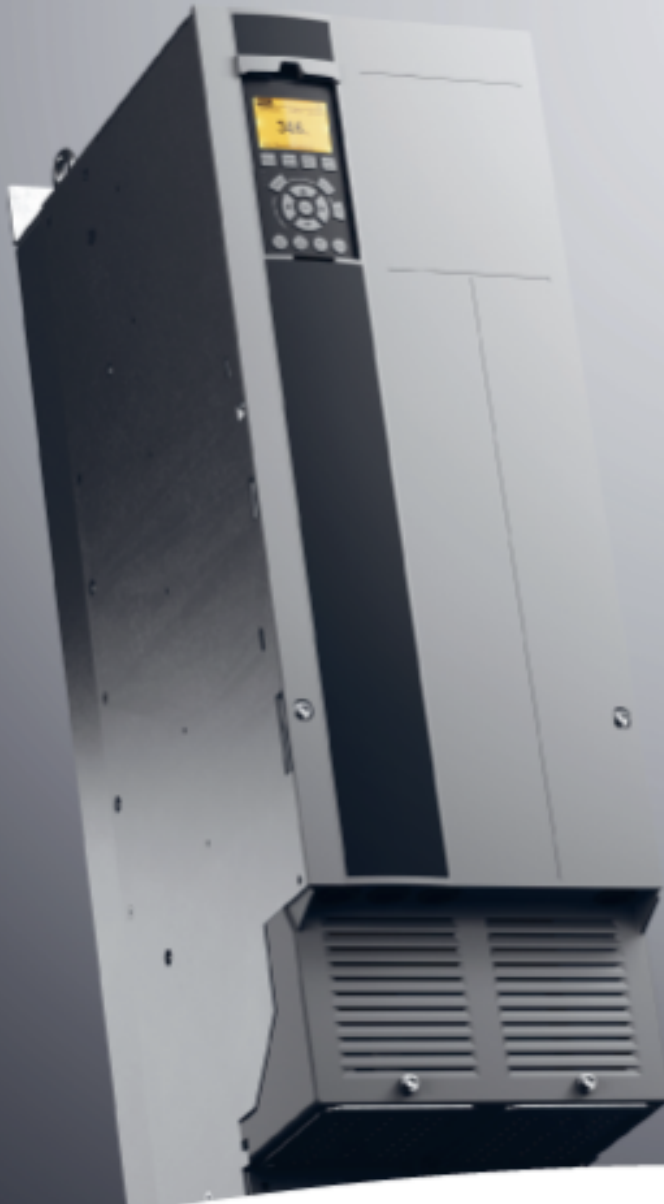




Design Guide

VLT[®] AutomationDrive FC 361

90–315 kW, Enclosure Sizes J8–J9



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1 Introduction

1.1 Purpose of the Design Guide

This design guide is intended for:

- 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.

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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. See www.danfoss.com/en/search/?filter=type%3Adocumentation%2Csegment%3Aadds for listings.

1.3 Document and Software Version

This manual is regularly reviewed and updated. All suggestions for improvement are welcome. *Table 1.1* shows the version of the manual and the corresponding software version.

Manual version	Remarks	Software version
MG06K1xx	First edition.	1.0x

Table 1.1 Manual and Software Version

1.4 Approvals and Certifications

Drives are designed in compliance with the directives described in this section.

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 stand-alone device or as part of a more complex installation. Devices in either of these cases must bear the CE mark. Systems must not be CE-marked but must comply with the basic protection requirements of the EMC directive.

1.5 Conventions

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

2 Safety

2.1 Safety Symbols

The following symbols are used in this guide:

⚠ WARNING

Indicates a potentially hazardous situation that could result in death or serious injury.

⚠ CAUTION

Indicates a potentially hazardous situation that could result in minor or moderate injury. It can also be used to alert against unsafe practices.

NOTICE

Indicates important information, including situations that can result in damage to equipment or property.

2.2 Qualified Personnel

Only qualified personnel are allowed to install or 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 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.

⚠ WARNING

DISCHARGE TIME

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 the specified time 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

LEAKAGE CURRENT HAZARD

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

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

3 Product Overview and Features

3.1 Power Ratings, Weights, and Dimensions

For enclosure sizes and power ratings of the drives, refer to *Table 3.1*. For more dimensions, see *chapter 5.8 Exterior and Terminal Dimensions*.

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)

Table 3.1 Power Ratings, Weight, and Dimensions, Enclosure Sizes J8–J9, 380–480 V

3.2 Automated Operational Features

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

For details of any set-up required, in particular motor parameters, refer to the *programming guide*.

3.2.1 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.

3.2.2 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 high RPM, 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

OVC can be activated for a PM motor.

NOTICE

Do not enable OVC in hoisting applications.

3.2.3 Missing Motor Phase Detection

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

3.2.4 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 (*parameter 14-12 Response to Mains Imbalance*).

3.2.5 Switching on the Output

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

3.2.6 Overload Protection

Torque limit

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

Current limit

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

Speed limit

Minimum speed limit: *Parameter 4-11 Motor Speed Low Limit [RPM]* or *parameter 4-12 Motor Speed Low Limit [Hz]* limit the minimum operating speed range of the drive. Maximum speed limit: *Parameter 4-13 Motor Speed High Limit [RPM]* or *parameter 4-19 Max Output Frequency* 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 *Illustration 3.1*.

Voltage limit

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

Overtemperature

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

3.2.7 Locked Rotor Protection

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

3.2.8 Automatic Derating

The drive constantly checks for the following critical levels:

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

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

NOTICE

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

3.2.9 Automatic Energy Optimization

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

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

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

3.2.10 Automatic Switching Frequency Modulation

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

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

3.2.11 Automatic Derating for High Switching Frequency

The drive is designed for continuous, full-load operation at switching frequencies between 1.5–2 kHz for 380–480 V. The frequency range depends on power size and voltage rating. A switching frequency exceeding the maximum allowed range generates increased heat in the drive and requires the output current to be derated.

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

3.2.12 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.

3.2.13 Resonance Damping

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

3.2.14 Temperature-controlled Fans

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

3.2.15 EMC Compliance

Electromagnetic interference (EMI) and radio frequency interference (RFI) are disturbances that can affect an electrical circuit due to electromagnetic induction or radiation from an external source. The drive is designed to comply with the EMC product standard for drives IEC 61800-3 and the European standard EN 55011. Motor cables must be shielded and properly terminated to comply with the emission levels in EN 55011. For more information regarding EMC performance, see *chapter 7.13.1 EMC Test Results*.

3.2.16 Galvanic Isolation of Control Terminals

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

The components that make up the galvanic isolation are:

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

3.3 Custom Application Features

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

3.3.1 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.

3.3.2 Built-in PID Controller

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

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

3.3.3 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 *Illustration 3.1*.

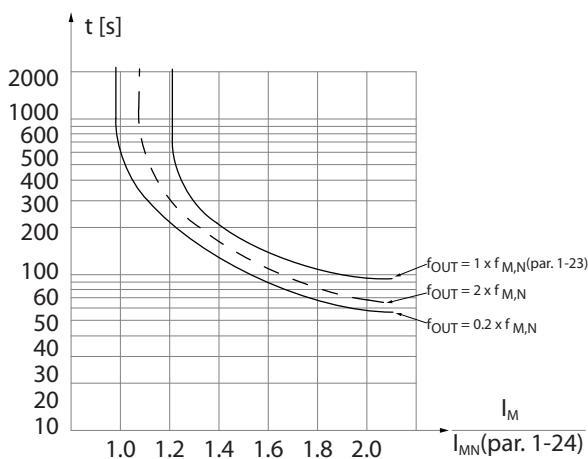


Illustration 3.1 ETR

The X-axis shows the ratio between I_{motor} and I_{motor} nominal. The Y-axis shows the time in seconds before the ETR cuts off and trips the drive. The curves show the characteristic nominal speed at twice the nominal speed and at 0.2 x the nominal speed.

At lower speed, the ETR cuts off at lower heat due to less cooling of the motor. In that way, the motor is protected from being overheated even at low speed. The ETR feature calculates the motor temperature based on actual current and speed. The calculated temperature is visible as a readout parameter in *parameter 16-18 Motor Thermal*.

3.3.4 Mains Drop-out

During a mains drop-out, 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 drop-out 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 drop-out:

- 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 drop-out. This option is relevant for centrifuges and fans.

Kinetic back-up

This selection ensures that the drive runs as long as there is energy in the system. For short mains drop-out, 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 drop-out in *parameter 14-10 Mains Failure* and *parameter 1-73 Flying Start*.

3.3.5 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.

3.3.6 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.

3.3.7 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

3.3.8 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.

3.3.9 Programmable Set-ups

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

Set-up data can be copied from drive to drive by downloading the information from the removable LCP.

3.3.10 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 *Illustration 3.2*.

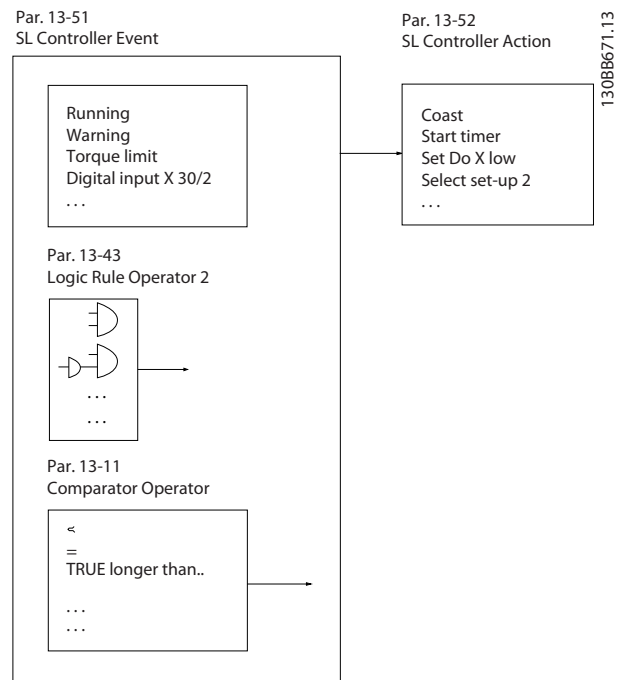
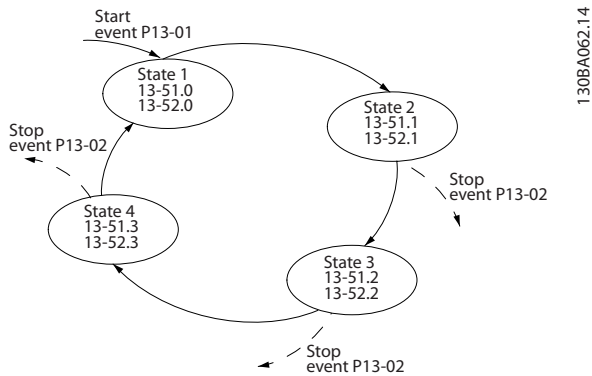


Illustration 3.2 SLC Event and Action

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]. *Illustration 3.3* shows an example with 4 event/actions:



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Illustration 3.3 Order of Execution when 4 Events/Actions are Programmed

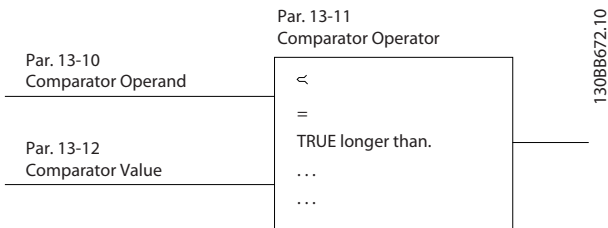
3.4 Dynamic Braking Overview

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

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

Comparators

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

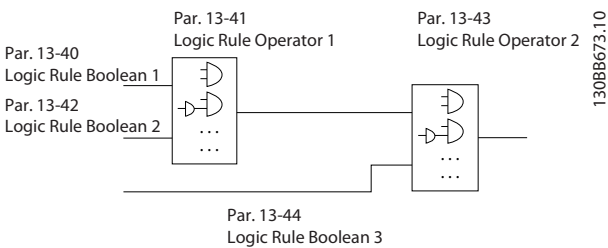


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Illustration 3.4 Comparators

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.



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Illustration 3.5 Logic Rules

3

3.5 Back-channel Cooling Overview

A unique back-channel duct passes cooling air over the heat sinks with minimal air passing through the electronics area. There is an IP54/Type 12 seal between the back-channel cooling duct and the electronics area of the VLT® drive. This back-channel cooling allows 90% of the heat losses to be exhausted directly outside the enclosure. 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.

3.5.1 Airflow for J8 & J9 Enclosures

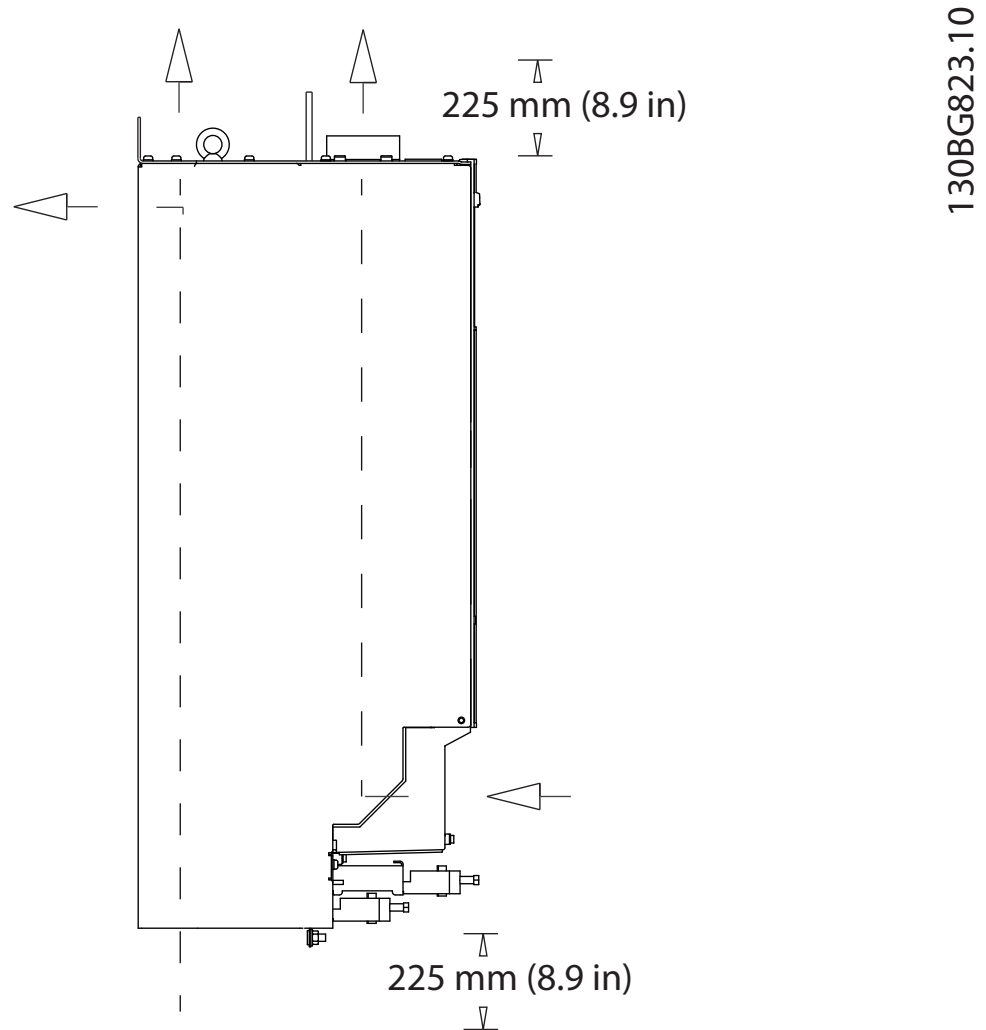


Illustration 3.6 Standard Airflow Configuration for Enclosures J8 and J9

4 Options and Accessories Overview

4.1 Fieldbus Devices

This section describes the fieldbus devices that are available with the VLT® AutomationDrive FC 361 series. Using a fieldbus device reduces system cost, delivers faster and more efficient communication, and provides an easier user interface. For ordering numbers, refer to *chapter 10.2 Ordering Numbers for Options and Accessories*.

4.1.1 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.

4.1.2 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.
- Supports DP-V1. Diagnostic allows easy, fast, and standardized handling of warning and fault information into the PLC, improving bandwidth in the system.
- Implementation in accordance with Conformance Class B.

4.2 Functional Extensions

This section describes the functional extension options that are available with the VLT® AutomationDrive FC 361 series. For ordering numbers, refer to *chapter 10.2 Ordering Numbers for Options and Accessories*.

4.2.1 VLT® General Purpose I/O Module MCB 101

The VLT® General Purpose I/O Module MCB 101 offers an extended number of control inputs and outputs:

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

4.2.2 VLT® Encoder Input MCB 102

The 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 and closed-loop flux motor control.

The following encoder types are supported:

- 5 V TTL (RS 422).
- 1VPP SinCos.

4.2.3 VLT® Resolver Option MCB 103

The 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.

5 Specifications

5.1 Electrical Data, 380-480 V

VLT® AutomationDrive FC 361	N90K		N110		N132		N160	
High/normal overload (High overload=150% current during 60 s, normal overload=110% current during 60 s)	NO	HO	NO	HO	NO	HO	NO	
Typical shaft output at 400 V [kW]	90	90	110	110	132	132	160	
Typical shaft output at 460 V [hp]	125	125	150	150	200	200	250	
Enclosure size	J8							
Output current (3-phase)								
Continuous (at 400 V) [A]	177	177	212	212	260	260	315	
Intermittent (60 s overload) (at 400 V) [A]	195	266	233	318	286	390	347	
Continuous (at 460 V) [A]	160	160	190	190	240	240	302	
Intermittent (60 s overload) (at 460 V) [kVA]	176	240	209	285	264	360	332	
Continuous kVA (at 400 V) [kVA]	123	123	147	147	180	180	218	
Continuous kVA (at 460 V) [kVA]	127	127	151	151	191	191	241	
Maximum input current								
Continuous (at 400 V) [A]	171	171	204	204	251	251	304	
Continuous (at 460 V) [A]	154	154	183	183	231	231	291	
Maximum number and size of cables per phase								
Mains and motor [mm ² (AWG)]	2x95 (2x3/0)							
Maximum external mains fuses [A] ¹⁾	315	315		350		400		
Estimated power loss at 400 V [W] ^{2), 3)}	2031	2031	2559	2289	2954	2923	3770	
Estimated power loss at 460 V [W] ^{2), 3)}	1828	1828	2261	2051	2724	2089	3628	
Efficiency ³⁾	0.98							
Output frequency [Hz]	0–590							
Heat sink overtemperature trip [°C (°F)]	110 (230)							
Weight, enclosure protection rating IP20 kg (lbs)	98 (216)							
Efficiency ³⁾	0.98							
Output frequency [Hz]	0–590							
Heat sink overtemperature trip [°C (°F)]	110 (230)							
Control card overtemperature trip [°C (°F)]	75 (167)							

Table 5.1 Electrical Data for Enclosures J8, Mains Supply 3x380–480 V AC

1) For fuse ratings, see chapter 7.5 Fuses and Circuit Breakers.

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

3) Measured using 5 m (16.4 ft) shielded motor cables at rated load and rated frequency. Efficiency measured at nominal current. For energy efficiency class, see chapter 5.4 Ambient Conditions. For part load losses, see drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/.

VLT® AutomationDrive FC 361	N200		N250		N315	
High/normal overload (High overload=150% current during 60 s, normal overload=110% current during 60 s)	HO	NO	HO	NO	HO	NO
Typical shaft output at 400 V [kW]	160	200	200	250	250	315
Typical shaft output at 460 V [hp]	250	300	300	350	350	450
Enclosure size	J9					
Output current (3-phase)						
Continuous (at 400 V) [A]	315	395	395	480	480	588
Intermittent (60 s overload) (at 400 V) [A]	473	435	593	528	720	647
Continuous (at 460 V) [A]	302	361	361	443	443	535
Intermittent (60 s overload) (at 460 V) [kVA]	453	397	542	487	665	589
Continuous kVA (at 400 V) [kVA]	218	274	274	333	333	407
Continuous kVA (at 460 V) [kVA]	241	288	288	353	353	426
Maximum input current						
Continuous (at 400 V) [A]	304	381	381	463	463	567
Continuous (at 460 V) [A]	291	348	348	427	427	516
Maximum number and size of cables per phase						
Mains and motor [mm ² (AWG)]	2x185 (2x350 mcm)					
Maximum external mains fuses [A] ¹⁾	550		630		800	
Estimated power loss at 400 V [W] ^{2), 3)}	3093	4116	4039	5137	5004	6674
Estimated power loss at 460 V [W] ^{2), 3)}	2872	3569	3575	4566	4458	5714
Efficiency ³⁾	0.98					
Output frequency [Hz]	0-590					
Heat sink overtemperature trip [°C (°F)]	110 (230)					
Weight, enclosure protection rating IP20 kg (lbs)	164 (362)					
Efficiency ³⁾	0.98					
Output frequency [Hz]	0-590					
Heat sink overtemperature trip [°C (°F)]	110 (230)					
Control card overtemperature trip [°C (°F)]	80 (176)					

Table 5.2 Electrical Data for Enclosures J9, Mains Supply 3x380-480 V AC

1) For fuse ratings, see chapter 7.5 Fuses and Circuit Breakers.

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

3) Measured using 5 m (16.4 ft) shielded motor cables at rated load and rated frequency. Efficiency measured at nominal current. For energy efficiency class, see chapter 5.4 Ambient Conditions. For part load losses, see drives.danfoss.com/knowledge-center/energy-efficiency-directive/#/.

5.2 Mains Supply

Mains supply (L1, L2, L3)

Supply voltage 380–480 V ±10%

Mains voltage low/mains voltage drop-out:

During low mains voltage or a mains drop-out, the drive continues until the DC-link voltage drops below the minimum stop level, which corresponds typically to 15% below the 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.

Supply frequency 50/60 Hz ±5%

Maximum imbalance temporary between mains phases 3.0% of rated supply voltage¹⁾

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

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.

1) Calculations based on IEC61800-3.

5.3 Motor Output and Motor Data

Motor output (U, V, W)

Output voltage 0–100% of supply voltage

Output frequency 0–590 Hz¹⁾

Output frequency in flux mode 0–300 Hz

Switching on output Unlimited

Ramp times 0.01–3600 s

1) Dependent on voltage and power.

Torque characteristics

Starting torque (constant torque) Maximum 150% for 60 s^{1), 2)}

Overload torque (constant torque) Maximum 150% for 60 s^{1), 2)}

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

2) Once every 10 minutes.

5.4 Ambient Conditions

Environment

J8/J9 enclosure IP20/Chassis

Vibration test (standard/ruggedized) 0.7 g/1.0 g

Relative humidity 5%–95% (IEC 721-3-3; Class 3K3 (non-condensing) during operation)

Aggressive environment (IEC 60068-2-43) H₂S test Class Kd

Aggressive gases (IEC 60721-3-3) Class 3C3

Test method according to IEC 60068-2-43 H2S (10 days)

Ambient temperature (at SFAVM switching mode)

- with derating Maximum 55 °C (131 °F)¹⁾

- with full output power of typical EFF2 motors (up to 90% output current) Maximum 50 °C (122 °F)¹⁾

- at full continuous FC output current Maximum 45 °C (113 °F)¹⁾

Minimum ambient temperature during full-scale operation 0 °C (32 °F)

Minimum ambient temperature at reduced performance -10 °C (14 °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)

1) For more information on derating, see chapter 6.6 Derating.

EMC standards, Emission

EN 61800-3

EMC standards, Immunity	EN 61800-3
Energy efficiency class ¹⁾	IE2

1) Determined according to EN 50598-2 at:

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

5.5 Cable Specifications

Cable lengths and cross-sections for control cables

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 chapter 5.1 Electrical Data, 380-480 V ¹⁾
Maximum cross-section to control terminals, rigid wire	1.5 mm ² /16 AWG (2x0.75 mm ²)
Maximum cross-section to control terminals, flexible cable	1 mm ² /18 AWG
Maximum cross-section to control terminals, cable with enclosed core	0.5 mm ² /20 AWG
Minimum cross-section to control terminals	0.25 mm ² /23 AWG

1) For power cables, see electrical data in chapter 5.1 Electrical Data, 380-480 V.

