter block is used to transfer parameters between master and follower. The data block is made up of 12 bytes (6 words) and also contains the process block.

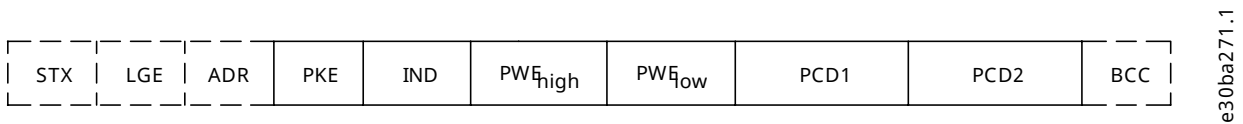


Figure 54: Parameter Block

### Text block

The text block is used to read or write texts via the data block.

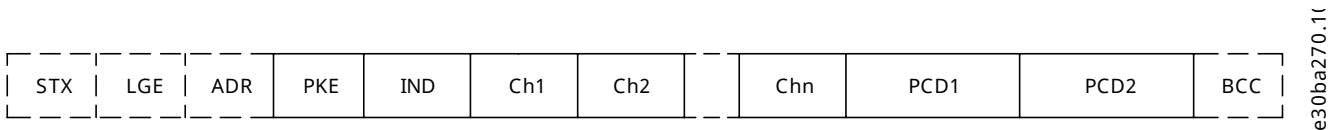


Figure 55: Text Block

## 9.4.7 The PKE Field

The PKE field contains 2 subfields:

- Parameter command and response (AK).
- Parameter number (PNU).

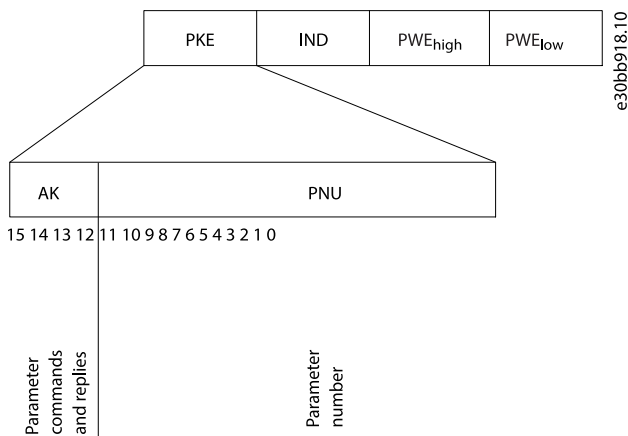


Figure 56: PKE Field

Bits 12–15 transfer parameter commands from master to follower and return processed follower responses to the master.



Table 33: Parameter Commands

Parameter commands master to follower				
Bit number				Parameter command
15	14	13	12	
0	0	0	0	No command.
0	0	0	1	Read parameter value.
0	0	1	0	Write parameter value in RAM (word).
0	0	1	1	Write parameter value in RAM (double word).
1	1	0	1	Write parameter value in RAM and EEPROM (double word).
1	1	1	0	Write parameter value in RAM and EEPROM (word).
1	1	1	1	Read text.

Table 34: Response

Response follower to master				
Bit number				Response
15	14	13	12	
0	0	0	0	No command.
0	0	0	1	Parameter value transferred (word).
0	0	1	0	Parameter value transferred (double word).
0	1	1	1	Command cannot be performed.
1	1	1	1	Text transferred.

If the command cannot be performed, the follower sends 0111 Command cannot be performed response and issues the following fault reports in the table.

Table 35: Follower Report

Fault code	FC specification
0	Illegal parameter number.
1	Parameter cannot be changed.

Table 35: Follower Report (continued)

Fault code	FC specification
2	Upper or lower limit is exceeded.
3	Sub-index is corrupted.
4	No array.
5	Wrong data type.
6	Not used.
7	Not used.
9	Description element is not available.
11	No parameter write access.
15	No text available.
17	Not applicable while running.
18	Other errors.
100	–
>100	–
130	No bus access for this parameter.
131	Write to factory setup is not possible.
132	No LCP access.
252	Unknown viewer.
253	Request is not supported.
254	Unknown attribute.
255	No error.

#### 9.4.8 Parameter Number (PNU)

Bits 0–11 transfer parameter numbers. The function of the relevant parameter is defined in the parameter description in the programming guide of the drive.

#### 9.4.9 Index (IND)

The index is used with the parameter number to read/write access parameters with an index, for example, **parameter 15-30 Alarm Log: Error Code**. The index consists of 2 bytes: a low byte and a high byte.

Only the low byte is used as an index.

#### 9.4.10 Parameter Value (PWE)

The parameter value block consists of 2 words (4 bytes), and the value depends on the defined command (AK). The master prompts for a parameter value when the PWE block contains no value. To change a parameter value (write), write the new value in the PWE block and send from the master to the follower.

When a follower responds to a parameter request (read command), the present parameter value in the PWE block is transferred and returned to the master. If a parameter contains several data options, for example, **parameter 0-01 Language**, select the data value by entering the value in the PWE block. Serial communication is only capable of reading parameters containing data type 9 (text string).

**Parameter 15-40 FC Type** to **parameter 15-53 Power Card Serial Number** contain data type 9. For example, read the unit size and mains voltage range in **parameter 15-40 FC Type**. When a text string is transferred (read), the length of the telegram is variable, and the texts are of different lengths. The telegram length is defined in the 2nd byte of the telegram (LGE). When using text transfer, the index character indicates whether it is a read, or a write command.

To read a text via the PWE block, set the parameter command (AK) to F hex. The index character high-byte must be 4.

### 9.4.11 Data Types Supported by the Drive

Unsigned means that there is no operational sign in the telegram.

Table 36: Data Types

Data types	Description
3	Integer 16
4	Integer 32
5	Unsigned 8
6	Unsigned 16
7	Unsigned 32
9	Text string

### 9.4.12 Conversion

The programming guide contains the descriptions of attributes of each parameter. Parameter values are transferred as whole numbers only. Conversion factors are used to transfer decimals.

**Parameter 4-12 Motor Speed Low Limit [Hz]** has a conversion factor of 0.1. To preset the minimum frequency to 10 Hz, transfer the value 100. A conversion factor of 0.1 means that the value transferred is multiplied by 0.1. The value 100 is thus perceived as 10.0.

Table 37: Conversion

Conversion index	Conversion factor
74	3600
2	100
1	10
0	1
-1	0.1
-2	0.01
-3	0.001
-4	0.0001
-5	0.00001

### 9.4.13 Process Words (PCD)

The block of process words is divided into 2 blocks of 16 bits, which always occur in the defined sequence.

Table 38: Process Words (PCD)

PCD 1	PCD 2
Control telegram (master to follower control word)	Reference value
Control telegram (follower to master) status word	Present output frequency

## 9.5 Examples

### 9.5.1 Writing a Parameter Value

Change *parameter 4-14 Motor Speed High Limit [Hz]* to 100 Hz.

Write the data in EEPROM.

PKE = E19E hex - Write single word in *parameter 4-14 Motor Speed High Limit [Hz]*:

- IND = 0000 hex.
- PWEHIGH = 0000 hex.
- PWELOW = 03E8 hex.

Data value 1000, corresponding to 100 Hz, see the chapter [9.4.12 Conversion](#).

The telegram looks like the [Figure 57](#).

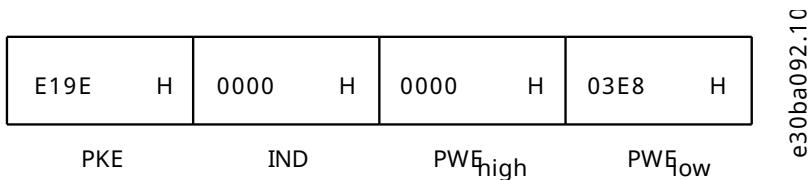


Figure 57: Telegram

#### NOTICE

*Parameter 4-14 Motor Speed High Limit [Hz]* is a single word, and the parameter command for write in EEPROM is E. *Parameter 4-14 Motor Speed High Limit [Hz]* is 19E in hexadecimal.

The response from the follower to the master is shown in the [Figure 58](#).

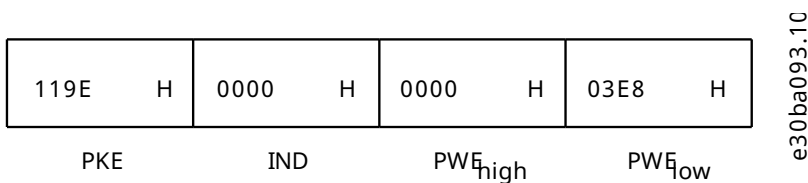


Figure 58: Response from Master

### 9.5.2 Reading a Parameter Value

Read the value in *parameter 3-41 Ramp 1 Ramp Up Time*.

PKE = 1155 hex - Read parameter value in *parameter 3-41 Ramp 1 Ramp Up Time*:

- IND = 0000 hex.
- PWE<sub>HIGH</sub> = 0000 hex.
- PWE<sub>LOW</sub> = 0000 hex.

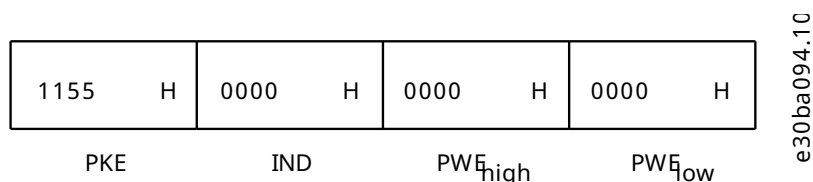


Figure 59: Telegram

If the value in *parameter 3-41 Ramp 1 Ramp Up Time* is 10 s, the response from the follower to the master is shown in .

