ENGINEERING TOMORROW

Design Guide
VLT® Parallel Drive Modules
250–1200 kW

vlt-drives.danfoss.com

Contents

1 Introduction

1.1 Purpose of the Design Guide

This design guide is intended for project and systems engineers, design consultants, and application and product specialists. Technical information is provided to understand the capabilities of the frequency converter for integration into motor control and monitoring systems. Details concerning operation, requirements, and recommendations for system integration are described. Information is provided for input power characteristics, output for motor control, and ambient operating conditions for the frequency converter.

Also included are safety features, fault condition monitoring, operational status reporting, serial communication capabilities, and programmable options. Design details such as site requirements, cables, fuses, control wiring, the size and weight of units, and other critical information necessary to plan for system integration is also provided.

Reviewing the detailed product information in the design stage enables developing a well-conceived system with optimal functionality and efficiency.

VLT® is a registered trademark.

1.2 Manual and Software Version

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

Manual version	Remarks	Software version
MG37N3xx	Updated minimum system requirements	FC 102 (5.0x), FC 202 (3.0x), FC 302 (7.6x)

Table 1.1 Manual and Software Version

1.3 Additional Resources

Resources available to understand advanced frequency converter functions and programming:

- The *VLT® Parallel Drive Modules 250–1200 kW Installation Guide* provides instructions for mechanical and electrical installation of these drive modules.
- The *VLT® Parallel Drive Modules 250–1200 kW User Guide* contains detailed procedures for start-up, basic operational programming, and functional testing. Additional information describes the user interface, application examples, troubleshooting, and specifications.
- Refer to the programming guides for VLT® HVAC Drive FC 102, VLT® AQUA Drive FC 202, and VLT® AutomationDrive FC 302 applicable to the particular series of VLT® Parallel Drive Modules used in creating the drive system. The programming guide describes in greater detail how to work with parameters and provides application examples.
- The *VLT® FC Series, D-frame Service Manual* contains detailed service information, including information applicable to the VLT® Parallel Drive Modules.
- The *VLT® Frequency Converters – Safe Torque Off Operating Guide* contains safety guidelines and describes the operation and specifications of the Safe Torque Off function.
- The *VLT® Brake Resistor MCE 101 Design Guide* describes how to select the proper brake resistor for any application.
- The *VLT® FC-Series Output Filter Design Guide* describes how to select the proper output filter for any application.
- The *VLT® Parallel Drive Modules Busbar Kit Installation Instructions* contain detailed information about installing the busbar option kit.
- The *VLT® Parallel Drive Modules Duct Kit Installation Instructions* contain detailed information about installing the duct option kit.

Supplementary publications and manuals are available from Danfoss. See *drives.danfoss.com/knowledge-center/technical-documentation/* for listings.

2 Safety

2

2.1 Safety Symbols

The following symbols are used in this manual:

⚠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

Correct and reliable transport, storage, and installation are required for the trouble-free and safe operation of the VLT® Parallel Drive Modules. Only qualified personnel are allowed to install this equipment.

Qualified personnel are defined as trained staff, who are authorized to install 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

The drive system contains high voltage when connected to AC mains input. Failure to ensure that only qualified personnel install the drive system can result in death or serious injury.

- Only qualified personnel are allowed to install the drive system.

⚠WARNING

DISCHARGE TIME

The drive module contains DC-link capacitors. Once mains power has been applied to the drive, these capacitors can remain charged even after the power has been removed. High voltage can be present even when the warning indicator lights are off. Failure to wait 20 minutes after power has been removed before performing service or repair work can result in death or serious injury.

1. **Stop the motor.**
2. **Disconnect AC mains and remote DC-link supplies, including battery back-ups, UPS, and DC-link connections to other drives.**
3. **Disconnect or lock the PM motor.**
4. **Wait 20 minutes for the capacitors to discharge fully before performing any service or repair work.**

⚠WARNING

LEAKAGE CURRENT HAZARD (>3.5 mA)

Leakage currents exceed 3.5 mA. Failure to ground the drive system properly can result in death or serious injury. Follow national and local codes regarding protective earthing of equipment with a leakage current >3.5 mA. Frequency converter technology implies high frequency switching at high power. This switching generates a leakage current in the ground connection. A fault current in the drive system at the output power terminals sometimes contain a DC component, which can charge the filter capacitors and cause a transient ground current. The ground leakage current depends on various system configurations including RFI filtering, shielded motor cables, and drive system power.
If the leakage current exceeds 3.5 mA, EN/IEC 61800-5-1 (Power Drive System Product Standard) requires special care.

Grounding must be reinforced in 1 of the following ways:

- **Ensure the correct grounding of the equipment by a certified electrical installer.**
- **Ground wire of at least 10 mm^2 (6 AWG).**
- **Two separate ground wires, both complying with the dimensioning rules.**

See EN 60364-5-54 § 543.7 for further information.

3 Approvals and Certifications

Frequency converters are designed in compliance with the directives described in this section.

Table 3.1 Approvals

3.1 CE Mark

The CE mark (Communauté européenne) indicates that the product manufacturer conforms to all applicable EU directives. The EU directives applicable to the design and manufacture of frequency converters are the Low Voltage Directive, the EMC Directive, and (for units with an integrated safety function) the Machinery Directive.

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.

3.2 Low Voltage Directive

Frequency converters are classified as electronic components and must be CE labeled in accordance with the 2014/35/EU 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 are not endangered and the preservation of material worth so long as the equipment is properly installed, maintained, and used as intended. Danfoss CE-labels comply with the Low Voltage Directive and provide a declaration of conformity on request.

3.3 EMC Directive

Electromagnetic compatibility (EMC) means that electromagnetic interference between apparatus 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 frequency converter can be used as standalone device or as part of a more complex installation. Devices used as standalone or as part of a system must bear the CE mark. Systems must not be CE marked but must comply with the basic protection requirements of the EMC directive.

3.4 Machinery Directive

Frequency converters are classified as electronic components subject to the Low Voltage Directive, however frequency converters with an integrated safety function must comply with the Machinery Directive 2006/42/EC. Frequency converters without safety function do not fall under the Machinery Directive. If a frequency converter is integrated into machinery system, Danfoss provides information on safety aspects relating to the frequency converter.

Machinery Directive 2006/42/EC covers a machine consisting of an aggregate of interconnected components or devices of which at least 1 is capable of mechanical movement. The directive mandates that the equipment design must ensure the safety and health of people and livestock are not endangered and the preservation of material worth so long as the equipment is properly installed, maintained, and used as intended.

When frequency converters are used in machines with at least 1 moving part, the machine manufacturer must provide declaration stating compliance with all relevant statutes and safety measures. Danfoss CE-labels comply with the Machinery Directive for frequency converters with an integrated safety function and provide a declaration of conformity on request.

3.5 UL Compliance

To ensure that the frequency converter meets the UL safety requirements, see *chapter 8.3 Electrical Requirements for Certifications and Approvals*.

3.6 RCM Mark Compliance

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

3.7 Export Control Regulations

Frequency converters can be subject to regional and/or national export control regulations.

An ECCN number is used to classify all frequency converters that are subject to export control regulations.

The ECCN number is provided in the documents accompanying the frequency converter.

In case of re-export, it is the responsibility of the exporter to ensure compliance with the relevant export control regulations.

4 Product Overview

4.1 Datasheet for Drive Module

- Power rating for 380–500 V
  - HO: 160–250 kW (250–350 hp).
- Power rating for 525–690 V
  - HO: 160–315 kW (200–450 hp).
- Weight
  - 125 kg (275 lb).
- Protection rating
  - IP 00.
  - NEMA Type 00.

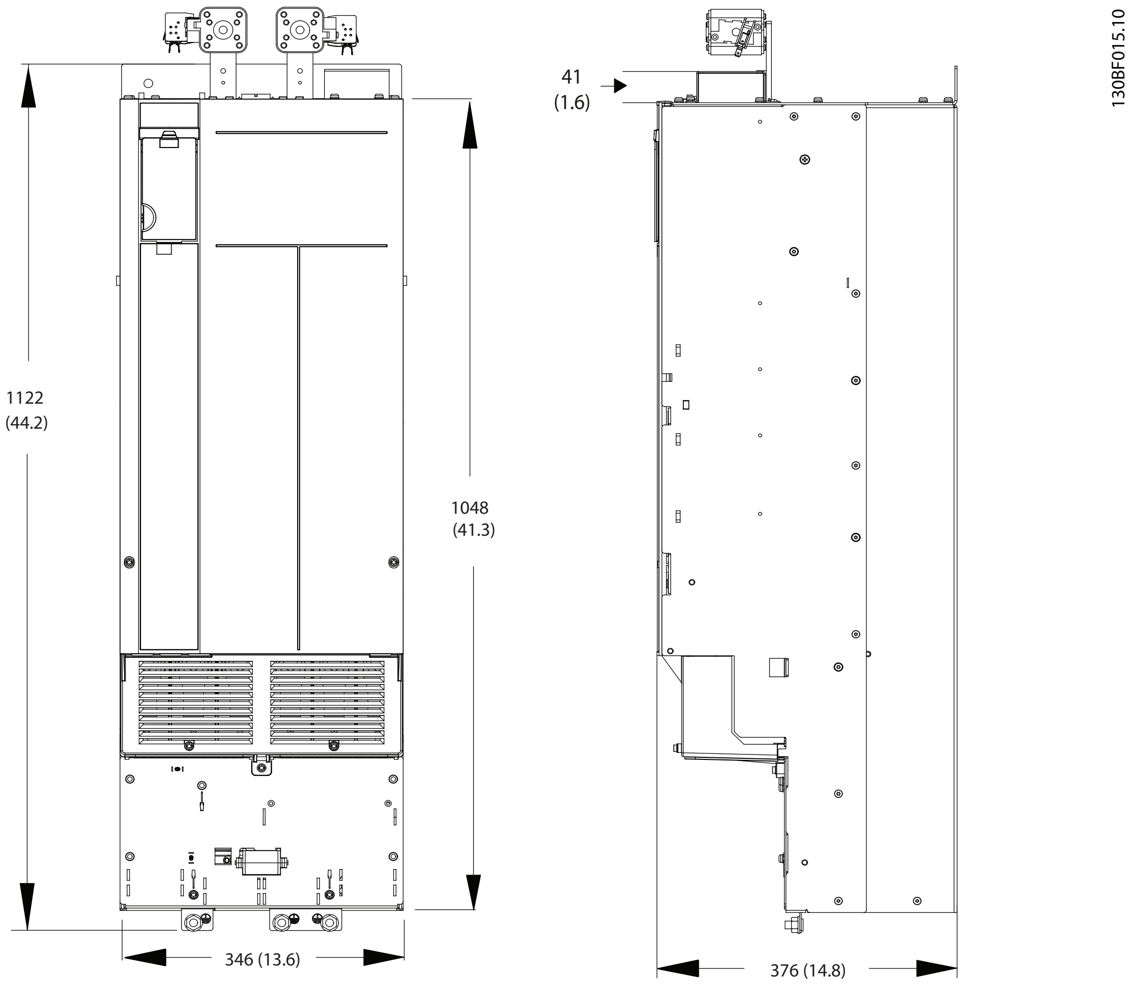


Illustration 4.1 Drive Module Dimensions

Available Danfoss options:

- 2-drive module system
- 4-drive module system

4.2 Datasheet for a 2-drive System

- Power rating for 380–500 V
  - HO: 250–450 kW (350–600 hp).
  - NO: 315–500 kW (450–600 hp).
- Power rating for 525–690 V
  - HO: 250–560 kW (300–600 hp).
  - NO: 315–630 kW (350–650 hp).
- Weight
  - 450 kg (992 lb).
- Protection rating
  - IP54 (shown). IP rating determined by customer requirement.
  - NEMA Type 12 (shown).

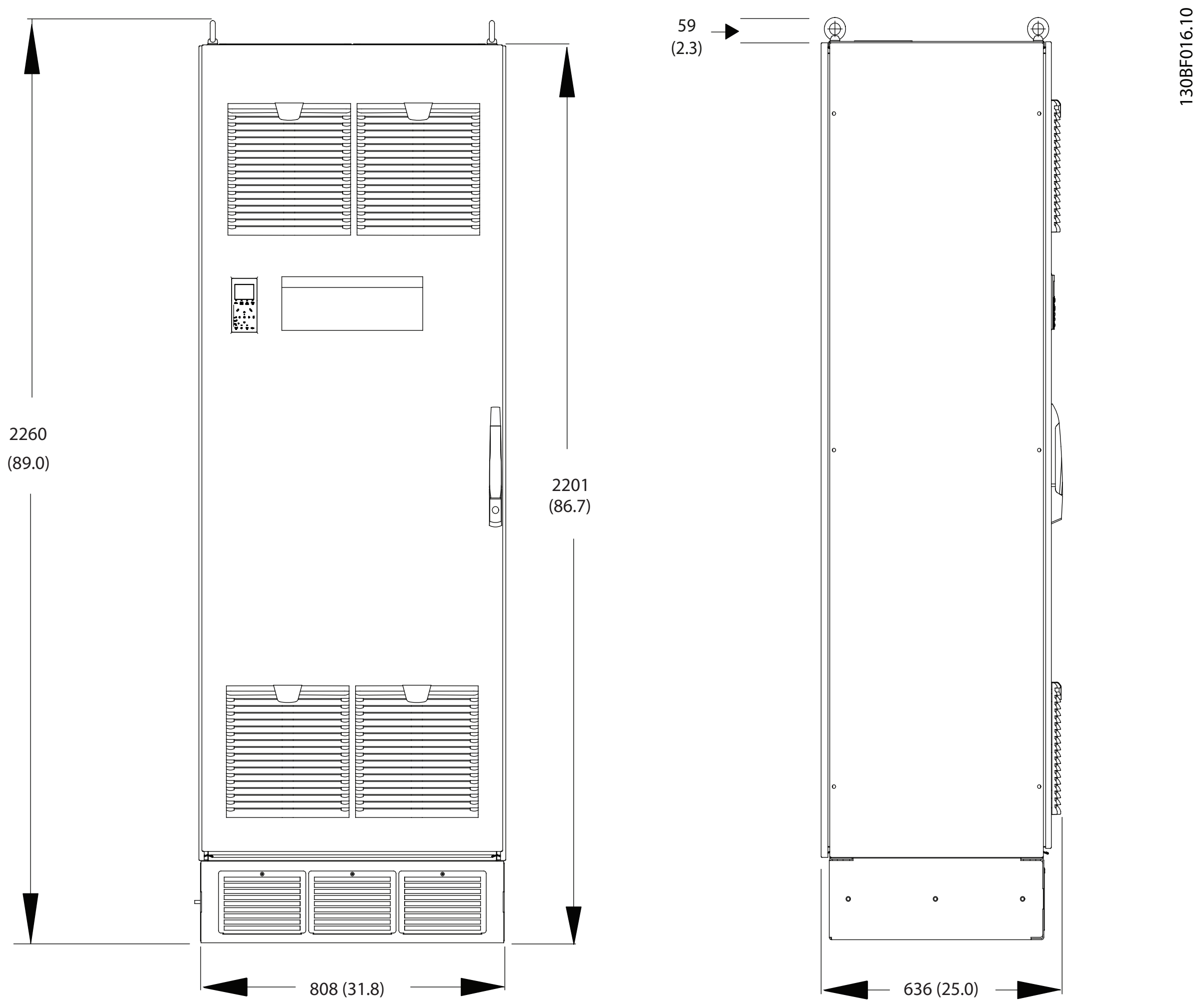


Illustration 4.2 2-drive System with Minimum Cabinet Dimensions

Available Danfoss options:

- 6-pulse busbar kit
- 12-pulse busbar kit
- In-back/out-back cooling kit
- In-back/out-top cooling kit
- In-bottom/out-back cooling kit
- In-bottom/out-top cooling kit

4.3 Datasheet for a 4-drive System

- Power rating for 380–500 V
  - HO: 500–800 kW (650–1200 hp).
  - NO: 560–1000 kW (750–1350 hp).
- Power rating for 525–690 V
  - HO: 630–1000 kW (650–1150 hp).
  - NO: 710–1200 kW (750–1350 hp).
- Weight
  - 910 kg (2000 lb).
- Protection rating
  - IP54 (shown). IP rating determined by customer requirement.
  - NEMA Type 12 (shown).

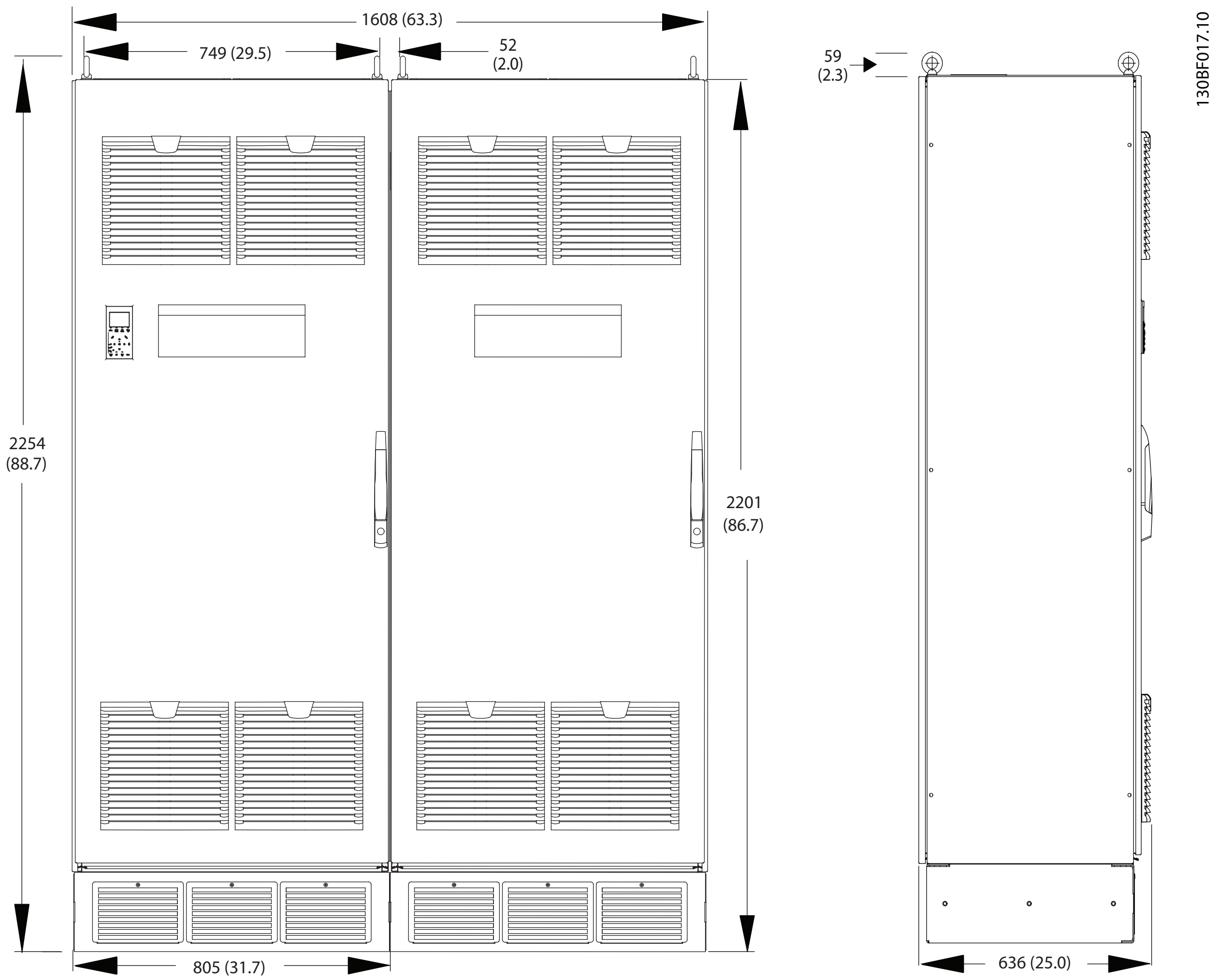


Illustration 4.3 4-drive System with Minimum Cabinet Dimensions

Available Danfoss options:

- 6-pulse busbar kit
- 12-pulse busbar kit
- In-back/out-back cooling kit
- In-back/out-top cooling kit
- In-bottom/out-back cooling kit
- In-bottom/out-top cooling kit

4.4 Internal Components

The drive system is designed by the installer to meet specified power requirements, using the VLT® Parallel Drive Modules basic kit and any selected options kits. The basic kit consists of connecting hardware and either 2 or 4 drive modules, which are connected in parallel.

The basic kit contains the following components:

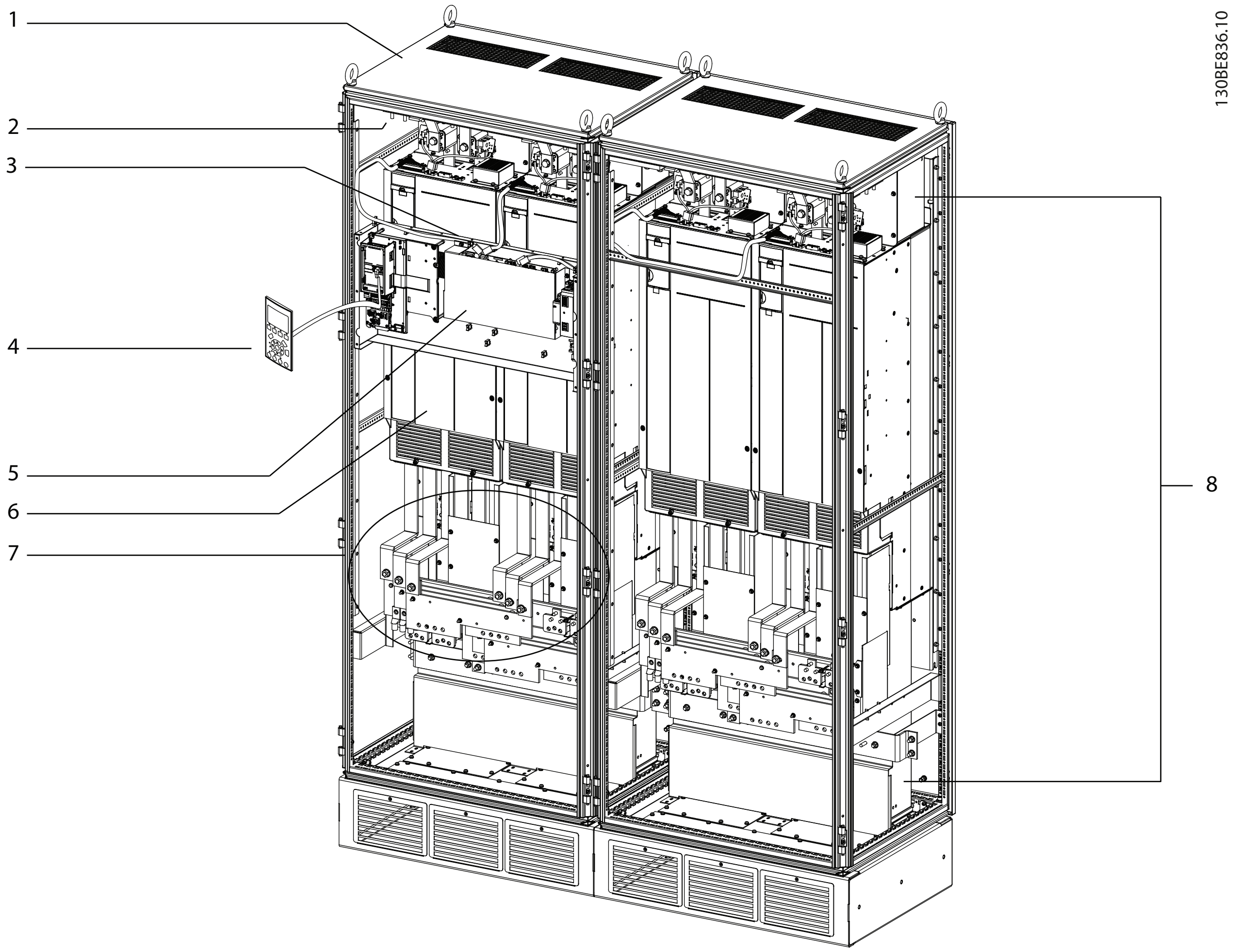
- Drive modules
- Control shelf
- Wire harnesses
    - Ribbon cable with 44-pin connector (on both ends of the cable).
    - Relay cable with 16-pin connector (on 1 end of the cable).
    - DC fuse microswitch cable with 2-pin connectors (on 1 end of the cable).
- DC fuses
- Microswitches

Other components, such as busbar kits and back-channel cooling duct kits, are available as options to customize the drive system.

The drive system in *Illustration 4.4* shows a system using 4 drive modules. A system using 2 drive modules is similar, except for the connecting hardware used. The illustrated drive system shows the cooling kit and the busbar option kit. However, the installer can use other connection methods, including custom manufactured busbars or electrical cables.

NOTICE

The installer is responsible for the details of the drive system construction, including connections. Also, if the installer does not use the Danfoss recommended design, the installer must obtain separate regulatory approvals.



Area	Title	Functions
1	Cabinet (installer-provided)	Used to house the drive modules and other drive system components.
2	DC busbars (part of busbar kit option)	Used to connect the DC terminals of the drive modules in parallel. The kit can be ordered from Danfoss or fabricated by the panel builder.
3	Wire harness	Used to link various components to the control shelf.
4	LCP	The local control module, shown mounted on the cabinet door. Allows the operator to monitor and control the system and motor.
5	Control shelf	Consists of an MDCIC (multi-drive control interface card), a control card, an LCP, a safety relay, and an SMPS (switched-mode power supply). The MDCIC interfaces the LCP and control card with the power card in each drive module.
6	Drive modules	2 or 4 drive modules can be installed in parallel to create a drive system.
7	Busbar kit (optional)	Used to connect the motor, mains, and ground terminals of the drive modules in parallel. The kit can be either ordered from Danfoss as an optional kit or fabricated by the panel builder.
8	In-bottom/out-back cooling (optional)	Used to direct air in from the base of the enclosure, through the back channel of the drive module, and out through the top of the enclosure. Reduces heat inside the enclosure by 85%. The kit can be ordered from Danfoss as an optional kit. Refer to *chapter 4.5.1 Back-channel Cooling Examples*.

Illustration 4.4 Overview of 4-drive System without EMI/EMC Shields

4.5 Back-channel Cooling Examples

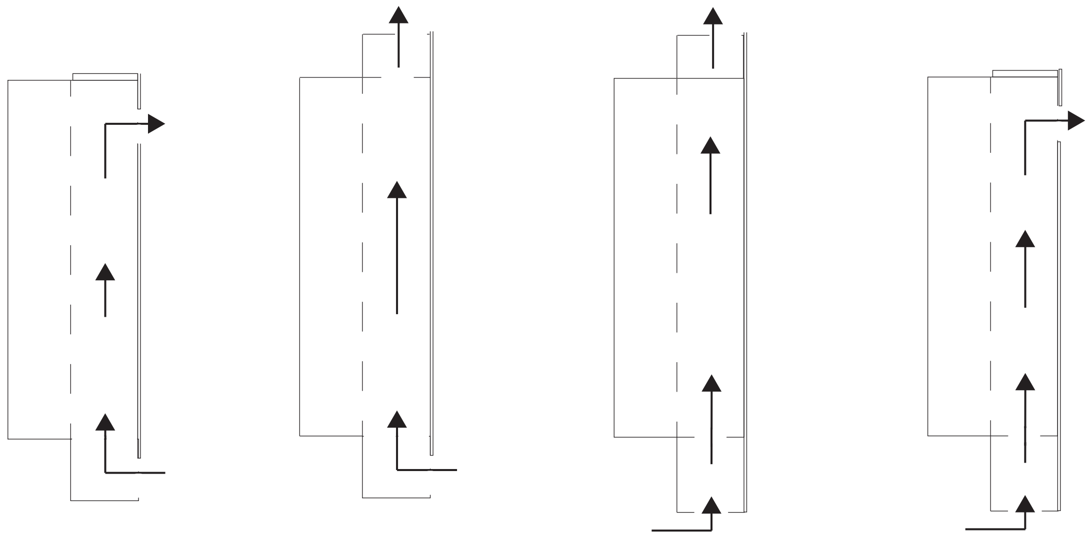


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Illustration 4.5 Cooling Kit Airflow (from Left to Right), In-back/Out-back, In-back/Out-top, In-bottom/Out-top, In-bottom/Out-back

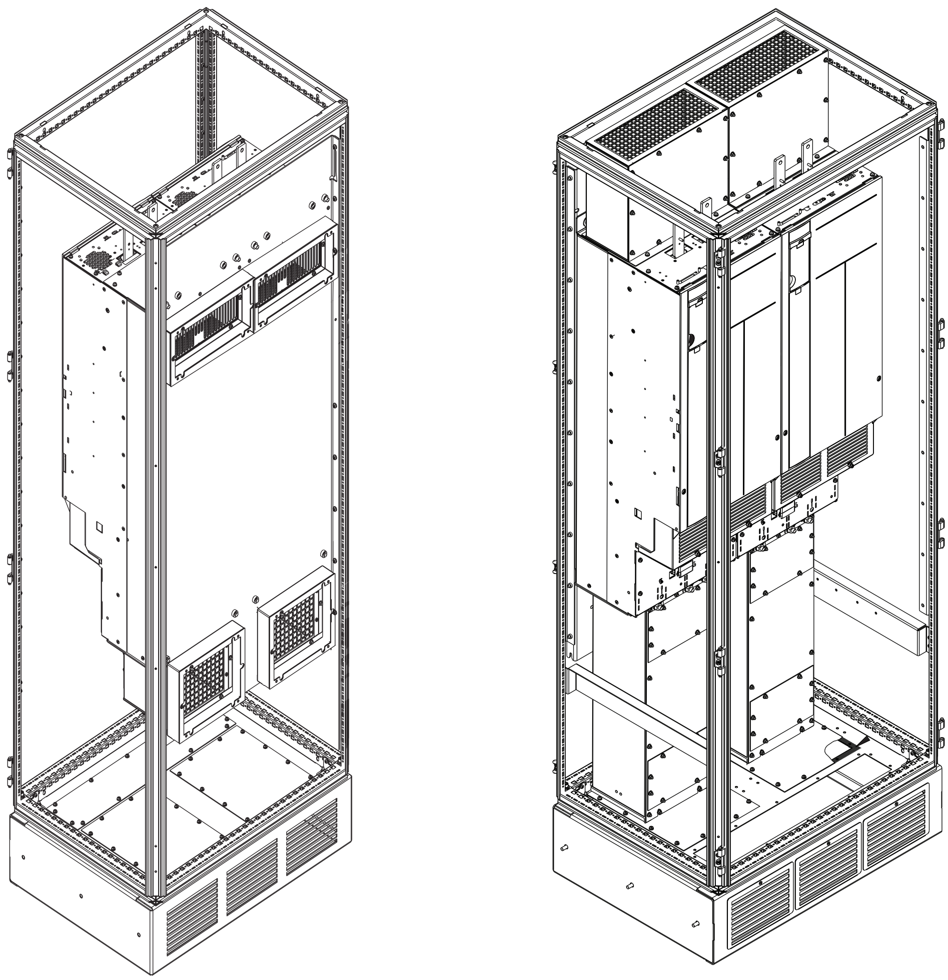

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Illustration 4.6 2-drive Cabinet with In-back/Out-back Cooling Kit (Left) and In-bottom/Out-top Cooling Kit (Right)

5 Product Features

5.1 Automated Functions

These automated functions fall into 3 categories:

- Turned on by default, but can be disabled by programming.
- Turned off by default, but can be enabled by programming.
- Always enabled.

5.1.1 Automatic Energy Optimization

Automatic energy optimization (AEO) is used in HVAC applications. This feature directs the frequency converter to continuously monitor the load on the motor 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, and quieter operation. There is no need to select a V/Hz curve because the frequency converter automatically adjusts motor voltage.

5.1.2 Automatic Switching Frequency Modulation

The frequency converter generates short electrical pulses to form an AC wave pattern. The carrier frequency is the rate of these pulses. A low carrier frequency (slow pulsing rate) causes noise in the motor, making a higher carrier frequency preferable. A high carrier frequency, however, generates heat in the frequency converter which can limit the amount of current available to the motor. The use of insulated gate bipolar transistors (IGBT) means high-speed switching.

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

5.1.3 Automatic Derating for High Carrier Frequency

The frequency converter is designed for continuous and full load operation between the carrier frequencies between the minimum and maximum frequencies shown in *Table 5.1*. If the carrier frequency is higher than the maximum frequency, the output current of the frequency converter is derated automatically.

Power kW (hp)	Switching frequency Hz	Minimum Hz	Maximum Hz	Factory setting Hz
250 (350)	3000	2000	8000	3000
315 (450)	2000	1500	6000	2000
355 (500)	2000	1500	6000	2000
400 (550)	2000	1500	6000	2000
450 (600)	2000	1500	6000	2000
500 (650)	2000	1500	6000	2000
560 (750)	2000	1500	6000	2000
630 (900)	2000	1500	6000	2000
710 (1000)	2000	1500	6000	2000
800 (1200)	2000	1500	6000	2000

Table 5.1 Carrier Frequency Operational Ranges for 380–500 V

Power kW (hp)	Switching frequency Hz	Minimum Hz	Maximum Hz	Factory setting Hz
250 (300)	3000	2000	8000	3000
315 (350)	2000	1500	6000	2000
355 (400)	2000	1500	6000	2000
400 (400)	2000	1500	6000	2000
500 (500)	2000	1500	6000	2000
560 (600)	2000	1500	6000	2000
630 (650)	2000	1500	6000	2000
710 (750)	2000	1500	6000	2000
800 (950)	2000	1500	6000	2000
900 (1050)	2000	1500	6000	2000
1000 (1150)	2000	1500	6000	2000

Table 5.2 Carrier Frequency Operational Ranges for 525–690 V

5.1.4 Automatic Derating for Overtemperature

Automatic overtemperature derating works to prevent tripping the frequency converter at high temperature. Internal temperature sensors measure conditions to protect the power components from overheating. The frequency converter can automatically reduce its carrier frequency to maintain its operating temperature within safe limits. After reducing the carrier frequency, the frequency converter can also reduce the output frequency and current by as much as 30% to avoid an overtemperature trip.

5.1.5 Auto Ramping

A motor trying to accelerate a load too quickly for the current available can cause the frequency converter to trip. The same is true for too quick of a deceleration. Auto ramping protects against this scenario by extending the motor ramping rate (acceleration or deceleration) to match the available current.

5.1.6 Current Limit Control

If a load exceeds the current capability of the frequency converter normal operation (from an undersized frequency converter or motor), current limit reduces the output frequency to slow the motor and reduce the load. An adjustable timer is available to limit operation in this condition for 60 s or less. The factory default limit is 110% of the rated motor current to minimize overcurrent stress.

5.1.7 Short-circuit Protection

The frequency converter provides inherent short-circuit protection with a fast acting fault-trip circuit. Current is measured in each of the 3 output phases. After 5–10 ms, if the current exceeds the allowed value, all transistors in the inverter turn off. This circuit provides the most rapid current sensing and the greatest protection against nuisance trips. A short circuit between 2 output phases can cause an overcurrent trip.

5.1.8 Ground Fault Protection

After receiving feedback from current sensors, the control circuitry sums up the 3-phase currents from each drive module. If the sum of all 3 output phase currents is not 0, it indicates a leakage current. If the deviation from 0 exceeds a predetermined amount, the frequency converter issues a ground fault alarm.

5.1.9 Power Fluctuation Performance

The frequency converter withstands mains fluctuations such as:

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

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

5.1.10 Motor Soft Start

The frequency converter supplies the right amount of current to the motor to overcome load inertia and bring the motor up to speed. This action avoids full mains voltage being applied to a stationary or slow turning motor, which generates high current and heat. This inherent soft start feature reduces thermal load and mechanical stress, extends motor life, and provides quieter system operation.

5.1.11 Resonance Damping

High frequency motor resonance noise can be eliminated by using resonance damping. Automatic or manually selected frequency damping is available.

5.1.12 Temperature-controlled Fans

The internal cooling fans are temperature-controlled by sensors in the frequency converter. The cooling fan often is not running during low-load operation, or when in sleep mode or standby. This feature reduces noise, increases efficiency, and extends the operating life of the fan.

5.1.13 EMC Compliance

Electromagnetic interference (EMI) or radio frequency interference (RFI) is disturbance that can affect an electrical circuit due to electromagnetic induction or radiation from an external source. The frequency converter is designed to comply with the EMC product standard for IEC/EN 61800-3. For more information regarding EMC performance, see *chapter 9.2 EMC Test Results*.

5.2 Programmable Functions

The following functions are the most common functions programmed for use in the frequency converter for enhanced system performance. They require minimum programming or set-up. Understanding that these functions are available can optimize a system design and possibly avoid introducing redundant components or functionality. See the product-specific *programming guide*, for instructions on activating these functions.

5.2.1 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. It allows the frequency converter to calculate optimal performance and efficiency with the motor. Running the AMA procedure also maximizes the automatic energy optimization feature of the frequency converter. AMA is performed without the motor rotating and without uncoupling the load from the motor.

5.2.2 Motor Thermal Protection

Motor thermal protection can be provided in 2 ways.

One method uses a motor thermistor. The frequency converter monitors motor temperature as the speed and load vary to detect overheating conditions.

The other method calculates motor temperature by measuring current, frequency, and operating time. The frequency converter shows the thermal load on the motor in percentage and can issue a warning at a programmable overload setpoint. Programmable options at the overload allow the frequency converter to stop the motor, reduce output, or ignore the condition. Even at low speeds, the frequency converter meets I^2t Class 20 electronic motor overload standards.

5.2.3 Built-in PID Controller

The built-in proportional, integral, derivative (PID) controller is available, eliminating 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 frequency converter can provide self-reliant control the motor speed in response to feedback signals from remote sensors.

The frequency converter accommodates 2 feedback signals from 2 different devices. This feature allows regulating a system with different feedback requirements. The frequency converter makes control decisions by comparing the 2 signals to optimize system performance.

5.2.4 Automatic Restart

The frequency converter 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.

5.2.5 Flying Start

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

5.2.6 Sleep Mode

Sleep mode automatically stops the motor when demand is at a low level for a specified time. When the system demand increases, the frequency converter restarts the motor. Sleep mode provides energy savings and reduces motor wear. Unlike a setback clock, the frequency converter is always available to run when the preset wake-up demand is reached.

5.2.7 Run Permissive

The frequency converter can wait for a remote system-ready signal before starting. When this feature is active, the frequency converter remains stopped until receiving permission to start. Run permissive ensures that the system or auxiliary equipment is in the proper state before the frequency converter is allowed to start the motor.

5.2.8 Full Torque at Reduced Speed

The frequency converter 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 variable torque curve is unlike variable torque converters that provide reduced motor torque at low speed, or constant torque converters that provide excess voltage, heat, and motor noise at less than full speed.

5.2.9 Frequency Bypass

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

5.2.10 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 a cold start. This function can eliminate the need for a space heater.

5.2.11 4 Programmable Set-ups

The frequency converter has 4 set-ups which 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 active set-up is shown on the LCP.

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

5.2.12 DC Brake

Some applications can require braking a motor to slow or stop it. Applying DC current to the motor brakes the motor and can eliminate the need for a separate motor brake. The DC brake can be set to activate at a predetermined frequency or after receiving a signal. The rate of braking can also be programmed.