5.6 Control Input/Output and Control Data

Digital inputs

Programmable digital inputs	4 (6)
Terminal number	18, 19, 27 ¹⁾ , 29 ¹⁾ , 32, 33
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
Input resistance, R _i	Approximately 4 kΩ

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

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

Analog inputs

Number of analog inputs	2
Terminal number	53, 54
Modes	Voltage or current
Mode select	Switches A53 and A54
Voltage mode	Switch A53/A54=(U)
Voltage level	0 V to +10 V (scaleable)
Input resistance, R _i	Approximately 10 kΩ
Maximum voltage	±20 V
Current mode	Switch A53/A54=(I)
Current level	0/4 to 20 mA (scaleable)
Input resistance, R _i	Approximately 200 Ω
Maximum current	30 mA
Resolution for analog inputs	10 bit (+ sign)
Accuracy of analog inputs	Maximum error 0.5% of full scale
Bandwidth	100 Hz

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

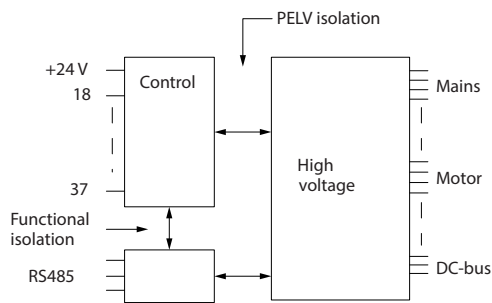


Illustration 5.1 PELV Isolation

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Pulse inputs

Programmable pulse inputs	2
Terminal number pulse	29, 33
Maximum frequency at terminal 29, 33 (push-pull driven)	110 kHz
Maximum frequency at terminal 29, 33 (open collector)	5 kHz
Minimum frequency at terminal 29, 33	4 Hz
Voltage level	See <i>Digital Inputs</i> in chapter 5.6 <i>Control Input/Output and Control Data</i>
Maximum voltage on input	28 V DC
Input resistance, R_i	Approximately 4 k Ω
Pulse input accuracy (0.1–1 kHz)	Maximum error: 0.1% of full scale

Analog output

Number of programmable analog outputs	1
Terminal number	42
Current range at analog output	0/4–20 mA
Maximum resistor load to common at analog output	500 Ω
Accuracy on analog output	Maximum error: 0.8% of full scale
Resolution on analog output	8 bit

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

Control card, 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 functionally separated from other central circuits and galvanically isolated from the supply voltage (PELV).

Digital output

Programmable digital/pulse outputs	2
Terminal number	27, 29 ¹⁾
Voltage level at digital/frequency output	0–24 V
Maximum output current (sink or source)	40 mA
Maximum load at frequency output	1 k Ω
Maximum capacitive load at frequency output	10 nF
Minimum output frequency at frequency output	0 Hz
Maximum output frequency at frequency output	32 kHz
Accuracy of frequency output	Maximum error: 0.1% of full scale
Resolution of frequency outputs	12 bit

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

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

Control card, 24 V DC output

Terminal number	12, 13
Maximum load	200 mA

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

Relay outputs

Programmable relay outputs	2
Maximum cross-section to relay terminals	2.5 mm ² (12 AWG)
Minimum cross-section to relay terminals	0.2 mm ² (30 AWG)
Length of stripped wire	8 mm (0.3 in)
Relay 01 terminal number	1–3 (break), 1–2 (make)
Maximum terminal load (AC-1) ¹⁾ on 1–2 (NO) (Resistive load) ^{2), 3)}	400 V AC, 2 A
Maximum terminal load (AC-15) ¹⁾ on 1–2 (NO) (Inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1) ¹⁾ on 1–2 (NO) (Resistive load)	80 V DC, 2 A
Maximum terminal load (DC-13) ¹⁾ on 1–2 (NO) (Inductive load)	24 V DC, 0.1 A
Maximum terminal load (AC-1) ¹⁾ on 1–3 (NC) (Resistive load)	240 V AC, 2 A
Maximum terminal load (AC-15) ¹⁾ on 1–3 (NC) (Inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1) ¹⁾ on 1–3 (NC) (Resistive load)	50 V DC, 2 A
Maximum terminal load (DC-13) ¹⁾ 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
Relay 02 terminal number	4–6 (break), 4–5 (make)
Maximum terminal load (AC-1) ¹⁾ on 4–5 (NO) (Resistive load) ^{2), 3)}	400 V AC, 2 A
Maximum terminal load (AC-15) ¹⁾ on 4–5 (NO) (Inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1) ¹⁾ on 4–5 (NO) (Resistive load)	80 V DC, 2 A
Maximum terminal load (DC-13) ¹⁾ on 4–5 (NO) (Inductive load)	24 V DC, 0.1 A
Maximum terminal load (AC-1) ¹⁾ on 4–6 (NC) (Resistive load)	240 V AC, 2 A
Maximum terminal load (AC-15) ¹⁾ on 4–6 (NC) (Inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1) ¹⁾ on 4–6 (NC) (Resistive load)	50 V DC, 2 A
Maximum terminal load (DC-13) ¹⁾ 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

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

1) IEC 60947 part 4 and 5.

2) Overvoltage Category II.

Control card, +10 V DC output

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

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

Control characteristics

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

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

Control card performance

Scan interval	5 M/S
---------------	-------

Control card, USB serial communication

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

NOTICE

Connection to PC is carried out via a standard host/device USB cable.

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

The USB connection is not galvanically isolated from ground. Use only isolated laptop/PC as connection to the USB connector on the drive or an isolated USB cable/converter.

5.7 Enclosure Weights

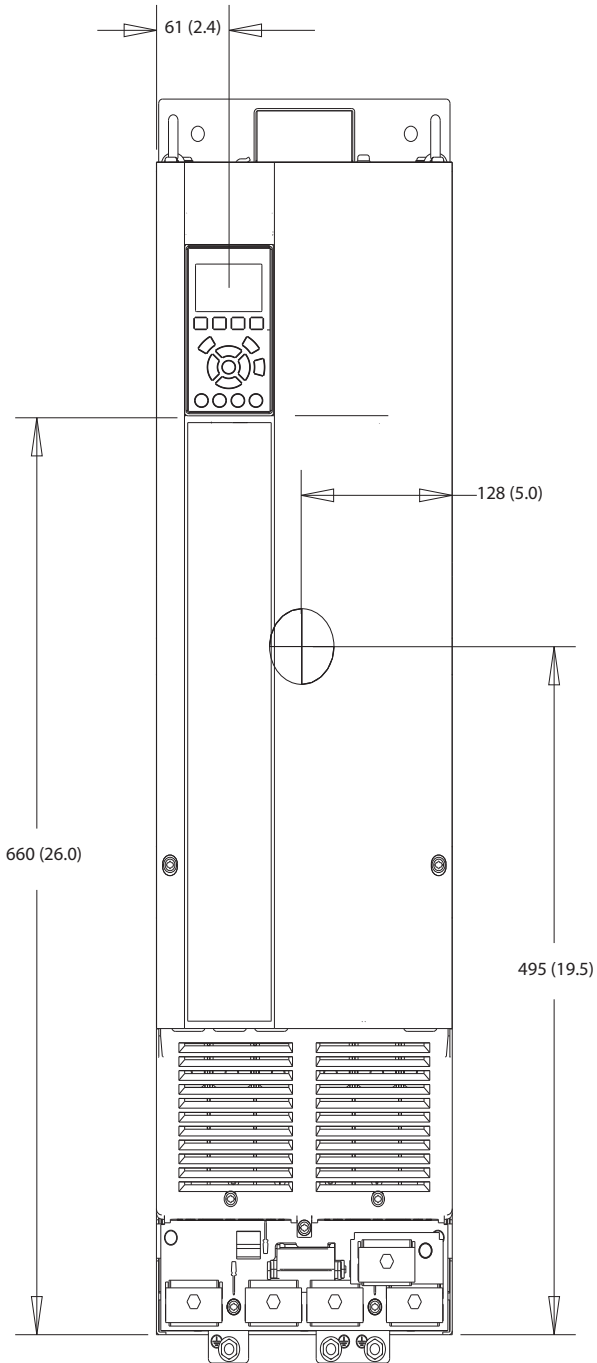
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Enclosure	380–480 V
J8	98 (216)
J9	164 (362)

Table 5.3 Enclosure J8–J9 Weights, kg (lb)

5.8 Exterior and Terminal Dimensions

5.8.1 J8 Exterior Dimensions



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Illustration 5.2 Front View of J8

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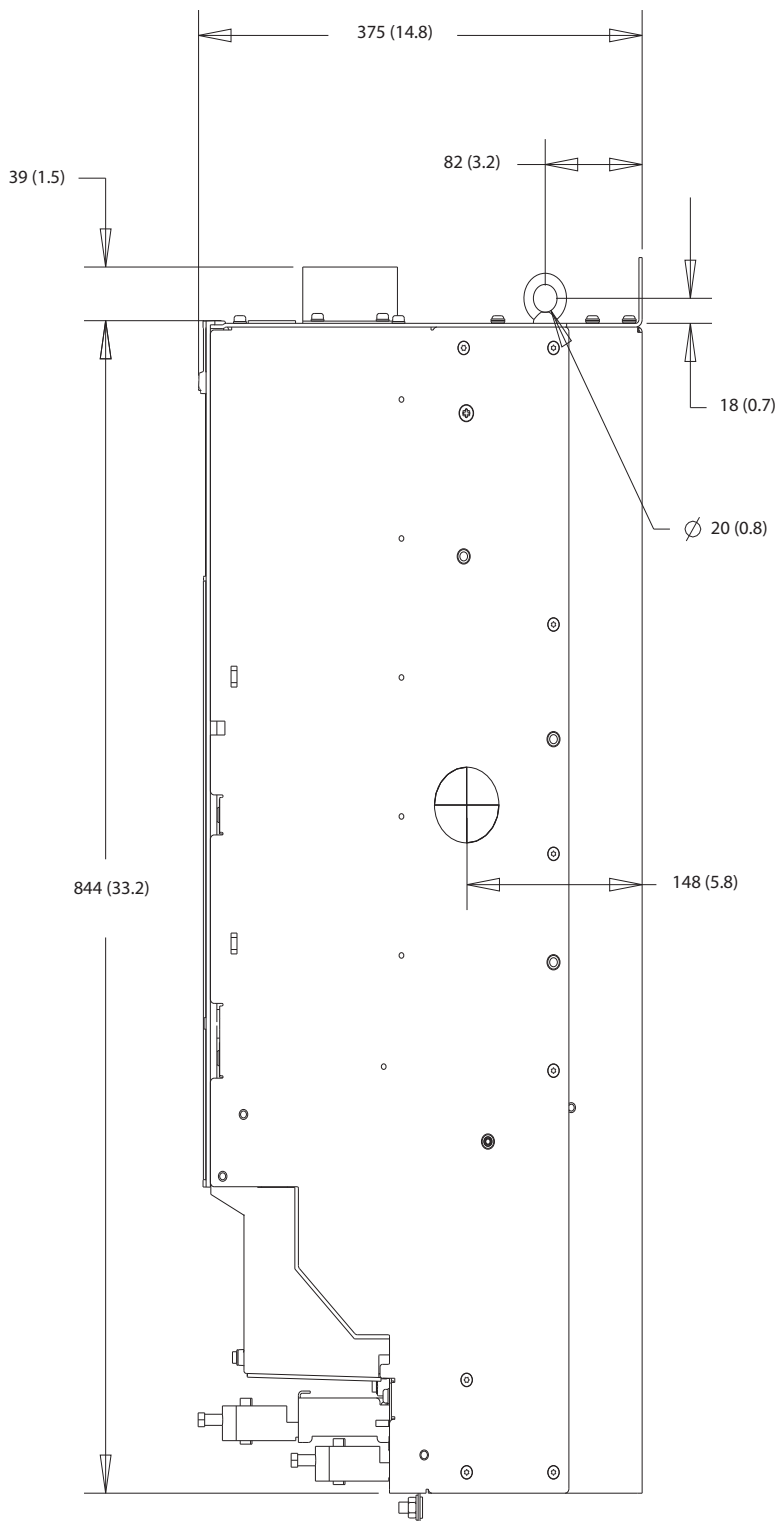
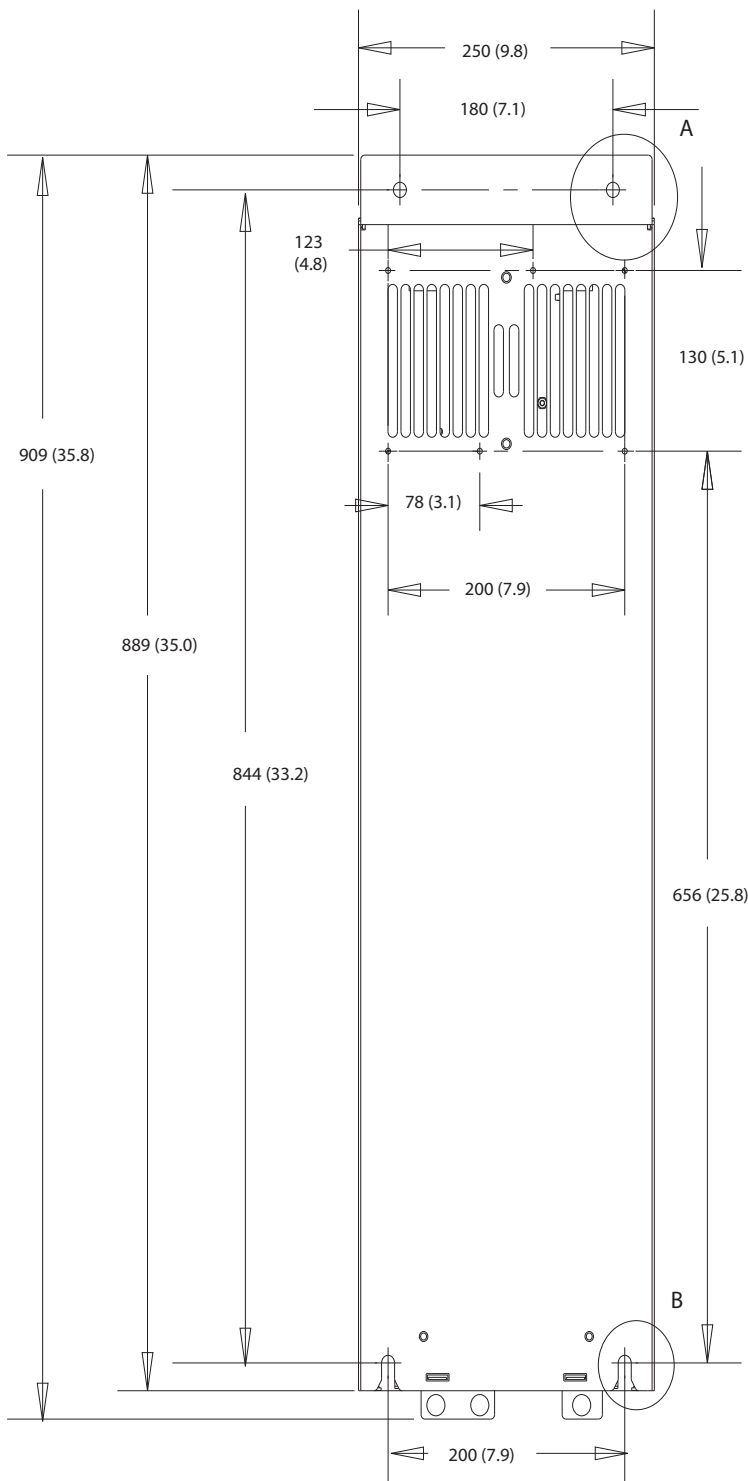
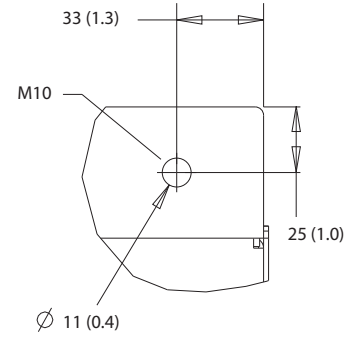


Illustration 5.3 Side View of J8



A



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B

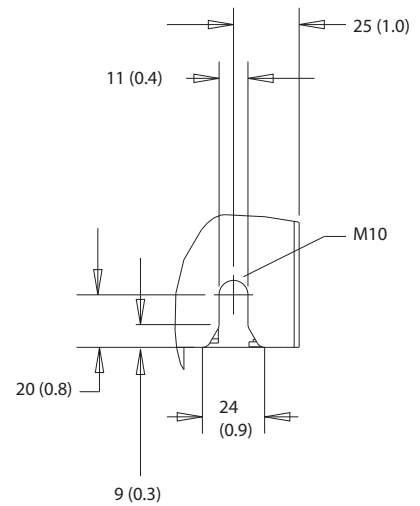


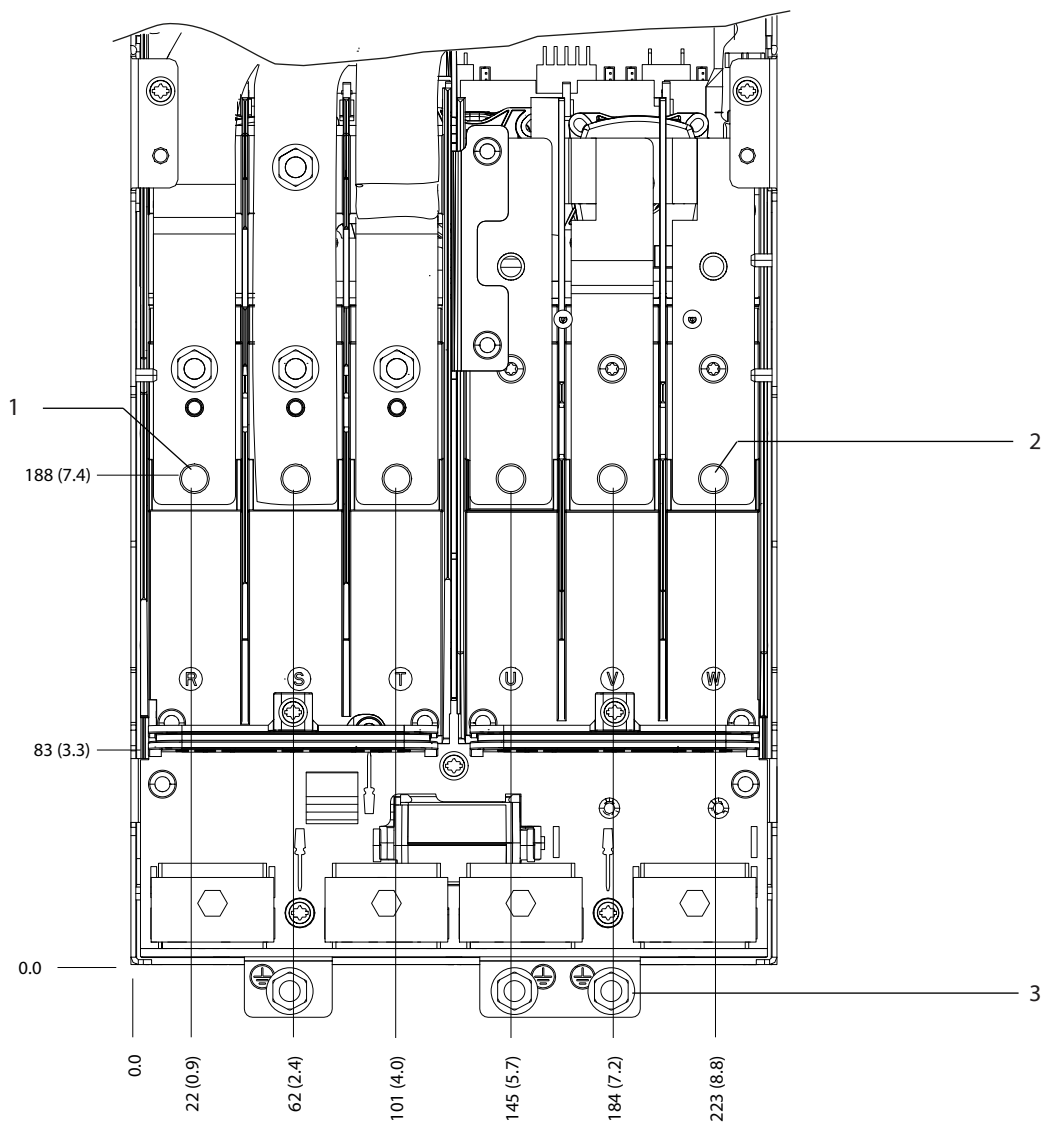
Illustration 5.4 Back View of J8

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5.8.2 J8 Terminal Dimensions

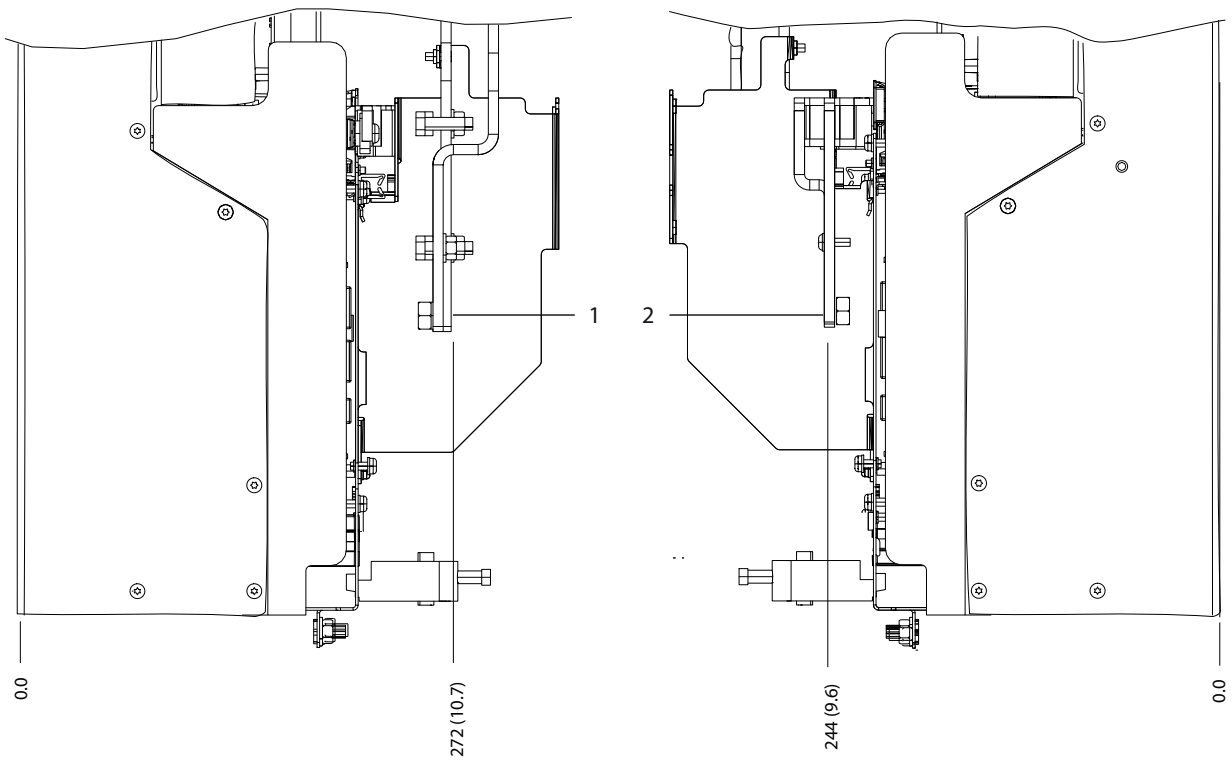
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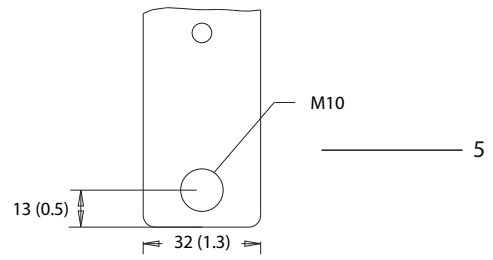
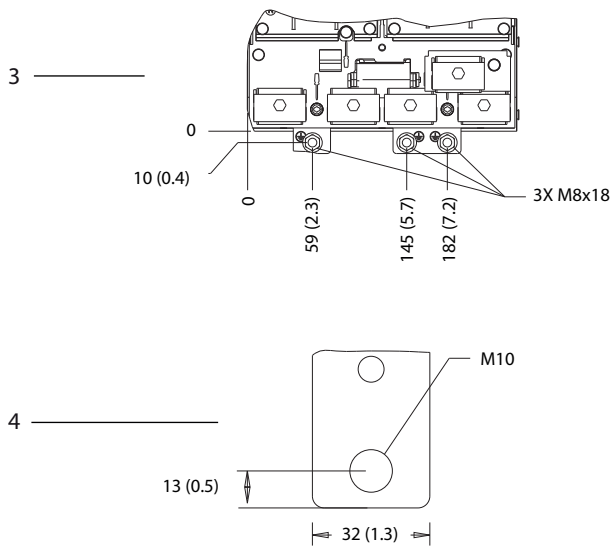