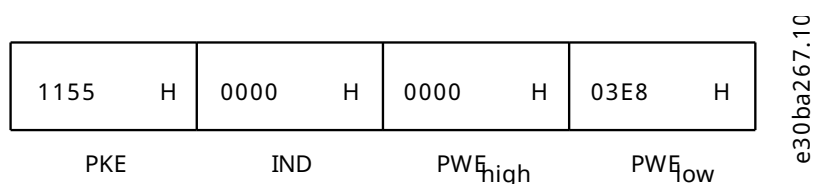


Figure 60: Response

3E8 hex corresponds to 1000 decimal. The conversion index for *parameter 3-41 Ramp 1 Ramp Up Time* is -2, that is, 0.01.

*Parameter 3-41 Ramp 1 Ramp Up Time* is of the type Unsigned 32.

## 9.6 Modbus RTU

### 9.6.1 Prerequisite Knowledge

Danfoss assumes that the installed controller supports the interfaces in this manual and strictly observes all requirements and limitations stipulated in the controller and the drive.

The built-in Modbus RTU (remote terminal unit) is designed to communicate with any controller that supports the interfaces defined in this manual. It is assumed that the user has full knowledge of the capabilities and limitations of the controller.

### 9.6.2 Overview

Regardless of the type of physical communication networks, this section describes the process that a controller uses to request access to another device. This process includes how the Modbus RTU responds to requests from another device, and how errors are detected and reported. It also establishes a common format for the layout and contents of telegram fields.

During communications over a Modbus RTU network, the protocol:

- Determines how each controller learns its device address.
- Recognizes a telegram addressed to it.
- Determines which actions to take.
- Extracts any data or other information contained in the telegram.

If a reply is required, the controller constructs the reply telegram and sends it.

Controllers communicate using a master/follower technique in which only the master can initiate transactions (called queries). Followers respond by supplying the requested data to the master, or by acting as requested in the query. The master can address individual followers, or initiate a broadcast telegram to all followers. Followers return a response to queries that are addressed to them individually. No responses are returned to broadcast queries from the master.

The Modbus RTU protocol establishes the format for the master query by providing the following information:

- The device (or broadcast) address.
- A function code defining the requested action.
- Any data to be sent.
- An error-checking field.

The response telegram of the follower device is also constructed using Modbus protocol. It contains fields confirming the action taken, any data to be returned, and an error-checking field. If an error occurs in receipt of the telegram, or if the follower is unable to perform the requested action, the follower constructs and sends an error message. Alternatively, a timeout occurs.

### 9.6.3 Drive with Modbus RTU

The drive communicates in Modbus RTU format over the built-in RS485 interface. Modbus RTU provides access to the control word and bus reference of the drive.

The control word allows the Modbus master to control several important functions of the drive:

- Start.
- Various stops:
  - Coast stop.
  - Quick stop.
  - DC brake stop.
  - Normal (ramp) stop.
- Reset after a fault trip.
- Run at various preset speeds.
- Run in reverse.
- Change the active setup.
- Control built-in relay of the drive.

The bus reference is commonly used for speed control. It is also possible to access the parameters, read their values, and, where possible, write values to them. Accessing the parameters offers a range of control options, including controlling the setpoint of the drive when its internal PI controller is used.

## 9.7 Modbus RTU Network Configuration

To enable Modbus RTU on the drive, set the following parameters:

Table 39: Parameters to Enable the Modbus RTU

Parameter	Setting
<i>Parameter 8-30 Protocol</i>	Modbus RTU
<i>Parameter 8-31 Address</i>	1–247
<i>Parameter 8-32 Baud Rate</i>	2400–115200
<i>Parameter 8-33 Parity/Stop Bits</i>	Even parity, 1 stop bit (default)

## 9.8 Modbus RTU Message Framing Structure

### 9.8.1 Introduction

The controllers are set up to communicate on the Modbus network using RTU (remote terminal unit) mode, with each byte in a telegram containing 2 4-bit hexadecimal characters. The format for each byte is shown in the following table.

**Table 40: Format for Each Byte**

Start bit	Data byte	Stop/parity	Stop

**Table 41: Byte Details**

Coding system	8-bit binary, hexadecimal 0–9, A–F. 2 hexadecimal characters contained in each 8-bit field of the telegram.
Bits per byte	<ul style="list-style-type: none"> <li>• 1 start bit.</li> <li>• 8 data bits, least significant bit sent first.</li> <li>• 1 bit for even/odd parity; no bit for no parity.</li> <li>• 1 stop bit if parity is used; 2 bits if no parity.</li> </ul>
Error check field	Cyclic redundancy check (CRC).

### 9.8.2 Modbus RTU Telegram Structure

The transmitting device places a Modbus RTU telegram into a frame with a known beginning and ending point. This allows receiving devices to begin at the start of the telegram, read the address portion, determine which device is addressed (or all devices, if the telegram is broadcast), and to recognize when the telegram is completed. Partial telegrams are detected and errors set as a result. Characters for transmission must be in hexadecimal 00–FF format in each field. The drive continuously monitors the network bus, also during silent intervals. When the first field (the address field) is received, each drive or device decodes it to determine which device is being addressed. Modbus RTU telegrams addressed to 0 are broadcast telegrams. No response is allowed for broadcast telegrams. A typical telegram frame is shown in the following table.

**Table 42: Typical Modbus RTU Telegram Structure**

Start	Address	Function	Data	CRC check	End
T1-T2-T3-T4	8 bits	8 bits	N x 8 bits	16 bits	T1-T2-T3-T4

### 9.8.3 Start/Stop Field

Telegrams start with a silent period of at least 3.5 character intervals. The silent period is implemented as a multiple of character intervals at the selected network baud rate (shown as Start T1-T2-T3-T4). The first field to be transmitted is the device address. Following the last transmitted character, a similar period of at least 3.5 character intervals marks the end of the telegram. A new telegram can begin after this period.

Transmit the entire telegram frame as a continuous stream. If a silent period of more than 1.5 character intervals occurs before completion of the frame, the receiving device flushes the incomplete telegram and assumes that the next byte is the address field of a new telegram. Similarly, if a new telegram begins before 3.5 character intervals after a previous telegram, the receiving device considers it a continuation of the previous telegram. This behavior causes a timeout (no response from the follower), since the value in the final CRC field is not valid for the combined telegrams.

#### 9.8.4 Address Field

The address field of a telegram frame contains 8 bits. Valid follower device addresses are in the range of 0–247 decimal. The individual follower devices are assigned addresses in the range of 1–247. 0 is reserved for broadcast mode, which all slaves recognize. A master addresses a follower by placing the follower address in the address field of the telegram. When the follower sends its response, it places its own address in this address field to let the master know which follower is responding.

#### 9.8.5 Function Field

The function field of a telegram frame contains 8 bits. Valid codes are in the range of 1–FF. Function fields are used to send telegrams between master and follower. When a telegram is sent from a master to a follower device, the function code field tells the follower what kind of action to perform. When the follower responds to the master, it uses the function code field to indicate either a normal (error-free) response, or that some kind of error occurred (called an exception response).

For a normal response, the follower simply echoes the original function code. For an exception response, the follower returns a code that is equivalent to the original function code with its most significant bit set to logic 1. In addition, the follower places a unique code into the data field of the response telegram. This code tells the master what kind of error occurred, or the reason for the exception. Also refer to *chapter Function Codes Supported by Modbus RTU* and *chapter Modbus Exception Codes*.

#### 9.8.6 Data Field

The data field is constructed using sets of 2 hexadecimal digits, in the range of 00–FF hexadecimal. These digits are made up of 1 RTU character. The data field of telegrams sent from a master to a follower device contains additional information which the follower must use to perform accordingly.

The information can include items such as:

- Coil or register addresses.
- The quantity of items to be handled.
- The count of actual data bytes in the field.

#### 9.8.7 CRC Check Field

Telegrams include an error-checking field, operating based on a cyclic redundancy check (CRC) method. The CRC field checks the contents of the entire telegram. It is applied regardless of any parity check method used for the individual characters of the telegram. The transmitting device calculates the CRC value and appends the CRC as the last field in the telegram. The receiving device recalculates a CRC during receipt of the telegram and compares the calculated value to the actual value received in the CRC field. 2 unequal values result in bus timeout. The error-checking field contains a 16-bit binary value implemented as 2 8-bit bytes. After the implementation, the low-order byte of the field is appended first, followed by the high-order byte. The CRC high-order byte is the last byte sent in the telegram.

#### 9.8.8 Coil Register Addressing

In Modbus, all data is organized in coils and holding registers. Coils hold a single bit, whereas holding registers hold a 2 byte word (that is 16 bits). All data addresses in Modbus telegrams are referenced to 0. The first occurrence of a data item is addressed as item number 0. For example: The coil known as coil 1 in a programmable controller is addressed as coil 0000 in the data address field of a Modbus telegram. Coil 127 decimal is addressed as coil 007Ehex (126 decimal).



Holding register 40001 is addressed as register 0000 in the data address field of the telegram. The function code field already specifies a holding register operation. Therefore, the 4XXXX reference is implicit. Holding register 40108 is addressed as register 006Bhex (107 decimal).