5.2.13 High Breakaway Torque

For high inertia or high friction loads, extra torque is available for starting. The breakaway current of 110% or 160% of maximum can be set for a limited amount of time.

5.2.14 Bypass

An automatic or manual bypass is an available option. The bypass allows the motor to operate at full speed when the frequency converter is not operating and allows for routine maintenance or emergency bypass.

5.2.15 Power Loss Ride-through

During a power loss, the frequency converter continues to rotate the motor until the DC-link voltage drops below the minimum operating level, which corresponds to 15% below the lowest rated drive voltage. Frequency converters are rated for operation on 380–460 V, 550–600 V, and some at 690 V. The power loss ride-through time depends, after the load, on the frequency converter and the mains voltage at the time of the power loss.

5.2.16 Overload

When the torque required to maintain or accelerate to a determined frequency exceeds the current limit, the frequency converter attempts to continue operating. It automatically reduces the rate of acceleration or reduces the output frequency. If the overcurrent demand is not reduced enough, the frequency converter shuts down and shows a fault within 1.5 s. The current limit level is programmable. The overcurrent trip delay is used to specify the time that the frequency converter operates in current limit before shutting down. The limit level can be set from 0–60 s, or for infinite operation, subject to the frequency converter and motor thermal protection.

5.3 Safe Torque Off (STO)

The VLT® AutomationDrive FC 302 comes standard with Safe Torque Off functionality via control terminal 37. The STO function is also available on VLT® HVAC Drive FC 102 and VLT® AQUA Drive FC 202.

STO disables the control voltage of the power semiconductors of the frequency converter output stage, which in turn prevents it from generating the voltage required to rotate the motor. When the Safe Torque Off (T37) is activated, the frequency converter issues an alarm, trips the unit, and coasts the motor to a stop. Manual restart is required. The Safe Torque Off function can be used for stopping the frequency converter in emergency stop situations. In the normal operating mode when Safe Torque Off is not required, use the regular stop function instead. When automatic restart is used, the requirements according to ISO 12100-2 paragraph 5.3.2.5 must be fulfilled.

The Safe Torque Off function with VLT® AutomationDrive FC 302 can be used for asynchronous, synchronous, and permanent magnet motors. It is possible that 2 faults occur in the power semiconductors. If 2 faults in the power semiconductors occur while using synchronous or permanent magnet motors, it can cause a residual rotation in the motor. The rotation can be calculated to angle=360/(number of poles). The application using synchronous or permanent magnet motors must take this possibility into consideration and ensure that this scenario is not a critical safety issue. This situation does not apply to asynchronous motors.

5.3.1 Liability Conditions

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

- Reading and understanding the safety regulations concerning health, safety and accident prevention.
- Understanding the generic and safety guidelines given in this description and the extended description in the *VLT® Frequency Converters – Safe Torque Off Operating Guide*.
- Having a good knowledge of the generic and safety standards for the specific application.

The user is defined as integrator, operator, service, and maintenance staff.

5.3.2 Additional Information

For more information regarding Safe Torque Off, including installation and commissioning, refer to the *VLT® Frequency Converters – Safe Torque Off Operating Guide*.

5.3.3 Installation of External Safety Device in Combination with VLT® PTC Thermistor Card MCB 112

If the ex-certified thermistor module MCB 112, which uses terminal 37 as its safety-related switch-off channel, is connected, then the output X44/12 of MCB 112 must be AND-ed with a safety-related sensor (emergency stop key or safety-guard switch) that activates Safe Torque Off. The output to Safe Torque Off terminal 37 is high (24 V) only if both the signal from MCB 112 output X44/12 and the signal from the safety-related sensor are high. If at least 1 of the 2 signals are low, then the output to terminal 37 must be low, too. The safety device with this AND logic itself must conform to IEC 61508, SIL 2. The connection from the output of the safety device with safe AND logic to Safe Torque Off terminal 37 must be short circuit protected. *Illustration 5.1* shows a restart input for the external safety device. In this installation, for example, set *[7] PTC 1 & Relay W* or *[8] PTC 1 & Relay A/W* in *parameter 5-19 Terminal 37 Safe Stop*. Refer to the *VLT® PTC Thermistor Card MCB 112 Operating Instructions* for further details.

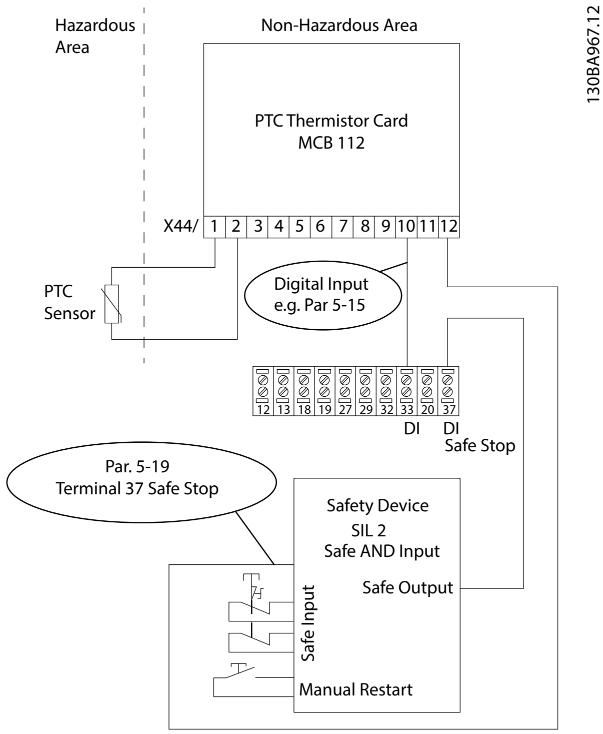


Illustration 5.1 Illustration of the Essential Aspects for Installing a Combination of a Safe Torque Off Application and an MCB 112 Application

Parameter settings for external safety device with MCB 112

If MCB 112 is connected, then selections *[4]* through *[9]* become possible for *parameter 5-19 Terminal 37 Safe Stop* (Terminal 37 Safe Torque Off).

Selections *[1]* Safe Stop Alarm* and *[3] Safe Stop Warning* in *parameter 5-19 Terminal 37 Safe Stop* are still available, but are used only for installations without MCB 112 or any external safety devices. If *[1]* Safe Stop Alarm* or *[3] Safe Stop Warning* in *parameter 5-19 Terminal 37 Safe Stop* is selected by mistake and MCB 112 is triggered, then the frequency converter reacts with *alarm 72, Dangerous Failure* and coasts the frequency converter safely without an automatic restart.

Selections *[4] PTC 1 Alarm* and *[5] PTC 1 Warning* in *parameter 5-19 Terminal 37 Safe Stop* are only selected when MCB 112 uses the Safe Torque Off. If selections *[4]* or *[5]* in *parameter 5-19 Terminal 37 Safe Stop* is selected by mistake and the external safety device triggers Safe Torque Off, the frequency converter reacts with *alarm 72, Dangerous Failure* and coasts the frequency converter safely without an automatic restart.

Selections *[6]* through *[9]* in *parameter 5-19 Terminal 37 Safe Stop* must be selected for the combination of external safety device and MCB 112.

NOTICE

***[7] PTC 1 & Relay W* and *[8] PTC 1 & Relay A/W* in *parameter 5-19 Terminal 37 Safe Stop* opens up for automatic restart when the external safety device is de-activated again.**

The automatic restart is only allowed in the following cases:

- The unintended restart prevention is implemented by other parts of the Safe Torque Off installation.
- A presence in the dangerous zone can be physically excluded when Safe Torque Off is not activated. In particular, paragraph 5.3.2.5 of ISO 12100-2 2003 must be observed.

See *chapter 7.3.11 VLT® PTC Thermistor Card MCB 112* and the *VLT® PTC Thermistor Card MCB 112 Operating Guide* for more information about MCB 112.

5.4 System Monitoring

The frequency converter monitors many aspects of system operation including:

- Mains conditions.
- Motor load and performance.
- Frequency converter status.

An alarm or warning does not necessarily indicate a problem with the frequency converter itself. It can be a condition outside of the frequency converter that is being monitored for performance limits. The frequency converter has various preprogrammed fault, warning, and alarm responses. Extra alarm and warning functions can be selected to enhance or modify system performance.

This section describes common alarm and warning functions. Understanding that these functions are available can optimize a system design and possibly avoid introducing redundant components or functionality.

5.4.1 Operation at Overtemperature

By default, the frequency converter issues an alarm and trips at overtemperature. If *Autoderate and Warning* are selected, the frequency converter warns of the condition but continues to run and attempts to cool itself by first reducing its carrier frequency. Then, if necessary, it reduces the output frequency.

5.4.2 High and Low Reference Warning

In open-loop operation, the reference signal directly determines the speed of the frequency converter. The display shows a flashing reference high or low warning when the programmed maximum or minimum is reached.

5.4.3 High and Low Feedback Warning

In closed-loop operation, the frequency converter monitors selected high and low feedback values. The display shows a flashing high or flashing low warning when appropriate. The frequency converter can also monitor feedback signals in open loop operation. While the signals do not affect the operation of the frequency converter in open-loop, they can be useful for system status indication locally or via serial communication. The frequency converter handles 39 different units of measure.

5.4.4 Imbalance of Supply Voltage or Phase Loss

Excessive ripple current in the DC bus indicates either a mains imbalance of supply voltage or phase loss. When a power phase to the frequency converter is lost, the default is to issue an alarm and trip the unit to protect the DC bus capacitors. Other options are to issue a warning and to reduce output current to 30% of full current, or to issue a warning and continue normal operation. Operating a unit connected to an imbalanced line can be desirable until the imbalance is corrected.

5.4.5 High Frequency Warning

Useful in staging on extra equipment such as pumps or cooling fans, the frequency converter can warn when the motor speed is high. A specific high frequency setting can be entered into the frequency converter. When the output of the unit exceeds the set warning frequency, the unit shows a high frequency warning. A digital output from the frequency converter can signal external devices to turn on.

5.4.6 Low-frequency Warning

Useful in staging off equipment, the frequency converter can warn when the motor speed is low. A specific low-frequency setting can be selected for warning and to turn off external devices. The unit does not issue a low-frequency warning when it is stopped nor after start-up until after the operating frequency has been reached.

5.4.7 High Current Warning

This function is similar to high frequency warning (see *chapter 5.4.5 High Frequency Warning*), except a high current setting is used to issue a warning and turn on external equipment. The function is not active when stopped or at start-up until the set operating current has been reached.

5.4.8 Low Current Warning

This function is similar to low-frequency warning (see *chapter 5.4.6 Low-frequency Warning*), except a low current setting is used to issue a warning and turn off external equipment. The function is not active when stopped or at start-up until the set operating current has been reached.

5.4.9 No Load/Broken-belt Warning

This feature can be used for monitoring a V-belt. After a low current limit has been stored in the frequency converter, if loss of the load is detected, the frequency converter can be programmed to issue an alarm and trip or to continue operation and issue a warning.

5.4.10 Lost Serial Interface

The frequency converter can detect loss of serial communication. A time delay of up to 18000 s is selectable to avoid a response due to interruptions on the serial communications bus. When the delay is exceeded, available options can:

- Maintain the last speed.
- Go to maximum speed.
- Go to a preset speed.
- Stop and issue a warning.

6 Specifications

6.1 Drive Module Dimensions

6.1.1 Exterior Dimensions

Illustration 6.1 shows the dimensions of the drive module related to its installation.

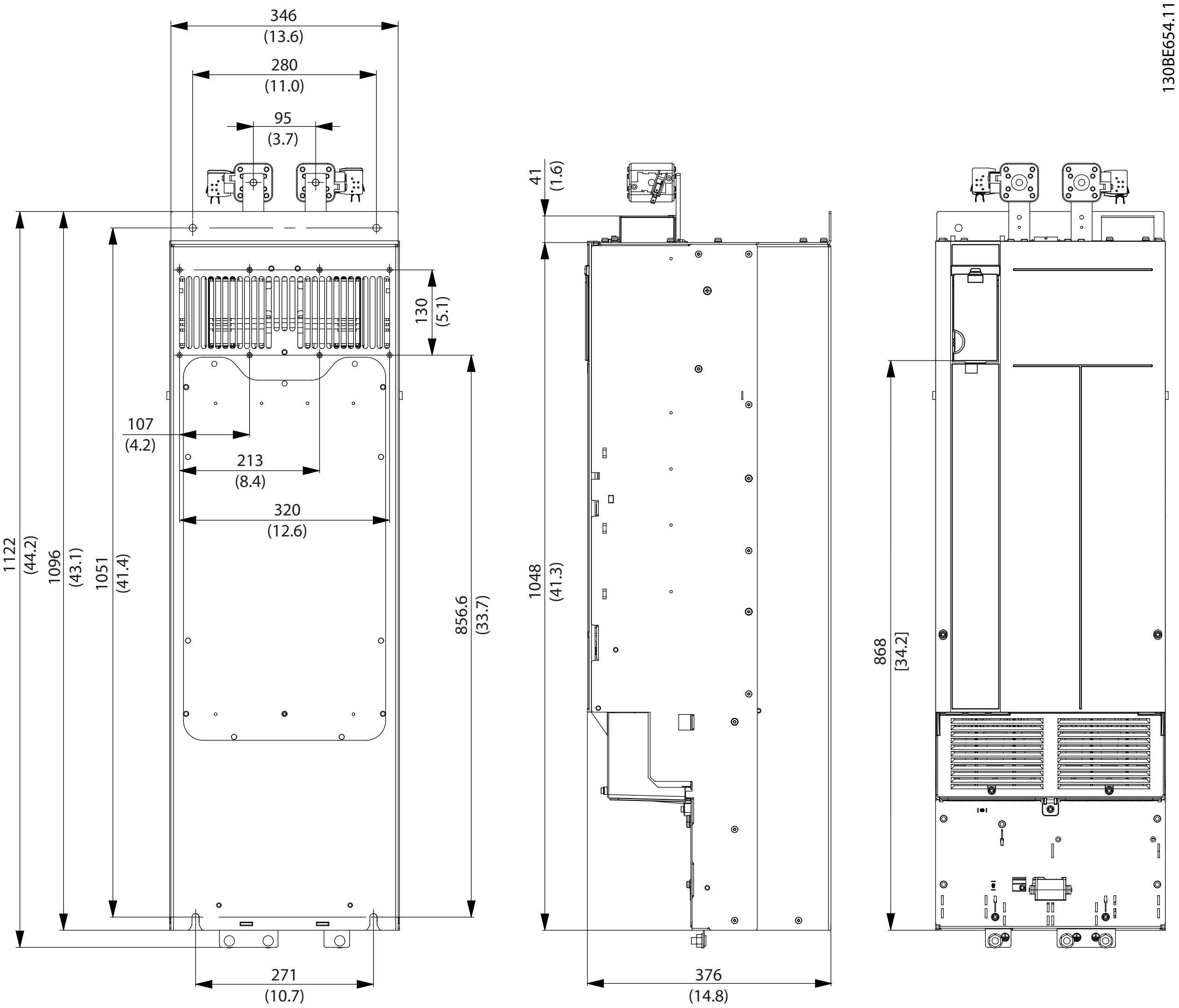


Illustration 6.1 VLT® Parallel Drive Modules Installation Dimensions

Description	Module weight [kg (lb)]	Length x width x depth [mm (in)]
Drive module	125 (275)	1121.7 x 346.2 x 375 (44.2 x 13.6 x 14.8)

Table 6.1 Drive Module Weight and Dimensions

6.1.2 Terminal Dimensions

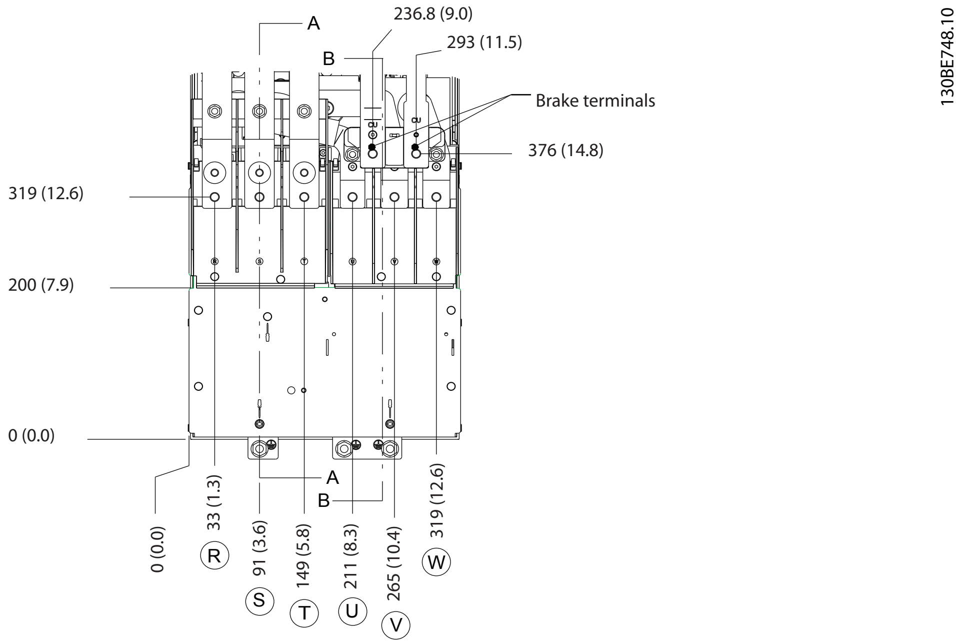


Illustration 6.2 Drive Module Terminal Dimensions (Front View)

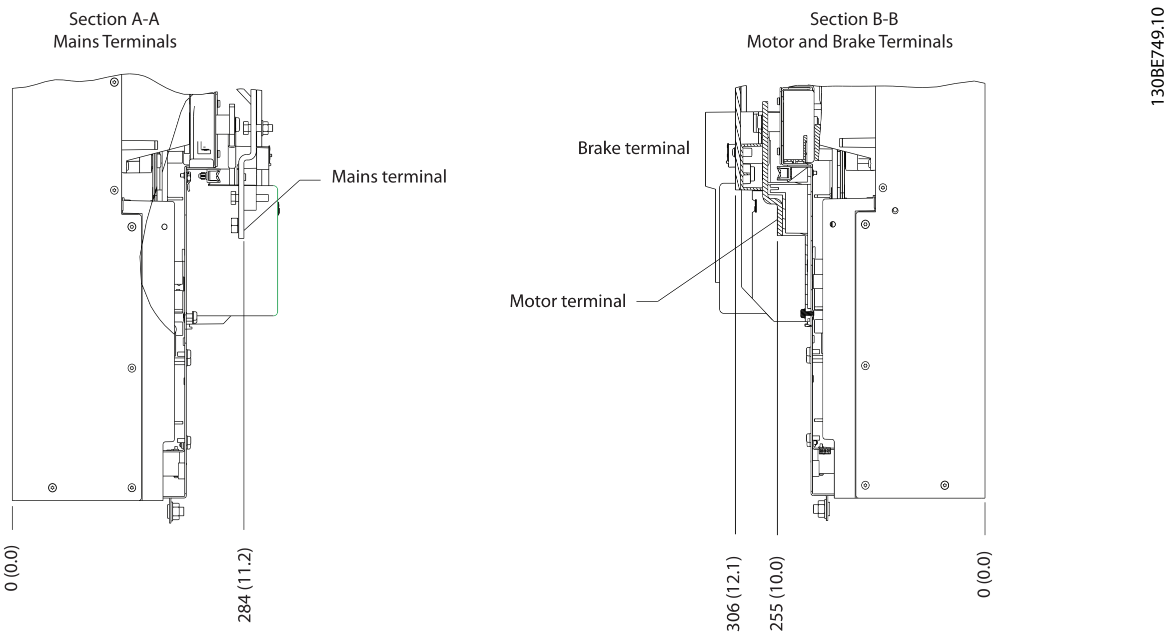


Illustration 6.3 Drive Module Terminal Dimensions (Side Views)

6.1.3 DC Bus Dimensions

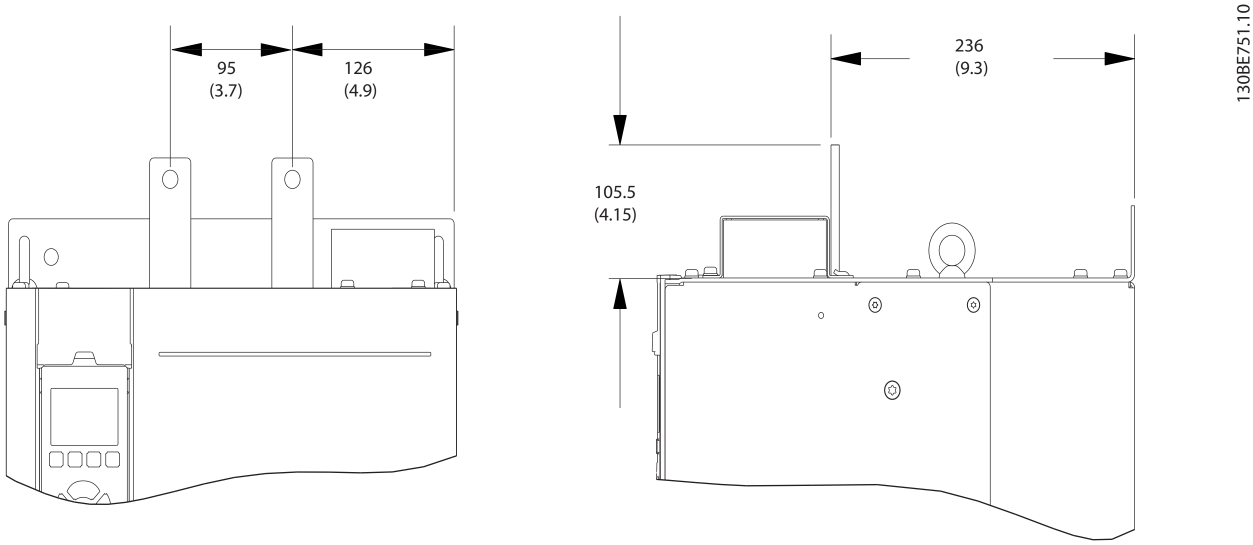


Illustration 6.4 DC Bus Dimensions (Front and Side Views)

6.2 Control Shelf Dimensions

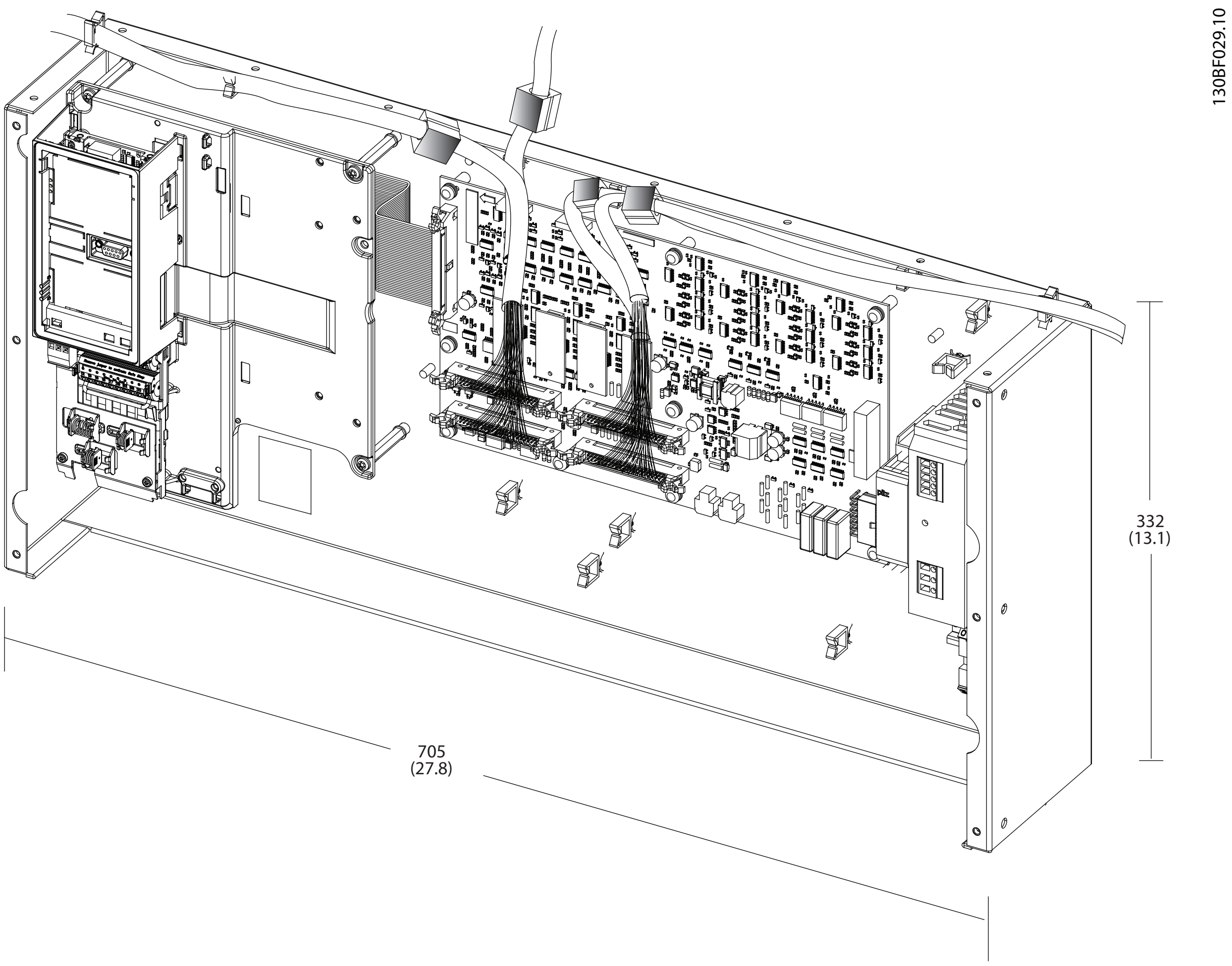


Illustration 6.5 Control Shelf Dimensions

6

6.3 2-drive System Dimensions

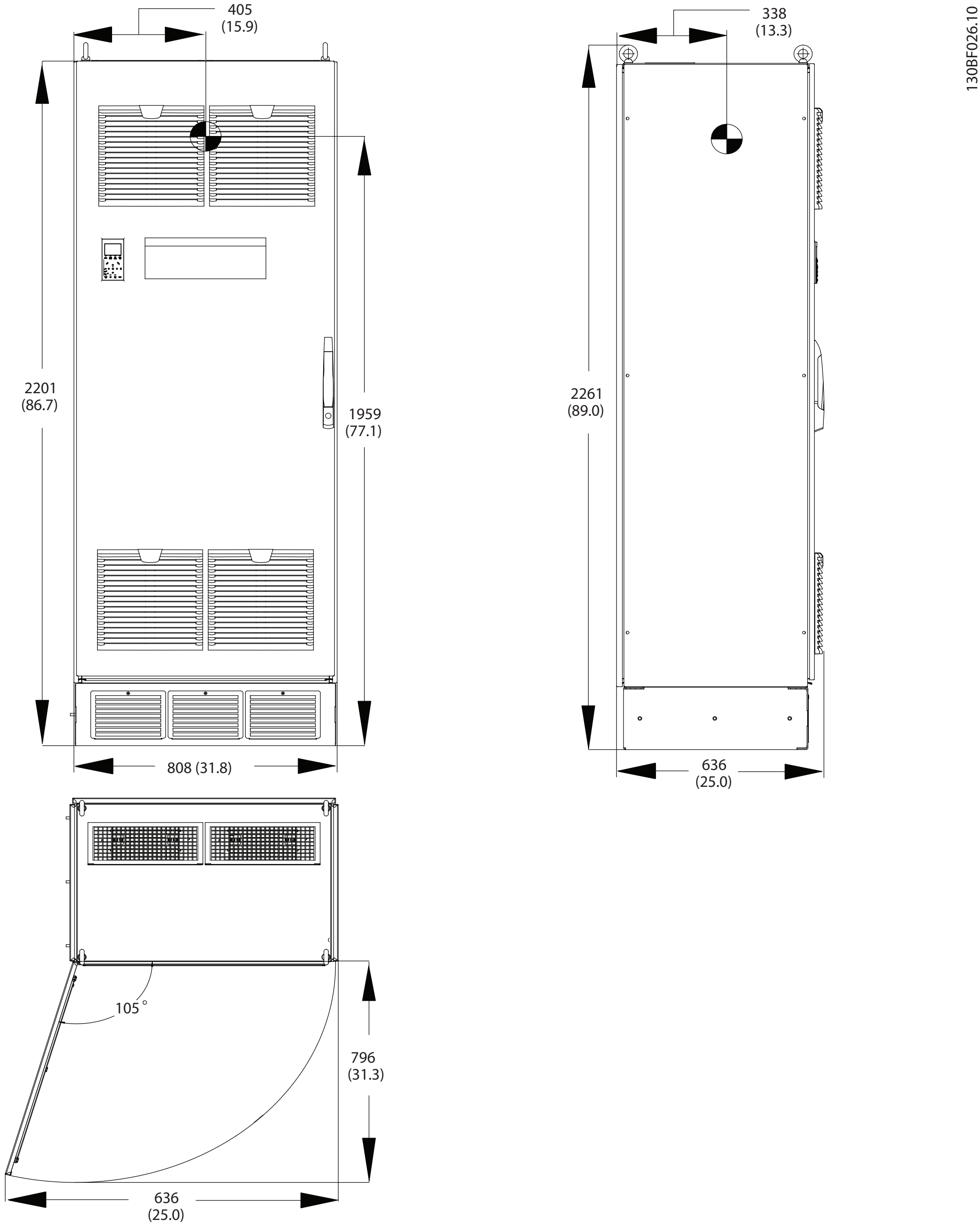
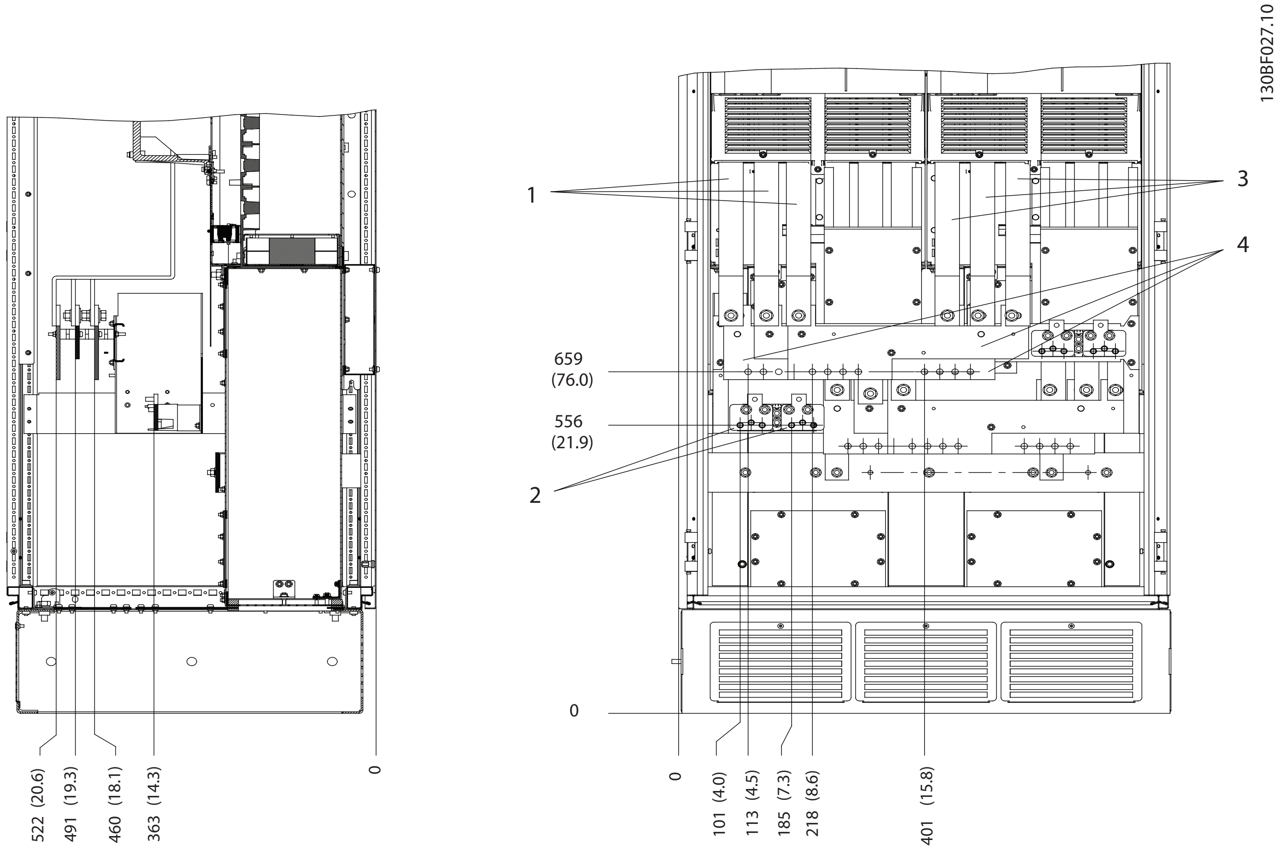
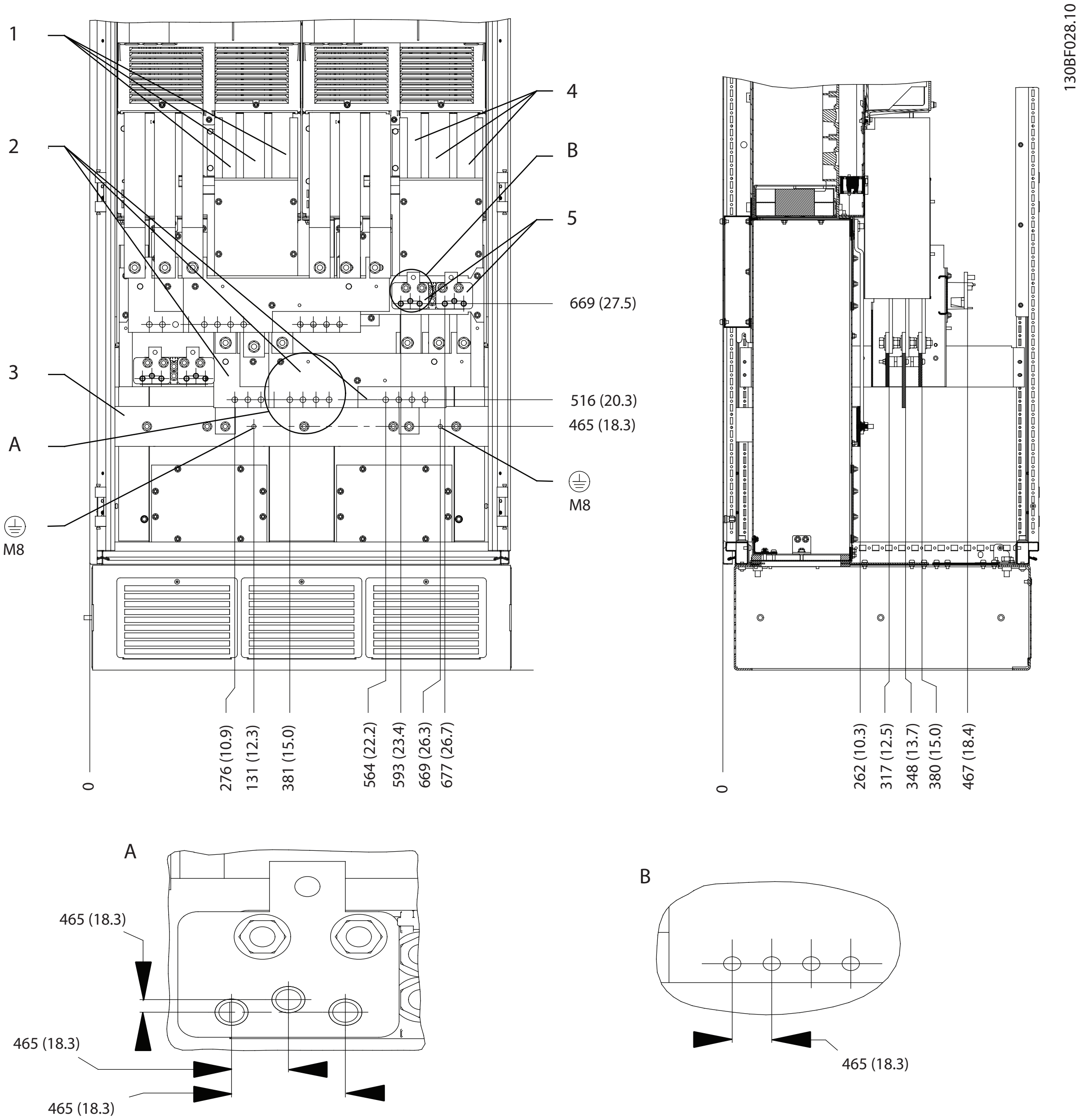


Illustration 6.6 2-drive System Exterior Dimensions (Front, Side, and Door Opening Views)



1	Mains jumper busbars (module 1)	3	Mains jumper busbars (module 2)
2	Brake terminals	4	Mains terminals

Illustration 6.7 2-drive System Mains Terminals (Side and Front Views)



1	Motor jumper busbars (module 1)	4	Motor jumper busbars (module 2)
2	Motor terminals	5	Brake terminals
3	Ground terminals	–	–

Illustration 6.8 2-drive System Motor and Ground Terminals (Front and Side Views)

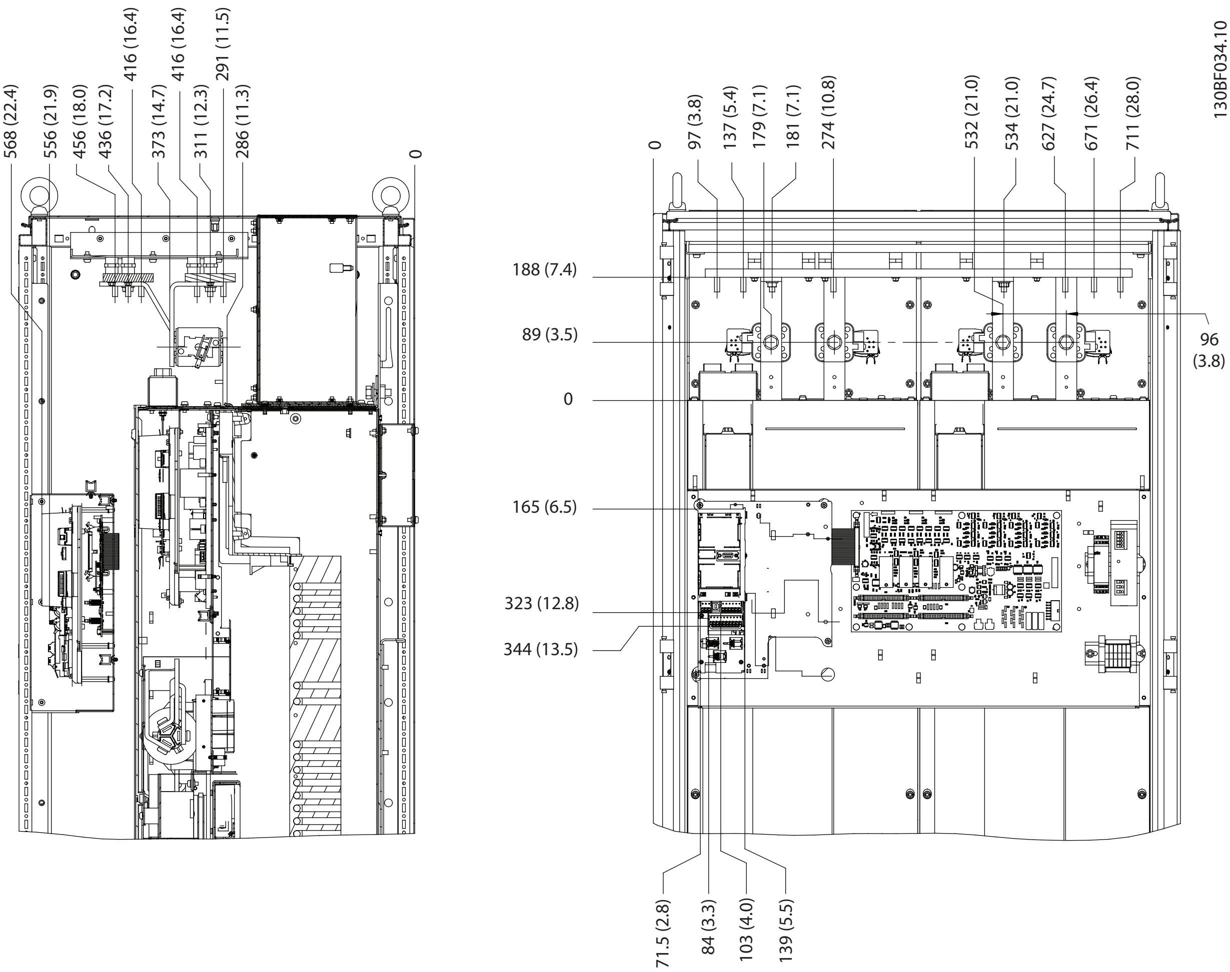


Illustration 6.9 2-drive System DC Bus and Relays (Side and Front Views)