1	Mains terminals	3	Ground terminals
2	Motor terminals	-	-

Illustration 5.5 J8 Terminal Dimensions (Front View)



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

Illustration 5.6 J8 Terminal Dimensions (Side Views)

5.8.3 J9 Exterior Dimensions

5

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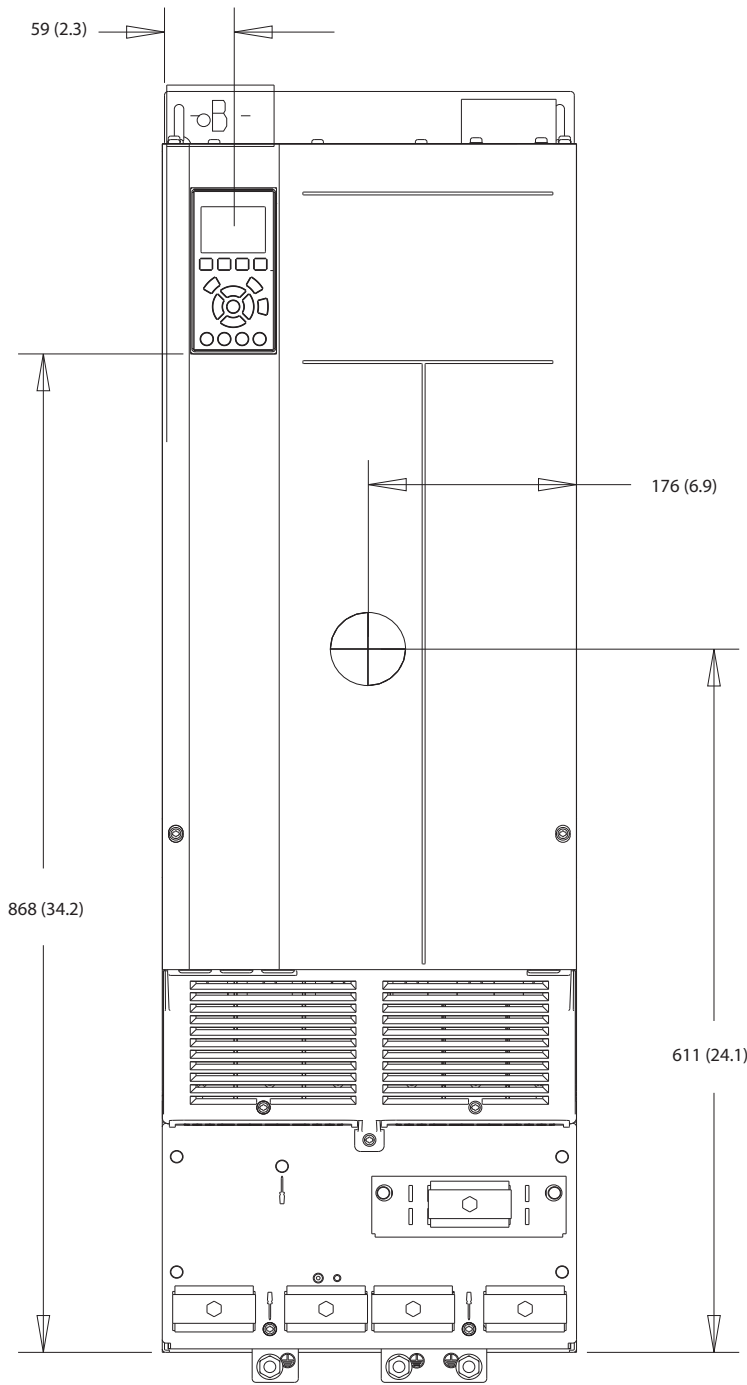


Illustration 5.7 Front View of J9

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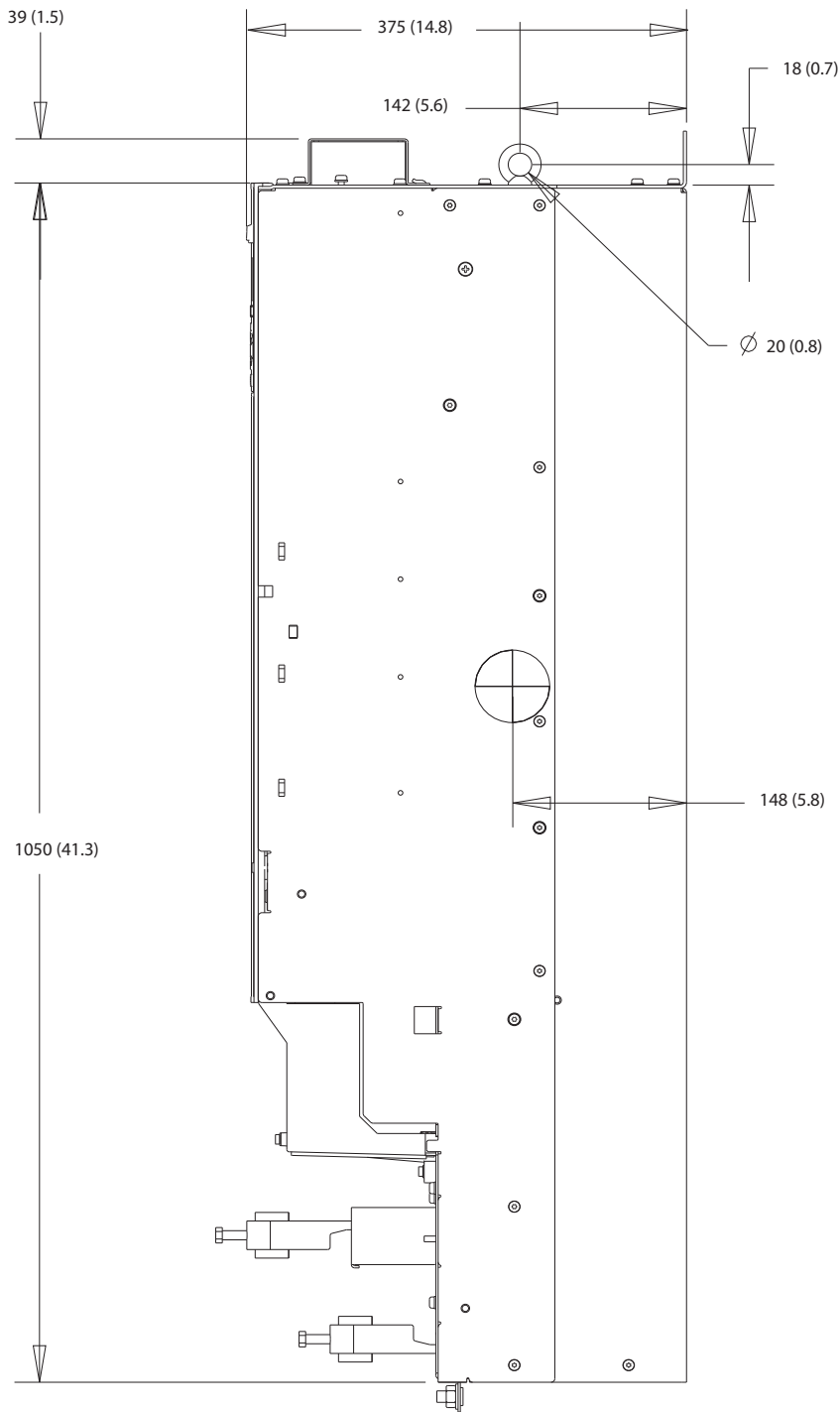


Illustration 5.8 Side View of J9

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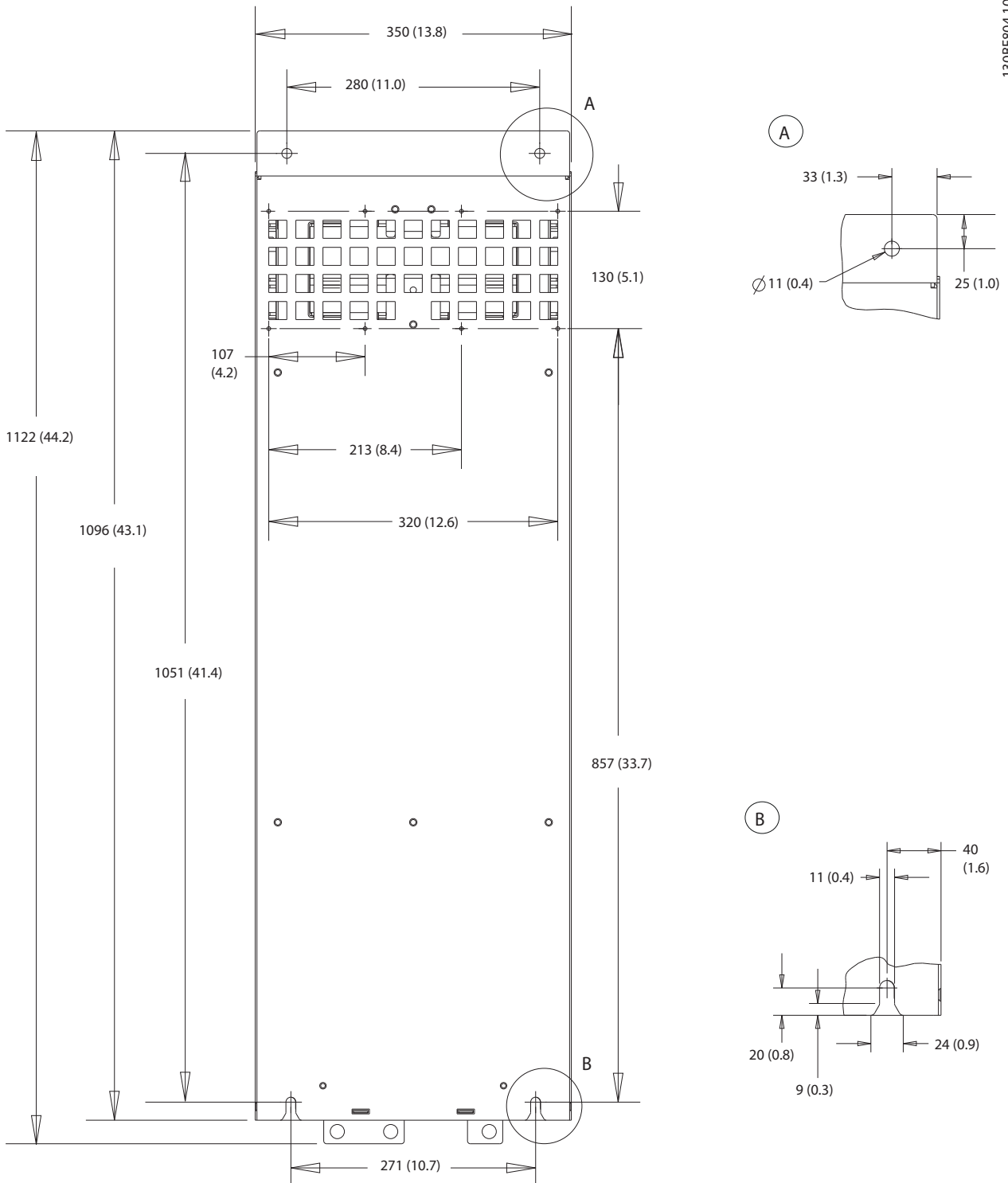
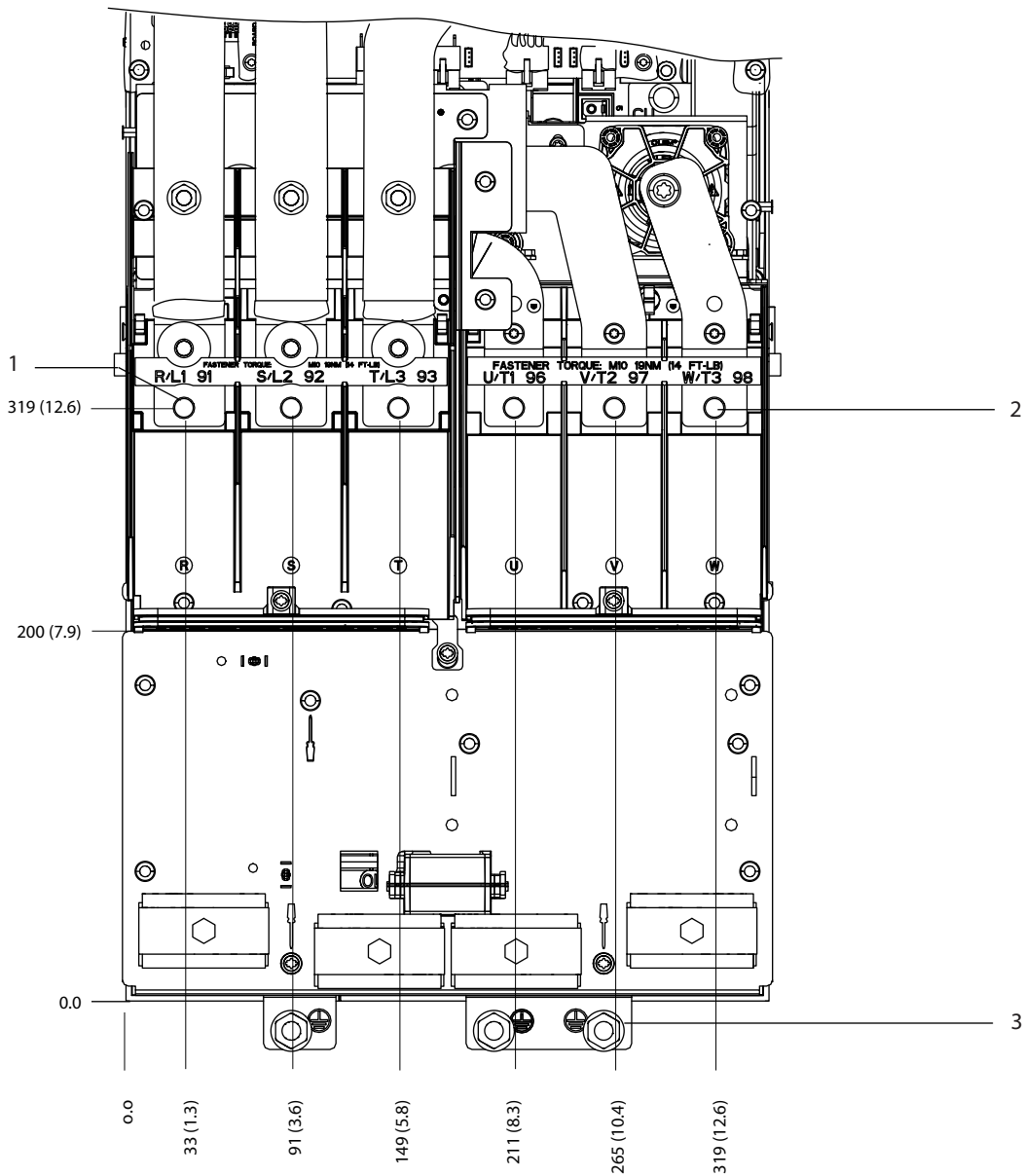


Illustration 5.9 Back View of J9

5.8.4 J9 Terminal Dimensions

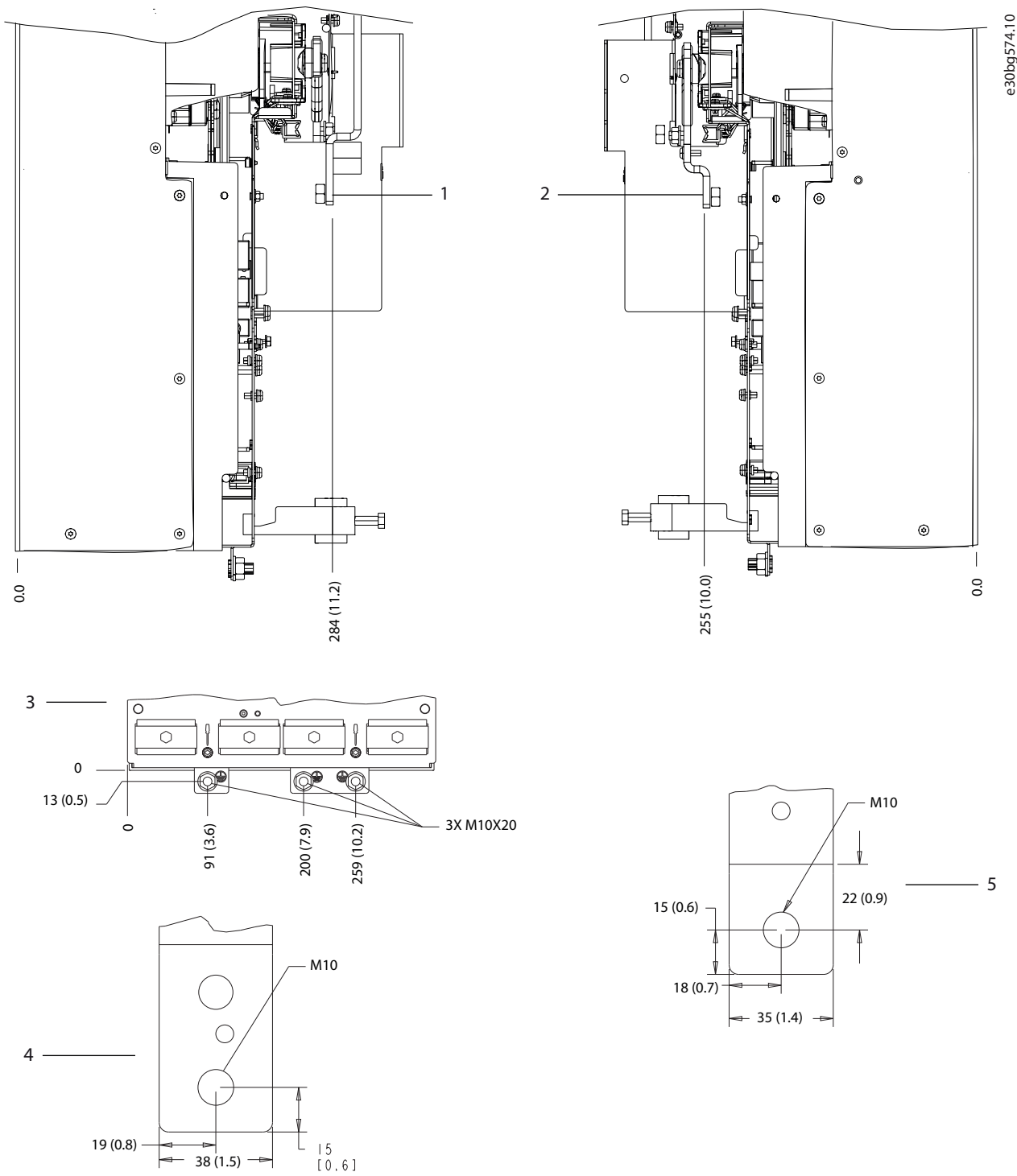


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1	Mains terminals	3	Ground terminals
2	Motor terminals	-	-

Illustration 5.10 J9 Terminal Dimensions (Front View)

5



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

Illustration 5.11 J9 Terminal Dimensions (Side Views)

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 5.4 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 3 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.

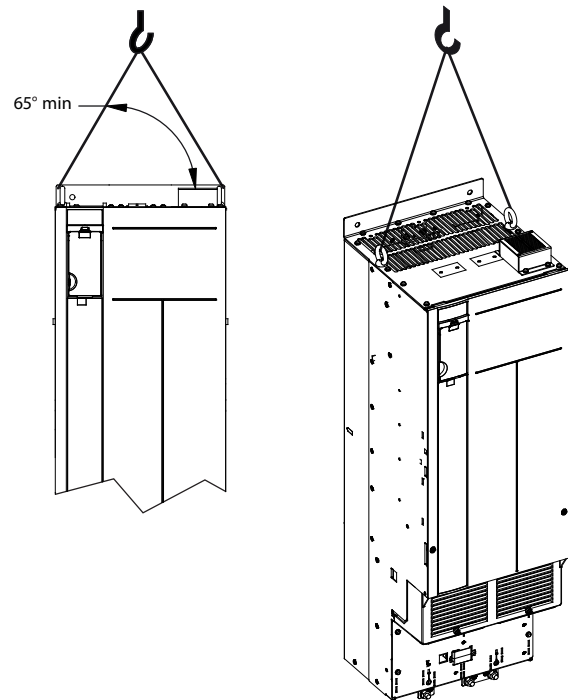


Illustration 6.1 Recommended Lifting Method

6.3 Operating Environment

In environments with airborne liquids, particles, or corrosive gases, ensure that the IP/Type rating of the equipment matches the installation environment. For specifications regarding ambient conditions, see *chapter 5.4 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.

6.3.1 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 5.4 Ambient Conditions*.

6.3.2 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. For more service and maintenance information, refer to the *operating guide*.

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

Table 6.1 lists the available mounting configurations for each enclosure. For specific panel/wall mounting or pedestal mounting installation instructions, see the *operating guide*. See also *chapter 5.8 Exterior and Terminal Dimensions*.

NOTICE

Improper mounting can result in overheating and reduced performance.

Enclosure	Wall/cabinet mount	Pedestal mount (Standalone)
J8	X ¹⁾	–
J9	X ¹⁾	–

Table 6.1 Mounting Configurations

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 *chapter 5.5 Cable Specifications* 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 *chapter 3.5 Back-channel Cooling Overview*.
- Ensure enough access to open the door.
- Ensure cable entry from the bottom.

6.5 Cooling

NOTICE

Improper mounting can result in overheating and reduced performance. For proper mounting, refer to chapter 6.4 Mounting Configurations.

- Ensure that top and bottom clearance for air cooling is provided. Clearance requirement: 225 mm (9 in).
- Provide sufficient airflow flow rate. See Table 6.2.
- 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 chapter 6.6 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 reduce 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.

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

Table 6.2 J8-J9 Airflow Rate

6.6 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 N132 instead of N110):

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

Automatic derating

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

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

6.6.1 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.

6.6.2 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 *Illustration 6.2*.

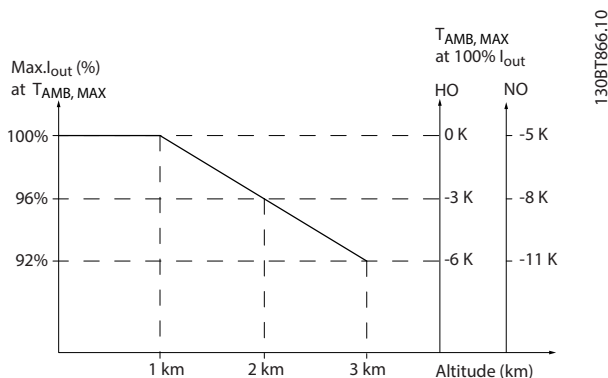


Illustration 6.2 Derating of Output Current Based on Altitude at $T_{AMB, MAX}$

Illustration 6.2 shows that at 41.7 °C (107 °F), 100% of the rated output current is available. At 45 °C (113 °F) ($T_{AMB, MAX}$ -3 K), 91% of the rated output current is available.

6.6.3 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 Table 6.3 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.

Enclosure	Switching pattern	High overload HO, 150%	Normal overload NO, 110%
J8-J9 380-480 V	60 AVM		
	SFAVM		

6

Table 6.3 Derating Tables for Drives Rated 380-480 V

7 Electrical Installation Considerations

7.1 Safety Instructions

See *chapter 2 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.

- 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.

Failure to follow the recommendation means that the RCD cannot provide the intended protection.

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 *chapter 7.5 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.