**Table 43: Coil Register**

Coil number	Description	Signal direction
1–16	Drive control word.	Master to follower
17–32	Drive speed or setpoint reference range 0x0–0xFFFF (-200% ... ~200%).	Master to follower
33–48	Drive status word.	Follower to master
49–64	Open-loop mode: Drive output frequency. Closed-loop mode: Drive feedback signal.	Follower to master
65	Parameter write control (master to slave).	Master to follower
	0 = Parameter changes are written to the RAM of the drive.	
	1 = Parameter changes are written to the RAM and EEPROM of the drive.	
66–65536	Reserved.	–

**Table 44: Drive Control Word (FC Profile)**

Coil	0	1
01	Preset reference lsb	
02	Preset reference msb	
03	DC brake	No DC brake
04	Coast stop	No coast stop
05	Quick stop	No quick stop
06	Freeze frequency	No freeze frequency
07	Ramp stop	Start
08	No reset	Reset
09	No jog	Jog
10	Ramp 1	Ramp 2
11	Data not valid	Data valid
12	Relay 1 off	Relay 1 on
13	Relay 2 off	Relay 2 on
14	Set up lsb	
15	–	
16	No reversing	Reversing

Table 45: Drive Status Word (FC Profile)

Coil	0	1
33	Control not ready	Control ready
34	Drive not ready	Drive ready
35	Coast stop	Safety closed
36	No alarm	Alarm
37	Not used	Not used
38	Not used	Not used
39	Not used	Not used
40	No warning	Warning
41	Not at reference	At reference
42	Hand-on mode	Auto mode
43	Out of frequency range	In frequency range
44	Stopped	Running
45	Not used	Not used
46	No voltage warning	Voltage warning
47	Not in current limit	Current limit
48	No thermal warning	Thermal warning

Table 46: Address/Registers

Bus address	Bus register <sup>(1)</sup>	PLC register	Content	Access	Description
0	1	40001	Reserved	–	Reserved for legacy frequency converters VLT® 5000 and VLT® 2800.
1	2	40002	Reserved	–	Reserved for legacy frequency converters VLT® 5000 and VLT® 2800.
2	3	40003	Reserved	–	Reserved for legacy frequency converters VLT® 5000 and VLT® 2800.
3	4	40004	Free	–	–
4	5	40005	Free	–	–
5	6	40006	Modbus configuration	Read/Write	TCP only. Reserved for Modbus TCP ( <i>parameter 12-28 Store Data Values</i> and <i>parameter 12-29 Store Always - stored in</i> , for example, EEPROM).
6	7	40007	Last fault code	Read only	Fault code received from parameter database, refer to WHAT 38295 for details.

Table 46: Address/Registers (continued)

Bus address	Bus register <sup>(1)</sup>	PLC register	Content	Access	Description
7	8	40008	Last error register	Read only	Address of register with which last error occurred, refer to WHAT 38296 for details.
8	9	40009	Index pointer	Read/Write	Sub-index of parameter to be accessed. Refer to WHAT 38297 for details.
9	10	40010	<b>Parameter 0-01 Language</b>	Dependent on parameter access	<b>Parameter 0-01 Language</b> (Modbus register = 10 parameter number) 20 bytes space reserved for parameter in Modbus map.
19	20	40020	<b>Parameter 0-02 Motor Speed Unit</b>	Dependent on parameter access	<b>Parameter 0-02 Motor Speed Unit</b> 20 bytes space reserved for parameter in Modbus map.
29	30	40030	<b>Parameter 0-03 Regional Settings</b>	Dependent on parameter access	<b>Parameter 0-03 Regional Settings</b> 20 bytes space reserved for parameter in Modbus map.

1) Value written in the Modbus RTU telegram must be 1 or less than the register number. For example, Read Modbus Register 1 by writing value 0 in the telegram.

### 9.8.9 How to Control the Drive

This section describes codes which can be used in the function and data fields of a Modbus RTU telegram.

#### 9.8.10 Function Codes Supported by Modbus RTU

Modbus RTU supports use of the following function codes in the function field of a telegram:

Table 47: Function Codes

Function	Function code (hex)
Read coils	1
Read holding registers	3
Write single coil	5
Write single register	6
Diagnostics	8
Get comm. event counter	B
Write multiple coils	F
Write multiple registers	10
Report follower ID	11
Read/Write multiple registers	17
Encapsulated Interface Transport	2b

Table 48: Subfunction Code of Function Code 8

Function	Function code	Subfunction code	Subfunction
Diagnostics	8	1	Restart communication.
		2	Return diagnostic register.
		10	Clear counters and diagnostic register.
		11	Return bus message count.
		12	Return bus communication error count.
		13	Return follower error count.
		14	Return follower message count.

### 9.8.11 Modbus Exception Codes

For a full explanation of the structure of an exception code response, refer to [9.8.5 Function Field](#).

Table 49: Modbus Exception Codes

Code	Name	Meaning
1	Illegal function	The function code received in the query is not an allowable action for the server (or follower). This may be because the function code is only applicable to newer devices and was not implemented in the unit selected. It could also indicate that the server (or follower) is in the wrong state to process a request of this type, for example because it is not configured and is being asked to return register values.
2	Illegal data address	The data address received in the query is not an allowable address for the server (or follower). More specifically, the combination of reference number and transfer length is invalid. For a controller with 100 registers, a request with offset 96 and length 4 succeeds, while a request with offset 96 and length 5 generates exception 02.
3	Illegal data value	A value contained in the query data field is not an allowable value for server (or follower). This indicates a fault in the structure of the remainder of a complex request, such as that the implied length is incorrect. It does NOT mean that a data item submitted for storage in a register has a value outside the expectation of the application program, since the Modbus protocol is unaware of the significance of any value of any register.
4	Follower device failure	An unrecoverable error occurred while the server (or follower) was attempting to perform the requested action.

## 9.9 How to Access Parameters

### 9.9.1 Parameter Handling

The PNU (parameter number) is translated from the register address contained in the Modbus read or write message. The parameter number is translated to Modbus as (10 x parameter number) decimal. Example: Reading **parameter 3-12 Catch up/slow Down Value** (16 bit): The holding register 3120 holds the values of the parameters. A value of 1352 (decimal) means that the parameter is set to 12.52%.

Reading **parameter 3-14 Preset Relative Reference** (32 bit): The holding registers 3410 and 3411 hold the parameters' values. A value of 11300 (decimal) means that the parameter is set to 1113.00.

For information on the parameters, size, and conversion index, see the programming guide.

### 9.9.2 Storage of Data

The coil 65 decimal determines whether data written to the drive is stored in EEPROM and RAM (coil 65 = 1), or only in RAM (coil 65 = 0).

### 9.9.3 IND (Index)

Some parameters in the drive are array parameters, for example *parameter 3-10 Preset Reference*. Since the Modbus does not support arrays in the holding registers, the drive has reserved the holding register 9 as pointer to the array. Before reading or writing an array parameter, set the holding register 9. Setting holding register to the value of 2 causes all following read/ write to array parameters to be to the index 2.

### 9.9.4 Text Blocks

Parameters stored as text strings are accessed in the same way as the other parameters. The maximum text block size is 20 characters. If a read request for a parameter is for more characters than the parameter stores, the response is truncated. If the read request for a parameter is for fewer characters than the parameter stores, the response is space filled.

### 9.9.5 Conversion Factor

A parameter value can only be transferred as a whole number. To transfer decimals, use a conversion factor.

### 9.9.6 Parameter Values

#### Standard data types

Standard data types are int 16, int 32, uint 8, uint 16, and uint 32. They are stored as 4x registers (40001–4FFFF). The parameters are read using function 03 hex read holding registers. Parameters are written using the function 6 hex preset single register for 1 register (16 bits), and the function 10 hex preset multiple registers for 2 registers (32 bits). Readable sizes range from 1 register (16 bits) up to 10 registers (20 characters).

#### Non-standard data types

Non-standard data types are text strings and are stored as 4x registers (40001–4FFFF). The parameters are read using function 03 hex read holding registers and written using function 10 hex preset multiple registers. Readable sizes range from 1 register (2 characters) up to 10 registers (20 characters).

## 9.10 Examples

### 9.10.1 Overview of the Examples

The examples in the following chapters show various Modbus RTU commands.

### 9.10.2 Read Coil Status (01 hex)

#### Description

This function reads the ON/OFF status of discrete outputs (coils) in the drive. Broadcast is never supported for reads.

#### Query

The query telegram specifies the starting coil and quantity of coils to be read. Coil addresses start at 0, that is, coil 33 is addressed as 32.

Example of a request to read coils 33–48 (status word) from follower device 01.

Table 50: Query

Field name	Example (hex)
Follower address	01 (drive address)
Function	01 (read coils)
Starting address HI	00
Starting address LO	20 (32 decimals) coil 33
Number of points HI	00
Number of points LO	10 (16 decimals)
Error check (CRC)	–

### Response

The coil status in the response telegram is packed as 1 coil per bit of the data field. Status is indicated as: 1 = ON; 0 = OFF. The lsb of the 1st data byte contains the coil addressed in the query. The other coils follow toward the high-order end of this byte, and from low order to high order in subsequent bytes.

If the returned coil quantity is not a multiple of 8, the remaining bits in the final data byte are padded with values 0 (toward the high-order end of the byte). The byte count field specifies the number of complete bytes of data.

Table 51: Response

Field name	Example (hex)
Follower address	01 (drive address)
Function	01 (read coils)
Byte count	02 (2 bytes of data)
Data (coils 40–33)	07
Data (coils 48–41)	06 (STW = 0607hex)
Error check (CRC)	–

### NOTICE

Coils and registers are addressed explicitly with an offset of -1 in Modbus. For example, coil 33 is addressed as coil 32.