6.4 4-drive System Dimensions

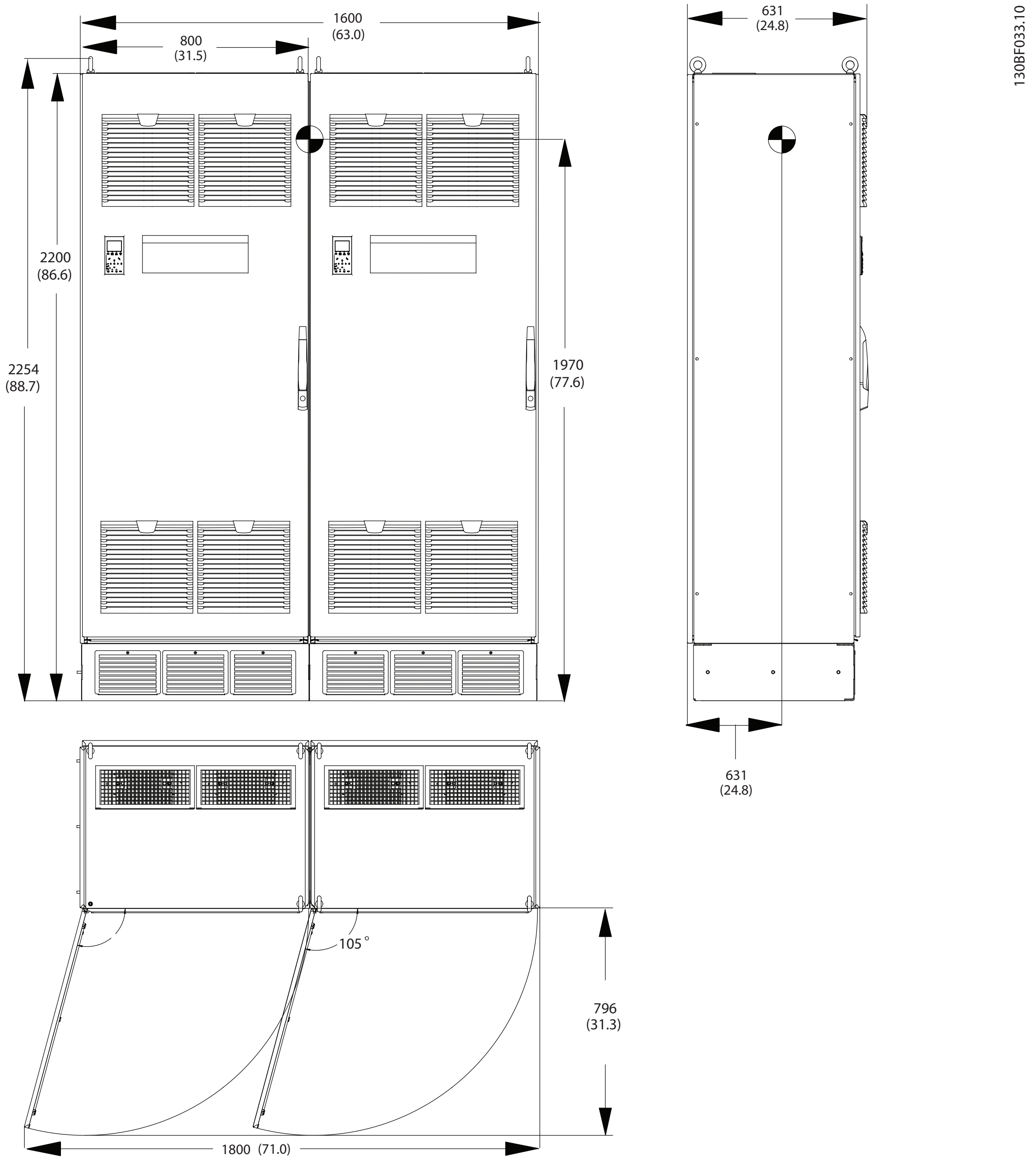


Illustration 6.10 4-drive System Exterior Dimensions (Front, Side, and Door Opening Views)

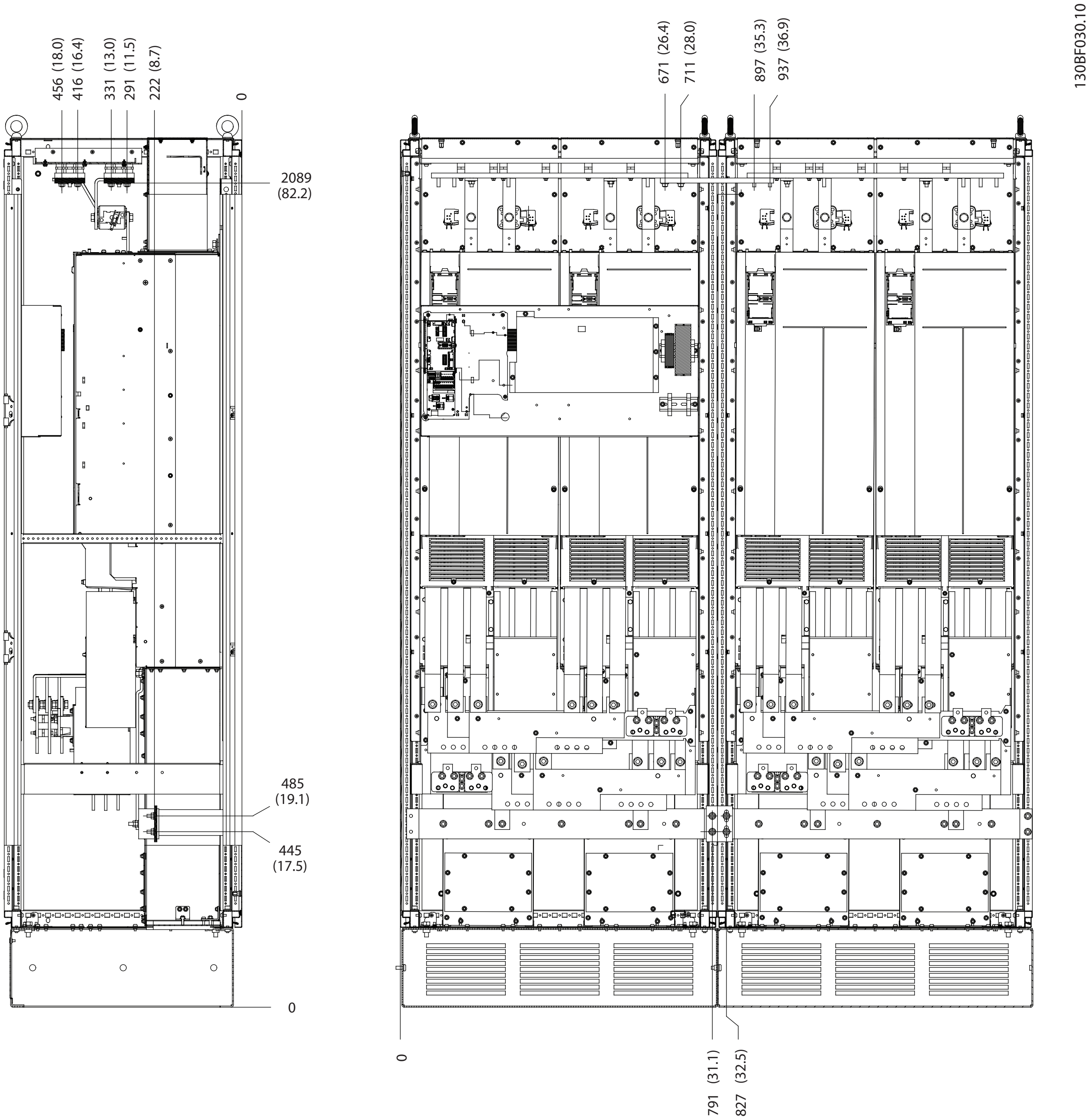
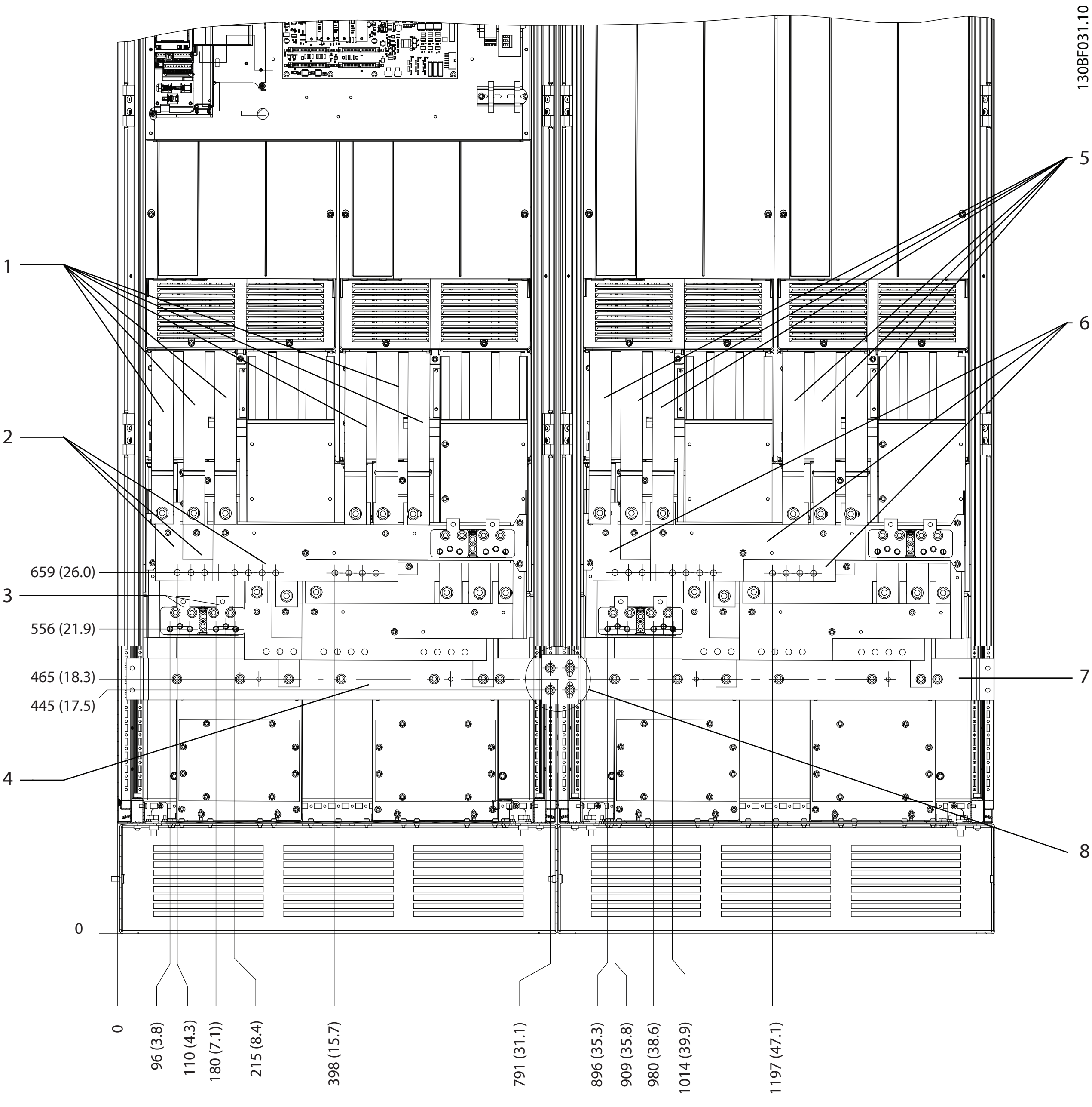


Illustration 6.11 4-drive Jumper Connections (Side and Front Views)



1	Mains jumper busbars (modules 1 and 2)	5	Mains jumper busbars (modules 3 and 4)
2	Mains terminals (modules 1 and 2)	6	Mains terminals (modules 3 and 4)
3	Brake terminals (modules 1 and 2)	7	Ground terminals (modules 3 and 4)
4	Ground terminals (modules 1 and 2)	8	Connecting ground terminal (see *Illustration 6.13*)

Illustration 6.12 4-drive System Mains and Ground Terminals (Front View)

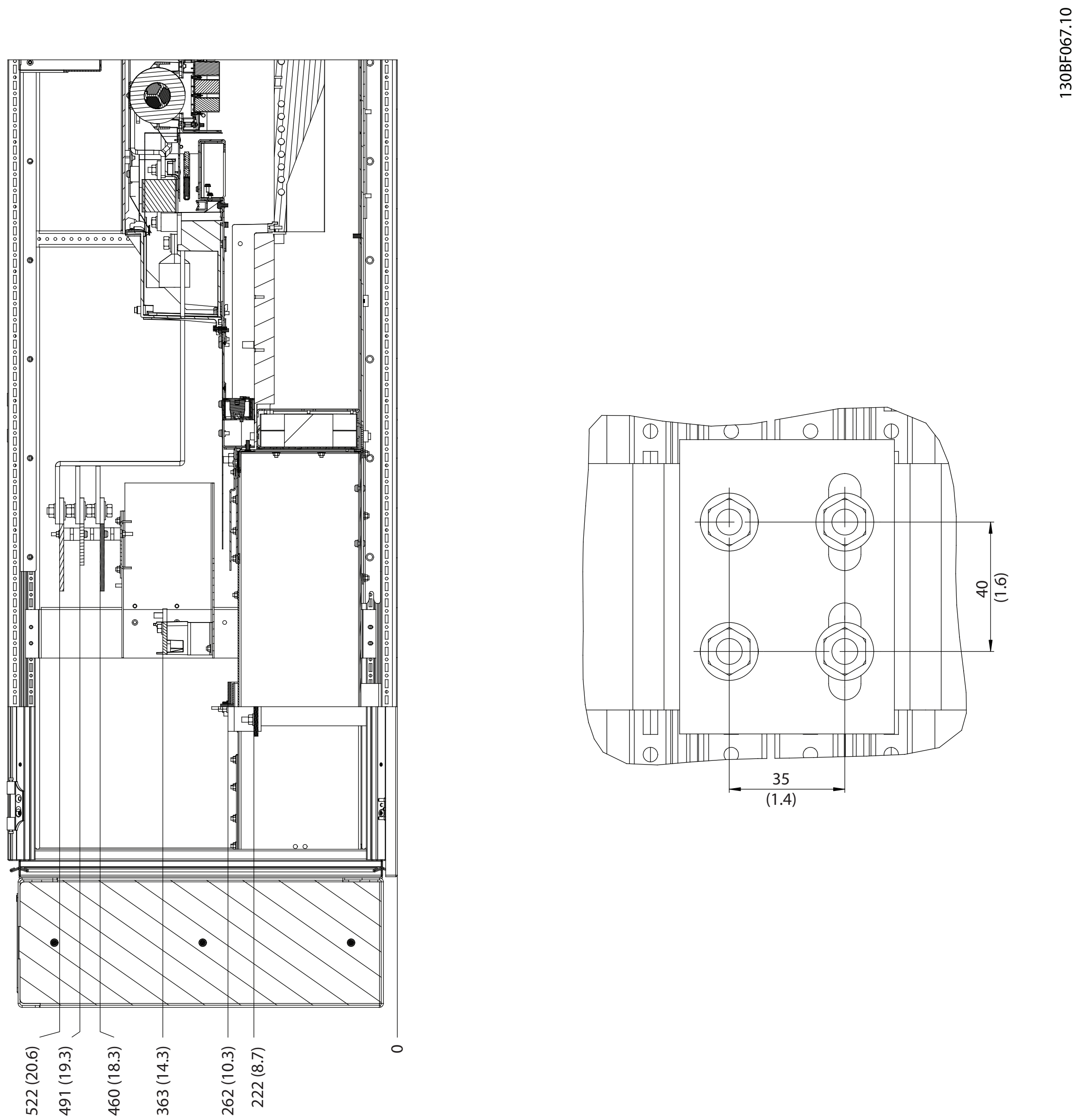
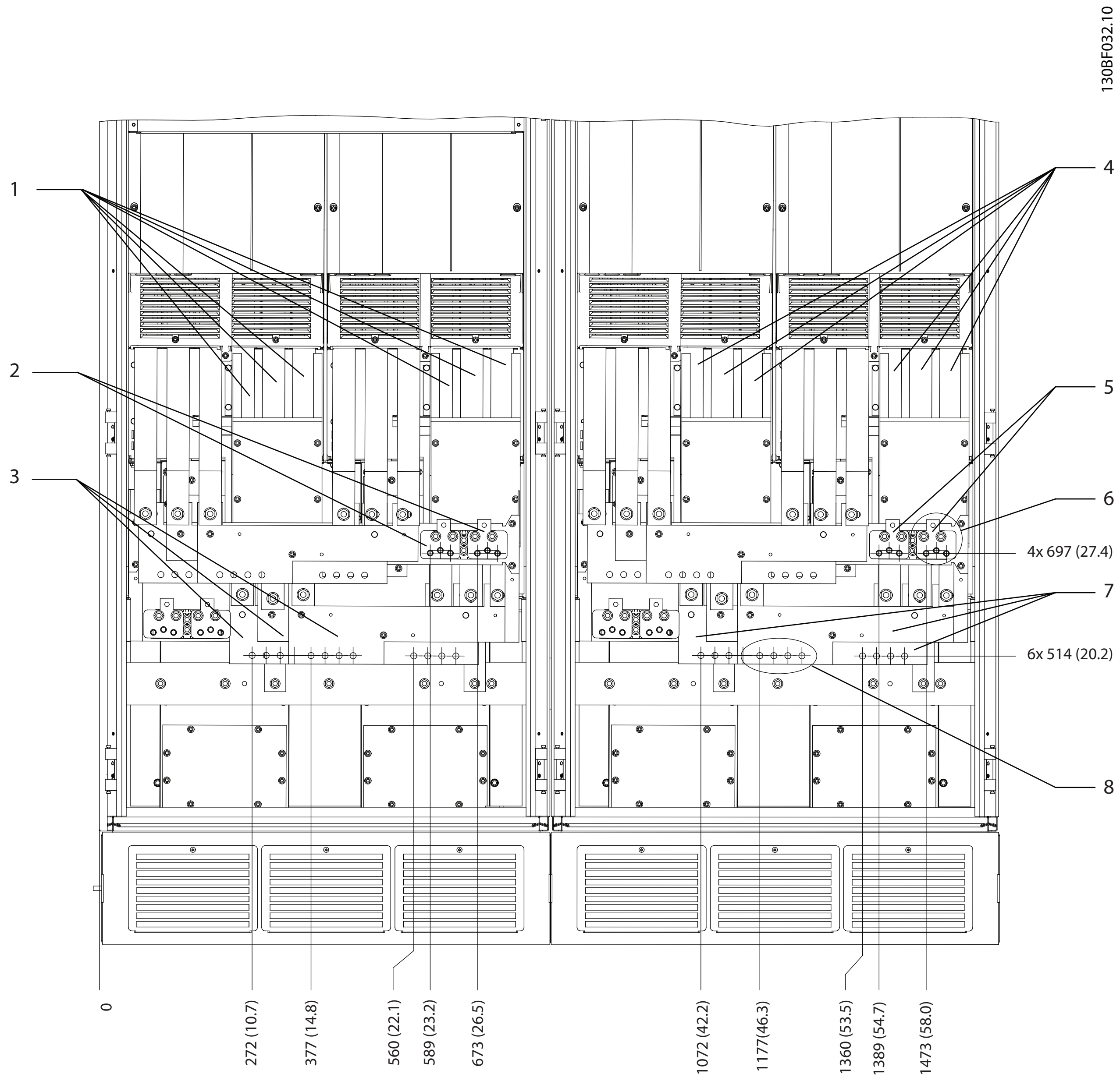
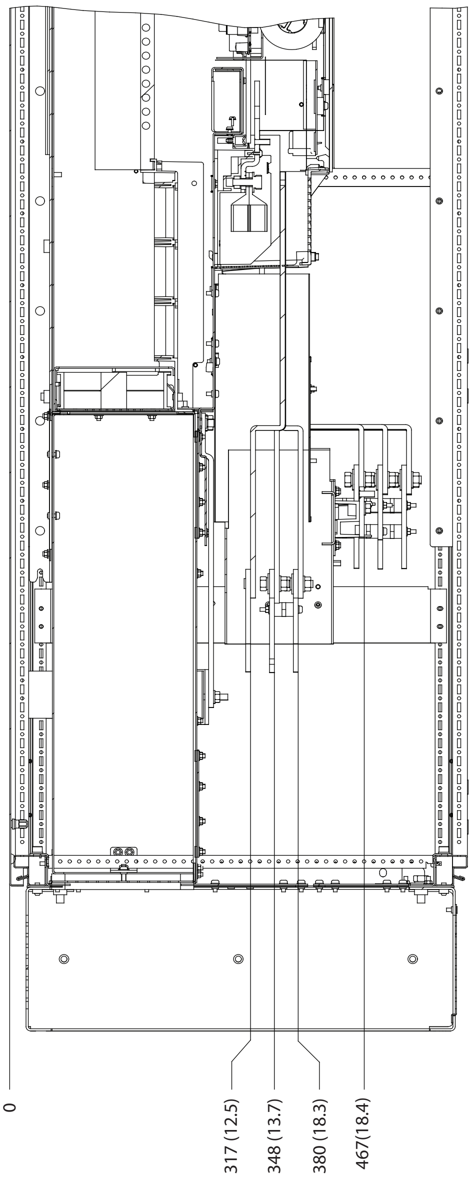


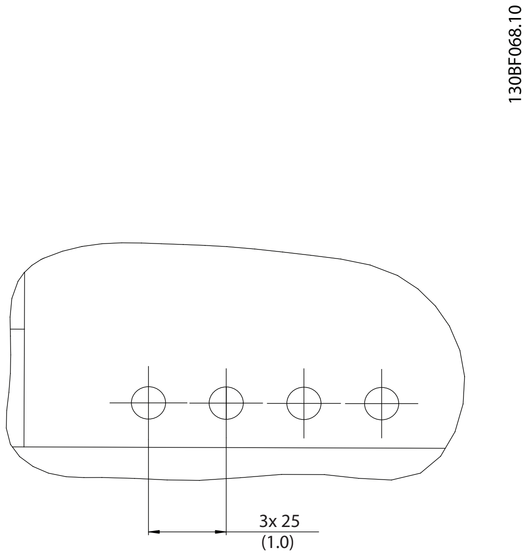
Illustration 6.13 4-drive System Mains and Ground Terminals (Side View, Left, and Connecting Ground Terminal View, Right)



1	Motor jumper busbars (modules 1 and 2)	5	Brake terminals (modules 3 and 4)
2	Brake terminals (modules 1 and 2)	6	Brake terminal detail (see *Illustration 6.15*)
3	Motor terminals (modules 1 and 2)	7	Motor terminals (modules 3 and 4)
4	Motor jumper busbars (module 3 and 4)	8	Motor terminal detail (see *Illustration 6.15*)

Illustration 6.14 4-drive System Motor and Brake Terminals (Front View)





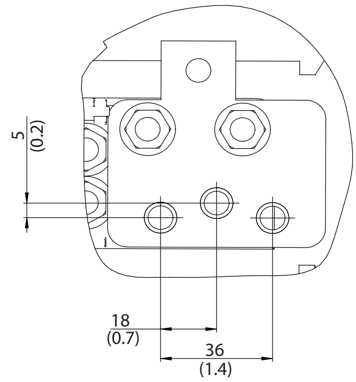
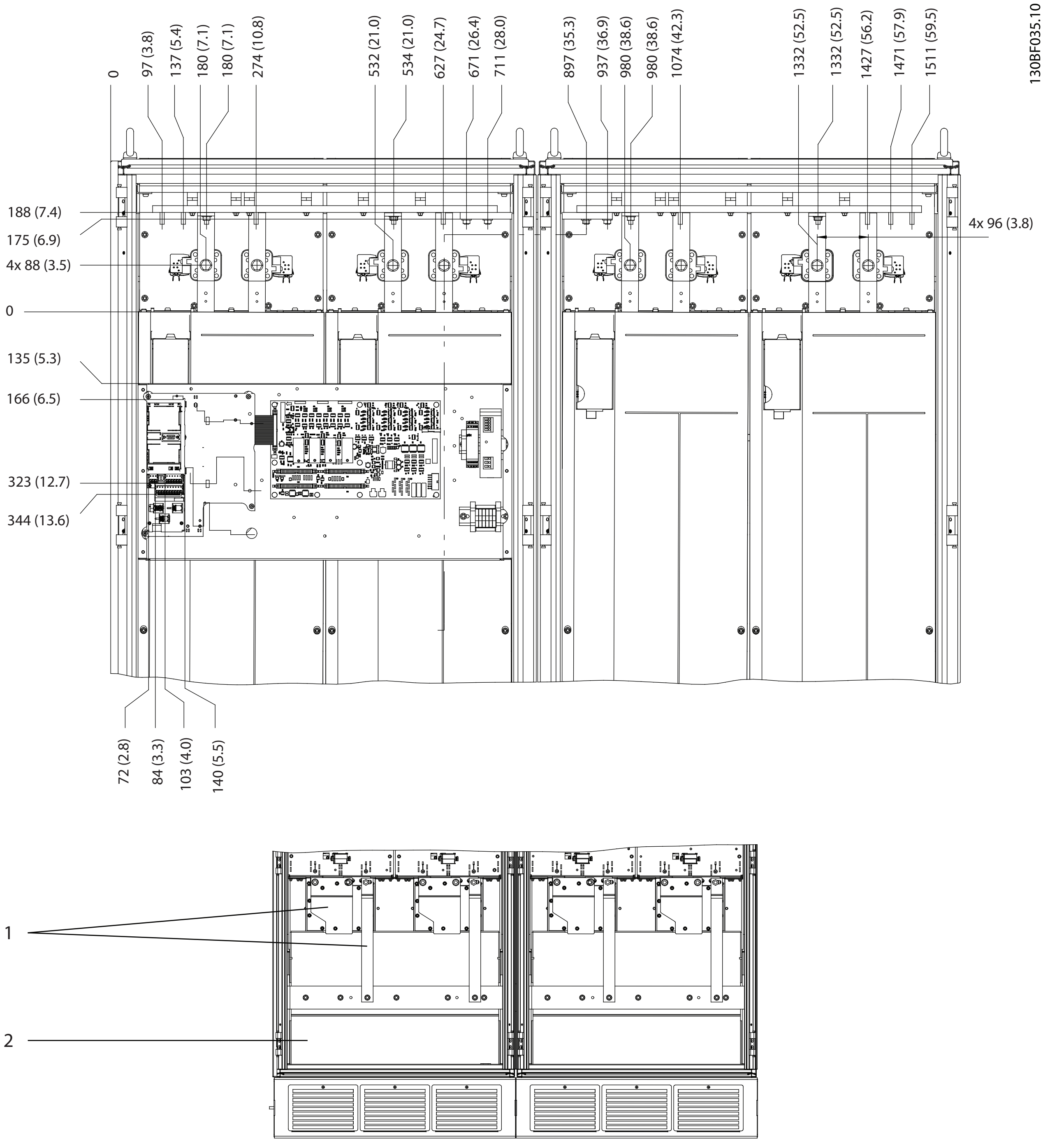


Illustration 6.15 4-drive System Motor and Brake Terminals (Side View, Left, Motor Terminals, Top Right, and Brake Terminals, Bottom Right)



1	Ground jumper busbars (module 1)	2	Grounding shield (module 1)

Illustration 6.16 4-drive System DC Bus/Relays and Grounding Shield (Front View)

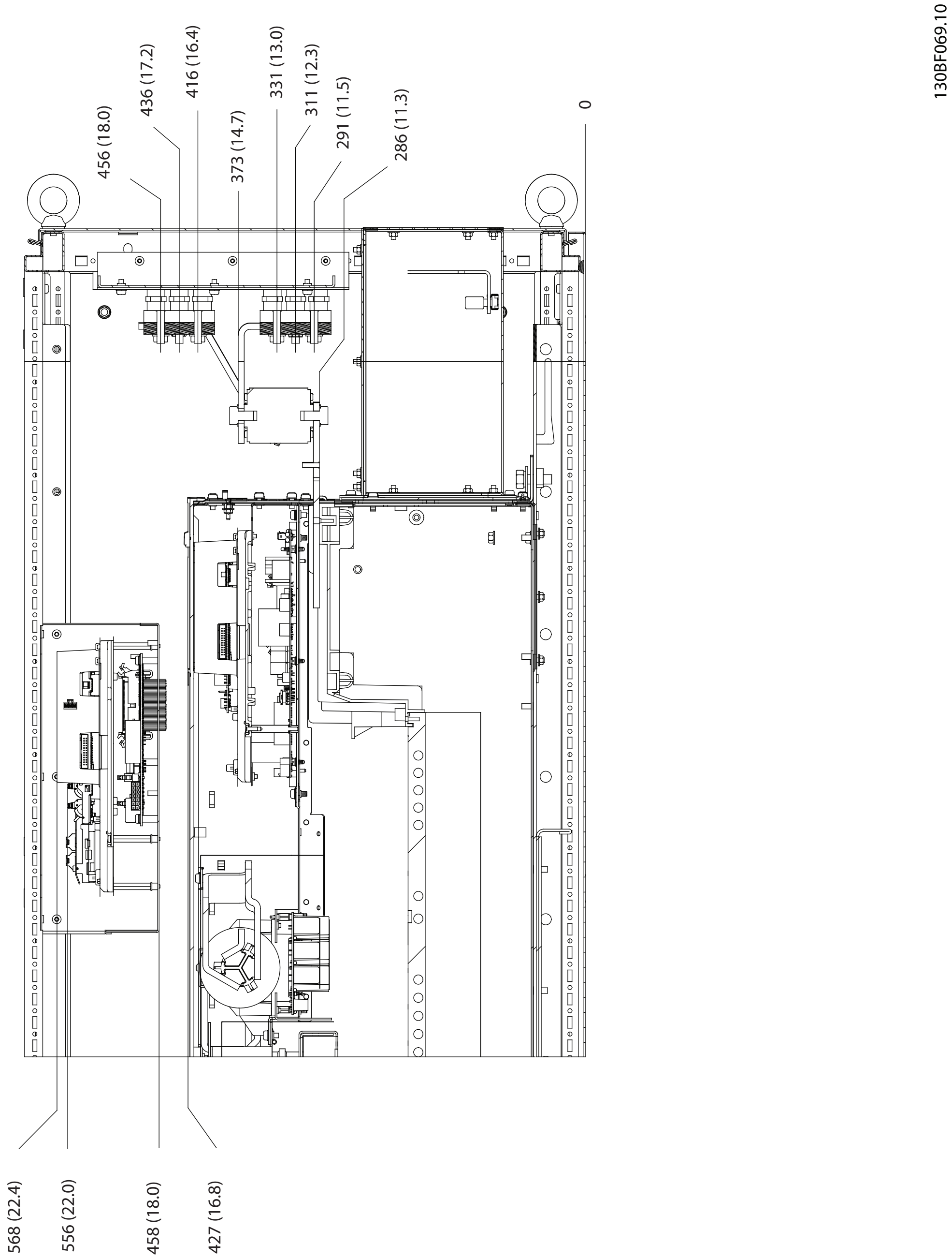


Illustration 6.17 4-drive System DC Bus and Relays (Side View)

6.5 Power-dependent Specifications

6.5.1 VLT® HVAC Drive FC 102

Power range	N315	N355	N400	N450	N500
Drive modules	2	2	2	2	2
Rectifier configuration	12-pulse				6-pulse/12-pulse
High/normal load	NO	NO	NO	NO	NO
Typical shaft output at 400 V [kW]	315	355	400	450	500
Typical shaft output at 460 V [hp]	450	500	600	600	700/650
Protection rating	IP00				
Efficiency	0.98				
Output frequency [Hz]	0–590				
Heat sink overtemperature trip [°C (°F)]	110 (230)				
Power card ambient trip [°C (°F)]	80 (176)				
Output current [A]					
Continuous (at 380–440 V)	588	658	745	800	880
Intermittent (60 s overload) at 400 V	647	724	820	880	968
Continuous (at 460/500 V)	535	590	678	730	780
Intermittent (60 s overload) at 460/500 V	588	649	746	803	858
Continuous (at 400 V) [kVA]	407	456	516	554	610
Continuous (at 460 V) [kVA]	426	470	540	582	621
Continuous (at 500 V) [kVA]	463	511	587	632	675
Input current [A]					
Continuous (at 400 V)	567	647	733	787	875
Continuous (at 460/500 V)	516	580	667	718	759
Power losses [W]					
Drive modules at 400 V	5825	6110	7069	7538	8468
Drive modules at 460 V	4998	5964	6175	6609	7140
AC busbars at 400 V	550	555	561	565	575
AC busbars at 460 V	548	551	556	560	563
DC busbars during regeneration	93	95	98	101	105
Maximum cable size [mm^2 (mcm)]					
Mains[1)]	4x120 (250)				4x150 (300)
Motor	4x120 (250)				4x150 (300)
Brake	4x70 (2/0)			4x95 (3/0)	
Regeneration terminals	4x120 (250)		4x150 (300)	6x120 (250)	
Maximum external mains fuses					
6-pulse configuration	–	–	–	–	600 V, 1600 A
12-pulse configuration	700 A, 600 V				–

Table 6.2 FC 102, 380–480 V AC Mains Supply (2-module System)

1) For 12-pulse units, the cables between the star and delta terminals must be equal in number and length.

<table>
<tr><th>Power range</th><th>N560</th><th>N630</th><th>N710</th><th>N800</th><th>N1M0</th></tr>
<tr><td>Drive modules</td><td>4</td><td>4</td><td>4</td><td>4</td><td>4</td></tr>
<tr><td>Rectifier configuration</td><td colspan="5">6-pulse/12-pulse</td></tr>
<tr><td>High/normal load</td><td>NO</td><td>NO</td><td>NO</td><td>NO</td><td>NO</td></tr>
<tr><td>Typical shaft output at 400 V [kW]</td><td>560</td><td>630</td><td>710</td><td>800</td><td>1000</td></tr>
<tr><td>Typical shaft output at 460 V [hp]</td><td>750</td><td>900</td><td>1000</td><td>1200</td><td>1350</td></tr>
<tr><td>Protection rating</td><td colspan="5">IP00</td></tr>
<tr><td>Efficiency</td><td colspan="5">0.98</td></tr>
<tr><td>Output frequency [Hz]</td><td colspan="5">0–590</td></tr>
<tr><td>Heat sink overtemperature trip [°C (°F)]</td><td colspan="5">110 (230)</td></tr>
<tr><td>Power card ambient trip [°C (°F)]</td><td colspan="5">80 (176)</td></tr>
<tr><td>Output current [A]</td><td colspan="5"></td></tr>
<tr><td>Continuous (at 380–440 V)</td><td>990</td><td>1120</td><td>1260</td><td>1460</td><td>1720</td></tr>
<tr><td>Intermittent (60 s overload) at 400 V</td><td>1089</td><td>1232</td><td>1386</td><td>1606</td><td>1892</td></tr>
<tr><td>Continuous (at 460/500 V)</td><td>890</td><td>1050</td><td>1160</td><td>1380</td><td>1530</td></tr>
<tr><td>Intermittent (60 s overload) at 460/500 V</td><td>979</td><td>1155</td><td>1276</td><td>1518</td><td>1683</td></tr>
<tr><td>Continuous (at 400 V) [kVA]</td><td>686</td><td>776</td><td>873</td><td>1012</td><td>1192</td></tr>
<tr><td>Continuous (at 460 V) [kVA]</td><td>709</td><td>837</td><td>924</td><td>1100</td><td>1219</td></tr>
<tr><td>Continuous (at 500 V) [kVA]</td><td>771</td><td>909</td><td>1005</td><td>1195</td><td>1325</td></tr>
<tr><td>Input current [A]</td><td colspan="5"></td></tr>
<tr><td>Continuous (at 400 V)</td><td>964</td><td>1090</td><td>1227</td><td>1422</td><td>1675</td></tr>
<tr><td>Continuous (at 460/500 V)</td><td>867</td><td>1022</td><td>1129</td><td>1344</td><td>1490</td></tr>
<tr><td>Power losses [W]</td><td colspan="5"></td></tr>
<tr><td>Drive modules at 400 V</td><td>8810</td><td>10199</td><td>11632</td><td>13253</td><td>16463</td></tr>
<tr><td>Drive modules at 460 V</td><td>7628</td><td>9324</td><td>10375</td><td>12391</td><td>13958</td></tr>
<tr><td>AC busbars at 400 V</td><td>665</td><td>680</td><td>695</td><td>722</td><td>762</td></tr>
<tr><td>AC busbars at 460 V</td><td>656</td><td>671</td><td>683</td><td>710</td><td>732</td></tr>
<tr><td>DC busbars during regeneration</td><td>218</td><td>232</td><td>250</td><td>276</td><td>318</td></tr>
<tr><td>Maximum cable size [mm^2 (mcm)]</td><td colspan="5"></td></tr>
<tr><td>Mains[1)]</td><td>4x185 (350)</td><td colspan="4">8x120 (250)</td></tr>
<tr><td>Motor</td><td>4x185 (350)</td><td colspan="4">8x120 (250)</td></tr>
<tr><td>Brake</td><td colspan="3">8x70 (2/0)</td><td colspan="2">8x95 (3/0)</td></tr>
<tr><td>Regeneration terminals</td><td>6x120 (250)</td><td colspan="2">8x120 (250)</td><td>8x150 (300)</td><td>10x150 (300)</td></tr>
<tr><td>Maximum external mains fuses</td><td colspan="5"></td></tr>
<tr><td>6-pulse configuration</td><td>600 V, 1600 A</td><td colspan="2">600 V, 2000 A</td><td colspan="2">600 V, 2500 A</td></tr>
<tr><td>12-pulse configuration</td><td>600 V, 700 A</td><td colspan="3">600 V, 900 A</td><td>600 V, 1500 A</td></tr>
</table>

Table 6.3 FC 102, 380–480 V AC Mains Supply (4-module System)

1) For 12-pulse units, the cables between the star and delta terminals must be equal in number and length.