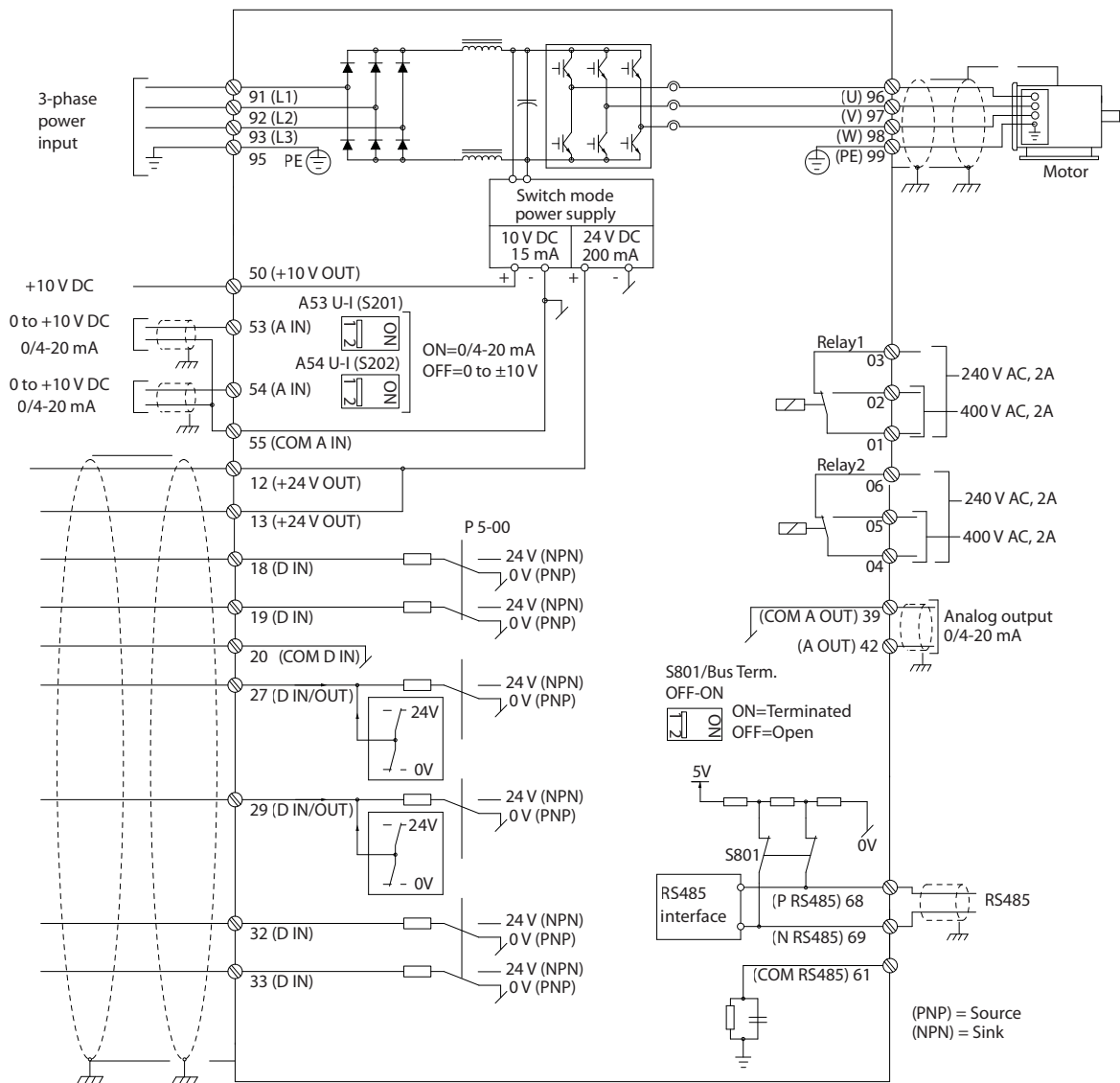
See *chapter 5.5 Cable Specifications* for recommended wire sizes and types.

⚠ 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 Schematic



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Illustration 7.1 Basic Wiring Schematic

7.3 Connections

7.3.1 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 *Illustration 7.2*. See *chapter 5 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 *chapter 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.

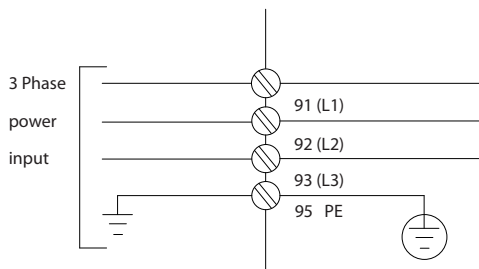


Illustration 7.2 Power Cable Connections

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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*.

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

Table 7.1 Motor Cable Connection

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.

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 7.14 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.

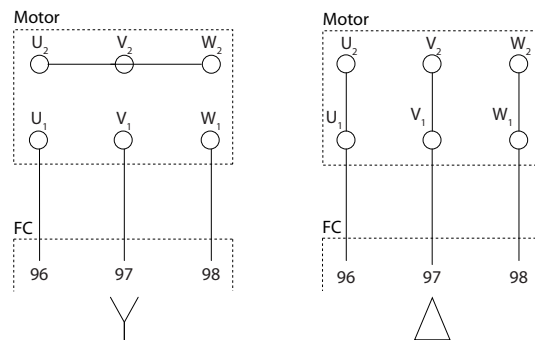


Illustration 7.3 Motor Cable Connection

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7.3.2 Personal Computer Connection

To control the drive from a PC, install the MCT 10 Set-up Software. The PC is connected via a standard (host/device) USB cable, or via the RS485 interface. For more information on RS485, see *chapter 11.3 RS485 Installation and Set-up*.

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

To prevent damage to the USB host controller through the shield of the USB cable, follow the ground recommendations described in the *operating guide*.

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

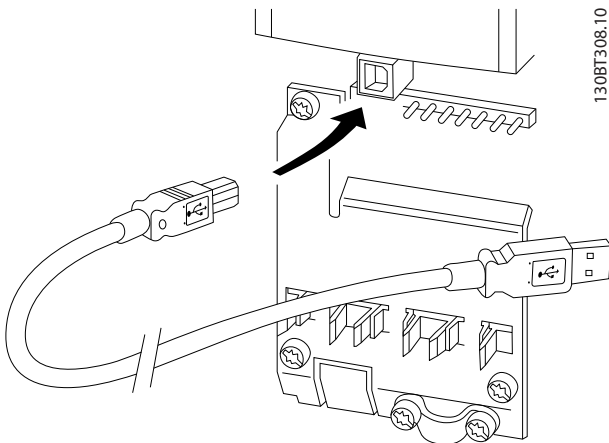
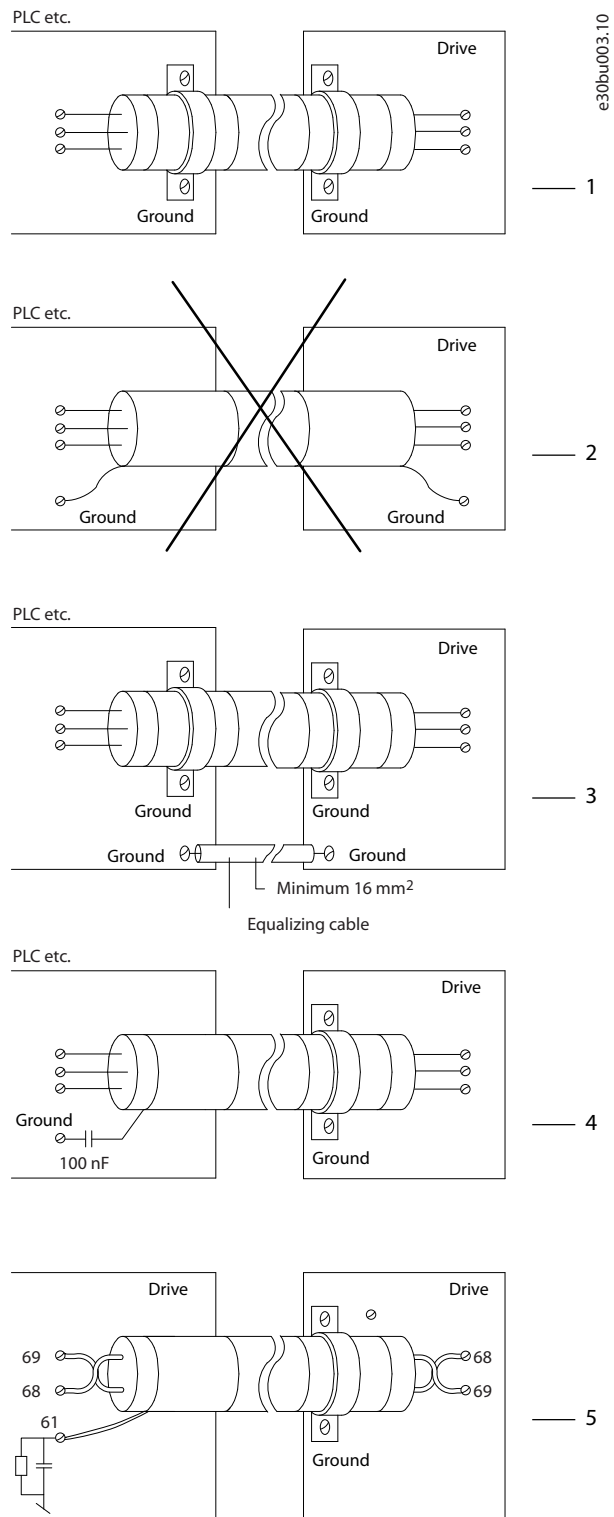


Illustration 7.4 USB Connection

7.4 Control Wiring and Terminals

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 *Illustration 7.5*.



1	Control cables and serial communication cables must be fitted with cable clamps at both ends to ensure the best possible electrical contact.
2	Do not use twisted cable ends (pigtails). They increase the shield impedance at high frequencies.

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 ² (6 AWG).
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).
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.

Illustration 7.5 Grounding Examples

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7.4.1 Control Cable Routing

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

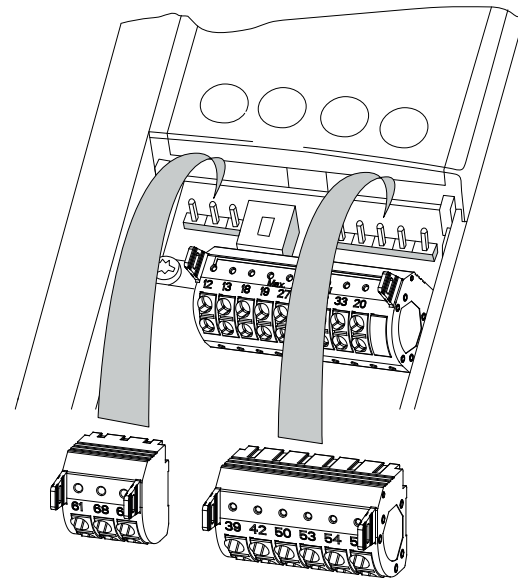
- Isolate control wiring from high-power cables.
- When the drive is connected to a thermistor, ensure that the thermistor control wiring is shielded and reinforced/double insulated. A 24 V DC supply voltage is recommended.

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.

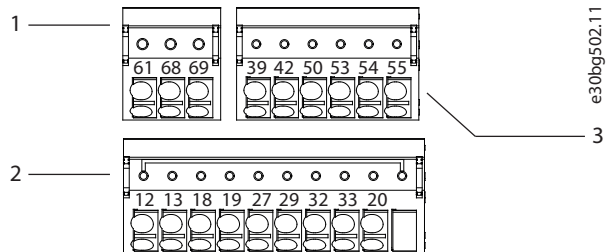
7.4.2 Control Terminals

Illustration 7.6 shows the removable drive connectors. Terminal functions and default settings are summarized in Table 7.2 – Table 7.4.



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Illustration 7.6 Control Terminal Locations



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1	Serial communication terminals
2	Digital input/output terminals
3	Analog input/output terminals

Illustration 7.7 Terminal Numbers Located on the Connectors

Terminal	Parameter	Default setting	Description
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 (BUS TER.) is provided on the control card for bus termination resistance.
69 (-)	<i>Parameter group 8-3* FC Port Settings</i>	–	

Table 7.2 Serial Communication Terminal Descriptions

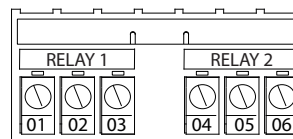
Terminal	Parameter	Default setting	Description
12, 13	–	+24 V DC	24 V DC supply voltage for digital inputs and external transducers. Maximum output current 200 mA for all 24 V loads.
18	<i>Parameter 5-10 Terminal 18 Digital Input</i>	<i>[8] Start</i>	Digital inputs.
19	<i>Parameter 5-11 Terminal 19 Digital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

Table 7.3 Digital Input/Output Terminal Descriptions

Terminal	Parameter	Default setting	Description
39	–	–	Common for analog output.
42	<i>Parameter 6-50 Terminal 42 Output</i>	<i>[0] No operation</i>	Programmable analog output. 0–20 mA or 4–20 mA at a maximum of 500 Ω.
50	–	+10 V DC	10 V DC analog supply voltage for potentiometer or thermistor. 15 mA maximum.
53	<i>Parameter group 6-1* Analog Input 1</i>	Reference	Analog input. For voltage or current. Switches A53 and A54 select mA or V.
54	<i>Parameter group 6-2* Analog Input 2</i>	Feedback	
55	–	–	Common for analog input.

Table 7.4 Analog Input/Output Terminal Descriptions

Relay terminals



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Illustration 7.8 Relay 1 and Relay 2 Terminals

- Relay 1 and relay 2. Location depends on drive configuration. See the *operating guide*.
- Terminals on built-in optional equipment. See the instructions provided with the equipment option.

Terminal	Parameter	Default setting	Description
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>	

Table 7.5 Relay Terminal Descriptions

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.

J8–J9 recommended fuses

Type aR fuses are recommended for enclosures J8–J9. See *Table 7.6*.

Model	380–480 V
N90K	ar-315
N110	ar-315
N132	ar-350
N160	ar-400
N200	ar-500
N250	ar-630
N315	ar-800

Table 7.6 J8–J9 Power/Semiconductor Fuse Sizes

Model	Fuse Options						
	Bussman	Littelfuse	Littelfuse	Bussmann	Siba	Ferraz-Shawmut	Ferraz-Shawmut (Europe)
N90K	170M2619	LA50QS300-4	L50S-300	FWH-300A	20 189 20.315	A50QS300-4	6,9URD31D08A0315
N110	170M2619	LA50QS300-4	L50S-300	FWH-300A	20 189 20.315	A50QS300-4	6,9URD31D08A0315
N132	170M2620	LA50QS350-4	L50S-350	FWH-350A	20 189 20.350	A50QS350-4	6,9URD31D08A0350
N160	170M2621	LA50QS400-4	L50S-400	FWH-400A	20 189 20.400	A50QS400-4	6,9URD31D08A0400
N200	170M4015	LA50QS500-4	L50S-500	FWH-500A	20 610 31.550	A50QS500-4	6,9URD31D08A0550
N250	170M4016	LA50QS600-4	L50S-600	FWH-600A	20 610 31.630	A50QS600-4	6,9URD31D08A0630
N315	170M4017	LA50QS800-4	L50S-800	FWH-800A	20 610 31.800	A50QS800-4	6,9URD32D08A0800

Table 7.7 J8–J9 Power/Semiconductor Fuse Options, 380–480 V

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

Table 7.8 J8–J9 Space Heater Fuse Recommendation

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. For more information regarding the nameplate, see *chapter 6 Mechanical Installation Considerations*.

7.6 Motor

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

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

Table 7.9 Motor Cable Terminals Providing Clockwise Rotation (Factory Default)

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*.

Motor rotation check can be performed using *parameter 1-28 Motor Rotation Check* and following the configuration shown in *Illustration 7.9*.

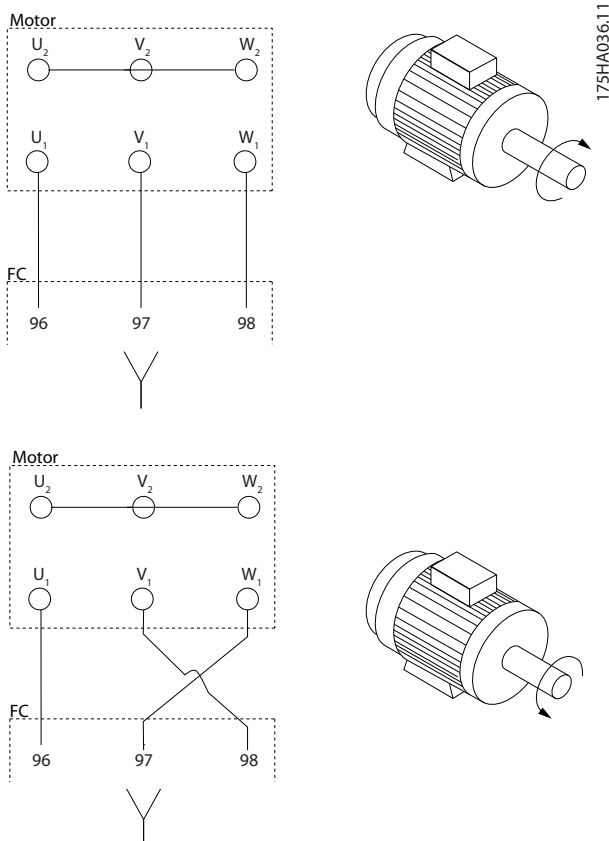


Illustration 7.9 Changing Motor Rotation

7.6.1 Motor Thermal Protection

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

7.6.2 Parallel Connection of Motors

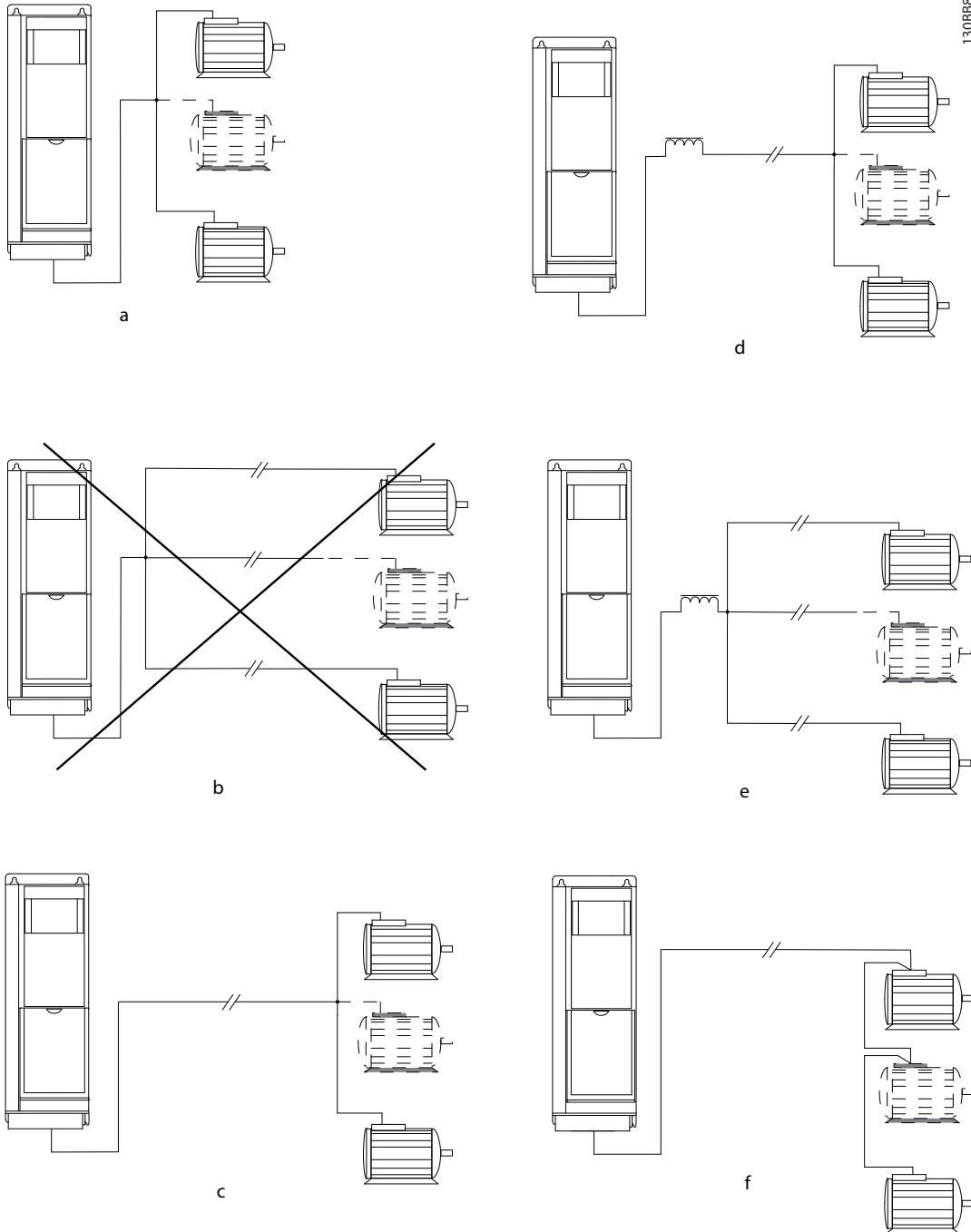
The drive can control several parallel-connected motors. For different configurations of parallel-connected motors, see *Illustration 7.10*.

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 I_{INV} 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.
- When motors are connected in parallel, *parameter 1-01 Motor Control Principle* must be set to [0] U/f.

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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 <i>chapter 5.5 Cable Specifications</i> .
C	The total motor cable length specified in <i>chapter 5.5 Cable Specifications</i> 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 <i>chapter 5.5 Cable Specifications</i> is valid as long as the parallel cables are kept less than 10 m (32 ft) each.

Illustration 7.10 Different Parallel Connections of Motors

7.6.3 Motor Insulation

For motor cable lengths that are less than or equal to the maximum cable length listed in *chapter 5.5 Cable Specifications*, use the motor insulation ratings shown in *Table 7.10*. If a motor has lower insulation rating, Danfoss recommends using a dU/dt or sine-wave filter.

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

Table 7.10 Motor Insulation Ratings

7.6.4 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° AVFM vs. SFVFM.
- 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 grounding, 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 7.8 Leakage Current* for more details.

7.8 Leakage Current

Follow national and local codes regarding protective grounding 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.

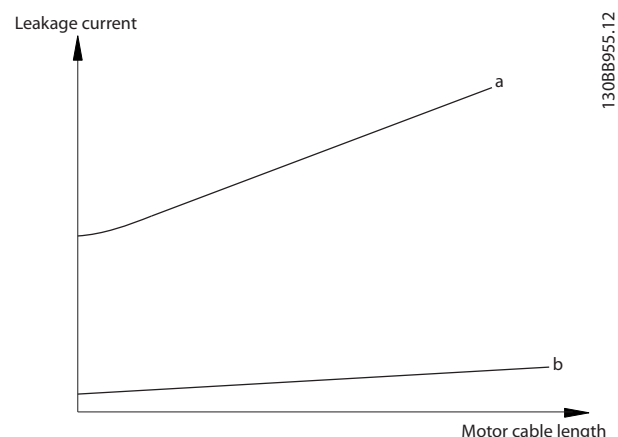


Illustration 7.11 Motor Cable Length and Power Size Influence the Leakage Current. Power Size a > Power Size b.

The leakage current also depends on the line distortion.

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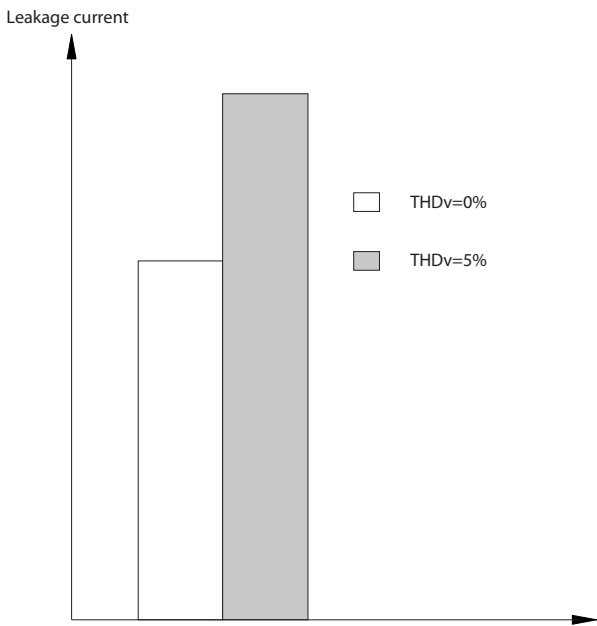


Illustration 7.12 Line Distortion Influences Leakage Current

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 ground connection requirements:

- Ground wire (terminal 95) of at least 10 mm² (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.