### 9.10.3 Force/Write Single Coil (05 hex)

#### Description

This function forces the coil to either ON or OFF. When broadcast, the function forces the same coil references in all attached followers.

#### Query

The query telegram specifies the coil 65 (parameter write control) to be forced. Coil addresses start at 0, that is, coil 65 is addressed as 64. Force data = 00 00 hex (OFF) or FF 00 hex (ON).

Table 52: Query

Field name	Example (hex)
Follower address	01 (drive address)
Function	05 (write single coil)
Coil address HI	00
Coil address LO	40 (64 decimal) Coil 65
Force data HI	FF
Force data LO	00 (FF 00 = ON)
Error check (CRC)	–

## Response

The normal response is an echo of the query, returned after the coil state has been forced.

Table 53: Response

Field name	Example (hex)
Follower address	01
Function	05
Force data HI	FF
Force data LO	00
Quantity of coils HI	00
Quantity of coils LO	01
Error check (CRC)	–

### 9.10.4 Force/Write Multiple Coils (0F hex)

#### Description

This function forces each coil in a sequence of coils to either on or off. When broadcasting, the function forces the same coil references in all attached followers.

#### Query

The query telegram specifies the coils 17–32 (speed setpoint) to be forced.

#### NOTICE

Coil addresses start at 0, that is, coil 17 is addressed as 16.

Table 54: Query

Field name	Example (hex)
Follower address	01 (drive address)
Function	0F (write multiple coils)
Coil address HI	00
Coil address LO	10 (coil address 17)
Quantity of coils HI	00
Quantity of coils LO	10 (16 coils)
Byte count	02
Force data HI (Coils 8–1)	20
Force data LO (Coils 16–9)	00 (reference = 2000 hex)
Error check (CRC)	–

## Response

The normal response returns the follower address, function code, starting address, and quantity of coils forced.

Table 55: Response

Field name	Example (hex)
Follower address	01 (drive address)
Function	0F (write multiple coils)
Coil address HI	00
Coil address LO	10 (coil address 17)
Quantity of coils HI	00
Quantity of coils LO	10 (16 coils)
Error check (CRC)	–

## 9.10.5 Read Holding Registers (03 hex)

### Description

This function reads the contents of holding registers in the follower.

### Query

The query telegram specifies the starting register and quantity of registers to be read. Register addresses start at 0, that is, registers 1–4 are addressed as 0–3.

Example: Read *parameter 3-03 Maximum Reference*, register 03030.



Table 56: Query

Field name	Example (hex)
Follower address	01
Function	03 (Read holding registers)
Starting address HI	0B (Register address 3029)
Starting address LO	D5 (Register address 3029)
Number of points HI	00
Number of points LO	02 – ( <i>parameter 3-03 Maximum Reference</i> is 32 bits long, that is, 2 registers)
Error check (CRC)	–

### Response

The register data in the response telegram is packed as 2 bytes per register, with the binary contents right justified within each byte. For each register, the 1st byte contains the high-order bits, and the 2nd contains the low-order bits.

Example: hex 000088B8 = 35.000 = 35 Hz.

Table 57: Response

Field name	Example (hex)
Follower address	01
Function	03
Byte count	04
Data HI (register 3030)	00
Data LO (register 3030)	16
Data HI (register 3031)	E3
Data LO (register 3031)	60
Error check (CRC)	–

## 9.10.6 Preset Single Register (06 hex)

### Description

This function presets a value into a single holding register.

### Query

The query telegram specifies the register reference to be preset. Register addresses start at 0, that is, register 1 is addressed as 0.

Example: Write to *parameter 1-00 Configuration Mode*, register 1000.

Table 58: Query

Field name	Example (hex)
Follower address	01
Function	06
Register address HI	03 (register address 999)
Register address LO	E7 (register address 999)
Preset data HI	00
Preset data LO	01
Error check (CRC)	–

## Response

The normal response is an echo of the query, returned after the register contents have been passed.

Table 59: Response

Field name	Example (hex)
Follower address	01
Function	06
Register address HI	03
Register address LO	E7
Preset data HI	00
Preset data LO	01
Error check (CRC)	–

## 9.10.7 Preset Multiple Registers (10 hex)

### Description

This function presets values into a sequence of holding registers.

### Query

The query telegram specifies the register references to be preset. Register addresses start at 0, that is, register 1 is addressed as 0.

Example of a request to preset 2 registers (set *parameter 1-24 Motor Current* to 738 (7.38 A)):

Table 60: Query

Field name	Example (hex)
Follower address	01
Function	10
Starting address HI	04
Starting address LO	07

Table 60: Query (continued)

Field name	Example (hex)
Number of registers HI	00
Number of registers LO	02
Byte count	04
Write data HI (Register 4: 1049)	00
Write data LO (Register 4: 1049)	00
Write data HI (Register 4: 1050)	02
Write data LO (Register 4: 1050)	E2
Error check (CRC)	–

## Response

The normal response returns the follower address, function code, starting address, and quantity of registers preset.

Table 61: Response

Field name	Example (hex)
Follower address	01
Function	10
Starting address HI	04
Starting address LO	19
Number of registers HI	00
Number of registers LO	02
Error check (CRC)	–

## 9.11 Danfoss FC Control Profile

### 9.11.1 Control Word According to FC Profile (8-10 Protocol = FC Profile)

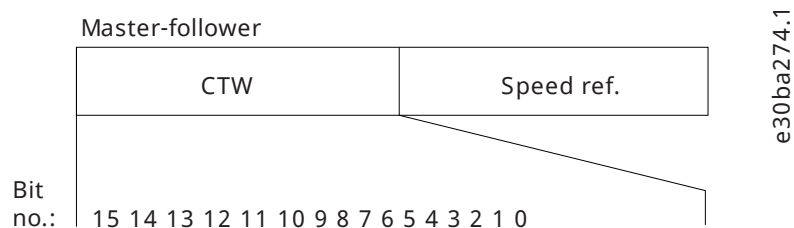


Figure 61: Control Word According to FC Profile

Table 62: Control Word According to FC Profile

Bit	Bit value=0	Bit value=1
00	Reference value	External selection lsb
01	Reference value	External selection msb
02	DC brake	Ramp
03	Coasting	No coasting
04	Quick stop	Ramp
05	Hold output frequency	Use ramp
06	Ramp stop	Start
07	No function	Reset
08	No function	Jog
09	Ramp 1	Ramp 2
10	Data invalid	Data valid
11	Relay 01 open	Relay 01 active
12	Relay 02 open	Relay 02 active
13	Parameter setup	Selection lsb
15	No function	Reverse

## Explanation of the control bits

### Bits 00/01

Bits 00 and 01 are used to select among the 4 reference values, which are preprogrammed in *parameter 3-10 Preset Reference* according to the following table.

Table 63: Control Bits

Programmed reference value	Parameter	Bit 01	Bit 00
1	<i>Parameter 3-10 Preset Reference</i> [0]	0	0
2	<i>Parameter 3-10 Preset Reference</i> [1]	0	1
3	<i>Parameter 3-10 Preset Reference</i> [2]	1	0
4	<i>Parameter 3-10 Preset Reference</i> [3]	1	1

## NOTICE

In *parameter 8-56 Preset Reference Select*, define how bit 00/01 gates with the corresponding function on the digital inputs.

### Bit 02, DC brake

Bit 02 = 0: Leads to DC brake and stop. Set braking current and duration in *parameter 2-01 DC Brake Current* and *parameter 2-02 DC Braking Time*.

Bit 02 = 1: Leads to ramping.

#### Bit 03, Coasting

Bit 03 = 0: The drive immediately releases the motor (the output transistors are shut off), and it coasts to a standstill.

Bit 03 = 1: If the other starting conditions are met, the drive starts the motor.

In *parameter 8-50 Coasting Select*, define how bit 03 gates with the corresponding function on a digital input.

#### Bit 04, Quick stop

Bit 04 = 0: Makes the motor speed ramp down to stop (set in *parameter 3-81 Quick Stop Ramp Time*).

#### Bit 05, Hold output frequency

Bit 05 = 0: The present output frequency (in Hz) freezes. Change the frozen output frequency only with the digital inputs programmed to [21] *Speed up* and [22] *Speed down* (*parameter 5-10 Terminal 18 Digital Input* to *parameter 5-13 Terminal 29 Digital Input*).

### NOTICE

If freeze output is active, the drive can only be stopped in 1 of the following ways:

- Bit 03 coast stop.
- Bit 02 DC brake
- Digital input programmed to [5] *DC brake inverse*, [2] *Coast inverse*, or [3] *Coast and reset inv* (*parameter 5-10 Terminal 18 Digital Input* to *parameter 5-13 Terminal 29 Digital Input*).

#### Bit 06, Ramp stop/start

Bit 06 = 0: Causes a stop and makes the motor speed ramp down to stop via the selected ramp-down parameter.

Bit 06 = 1: If the other starting conditions are met, bit 06 allows the drive to start the motor.

In *parameter 8-53 Start Select*, define how bit 06 ramp stop/start gates with the corresponding function on a digital input.

#### Bit 07, Reset

Bit 07 = 0: No reset.

Bit 07 = 1: Resets a trip. Reset is activated on the leading signal edge, that is, when changing from logic 0 to logic 1.

#### Bit 08, Jog

Bit 08 = 1: *Parameter 3-11 Jog Speed [Hz]* determines the output frequency.