6

Power range	N315	N400	N450	N500	N560	N630
Drive modules	2	2	2	2	2	2
Rectifier configuration	12-pulse					
High/normal load	NO	NO	NO	NO	NO	NO
Typical shaft output at 525–550 V [kW]	250	315	355	400	450	500
Typical shaft output at 575 V [hp]	350	400	450	500	600	650
Typical shaft output at 690 V [kW]	315	400	450	500	560	630
Protection rating	IP00					
Efficiency	0.98					
Output frequency [Hz]	0–590					
Heat sink overtemperature trip [°C (°F)]	110 (230)					
Power card ambient trip [°C (°F)]	80 (176)					
Output current [A]						
Continuous (at 550 V)	360	418	470	523	596	630
Intermittent (60 s overload) at 550 V	396	360	517	575	656	693
Continuous (at 575/690 V)	344	400	450	500	570	630
Intermittent (60 s overload) at 575/690 V	378	440	495	550	627	693
Continuous (at 550 V) kVA	343	398	448	498	568	600
Continuous (at 575 V) kVA	343	398	448	498	568	627
Continuous (at 690 V) kVA	411	478	538	598	681	753
Input current [A]						
Continuous (at 550 V)	355	408	453	504	574	607
Continuous (at 575 V)	339	490	434	482	549	607
Continuous (at 690 V)	352	400	434	482	549	607
Power losses [W]						
Drive modules at 575 V	4401	4789	5457	6076	6995	7431
Drive modules at 690 V	4352	4709	5354	5951	6831	7638
AC busbars at 575 V	540	541	544	546	550	553
DC busbars during regeneration	88	88.5	90	91	186	191
Maximum cable size [mm² (mcm)]						
Mains[1)]	2x120 (250)	4x120 (250)				
Motor	2x120 (250)	4x120 (250)				
Brake	4x70 (2/0)				4x95 (3/0)	
Regeneration terminals	4x120 (250)					
Maximum external mains fuses	700 V, 550 A		700 V, 630 A			

Table 6.4 FC 102, 525–690 V AC Mains Supply (2-module System)

1) For 12-pulse units, the cables between the star and delta terminals must be equal in number and length.

Power range	N710	N800	N900	N1M0	N1M2
Drive modules	4	4		4	4
Rectifier configuration	6-pulse/12-pulse				
High/normal load	NO	NO	NO	NO	NO
Typical shaft output at 525–550 V [kW]	560	670	750	850	1000
Typical shaft output at 575 V [hp]	750	950	1050	1150	1350
Typical shaft output at 690 V [kW]	710	800	900	1000	1200
Protection rating	IP00				
Efficiency	0.98				
Output frequency [Hz]	0–590				
Heat sink overtemperature trip [°C (°F)]	110 (230)				
Power card ambient trip [°C (°F)]	80 (176)				
Output current [A]					
Continuous (at 550 V)	763	889	988	1108	1317
Intermittent (60 s overload) at 550 V	839	978	1087	1219	1449
Continuous (at 575/690 V)	730	850	945	1060	1260
Intermittent (60 s overload) at 575/690 V	803	935	1040	1166	1590
Continuous (at 550 V)	727	847	941	1056	1056
Continuous (at 575 V)	727	847	941	1056	1056
Continuous (at 690 V)	872	1016	1129	1267	1506
Input current [A]					
Continuous (at 550 V)	743	866	962	1079	1282
Continuous (at 575 V)	711	828	920	1032	1227
Continuous (at 690 V)	711	828	920	1032	1227
Power losses [W]					
Drive modules at 575 V	8683	10166	11406	12852	15762
Drive modules at 690 V	8559	9996	11188	12580	15358
AC busbars at 575 V	644	653	661	672	695
DC busbars during regeneration	198	208	218	231	256
Maximum cable size [mm^2 (mcm)]					
Mains[1)]	4x120 (250)	6x120 (250)			8x120 (250)
Motor	4x120 (250)	6x120 (250)			8x120 (250)
Brake	8x70 (2/0)			8x95 (3/0)	
Regeneration terminals	4x150 (300)	6x120 (250)		6x150 (300)	8x120 (250)
Maximum external mains fuses					
6-pulse configuration	700 V, 1600 A				700 V, 2000 A
12-pulse configuration	700 V, 900 A			700 V, 1500 A	

Table 6.5 FC 102, 525–690 V AC Mains Supply (4-module System)

1) For 12-pulse units, the cables between the star and delta terminals must be equal in number and length.

6

6.5.2 VLT® AQUA Drive FC 202

Power range	N315		N355		N400		N450		N500	
Drive modules	2		2		2		2		2	
Rectifier configuration	12-pulse								6-pulse/12-pulse	
High/normal load	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output at 400 V [kW]	250	315	315	355	355	400	400	450	450	500
Typical shaft output at 460 V [hp]	350	450	450	500	500	600	550	600	600	650
Protection rating	IP00									
Efficiency	0.98									
Output frequency [Hz]	0–590									
Heat sink overtemperature trip [°C (°F)]	110 (230)									
Power card ambient trip [°C (°F)]	80 (176)									
Output current [A]										
Continuous (at 400 V)	480	588	600	658	658	745	695	800	810	880
Intermittent (60 s overload) at 400 V	720	647	900	724	987	820	1043	880	1215	968
Continuous (at 460/500 V)	443	535	540	590	590	678	678	730	730	780
Intermittent (60 s overload) at 460/500 V	665	588	810	649	885	746	1017	803	1095	858
Continuous (at 400 V) [kVA]	333	407	416	456	456	516	482	554	554	610
Continuous (at 460 V) [kVA]	353	426	430	470	470	540	540	582	582	621
Continuous (at 500 V) [kVA]	384	463	468	511	511	587	587	632	632	675
Input current [A]										
Continuous (at 400 V)	463	567	590	647	647	733	684	787	779	857
Continuous (at 460/500 V)	427	516	531	580	580	667	667	718	711	759
Power losses [W]										
Drive modules at 400 V	4505	5825	5502	6110	6110	7069	6375	7538	7526	8468
Drive modules at 460 V	4063	4998	5384	5964	5271	6175	6070	6609	6604	7140
AC busbars at 400 V	545	550	551	555	555	561	557	565	566	575
AC busbars at 460 V	543	548	548	551	551	556	556	560	560	563
DC busbars during regeneration	93	93	95	95	98	98	101	101	105	105
Maximum cable size [mm² (mcm)]										
Mains[1)]	4x120 (250)								4x150 (300)	
Motor	4x120 (250)								4x150 (300)	
Brake	4x70 (2/0)						4x95 (3/0)			
Regeneration terminals	4x120 (250)				6x120 (250)		6x120 (250)			
Maximum external mains fuses										
6-pulse configuration	–		–		–		–		600 V, 1600 A	
12-pulse configuration	600 V, 700 A								600 V, 900 A	

Table 6.6 FC 202, 380–480 V AC Mains Supply (2-module System)

1) For 12-pulse units, the cables between the star and delta terminals must be equal in number and length.

Power range	N560		N630		N710		N800		N1M0	
Drive modules	4		4		4		4		4	
Rectifier configuration	6-pulse/12-pulse									
High/normal load	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output at 400 V [kW]	500	560	560	630	630	710	710	800	800	1000
Typical shaft output at 460 V [hp]	650	750	750	900	900	1000	1000	1200	1200	1350
Protection rating	IP00									
Efficiency	0.98									
Output frequency [Hz]	0–590									
Heat sink overtemperature trip [°C (°F)]	110 (230)									
Power card ambient trip [°C (°F)]	80 (176)									
Output current [A]										
Continuous (at 400 V)	880	990	990	1120	1120	1260	1260	1460	1460	1720
Intermittent (60 s overload) at 400 V	1320	1089	1485	1232	1680	1386	1890	1606	2190	1892
Continuous (at 460/500 V)	780	890	890	1050	1050	1160	1160	1380	1380	1530
Intermittent (60 s overload) at 460/500 V	1170	979	1335	1155	1575	1276	1740	1518	2070	1683
Continuous (at 400 V) [kVA]	610	686	686	776	776	873	873	1012	1012	1192
Continuous (at 460 V) [kVA]	621	709	709	837	837	924	924	1100	1100	1219
Continuous (at 500 V) [kVA]	675	771	771	909	909	1005	1005	1195	1195	1325
Input current [A]										
Continuous (at 400 V)	857	964	964	1090	1090	1227	1127	1422	1422	1675
Continuous (at 460 V)	759	867	867	1022	1022	1129	1129	1344	1344	1490
Power losses [W]										
Drive modules at 400 V	7713	8810	8918	10199	10181	11632	11390	13253	13479	16463
Drive modules at 460 V	6641	7628	7855	9324	9316	10375	12391	12391	12376	13958
AC busbars at 400 V	655	665	665	680	680	695	695	722	722	762
AC busbars at 460 V	647	656	656	671	671	683	683	710	710	732
DC busbars during regeneration	218	218	232	232	250	250	276	276	318	318
Maximum cable size [mm² (mcm)]										
Mains[1)]	4x185 (350)		8x125 (250)							
Motor	4x185 (350)		8x125 (250)							
Brake	8x70 (2/0)						8x95 (3/0)			
Regeneration terminals	6x125 (250)		8x125 (250)				8x150 (300)		10x150 (300)	
Maximum external mains fuses										
6-pulse configuration	600 V, 1600 A		600 V, 2000 A				600 V, 2500 A			
12-pulse configuration	600 V, 900 A				600 V, 1500 A					

Table 6.7 FC 202, 380–480 V AC Mains Supply (4-module System)

1) For 12-pulse units, the cables between the star and delta terminals must be equal in number and length.

6

Power range	N315		N400		N450	
Drive modules	2		2		2	
Rectifier configuration	12-pulse					
High/normal load	HO	NO	HO	NO	HO	NO
Typical shaft output at 525–550 V [kW]	200	250	250	315	315	355
Typical shaft output at 575 V [hp]	300	350	350	400	400	450
Typical shaft output at 690 V [kW]	250	315	315	400	355	450
Protection rating	IP00					
Efficiency	0.98					
Output frequency [Hz]	0–590					
Heat sink overtemperature trip [°C (°F)]	110 (230)					
Power card ambient trip [°C (°F)]	80 (176)					
Output current [A]						
Continuous (at 550 V)	303	360	360	418	395	470
Intermittent (60 s overload) at 550 V	455	396	560	460	593	517
Continuous (at 575/690 V)	290	344	344	400	380	450
Intermittent (60 s overload) at 575/690 V	435	378	516	440	570	495
Continuous (at 550 V)	289	343	343	398	376	448
Continuous (at 575 V)	289	343	343	398	378	448
Continuous (at 690 V)	347	411	411	478	454	538
Input current [A]						
Continuous (at 550 V)	299	355	355	408	381	453
Continuous (at 575 V)	286	339	339	490	366	434
Continuous (at 690 V)	296	352	352	400	366	434
Power losses [W]						
Drive modules at 575 V	3688	4401	4081	4789	4502	5457
Drive modules at 690 V	3669	4352	4020	4709	4447	5354
AC busbars at 575 V	538	540	540	541	540	544
DC busbars during regeneration	88	88	89	89	90	90
Maximum cable size [mm² (mcm)]						
Mains1)	2x120 (250)		4x120 (250)			
Motor	2x120 (250)		4x120 (250)			
Brake	4x70 (2/0)					
Regeneration terminals	4x120 (250)					
Maximum external mains fuses	700 V, 550 A					

Table 6.8 FC 202, 525–690 V AC Mains Supply (2-module System)

1) For 12-pulse units, the cables between the star and delta terminals must be equal in number and length.

Power range	N500		N560		N630	
Drive modules	2		2		2	
Rectifier configuration	12-pulse					
High/normal load	HO	NO	HO	NO	HO	NO
Typical shaft output at 525–550 V [kW]	315	400	400	450	450	500
Typical shaft output at 575 V [hp]	400	500	500	600	600	650
Typical shaft output at 690 V [kW]	400	500	500	560	560	630
Protection rating	IP00					
Efficiency	0.98					
Output frequency [Hz]	0–590					
Heat sink overtemperature trip [°C (°°F)]	110 (230)					
Power card ambient trip [°C (°F)]	80 (176)					
Output current [A]						
Continuous (at 550 V)	429	523	523	596	596	630
Intermittent (60 s overload) at 550 V	644	575	785	656	894	693
Continuous (at 575/690 V)	410	500	500	570	570	630
Intermittent (60 s overload) at 575/690 V	615	550	750	627	627	693
Continuous (at 550 V) [kVA]	409	498	498	568	568	600
Continuous (at 575 V) [kVA]	408	498	598	568	568	627
Continuous (at 690 V) [kVA]	490	598	598	681	681	753
Input current [A]						
Continuous (at 550 V)	413	504	504	574	574	607
Continuous (at 575 V)	395	482	482	549	549	607
Continuous (at 690 V)	395	482	482	549	549	607
Power losses [W]						
Drive modules at 575 V	4892	6076	6016	6995	6941	7431
Drive modules at 690 V	4797	5951	5886	6831	6766	7638
AC busbars at 575 V	542	546	546	550	550	553
DC busbars during regeneration	91	91	186	186	191	191
Maximum cable size [mm^2 (mcm)]						
Mains[1)]	4x120 (250)					
Motor	4x120 (250)					
Brake	4x70 (2/0)		4x95 (3/0)			
Regeneration terminals	4x120 (250)					
Maximum external mains fuses	700 V, 630 A					

Table 6.9 FC 202, 525–690 V AC Mains Supply (2-module System)

1) For 12-pulse units, the cables between the star and delta terminals must be equal in number and length.

Power range	N710		N800		N900		N1M0		N1M2	
Drive modules	4		4		4		4		4	
Rectifier configuration	6-pulse/12-pulse									
High/normal load	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output at 525–550 V [kW]	500	560	560	670	670	750	750	850	850	1000
Typical shaft output at 575 V [hp]	650	750	750	950	950	1050	1050	1150	1150	1350
Typical shaft output at 690 V [kW]	630	710	710	800	800	900	900	1000	1000	1200
Protection rating	IP00									
Efficiency	0.98									
Output frequency [Hz]	0–590									
Heat sink overtemperature trip [°C (°F)]	110 (230)									
Power card ambient trip [°C (°F)]	80 (176)									
Output current [A]										
Continuous (at 550 V)	659	763	763	889	889	988	988	1108	1108	1317
Intermittent (60 s overload) at 550 V	989	839	1145	978	1334	1087	1482	1219	1662	1449
Continuous (at 575/690 V)	630	730	730	850	850	945	945	1060	1060	1260
Intermittent (60 s overload) at 575/690 V	945	803	1095	935	1275	1040	1418	1166	1590	1590
Continuous (at 550 V) [kVA]	628	727	727	847	847	941	941	1056	1056	1255
Continuous (at 575 V) [kVA]	627	727	727	847	847	941	941	1056	1056	1255
Continuous (at 690 V) [kVA]	753	872	872	1016	1016	1129	1129	1267	1267	1506
Input current [A]										
Continuous (at 550 V)	642	743	743	866	866	962	1079	1079	1079	1282
Continuous (at 575 V)	613	711	711	828	828	920	1032	1032	1032	1227
Continuous (at 690 V)	613	711	711	828	828	920	1032	1032	1032	1227
Power losses [W]										
Drive modules at 575 V	7469	8683	8668	10166	10163	11406	11292	12852	12835	15762
Drive modules at 690 V	7381	8559	8555	9996	9987	11188	11077	12580	12551	15358
AC busbars at 575 V	637	644	644	653	653	661	661	672	672	695
DC busbars during regeneration	198	198	208	208	218	218	231	231	256	256
Maximum cable size [mm² (mcm)]										
Mains[1)]	4x120 (250)		6x120 (250)						8x120 (250)	
Motor	4x120 (250)		6x120 (250)						8x120 (250)	
Brake	8x70 (2/0)						8x95 (3/0)			
Regeneration terminals	4x150 (300)		6x120 (250)				6x150 (300)		8x120 (250)	
Maximum external mains fuses										
6-pulse configuration	700 V, 1600 A								700 V, 2000 A	
12-pulse configuration	700 V, 900 A						700 V, 1500 A			

Table 6.10 FC 202, 525–690 V AC Mains Supply (4-module System)

1) For 12-pulse units, the cables between the star and delta terminals must be equal in number and length.

6.5.3 VLT® AutomationDrive FC 302

Power range	**N250**		**N315**		**N355**		**N400**		**N450**	
Drive modules	2		2		2		2		2	
Rectifier configuration	12-pulse								6-pulse/12-pulse	
High/normal load	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output at 400 V [kW]	250	315	315	355	355	400	400	450	450	500
Typical shaft output at 460 V [hp]	350	450	450	500	500	600	550	600	600	650
Typical shaft output at 500 V [kW]	315	355	355	400	400	500	500	530	530	560
Protection rating	IP00									
Efficiency	0.98									
Output frequency [Hz]	0–590									
Heat sink overtemperature trip [°C (°F)]	110 (230)									
Power card ambient trip [°C (°F)]	80 (176)									
Output current [A]										
Continuous (at 380–440 V)	480	588	600	658	658	745	695	800	810	880
Intermittent (60 s overload) at 400 V	720	647	900	724	987	820	1043	880	1215	968
Continuous (at 460/500 V)	443	535	540	590	590	678	678	730	730	780
Intermittent (60 s overload) at 460/500 V	665	588	810	649	885	746	1017	803	1095	858
Continuous (at 400 V) [kVA]	333	407	416	456	456	516	482	554	554	610
Continuous (at 460 V) [kVA]	353	426	430	470	470	540	540	582	582	621
Continuous (at 500 V) [kVA]	384	463	468	511	511	587	587	632	632	675
Input current [A]										
Continuous (at 400 V)	463	567	590	647	647	733	684	787	779	857
Continuous (at 460/500 V)	427	516	531	580	580	667	667	718	711	759
Power losses [W]										
Drive modules at 400 V	4505	5825	5502	6110	6110	7069	6375	7538	7526	8468
Drive modules at 460 V	4063	4998	5384	5964	5721	6175	6070	6609	6604	7140
AC busbars at 400 V	545	550	551	555	555	561	557	565	566	575
AC busbars at 460 V	543	548	548	551	556	556	556	560	560	563
Maximum cable size [mm² (mcm)]										
Mains[1)]	4x120 (250)								4x150 (300)	
Motor	4x120 (250)								4x150 (300)	
Brake	4x70 (2/0)								4x95 (3/0)	
Regeneration terminals	4x120 (250)				4x150 (300)		6x120 (250)			
Maximum external mains fuses										
6-pulse configuration	–		–		–		–		600 V, 1600 A	
12-pulse configuration	600 V, 700 A								600 V, 900 A	

Table 6.11 FC 302, 380–500 V AC Mains Supply (2-module System)

1) For 12-pulse units, the cables between the star and delta terminals must be equal in number and length.

Power range	N500		N560		N630		N710		N800	
Drive modules	4		4		4		4		4	
Rectifier configuration	6-pulse/12-pulse									
High/normal load	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output at 400 V [kW]	500	560	560	630	630	710	710	800	800	1000
Typical shaft output at 460 V [hp]	650	750	750	900	900	1000	1000	1200	1200	1350
Typical shaft output at 500 V [kW]	560	630	630	710	710	800	800	1000	1000	1100
Protection rating	IP00									
Efficiency	0.98									
Output frequency [Hz]	0–590									
Heat sink overtemperature trip [°C (°F)]	110 (230)									
Power card ambient trip [°C (°F)]	80 (176)									
Output current [A]										
Continuous (at 380–440 V)	880	990	990	1120	1120	1260	1260	1460	1460	1720
Intermittent (60 s overload) at 400 V	1320	1089	1485	1232	1680	1386	1890	1606	2190	1892
Continuous (at 460/500 V)	780	890	890	1050	1050	1160	1160	1380	1380	1530
Intermittent (60 s overload) at 460/500 V	1170	979	1335	1155	1575	1276	1740	1518	2070	1683
Continuous (at 400 V) [kVA]	610	686	686	776	776	873	873	1012	1012	1192
Continuous (at 460 V) [kVA]	621	709	709	837	837	924	924	1100	1100	1219
Continuous (at 500 V) [kVA]	675	771	771	909	909	1005	1005	1195	1195	1325
Input current [A]										
Continuous (at 400 V)	857	964	964	1090	1090	1227	1227	1422	1422	1675
Continuous (at 460/500 V)	759	867	867	1022	1022	1129	1129	1344	1344	1490
Power losses [W]										
Drive modules at 400 V	7713	8810	8918	10199	10181	11632	11390	13253	13479	16463
Drive modules at 460 V	6641	7628	7855	9324	9316	10375	12391	12391	12376	13958
AC busbars at 400 V	655	665	665	680	680	695	695	722	722	762
AC busbars at 460 V	647	656	656	671	671	683	683	710	710	732
DC busbars during regeneration	218	218	232	232	250	276	276	276	318	318
Maximum cable size [mm^2 (mcm)]										
Mains[1)]	4x185 (350)		8x120 (250)							
Motor	4x185 (350)		8x120 (250)							
Brake	8x70 (2/0)						8x95 (3/0)			
Regeneration terminals	6x125 (250)		8x125 (250)				8x150 (300)		10x150 (300)	
Maximum external mains fuses										
6-pulse configuration	600 V, 1600 A		600 V, 2000 A				600 V, 2500 A			
12-pulse configuration	600 V, 900 A				600 V, 1500 A					

Table 6.12 FC 302, 380–500 V AC Mains Supply (4-module System)

1) For 12-pulse units, the cables between the star and delta terminals must be equal in number and length.

Power range	**N250**		**N315**		**N355**		**N400**	
Drive modules	2		2		2		2	
Rectifier configuration	12-pulse							
High/normal load	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output at 525–550 V [kW]	200	250	250	315	315	355	315	400
Typical shaft output at 575 V [hp]	300	350	350	400	400	450	400	500
Typical shaft output at 690 V [kW]	250	315	315	400	355	450	400	500
Protection rating	IP00							
Efficiency	0.98							
Output frequency [Hz]	0–590							
Heat sink overtemperature trip [°C (°F)]	110 (230)							
Power card ambient trip [°C (°F)]	80 (176)							
Output current [A]								
Continuous (at 550 V)	303	360	360	418	395	470	429	523
Intermittent (60 s overload) at 550 V	455	396	560	360	593	517	644	575
Continuous (at 575/690 V)	290	344	344	400	380	450	410	500
Intermittent (60 s overload) at 575/690 V	435	378	516	440	570	495	615	550
Continuous (at 550 V) [kVA]	289	343	343	398	376	448	409	498
Continuous (at 575 V) [kVA]	289	343	343	398	378	448	408	498
Continuous (at 690 V) [kVA]	347	411	411	478	454	538	490	598
Input current [A]								
Continuous (at 550 V)	299	355	355	408	381	453	413	504
Continuous (at 575 V)	286	339	339	490	366	434	395	482
Continuous (at 690 V)	296	352	352	400	366	434	395	482
Power losses [W]								
Drive modules at 600 V	3688	4401	4081	4789	4502	5457	4892	6076
Drive modules at 690 V	3669	4352	4020	4709	4447	5354	4797	5951
AC busbars at 575 V	538	540	540	541	540	544	542	546
DC busbars during regeneration	88	88	89	89	90	90	91	91
Maximum cable size [mm² (mcm)]								
Mains1)	2x120 (250)		4x120 (250)					
Motor	2x120 (250)		4x120 (250)					
Brake	4x70 (2/0)							
Regeneration terminals	4x120 (250)							
Maximum external mains fuses	700 V, 550 A							

Table 6.13 FC 302, 525–690 V AC Mains Supply (2-module System)

1) For 12-pulse units, the cables between the star and delta terminals must be equal in number and length.

Power range	N500		N560	
Drive modules	2		2	
Rectifier configuration	12-pulse			
High/normal load	HO	NO	HO	NO
Typical shaft output at 525–550 V [kW]	400	450	450	500
Typical shaft output at 575 V [hp]	500	600	600	650
Typical shaft output at 690 V [kW]	500	560	560	630
Protection rating	IP00			
Efficiency	0.98			
Output frequency [Hz]	0–590			
Heat sink overtemperature trip [°C (°F)]	110 (230)			
Power card ambient trip [°C (°F)]	80 (176)			
Output current [A]				
Continuous (at 550 V)	523	596	596	630
Intermittent (60 s overload) at 550 V	785	656	894	693
Continuous (at 575/690 V)	500	570	570	630
Intermittent (60 s overload) at 575/690 V	750	627	627	693
Continuous (at 550 V) [kVA]	498	568	568	600
Continuous (at 575 V) [kVA]	498	568	568	627
Continuous (at 690 V) [kVA]	598	681	681	753
Input current [A]				
Continuous (at 550 V)	504	574	574	607
Continuous (at 575 V)	482	549	549	607
Continuous (at 690 V)	482	549	549	607
Power losses [W]				
Drive modules at 600 V	6016	6995	6941	7431
Drive modules at 690 V	5886	6831	6766	7638
AC busbars at 575 V	546	550	550	553
DC busbars during regeneration	186	186	191	191
Maximum cable size [mm² (mcm)]				
Mains[1)]	4x120 (250)			
Motor	4x120 (250)			
Brake	4x95 (3/0)			
Regeneration terminals	4x120 (250)			
Maximum external mains fuses	700 V, 630 A			

Table 6.14 FC 302, 525–690 V AC Mains Supply (2-module System)

1) For 12-pulse units, the cables between the star and delta terminals must be equal in number and length.

Power range	N630		N710		N800		N900		N1M0	
Drive modules	4		4		4		4		4	
Rectifier configuration	6-pulse/12-pulse									
High/normal load	HO	NO	HO	NO	HO	NO	HO	NO	HO	NO
Typical shaft output at 525–550 V [kW]	500	560	560	670	670	750	750	850	850	1000
Typical shaft output at 575 V [hp]	650	750	750	950	950	1050	1050	1150	1150	1350
Typical shaft output at 690 V [kW]	630	710	710	800	800	900	900	1000	1000	1200
Protection rating	IP00									
Efficiency	0.98									
Output frequency [Hz]	0–590									
Heat sink overtemperature trip [°C (°F)]	110 (230)									
Power card ambient trip [°C (°F)]	80 (176)									
Output current [A]										
Continuous (at 550 V)	659	763	763	889	889	988	988	1108	1108	1317
Intermittent (60 s overload) at 550 V	989	839	1145	978	1334	1087	1482	1219	1662	1449
Continuous (at 575/690 V)	630	730	730	850	850	945	945	1060	1060	1260
Intermittent (60 s overload) at 575/690 V	945	803	1095	935	1275	1040	1418	1166	1590	1590
Continuous (at 550 V) [kVA]	628	727	727	847	847	941	941	1056	1056	1255
Continuous (at 575 V) [kVA]	627	727	727	847	847	941	941	1056	1056	1255
Continuous (at 690 V) [kVA]	753	872	872	1016	1016	1129	1129	1267	1267	1506
Input current [A]										
Continuous (at 550 V)	642	743	743	866	866	962	1079	1079	1079	1282
Continuous (at 575 V)	613	711	711	828	828	920	1032	1032	1032	1227
Continuous (at 690 V)	613	711	711	828	828	920	1032	1032	1032	1227
Power losses [W]										
Drive modules at 600 V	7469	8683	8668	10166	10163	11406	11292	12852	12835	15762
Drive modules at 690 V	7381	8559	8555	9996	9987	11188	11077	12580	12551	15358
AC busbars at 575 V	637	644	644	653	653	661	661	672	672	695
DC busbars during regeneration	198	198	208	208	218	218	231	231	256	256
Maximum cable size [mm² (mcm)]										
Mains[1)]	4x120 (250)		6x120 (250)						8x120 (250)	
Motor	4x120 (250)		6x120 (250)						8x120 (250)	
Brake	8x70 (2/0)						8x95 (3/0)			
Regeneration terminals	4x150 (300)		6x120 (250)				6x150 (300)		8x120 (250)	
Maximum external mains fuses										
6-pulse configuration	700 V, 1600 A								700 V, 2000 A	
12-pulse configuration	700 V, 900 A						700 V, 1500 A			

Table 6.15 FC 302, 525–690 V AC Mains Supply (4-module System)

1) For 12-pulse units, the cables between the star and delta terminals must be equal in number and length.

6.6 Mains Supply to Drive Module

Mains supply[1]	
Supply terminals	R/91, S/92, T/93
Supply voltage[2]	380–480, 500 V 690 V, ±10%, 525–690 V ±10%
Supply frequency	50/60 Hz ±5%
Maximum temporary imbalance between mains phases	3.0% of rated supply voltage
True power factor (λ)	≥0.98 nominal at rated load
Displacement power factor (cos Φ)	(Approximately 1)
Switching on input supply L1, L2, L3	Maximum 1 time per 2 minutes
Environment according to EN 60664-1	Overvoltage category III/pollution degree 2

1) The unit is suitable for use on a circuit capable of delivering not more than 85000 RMS symmetrical Amperes, 480/600 V.
2) Mains voltage low/mains voltage drop-out:
During low mains voltage, the drive module continues until the DC-link voltage drops below the minimum stop level, which corresponds typically to 15% below the lowest rated supply voltage. Power-up and full torque cannot be expected at mains voltage lower than 10% below the lowest rated supply voltage. The drive module trips for a detected mains drop-out.

6

6.7 Motor Output and Motor Data

Motor output	
Motor terminals	U/96, V/97, W/98
Output voltage	0–100% of supply voltage
Output frequency	0–590 Hz
Switching on output	Unlimited
Ramp times	1–3600 s

Torque characteristics	
Overload torque (constant torque)	Maximum 150% for 60 s[1]
Starting torque	Maximum 180% up to 0.5 s[1]
Overload torque (variable torque)	Maximum 110% for s[1]
Starting torque (variable torque)	Maximum 135% for s

1) Percentage relates to the nominal torque.

Efficiency	
Efficiency	98%[1]

1) Efficiency measured at nominal current. For energy efficiency class, see chapter 6.9 Ambient Conditions for Drive Modules. For part load losses, see www.danfoss.com/vltenergyefficiency.

6.8 12-Pulse Transformer Specifications

Connection	Dy11 d0 or Dyn 11d0
Phase shift between secondaries	30°
Voltage difference between secondaries	<0.5%
Short circuit impedance of secondaries	>5%
Short circuit impedance difference between secondaries	<5% of short circuit impedance
Other	No grounding of the secondaries allowed. Static shield recommended

6.9 Ambient Conditions for Drive Modules

Environment	
IP rating	IP00
Acoustic noise	84 dB (running at full load)
Vibration test	1.0 g
Vibration and shock (IEC 60721-33-3)	Class 3M3
Maximum relative humidity	5–95% (IEC 721–3–3; Class 3K3 (non-condensing)) during operation
Aggressive environment (IEC 60068-2-43) H_2S test	Class Kd
Aggressive gases (IEC 60721-3-3)	Class 3C3
Ambient temperature[1)]	Maximum 45 °C (113 °F) (24-hour average maximum 40 °C (104 °F))
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 °C (-13 to 149 °F)
Maximum altitude above sea level without derating[1)]	1000 m (3281 ft)
EMC standards, Emission	EN 61800-3
EMC standards, Immunity	EN 61800-4-2, EN 61800-4-3, EN 61800-4-4, EN 61800-4-5, and EN 61800-4-6
Energy efficiency class[2)]	IE2

1) Refer to chapter 6.12 Derating Specifications for derating for high ambient temperature and derating for high altitude.

2) Determined according to EN 50598-2 at:

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

6

6.10 Cable Specifications

Cable lengths and cross-sections for control cables[1)]	
Maximum motor cable length, shielded	150 m (492 ft)
Maximum motor cable length, unshielded	300 m (984 ft)
Maximum cross-section to control terminals, flexible or rigid wire without cable end sleeves	1.5 mm^2/16 AWG
Maximum cross-section to control terminals, flexible wire with cable end sleeves	1 mm^2/18 AWG
Maximum cross-section to control terminals, flexible wire with cable end sleeves with collar	0.5 mm^2/20 AWG
Minimum cross-section to control terminals	0.25 mm^2/24 AWG
Maximum cross-section to 230 V terminals	2.5 mm^2/14 AWG
Minimum cross-section to 230 V terminals	0.25 mm^2/24 AWG

1) For power cables, see electrical data tables in chapter 6.5 Power-dependent Specifications.

6.11 Control Input/Output and Control Data

Digital inputs	
Programmable digital inputs	4 (6)[1)]
Terminal number	18, 19, 27[1)], 29[1)], 32, 33
Logic	PNP or NPN
Voltage level	0–24 V DC
Voltage level, logic 0 PNP	<5 V DC
Voltage level, logic 1 PNP	>10 V DC
Voltage level, logic 0 NPN[2)]	>19 V DC
Voltage level, logic 1 NPN[2)]	<14 V DC
Maximum voltage on input	28 V DC
Pulse frequency range	0–110 kHz
(Duty cycle) Minimum pulse width	4.5 ms

Input resistance, R_i	Approximately 4 kΩ

All digital inputs are galvanically isolated from the supply voltage (PELV) and other high voltage terminals.
1) Terminals 27 and 29 can also be programmed as output.
2) Except Safe Torque Off input terminal 37.

Safe Torque Off (STO) Terminal 37[1), 2)] (Terminal 37 is fixed PNP logic)	
Voltage level	0–24 V DC
Voltage level, logic 0 PNP	<4 V DC
Voltage level, logic 1 PNP	>20 V DC
Maximum voltage on input	28 V DC
Typical input current at 24 V	50 mA_{rms}
Typical input current at 20 V	60 mA_{rms}
Input capacitance	400 nF

All digital inputs are galvanically isolated from the supply voltage (PELV) and other high voltage terminals.
1) See VLT® Frequency Converters – Safe Torque Off Operating Guide for further information about terminal 37 and Safe Torque Off.
2) When using a contactor with a DC coil with STO, always make a return path for the current from the coil when turning it off. The return path can be made by using a freewheel diode across the coil. Alternatively, use a 30 V or 50 V MOV for quicker response time. Typical contactors can be bought with this diode.

Analog inputs	
Number of analog inputs	2
Terminal number	53, 54
Modes	Voltage or current
Mode select	Switch S201 and switch S202
Voltage mode	Switch S201/switch S202 = OFF (U)
Voltage level	-10 V to +10 V (scalable)
Input resistance, R_i	Approximately 10 kΩ
Maximum voltage	±20 V
Current mode	Switch S201/switch S202 = ON (I)
Current level	0/4–20 mA (scalable)
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	20 Hz/100 Hz

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

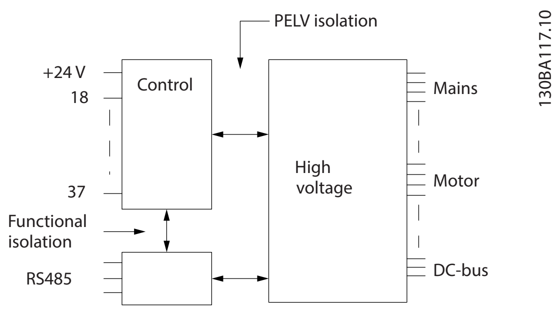


Illustration 6.18 PELV Isolation

Pulse input	
Programmable pulse	2/1
Terminal number pulse	29[1)], 32/33
Maximum frequency at terminal 29, 33	110 kHz (Push-pull driven)
Maximum frequency at terminal 29, 33	5 kHz (open collector)
Minimum frequency at terminal 29, 33	4 Hz

Voltage level	0–24 V DC
Maximum voltage on input	28 V DC
Input resistance, R_i	Approximately 4 kΩ
Pulse input accuracy (0.1–1 kHz)	Maximum error: 0.1% of full scale
Encoder input accuracy (1–11 kHz)	Maximum error: 0.05% of full scale

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

Analog output	
Number of programmable analog outputs	1
Terminal number	42
Current range at analog output	0/4–20 mA
Maximum load GND - analog output	500 Ω
Accuracy on analog output	Maximum error: 0.5% of full scale
Resolution on analog output	12 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 kΩ
Maximum capacitive load at frequency output	10 nF
Minimum output frequency at frequency output	0 Hz
Maximum output frequency at frequency output	32 kHz
Accuracy of frequency output	Maximum error: 0.1% of full scale
Resolution of frequency outputs	12 bit

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

Control card, 24 V DC output	
Terminal number	12, 13
Output voltage	24 V +1, -3 V
Maximum load	200 mA

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

Relay outputs	
Programmable relay outputs	2
Relay 01 terminal number	1–3 (break), 1–2 (make)
Maximum terminal load (AC-1)[1)] on 1–3 (NC), 1–2 (NO) (resistive load)	240 V AC, 2 A
Maximum terminal load (AC-15)[1)] (inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Maximum terminal load (DC-1)[1)] on 1–2 (NO), 1–3 (NC) (resistive load)	60 V DC, 1 A
Maximum terminal load (DC-13)[1)] (inductive load)	24 V DC, 0.1 A
Relay 02 (VLT® AutomationDrive FC 302 only) terminal number	4–6 (break), 4–5 (make)
Maximum terminal load (AC-1)[1)] on 4–5 (NO) (resistive load)[2)3)] overvoltage category II	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 1–3 (NC), 1–2 (NO), 4–6 (NC), 4–5 (NO)	24 V DC 10 mA, 24 V AC 20 mA
Environment according to EN 60664-1	Overvoltage category III/pollution degree 2

1) IEC 60947 part 4 and 5.
The relay contacts are galvanically isolated from the rest of the circuit by reinforced isolation (PELV).
2) Overvoltage Category II.
3) UL applications 300 V AC 2A.

6

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 0–590 Hz	±0.003 Hz
Repeat accuracy of precise start/stop (terminals 18, 19)	≤±0.1 ms
System response time (terminals 18, 19, 27, 29, 32, 33)	≤10 ms
Speed control range (open loop)	1:100 of synchronous speed
Speed control range (closed loop)	1:1000 of synchronous speed
Speed accuracy (open loop)	30–4000 RPM: Error ±8 RPM
Speed accuracy (closed loop), depending on resolution of feedback device	0–6000 RPM: Error ±0.15 RPM

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

Control card performance

Scan interval (VLT® HVAC Drive FC 102, VLT® Refrigeration Drive FC 103, VLT® AQUA Drive FC 202)	5 ms (VLT® AutomationDrive FC 302)
Scan interval (FC 302)	1 ms

Control card, USB serial communication

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

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 ground connection is NOT galvanically isolated from protective earth. Use only an isolated laptop as PC connection to the USB connector on the frequency converter.

6.12 Derating Specifications

Consider derating when any of the following conditions are present:

- Low air pressure operating above 1000 m (3281 ft).
- High ambient temperature.
- High switching frequency.
- Low-speed operation.
- Long motor cables.
- Cables with a large cross-section.

If these conditions are present, Danfoss recommends stepping up 1 power size.