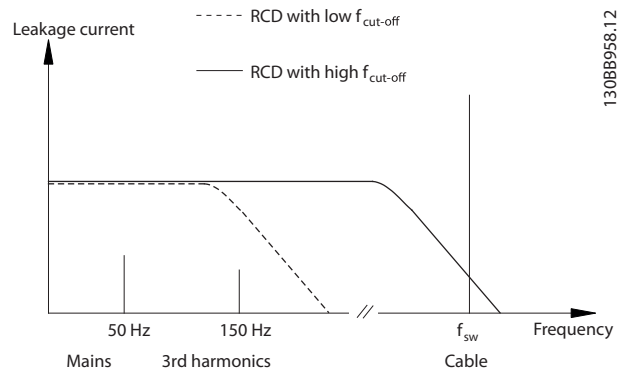


Illustration 7.13 Main Contributions to Leakage Current

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

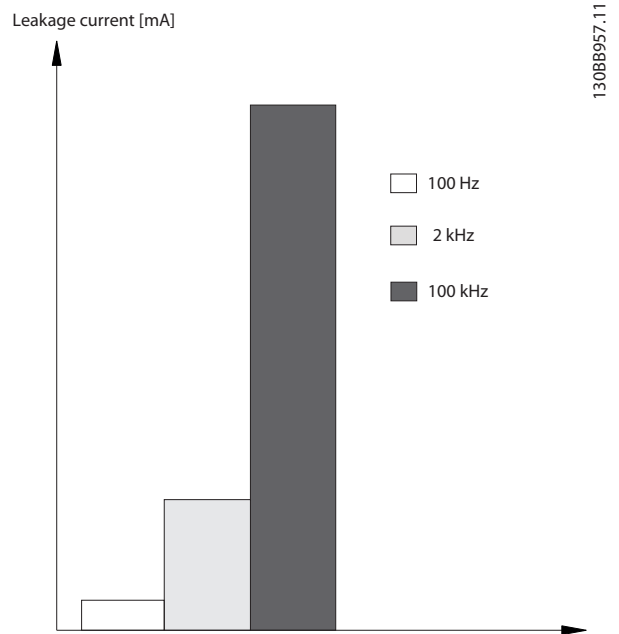


Illustration 7.14 Influence of the RCD Cut-off Frequency on Leakage Current

7.9 IT Mains

Mains supply isolated from ground

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

If optimum EMC performance is needed, or parallel motors are connected, or the motor cable length is above 25 m (82 ft), Danfoss recommends setting *parameter 14-50 RFI Filter* to [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 (η_{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%, in case of 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 *Illustration 7.15*. The factor in this graph must be multiplied by the specific efficiency factor listed in the specification tables in *chapter 5.1 Electrical Data, 380-480 V*.

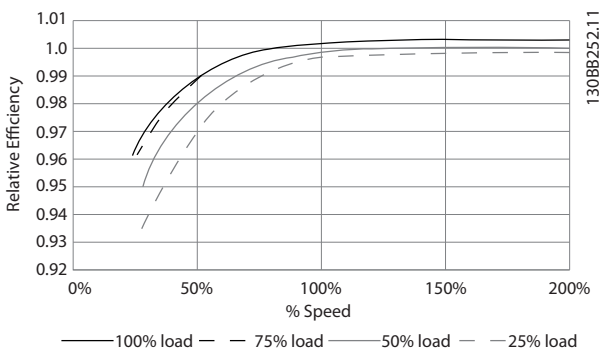


Illustration 7.15 Typical Efficiency Curves

Example: Assume a 160 kW, 380–480/500 V AC drive at 25% load at 50% speed. *Illustration 7.15* 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 (η_{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 (η_{SYSTEM})

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

7.11 Acoustic Noise

The acoustic noise from the drive comes from 3 sources:

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

Table 7.11 lists the typical acoustic noise values measured at a distance of 1 m (9 ft) from the unit.

Enclosure size	dBA at full fan speed
J8	73
J9	75

Table 7.11 Acoustic Noise

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 intermediate circuit. 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 *Table 7.12* to *Table 7.13* 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 *Table 7.12* to *Table 7.13* do not comply with NEMA MG 1-1998 Part 30.2.2.8 for general purpose motors.

7.12.1 dU/dt Test Results for Enclosures J8–J9

Power size [kW (hp)]	Cable [m (ft)]	Mains voltage [V]	Rise time [μ s]	Peak voltage [V]	dU/dt [V/ μ 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 7.12 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 [μ s]	Peak voltage [V]	dU/dt [V/ μ 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

Table 7.13 IEC dU/dt Test Results for J8–J9 with Shielded Cables and No Output Filter, 380–480 V

7.13 Electromagnetic Compatibility (EMC) 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.

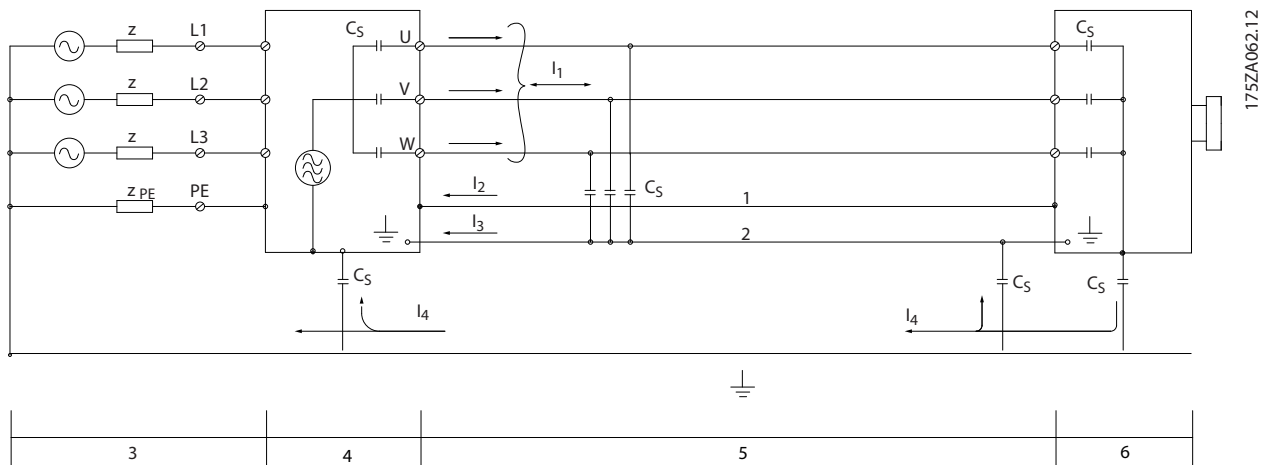
Uncontrolled interaction between electrical devices in a system can degrade compatibility and impair reliable operation. Interference takes the form of the following:

- 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 *Illustration 7.16*. 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 (I_1) is carried back to the unit through the PE (I_3), leaving only a small electromagnetic field (I_4) from the shielded motor cable. The shield reduces the radiated interference but increases the low-frequency interference on the mains.

7



1	Ground wire	C_s	Possible shunt parasitic capacitance paths (varies with different installations)
2	Shield	I_1	Common-mode leakage current
3	AC mains supply	I_2	Shielded motor cable
4	Drive	I_3	Safety ground (4 th conductor in motor cables)
5	Shielded motor cable	I_4	Unintended common-mode current
6	Motor	–	–

Illustration 7.16 Electric Model Showing Possible Leakage Currents

7.13.1 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.

RFI filter type		Conducted emission			Radiated emission		
Standards and requirements	EN 55011	Class B Housing, trades, and light industries	Class A group 1 Industrial environment	Class A group 2 Industrial environment	Class B Housing, trades, and light industries	Class A group 1 Industrial environment	Class A group 2 Industrial environment
	EN/IEC 61800-3	Category C1 First environment Home and office	Category C2 First environment Home and office	Category C3 Second environment Industrial	Category C1 First environment Home and office	Category C2 First environment Home and office	Category C3 First environment Home and office
FC 361	90–315 kW 380–480 V	No	No	150 m (492 ft)	No	No	Yes

Table 7.14 EMC Test Results (Emission and Immunity)

7.13.2 Emission Requirements

According to the EMC product standard for adjustable speed drives EN/IEC 61800-3:2004, 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 *Table 7.15*.

The drives comply with EMC requirements described in IEC/EN 61800-3 (2004)+AM1 (2011), 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.

Category (EN 61800-3)	Definition	Conducted emission (EN 55011)
C1	First environment (home and office) with a supply voltage less than 1000 V.	Class B
C2	First environment (home and office) with a supply voltage less than 1000 V, which is not plug-in or movable and where a professional is intended to be used to install or commission the system.	Class A Group 1
C3	Second environment (industrial) with a supply voltage lower than 1000 V.	Class A Group 2
C4	Second environment with the following: <ul style="list-style-type: none"> Supply voltage equal to or above 1000 V. Rated current equal to or above 400 A. Intended for use in complex systems. 	No limit line. An EMC plan must be made.

Table 7.15 Emission Requirements

When the generic emission standards are used, the drives are required to comply with *Table 7.16*.

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

Table 7.16 Generic Emission Standard Limits

7.13.3 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 *Table 7.17*.

- **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.

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

Table 7.17 EMC Immunity Form, Voltage Range: 380–480

1) Injection on cable shield.

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

7.13.4 EMC Compatibility

NOTICE

OPERATOR RESPONSIBILITY

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

There are 2 options for ensuring electromagnetic compatibility.

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

RFI filters

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

NOTICE

RADIO INTERFERENCE

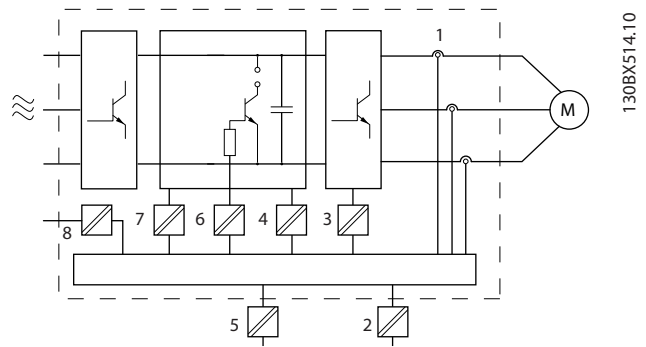
In a residential environment, this product can cause radio interference, in which case supplementary mitigation measures may be required.

PELV and galvanic isolation compliance

All E1h-E4h 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 *Illustration 7.17*). The components described comply with both PELV and the galvanic isolation requirements.



130BX514.10

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 back-up option
6	Opto-coupler, brake module (optional)
7	Internal inrush, RFI, and temperature measurement circuits
8	Customer relays

Illustration 7.17 Galvanic Isolation

7.14 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 *Illustration 7.18*.

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.

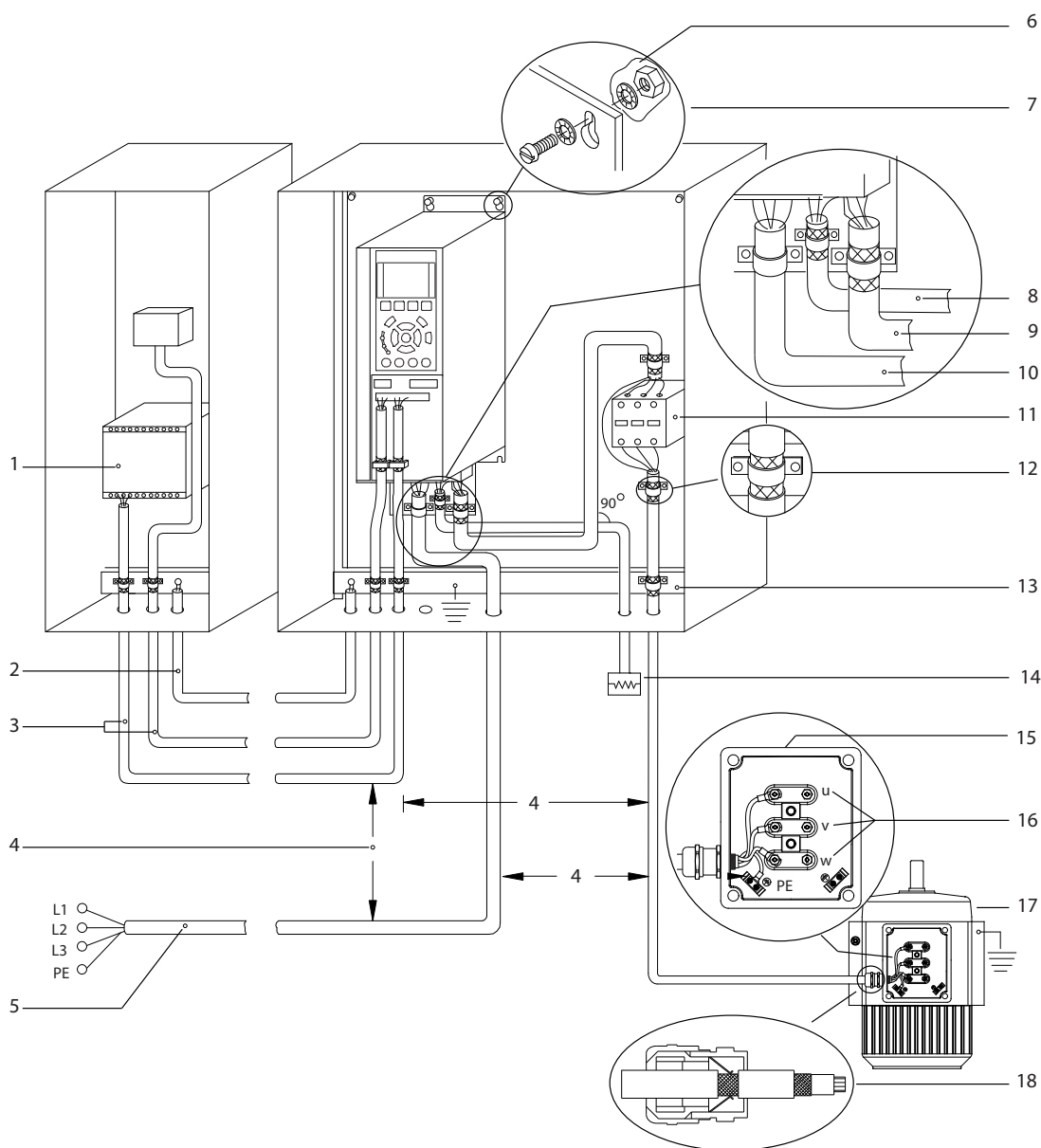
For installations above 2000 m (6500 ft) altitude, contact Danfoss regarding PELV compliance.

NOTICE

PELV COMPLIANCE

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

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e30bf228.11

1	PLC	10	Mains cable (unshielded)
2	Minimum 16 mm ² (6 AWG) equalizing cable	11	Output contactor
3	Control cables	12	Cable insulation stripped
4	Minimum 200 mm (7.9 in) between control cables, motor cables, and mains cables	13	Common ground busbar. Follow local and national requirements for cabinet grounding
5	Mains supply	14	Brake resistor
6	Bare (unpainted) surface	15	Metal box
7	Star washers	16	Connection to motor
8	Brake cable (shielded)	17	Motor
9	Motor cable (shielded)	18	EMC cable gland

Illustration 7.18 Example of Proper EMC Installation

7.15 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.

7.15.1 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.

Abbreviation	Description
f_1	Basic frequency (50 Hz or 60 Hz)
I_1	Current at the basic frequency
U_1	Voltage at the basic frequency
I_n	Current at the n^{th} harmonic frequency
U_n	Voltage at the n^{th} harmonic frequency
n	Harmonic order

Table 7.18 Harmonics-related Abbreviations

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

Table 7.19 Basic Currents and Harmonic Currents

Current	Harmonic current				
	I_{RMS}	I_1	I_5	I_7	I_{11-49}
Input current	1.0	0.9	0.5	0.2	<0.1

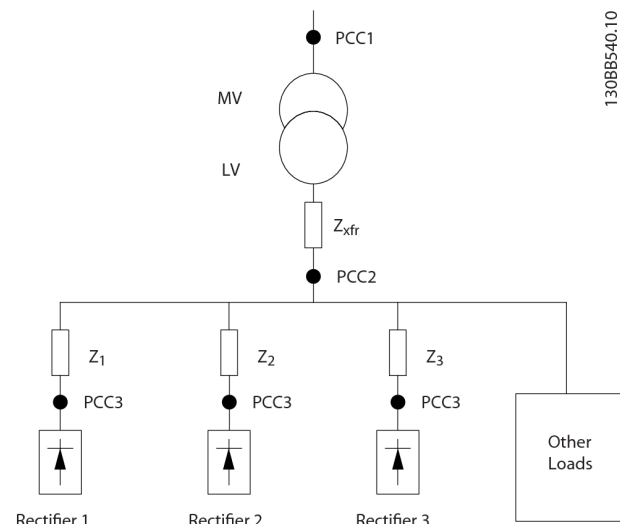
Table 7.20 Harmonic Currents vs. RMS Input Current

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:

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

7.15.2 Effect of Harmonics in a Power Distribution System

In *Illustration 7.19*, 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 .



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

Illustration 7.19 Small Distribution System

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

Current distortion relates to apparatus performance and it relates to the individual load. Voltage distortion relates to system performance. It is not possible to determine the voltage distortion in the PCC knowing only the 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.

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

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

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.

7.15.3 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.

7

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.

Table 7.21 EN Design Standards for Mains Power Quality

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 $v_k \text{ Line} < 10\%$).

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

Table 7.22 Compatibility Levels for Harmonics

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

Table 7.23 Compatibility Levels for the Total Harmonic Voltage Distortion THDv

7.15.4 Harmonic Compliance

Danfoss drives comply with the following standards:

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

8 Basic Operating Principles of a Drive

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.

8.1 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)

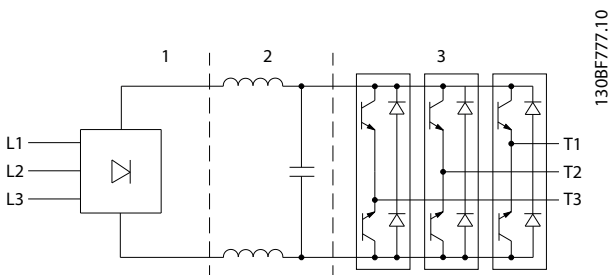
The DC link consists of inductors and capacitor banks that stabilize the pulsating DC voltage.

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.



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

Illustration 8.1 Internal Processing

8.2 Drive Controls

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

- User input/reference.
- Feedback handling.
- User-defined control structure.
 - Open loop/closed-loop mode.
 - Motor control (speed, torque, or process).
- Control algorithms (VVC⁺, flux sensorless, flux with motor feedback, and internal current control VVC⁺).

8.2.1 User Inputs/References

The drive uses an input source (also called reference) to control and regulate the motor. The drive receives this input either:

- Manually via the LCP. This method is referred to as local (Hand On).
- Remotely via analog/digital inputs and various serial interfaces (RS485, USB, or an optional fieldbus). This method is referred to as remote (Auto On) and is the default input setting.

Active reference

The term active reference refers to the active input source. The active reference is configured in *parameter 3-13 Reference Site*. See *Illustration 8.2* and *Table 8.1*.

For more information, see the *programming guide*.

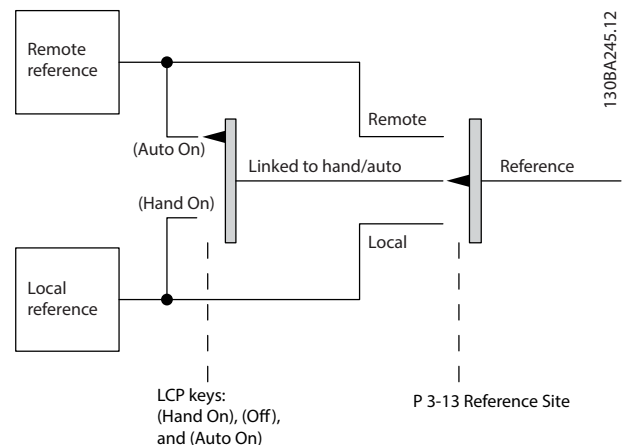


Illustration 8.2 Selecting Active Reference

LCP keys	Parameter 3-13 Reference Site	Active Reference
[Hand On]	Linked to hand/auto	Local
[Hand On]⇒(Off)	Linked to hand/auto	Local
[Auto On]	Linked to hand/auto	Remote
[Auto On]⇒(Off)	Linked to hand/auto	Remote
All keys	Local	Local
All keys	Remote	Remote

Table 8.1 Local and Remote Reference Configurations

8.2.2 Remote Handling of References

Remote handling of reference applies to both open-loop and closed-loop operation. See *Illustration 8.3*.

Up to 8 internal preset references can be programmed into the drive. The active internal preset reference can be selected externally through digital control inputs or through the serial communications bus.

External references can also be supplied to the drive, most commonly through an analog control input. All reference

sources and the bus reference are added to produce the total external reference.

The active reference can be selected from the following:

- External reference.
- Preset reference.
- Setpoint.
- Sum of the external reference, preset reference, and setpoint.

The active reference can be scaled. The scaled reference is calculated as follows:

$$Reference = X + X \times \left(\frac{Y}{100} \right)$$

Where X is the external reference, the preset reference, or the sum of these references, and Y is *parameter 3-14 Preset Relative Reference* in [%].

If Y, *parameter 3-14 Preset Relative Reference*, is set to 0%, the scaling does not affect the reference.

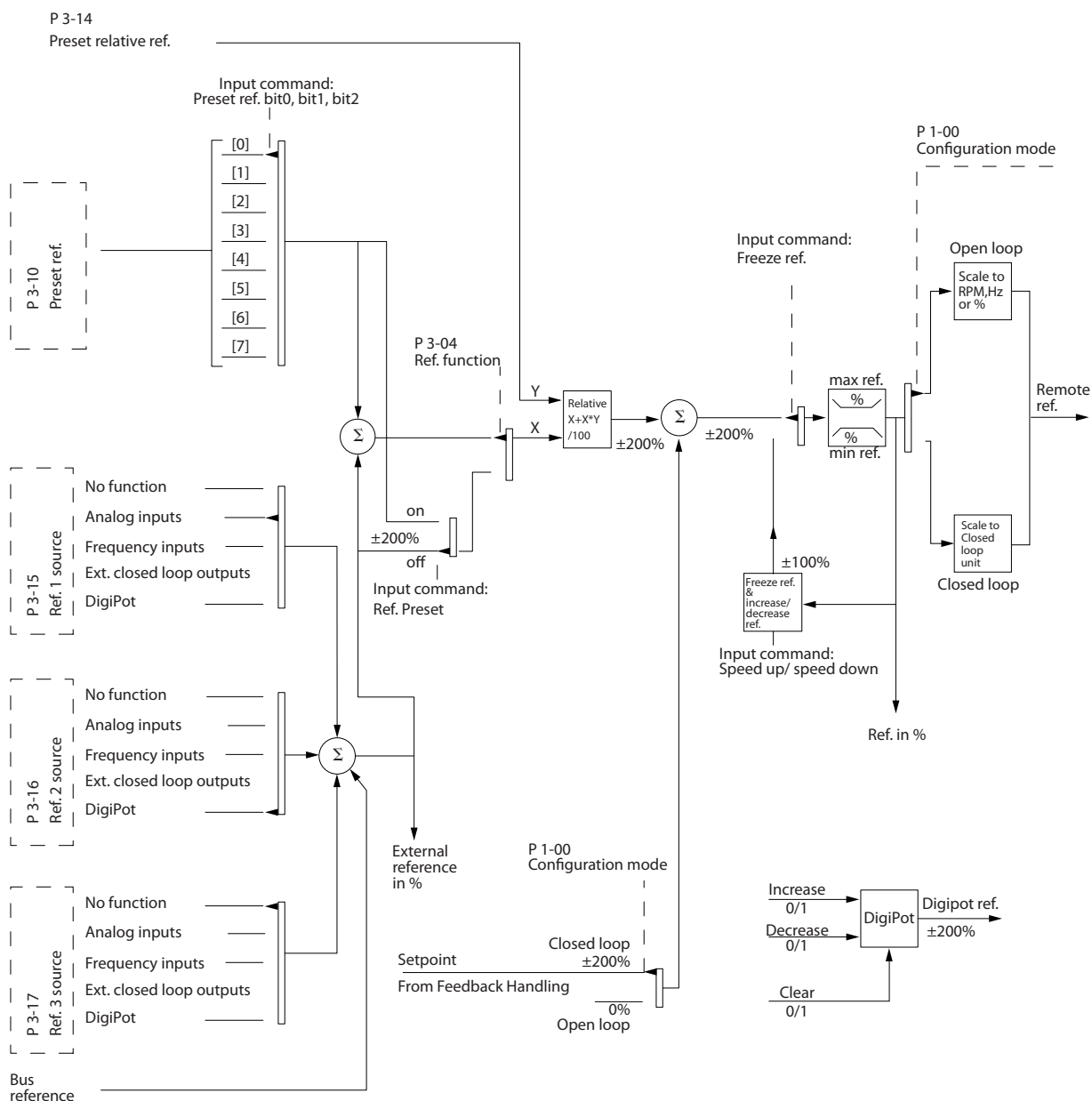


Illustration 8.3 Remote Handling of Reference

8.2.3 Feedback Handling

Feedback handling can be configured to work with applications requiring advanced control, such as multiple setpoints and multiple types of feedback. See *Illustration 8.4*. Three types of control are common:

Single zone (single setpoint)

This control type is a basic feedback configuration. Setpoint 1 is added to any other reference (if any) and the feedback signal is selected.

Multi-zone (single setpoint)

This control type uses 2 or 3 feedback sensors but only 1 setpoint. The feedback can be added, subtracted, or averaged. In addition, the maximum or minimum value can be used. Setpoint 1 is used exclusively in this configuration.