#### Bit 09, Selection of ramp 1/2

Bit 09 = 0: Ramp 1 is active (*parameter 3-41 Ramp 1 Ramp Up Time* to *parameter 3-42 Ramp 1 Ramp Down Time*).

Bit 09 = 1: Ramp 2 is active (*parameter 3-51 Ramp 2 Ramp Up Time* to *parameter 3-52 Ramp 2 Ramp Down Time*).

#### Bit 10, Data not valid/Data valid

Tell the drive whether to use or ignore the control word.

Bit 10 = 0: The control word is ignored.

Bit 10 = 1: The control word is used. This function is relevant because the telegram always contains the control word, regardless of the telegram type. If the control word is not needed when updating or reading parameter, turn it off.

#### Bit 11, Relay 01

Bit 11 = 0: Relay not activated.

Bit 11 = 1: Relay 01 activated if [36] Control word bit 11 is selected in parameter 5-40 Function Relay.

**Bit 12, Relay 02**

Bit 12 = 0: Relay 02 is not activated.

Bit 12 = 1: Relay 02 is activated if [37] Control word bit 12 is selected in parameter 5-40 Function Relay.

**Bit 13, Set-up selection**

Use bit 13 to select from the 2 menu setups according to the following table.

Table 64: Menu Setups

Setup	Bit 13
1	0
2	1

The function is only possible when [9] Multi set-ups is selected in parameter 0-10 Active Set-up.

To define how bit 13 gates with the corresponding function on the digital inputs, use parameter 8-55 Set-up Select.

**Bit 15 Reverse**

Bit 15 = 0: No reversing.

Bit 15 = 1: Reversing. In the default setting, reversing is set to digital in parameter 8-54 Reversing Select. Bit 15 causes reversing only when serial communication [2] Logic OR or [3] Logic AND is selected.

**9.11.2 Status Word According to FC Profile (STW)**

Set parameter 8-30 Protocol to [0] FC.

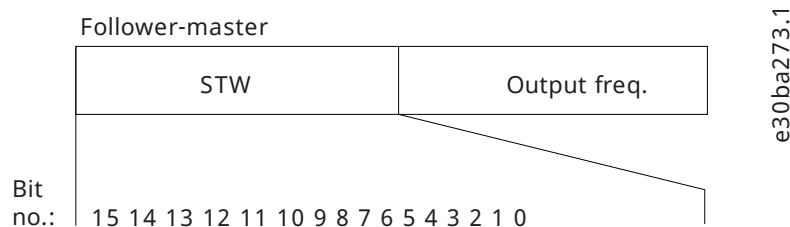


Figure 62: Status Word

Table 65: Status Word According to FC Profile

Bit	Bit value=0	Bit value=1
00	Control not ready	Control ready
01	Drive not ready	Drive ready
02	Coasting	Enable
03	No error	Trip
04	No error	Error (no trip)
05	Reserved	-
06	No error	Trip lock

Table 65: Status Word According to FC Profile (continued)

Bit	Bit value=0	Bit value=1
07	No warning	Warning
08	Speed≠reference	Speed=reference
09	Local operation	Bus control
10	Out of frequency limit	Frequency limit OK
11	No operation	In operation
12	Drive OK	Stopped, auto start
13	Voltage OK	Voltage exceeded
14	Torque OK	Torque exceeded
15	Timer OK	Timer exceeded

### Explanation of the status bits

#### Bit 00, Control not ready/ready

Bit 00=0: The drive trips.

Bit 00=1: The drive controls are ready but the power component does not necessarily receive any supply (if there is 24 V external supply to controls).

#### Bit 01, Drive ready

Bit 01=0: The drive is not ready.

Bit 01=1: The drive is ready for operation, but the coasting command is active via the digital inputs or via serial communication.

#### Bit 02, Coast stop

Bit 02=0: The drive releases the motor.

Bit 02=1: The drive starts the motor with a start command.

#### Bit 03, No error/trip

Bit 03=0: The drive is not in fault mode.

Bit 03=1: The drive trips. To re-establish operation, press *[Reset]*.

#### Bit 04, No error/error (no trip)

Bit 04=0: The drive is not in fault mode.

Bit 04=1: The drive shows an error but does not trip.

#### Bit 05, Not used

Bit 05 is not used in the status word.

#### Bit 06, No error/triplock

Bit 06=0: The drive is not in fault mode.

Bit 06=1: The drive is tripped and locked.

#### Bit 07, No warning/warning

Bit 07=0: There are no warnings.

Bit 07=1: A warning has occurred.

#### **Bit 08, Speed reference/speed=reference**

Bit 08=0: The motor runs, but the present speed is different from the preset speed reference. It might happen when the speed ramps up/down during start/stop.

Bit 08=1: The motor speed matches the preset speed reference.

#### **Bit 09, Local operation/bus control**

Bit 09=0: [Off/Reset] is activated on the control unit or [2] Local in **parameter 3-13 Reference Site** is selected. It is not possible to control the drive via serial communication.

Bit 09=1: It is possible to control the drive via the fieldbus/serial communication.

#### **Bit 10, Out of frequency limit**

Bit 10=0: The output frequency has reached the value in **parameter 4-12 Motor Speed Low Limit [Hz]** or **parameter 4-14 Motor Speed High Limit [Hz]**.

Bit 10=1: The output frequency is within the defined limits.

#### **Bit 11, No operation/in operation**

Bit 11=0: The motor is not running.

Bit 11=1: The drive has a start signal without coast.

#### **Bit 12, Drive OK/stopped, auto start**

Bit 12=0: There is no temporary overtemperature on the drive.

Bit 12=1: The drive stops because of overtemperature, but the unit does not trip and resumes operation once the overtemperature normalizes.

#### **Bit 13, Voltage OK/limit exceeded**

Bit 13=0: There are no voltage warnings.

Bit 13=1: The DC voltage in the drive's DC link is too low or too high.

#### **Bit 14, Torque OK/limit exceeded**

Bit 14=0: The motor current is lower than the current limit selected in **parameter 4-18 Current Limit**.

Bit 14=1: The current limit in **parameter 4-18 Current Limit** is exceeded.

#### **Bit 15, Timer OK/limit exceeded**

Bit 15=0: The timers for motor thermal protection and thermal protection are not exceeded 100%.

Bit 15=1: 1 of the timers exceeds 100%.

### 9.11.3 Bus Speed Reference Value

Speed reference value is transmitted to the drive in a relative value in %. The value is transmitted in the form of a 16-bit word. The integer value 16384 (4000 hex) corresponds to 100%. Negative figures are formatted using 2's complement. The actual output frequency (MAV) is scaled in the same way as the bus reference.



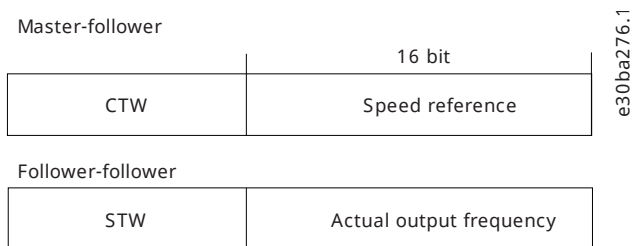


Figure 63: Actual Output Frequency (MAV)

The reference and MAV are scaled as follows:

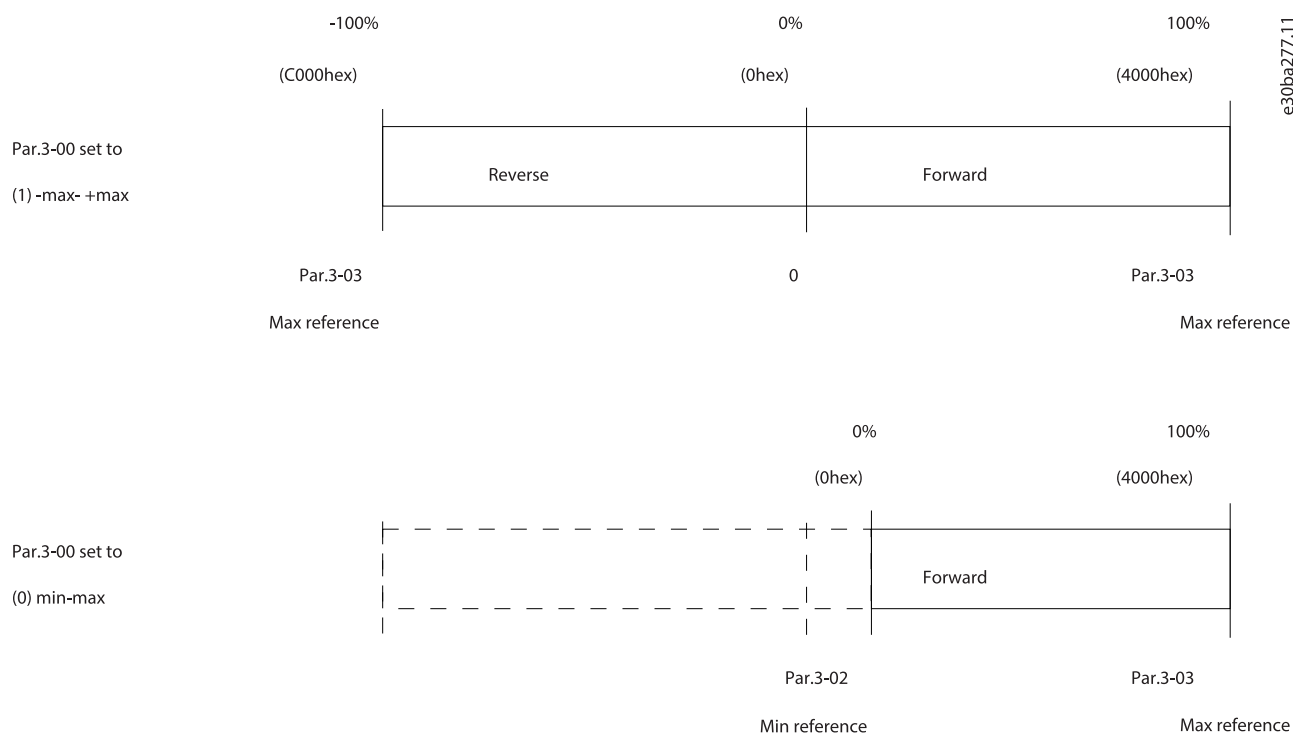


Figure 64: Reference and MAV

## 10 Application Examples

### 10.1 Introduction

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 53 or 54 are also shown.