6.12.1 Derating for Altitude and Ambient Temperature

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

At or below 1000 m (3281 ft) no derating is necessary.
Above 1000 m (3281 ft), the ambient temperature (T_{AMB}) or maximum output current (I_{MAX}) should be derated. Refer to *Illustration 6.19*.

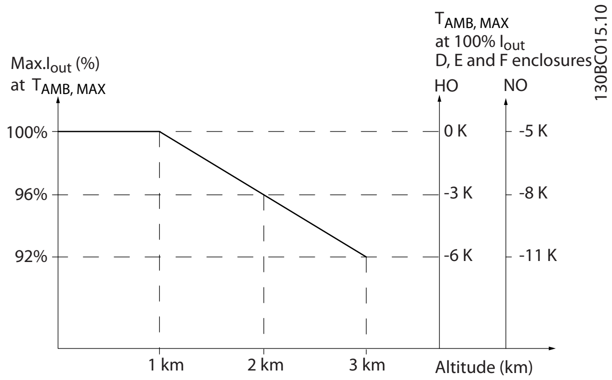


Illustration 6.19 Derating of Output Current Based on Altitude at $T_{AMB,MAX}$

Illustration 6.19 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.

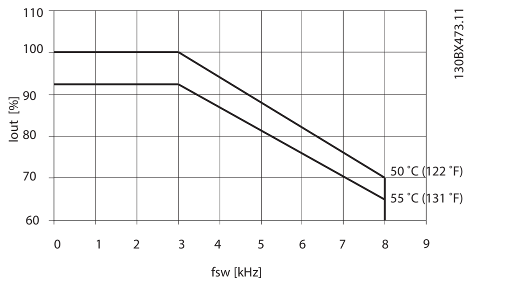
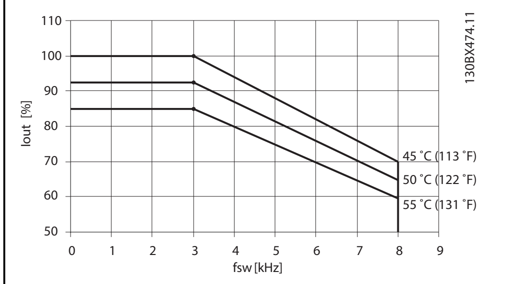
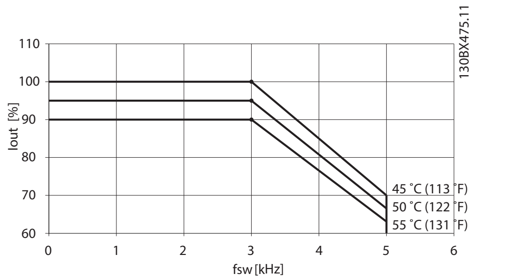
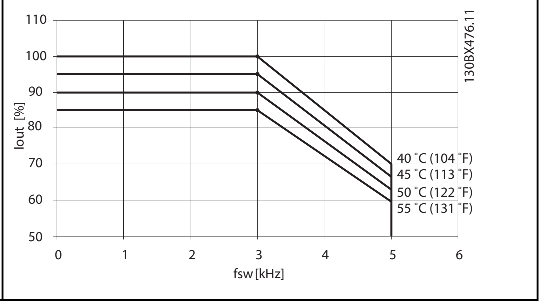
6.12.2 Derating for Switching Frequency and Ambient Temperature

NOTICE

FACTORY DERATING

The VLT® Parallel Drive Modules are already derated for operational temperature (55 °C (131 °F) $T_{AMB,MAX}$ and 50 °C (122 °F) $T_{AMB,AVG}$).

The following graphs indicate if the output current needs to be derated based on switching frequency and ambient temperature. When refering to the graphs, I_{out} indicates the percentage of rated output current, and *fsw* indicates the switching frequency.

<table>
<tr><th>Voltage range</th><th>Switching pattern</th><th>High overload HO, 150%</th><th>Normal overload NO, 110%</th></tr>
<tr><td rowspan="2">380–500 V</td><td>60 AVM</td><td>
</td><td>
</td></tr>
<tr><td>SFAVM</td><td>
</td><td>
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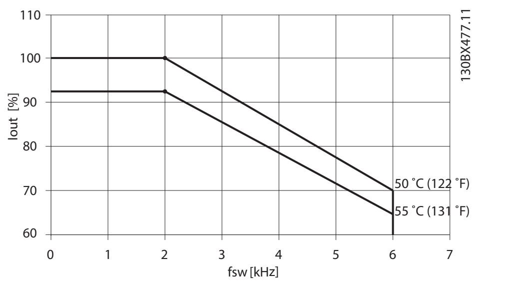
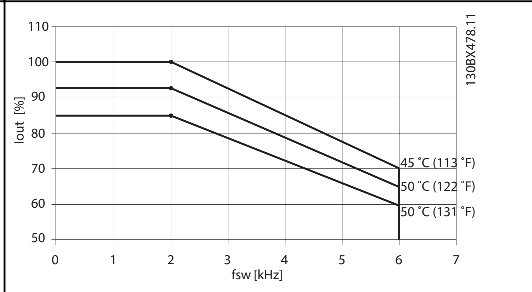
</table>

Table 6.16 Derating for Switching Frequency, 250 kW at 400 V AC (350 hp at 460 V AC)

<table>
<tr><th>Voltage range</th><th>Switching pattern</th><th>High overload HO, 150%</th><th>Normal overload NO, 110%</th></tr>
<tr><td rowspan="2">525–690 V</td><td>60 AVM</td><td>
</td><td>
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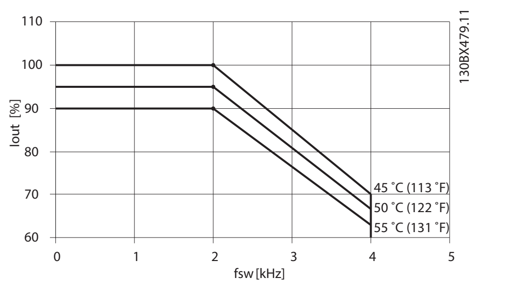
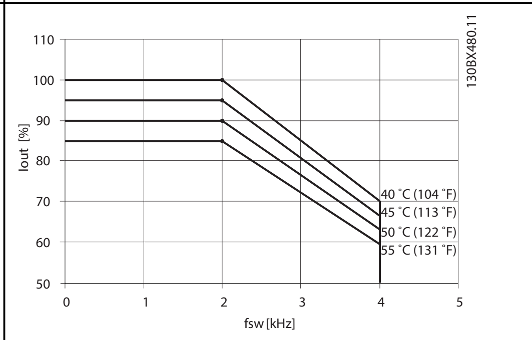
<tr><td>SFAVM</td><td>
</td><td>
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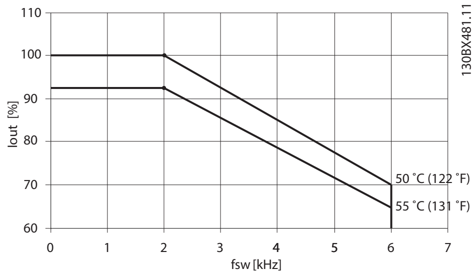
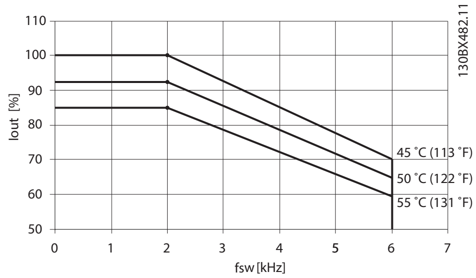
Table 6.17 Derating for Switching Frequency, 250 kW at 690 V AC (300 hp at 575 V AC)

<table>
<tr><th>Voltage range</th><th>Switching pattern</th><th>High overload HO, 150%</th><th>Normal overload NO, 110%</th></tr>
<tr><td rowspan="2">380–500 V</td><td>60 AVM</td><td>
</td><td>
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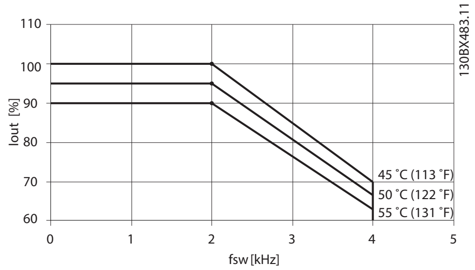
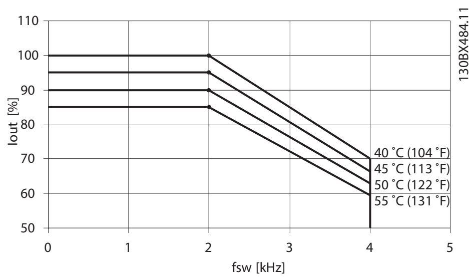
<tr><td>SFAVM</td><td>
</td><td>
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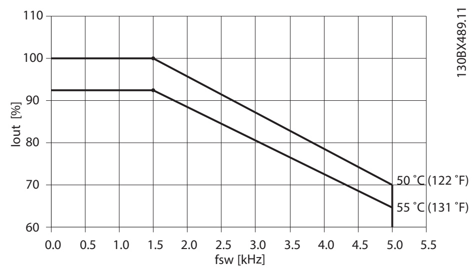
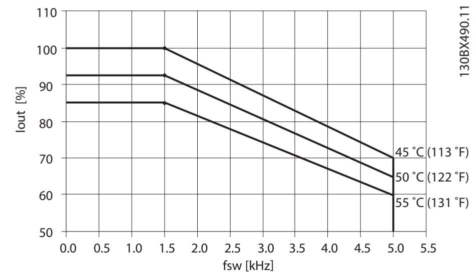
</table>

Table 6.18 Derating for Switching Frequency, 315–800 kW at 400 V AC (450–1200 hp at 460 V AC)

<table>
<tr><th>Voltage range</th><th>Switching pattern</th><th>High overload HO, 150%</th><th>Normal overload NO, 110%</th></tr>
<tr><td rowspan="2">525–690 V</td><td>60 AVM</td><td>
</td><td>
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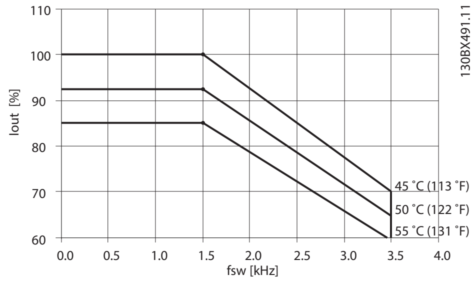
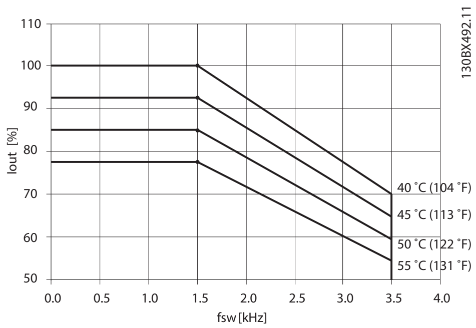
<tr><td>SFAVM</td><td>
</td><td>
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</table>

Table 6.19 Derating for Switching Frequency, 315–1000 kW at 400 V AC (350–1150 hp at 575 V AC)

7 Ordering Information

7.1 Ordering Form

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
F	C	-								T											X	X	S	X	X	X	X	A		B		C					D	

130BC530.10

Table 7.1 Type Code String

Product groups	1–3	
Frequency converter series	4–6	
Generation code	7	
Power rating	8–10	
Phases	11	
Mains Voltage	12	
Enclosure Enclosure size Enclosure class Control supply voltage	13–15	
Hardware configuration	**16–23**	
RFI filter/Low Harmonic Drive/12-pulse	16–17	
Brake	18	
Display (LCP)	19	
Coating PCB	20	
Mains option	21	
Adaptation A	22	
Adaptation B	23	
Software release	24–27	
Software language	28	
A options	29–30	
B options	31–32	
C0 options, MCO	33–34	
C1 options	35	
C option software	36–37	
D options	38–39	

Table 7.2 Type Code Example for Ordering a Frequency Converter

Not all choices/options are available for each variant. To verify if the appropriate version is available, consult the Drive Configurator on the Internet.

7.2 Drive Configurator

It is possible to design a frequency converter according to the application requirements by using the ordering number system shown in *Table 7.1* and *Table 7.2*.

Order standard frequency converters and frequency converters with integral options by sending a type code string describing the product to the local Danfoss sales office, for example:

FC-302N800T5E00P2BGC7XXSXXXXAXBXCXXXXDX

The meaning of the characters in the string are defined in *Table 7.3* and *Table 7.4*.

Match the appropriate frequency converter for the proper application using the Drive Configurator. The Drive Configurator automatically generates an 8-digit sales number to be delivered to the local sales office. It is also possible to establish a project list with several products and send it to a Danfoss sales representative.

The Drive Configurator can be found on the global internet site: *www.danfoss.com/drives*.

Frequency converters are delivered automatically with a language package relevant to the region from which they are ordered. Four regional language packages cover the following languages:

Language package 1
English, German, French, Danish, Dutch, Spanish, Swedish, Italian, and Finnish.

Language package 2
English, German, Chinese, Korean, Japanese, Thai, Traditional Chinese, and Bahasa Indonesian.

Language package 3
English, German, Slovenian, Bulgarian, Serbian, Romanian, Hungarian, Czech, and Russian.

Language package 4
English, German, Spanish, English US, Greek, Brazilian Portuguese, Turkish, and Polish.

To order frequency converters with a different language package, contact the local Danfoss sales office.

Description	Pos	Possible option
Product group	1–6	102: FC 102 202: FC 202 302: FC 302
Generation Code	7	N
Power rating	8–10	250 kW 315 kW 355 kW 400 kW 450 kW 500 kW 560 kW 630 kW 710 kW 800 kW 900 kW 1M0 kW 1M2 kW
Phases	11	3-phases (T)
Mains voltage	11–12	T 4: 380–480 V AC T 5: 380–500 V AC T 7: 525–690 V AC
Enclosure	13–15	E00: IP00 C00: IP00 + stainless steel back channel
RFI filter, hardware	16–17	P2: Parallel drive + RFI filter, class A2 (6-pulse) P4: Parallel drive + RFI filter, class A1 (6-pulse) P6: Parallel drive + RFI filter, class A2 (12-pulse) P8: Parallel drive + RFI filter, class A1 (12-pulse)
Brake	18	X: No brake IGBT B: Brake IGBT mounted R: Regeneration terminals S: Brake + regeneration T: Safe Torque Off (STO) U: Safe Torque Off + brake
Display	19	G: Graphical local control panel (LCP)
Coating PCB	20	C: Coated PCB
Mains option	21	J: Circuit breaker + fuses
Adaptation	22	X: Standard cable entries
Adaptation	23	X: No adaptation Q: Heat sink access panel
Software release	24–27	S067: Integrated motion control
Software language	28	X: Standard language pack

Table 7.3 Ordering Type Code for VLT® Parallel Drive Modules

7

Description	Pos	Possible option
A options	29-30	AX: No A option A0: VLT® PROFIBUS DP MCA 101 A4: VLT® DeviceNet MCA 104 A6: VLT® CANopen MCA 105 A8: VLT® EtherCAT MCA 124 AG: VLT® LonWorks MCA 108 AJ: VLT® BACnet MCA 109 AT: VLT® PROFIBUS Converter MCA 113 AU: VLT® PROFIBUS Converter MCA 114 AL: VLT® PROFINET MCA 120 AN: VLT® EtherNet/IP MCA 121 AQ: VLT® Modbus TCP MCA 122 AY: VLT® EtherNet/IP MCA 121
B options	31-32	BX: No option BK: VLT® General Purpose I/O MCB 101 BR: VLT® Encoder Input MCB 102 BU: VLT® Resolver Input MCB 103 BP: VLT® Relay Card MCB 105 BY: VLT® Extended Cascade Controller MCO 101 BZ: VLT® Safe PLC I/O MCB 108 B0: VLT® Analog I/O MCB 109 B2: VLT® PTC Thermistor Card MCB 112 B4: VLT® Sensor Input MCB-114 B6: VLT® Safety Option MCB 150 B7: VLT® Safety Options MCB 151
C0/ E0 options	33-34	CX: No option C4: VLT® Motion Control Option MCO 305
C1 options/ A/B in C Option Adapter	35	X: No option R: VLT® Extended Relay Card MCB 113 S: VLT® Advanced Cascade Controller MCO 102
C option software/ E1 options	36-37	XX: Standard controller 10: VLT® Synchronizing Controller MCO 350 11: VLT® Position Controller MCO 351 12: VLT® Center Winder MCO 352
D options	38-39	DX: No option D0: VLT® 24 V DC Supply MCB 107

Table 7.4 Ordering Options

7.2.1 Output Filters

The high-speed switching of the frequency converter produces some secondary effects that influence the motor and the enclosed environment. Two different filter types, the dU/dt and the sine-wave filters, are available to address these side effects. For more detail, see *VLT® FC-Series Output Filter Design Guide*.

380–500 V							Common		Individual	
400 V, 50 Hz		460 V, 60 Hz		500 V, 50 Hz		FsW				
kW	A	Hp	A	kW	A	kHz	IP00	IP23	IP00	IP23
250	480	350	443	315	443	3	130B2849	130B2850	130B2844	130B2845
315	600	450	540	355	540	2	130B2851	130B2852	130B2844	130B2845
355	658	500	590	400	590	2	130B2851	130B2852	130B2844	130B2845
400	745	600	678	500	678	2	130B2853	130B2854	130B2844	130B2845
450	800	600	730	530	730	2	130B2853	130B2854	130B2847	130B2848
500	880	650	780	560	780	2	130B2853	130B2854	130B2847	130B2848
560	990	750	890	630	890	2	2x130B2849	2x130B2850	130B2847	130B2848
630	1120	900	1050	710	1050	2	3x130B2849	2x130B2850	130B2847	130B2848
710	1260	1000	1160	800	1160	2	3x130B2849	2x130B2850	130B2847	130B2848
800	1460	1200	1380	1000	1380	2	3x130B2851	3x130B2852	130B2849	130B2850

Table 7.5 Available dU/dt Filters, 380–500 V

525–690 V							Common		Individual	
525 V, 50 Hz		575 V, 60 Hz		690 V, 50 Hz		FsW				
kW	A	Hp	A	kW	A	kHz	IP00	IP23	IP00	IP23
250	360	350	344	315	344	2	130B2851	130B2852	130B2841	130B2842
300	395	400	410	355	380	1.5	130B2851	130B2852	130B2841	130B2842
315	429	450	450	400	410	1.5	130B2851	130B2852	130B2841	130B2842
400	523	500	500	500	500	1.5	130B2853	130B2854	130B2844	130B2845
450	596	600	570	560	570	1.5	130B2853	130B2854	130B2844	130B2845
500	630	650	630	630	630	1.5	130B2853	130B2854	130B2844	130B2845
560	763	750	730	710	730	1.5	130B2853	130B2854	130B2847	130B2848
670	889	950	850	800	850	1.5	130B2853	130B2854	130B2847	130B2848
750	988	1050	945	–	–	–	3x130B2849	3x130B2850	130B2847	130B2848
850	1108	1150	1060	1000	1060	1.5	3x130B2849	3x130B2850	130B2847	130B2848
1000	1317	1350	1260	1200	1260	1.5	3x130B2851	3x130B2852	130B2849	130B2850

Table 7.6 Available dU/dt Filters, 525–690 V

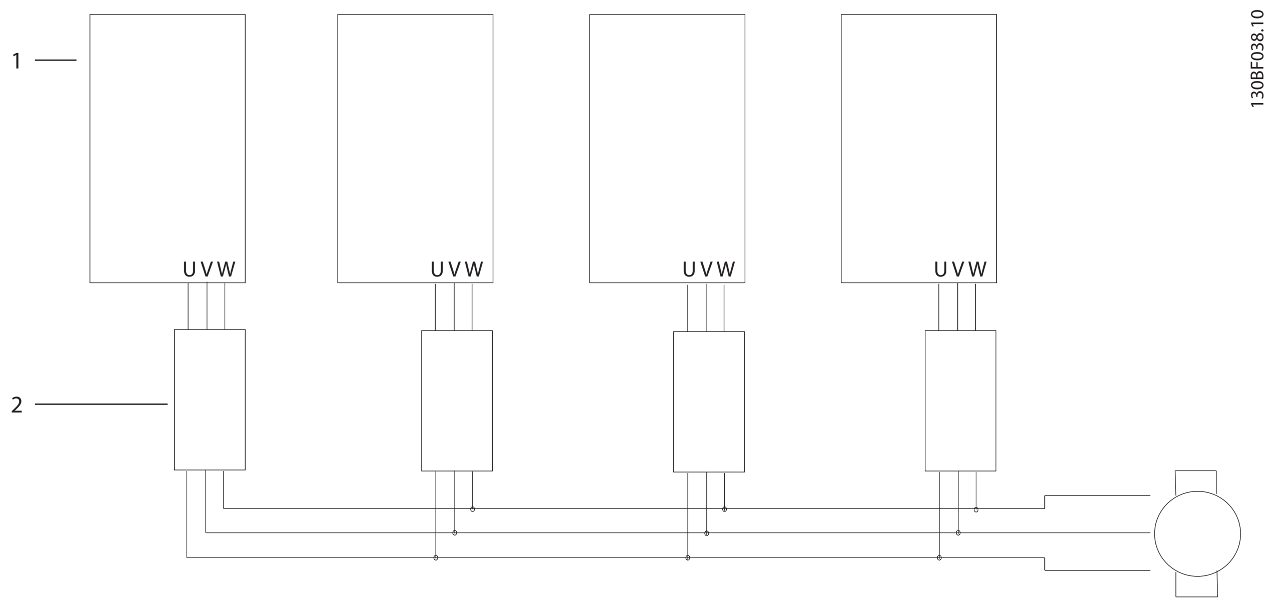
380–500 V							Common		Individual	
400 V, 50 Hz		460 V, 60 Hz		500 V, 50 Hz		FsW				
kW	A	Hp	A	kW	A	kHz	IP00	IP23	IP00	IP23
250	480	350	443	315	443	3	130B3188	130B3189	130B3186	130B3187
315	600	450	540	355	540	2	130B3191	130B3192	130B3186	130B3187
355	658	500	590	400	590	2	130B3191	130B3192	130B3186	130B3187
400	745	600	678	500	678	2	130B3193	130B3194	130B3188	130B3189
450	800	600	730	530	730	2	2x130B3188	2x130B3189	130B3188	130B3189
500	880	650	780	560	780	2	2x130B3188	2x130B3189	130B3186	130B3187
560	990	750	890	630	890	2	2x130B3191	2x130B3192	130B3186	130B3187
630	1120	900	1050	710	1050	2	2x130B3191	2x130B3192	130B3186	130B3187
710	1260	1000	1160	800	1160	2	3x130B3188	2x130B3189	130B3188	130B3189
800	1460	1200	1380	1000	1380	2	3x130B3188	2x130B3189	130B3188	130B3189

Table 7.7 Available Sine-wave Filters, 380–500 V

525–690 V							Common		Individual	
kW	A	Hp	A	kW	A	kHz	IP00	IP23	IP00	IP23
525 V, 50 Hz		575 V, 60 Hz		690 V, 50 Hz		FsW				
250	360	350	344	315	344	2	130B4129	130B4151	130B4125	130B4126
300	395	400	410	355	380	1.5	130B4129	130B4151	130B4125	130B4126
315	429	450	450	400	410	1.5	130B4152	130B4153	130B4125	130B4126
400	523	500	500	500	500	1.5	130B4154	130B4153	130B4129	130B4151
450	596	600	570	560	570	1.5	130B4156	130B4157	–	–
500	630	650	630	630	630	1.5	130B4156	130B4157	130B4129	130B4151
560	763	750	730	710	730	1.5	2x130B4142	2x130B4143	130B4129	130B4151
670	889	950	850	800	850	1.5	2x130B4142	2x130B4143	130B4125	130B4126
750	988	1050	945	–	–	–	2x130B4142	2x130B4143	130B4129	130B4151
850	1108	1150	1060	1000	1060	1.5	3x130B4154	3x130B4155	130B4129	130B4151
1000	1317	1350	1260	1200	1260	1.5	3x130B4154	3x130B4155	130B4129	130B4151

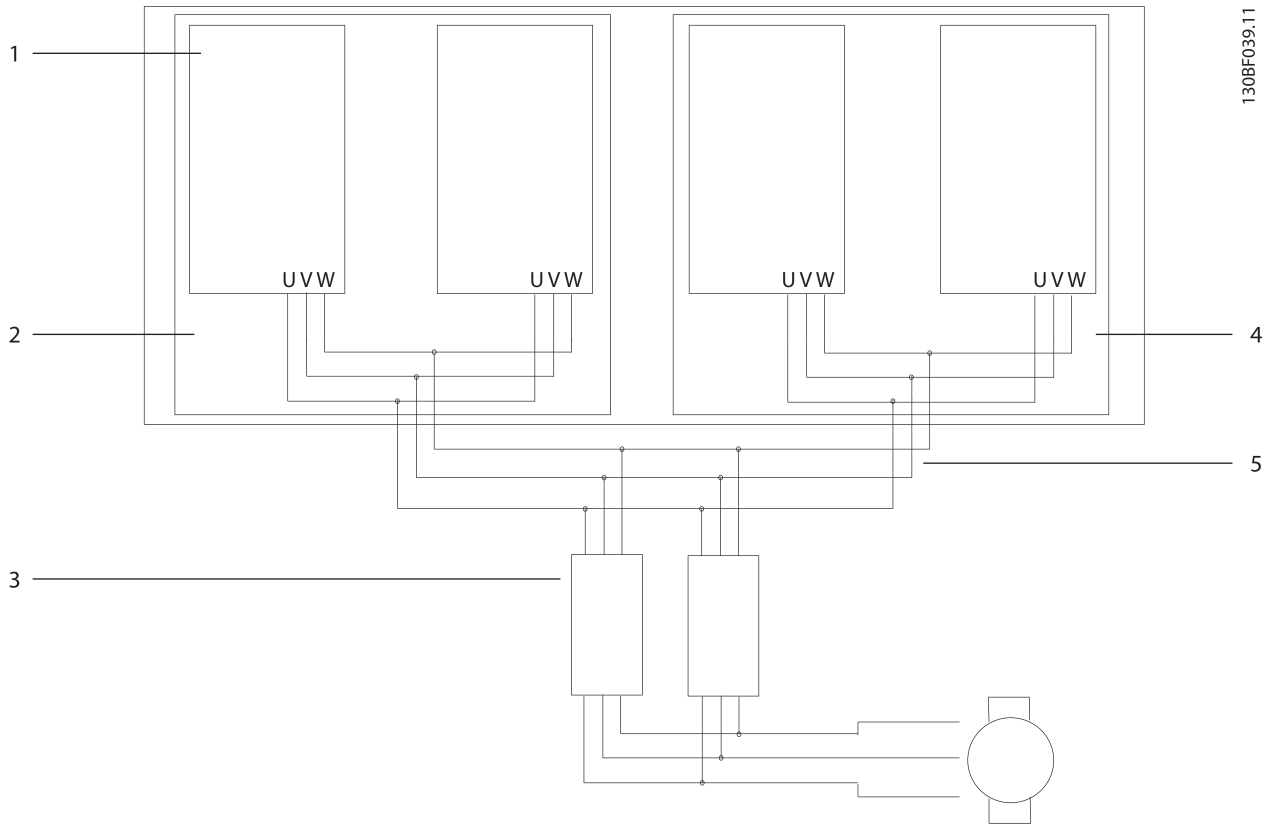
Table 7.8 Available Sine-wave Filters, 525–690 V

7



1	Drive module	2	Filter

Illustration 7.1 Filter Configuration Without Common Busbars (Individual)

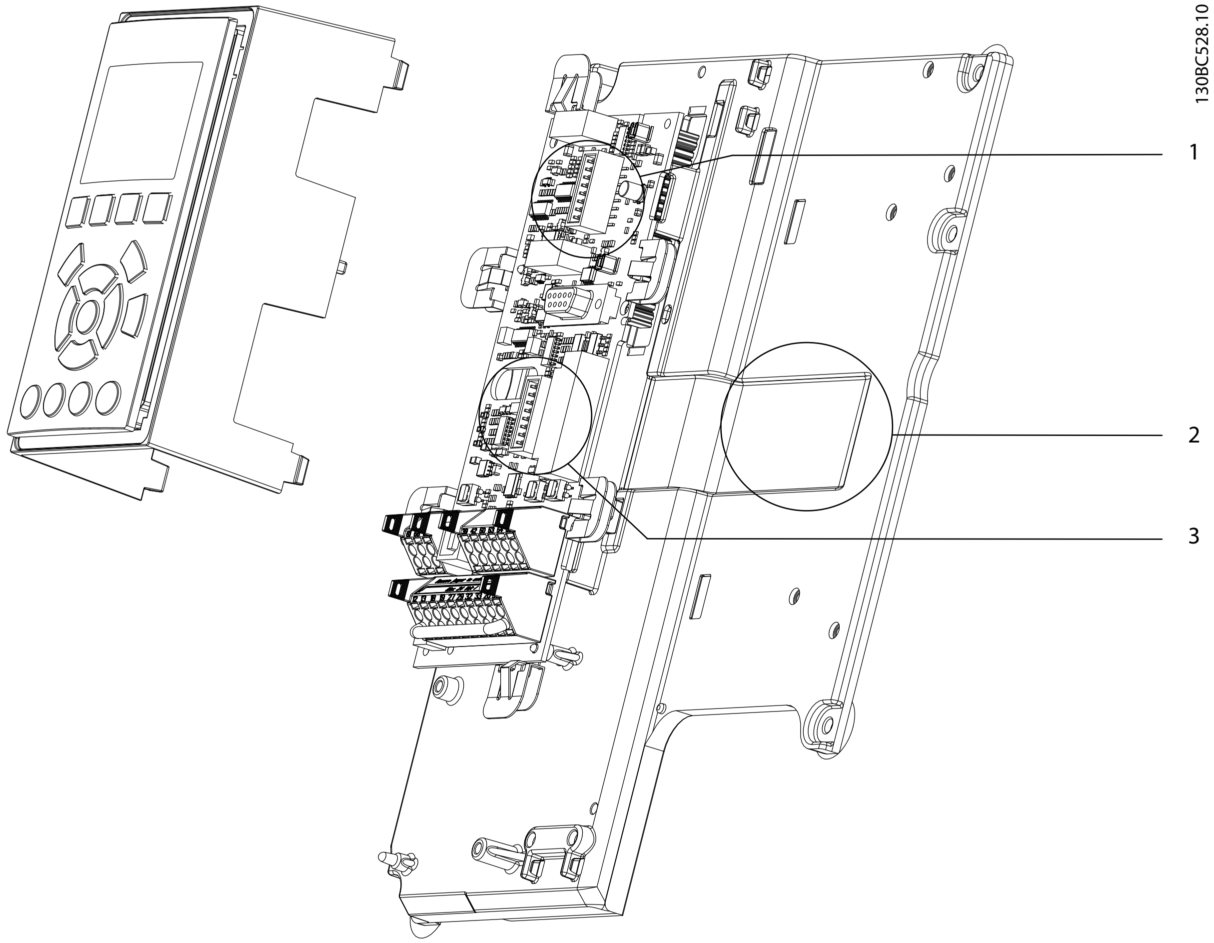


1	Drive module	4	Cabinet 2
2	Cabinet 1	5	Cables
3	Filter	–	–

Illustration 7.2 Filter Configuration With Common Busbars (Common)

7.3 Options and Accessories

Danfoss offers a wide range of options and accessories for the VLT® AutomationDrive FC 302, VLT® HVAC Basic Drive FC 102 and VLT® AQUA Drive FC 202. The following options are installed on the control card in either slot A, slot B, or slot C. Refer to *Illustration 7.3*. For further information, see the instructions that accompany the optional equipment.



1	Slot A
2	Slot B
3	Slot C

Illustration 7.3 Slot Options on the Control Card

7.3.1 General Purpose Input Output Module MCB 101

VLT® General Purpose I/O MCB 101 is used for extension of digital and analog inputs and outputs of FC 102, FC 103, FC 202, FC 301 and FC 302. MCB 101 must be fitted into slot B in the frequency converter.

Contents:

- MCB 101 option module.
- Extended fixture for the LCP.
- Terminal cover.

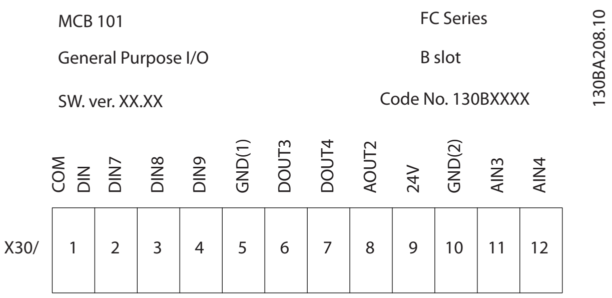


Illustration 7.4 MCB 101 Options Module

7.3.2 Galvanic Isolation in the VLT® General Purpose I/O MCB 101

Digital/analog inputs are galvanically isolated from other inputs/outputs on the MCB 101 and in the control card of the frequency converter.

Digital/analog outputs in the MCB 101 are galvanically isolated from other inputs/outputs on the MCB 101, but not from the inputs/outputs on the control card of the frequency converter.

Connect terminals 1 and 5 if the digital inputs 7, 8, or 9 are to be switched by use of the internal 24 V supply (terminal 9). See *Illustration 7.5*.

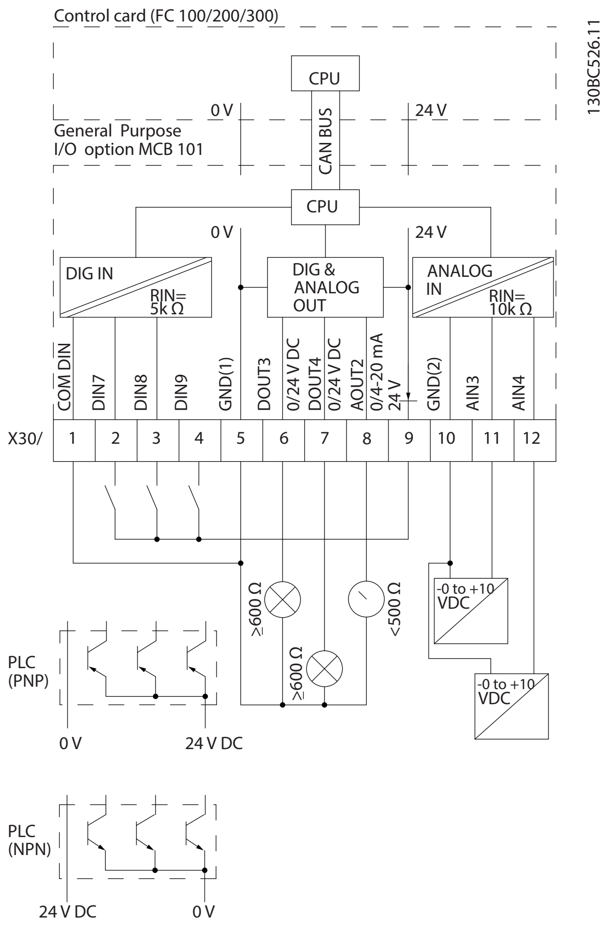


Illustration 7.5 Principle Diagram

7

7.3.3 Digital Inputs - Terminal X30/1-4

Digital input	
Number of digital inputs	4 (6)
Terminal number	18, 19, 27, 29, 32, 33
Logic	PNP or NPN
Voltage level	0–24 V DC
Voltage level, logic 0 PNP (GND=0 V)	<5 V DC
Voltage level, logic 1 PNP (GND=0 V)	>10 V DC
Voltage level, logic 0 NPN (GND=24 V)	<14 V DC
Voltage level, logic 1 NPN (GND=24 V)	>19 V DC
Maximum voltage on input	28 V continuous
Pulse frequency range	0–110 kHz
Duty cycle, minimum pulse width	4.5 ms
Input impedance	>2 kΩ

7.3.4 Analog Inputs - Terminal X30/11, 12

Analog input	
Number of analog inputs	2
Terminal number	53, 54, X30.11, X30.12
Modes	Voltage
Voltage level	-10 V to +10 V
Input impedance	>10 kΩ
Maximum voltage	20 V
Resolution for analog inputs	10 bit (+ sign)
Accuracy of analog inputs	Maximum error 0.5% of full scale
Bandwidth	100 Hz

7.3.5 Digital Outputs - Terminal X30/6, 7

Digital output	
Number of digital outputs	2
Terminal number	X30.6, X30.7
Voltage level at digital/frequency output	0–24 V
Maximum output current	40 mA
Maximum load	≥600 Ω
Maximum capacitive load	<10 nF
Minimum output frequency	0 Hz
Maximum output frequency	≤32 kHz
Accuracy of frequency output	Maximum error: 0.1% of full scale

7.3.6 Analog Output - Terminal X30/8

Analog output	
Number of analog outputs	1
Terminal number	42
Current range at analog output	0–20 mA
Maximum load GND - analog output	500 Ω
Accuracy on analog output	Maximum error: 0.5% of full scale
Resolution on analog output	12 bit

7.3.7 VLT® Encoder Input MCB 102

The VLT® Encoder Input MCB 102 module can be used as a feedback source for closed-loop flux control (*parameter 1-02 Flux Motor Feedback Source*) and closed-loop speed control (*parameter 7-00 Speed PID Feedback Source*). Configure the encoder option in *parameter group 17-** Motor Feedback Option*.

The MCB 102 is used for:
- VVC+ closed loop.
- Flux vector speed control.
- Flux vector torque control.
- Permanent magnet motor.

Supported encoder types:
- Incremental encoder: 5 V TTL type, RS422, maximum frequency: 410 kHz.
- Incremental encoder: 1Vpp, sine-cosine.
- HIPERFACE® Encoder: Absolute and Sine-Cosine (Stegmann/SICK).
- EnDat encoder: Absolute and Sine-Cosine (Heidenheim) Supports version 2.1.
- SSI encoder: Absolute.

NOTICE

The LEDs are only visible when removing the LCP. Reaction if there is an encoder error can be selected in *parameter 17-61 Feedback Signal Monitoring*: *[0] Disabled*, *[1] Warning*, or *[2] Trip*.

When the encoder option kit is ordered separately, the kit includes:
- VLT® Encoder Input MCB 102.
- Enlarged LCP fixture and enlarged terminal cover.

The encoder option does not support VLT® AutomationDrive FC 302 frequency converters manufactured before week 50/2004.
Minimum software version: 2.03 (*parameter 15-43 Software Version*)

Connector Designation X31	Incremental encoder (refer to *Illustration 7.6*)	SinCos encoder HIPERFACE® (refer to *Illustration 7.7*)	EnDat encoder	SSI encoder	Description
1	NC			24 V1)	24 V output (21–25 V, I_{max} 125 mA)
2	NC	8 VCC			8 V output (7–12 V, I_{max}: 200 mA)
3	5 VCC		5 VCC	5 V1)	5 V output (5 V ±5%, I_{max}: 200 mA)
4	GND		GND	GND	GND
5	A input	+COS	+COS		A input
6	A inv input	REFCOS	REFCOS		A inv input
7	B input	+SIN	+SIN		B input
8	B inv input	REFSIN	REFSIN		B inv input
9	Z input	+Data RS485	Clock out	Clock out	Z input OR +Data RS485
10	Z inv input	-Data RS485	Clock out inv.	Clock out inv.	Z input OR -Data RS485
11	NC	NC	Data in	Data in	Future use
12	NC	NC	Data in inv.	Data in inv.	Future use
Max. 5 V on X31.5-12					

Table 7.9 Encoder Option MCB 102 Terminal Descriptions for Supported Encoder Types

1) Supply for encoder: See data on encoder.