Multi-zone (setpoint/feedback)

The setpoint/feedback pair with the largest difference controls the speed of the drive. The maximum value attempts to keep all zones at or below their respective setpoints, while the minimum value attempts to keep all zones at or above their respective setpoints.

Example

A 2-zone, 2-setpoint application. Zone 1 setpoint is 15 bar, and the feedback is 5.5 bar. Zone 2 setpoint is 4.4 bar, and the feedback is 4.6 bar. If maximum is selected, the zone 2 setpoint and feedback are sent to the PID controller, since it has the smaller difference (feedback is higher than setpoint, resulting in a negative difference). If minimum is selected, the zone 1 setpoint and feedback is sent to the PID controller, since it has the larger difference (feedback is lower than setpoint, resulting in a positive difference).

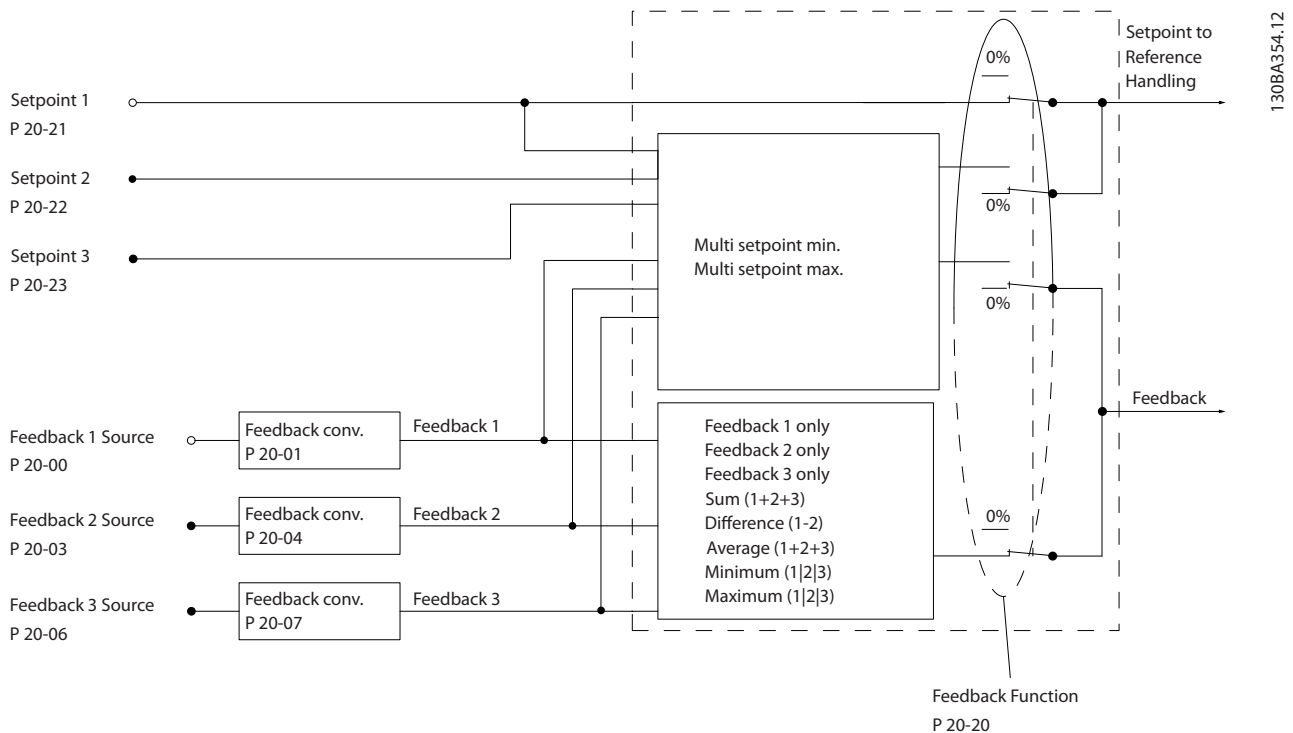
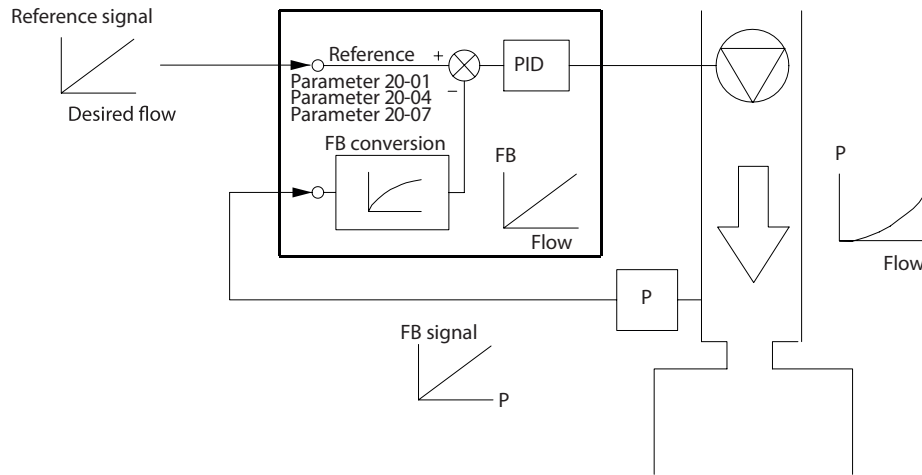


Illustration 8.4 Block Diagram of Feedback Signal Processing

Feedback conversion

In some applications, it is useful to convert the feedback signal. One example is using a pressure signal to provide flow feedback. Since the square root of pressure is proportional to flow, the square root of the pressure signal yields a value proportional to the flow, see *Illustration 8.5*.



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8

Illustration 8.5 Feedback Conversion

8.2.4 Control Structure Overview

The control structure is a software process that controls the motor based on user-defined references (for example, RPM) and whether feedback is used/not used (closed loop/open loop). The operator defines the control in *parameter 1-00 Configuration Mode*.

The control structures are as follows:

Open-loop control structure

- Speed (RPM).
- Torque (Nm).

Closed-loop control structure

- Speed (RPM).
- Torque (Nm).
- Process (user-defined units, for example, feet, lpm, psi, %, bar).

8.2.5 Open-loop Control Structure

In open-loop mode, the drive uses 1 or more references (local or remote) to control the speed or torque of the motor. There are 2 types of open-loop control:

- Speed control. No feedback from the motor.
- Torque control. Used in VVC⁺ mode. The function is used in mechanically robust applications, but its accuracy is limited. Open-loop torque function works only in 1 speed direction. The torque is calculated based on current measurement within the drive. See *chapter 9 Application Examples*.

In the configuration shown in *Illustration 8.6*, the drive operates in open-loop mode. It receives input from either the LCP (hand-on mode) or via a remote signal (auto-on mode).

The signal (speed reference) is received and conditioned with the following:

- Programmed minimum and maximum motor speed limits (in RPM and Hz).
- Ramp-up and ramp-down times.
- Motor rotation direction.

The reference is then passed on to control the motor.

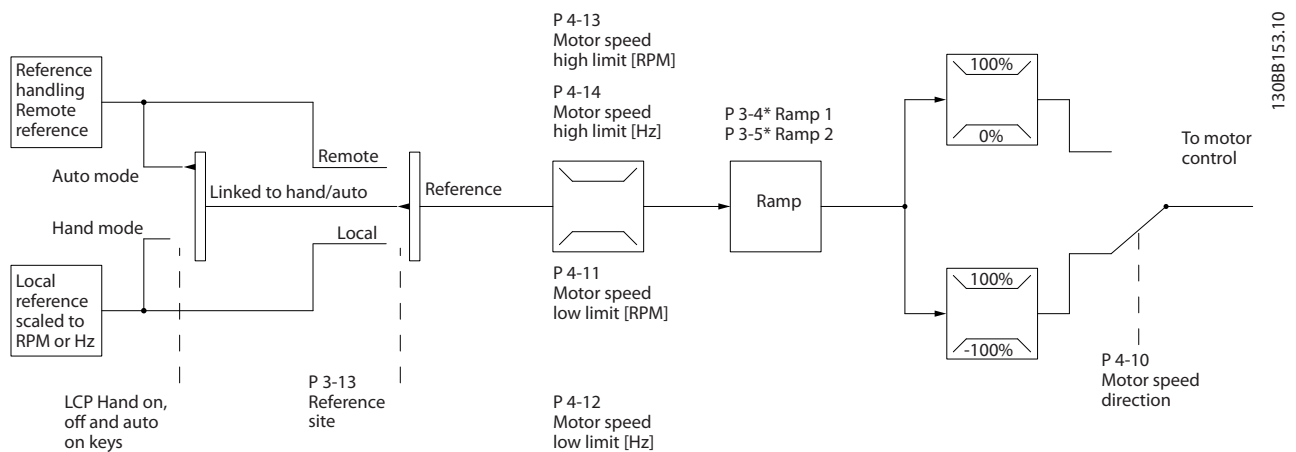


Illustration 8.6 Block Diagram of an Open-loop Control Structure

8.2.6 Closed-loop Control Structure

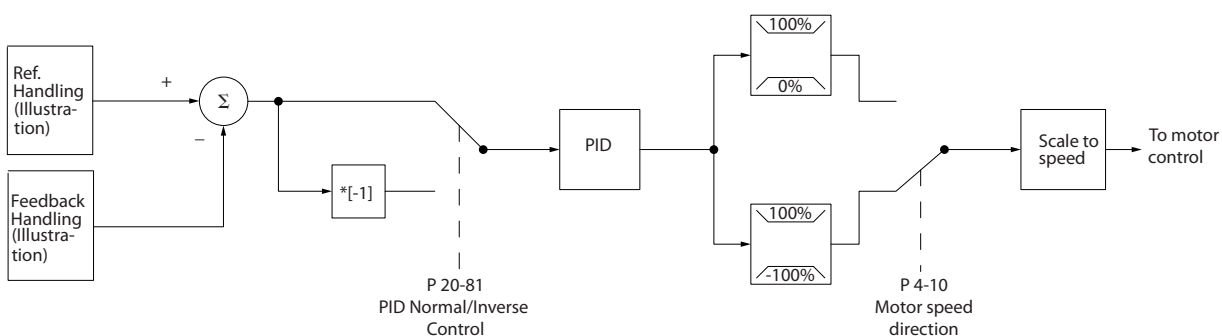
In closed-loop mode, the drive uses 1 or more references (local or remote) and feedback sensors to control the motor. The drive receives a feedback signal from a sensor in the system. It then compares this feedback to a setpoint reference value and determines if there is any discrepancy between these 2 signals. The drive then adjusts the speed of the motor to correct the discrepancy.

For example, consider a pump application in which the speed of the pump is controlled so that the static pressure in a pipe is constant (see *Illustration 8.7*). The drive receives a feedback signal from a sensor in the system. It compares this feedback to a setpoint reference value and determines the discrepancy if any, between these 2 signals. It then adjusts the speed of the motor to compensate for the discrepancy.

The static pressure setpoint is the reference signal to the drive. A static pressure sensor measures the actual static pressure in the pipe and provides this information to the drive as a feedback signal. If the feedback signal exceeds the setpoint reference, the drive ramps down to reduce the pressure. Similarly, if the pipe pressure is lower than the setpoint reference, the drive ramps up to increase the pump pressure.

There are 3 types of closed-loop control:

- Speed control. This type of control requires a speed PID feedback for an input. A properly optimized speed closed-loop control has higher accuracy than a speed open-loop control.
- Process control. Used to control application parameters that are measured by different sensors (pressure, temperature, and flow) and are affected by the connected motor through a pump or fan.



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Illustration 8.7 Block Diagram of Closed-loop Controller

Programmable features

While the default values for the drive in closed loop often provide satisfactory performance, system control can often be optimized by tuning the PID parameters. *Auto tuning* is provided for this optimization.

- Inverse regulation - motor speed increases when a feedback signal is high.
- Start-up frequency - lets the system quickly reach an operating status before the PID controller takes over.
- Built-in lowpass filter - reduces feedback signal noise.

8.2.7 Control Processing

See *Active/Inactive Parameters in Different Drive Control Modes* in the *programming guide* for an overview of which control configuration is available for your application, depending on selection of AC motor or PM motor.

8.2.7.1 Control Structure in VVC⁺

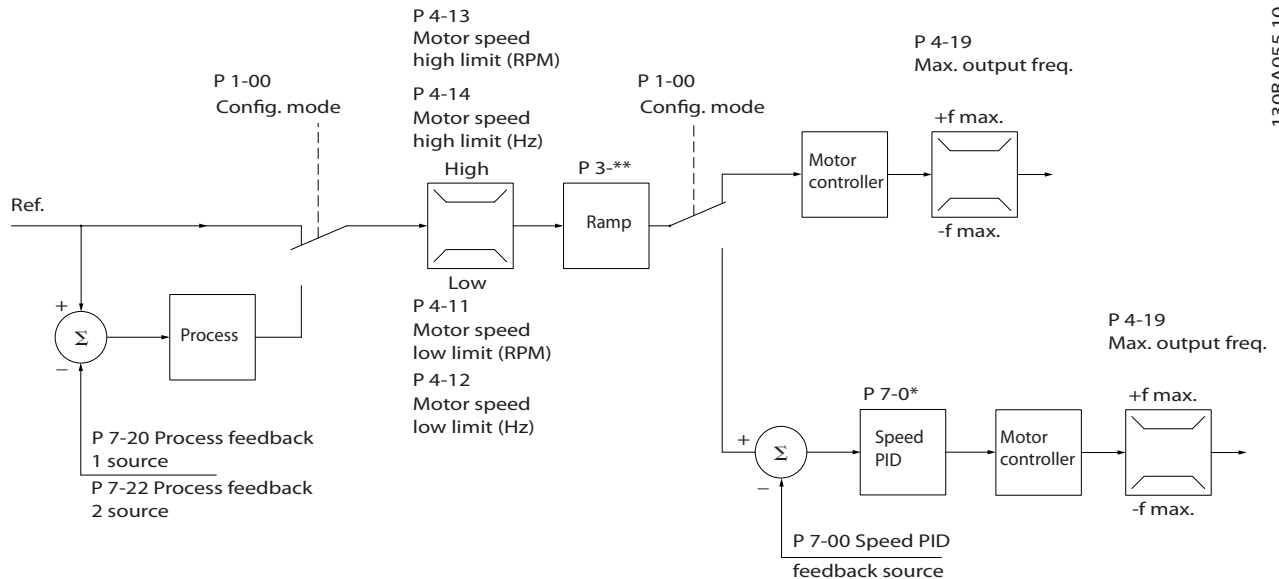


Illustration 8.8 Control Structure in VVC⁺ Open-loop and Closed-loop Configurations

In *Illustration 8.8*, the resulting reference from the reference handling system is received and fed through the ramp limitation and speed limitation before being sent to the motor control. The output of the motor control is then limited by the maximum frequency limit.

Parameter 1-01 Motor Control Principle is set to [1] VVC⁺ and *parameter 1-00 Configuration Mode* is set to [0] Speed open loop. If *parameter 1-00 Configuration Mode* is set to [1] Speed closed loop, the resulting reference is passed from the ramp limitation and speed limitation into a speed PID control. The speed PID control parameters are located in *parameter group 7-0* Speed PID 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, for example, speed or pressure in the controlled application. The process PID parameters are in *parameter groups 7-2* Process Ctrl. Feedb* and *7-3* Process PID Ctrl.*

8.2.7.2 Internal Current Control in VVC⁺ Mode

When the motor torque exceeds the torque limits set in *parameter 4-16 Torque Limit Motor Mode*, *parameter 4-17 Torque Limit Generator Mode*, and *parameter 4-18 Current Limit*, the integral current limit control is activated.

When the drive is at the current limit during motor operation or regenerative operation, it tries to get below the preset torque limits as quickly as possible without losing control of the motor.

9 Application Examples

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

- Parameters associated with the terminals and their settings are shown next to the drawings.
- Switch settings for analog terminals A53 or A54 are shown where required.

9.1 Programming a Closed-loop Drive System

A closed-loop drive system usually consists of the following:

- Motor.
- Drive.
- Encoder as feedback system.
- Transmission.
- Gearbox.
- Load.

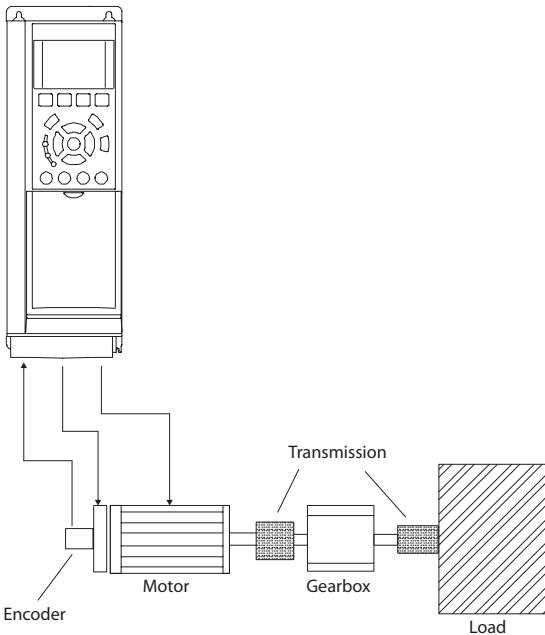


Illustration 9.1 Basic Set-up for Closed-loop Speed Control

9.2 Wiring for Open-loop Speed Control

		Parameters	
		Function	Setting
	FC e30bb926.11	Parameter 6-10 Terminal 53 Low Voltage	0.07 V*
		Parameter 6-11 Terminal 53 High Voltage	10 V*
		Parameter 6-14 Terminal 53 Low Ref./Feedb. Value	0 Hz
		Parameter 6-15 Terminal 53 High Ref./Feedb. Value	50 Hz
		* = Default value	
		Notes/comments: Assumptions are 0 V DC input = 0 Hz speed and 10 V DC input = 50 Hz speed.	

Table 9.1 Analog Speed Reference (Voltage)

		Parameters	
		Function	Setting
	FC e30bb927.11	Parameter 6-12 Terminal 53 Low Current	4 mA*
		Parameter 6-13 Terminal 53 High Current	20 mA*
		Parameter 6-14 Terminal 53 Low Ref./Feedb. Value	0 Hz
		Parameter 6-15 Terminal 53 High Ref./Feedb. Value	50 Hz
		* = Default value	
		Notes/comments: Assumptions are 4 mA input = 0 Hz speed and 20 mA input = 50 Hz speed.	

Table 9.2 Analog Speed Reference (Current)

		Parameters	
FC		Function	Setting
	Parameter 6-12 Terminal 53 Low Current	4 mA*	
	Parameter 6-13 Terminal 53 High Current	20 mA*	
	Parameter 6-14 Terminal 53 Low Ref./Feedb. Value	0 Hz	
	Parameter 6-15 Terminal 53 High Ref./Feedb. Value	50 Hz	
	* = Default value		
Notes/comments:		Assumptions are 0 V DC input = 0 RPM speed and 10 V DC input = 1500 RPM speed.	

Table 9.3 Speed Reference (Using a Manual Potentiometer)

9.3 Wiring for Start/Stop

		Parameters	
FC		Function	Setting
	Parameter 5-10 Terminal 18 Digital Input	[8] Start*	
	Parameter 5-12 Terminal 27 Digital Input	[0] No operation	
	* = Default value		
	Notes/comments:		If parameter 5-12 Terminal 27 Digital Input is set to [0] No operation, a jumper wire to terminal 27 is not needed.

Table 9.5 Start/Stop Command

		Parameters	
FC		Function	Setting
	Parameter 5-10 Terminal 18 Digital Input	[8] Start*	
	Parameter 5-12 Terminal 27 Digital Input	[19] Freeze Reference	
	Parameter 5-13 Terminal 29 Digital Input	[21] Speed Up	
	Parameter 5-14 Terminal 32 Digital Input	[22] Speed Down	
	* = Default value		
Notes/comments:			

Table 9.4 Speed Up/Speed Down

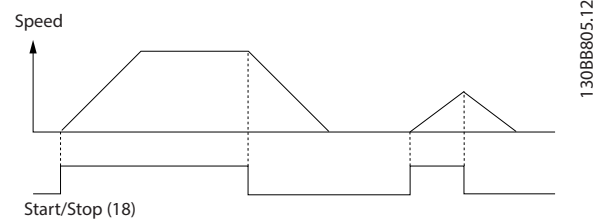


Illustration 9.3 Start/Stop Command

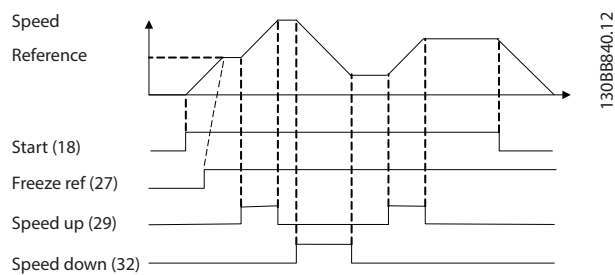


Illustration 9.2 Speed Up/Speed Down

		Parameters	
FC		Function	Setting
	Parameter 5-1 Terminal 18 Digital Input	[9] Latched Start	
	Parameter 5-1 Terminal 27 Digital Input	[6] Stop Inverse	
	* = Default value		
	Notes/comments:		

Table 9.6 Pulse Start/Stop

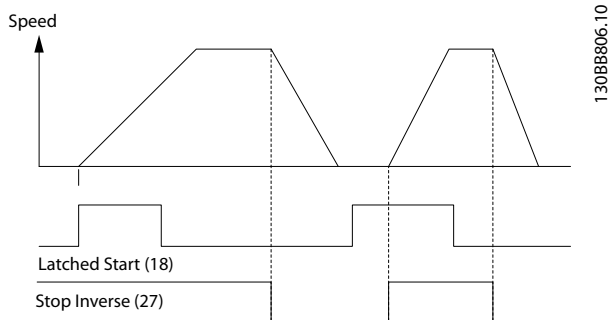


Illustration 9.4 Latched Start/Stop Inverse

9.4 Wiring for External Alarm Reset

		Parameters	
FC		Function	Setting
+24 V	12	Parameter 5-11 Terminal 19 Digital Input	[1] Reset
+24 V	13		
D IN	18	* = Default value	
D IN	19		
COM	20	Notes/comments:	
D IN	27		
D IN	29		
D IN	32		
D IN	33		
+10 V	50		
A IN	53		
A IN	54		
COM	55		
A OUT	42		
COM	39		

Table 9.8 External Alarm Reset

		Parameters	
FC		Function	Setting
+24 V	12	Parameter 5-10 Terminal 18 Digital Input	[8] Start
+24 V	13		
D IN	18	Parameter 5-11 Terminal 19 Digital Input	[10] Reversing*
D IN	19		
COM	20	Notes/comments:	
D IN	27		
D IN	29		
D IN	32		
D IN	33		
+10 V	50		
A IN	53		
A IN	54		
COM	55		
A OUT	42		
COM	39		
		Parameter 3-10 Preset Reference	
		Preset ref. 0	25%
		Preset ref. 1	50%
		Preset ref. 2	75%
		Preset ref. 3	100%
		* = Default value	

Table 9.7 Start/Stop with Reversing and 4 Preset Speeds

9.5 Wiring for a Motor Thermistor

⚠ WARNING

THERMISTOR INSULATION

Risk of personal injury or equipment damage.

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

		Parameters																																			
		Function	Setting																																		
<table border="1"> <tr><td>VLT</td><td></td></tr> <tr><td>+24 V</td><td>120</td></tr> <tr><td>+24 V</td><td>130</td></tr> <tr><td>D IN</td><td>180</td></tr> <tr><td>D IN</td><td>190</td></tr> <tr><td>COM</td><td>200</td></tr> <tr><td>D IN</td><td>270</td></tr> <tr><td>D IN</td><td>290</td></tr> <tr><td>D IN</td><td>320</td></tr> <tr><td>D IN</td><td>330</td></tr> <tr><td colspan="2"> </td></tr> <tr><td>+10 V</td><td>500</td></tr> <tr><td>A IN</td><td>530</td></tr> <tr><td>A IN</td><td>540</td></tr> <tr><td>COM</td><td>550</td></tr> <tr><td>A OUT</td><td>420</td></tr> <tr><td>COM</td><td>390</td></tr> </table>		VLT		+24 V	120	+24 V	130	D IN	180	D IN	190	COM	200	D IN	270	D IN	290	D IN	320	D IN	330			+10 V	500	A IN	530	A IN	540	COM	550	A OUT	420	COM	390	e30bg507.10	
VLT																																					
+24 V	120																																				
+24 V	130																																				
D IN	180																																				
D IN	190																																				
COM	200																																				
D IN	270																																				
D IN	290																																				
D IN	320																																				
D IN	330																																				
+10 V	500																																				
A IN	530																																				
A IN	540																																				
COM	550																																				
A OUT	420																																				
COM	390																																				
		Parameter 1-90 Motor Thermal Protection	[2] Thermistor trip																																		
		Parameter 1-93 Thermistor Resource	[1] Analog input 53																																		
		* = Default value																																			
		Notes/comments: If only a warning is desired, set parameter 1-90 Motor Thermal Protection to [1] Thermistor warning.																																			