### 10.2 AMA

Table 66: AMA with T27 Connected

	Parameter function	Parameter setting
	<b>Parameter 1-29 Automatic Motor Adaptation (AMA)</b>	[1] Enable complete AMA
	<b>Parameter 5-12 Terminal 27 Digital Input</b>	*[2] Coast inverse
*=Default value		
<b>Notes/comments:</b> Set <i>parameter group 1-2* Motor Data</i> according to motor specifications.		
<div style="background-color: #0056b3; color: white; padding: 5px; font-weight: bold;">NOTICE</div> <p>If terminals 12 and 27 are not connected, set <i>parameter 5-12 Terminal 27 Digital Input</i> to [0] No operation.</p>		

## 10.3 Speed

**Table 67: Analog Speed Reference (Voltage)**

	Parameter function	Parameter setting
	<b>Parameter 6-10 Terminal 53 Low Voltage</b>	*0.07 V
	<b>Parameter 6-11 Terminal 53 High Voltage</b>	*10 V
	<b>Parameter 6-14 Terminal 53 Low Ref./ Feedb. Value</b>	*0
	<b>Parameter 6-15 Terminal 53 High Ref./ Feedb. Value</b>	50 Hz
	<b>Parameter 6-19 Terminal 53 mode</b>	*[1] Voltage
	* = Default value	
	<b>Notes/comments:</b>	

Table 68: Analog Speed Reference (Current)

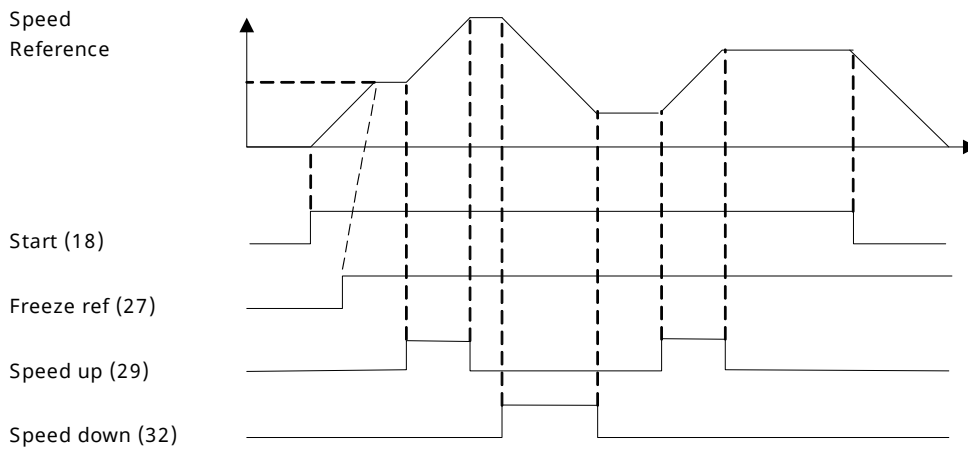
	Parameter function	Parameter setting
<p style="text-align: right;">e30bf819.1</p>	<b>Parameter 6-22 Terminal 54 Low Current</b>	*4 mA
	<b>Parameter 6-23 Terminal 54 High Current</b>	*20 mA
	<b>Parameter 6-24 Terminal 54 Low Ref./ Feedb. Value</b>	*0
	<b>Parameter 6-25 Terminal 54 High Ref./ Feedb. Value</b>	50 Hz
	<b>Parameter 6-29 Terminal 54 mode</b>	[0] Current
	* = Default value	
	Notes/comments:	

Table 69: Speed Reference (Using a Manual Potentiometer)

	Parameter function	Parameter setting
<p style="text-align: right;">e30bf820.1</p>	<b>Parameter 6-10 Terminal 53 Low Voltage</b>	*0.07 V
	<b>Parameter 6-11 Terminal 53 High Voltage</b>	*10 V
	<b>Parameter 6-14 Terminal 53 Low Ref./ Feedb. Value</b>	*0
	<b>Parameter 6-15 Terminal 53 High Ref./ Feedb. Value</b>	50 Hz
	<b>Parameter 6-19 Terminal 53 mode</b>	*[1] Voltage
	* = Default value	
Notes/comments:		

Table 70: Speed Up/Speed Down

	Parameter function	Parameter setting
	<b>Parameter 5-10 Terminal 18 Digital Input</b>	<b>*[8] Start</b>
	<b>Parameter 5-12 Terminal 27 Digital Input</b>	<b>[19] Freeze Reference</b>
	<b>Parameter 5-13 Terminal 29 Digital Input</b>	<b>[21] Speed Up</b>
	<b>Parameter 5-14 Terminal 32 Digital Input</b>	<b>[21] Speed Down</b>
	* = Default value	
	<b>Notes/comments:</b>	



e30bb840.1:

Figure 65: Speed Up/Speed Down

## 10.4 Start/Stop

Table 71: Start/Stop with Reversing and 4 Preset Speeds

	Parameter function	Parameter setting
	<b>Parameter 5-10 Terminal 18 Digital Input</b>	<b>*[8] Start</b>
	<b>Parameter 5-11 Terminal 19 Digital Input</b>	<b>*[10] Reversing</b>
	<b>Parameter 5-12 Terminal 27 Digital Input</b>	<b>[0] No operation</b>
	<b>Parameter 5-14 Terminal 32 Digital Input</b>	<b>[16] Preset ref bit 0</b>
	<b>Parameter 5-15 Terminal 33 Digital Input</b>	<b>[17] Preset ref bit 1</b>
	<b>Parameter 3-10 Preset Reference</b>	
	Preset ref. 0	25%
	Preset ref. 1	50%
	Preset ref. 2	75%
	Preset ref. 3	100%
	* = Default value	
	<b>Notes/comments:</b>	

## 10.5 External Alarm Reset

Table 72: External Alarm Reset

	Parameter function	Parameter setting
	<b>Parameter 5-11 Terminal 19 Digital Input</b>	<b>[1] Reset</b>
	* = Default value	
	<b>Notes/comments:</b>	

## 10.6 Motor Thermistor

<b>NOTICE</b>
To meet PELV insulation requirements, use reinforced or double insulation on the thermistors.

Table 73: Motor Thermistor

		Parameter function	Parameter setting
	e30bf824.1	<b>Parameter 1-90 Motor Thermal Protection</b>	[2] Thermistor trip
		<b>Parameter 1-93 Motor Thermal Source</b>	[1] Analog input 53
		<b>Parameter 6-19 Terminal 53 mode</b>	*[1] Voltage
		*=Default value	
		<b>Notes/comments:</b> If only a warning is needed, set <i>parameter 1-90 Motor Thermal Protection</i> to [1] Thermistor warning.	