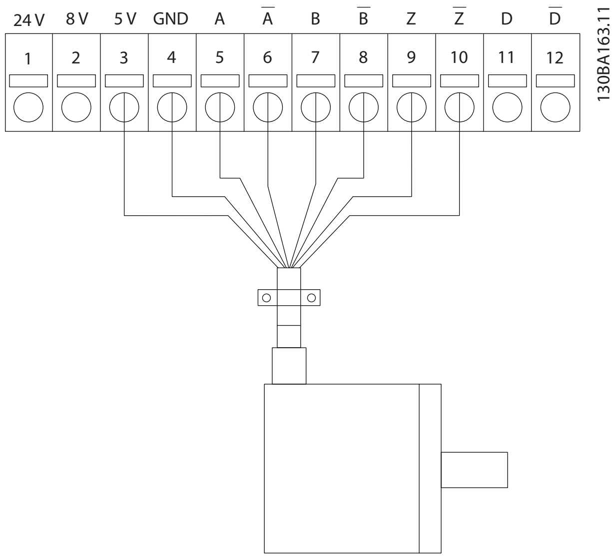


Illustration 7.6 Incremental Encoder

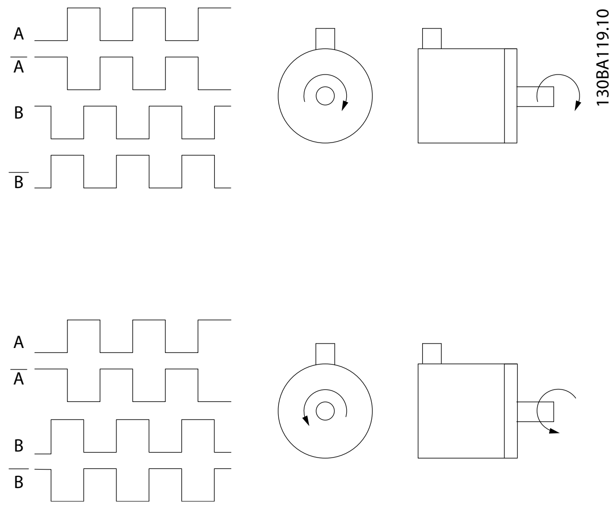


Illustration 7.8 Rotation Direction

Maximum cable length 150 m (492 ft).

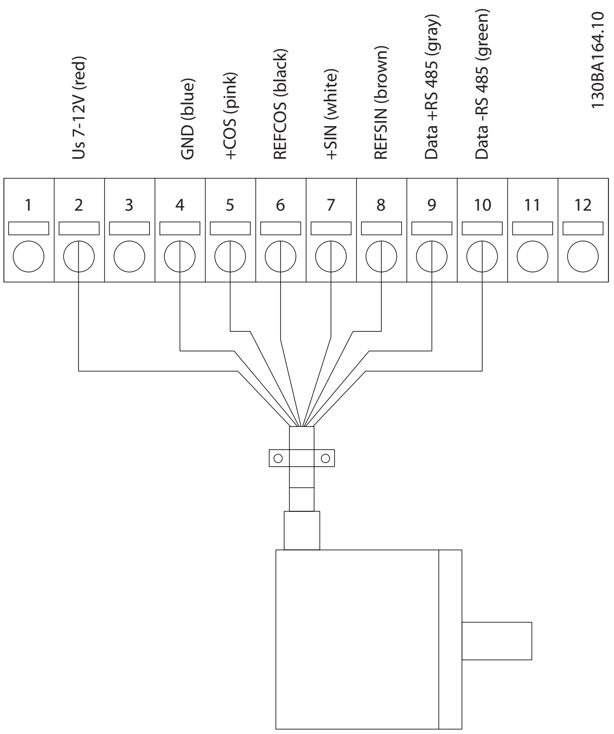


Illustration 7.7 SinCos Encoder HIPERFACE

7.3.8 VLT® Resolver Input MCB 103

The VLT® Resolver Option MCB 103 is used for interfacing resolver motor feedback to VLT® AutomationDrive FC 301/FC 302. Resolvers are used as motor feedback devices for permanent magnet brushless synchronous motors.

When the resolver option is ordered separately, the kit includes:

- VLT® Resolver Option MCB 103.
- Enlarged LCP fixture and enlarged terminal cover.

Selection of parameters: *17-5* Resolver Interface*.

MCB 103 supports a various number of rotor resolver types.

Resolver poles	*Parameter 17-50 Poles*: 2 x 2
Resolver input voltage	*Parameter 17-51 Input Voltage*: 2.0–8.0 V_{rms} x 7.0 V_{rms}
Resolver input frequency	*Parameter 17-52 Input Frequency*: 2–15 kHz x 10.0 kHz
Transformation ratio	*Parameter 17-53 Transformation Ratio*: 0.1–1.1 x 0.5
Secondary input voltage	Maximum 4 V_{rms}
Secondary load	Approximately 10 kΩ

Table 7.10 Resolver Specifications

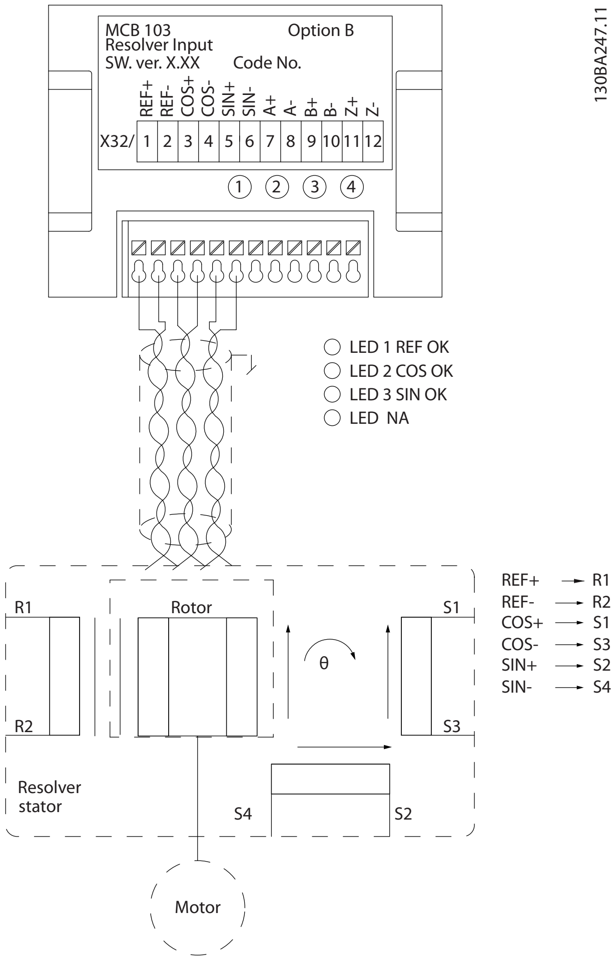


Illustration 7.9 Resolver Input MCB 103 used with a Permanent Magnet Motor

NOTICE

The MCB 103 can be used with only rotor-supplied resolver types. Stator-supplied resolvers cannot be used.

LED indicators

The LEDs are active when *parameter 17-61 Feedback Signal Monitoring* is set to *[1] Warning* or *[2] Trip*.

LED 1 is on when the reference signal is OK to resolver.

LED 2 is on when cosinus signal is OK from resolver.

LED 3 is on when sinus signal is OK from resolver.

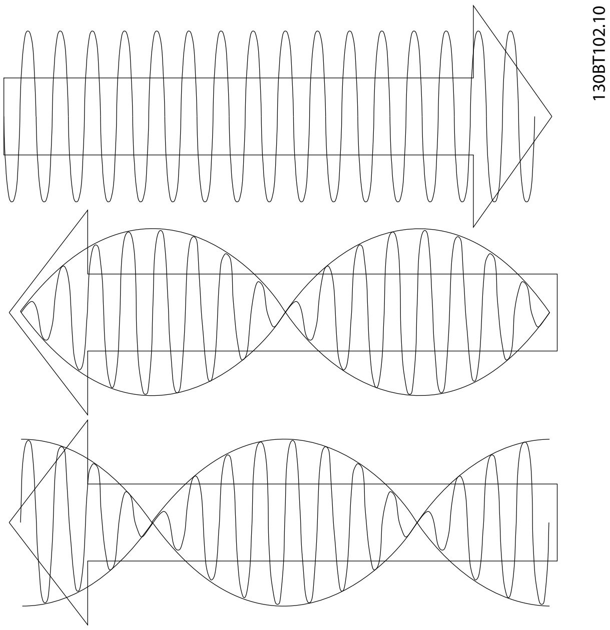


Illustration 7.10 Permanent Magnet (PM) Motor with Resolver as Speed Feedback

Set-up example

In *Illustration 7.9*, a permanent magnet (PM) motor is used with resolver as speed feedback. A PM motor must usually operate in flux mode.

Wiring

The maximum cable length is 150 m (492 ft) when a twisted pair type of cable is used.

NOTICE

Always use shielded motor cables and brake chopper cables. Resolver cables must be shielded and separated from the motor cables. The shield of the resolver cable must be correctly connected to the decoupling plate and connected to chassis (ground) on the motor side.

Parameter 1-00 Configuration Mode	*[1] Speed closed loop*
Parameter 1-01 Motor Control Principle	*[3] Flux with feedback*
Parameter 1-10 Motor Construction	*[1] PM, non-salient SPM*
Parameter 1-24 Motor Current	Nameplate
Parameter 1-25 Motor Nominal Speed	Nameplate
Parameter 1-26 Motor Cont. Rated Torque	Nameplate
AMA is not possible on PM motors	
Parameter 1-30 Stator Resistance (Rs)	Motor datasheet
Parameter 30-80 d-axis Inductance (Ld)	Motor datasheet (mH)
Parameter 1-39 Motor Poles	Motor datasheet
Parameter 1-40 Back EMF at 1000 RPM	Motor datasheet
Parameter 1-41 Motor Angle Offset	Motor datasheet (usually zero)
Parameter 17-50 Poles	Resolver datasheet
Parameter 17-51 Input Voltage	Resolver datasheet
Parameter 17-52 Input Frequency	Resolver datasheet
Parameter 17-53 Transformation Ratio	Resolver datasheet
Parameter 17-59 Resolver Interface	*[1] Enabled*

Table 7.11 Parameters to be Adjusted

7.3.9 VLT® Relay Card MCB 105

The VLT® Relay Card MCB 105 includes 3 pieces of SPDT contacts and must be fitted into option slot B.

When the relay option kit is ordered separately, the kit includes:

- VLT® Relay Card MCB 105.
- Enlarged LCP fixture and enlarged terminal cover.
- Label for covering access to switches S201 (A53), S202 (A54), and S801[1)].
- Cable strips for fastening cables to relay module.

1) **IMPORTANT!** The label MUST be placed on the LCP frame to meet UL Approval.

⚠WARNING

Warning dual supply. Do not combine 24/48 V systems with high voltage systems.

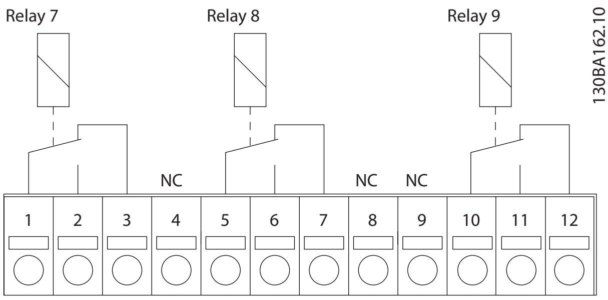


Illustration 7.11 Disconnect Relay Terminals

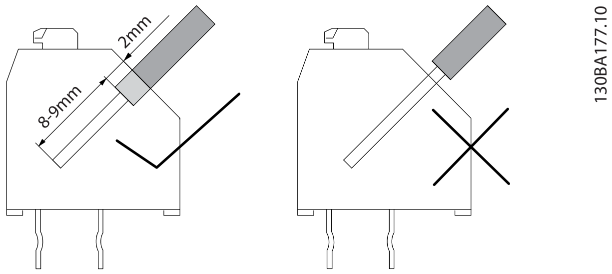


Illustration 7.12 Proper Length of Stripped Wire

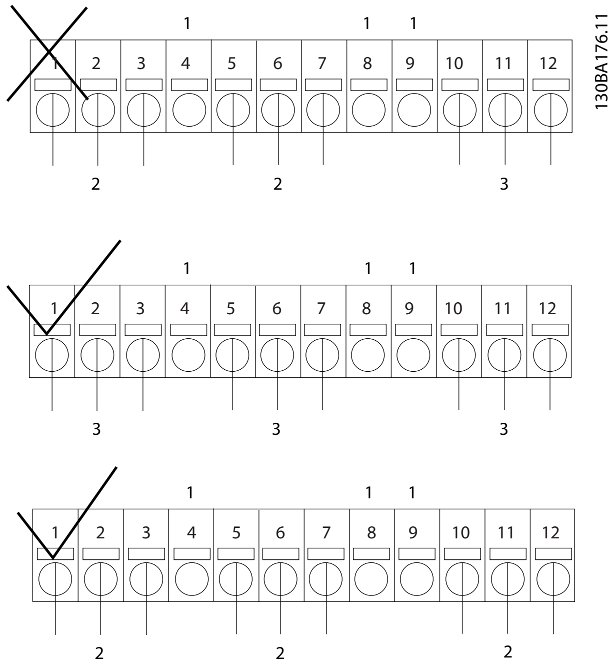


Illustration 7.13 Correct Method to Install Live Parts and Control Signals

Electrical data	
Maximum terminal load (AC-1)[1)] (Resistive load)	240 V AC 2 A
Maximum terminal load (AC-15)[1)] (Inductive load @ cosφ 0.4)	240 V AC 0.2 A
Maximum terminal load (DC-1)[1)] (Resistive load)	24 V DC 1 A
Maximum terminal load (DC-13)[1)] (Inductive load)	24 V DC 0.1 A
Minimum terminal load (DC)	5 V 10 mA
Maximum switching rate at rated load/minimum load	6 min^{-1}/20^{-1}

1) IEC 947 part 4 and 5

7.3.10 VLT® 24 V DC Supply MCB 107

A 24 V DC external supply can be installed for low voltage supply to the control card and any installed options card, enabling full operation of the LCP without connection to the mains. The inputs are protected.

Terminal numbers:

- Terminal 35: -24 V DC external supply.
- Terminal 36: +24 V DC external supply.

When VLT® 24 V DC Supply MCB 107 supplies the control circuit, the internal 24 V supply is automatically disconnected. For more information on installation, consult the separate instructions that accompany the optional equipment.

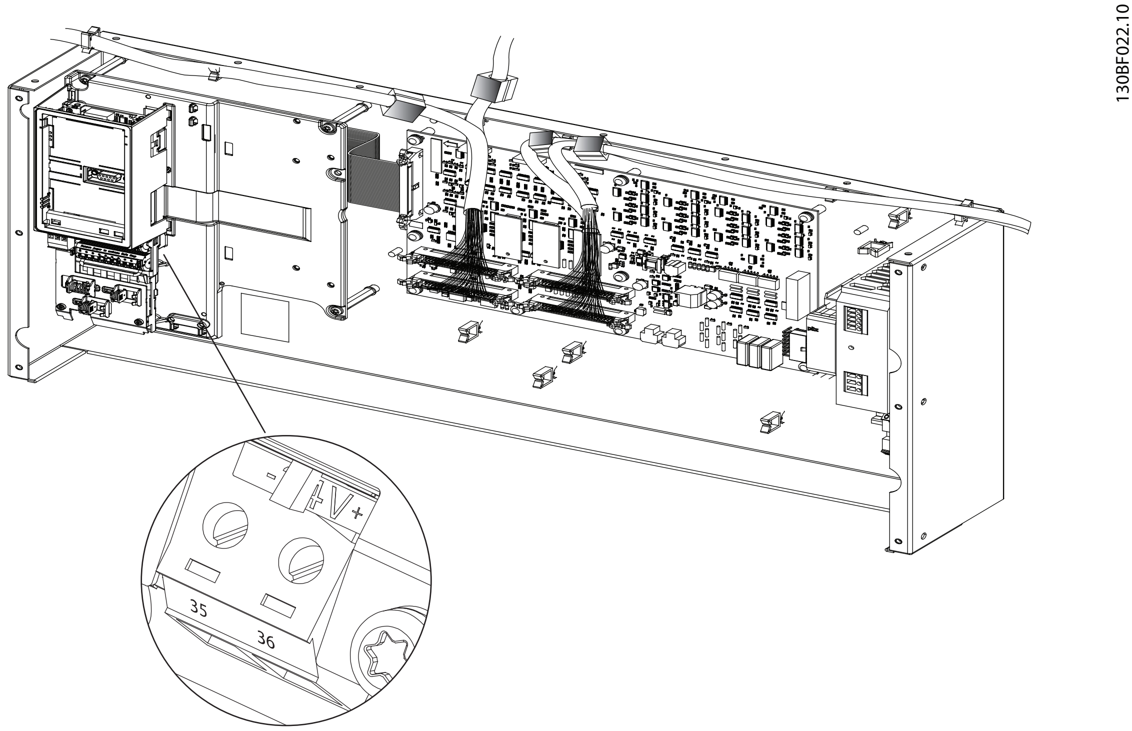


Illustration 7.14 24 V DC Supply Connection

Electrical data	
Input voltage range	24 V DC ±15% (maximum 37 V in 10 s)
Maximum input current	2.2 A
Average input current for	0.9 A
Maximum cable length	75 m (246 ft)
Input capacitance load	10 uF
Power-up delay	0.6 s

7.3.11 VLT® PTC Thermistor Card MCB 112

The VLT® PTC Thermistor Card MCB 112 option makes it possible to monitor the temperature of an electrical motor through a galvanically isolated PTC thermistor input. It is a B-option for VLT® HVAC Drive FC 102, VLT® AQUA Drive FC 202, and VLT® AutomationDrive FC 302 with Safe Torque Off (STO).

For information on mounting and installing the option, see the instructions that accompany it. For different application possibilities, see *chapter 17 Application Examples*.

X44/1 and X44/2 are the thermistor inputs. X44/12 enables Safe Torque Off of the frequency converter (T-37) if the thermistor values make it necessary, and X44/10 informs the frequency converter that a request for Safe Torque Off has come from the MCB 112 to ensure suitable alarm handling. To use the information from X44/10, 1 of the digital inputs of the frequency converter (or a DI of a mounted option) must be set to PTC Card 1 [80]. *Parameter 5-19 Terminal 37 Safe Stop* must be configured to the wanted Safe Torque Off functionality. Default is *[1] Safe Stop Alarm*.

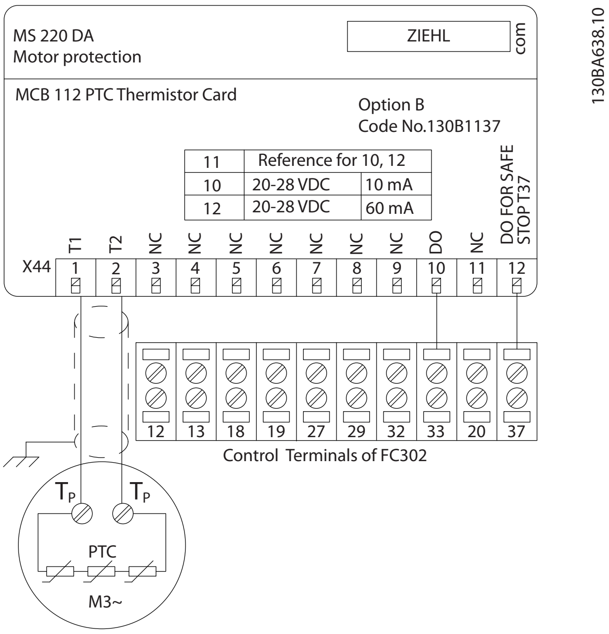


Illustration 7.15 Installation of MCB 112

ATEX Certification with FC 102/202/302 series

The VLT® PTC Thermistor Card MCB 112 has been certified for ATEX, which means that the FC 102/202/302 series together with the MCB 112 can now be used with motors in potentially explosive atmospheres. See the thermistor card for more information.

Illustration 7.16 ATmosphère EXplosive (ATEX) Symbol

Electrical data

Resistor connection	
PTC compliant with DIN 44081 and DIN 44082	
Number	1..6 resistors in series
Shut-off value	3.3 Ω ... 3.65 Ω ... 3.85 Ω
Reset value	1.7 Ω ... 1.8 Ω ... 1.95 Ω
Trigger tolerance	± 6 °C (10.8 °F)
Collective resistance of the sensor loop	<1.65 Ω
Terminal voltage	≤ 2.5 V for R ≤3.65 Ω, ≤9 V for R=∞
Sensor current	≤ 1 mA
Short circuit	20 Ω≤R ≤40 Ω
Power consumption	60 mA

Testing conditions	
EN 60 947-8	
Measurement voltage surge resistance	6000 V
Overvoltage category	III
Pollution degree	2
Measurement isolation voltage Vbis	690 V
Galvanic isolation until Vi	500 V
Permanent ambient temperature	-20 °C (-4 °F) ... +60 °C (140 °F) EN 60068-2-1 Dry heat
Moisture	5–95%, no condensation allowed
EMC resistance	EN 61000-6-2
EMC emissions	EN 61000-6-4
Vibration resistance	10 ... 1000 Hz 1.14 g
Shock resistance	50 g

Safety system values	
EN 61508 for Tu=75 °C (167 °F) ongoing	
SIL	2 for maintenance cycle of 2 years 1 for maintenance cycle of 3 years
HFT	0
PFD (for yearly functional test)	4.10×10^{-3}
SFF	78%
$\lambda_S+\lambda_{DD}$	8494 FIT
λ_{DU}	934 FIT
Ordering number	130B1137

7.3.12 VLT® Extended Relay Card MCB 113

The VLT® Extended Relay Card MCB 113 adds 7 digital inputs, 2 analog outputs, and 4 SPDT relays to the standard I/O of the frequency converter, providing increased flexibility and compliance with the German NAMUR NE37 recommendations.
The MCB 113 is a standard C1-option for the Danfoss VLT® HVAC Drive FC 102, VLT® Refrigeration Drive FC 103, VLT® AQUA Drive FC 202, VLT® AutomationDrive FC 301, and VLT® AutomationDrive FC 302 and is detected automatically after mounting.

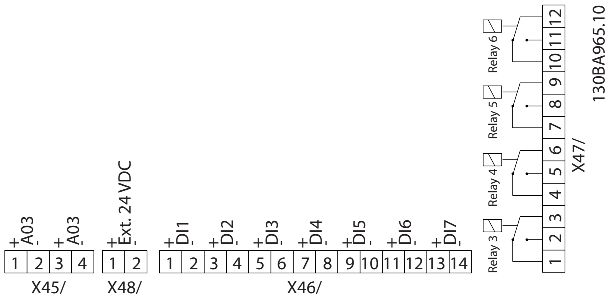


Illustration 7.17 Electrical Connections of MCB 113

Ensure galvanic isolation between the frequency converter and the option card MCB 113 by connecting to an external 24 V on X58/. If galvanic isolation is not needed, the option card can be powered through internal 24 V from the frequency converter.

NOTICE

It is acceptable to combine 24 V signals with high voltage signals in the relays as long as there is 1 unused relay in-between.

To set up MCB 113, use *parameter groups 5-1* Digital Inputs*, *6-7* Analog Output 3*, *6-8* Analog Output 4*, *14-8* Options*, *5-4* Relays*, and *16-6* Inputs and Outputs*.

NOTICE

In *parameter group 5-4* Relays*, array [2] is relay 3, array [3] is relay 4, array [4] is relay 5, and array [5] is relay 6.

Electrical data

Relays	
Numbers	4 SPDT
Load at 250 V AC/30 V DC	8 A
Load at 250 V AC/30 V DC with cosφ = 0.4	3.5 A
Overvoltage category (contact-earth)	III
Overvoltage category (contact-contact)	II
Combination of 250 V and 24 V signals	Possible with 1 unused relay in between
	10 ms
Maximum thru-put delay	Isolated from ground/chassis for use on IT mains systems

Digital inputs	
Numbers	7
Range	0/24 V
Mode	PNP/NPN
Input impedance	4 kW
Low trigger level	6.4 V
High trigger level	17 V
Maximum through-put delay	10 ms

Analog outputs	
Numbers	2
Range	0/4-20 mA
Resolution	11 bit
Linearity	<0.2%

EMC	
EMC	IEC 61000-6-2 and IEC 61800-3 regarding Immunity of BURST, ESD, SURGE, and Conducted Immunity

7.3.13 Brake Resistors

Brake resistors are used to dissipate the excess energy from the regenerative braking. The resistor is selected in respect to its ohmic value, its power dissipation rate, and its physical size. Danfoss offers a wide variety of different resistors that are specially designed to our frequency converters. For more information, see *chapter 13.2.1 Selection of Brake Resistor*. Also, see the *VLT® Brake Resistor MCE 101 Design Guide*.

7.3.14 Sine-wave Filters

When a frequency converter controls a motor, resonance noise is heard from the motor. This noise, which results from the motor design, occurs every time an inverter switch in the frequency converter is activated. The frequency of the resonance noise thus corresponds to the switching frequency of the frequency converter.

For the frequency converter, Danfoss can supply a sine-wave filter to dampen the acoustic motor noise. The filter reduces the ramp-up time of the voltage, the peak load voltage U_{PEAK}, and the ripple current ΔI to the motor. The filter results in the current and voltage becoming almost sinusoidal, which reduces the acoustic motor noise.

The ripple current in the sine-wave filter coils also causes some noise. This problem can be solved integrating the filter in a cabinet or similar enclosure.

For specific sine-wave filter part numbers, see *chapter 7.2.1 Output Filters*.

7.3.15 dU/dt Filters

The combination of rapid voltage and an increase in current stresses the motor insulation. These rapid energy fluctuations can be reflected back to the DC-line in the inverter, which can cause a shutdown. The dU/dt filter is designed to reduce the voltage rise time and the rapid energy change in the motor. This intervention avoids premature aging and flashover in the motor insulation.

The dU/dt filters have a positive influence on the radiation of magnetic noise in the cable that connects the frequency converter to the motor. The voltage wave form is still pulse shaped, but the dU/dt ratio is reduced in comparison to an installation without a filter.

7.3.16 Remote Mounting Kit for the LCP

The LCP can be moved to the front of a cabinet by using the remote built-in kit. Also available is an LCP kit without LCP. For IP66 units, the ordering number is 130B1117. Use ordering number 130B1129 for IP55 units.

Enclosure	IP54 front
Maximum cable length between the LCP and the unit	3 m (9 ft. 10 in)
Communication standard	RS485

Table 7.12 Technical Data for Mounting an LCP to the IP66 Enclosure

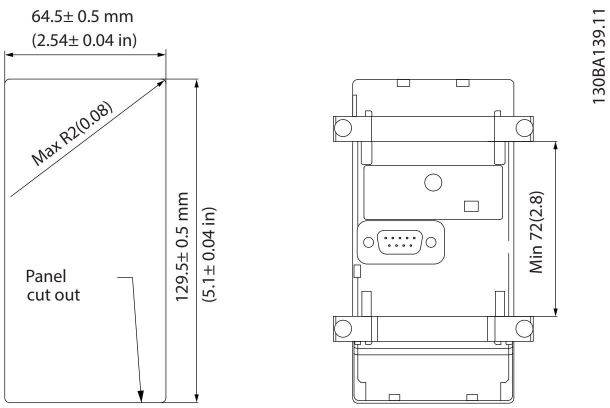


Illustration 7.18 Dimensions

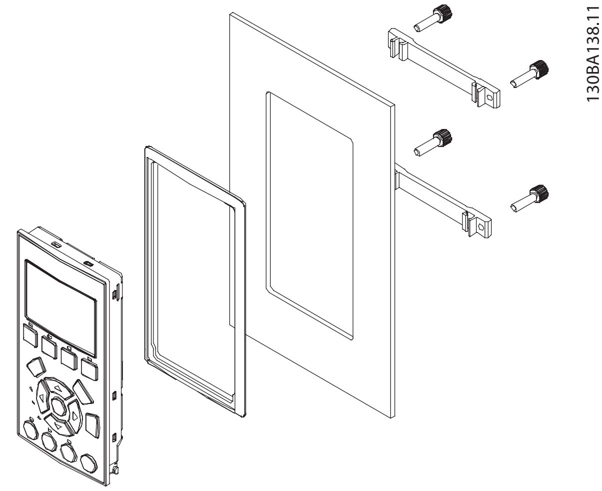


Illustration 7.19 Ordering Number 130B1113, LCP Kit with Graphical LCP, Fasteners, Cable, and Gasket

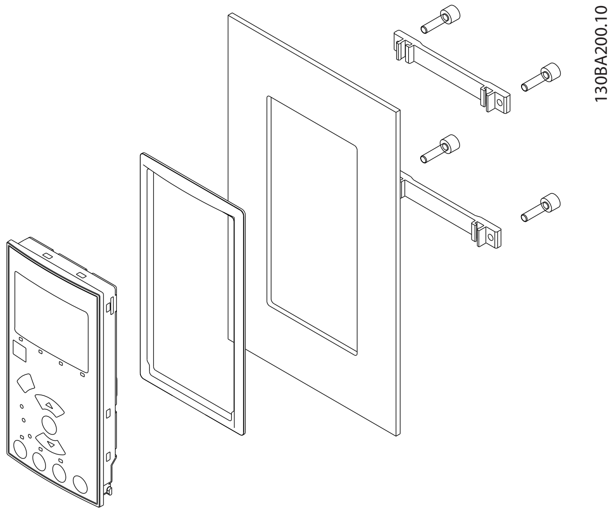


Illustration 7.20 Ordering Number 130B1114, LCP Kit with Numerical LCP, Fasteners, and Gasket

7

7.4 System Design Checklist

Table 7.13 provides a checklist for integrating a frequency converter into a motor control system. The list is intended as a reminder of the general categories and options necessary for specifying the system requirements.

Category	Details	Notes	☑
FC model			
Power			
	Volts		
	Current		
Physical			
	Dimensions		
	Weight		
Ambient operating conditions			
	Temperature		
	Altitude		
	Humidity		
	Air quality/dust		
	Derating requirements		
Enclosure size			
Input			
Cables			
	Type		
	Length		
Fuses			
	Type		
	Size		
	Rating		
Options			
	Connectors		
	Contacts		
	Filters		
Output			
Cables			
	Type		
	Length		
Fuses			
	Type		
	Size		
	Rating		
Options			
	Filters		
Control			
Wiring			
	Type		
	Length		
	Terminal connections		
Communication			
	Protocol		
	Connection		
	Wiring		
Options			
	Connectors		

Category	Details	Notes	☑
	Contacts		
	Filters		
Motor			
	Type		
	Rating		
	Voltage		
	Options		
Special tools and equipment			
	Moving and storage		
	Mounting		
	Connection of mains		

Table 7.13 System Design Checklist

8 Considerations During Installation

8.1 Operating Environment

For specifications regarding ambient conditions, see *chapter 6.9 Ambient Conditions for Drive Modules*.

NOTICE

CONDENSATION

Moisture can condense on the electronic components and cause short circuits. Avoid installation in areas subject to frost. Install a cabinet heater when the unit is colder than the ambient air. Operating in stand-by mode reduces the risk of condensation as long as the power dissipation keeps the circuitry free of moisture.

Aggressive gases, such as hydrogen sulphide, chlorine, or ammonia can damage the electrical and mechanical components. The VLT® Parallel Drive Modules uses conformal-coated circuit boards to reduce the effects of aggressive gases. For conformal-coating class specifications and ratings, see *chapter 6.9 Ambient Conditions for Drive Modules*.

When installing the unit 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 *VLT® Parallel Drive Modules Service Manual*.

Cooling fans
Fans provide airflow to cool the unit. When fans are exposed to dusty environments, the dust can damage the fan bearings and cause premature fan failure.

⚠WARNING

EXPLOSIVE ATMOSPHERE

Do not install the frequency converter in a potentially explosive atmosphere. Failure to follow this guideline increases risk of death or serious injury.

- **Install the unit in a cabinet outside of this area.**

Systems operated in potentially explosive atmospheres must fulfill special conditions. EU Directive 94/9/EC (ATEX 95) classifies the operation of electronic devices in potentially explosive atmospheres.

- Class d specifies that if a spark occurs, it is contained in a protected area.
- Class e prohibits any occurrence of a spark.

Motors with class d protection
Does not require approval. Special wiring and containment are required.

Motors with class e protection
When combined with an ATEX approved PTC monitoring device like the VLT® PTC Thermistor Card MCB 112, installation does not need an individual approval from an approbated organization.

Motors with class d/e protection
The motor itself has an e ignition protection class, while the motor cabling and connection environment is in compliance with the d classification. To attenuate the high peak voltage, use a sine-wave filter at the VLT® Parallel Drive Modules output.

When using the VLT® Parallel Drive Modules in a potentially explosive atmosphere, use the following:

- Motors with ignition protection class d or e.
- PTC temperature sensor to monitor the motor temperature.
- Short motor cables.
- Sine-wave output filters when shielded motor cables are not used.

NOTICE

MOTOR THERMISTOR SENSOR MONITORING

VLT® AutomationDrive units with the MCB 112 option are PTB-certified for potentially explosive atmospheres.

A frequency converter contains many mechanical and electronic components, many of which are vulnerable to environmental effects.

⚠CAUTION

The frequency converter should not be installed in environments with airborne liquids, particles, or gases capable of affecting and damaging the electronic components. Failure to take the necessary protective measures increases the risk of stoppages, thus reducing the life of the frequency converter.

Degree of protection as per IEC 60529
To prevent cross faults and short circuits between terminals, connectors, tracks, and safety-related circuitry caused by foreign objects, the Safe Torque Off (STO) function must be installed and operated in an IP54 or higher rated control cabinet (or equivalent environment).

Liquids can be carried through the air and condense in the frequency converter and can cause corrosion of components and metal parts. Steam, oil, and salt water can cause corrosion of components and metal parts. In such environments, use equipment with enclosure rating IP 54/55. As an extra protection, coated printed circuit boards can be ordered as an option.

Airborne particles such as dust can cause mechanical, electrical, or thermal failure in the frequency converter. A typical indicator of excessive levels of airborne particles is dust particles around the frequency converter fan. In dusty environments, use equipment with enclosure rating IP54/ IP55.

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

Such chemical reactions rapidly affect and damage the electronic components. In such environments, mount the equipment in a cabinet with fresh air ventilation, keeping aggressive gases away from the frequency converter. Optional coated PCBs also offer protection in such environments.

NOTICE

Mounting frequency converters in aggressive environments increases the risk of stoppages and considerably reduces the life of the frequency converter.

Before installing the frequency converter, check the ambient air for liquids, particles, and gases by observing existing installations in the environment. Typical indicators of harmful airborne liquids are water or oil on metal parts, or corrosion of metal parts.

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

8.2 Minimum System Requirements

8.2.1 Cabinet

The kit consists of either 2 or 4 drive modules, depending on the power rating. The cabinets have to meet the following minimum requirements:

Width [mm (in)]	2-drive: 800 (31.5), 4-drive: 1600 (63)
Depth [mm (in)]	600 (23.6)
Height [mm (in)]	2000 (78.7)[1)]
Weight capacity [kg (lb)]	2-drive: 450 (992), 4-drive: 910 (2006)
Ventilation openings	See *chapter 8.2.4 Cooling and Airflow Requirements*.

Table 8.1 Cabinet Requirements

1) Required if Danfoss busbar or cooling kits are used.

NOTICE

EXTERNAL 230 V SUPPLY

An external 230 V supply is required for the SMPS (switch mode power supply). Danfoss recommends using a 6 A, 10 A, or 16 A slow-blow fuse when installing the external supply.

8.2.2 Busbars

If the Danfoss busbar kit is not used, see *Table 8.2* for the cross-section measurements that are required when creating customized busbars. For terminal dimensions, refer to *chapter 6.1.2 Terminal Dimensions* and *chapter 6.1.3 DC Bus Dimensions*.

Description	Width [mm (in)]	Thickness [mm (in)]
AC motor	143.6 (5.7)	6.4 (0.25)
AC mains	143.6 (5.7)	6.4 (0.25)
DC bus	76.2 (3.0)	12.7 (0.50)

Table 8.2 Cross-section Measurements for Customized Busbars

NOTICE

Align busbars vertically to provide maximum airflow.

8.2.3 Thermal Considerations

For heat dissipation values, refer to *chapter 6.5 Power-dependent Specifications*. The following heat sources must be considered when determining cooling requirements:

- Ambient temperature outside enclosure.
- Filters (for example, sine-wave and RF).
- Fuses.
- Control components.

For required cooling air, refer to *chapter 8.2.4 Cooling and Airflow Requirements*.

8

8.2.4 Cooling and Airflow Requirements

The recommendations provided in this section are necessary for effective cooling of the drive modules within the panel enclosure. Each drive module contains a heat sink fan and a mixing fan. Typical enclosure designs utilize door fans along with the drive module fans to remove waste heat from the enclosure.

Danfoss provides several back-channel cooling kits as options. These kits remove 85% of the waste heat from the enclosure, reducing the need for large door fans.

NOTICE

Make sure that the total flow of the cabinet fans meets the recommended airflow.

Drive module cooling fans

The drive module is equipped with a heat sink fan, which provides the required flow rate of 840 m^3/h (500 cfm) across the heat sink. Also, there is a cooling fan mounted on the top of the unit, and a small 24 V DC mixing fan mounted under the input plate that operates any time the drive module is powered on.

In each drive module, the power card provides DC voltage to power the fans. The mixing fan is powered by 24 V DC from the main switch mode power supply. The heat sink fan and the top fan are powered by 48 V DC from a dedicated switch mode power supply on the power card. Each fan has a tachometer feedback to the control card to confirm that the fan is operating correctly. On/off and speed control of the fans help reduce unnecessary acoustical noise and extend the life of the fans.

Cabinet fans

When the back-channel option is not used, fans mounted in the cabinet must remove all the heat generated inside the enclosure.

For each enclosure housing 2 drive module, the cabinet fan flow recommendation is as follows:

- When back-channel cooling is used, 680 m^3/h (400 cfm) flow is recommended.
- When back-channel cooling is not used, 4080 m^3/h (2400 cfm) flow is recommended.