Table 9.9 Motor Thermistor

9.6 Wiring Configuration for the Encoder

The direction of the encoder, identified by looking into the shaft end, is determined by which order the pulses enter the drive. See *Illustration 9.5*.

- Clockwise (CW) direction means channel A is 90 electrical degrees before channel B.
- Counterclockwise (CCW) direction means channel B is 90 electrical degrees before A.

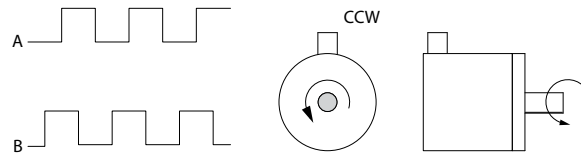
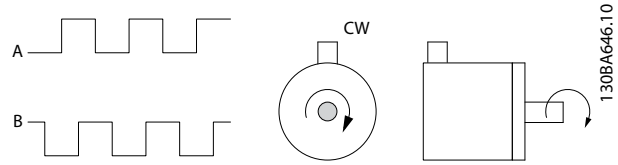


Illustration 9.5 Determining Encoder Direction

NOTICE

Maximum cable length 5 m (16 ft).

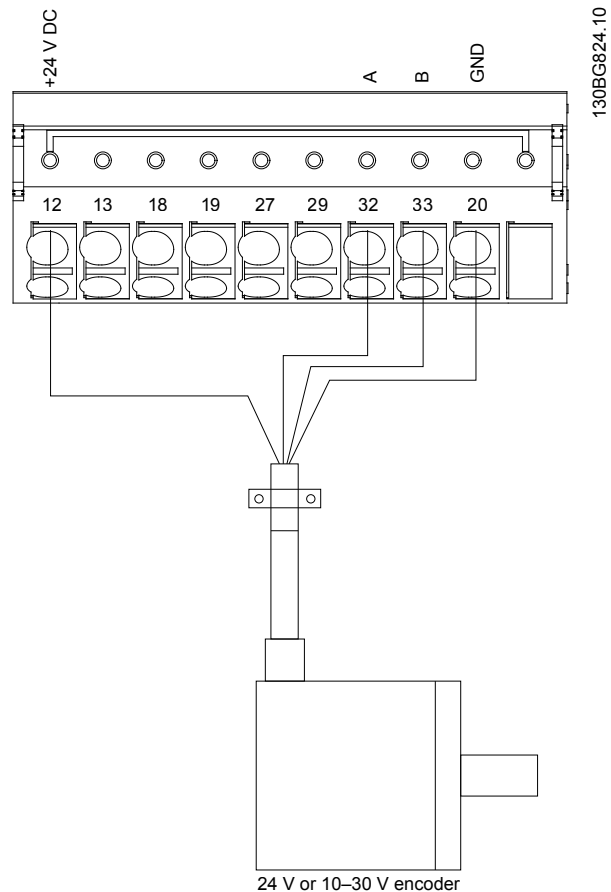


Illustration 9.6 Wire Configuration for the Encoder

10 How to Order a Drive

10.1 Drive Configurator

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
F	C	-	3	6	1					T	4	E	2	0	H	2	X	X	C	X	X	X	S	X	X	X	X	A		B	X

e30b108.11

Table 10.1 Type Code String

Product group	1-6	<input type="text"/>
Model	7-10	<input type="text"/>
Mains Voltage	11-12	<input type="text"/>
Enclosure	13-15	<input type="text"/>
Hardware configuration	16-23	<input type="text"/>
RFI filter	16-17	<input type="text"/>
Brake	18	<input type="text"/>
Display (LCP)	19	<input type="text"/>
PCB coating	20	<input type="text"/>
Mains option	21	<input type="text"/>
Adaptation A	22	<input type="text"/>
Adaptation B	23	<input type="text"/>
Software release	24-27	<input type="text"/>
Software language	28	<input type="text"/>
A options	29-30	<input type="text"/>
B options	31-32	<input type="text"/>

Table 10.2 Type Code Example for Ordering a Drive

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: www.danfoss.com/drives. 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.

An example of a type code string is:

FC-361N132T4E20H2XXCXXXSXXXXA0BX

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 and Chinese languages.

10.1.1 Ordering Type Code for Enclosures J8–J9

Description	Pos	Possible choice
Product group	1-6	FC-361
Model	7–10	N90: 90 kW (125 hp) N110: 110 kW (150 hp) N132: 132 kW (200 hp) N160: 160 kW (250 hp) N200: 200 kW (300 hp) N250: 250 kW (350 hp) N315: 315 kW (450 hp)
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
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

Table 10.3 Ordering Type Code for Enclosures J8–J9

1) Available for all D-frames.

10.1.2 Ordering Options for All VLT® AutomationDrive FC 361 Enclosures

10

Description	Pos	Possible option
A options	29–30	AX: No A option A0: VLT® PROFIBUS DP MCA 101 AL: VLT® PROFINET MCA 120
B options	31–32	BX: No option

Table 10.4 Ordering Type Codes for FC 361 Options

10.2 Ordering Numbers for Options and Accessories

10.2.1 Ordering Numbers for B Options: Functional Extensions

Description	Ordering number
VLT® General Purpose I/O MCB 101	134B6786
VLT® Encoder Input MCB 102	132b0282
VLT® Resolver Input MCB 103	132b0283

Table 10.5 Ordering Numbers for B Options

10.2.2 Ordering Numbers for J8–J9 Kits

Type	Description	Ordering number
LCP		
LCP 101	Numerical local control panel (NLCP).	130B1124
LCP 102	Graphical local control panel (GLCP).	130B1107
LCP cable	Separate LCP cable, 3 m (9 ft).	175Z0929
LCP kit, IP21	Panel mounting kit including graphical LCP, fasteners, 3 m (9 ft) cable and gasket.	130B1113
LCP kit, IP21	Panel mounting kit including numerical LCP, fasteners and gasket.	130B1114
LCP kit, IP21	Panel mounting kit for all LCPs including fasteners, 3 m (9 ft) cable and gasket.	130B1117

Table 10.6 Kits Available for Enclosures J8–J9

10

10.3 Spare Parts

Consult the VLT® Shop or the Drive Configurator (www.danfoss.com/drives) for the spare parts that are available for your application.

11 Appendix

11.1 Abbreviations and Symbols

60° AVM	60° asynchronous vector modulation
A	Ampere/AMP
AC	Alternating current
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
EMC	Electromagnetic compatibility
EMF	Electromotive force
ETR	Electronic thermal relay
°F	Degrees Fahrenheit
f _{JOG}	Motor frequency when jog function is activated
f _M	Motor frequency
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
HIPERFACE®	HIPERFACE® is a registered trademark by Stegmann
HO	High overload
Hp	Horse power
HTL	HTL encoder (10–30 V) pulses - High-voltage transistor logic
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
kHz	Kilohertz
LCP	Local control panel
Lsb	Least significant bit

m	Meter
mA	Milliamperere
MCM	Mille circular mil
MCT	Motion control tool
mH	Inductance in milli Henry
mm	Millimeter
ms	Millisecond
Msb	Most significant bit
η _{VLT}	Efficiency of the drive defined as ratio between power output and power input
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
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, etc
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
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
s	Second
SCCR	Short-circuit current rating
SFAVM	Stator flux-oriented asynchronous vector modulation
STW	Status word
SMPS	Switch mode power supply
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

Table 11.1 Abbreviations and Symbols

11.2 Definitions

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.

Break-away torque

$$n_s = \frac{2 \times par. 1 - 23 \times 60 s}{par. 1 - 39}$$

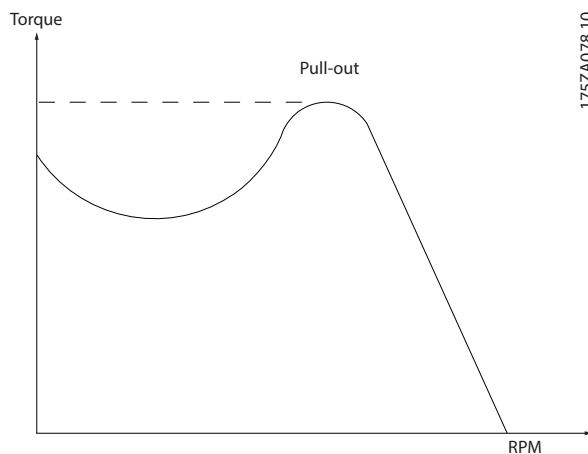


Illustration 11.1 Break-away Torque Chart

Coast

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

CT characteristics

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

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.

Power factor

The true power factor (lambda) takes all the harmonics into consideration and is always smaller than the power factor (cos phi) that only considers the 1st harmonics of current and voltage.

$$\cos\phi = \frac{P \text{ (kW)}}{P \text{ (kVA)}} = \frac{U\lambda \times I\lambda \times \cos\phi}{U\lambda \times I\lambda}$$

Cos phi is also known as displacement power factor.

Both lambda and cos phi are stated for Danfoss VLT® drives in *chapter 5.2 Mains Supply*.

The power factor indicates to which extent the drive imposes a load on the mains. The lower the power factor, the higher the I_{RMS} for the same kW performance. In addition, a high-power factor indicates that the harmonic currents are low.

All Danfoss drives have built-in DC coils in the DC link to have a high-power factor and reduce the THD on the main supply.

Pulse input/incremental encoder

An external digital sensor used for feedback information of motor speed and direction. Encoders are used for high-speed accuracy feedback and in high dynamic applications.

Set-up

Save parameter settings in 4 set-ups. Change between the 4 parameter set-ups and edit 1 set-up while another set-up is active.

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*).

FC standard bus

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

Thermistor

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

Trip

A state entered in fault situations, such as when the drive is subject to an overtemperature or when it protects the motor, process, or mechanism. Restart is prevented until the cause of the fault has disappeared and the trip state is canceled.

Trip lock

A state entered in fault situations when the drive is protecting itself and requires physical intervention. 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.

VT characteristics

Variable torque characteristics for pumps and fans.

11.3 RS485 Installation and Set-up

RS485 is a 2-wire bus interface compatible with multi-drop network topology. 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. Note each repeater function 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 always 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. If necessary, apply potential-equalizing cables to maintain the same ground potential throughout the network, particularly in installations with long cables.

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

Cable	Shielded twisted pair (STP)
Impedance	120 Ω
Cable length	Maximum 1200 m (3937 ft), including drop lines. Maximum 500 m (1640.5 ft) station-to-station

Table 11.2 Motor Cable

One or more drives can be connected to a control (or master) using the RS485 standardized interface. Terminal 68 is connected to the P signal (TX+, RX+), while terminal 69 is connected to the N signal (TX-, RX-). See illustrations in *chapter 7.14 EMC-compliant Installation*.

If more than 1 drive is connected to a master, use parallel connections.

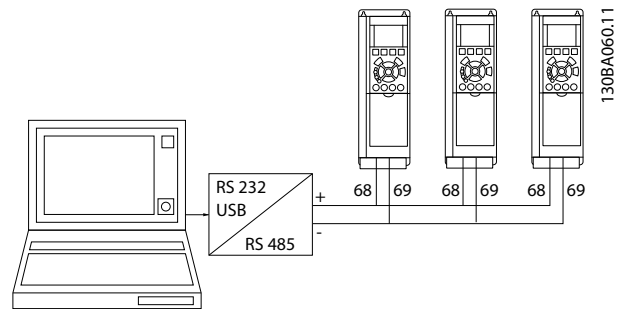


Illustration 11.2 Parallel Connections

To avoid potential equalizing currents in the shield, ground the cable shield via terminal 61, which is connected to the frame via an RC-link.

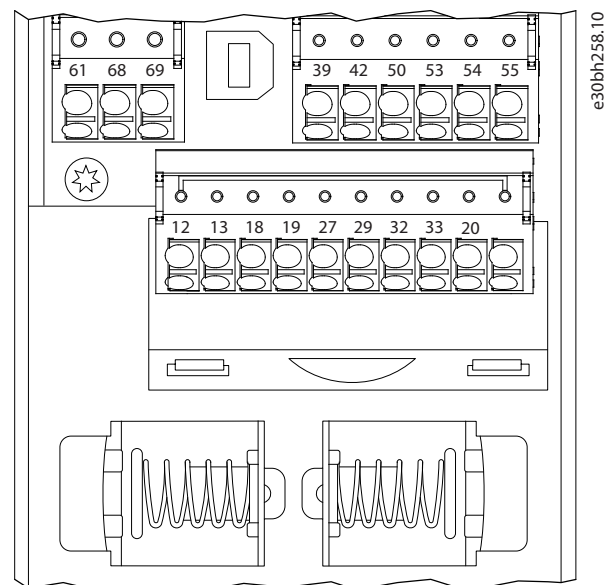


Illustration 11.3 Control Card Terminals

The RS485 bus must be terminated by using a resistor network at both ends. For this purpose, set switch S801 on the control card to "ON".

For more information, see *chapter 7.2 Wiring Schematic*.

Communication protocol must be set to *parameter 8-30 Protocol*.

11.3.1 EMC Precautions

To achieve interference-free operation of the RS485 network, the following EMC precautions are recommended.

Relevant national and local regulations regarding protective ground connection, for example, must be observed. The RS485 communication cable must be kept away from motor and brake resistor cables to avoid coupling of high-frequency noise from 1 cable to another. Normally a distance of 200 mm (8 in) is sufficient. However, in situations where cables run in parallel over long distances, keeping the greatest possible distance between cables is recommended. When crossing is unavoidable, the RS485 cable must cross motor and brake resistor cables at an angle of 90°.

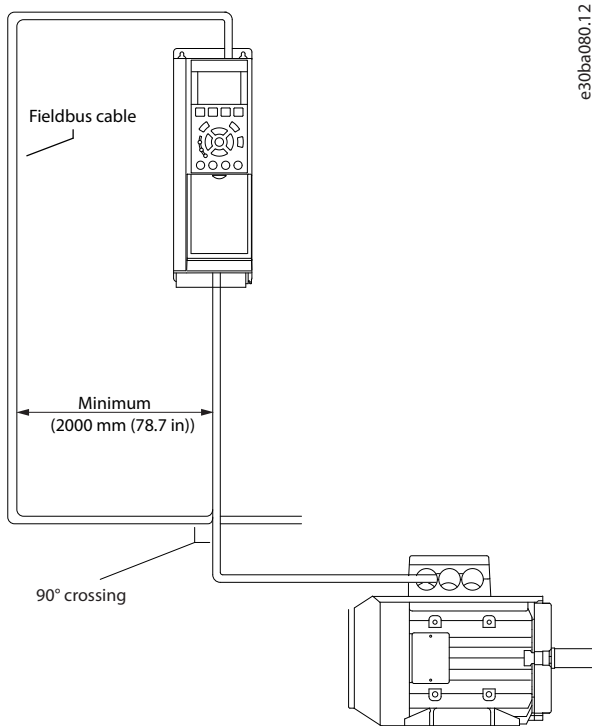


Illustration 11.4 EMC Precautions

11.4 RS485: FC Protocol Overview

11.4.1 FC Protocol 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/slave principle for communications via a field bus.

One master and a maximum of 126 slaves can be connected to the bus. The master selects the individual slaves via an address character in the telegram. The slave itself can never transmit without first being requested to do so, and direct message transfer between the individual slaves 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.

11.4.2 Drive Set-up

Set the following parameters to enable the FC protocol for the drive.

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

Table 11.3 FC Protocol Parameters

11.5 RS485: FC Protocol Telegram Structure

11.5.1 Content of a Character (Byte)

Each character transferred begins with a start bit. Then 8 data bits are transferred, each 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 1 characters in the 8 data bits and the parity bit in total. A stop bit completes a character, thus consisting of 11 bits in all.



Illustration 11.5 Character (Byte)

11.5.2 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).

A number of data bytes (variable, depending on the type of telegram) follows.

A data control byte (BCC) completes the telegram.

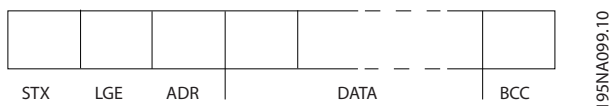


Illustration 11.6 Telegram Structure

11.5.3 Telegram Length (LGE)

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

- The length of telegrams with 4 data bytes is $LGE=4+1+1=6$ bytes.
- The length of telegrams with 12 data bytes is $LGE=12+1+1=14$ bytes.
- The length of telegrams containing texts is 10^1+n bytes.

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

11.5.4 Drive Address (ADR)

Two different address formats are used.

The address range of the drive is either 1–31 or 1–126.

- Address format 1–31
 - Bit 7=0 (address format 1–31 active).
 - Bit 6 is not used.
 - Bit 5=1: Broadcast, address bits (0–4) are not used.
 - Bit 5=0: No broadcast.
 - Bit 0–4=drive address 1–31.
- 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 slave returns the address byte unchanged to the master in the response telegram.

11.5.5 Data Control Byte (BCC)

The checksum is calculated as an XOR-function. Before the 1st byte in the telegram is received, the calculated checksum is 0.

11.5.6 Data Field

The structure of data blocks depends on the type of telegram. There are 3 types, and the type applies to both control telegrams (master⇒slave) and response telegrams (slave⇒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-slave).
- Status word and present output frequency (from slave-to-master).

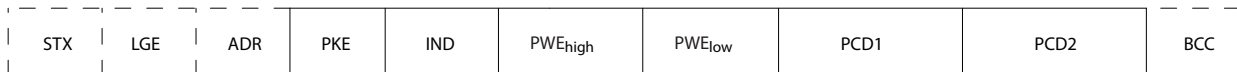


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Illustration 11.7 PCD

Parameter block

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



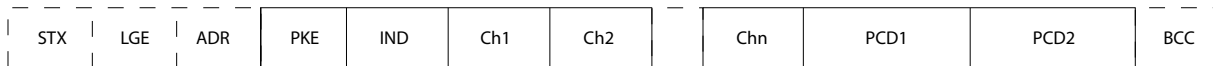
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Illustration 11.8 Parameter Block

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Text block

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



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Illustration 11.9 Text Block

11.5.7 PKE Field

The PKE field contains 2 sub-fields:

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

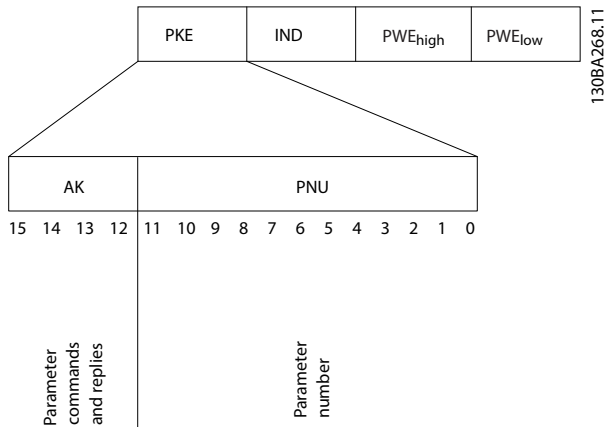


Illustration 11.10 PKE Field

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

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/write text.

Table 11.4 Parameter Commands Master⇒Slave

Bit number				Response
15	14	13	12	
0	0	0	0	No response.
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.

Table 11.5 Response Slave⇒Master

If the command cannot be performed, the slave sends this response:

0111 Command cannot be performed

- and issues the following fault report in the parameter value (PWE):

PWE low (hex)	Fault report
0	The parameter number used does not exist.
1	There is no write access to the defined parameter.
2	Data value exceeds the parameter limits.
3	The sub-index used does not exist.
4	The parameter is not the array type.
5	The data type does not match the defined parameter.
11	Data change in the defined parameter is not possible in the present mode of the drive. Certain parameters can only be changed when the motor is turned off.
82	There is no bus access to the defined parameter.
83	Data change is not possible because factory set-up is selected.

Table 11.6 Fault Report

11.5.8 Parameter Number (PNU)

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

11.5.9 Index (IND)

The index is used together 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 a low byte and a high byte.

Only the low byte is used as an index.

11.5.10 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 slave.

When a slave 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 not a numerical value but several data options, for example, *parameter 0-01 Language [0] English*, and *[4] Danish*, 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.

Some parameters contain text that can be written via the fieldbus. To write a text via the PWE block, set the parameter command (AK) to F hex. The index characters high-byte must be 5.

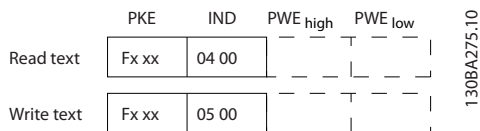


Illustration 11.11 PWE

11

11.5.11 Data Types Supported

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

Data types	Description
3	Integer 16
4	Integer 32
5	Unsigned 8
6	Unsigned 16
7	Unsigned 32
9	Text string
10	Byte string
13	Time difference
33	Reserved
35	Bit sequence

Table 11.7 Data Types Supported

11.5.12 Conversion

The various attributes of each parameter are shown in the section factory settings. Parameter values are transferred as whole numbers only. Conversion factors are therefore 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.

Examples:

- 0 s⇒conversion index 0
- 0.00 s⇒conversion index -2
- 0 M/S⇒conversion index -3
- 0.00 M/S⇒conversion index -5

Conversion index	Conversion factor
100	
75	
74	
67	
6	1000000
5	100000
4	10000
3	1000
2	100
1	10
0	1
-1	0.1
-2	0.01
-3	0.001
-4	0.0001
-5	0.00001
-6	0.000001
-7	0.0000001

Table 11.8 Conversion Table

11.5.13 Process Words (PCD)

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

PCD 1	PCD 2
Control telegram (master⇒slave control word)	Reference-value
Control telegram (slave⇒master) status word	Present output frequency

Table 11.9 PCD Sequence

11.6 RS485: FC Protocol Parameter Examples

11.6.1 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

PWE_{high}=0000 hex

PWE_{low}=03E8 hex - Data value 1000, corresponding to 100 Hz, see *chapter 11.5.12 Conversion*.

E19E	H	0000	H	0000	H	03E8	H
PKE		IND		PWE _{high}		PWE _{low}	

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Illustration 11.12 Telegram

NOTICE

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

119E	H	0000	H	0000	H	03E8	H
PKE		IND		PWE _{high}		PWE _{low}	

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Illustration 11.13 Response from Master-to-Slave

11.6.2 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_{high}=0000 hex

PWE_{low}=0000 hex

1155	H	0000	H	0000	H	0000	H
PKE		IND		PWE _{high}		PWE _{low}	

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Illustration 11.14 Parameter Value

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

1155	H	0000	H	0000	H	03E8	H
PKE		IND		PWE _{high}		PWE _{low}	

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Illustration 11.15 Response from Slave-to-Master

3E8 hex corresponds to 1000 decimal. The conversion index for *parameter 3-41 Ramp 1 Ramp Up Time* is -2. *Parameter 3-41 Ramp 1 Ramp Up Time* is of the type *Unsigned 32*.

11.7 RS485: Modbus RTU Overview

11.7.1 Assumptions

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

11.7.2 Prerequisite Knowledge

The 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 reader has full knowledge of the capabilities and limitations of the controller.

11.7.3 Modbus RTU Overview

Regardless of the type of physical communication networks, the Modbus RTU Overview describes the process 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 message fields.

During communications over a Modbus RTU network, the protocol determines:

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

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

Controllers communicate using a master-slave technique in which only 1 device (the master) can initiate transactions (called queries). The other devices (slaves) respond by supplying the requested data to the master, or by responding to the query.

The master can address individual slaves or can initiate a broadcast message to all slaves. Slaves return a message, called 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 placing into it the device (or broadcast) address, a function code defining the requested action, any data to send, and an error-checking field. The slave response message is also constructed using Modbus protocol. It contains fields confirming the action taken, any data to return, and an error-checking field. If an error occurs in receipt of the message, or if the slave is unable to perform the requested action, the slave constructs an error message, which it sends in response, or a timeout occurs.

11.7.4 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.
- 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 the active set-up.
- Control the 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, allowing a range of control options, including controlling the setpoint of the drive when its internal PI controller is used.

11.7.5 Drive with Modbus RTU

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

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

11.7.6 Drive with Modbus RTU

The controllers are set up to communicate on the Modbus network using RTU mode, with each byte in a message containing 2 4-bit hexadecimal characters. The format for each byte is shown in *Table 11.10*.