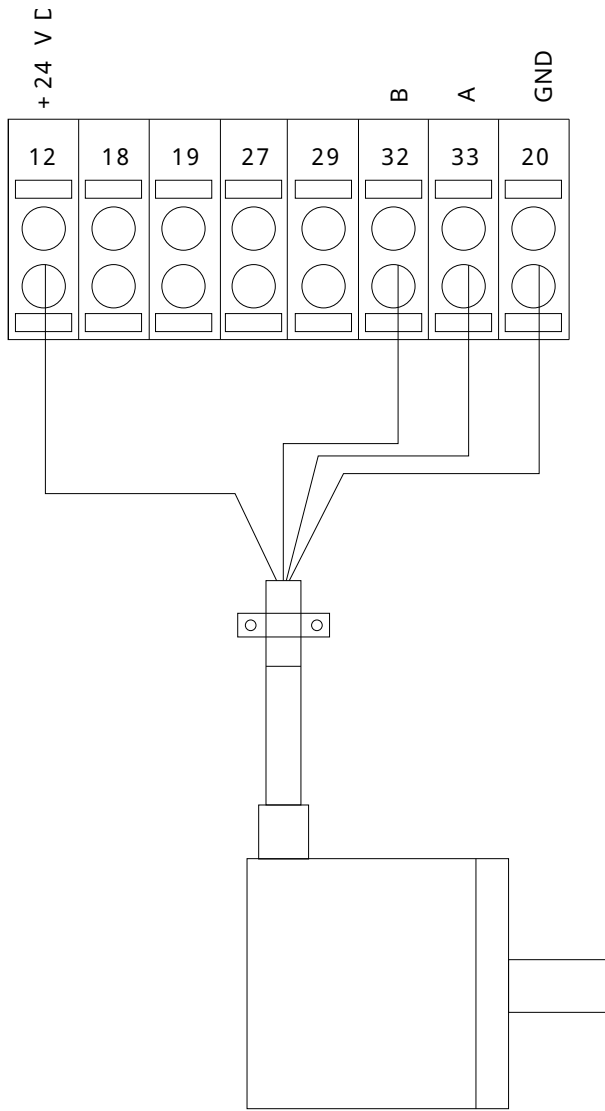


Table 74: Using SLC to Set a Relay

		Parameter function	Parameter setting
		<b>Parameter 4-30 Motor Feedback Loss Function</b>	[1] Warning
		<b>Parameter 4-31 Motor Feedback Speed Error</b>	100
		<b>Parameter 4-32 Motor Feedback Loss Timeout</b>	5 s
		<b>Parameter 7-00 Speed PID Feedback Source</b>	[2] MCB 102
		<b>Parameter 17-11 Resolution (PPR)</b>	*1024
		<b>Parameter 13-00 SL Controller Mode</b>	[1] On
		<b>Parameter 13-01 Start Event</b>	[19] Warning
		<b>Parameter 13-02 Stop Event</b>	[44] Reset key
		<b>Parameter 13-10 Comparator Operand</b>	[21] Warning no.
		<b>Parameter 13-11 Comparator Operator</b>	*[1]≈
		<b>Parameter 13-13 Comparator Value</b>	90
		<b>Parameter 13-51 SL Controller Event</b>	[22] Comparator 0
		<b>Parameter 13-52 SL Controller Action</b>	[32] Set digital out A low
		<b>Parameter 5-40 Function Relay</b>	[80] SL digital output A
		*≈Default value	
	<b>Notes/comments:</b> If the limit in the feedback monitor is exceeded, warning 90 feedback monitor is issued. The SLC monitors warning 90 feedback monitor. If warning 90 feedback monitor becomes true, relay 1 is triggered. External equipment could indicate that service is required. If the feedback error goes below the limit again within 5 s, the drive continues and the warning disappears. But relay 1 persists until [Off/Reset] is pressed.		

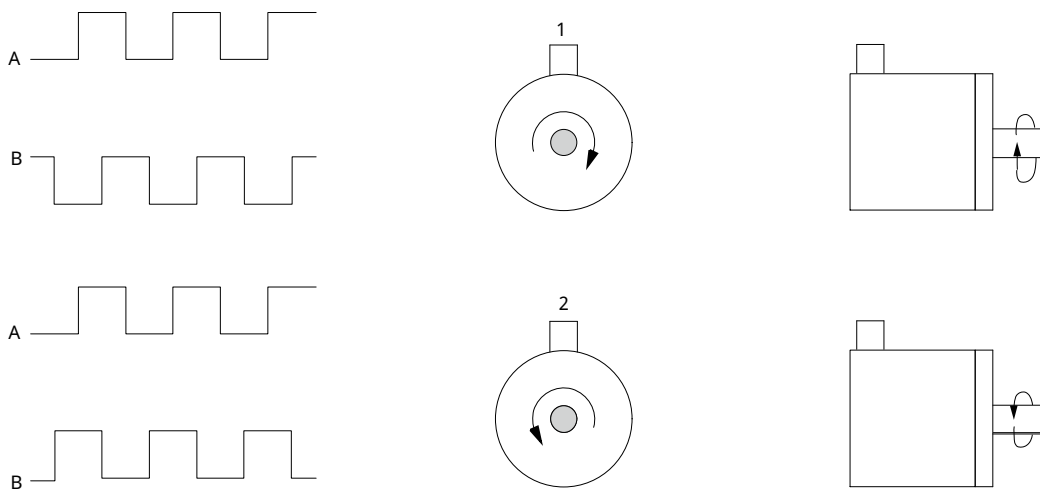
## 10.7 Encoder Connection

The purpose of this guideline is to ease the setup of encoder connection to the drive. Before setting up the encoder, the basic settings for a closed loop speed control system are shown.



e30bd366.1:

Figure 66: 24 V or 10–30 V Encoder



e30ba646.10

Figure 67: 24 V Incremental Encoder, Maximum Cable Length 5 m (16.4 ft)

## 10.8 Encoder Direction

The order in which the pulses enter the drive determines the direction of the encoder.

- Clockwise direction means that channel A is 90 electrical degrees before channel B.
- Counterclockwise direction means that channel B is 90 electrical degrees before A.

The direction is determined by looking into the shaft end.

## 10.9 Closed-loop Drive System

A drive system usually consists of more elements such as:

- Motor.
- Brake (gearbox, mechanical brake).
- Drive.
- Encoder as feedback system.
- Brake resistor for dynamic brake.
- Transmission.
- Load.

Applications demanding mechanical brake control usually need a brake resistor.

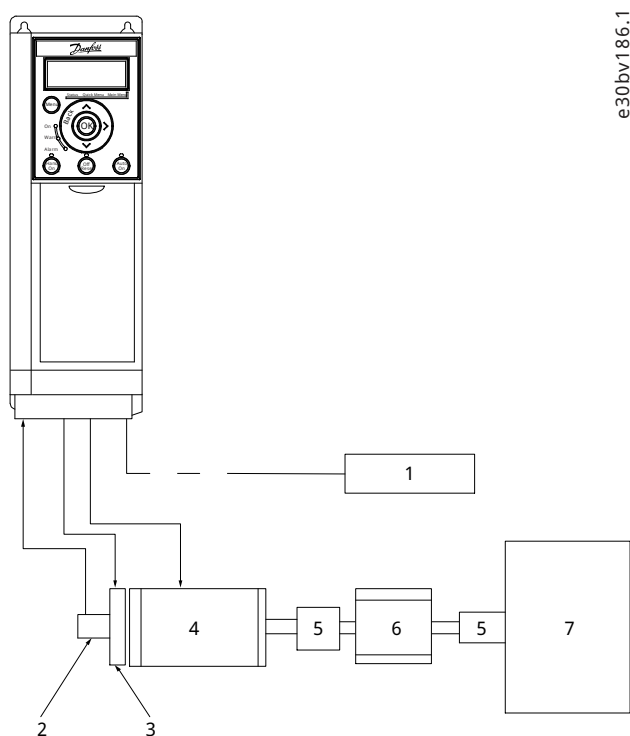


Figure 68: Basic Setup for Closed-loop Speed Control

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

# 11 How to Order a Drive

## 11.1 Drive Configurator

Configure the correct drive for the proper application by using the internet-based Drive Configurator. The Drive Configurator is found on the global internet site: [Low Voltage Drives | Danfoss Global Product Store](#). The configurator creates a type code string and an 8-digit sales number, which can be delivered to the local sales office. It is also possible to build a project list with several products and send it to a Danfoss sales representative.

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
F	C	-	3	6	0					T	4	E	2	0	H	2	X	X	C	X	X	X	S	X	X	X	X	A		B	X

e30bv168.1

Figure 69: Type Code String

An example of a type code string is:

FC-360Q110T4E20H2XXCXXXSXXXXA0BX

The meaning of the characters in the string is defined in this chapter. In the example above, a drive is configured with the following options:

- RFI filter, Class A2.
- 3C3.
- PROFIBUS DP-V1.

Drives are delivered automatically with English, Chinese, and Portuguese.

## 11.2 Ordering VLT® AutomationDrive FC 360 Enclosure Size J8–J9

Table 75: Ordering Type Code for Enclosures J8–J9

Description	Pos	Possible choice
Product group	1–6	FC-360
Model	7–10	<ul style="list-style-type: none"> <li>• Q110: 110 kW (150 hp)</li> <li>• Q132: 132 kW (200 hp)</li> <li>• Q160: 160 kW (250 hp)</li> <li>• Q200: 200 kW (300 hp)</li> <li>• Q250: 250 kW (350 hp)</li> <li>• Q315: 315 kW (450 hp)</li> <li>• H90K: 90 kW (125 hp)</li> <li>• H110: 110 kW (150 hp)</li> <li>• H132: 132 kW (200 hp)</li> <li>• H160: 160 kW (250 hp)</li> <li>• H200: 200 kW (300 hp)</li> <li>• H250: 250 kW (350 hp)</li> </ul>
Mains voltage	11–12	T4: 380–480 V AC
Enclosure	13–15	E20: IP20
RFI filter	16–17	H2: RFI filter, class A2
Brake	18	X: No brake IGBT

Table 75: Ordering Type Code for Enclosures J8–J9 (continued)

Description	Pos	Possible choice
Display	19	X: No Local Control Panel
PCB coating	20	C: 3C3
Mains option	21	X: No mains option
Adaptation	22	X: Standard cable entries
Adaptation	23	X: No adaptation
Software release	24–27	SXXX: Standard software
Software language	28	X: Standard language pack
A options	29–30	<ul style="list-style-type: none"> <li>• AX: No A option</li> <li>• A0: VLT® PROFIBUS DP MCA 101</li> <li>• AL: VLT® PROFINET MCA 120</li> </ul>
B options	31–32	BX: No option

### 11.3 Ordering Accessories and Spare Parts

Table 76: Code Numbers for Accessories

Description	Code number
VLT® PROFIBUS DP MCA 101	134B6778
VLT® PROFINET MCA 120	134B6779
VLT® encoder input MCB 102	132B0282
VLT® resolver input MCB 103	132B0283
VLT® 24 V DC supply MCB 107	130B1208
VLT® Sensor Input Option MCB 114	130B1272
VLT® graphical control panel LCP 23	132B0801
VLT® numeric control panel LCP 21	132B0254
Remote mounting kit for LCP with cable, 3 m	132B0102
LCP remote mounting cable, 3 m	132B0132

Table 77: Code Numbers for Spare Parts

Description	Code number
Control card for FC 360 J8–J9	132G0279

For more spare parts, contact Danfoss.