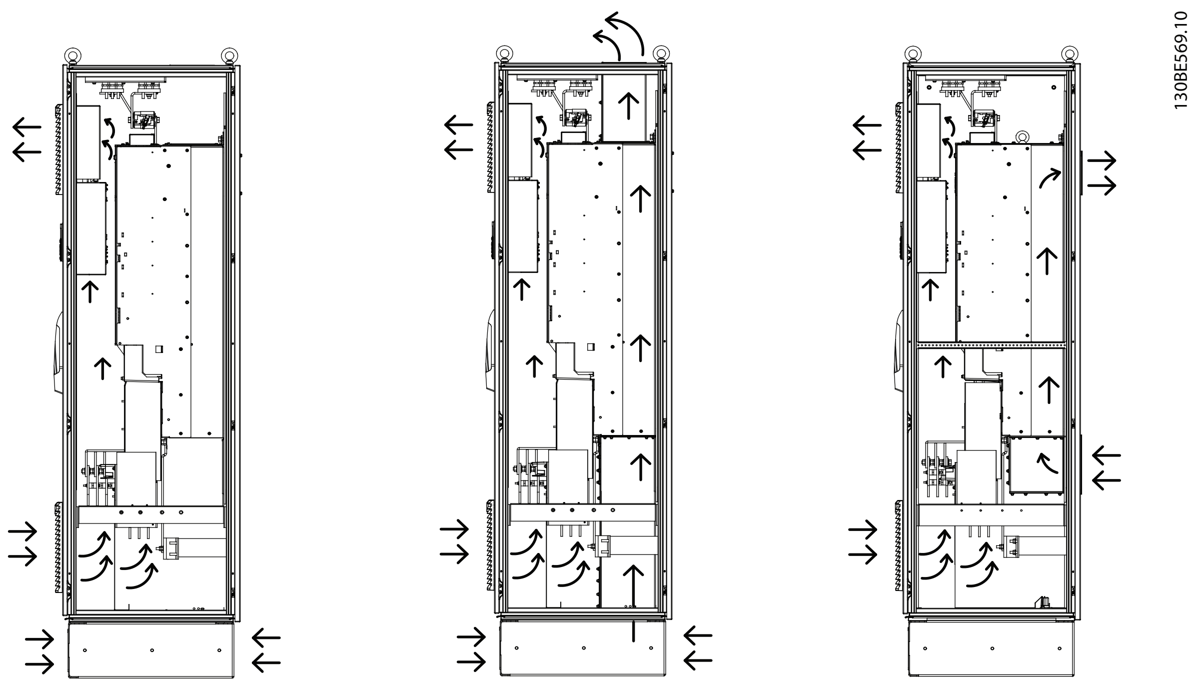


Illustration 8.1 Airflow, Standard Unit (Left), Bottom/Top Cooling Kit (Middle), and Back/Back Cooling Kit (Right)

8.3 Electrical Requirements for Certifications and Approvals

The standard configuration provided in this guide (drive modules, control shelf, wire harnesses, fuses, and microswitches) is UL and CE certified. The following conditions must be met apart from the standard configuration to obtain UL and CE regulatory approval requirements. For a list of disclaimers, see *chapter 18.1 Disclaimer*.

- Use the frequency converter in a heated, indoor-controlled environment. Cooling air must be clean, free from corrosive materials, and electrically conductive dust. See *chapter 6.9 Ambient Conditions for Drive Modules* for specific limits.
- Maximum ambient air temperature is 40 °C (104 °F) at rated current.
- The drive system must be assembled in clean air, according to enclosure classification. To obtain UL or CE certification regulatory approvals, drive modules must be installed according to the standard configuration provided in this guide.
- Maximum voltage and current must not exceed the values provided in *chapter 6.5 Power-dependent Specifications* for the specified drive configuration.
- The drive modules are suitable for use on a circuit capable of delivering not more than 100 kA rms symmetrical amperes at the drive nominal voltage (600 V maximum for 690 V units) when protected by fuses with the standard configuration. Refer to *chapter 8.4.1 Fuse Selection*. The ampere rating is based on tests done according to UL 508C.
- The cables located within the motor circuit must be rated for at least 75 °C (167 °F) in UL-compliant installations. The cable sizes have been provided in *chapter 6.5 Power-dependent Specifications* for the specified drive configuration.
- The input cable must be protected with fuses. Circuit breakers must not be used without fuses in the U.S. Suitable IEC (class aR) fuses and UL (class L or T) fuses are listed in *chapter 8.4.1 Fuse Selection*. In addition, country-specific regulatory requirements must be adhered to.
- For installation in the U.S., branch circuit protection must be provided according to the National Electrical Code (NEC) and any applicable local codes. To fulfill this requirement, use UL-classified fuses.
- For installation in Canada, branch circuit protection must be provided according to the Canadian Electrical Code and any applicable provincial codes. To fulfill this requirement, use the UL-classified fuses.

8.4 Fuses and Circuit Breakers

8.4.1 Fuse Selection

To protect the drive system in case 1 or more internal components break down within a drive module, use fuses and/or circuit breakers at the mains supply side.

8.4.1.1 Branch Circuit Protection

To protect the installation against electrical and fire hazards, protect all branch circuits in an installation against short circuit and overcurrent according to national and international regulations.

8.4.1.2 Short-circuit Protection

Danfoss recommends the fuses listed in *chapter 8.4.1.3 Recommended Fuses for CE Compliance* and *chapter 8.4.1.4 Recommended Fuses for UL Compliance* to achieve CE or UL Compliance in the protection of service personnel and property against the consequences of component breakdown in the drive modules.

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8.4.1.3 Recommended Fuses for CE Compliance

Number of drive modules	FC 302	FC 102/ FC 202	Recommended fuse (maximum)
2	N450	N500	aR-1600
4	N500	N560	aR-2000
4	N560	N630	aR-2000
4	N630	N710	aR-2500
4	N710	N800	aR-2500
4	N800	N1M0	aR-2500

Table 8.3 6-Pulse Drive Systems (380–500 V AC)

Number of drive modules	FC 302	FC 102/ FC 202	Recommended fuse (maximum)
2	N250	N315	aR-630
2	N315	N355	aR-630
2	N355	N400	aR-630
2	N400	N450	aR-800
2	N450	N500	aR-800
4	N500	N560	aR-900
4	N560	N630	aR-900
4	N630	N710	aR-1600
4	N710	N800	aR-1600
4	N800	N1M0	aR-1600

Table 8.4 12-Pulse Drive Systems (380–500 V AC)

Number of drive modules	FC 302	FC 102/ FC 202	Recommended fuse (maximum)
4	N630	N710	aR-1600
4	N710	N800	aR-2000
4	N800	N900	aR-2500
4	N900	N1M0	aR-2500
4	N1M0	N1M2	aR-2500

Table 8.5 6-Pulse Drive Systems (525–690 V AC)

Number of drive modules	FC 302	FC 102/ FC 202	Recommended fuse (maximum)
2	N250	N315	aR-550
2	N315	N355	aR-630
2	N355	N400	aR-630
2	N400	N500	aR-630
2	N500	N560	aR-630
2	N560	N630	aR-900
4	N630	N710	aR-900
4	N710	N800	aR-900
4	N800	N900	aR-900
4	N900	N1M0	aR-1600
4	N1M0	N1M2	aR-1600

Table 8.6 12-Pulse Drive Systems (525–690 V AC)

8.4.1.4 Recommended Fuses for UL Compliance

- The drive modules are supplied with built-in AC fuses. The modules have been qualified for 100 kA short-circuit current rating (SCCR) for the standard busbar configurations at all voltages (380–690 V AC).
- If no power options or extra busbars are connected externally, the drive system is qualified for 100 kA SCCR with any Class L or Class T UL-listed fuses connected at the input terminals of the drive modules.
- Do not exceed the listed fuse rating in *Table 8.8* to *Table 8.9* with the current rating of the Class L or Class T fuses.

Number of drive modules	FC 302	FC 102/ FC 202	Recommended fuse (maximum)
2	N450	N500	1600 A
4	N500	N560	2000 A
4	N560	N630	2000 A
4	N630	N710	2500 A
4	N710	N800	2500 A
4	N800	N1M0	2500 A

Table 8.7 6-Pulse Drive Systems (380–500 V AC)

Number of drive modules	FC 302	FC 102/ FC 202	Recommended fuse (maximum)
2	N250	N315	630 A
2	N315	N355	630 A
2	N355	N400	630 A
2	N400	N450	800 A
2	N450	N500	800 A
4	N500	N560	900 A
4	N560	N630	900 A
4	N630	N710	1600 A
4	N710	N800	1600 A
4	N800	N1M0	1600 A

Table 8.8 12-Pulse Drive Systems (380–500 V AC)

Any minimum 500 V UL-listed fuse can be used for the 380–500 V AC drive systems.

Number of drive modules	FC 302	FC 102/ FC 202	Recommended fuse (maximum)
4	N630	N710	1600 A
4	N710	N800	2000 A
4	N800	N900	2500 A
4	N900	N1M0	2500 A
4	N1M0	N1M2	2500 A

Table 8.9 6-Pulse Drive Systems (525–690 V AC)

Number of drive modules	FC 302	FC 102/ FC 202	Recommended fuse (maximum)
2	N250	N315	550 A
2	N315	N355	630 A
2	N355	N400	630 A
2	N400	N500	630 A
2	N500	N560	630 A
2	N560	N630	900 A
4	N630	N710	900 A
4	N710	N800	900 A
4	N800	N900	900 A
4	N900	N1M0	1600 A
4	N1M0	N1M2	1600 A

Table 8.10 12-Pulse Drive Systems (525–690 V AC)

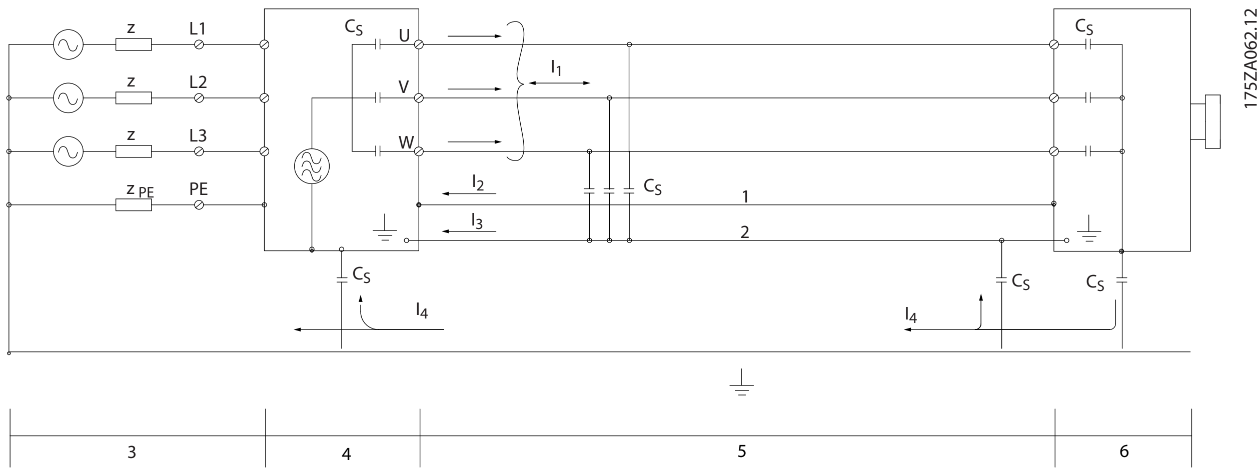
Any minimum 700 V UL-listed fuse can be used for the 525–690 V AC drive systems.

9 EMC and Harmonics

9.1 General Aspects of EMC Emissions

Burst transient is most commonly found at frequencies in the range 150 kHz to 30 MHz. Airborne interference from the frequency converter 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. Shielded motor cables increase the leakage current (see *Illustration 9.1*) because they have higher capacitance to ground than unshielded cables. If the leakage current is not filtered, it causes greater interference on the mains in the radio frequency range below 5 MHz. Since the leakage current (I_1) is carried back to the unit through the shield (I_3), there is only a small electromagnetic field (I_4) from the shielded motor cable.

While the shield reduces the radiated interference, it increases the low-frequency interference on the mains. Connect the motor cable shield to the frequency converter enclosure and to the motor enclosure. To connect the shield, use integrated shield clamps to avoid twisted shield ends. The twisted shield ends increase the shield impedance at higher frequencies, which reduces the shield effect and increases the leakage current (I_4).
If a shielded cable is used for fieldbus, relay, control cable, signal interface, or brake, mount the shield on the enclosure at both ends. In some situations, however, it is necessary to break the shield to avoid current loops.



1	Ground wire
2	Shield
3	AC mains supply
4	Frequency converter
5	Shielded motor cable
6	Motor

Illustration 9.1 Leakage Currents

Illustration 9.1 shows an example of a 6-pulse frequency converter, but could be applicable to a 12-pulse as well.

If placing the shield on a mounting plate, use a metal plate because the shield currents must be conveyed back to the frequency converter. Ensure good electrical contact from the mounting plate through the mounting screws to the frequency converter chassis. When unshielded cables are used, some emission requirements are not complied with, although the immunity requirements are observed.

To reduce the interference level from the entire system (unit and installation), make motor and brake cables as short as possible. Avoid placing cables with a sensitive signal level alongside motor and brake cables. Radio interference higher than 50 MHz (airborne) comes from the control electronics. For more information on EMC, see *chapter 9.5 EMC Recommendations*.

9.2 EMC Test Results

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

RFI filter type		Conducted emission		Radiated Emission	
Standards and requirements[1)]	**EN/IEC 61800-3**	**Category C2**	**Category C3**	**Category C2**	**Category C3**
P2, P4 (FC 302)		No	150 m	No	Yes
P6, P8 (FC 302)		150 m (492 ft)	150 m (492 ft)	Yes	Yes

Table 9.1 EMC Test Results (Emission and Immunity)

1) An external RFI filter is required to meet the C2 category.

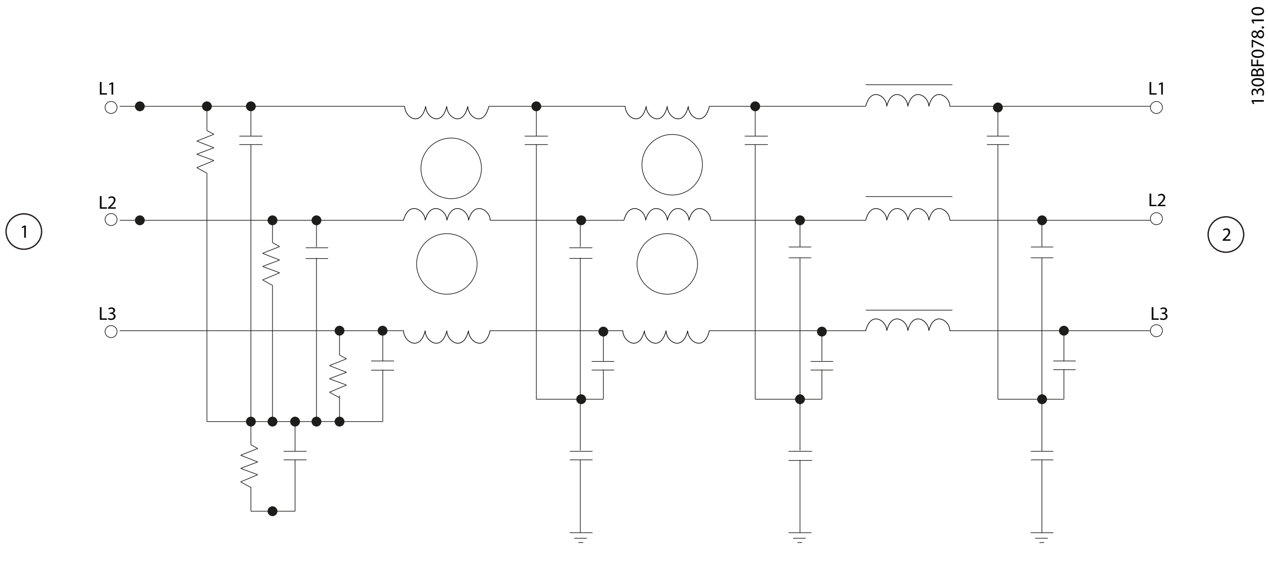
NOTICE

This type of power drive system is not intended to be used on a low voltage public network that supplies domestic premises. Radio frequency interference is expected if used on such a network, and supplementary mitigation measures may be required.

The frequency converter meets the emission requirement for C3 category with 150 m (492 ft) shielded cable. To meet the C2 category requirement, an external RFI filter is required.

Illustration 9.2 shows the electrical diagram of the RFI filter that was used to qualify the frequency converter. In this scenario, the RFI filter is isolated from the ground, and the RFI relay is disabled using *parameter 14-50 RFI Filter*.

The attenuation factor for the RFI filter is provided in *Illustration 9.3*.



1	Line	2	Load

Illustration 9.2 Electrical Diagram of RFI Filter

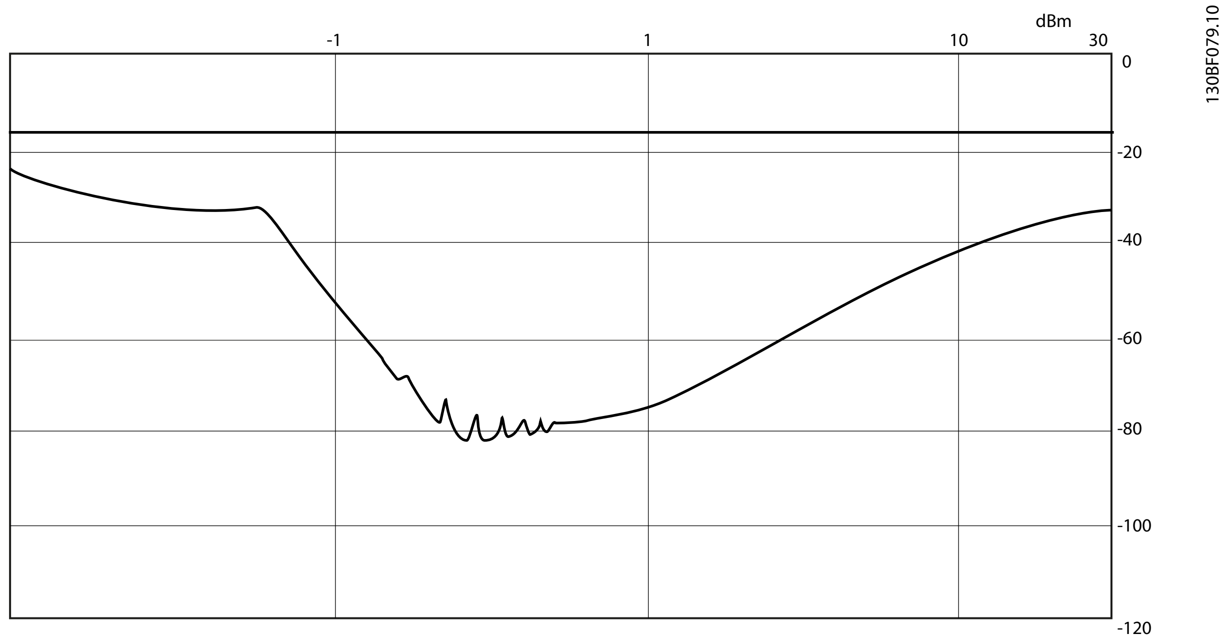


Illustration 9.3 Attenuation Requirement for an External Filter

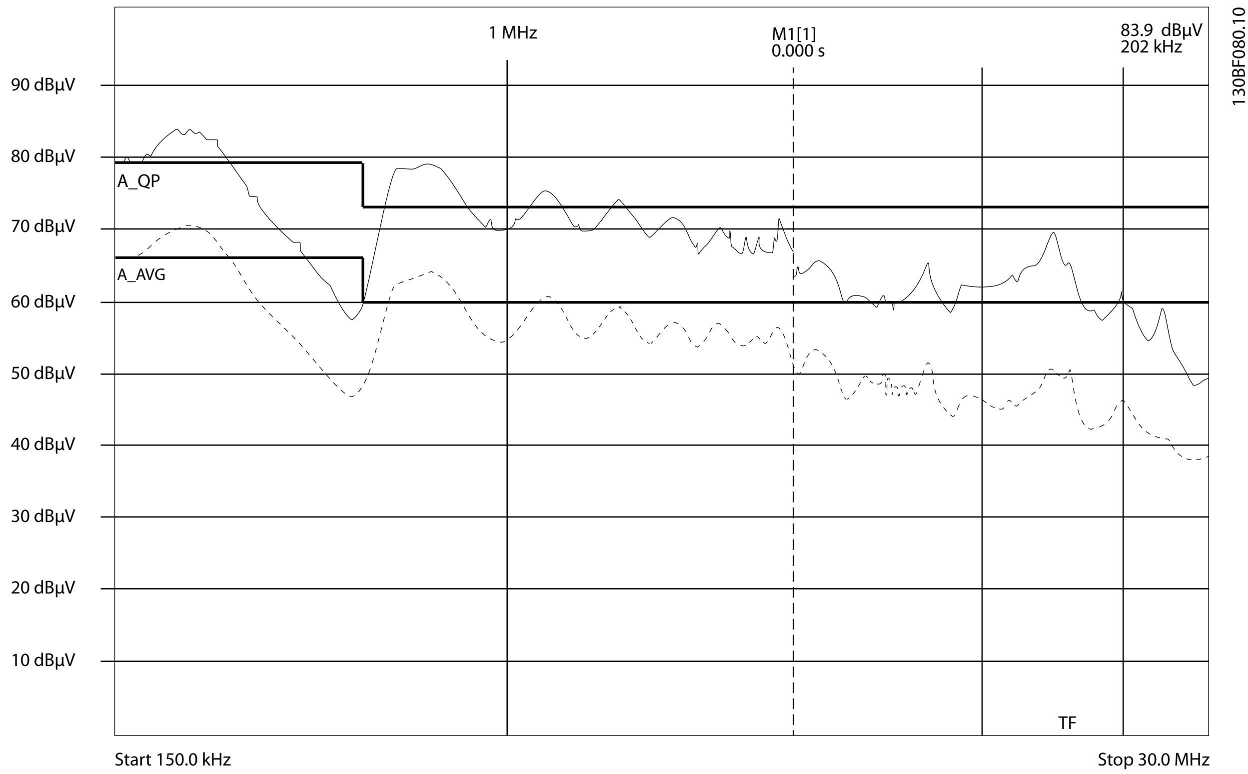


Illustration 9.4 Conducted Emission on the Mains in P4/P8 Configuration Without an External RFI Filter

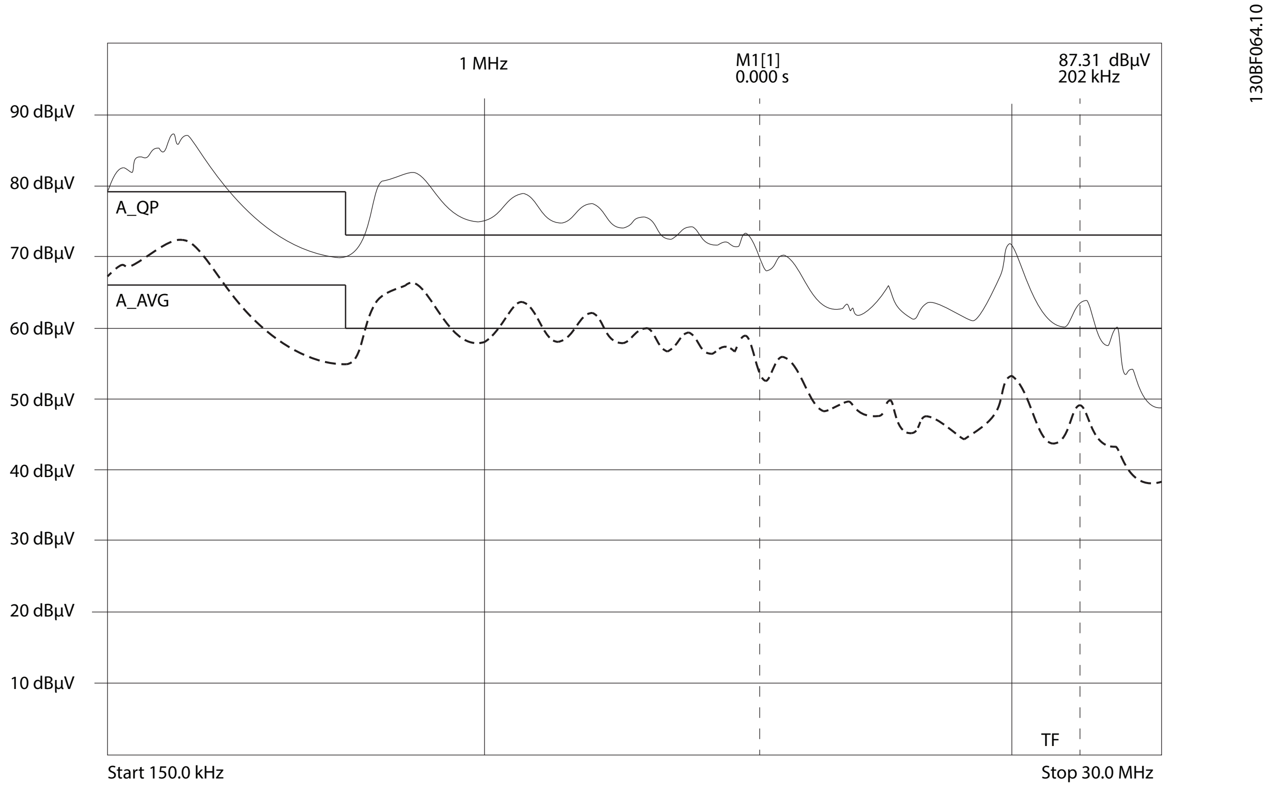


Illustration 9.5 Conducted Emission on the Mains in P4/P8 Configuration Without an External RFI Filter

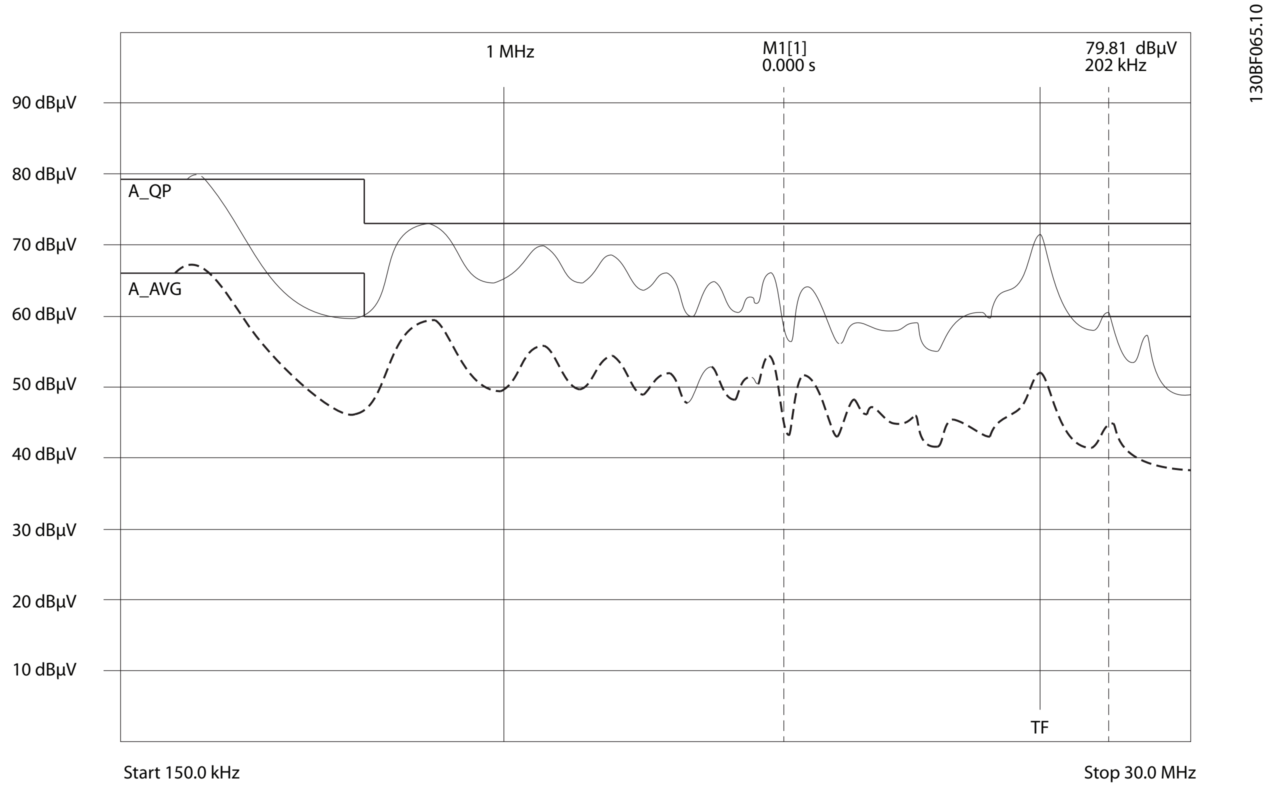


Illustration 9.6 Conducted Emission on the Mains in P4/P8 Configuration Without an External RFI Filter

9.3 Emission Requirements

According to the EMC product standard for frequency converters EN/IEC 61800-3, the EMC requirements depend on the environment in which the frequency converter is installed. These environments along with the mains voltage supply requirements are defined in *Table 9.2*.

Category	Definition	Conducted emission requirement according to EN 55011 limits
C1	Frequency converters installed in a home and office environment with a supply voltage less than 1000 V.	Class B
C2	Frequency converters installed in the home and office environment with a supply voltage less than 1000 V. These frequency converters are not plug-in and cannot be moved and are intended to for professional installation and commissioning.	Class A Group 1
C3	Frequency converters installed in an industrial environment with a supply voltage lower than 1000 V.	Class A Group 2
C4	Frequency converters installed in an industrial environment with a supply voltage equal to or above 1000 V or rated current equal to or above 400 A or intended for use in complex systems.	No limit line Make an EMC plan

Table 9.2 Emission Requirements

When the generic emission standards are used, the frequency converters are required to comply with *Table 9.3*.

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 9.3 Generic Emission Standard Limits

9.4 Immunity Requirements

The immunity requirements for frequency converters depend on the environment where they are installed. The requirements for the industrial environment are higher than the requirements for the home and office environment. All Danfoss frequency converters 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 frequency converter (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 9.4*.

- **EN/IEC 61000-4-2:** Electrostatic discharges (ESD): Simulation of electrostatic discharges from human beings.
- **EN/IEC 61000-4-3:** Incoming electromagnetic field radiation, amplitude modulated simulation of the effects of radar and radio communication equipment, as well as mobile communications equipment.
- **EN/IEC 61000-4-4:** Burst transients: Simulation of interference brought about by switching a contactor, relay, or similar devices.
- **EN/IEC 61000-4-5:** Surge transients: Simulation of transients brought about by lightning strikes near installations.
- **EN/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 electromagnetic field IEC 61000-4-3**	**RF common mode voltage IEC 61000-4-6**
Acceptance criterion	**B**	**B**	**B**	**A**	**A**
Line	4 kV CM	2 kV/2 Ω DM 4 kV/12 Ω CM	–	–	10 V_{RMS}
Motor	4 kV CM	4 kV/2 Ω[1)]	–	–	10 V_{RMS}
Brake	4 kV CM	4 kV/2 Ω[1)]	–	–	10 V_{RMS}
Load sharing	4 kV CM	4 kV/2 Ω[1)]	–	–	10 V_{RMS}
Control wires	2 kV CM	2 kV/2 Ω[1)]	–	–	10 V_{RMS}
Standard bus	2 kV CM	2 kV/2 Ω[1)]	–	–	10 V_{RMS}
Relay wires	2 kV CM	2 kV/2 Ω[1)]	–	–	10 V_{RMS}
Application and Fieldbus options	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 9.4 EMC Immunity Form, Voltage Range: 380–500 V, 525–600 V, 525–690 V

1) Injection on cable shield.

AD: Air discharge; CD: Contact discharge; CM: Common mode; DM: Differential mode.

9.5 EMC Recommendations

The following is a guideline to good engineering practice when installing frequency converters. Follow these guidelines in compliance with EN/IEC 61800-3 *First environment*. If the installation is in EN/IEC 61800-3 *Second environment,* industrial networks, or in an installation with its own transformer, deviation from these guidelines is allowed but not recommended.

Good engineering practice to ensure EMC-correct electrical installation:

- Use only braided shielded/armored motor cables and braided shielded control cables. The shield provides a minimum coverage of 80%. The shield material must be metal, not limited to but typically copper, aluminum, steel, or lead. There are no special requirements for the mains cable.
- Installations using rigid metal conduits are not required to use shielded cable, but the motor cable must be installed in conduit separate from the control and mains cables. Full connection of the conduit from the frequency converter to the motor is required. The EMC performance of flexible conduits varies a lot and information from the manufacturer must be obtained.
- Connect the shield conduit to ground at both ends for motor cables and for control cables. Sometimes, it is not possible to connect the shield in both ends. If so, connect the shield at the frequency converter. See also *chapter 9.5.2 Grounding of Shielded Control Cables*.
- Avoid terminating the shield with twisted ends (pigtails). It increases the high frequency impedance of the shield, which reduces its effectiveness at high frequencies. Use low impedance cable clamps or EMC cable glands instead.
- Avoid using unshielded motor or control cables inside cabinets housing the frequency converter, whenever possible.

Leave the shield as close to the connectors as possible.

Illustration 9.7 shows an example of an EMC-correct electrical installation of an IP20 frequency converter. The frequency converter is fitted in an installation cabinet with an output contactor and connected to a PLC, which is installed in a separate cabinet. Other ways of doing the installation could have just as good an EMC performance, provided the guidelines to engineering practice are followed.

If the installation is not carried out according to the guideline, and if unshielded cables and control wires are used, some emission requirements are not in compliance, although the immunity requirements are fulfilled.

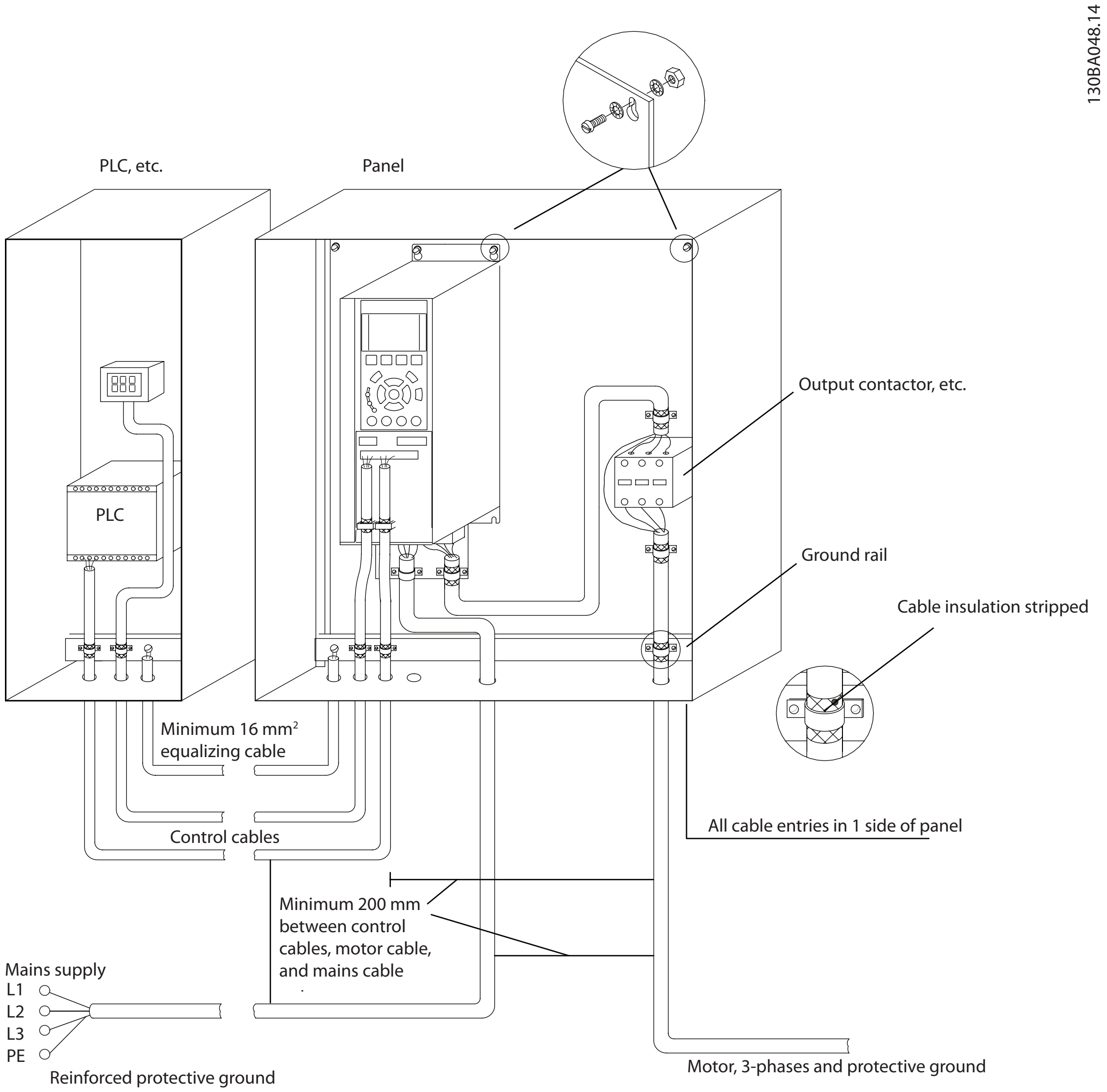


Illustration 9.7 EMC-correct Electrical Installation of a Frequency Converter in Cabinet

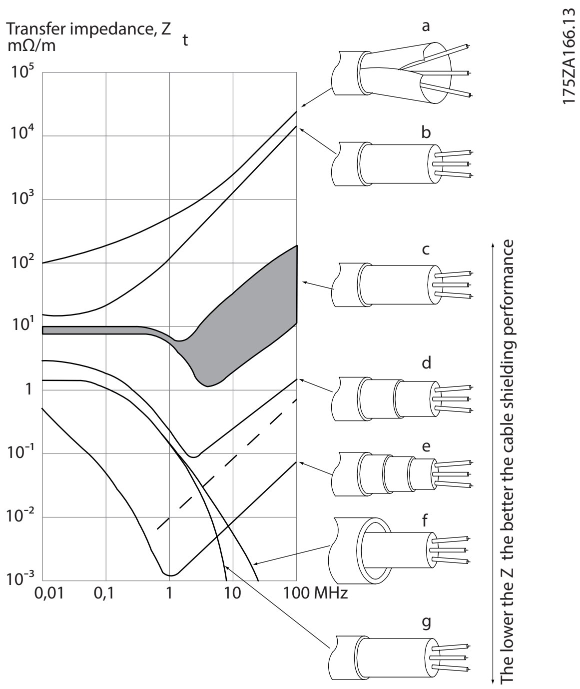
9.5.1 Using Shielded Control Cables

Danfoss recommends braided shielded/armored cables to optimize EMC immunity of the control cables and the EMC emission from the motor cables.

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

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

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

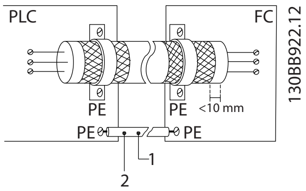


a	Aluminum-clad with copper wire.
b	Twisted copper wire or armored steel wire cable.
c	Single-layer braided copper wire with varying percentage shield coverage (this type of cable is the typical Danfoss reference cable).
d	Double-layer braided copper wire.
e	Twin layer of braided copper wire with a magnetic, shielded/armored intermediate layer.
f	Cable that runs in copper tube or steel tube.
g	Lead cable with 1.1 mm (0.04 in) wall thickness.

Illustration 9.8 Cable Shielding Performance

9.5.2 Grounding of Shielded Control Cables

Correct shielding
The preferred method usually is to secure control and serial communication cables with shielding clamps provided at both ends to ensure best possible high frequency cable contact. If the ground potential between the frequency converter and the PLC is different, electric noise can occur that disturbs the entire system. Solve this problem by fitting an equalizing cable next to the control cable. Minimum cable cross-section: 16 mm^2 (4 AWG).