Start bit	Data byte						Stop/parity	Stop

Table 11.10 Example Format

Coding system	8-bit binary, hexadecimal 0-9, A-F. 2 hexadecimal characters contained in each 8-bit field of the message.
Bits per byte	1 start bit. 8 data bits, least significant bit sent first. 1 bit for even/odd parity; no bit for no parity. 1 stop bit if parity is used; 2 bits if no parity.
Error check field	CRC (cyclical redundancy check)

Table 11.11 Bit Detail

11.8 RS485: Modbus RTU Telegram Structure

11.8.1 Modbus RTU Telegram Structure

The transmitting device places a Modbus RTU message into a frame with a known beginning and ending point. Receiving devices are able to begin at the start of the message, read the address portion, determine which device is addressed (or all devices, if the message is broadcast), and to recognize when the message is completed. Partial messages 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 1st field (the address field) is received, each drive or device decodes it to determine which device is being addressed. Modbus RTU messages addressed to 0 are broadcast messages. No response is allowed for broadcast messages. A typical message frame is shown in *Table 11.12*.

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

Table 11.12 Typical Modbus RTU Telegram Structure

11.8.2 Start/Stop Field

Messages start with a silent period of at least 3.5 character intervals, implemented as a multiple of character intervals at the selected network baud rate (shown as start T1-T2-T3-T4). The 1st transmitted field is the device address. Following the last transmitted character, a similar period of at least 3.5 character intervals marks the end of the message. A new message can begin after this period. The entire message frame must be transmitted 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 message and assumes that the next byte is the address field of a new message. Similarly, if a new message begins before 3.5 character intervals after a previous message, the receiving device considers it a continuation of the previous message, causing a timeout (no response from the slave), since the value in the final CRC (cyclical redundancy check) field is not valid for the combined messages.

11.8.3 Address Field

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

11.8.4 Function Field

The function field of a message frame contains 8 bits. Valid codes are in the range of 1–FF. Function fields are used to send messages between master and slave. When a message is sent from a master to a slave device, the function code field tells the slave what action to perform. When the slave responds to the master, it uses the function code field to indicate either a normal (error-free) response, or that an error has occurred (called an exception response). For a normal response, the slave simply echoes the original function code. For an exception response, the slave returns a code that is equivalent to the original function code with its most significant bit set to logic 1. In addition, the slave places a unique code into the data field of the response message. This code tells the master what error occurred, or the reason for the exception. See *chapter 11.9.1 Function Codes Supported by Modbus RTU*.

11.8.5 Data Field

The data field is constructed using sets of 2 hexadecimal digits, in the range of 00–FF hexadecimal. These sequences are made up of 1 RTU character. The data field of messages sent from a master-to-slave device contains more information, which the slave must use to do what is defined by the function code. This information can include items such as coil or register addresses, the quantity of items, and the count of actual data bytes in the field.

11.8.6 CRC Check Field

Messages include an error-checking field, operating based on a CRC (cyclical redundancy check) method. The CRC field checks the contents of the entire message. It is applied regardless of any parity check method used for the individual characters of the message. The transmitting device calculates the CRC value then appends the CRC as the last field in the message. The receiving device recalculates a CRC during receipt of the message and compares the calculated value to the actual value received in the CRC field. If the 2 values are unequal, a bus timeout results. The error-checking field contains a 16-bit binary value implemented as 2 8-bit bytes. After error-checking, 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 message.

11.8.7 Coil Register Addressing

In Modbus, all data are organized in coils and holding registers. Coils hold a single bit, whereas holding registers hold a 2 byte word (16 bits). All data addresses in Modbus messages are referenced to 0. The 1st 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 message. 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 message. 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).

Coil number	Description	Signal direction
1–16	Drive control word (see <i>Table 11.14</i>).	Master-to-slave
17–32	Drive speed or setpoint reference range 0x0–0xFFFF (-200% ... ~200%).	Master-to-slave
33–48	Drive status word (see <i>Table 11.14</i>).	Master-to-slave
49–64	Open-loop mode: Drive output frequency. Closed-loop mode: Drive feedback signal.	Slave-to-master
65	Parameter write control (master-to-slave).	Master-to-slave
	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 11.13 Coils and Holding Registers

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	Set up MSB	
16	No reversing	Reversing

Coil	0	1
33	Control not ready	Control ready
34	Drive not ready	Drive ready
35	Coasting 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 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 11.14 Drive Control Word (FC Profile)

Table 11.15 Drive Status Word (FC Profile)

Register number	Description
00001–00006	Reserved.
00007	Last fault code from an FC data object interface.
00008	Reserved.
00009	Parameter index ¹⁾ .
00010–00990	000 parameter group (parameters 001–099).
01000–01990	100 parameter group (parameters 100–199).
02000–02990	200 parameter group (parameters 200–299).
03000–03990	300 parameter group (parameters 300–399).
04000–04990	400 parameter group (parameters 400–499).
...	...
49000–49990	4900 parameter group (parameters 4900–4999).
50000	Input data: Drive control word register (CTW).
50010	Input data: Bus reference register (REF).
...	...
50200	Output data: Drive status word register (STW).
50210	Output data: Drive main actual value register (MAV).

Table 11.16 Holding Registers

1) Used to specify the index number used when accessing an indexed parameter.

11.9 RS485: Modbus RTU Message Function Codes

11.9.1 Function Codes Supported by Modbus RTU

Modbus RTU supports use of the function codes in *Table 11.17* in the function field of a message.

Function	Function code
Read coils	1 hex
Read holding registers	3 hex
Write single coil	5 hex
Write single register	6 hex
Write multiple coils	F hex
Write multiple registers	10 hex
Get comm. event counter	B hex
Report slave ID	11 hex

Table 11.17 Function Codes

Function	Function code	Sub-function code	Sub-function
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 bus exception error count.
		14	Return slave message count.

Table 11.18 Function Codes

11.9.2 Modbus Exception Codes

For a full explanation of the structure of an exception code response, refer to *chapter 11.8 RS485: Modbus RTU Telegram Structure*.

Code	Name	Meaning
1	Illegal function	The function code received in the query is not an allowable action for the server (or slave). This code can 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 slave) 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 slave). 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 would succeed, 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 slave). This code indicates a fault in the structure of the remainder of a complex request, such as that the implied length is incorrect. It specifically 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 particular value of any particular register.
4	Slave device failure	An unrecoverable error occurred while the server (or slave) was attempting to perform the requested action.

Table 11.19 Modbus Exception Codes

11.10 RS485: Modbus RTU Parameters

11.10.1 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 (10xparameter number) DECIMAL.

11.10.2 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).

11.10.3 IND

The array index is set in holding register 9 and used when accessing array parameters.

11.10.4 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.

11.10.5 Conversion Factor

Since a parameter value can only be transferred as a whole number, a conversion factor must be used to transfer decimals. See *chapter 11.6 RS485: FC Protocol Parameter Examples*.

11.10.6 Parameter Values

Standard data types

Standard data types are int16, int32, uint8, uint16, and uint32. 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).

11.11 RS485: FC Control Profile

11.11.1 Control Word According to FC Profile

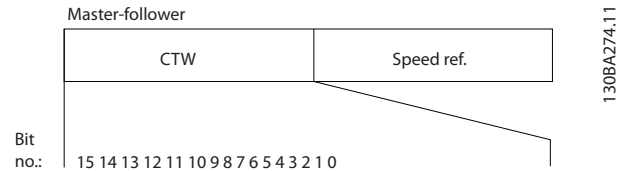


Illustration 11.16 CW Master-to-Slave

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	No function	Relay 01 active
12	No function	Relay 02 active
13	Parameter set-up	Selection lsb
14	Parameter set-up	Selection msb
15	No function	Reverse

Explanation of the control bits

Bits 00/01

Bits 00 and 01 are used to select between the 4 reference values, which are pre-programmed in *parameter 3-10 Preset Reference* according to *Table 11.20*.

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

Table 11.20 Control Bits

NOTICE

Make a selection in *parameter 8-56 Preset Reference Select* to define how bit 00/01 gates with the corresponding function on the digital inputs.

Bit 02, DC brake

Bit 02=0 leads to DC braking 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 shuts off the output transistors and the motor coasts to a standstill.

Bit 03=1: The drive starts the motor if the other starting conditions are met.

Make a selection in *parameter 8-50 Coasting Select* to 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 found in *parameter 5-10 Terminal 18 Digital Input* – *parameter 5-15 Terminal 33 Digital Input*.

NOTICE

If freeze output is active, only the following conditions can stop the drive:

- Bit 03 Coasting stop.
- Bit 02 DC braking.
- Digital input (*parameter 5-10 Terminal 18 Digital Input* – *parameter 5-15 Terminal 33 Digital Input*) programmed to *DC braking, Coasting stop, or Reset and Coasting stop*.

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: Allows the drive to start the motor if the other starting conditions are met.

Make a selection in *parameter 8-53 Start Select* to 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 edge of the signal, that is, when changing from logic 0 to logic 1.

Bit 08, Jog

Bit 08=1: The output frequency depends on *parameter 3-19 Jog Speed [RPM]*.

Bit 09, Selection of ramp 1/2

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

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

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. Thus, it is possible to turn off the control word if not in use when updating or reading parameters.

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 04

Bit 12=0: Relay 04 is not activated.

Bit 12=1: Relay 04 is activated if [37] *Control word bit 12* is selected in *parameter 5-40 Function Relay*.

Bit 13/14, Selection of set-up

Use bits 13 and 14 to select from the 4 menu set-ups according to *Table 11.21*.

Set-up	Bit 14	Bit 13
1	0	0
2	0	1
3	1	0
4	1	1

Table 11.21 Selection of Set-Up

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

Make a selection in *parameter 8-55 Set-up Select* to define how bit 13/14 gates with the corresponding function on the digital inputs.

Bit 15 Reverse

Bit 15=0: No reversing.

Bit 15=1: Reversing. In the default setting, reversing is set to [0] *Digital input* in *parameter 8-54 Reversing Select*. Bit 15 causes reversing only when the following is selected:

- Serial communication.
- Logic or.
- Logic and.

11.11.2 Status Word According to FC Profile

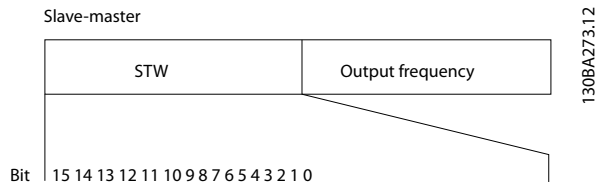


Illustration 11.17 STW Slave-to-Master

Bit	Bit=0	Bit=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	Triplock
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

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 in the case of a 24 V external supply to the controls.

Bit 01, Drive 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, Coasting 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 is running, but the present speed is different from the preset speed reference. For example, 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: [Stop/reset] is activated on the control unit or [2] Local in parameter 3-13 Reference Site is selected. The drive cannot be controlled 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 4-11 Motor Speed Low Limit [RPM] or parameter 4-13 Motor Speed High Limit [RPM].

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 or the output frequency is greater than 0 Hz.

Bit 12, Drive OK/stopped, autostart

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

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

Bit 13, Voltage OK/limit exceeded

Bit 13=0: There are no voltage warnings.

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

Bit 14, Torque OK/limit exceeded

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

Bit 14=1: The torque 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: One of the timers exceeds 100%.

If the connection between the InterBus option and the drive is lost, or an internal communication problem has occurred, all bits in the STW are set to 0.

11.11.3 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; in integers (0–32767) the value 16384 (4000 hex) corresponds to 100%. Negative figures are formatted with 2's complement. The actual output frequency (MAV) is scaled in the same way as the bus reference.

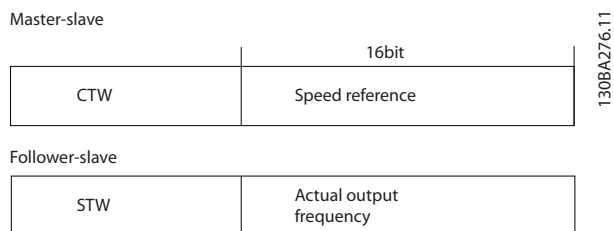


Illustration 11.18 Bus Speed Reference Value

The reference and MAV are scaled as shown in *Illustration 11.19*.

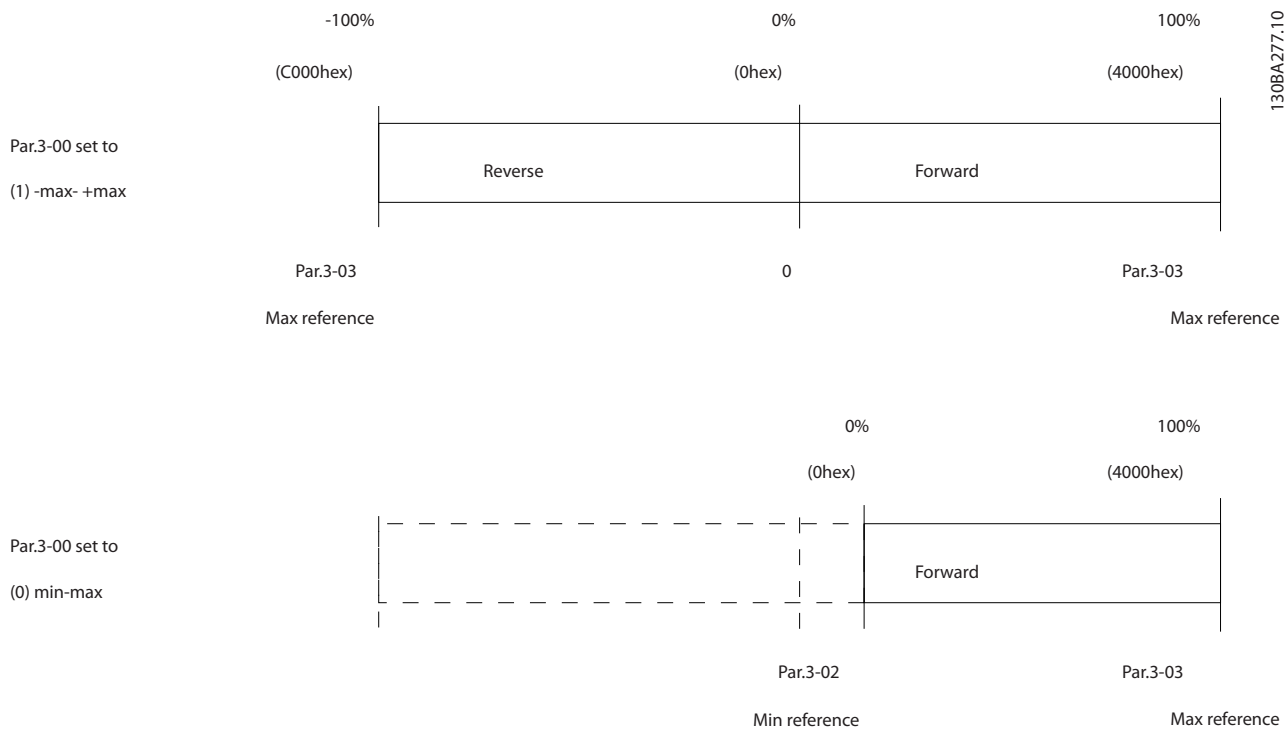


Illustration 11.19 Reference and MAV

11.11.4 Control Word According to PROFdrive Profile (CTW)

The control word is used to send commands from a master to a slave.

Bit	Bit=0	Bit=1
00	OFF 1	ON 1
01	OFF 2	ON 2
02	OFF 3	ON 3
03	Coasting	No coasting
04	Quick stop	Ramp
05	Hold frequency output	Use ramp
06	Ramp stop	Start
07	No function	Reset
08	Jog 1 OFF	Jog 1 ON
09	Jog 2 OFF	Jog 2 ON
10	Data invalid	Data valid
11	No function	Slow down
12	No function	Catch up
13	Parameter set-up	Selection lsb
14	Parameter set-up	Selection msb
15	No function	Reverse

Table 11.22 Bit Values for Control Word, PROFdrive Profile

Explanation of the control bits

Bit 00, OFF 1/ON 1

Normal ramp stops using the ramp times of the actual selected ramp.
 Bit 00=0 leads to the stop and activation of the output relay 1 or 2 if the output frequency is 0 Hz and if [31] Relay 123 has been selected in *parameter 5-40 Function Relay*.
 When bit 00=1, the drive is in State 1: Switching on inhibited.

Bit 01, OFF 2/ON 2

Coasting stop
 When bit 01=0, a coasting stop and activation of the output relay 1 or 2 occurs if the output frequency is 0 Hz and if [31] Relay 123 has been selected in *parameter 5-40 Function Relay*.
 When bit 01=1, the drive is in State 1: on inhibited. Refer to *Table 11.23* at the end of this section.

Bit 02, OFF 3/ON 3

Quick stop using the ramp time of *parameter 3-81 Quick Stop Ramp Time*.
 When bit 02=0, a quick stop and activation of the output relay 1 or 2 occurs if the output frequency is 0 Hz and if [31] Relay 123 has been selected in *parameter 5-40 Function Relay*.
 When bit 02=1, the drive is in State 1: Switching on inhibited.

Bit 03, Coasting/No coasting

Coasting stop bit 03=0 leads to a stop.

When bit 03=1, the drive can start if the other start conditions are satisfied.

NOTICE

The selection in *parameter 8-50 Coasting Select* determines how bit 03 is linked with the corresponding function of the digital inputs.

Bit 04, Quick stop/Ramp

Quick stop using the ramp time of *parameter 3-81 Quick Stop Ramp Time*.
 When bit 04=0, a quick stop occurs.
 When bit 04=1, the drive can start if the other start conditions are satisfied.

NOTICE

The selection in *parameter 8-51 Quick Stop Select* determines how bit 04 is linked with the corresponding function of the digital inputs.

Bit 05, Hold frequency output/Use ramp

When bit 05=0, the current output frequency is being maintained even if the reference value is modified.
 When bit 05=1, the drive can perform its regulating function again; operation occurs according to the respective reference value.

Bit 06, Ramp stop/Start

Normal ramp stop using the ramp times of the actual ramp as selected. In addition, activation of the output relay 01 or 04 if the output frequency is 0 Hz if [31] Relay 123 has been selected in *parameter 5-40 Function Relay*.
 Bit 06=0 leads to a stop.
 When bit 06=1, the drive can start if the other start conditions are fulfilled.

NOTICE

The selection in *parameter 8-53 Start Select* determines how bit 06 is linked with the corresponding function of the digital inputs.

Bit 07, No function/Reset

Reset after switching off.
 Acknowledges event in fault buffer.
 When bit 07=0, no reset occurs.
 When there is a slope change of bit 07 to 1, a reset occurs after switching off.

Bit 08, Jog 1 OFF/ON

Activates the pre-programmed speed in *parameter 8-90 Bus Jog 1 Speed*. JOG 1 is only possible if bit 04=0 and bit 00-03=1.

Bit 09, Jog 2 OFF/ON

Activates the pre-programmed speed in *parameter 8-91 Bus Jog 2 Speed*. JOG 2 is only possible if bit 04=0 and bit 00-03=1.

Bit 10, Data invalid/valid

Tells the drive whether the control word should be used or ignored.

Bit 10=0 causes the control word to be ignored.
 Bit 10=1 causes the control word to be used. This function is relevant because the control word is always contained in the telegram, regardless of which type of telegram is used. For example, it is possible to turn off the control word if it is not intended to be used with updating or reading parameters.

Bit 11, No function/slow down

Reduces the speed reference value by the amount given in *parameter 3-12 Catch up/slow Down Value*.
 When bit 11=0, no modification of the reference value occurs. When bit 11=1, the reference value is reduced.

Bit 12, No function/catch up

Increases the speed reference value by the amount given in *parameter 3-12 Catch up/slow Down Value*.
 When bit 12=0, no modification of the reference value occurs.
 When bit 12=1, the reference value is increased.
 If both slowing down and accelerating are activated (bits 11 and 12=1), slowing down has priority, for example the speed reference value is reduced.

Bits 13/14, Set-up selection

Selects between the 4 parameter set-ups according to *Table 11.23*.

The function is only possible if [9] *Multi Set-up* has been selected in *parameter 0-10 Active Set-up*. The selection in *parameter 8-55 Set-up Select* determines how bits 13 and 14 are linked with the corresponding function of the digital inputs. Changing set-up while running is only possible if the set-ups have been linked in *parameter 0-12 This Set-up Linked to*.

Set-up	Bit 13	Bit 14
1	0	0
2	1	0
3	0	1
4	1	1

Table 11.23 Bits 13/14 Set-up Options

Bit 15, No function/Reverse

Bit 15=0 causes no reversing.
 Bit 15=1 causes reversing.
 Note: In the factory setting, reversing is set to [0] *Digital input* in *parameter 8-54 Reversing Select*.

NOTICE

Bit 15 causes reversing only when the following is selected:

- Serial communication.
- Logic or.
- Logic and.

11.11.5 Status Word According to PROFIdrive Profile (STW)

The status word notifies a master about the status of a slave.

Bit	Bit=0	Bit=1
00	Control not ready	Control ready
01	Drive not ready	Drive ready
02	Coasting	Enable
03	No error	Trip
04	OFF 2	ON 2
05	OFF 3	ON 3
06	Start possible	Start not possible
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

Table 11.24 Bit Values for Status Word, PROFIdrive Profile

Explanation of the status bits

Bit 00, Control not ready/ready

When bit 00=0, bit 00, 01 or 02 of the control word is 0 (OFF 1, OFF 2 or OFF 3) - or the drive is switched off (trip).
 When bit 00=1, the drive control is ready, but supply to the unit is not necessarily present (in the event of 24 V external supply to the control system).

Bit 01, VLT not ready/ready

Same significance as bit 00, however, there is a supply of the power unit. The drive is ready when it receives the necessary start signals.

Bit 02, Coasting/enable

When bit 02=0, bit 00, 01, or 02 of the control word is 0 (OFF 1, OFF 2 or OFF 3 or coasting) - or the drive is switched off (trip).
 When bit 02=1, bit 00, 01, or 02 of the control word is 1; the drive has not tripped.

Bit 03, No error/trip

When bit 03=0, no error condition of the drive exists.
 When bit 03=1, the drive has tripped and requires a reset signal before it can start.

Bit 04, ON 2/OFF 2

When bit 01 of the control word is 0, then bit 04=0.
 When bit 01 of the control word is 1, then bit 04=1.

Bit 05, ON 3/OFF 3

When bit 02 of the control word is 0, then bit 05=0.
 When bit 02 of the control word is 1, then bit 05=1.

Bit 06, Start possible/start not possible

If [1] *PROFdrive profile* is selected in *parameter 8-10 Control Word Profile*, bit 06 is 1 after a switch-off acknowledgement, after activation of OFF2 or OFF3, and after switching on the mains voltage. Start not possible is reset with bit 00 of the control word being set to 0 and bit 01, 02, and 10 being set to 1.

Bit 07, No warning/Warning

Bit 07=0 means that there are no warnings.
Bit 07=1 means that a warning has occurred.

Bit 08, Speed ≠ reference/speed = reference

When bit 08=0, the current speed of the motor deviates from the set speed reference value. This scenario can occur, for example, when the speed is being changed during start/stop through ramp up/down.
When bit 08=1, the current speed of the motor corresponds to the set speed reference value.

Bit 09, Local operation/bus control

Bit 09=0 indicates that the drive is stopped with the [Stop] key on the LCP, or that option [2] *Linked to Hand/Auto* or [0] *Local* is selected in *parameter 3-13 Reference Site*.
When bit 09=1, the drive can be controlled through the serial interface.

Bit 10, Out of frequency limit/frequency limit OK

When bit 10=0, the output frequency is outside the limits set in *parameter 4-52 Warning Speed Low* and *parameter 4-53 Warning Speed High*.
When bit 10=1, the output frequency is within the indicated limits.

Bit 11, No operation/operation

When bit 11=0, the motor does not turn.
When bit 11=1, the drive has a start signal, or the output frequency is higher than 0 Hz.

Bit 12, Drive OK/stopped, auto start

When bit 12=0, there is no temporary overloading of the inverter.
When bit 12=1, the inverter has stopped due to overloading. However, the drive has not switched off (trip) and will start again after the overloading has ended.

Bit 13, Voltage OK/voltage exceeded

When bit 13=0, the voltage limits of the drive are not exceeded.
When bit 13=1, the direct voltage in the intermediate circuit of the drive is too low or too high.

Bit 14, Torque OK/torque exceeded

When bit 14=0, the motor torque is below the limit selected in *parameter 4-16 Torque Limit Motor Mode* and *parameter 4-17 Torque Limit Generator Mode*.
When bit 14=1, the limit selected in *parameter 4-16 Torque Limit Motor Mode* or *parameter 4-17 Torque Limit Generator Mode* is exceeded.

Bit 15, Timer OK/timer exceeded

When bit 15=0, the timers for the motor thermal protection and thermal drive protection have not exceeded 100%.
When bit 15=1, 1 of the timers has exceeded 100%.

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