## 11.4 Ordering Filters and Brake Resistors

Refer to the following design guides for dimensioning specifications and ordering numbers for filters and brake resistors:

- VLT® Brake Resistor MCE 101 Design Guide.
- VLT® Advanced Harmonic Filters AHF 005/AHF 010 Design Guide.
- Output Filters Design Guide.

## 12 Appendix

### 12.1 Abbreviations and Symbols

Table 78: Abbreviations and Symbols

60° AVM	60° asynchronous vector modulation
A	Ampere/AMP
AC	Alternating current
ACP	Application control processor
AD	Air discharge
AEO	Automatic energy optimization
AI	Analog input
AIC	Ampere interrupting current
AMA	Automatic motor adaptation
AWG	American wire gauge
°C	Degrees Celsius
CB	Circuit breaker
CD	Constant discharge
CDM	Complete Drive Module: The drive, feeding section, and auxiliaries.
CE	European conformity (European safety standards)
CM	Common-mode
CT	Constant torque
DC	Direct current
DI	Digital input
DM	Differential mode
D-TYPE	Drive dependent
EEPROM	Electrically erasable programmable read-only memory
EMC	Electromagnetic compatibility
EMF	Electromotive force
EMI	Electromagnetic interference
ESD	Electrostatic discharge
ETR	Electronic thermal relay
°F	Degrees Fahrenheit
$f_{JOG}$	Motor frequency when jog function is activated.
$f_M$	Motor frequency

Table 78: Abbreviations and Symbols (continued)

$f_{MAX}$	Maximum output frequency that the drive applies on its output.
$f_{MIN}$	Minimum motor frequency from the drive.
$f_{M,N}$	Nominal motor frequency
FC	Frequency converter (drive)
FSP	Fixed-speed pump
g	Gram
HO	High overload
Hp	Horse power
Hz	Hertz
$I_{INV}$	Rated inverter output current
$I_{LIM}$	Current limit
$I_{M,N}$	Nominal motor current
$I_{VLT,MAX}$	Maximum output current
$I_{VLT,N}$	Rated output current supplied by the drive
IGBT	Insulated-gate bipolar transistor
IP	Ingress protection
kHz	Kilohertz
LCP	Local control panel
LED	Light-emitting diode
$L_d$	Motor d-axis inductance
$L_q$	Motor q-axis inductance
Lsb	Least significant bit
m	Meter
mA	Milliampere
MCM	Mille circular mil
MCP	Motor control processor
MCT	Motion control tool
mH	Inductance in milli Henry
min	Minute
mm	Millimeter
ms	Millisecond
Msb	Most significant bit
$\eta_{VLT}$	Efficiency of the drive defined as ratio between power output and power input.



Table 78: Abbreviations and Symbols (continued)

NEMA	National Electrical Manufacturers Association
nF	Capacitance in nano Farad
NLCP	Numerical local control panel
Nm	Newton meter
NO	Normal overload
$n_s$	Synchronous motor speed
On/Offline parameters	Changes to online parameters are activated immediately after the data value is changed
$P_{br, cont.}$	Rated power of the brake resistor (average power during continuous braking)
PCB	Printed circuit board
PCD	Process data
PDS	Power drive system: CDM and a motor
PE	Protective earth
PELV	Protective extra low voltage
$P_m$	Drive nominal output power as high overload
$P_{M, N}$	Nominal motor power
PM motor	Permanent magnet motor
Process PID	Proportional integrated differential regulator that maintains the speed, pressure, temperature, and so on.
PWM	Pulse width modulation
$R_{br, nom}$	Nominal resistor value that ensures a brake power on the motor shaft of 150/160% for 1 minute.
RCD	Residual current device
Regen	Regenerative terminals
RFI	Radio frequency interference
$R_{min}$	Minimum allowed brake resistor value by the drive
RMS	Root average square
RPM	Revolutions per minute
$R_{rec}$	Recommended brake resistor resistance of Danfoss brake resistors
$R_s$	Stator resistance
s	Second
SCR	Silicon controlled rectifier
SCCR	Short-circuit current rating
SFAVM	Stator flux-oriented asynchronous vector modulation
STW	Status word
SMPS	Switch mode power supply

Table 78: Abbreviations and Symbols (continued)

THD	Total harmonic distortion
$T_{LIM}$	Torque limit
TTL	TTL encoder (5 V) pulses - transistor logic
$U_{M, N}$	Nominal motor voltage
UL	Underwriters Laboratories (US organization for the safety certification)
V	Volts
VSP	Variable-speed pump
VT	Variable torque
VVC+	Voltage vector control plus
$X_h$	Motor main reactance

## 12.2 Definitions

### 12.2.1 AC Drive

#### 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.

### 12.2.2 Input

#### Control commands

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

Functions are divided into 2 groups. Functions in group 1 have higher priority than functions in group 2.

Table 79: Function Groups

Group 1	Coast stop, reset and coast stop, quick stop, DC braking, stop, and [OFF].
Group 2	Start, latched start, start reversing, jog, freeze output, and [Hand On].

### 12.2.3 Motor

#### 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.  $n_s = \frac{2 \times \text{Parameter1} - 23 \times 60s}{\text{Parameter1} - 39}$

$n_{slip}$

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**

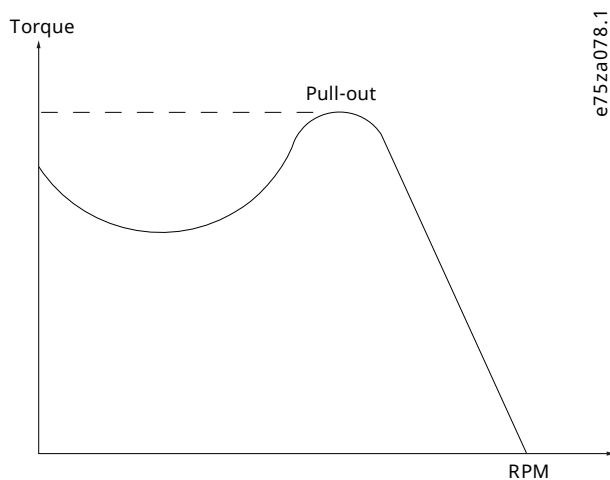


Figure 70: Break-away Torque

#### $\eta_{VLT}$

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. See the table in the *chapter Input* for more details.

#### Stop command

A stop command belonging to the control commands in group 1. See the table in the *chapter Input* for more details.

### 12.2.4 References

#### Analog reference

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

#### Binary reference

A signal transmitted 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 transmitted 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*.

### 12.2.5 Miscellaneous

#### 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: 0–10 V DC.

#### **Analog outputs**

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

#### **Automatic motor adaptation, AMA**

The 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 transmitted 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.

#### **ETR**

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

#### **FC standard bus**

Includes RS485 bus with FC protocol or MC protocol. See *parameter 8-30 Protocol*.

#### **Initializing**

If initializing is carried out (*parameter 14-22 Operation Mode*), the drive returns to the default setting.

#### **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 LCP is detachable. With the installation kit option, the LCP can be installed up to 3 m (9.8 ft) from the drive in a front panel.

#### **GLCP**

The graphic local control panel interface for control and programming of the drive. The display is graphic and the panel is used to show process values. The GLCP has storing and copy functions.

#### **NLCP**

The numerical local control panel interface for control and programming of the drive. The display is numerical and the panel is used to show process values. The NLCP has storing and copy functions.

#### **Isb**

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<sup>2</sup>.

**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 speed, pressure, and temperature 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 power on again.

**Power factor**

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

$$\text{Powerfactor} = \frac{\sqrt{3} \times U \times I_1 \cos\phi_1}{\sqrt{3} \times U \times I_{RMS}}$$

For this drive,  $\cos\phi_1 = 1$ , therefore:  $\text{Powerfactor} = \frac{I_1 \times \cos\phi_1}{I_{RMS}} = \frac{I_1}{I_{RMS}}$

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.

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

In addition, a high power factor indicates that the different harmonic currents are low.

The built-in DC coils produce a high power factor, minimizing the imposed load on the mains supply.

**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 2 setups. Change between the 2 parameter setups and edit 1 setup while the other setup is active.

**SFAVM**

Acronym describing the switching pattern stator flux-oriented asynchronous vector modulation.

**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.

**Smart logic control (SLC)**

The SLC is a sequence of user-defined actions executed when the associated user-defined events are evaluated as true by the SLC. (*Parameter group 13-\*\* Smart Logic*).

**STW**

Status word.

**THD**

Total harmonic distortion states the total contribution of harmonic distortion.

**Thermistor**

A temperature-dependent resistor 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**

Trip lock is a state entered in fault situations when the drive is protecting itself and requiring physical intervention. An example causing a trip lock is the drive being subject to a short circuit on the output. A locked trip can only be canceled by cutting off 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 trip lock for personal safety.

**VT characteristics**

Variable torque characteristics for pumps and fans.

**VVC+**

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

**60° AVM**

Refers to the switching pattern 60° asynchronous vector modulation.

## 12.3 Conventions

- Numbered lists indicate procedures and description of illustrations.
- Bullet lists indicate other information.
- Italicized text indicates:
  - Cross-reference.
  - Link.
  - Parameter name.
  - Parameter group name.
  - Parameter option.
  - Footnote.
- All dimensions in drawings are in [mm] (in).
- An asterisk (\*) indicates a default setting of a parameter.







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