1	Minimum 16 mm^2 (4 AWG)	2	Equalizing cable

Illustration 9.9 Correct Shielding

50/60 Hz ground loops
With long control cables, ground loops can occur. To eliminate ground loops, connect 1 end of the shield-to-ground with a 100 nF capacitor (keeping leads short).

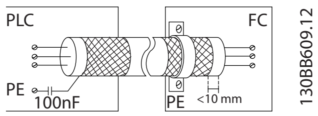
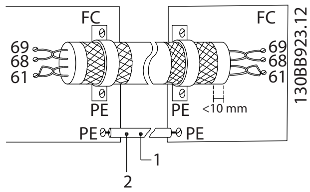


Illustration 9.10 Avoiding Ground Loops

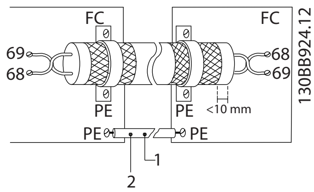
Avoid EMC noise on serial communication
This terminal is connected to ground via an internal RC link. To reduce interference between conductors, use twisted-pair cables.



1	Minimum 16 mm^2 (4 AWG)	2	Equalizing cable

Illustration 9.11 Recommended Method for Avoiding EMC Noise

Alternatively, the connection to terminal 61 can be omitted:



1	Minimum 16 mm^2 (4 AWG)	2	Equalizing cable

Illustration 9.12 Shielding without Using Terminal 61

9.6 General Aspects of Harmonics

Non-linear loads such as found with 6-pulse frequency converters 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.

9.7 Harmonics 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 9.5 Harmonics-related Abbreviations

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

Table 9.6 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

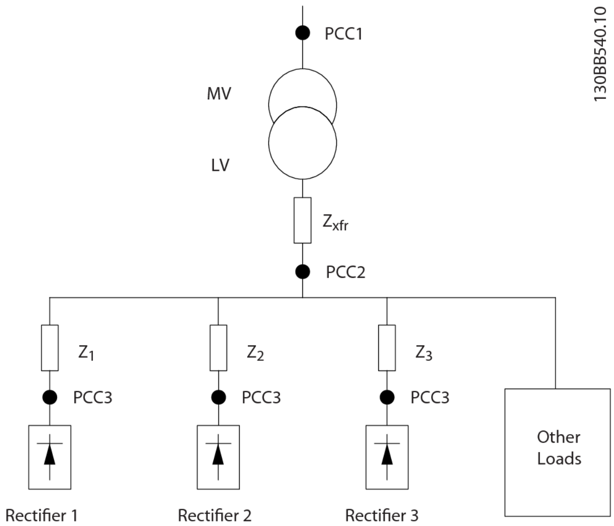
Table 9.7 Harmonic Currents Compared to the RMS Input Current

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:

$$THDi = \frac{\sqrt{U25\ +\ U27\ +\ ...\ +\ U2n}}{U}$$

9.8 Effect of Harmonics in a Power Distribution System

In *Illustration 9.13*, 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 is connected 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 9.13 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}. R_{sce} is defined as the ratio between the short circuit apparent power of the supply at the PCC (S_{sc}) and the rated apparent power of the load.

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

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

Negative effects of harmonics

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

9.9 Harmonic Limitation Standards and Requirements

The requirements for harmonic limitation can be

- Application specific
- Standards that must be observed

The application-specific requirements are related to a specific installation where there are technical reasons for limiting the harmonics.

Example: If 1 of the motors is connected directly online and the other is supplied through a frequency converter, a 250 kVA transformer with 2 110 kW motors connected is sufficient. However, the transformer is undersized if both motors are frequency converter supplied. Using additional means of harmonic reduction within the installation or selecting low harmonic drive variants makes it possible for both motors to run with frequency converters.

There are various harmonic mitigation standards, regulations, and recommendations. The following standards are the most common:

- IEC61000-3-2
- IEC61000-3-12
- IEC61000-3-4
- G5/4

See *VLT® Advanced Harmonic Filters AHF 005/AHF 010 Design Guide* for specific details on each standard.

9.10 VLT® Parallel Drive Modules Harmonics Compliance

The VLT® Parallel Drive Modules comply with the following standards:

- IEC 61000-2-4
- IEC 61000-3-4
- G5/4

9.11 Galvanic Isolation

NOTICE

INSTALLATION AT HIGH ALTITUDE

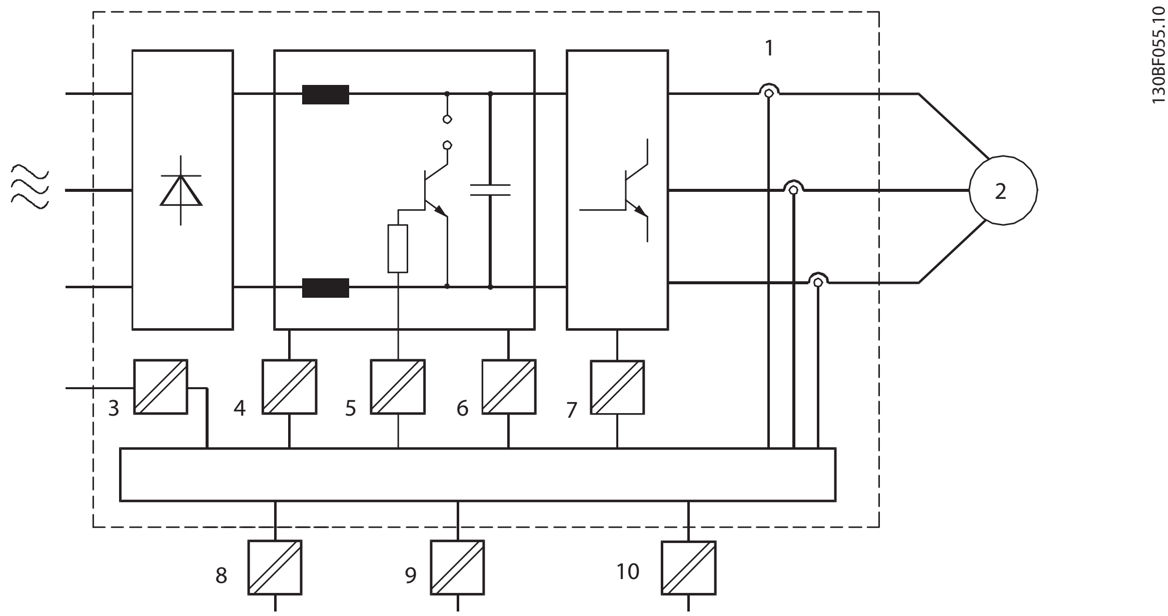
When installing 380–500 V units above 3000 m (9843 ft), contact Danfoss regarding PELV.
When installing 525–690 V units above 2000 m (6562 ft), contact Danfoss regarding PELV.

Protection against electric shock is ensured when the electrical supply is of the PELV type, and the installation complies with local/national regulations on PELV supplies.

All control terminals and relay terminals 01–03/04–06 comply with PELV. This does not apply to grounded Delta leg above 400 V. Galvanic 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.

To maintain PELV, all connections made to the control terminals must be PELV. The components that make up the electrical isolation also comply with the requirements for higher isolation and the relevant test as described in EN 61800-5-1.

The PELV galvanic isolation is shown in *Illustration 9.14*.



1	Current transducers	6	Supply (SMPS) including signal isolation of U_{DC}, indicating the intermediate current voltage
2	Motor	7	Gate drive that runs the IGBTs (trigger transformers/opto-couplers)
3	Custom relays	8	STO supply
4	Internal inrush, RFI, and temperature measurement circuits	9	24 V back-up
5	Optocoupler, brake module	10	RS485 standard bus interface

Illustration 9.14 Galvanic Isolation

10 Motor

10.1 Motor Cables

See *chapter 6.10 Cable Specifications* for more information on wire type and sizes.

Voltage rating

Peak voltages up to 2.8 times the mains voltage of the VLT® Parallel Drive Modules drive system can occur in the motor cable. High peak voltages can severely stress the motor cable. Use motor cables with rated voltage specification of at least 0.6/1 kV. Cables in this range provide good resistance to insulation breakdown.

Dimensions

Follow local codes for current capacity data for cables and conductors. Widely used codes include: NFPA 70, EN 60204-1, VDE 0113-1, and VDE 0298-4. Overdimensioning for harmonics is not required.

Length

Keep cables as short as possible. Voltage drop and heat dissipation depends on the frequency and are proportional to cable length. Consult the cable manufacturer specifications regarding the length and expected voltage drop when connected to the drive system. See *chapter 6.10 Cable Specifications*.

NOTICE

CABLE LENGTH

With a standard VLT® Parallel Drive Modules drive system, shielded cables up to 150 m (492 ft) long or unshielded up to 300 m (984 ft) long provide full voltage at the motor. If this cable length is exceeded, use a sine-wave filter. For information on the selection of a sine-wave filter, refer to the *VLT® FC-Series Output Filter Design Guide*.

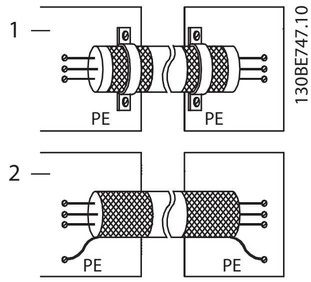
Shielding

See *chapter 9.5 EMC Recommendations* for information on effective shielding.

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. To avoid twisted shield ends, use integrated shield clamps. Refer to *Illustration 10.1*.



1	Correct grounding of shielded ends
2	Incorrect grounding using twisted shield ends (pigtail)

Illustration 10.1 Example of Shield Ends

10.2 Motor Coil Insulation

For motor cable lengths that are less than or equal to the maximum cable length listed in *chapter 6.10 Cable Specifications*, use the motor insulation ratings shown in *Table 10.1*. If a motor has lower insulation rating, Danfoss recommends using a dU/dt or sine-wave filter.

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

Table 10.1 Motor Insulation Ratings

10

10.3 Motor Bearing Currents

To eliminate circulating bearing currents in all motors installed with VLT® HVAC Drive FC 102, VLT® AQUA Drive FC 202 and VLT® AutomationDrive FC 302 90 kW or higher power frequency converters, install NDE (non-drive end) insulated bearings. To minimize DE (drive end) bearing and shaft currents, ensure proper grounding of the frequency converter, 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 frequency converter. Use a shielded cable that has a 360° connection in the motor and the frequency converter.
  - Ensure that the impedance from the frequency converter to building ground is lower than the grounding impedance of the machine. This procedure can be difficult for pumps.
  - Make a direct ground connection between the motor and load motor.
- Lower the IGBT switching frequency.
- Modify the inverter waveform, 60° AVM vs. SFAVM.
- Install a shaft grounding system or use an isolating coupling.
- Apply conductive lubrication.
- Use minimum speed settings if possible.
- Try to ensure that the mains voltage is balanced to ground. This procedure can be difficult for IT, TT, TN-CS, or grounded leg systems.
- Use a dU/dt or sine-wave filter.

10.4 Motor Thermal Protection

The electronic thermal relay in the frequency converter has received UL Approval for single motor 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).
For motor thermal protection, it is also possible to use the VLT® PTC Thermistor Card MCB 112 option. This card provides ATEX certificate to protect motors in explosion hazardous areas, Zone 1/21 and Zone 2/22. When *parameter 1-90 Motor Thermal Protection*, set to *[20] ATEX ETR*, is combined with the use of MCB 112, it is possible to control an Ex-e motor in explosion hazardous areas. Consult the *programming guide* for details on how to set up the frequency converter for safe operation of Ex-e motors.

10.4.1 Types of Thermal Protection

10.4.1.1 PTC Thermistor

Using a digital input and 10 V supply

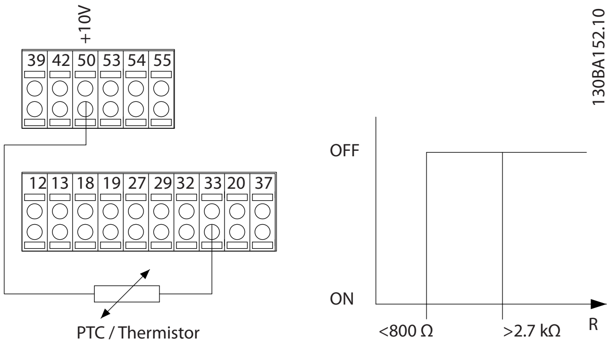


Illustration 10.2 PTC Thermistor Connection - Digital Input with 10 V Supply

Using an analog input and 10 V supply

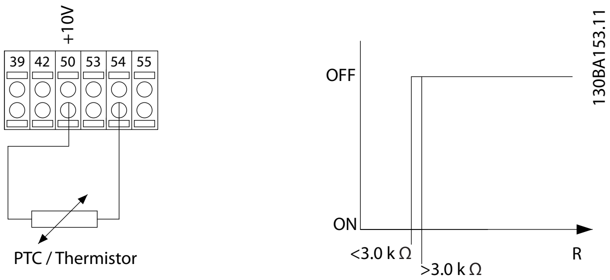


Illustration 10.3 PTC Thermistor Connection - Analog Input with 10 V Supply

Using a digital input and 24 V as supply

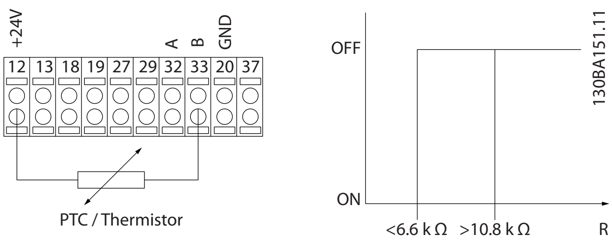


Illustration 10.4 PTC Thermistor Connection - Digital Input with 24 V Supply

Check that the selected supply voltage follows the specification of the used thermistor element.

Input digital/ analog	Supply voltage [V]	Trip resistance kΩ	Reset resistance
Digital	10	>2.7	<800 Ω
Analog	10	>3.0	<3.0 kΩ
Digital	24	>10.8	<6.6 kΩ

Table 10.2 PTC Thermistor Resistance Parameters

10.4.1.2 KTY Sensor

The frequency converter handles 3 types of KTY sensors:

- KTY Sensor 1: 1 kΩ at 100 °C (212 °F). Philips KTY 84-1 is an example.
- KTY Sensor 2: 1 kΩ at 25 °C (77 °F). Philips KTY 83-1 is an example.
- KTY Sensor 3: 1 kΩ at 25 °C (77 °F). Philips KTY-10 is an example.

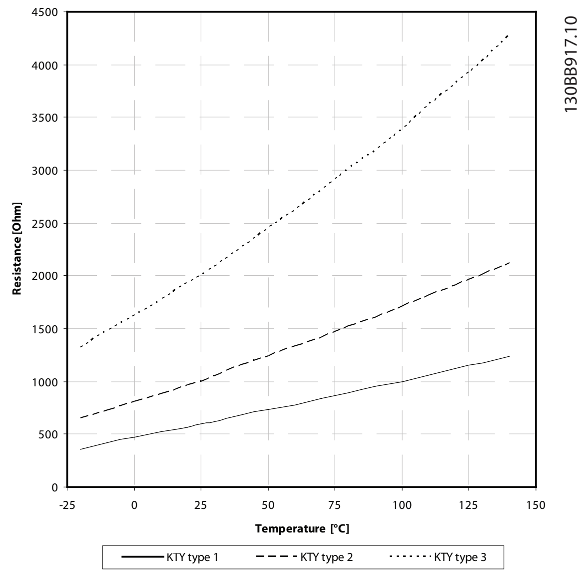


Illustration 10.5 KTY Type Selection

NOTICE

PELV COMPLIANCE

If short circuits occur between motor windings and the sensor, PELV compliance is not achieved when the motor temperature is monitored via a thermistor or KTY sensor. Ensure that the sensor is isolated better.

10.4.1.3 Brake Resistor Thermal Switch Installation

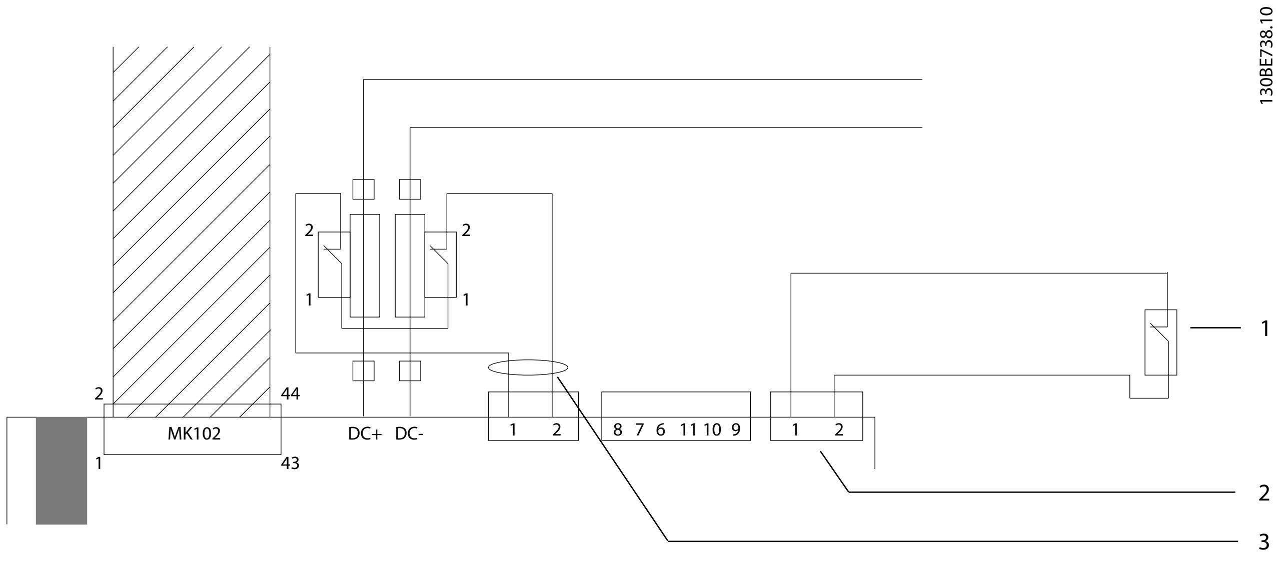
Each drive module has a brake fault jumper connector on the top plate, which is used to connect the Klixon thermal switch on the brake resistors. See *Illustration 10.6*. This connector has a pre-installed jumper. The brake fault jumper must always be in place to ensure proper operation of the drive module. Without this jumper connection, the drive module does not allow the inverter to operate, and a brake IGBT fault is shown.

The thermal switch is a normally closed type. If the brake resistor temperature exceeds recommended values, the thermal switch opens. Use 1 mm^2 (18 AWG), reinforced and double insulated wire for the connection.

10

NOTICE

Danfoss is not responsible for the failure of any Klixon thermal switch.



1	Klixon switch	3	Ferrite core
2	BRF connector	–	–

Illustration 10.6 Klixon Switch Connection

10.5 Motor Terminal Connections

WARNING

INDUCED VOLTAGE

Induced voltage from output motor cables from different frequency converters 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 frequency converters.**

Advice when connecting motor terminals:

- Comply with local and national electrical codes for cable sizes. For maximum cable sizes, see *chapter 6.5 Power-dependent Specifications*.
- Follow motor manufacturer wiring requirements.
- Do not wire a starting or pole-changing device (such as Dahlander motor or slip ring asynchronous motor) between the drive system and the motor.

10.5.1.1 Motor Cable Configuration

All types of 3-phase asynchronous standard motors can be used with the drive system.

Factory setting is for clockwise rotation with the drive system output connected as follows:

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

Table 10.3 Motor Cable Terminals

Changing motor rotation

- Terminal U/T1/96 connected to U-phase
- Terminal V/T2/97 connected to V-phase
- Terminal W/T3/98 connected to W-phase

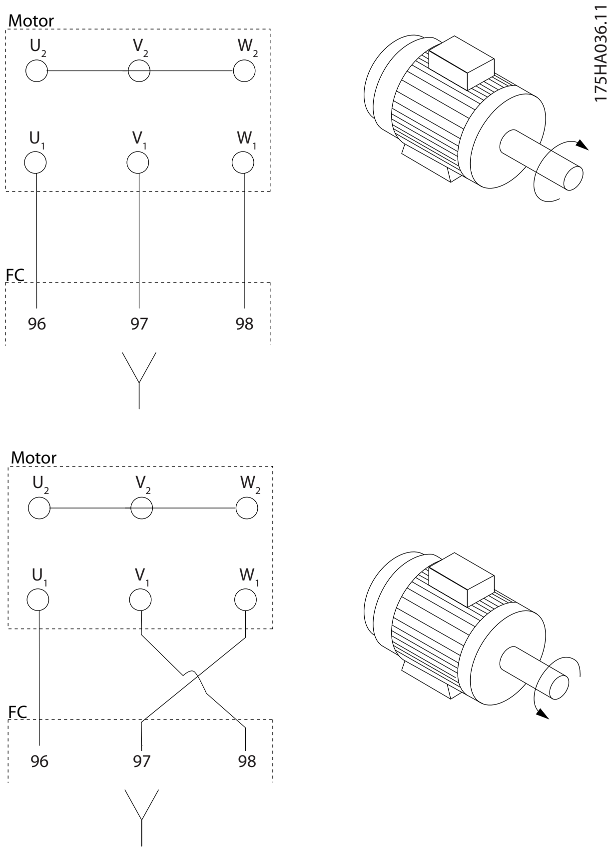


Illustration 10.7 Changing Motor Rotation

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 steps shown in *Illustration 10.7*.

10.5.1.2 Drive System Configuration

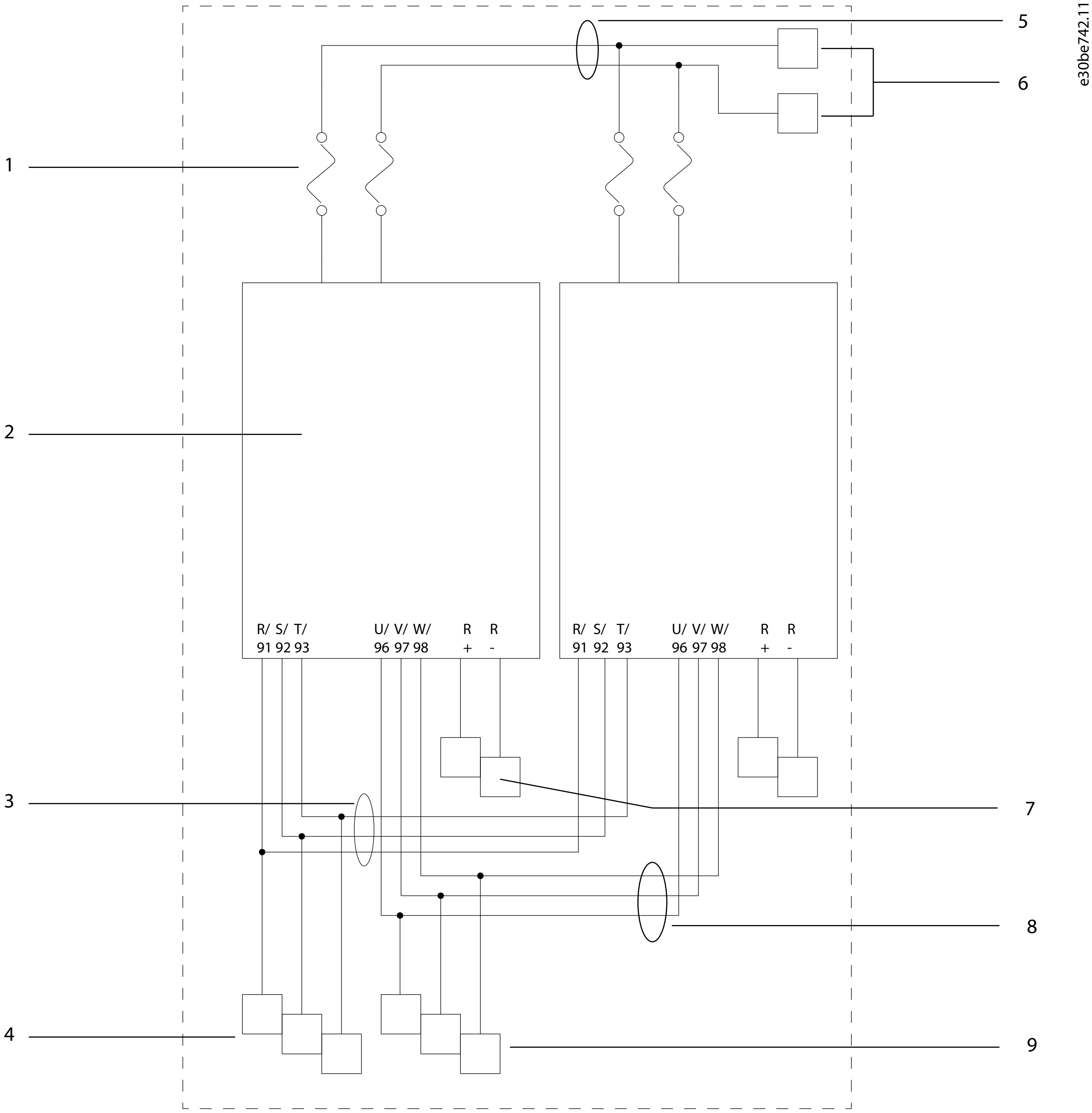
NOTICE

MULTIPLE MOTOR TERMINALS

If connecting more than 1 set of motor terminals, use the same number, size, and length of cables for each set of terminals. For example, do not use 1 cable on one motor terminal and 2 cables on another motor terminal.

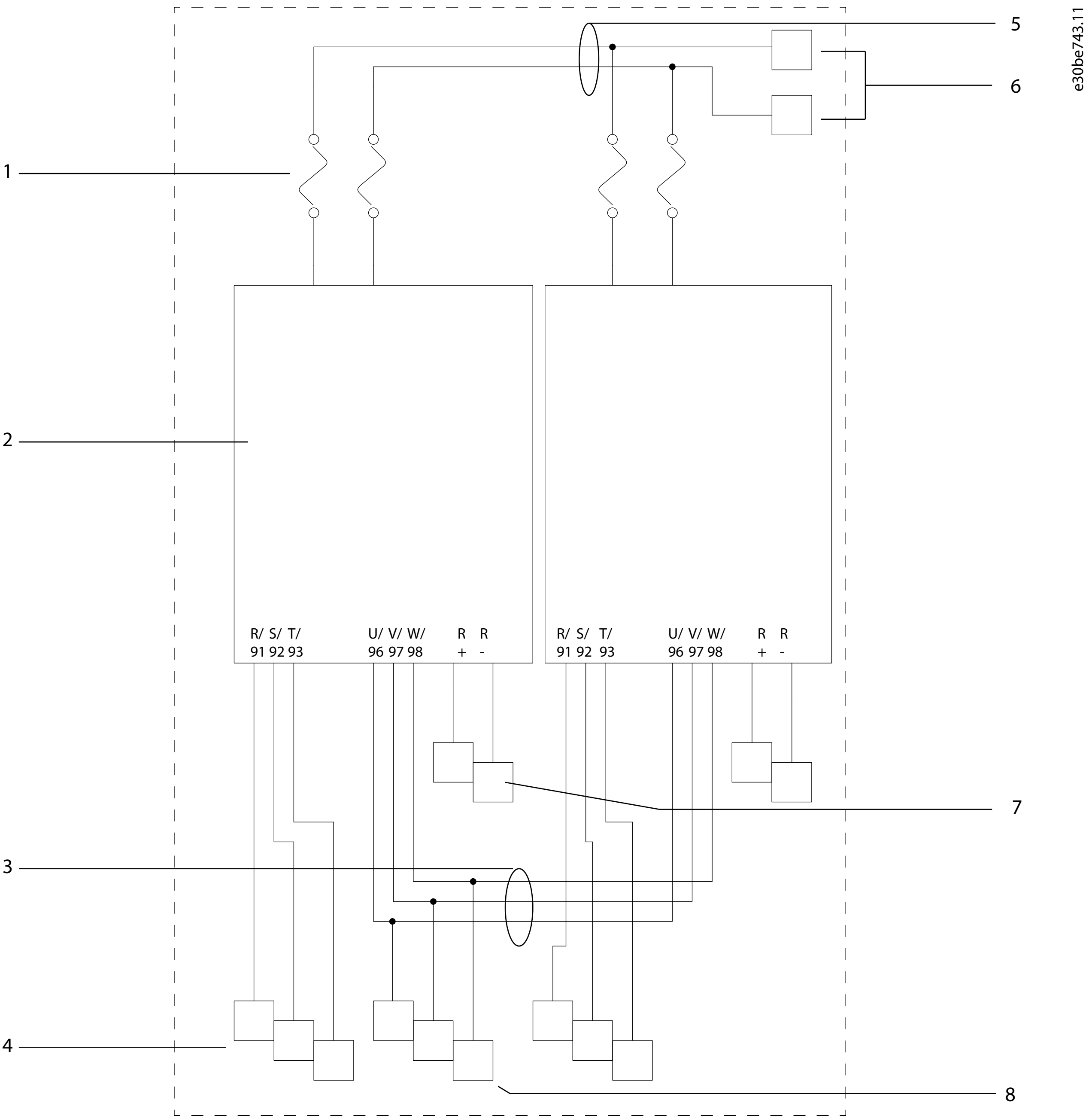
2-drive module systems

Illustration 10.8 and *Illustration 10.9* show the busbar connections for 6-pulse and 12-pulse 2-drive systems, respectively. If a common terminal design is used, there is 1 set of motor terminals.



1	DC fuses	5	DC-link busbars
2	Drive modules	6	DC terminals
3	Mains input busbars	7	Brake terminals
4	Mains input terminals	8	Motor output busbars

Illustration 10.8 Connections in 6-Pulse 2-Drive Module System

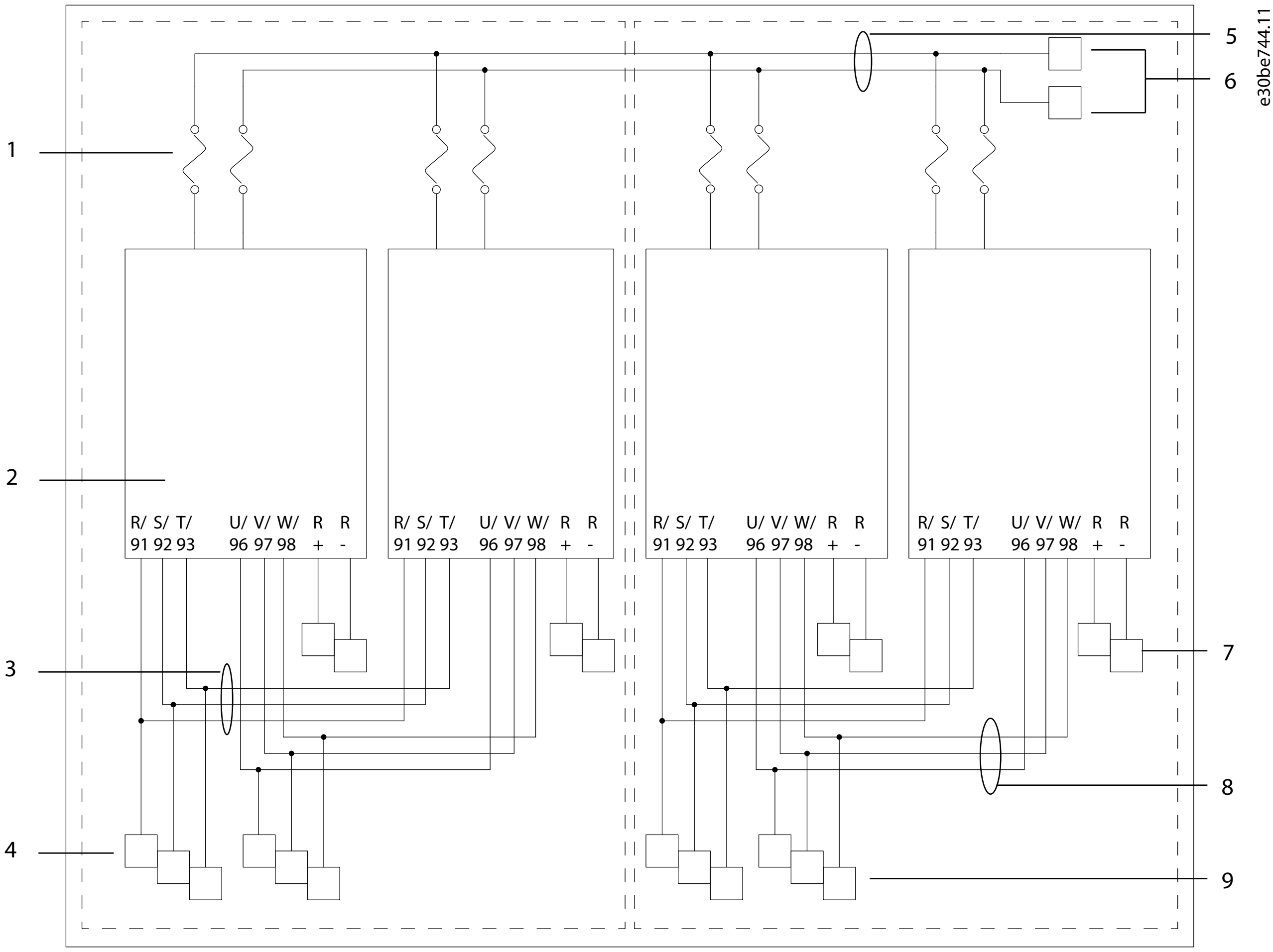


1	DC fuses	5	DC-link busbars
2	Drive modules	6	DC terminals
3	Motor output busbars	7	Brake terminals
4	Mains input terminals	8	Motor output terminals

Illustration 10.9 Connections in 12-Pulse 2-Drive Module System

4-drive module systems

Illustration 10.10 shows the busbar connections for a 4-drive system. If a common terminal design is used, there is 1 set of motor terminals in each cabinet.



1	DC fuses	6	DC terminals
2	Drive module	7	Brake terminals
3	Mains input busbars	8	Motor output busbars
4	Mains input terminals	9	Motor output terminals
5	DC-link busbars	–	–

Illustration 10.10 Connections in 4-Drive Module System

10.6 Extreme Running Conditions

Short circuit (motor phase–phase)
The frequency converter is protected against short circuits by current measurement in each of the 3 motor phases or in the DC link. A short circuit between 2 output phases causes an overcurrent in the inverter. The inverter turns off individually when the short-circuit current exceeds the allowed value (*alarm 16, Trip Lock*).
To protect the frequency converter against a short circuit at the load sharing and brake outputs, see *Application Note for FC 100, FC 200, and FC 300 Fuses and Circuit Breakers*.
See certificate in *chapter 3 Approvals and Certifications*.

Switching on the output
Switching on the output between the motor and the frequency converter is fully allowed. Switching on the output does not damage the frequency converter, but fault messages can appear.

Motor-generated overvoltage
The voltage in the DC link increases in the following cases:

- When the load generates energy, the load drives the motor at a constant output frequency from the frequency converter.
- During deceleration (ramp-down) when 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 in the frequency converter or motor.
- Incorrect slip compensation setting can cause 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 frequency converter and cause damage. To help prevent this scenario, 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*.
  If it is possible that the motor may overspeed, Danfoss recommends to equip the frequency converter with a brake resistor.

NOTICE

The frequency converter must be equipped with a brake chopper.

If possible, the control unit may attempt to correct the ramp (*parameter 2-17 Over-voltage Control*). The inverter turns off to protect the transistors and the DC-link capacitors when a certain voltage level is reached. To select the method used for controlling the DC-link voltage level, see *parameter 2-10 Brake Function* and *parameter 2-17 Over-voltage Control*.

NOTICE

OVC cannot be activated when running a PM motor (when *parameter 1-10 Motor Construction* is set to *[1] PM non-salient SPM*).

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

Static overload in VVC+ mode
An overload occurs when the torque limit in *parameter 4-16 Torque Limit Motor Mode*/ *parameter 4-17 Torque Limit Generator Mode* is reached. When the frequency converter is overloaded, the controls reduce the output frequency to reduce the load. If the overload is excessive, a current can occur that makes the frequency converter cut out after 5–10 s. Operation within the torque limit is limited in time (0–60 s) in *parameter 14-25 Trip Delay at Torque Limit*.

10.6.1 Motor Thermal Protection

To protect the application from serious damages, the frequency converter offers several dedicated features.

Torque limit
The motor is protected 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*. 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 current limit warning trips is controlled in *parameter 14-24 Trip Delay at Current Limit*.

Minimum speed limit
Parameter 4-11 Motor Speed Low Limit [RPM] or *parameter 4-12 Motor Speed Low Limit [Hz]* limit the operating speed range to between 30 and 50/60 Hz. *Parameter 4-13 Motor Speed High Limit [RPM]* or *parameter 4-19 Max Output Frequency* limit the maximum output speed the frequency converter can provide.

ETR (electronic thermal relay)
The frequency converter ETR function measures actual current, speed, and time to calculate motor temperature and protect 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. *Illustration 10.11* provides the following example, where 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 frequency converter. The curves show the characteristic nominal speed, at twice the nominal speed and at 0.2 x the nominal speed.
At lower speeds 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 is calculating the motor temperature based on actual current and speed. The calculated temperature is visible as a readout parameter in *parameter 16-18 Motor Thermal* in the frequency converter.

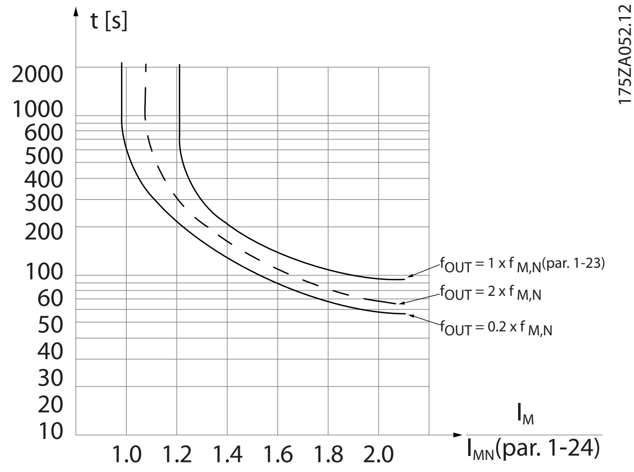


Illustration 10.11 ETR Example

10.7 dU/dt Conditions

NOTICE

To avoid the premature aging of motors that are not designed to be used with frequency converters, 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 frequency converter. For further information about dU/dt and sine-wave filters see the *VLT® FC-Series 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).
- Inductance.

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

Switching of the IGBTs causes peak voltage on the motor terminals. The frequency converter complies with the demands of IEC 60034-25 regarding motors designed for use with frequency converters. The frequency converter also complies with IEC 60034-17 regarding Norm motors controlled by frequency converters.

High-power range

The power sizes in *Table 10.4* and *Table 10.5* at the appropriate mains voltages comply with the requirements of IEC 60034-17 regarding normal motors controlled by frequency converters, IEC 60034-25 regarding motors designed for use with frequency converters, and NEMA MG 1-1998 Part 31.4.4.2 for inverter fed motors. The power sizes in *Table 10.4* do not comply with NEMA MG 1-1998 Part 30.2.2.8 for general-purpose motors.

Filter	Cable length (m (ft))	Mains voltage (V)	Raise time (µs)	Vpeak (kV)	dU/dt (kV/µs)
None	150 (492)	400	0.818	1.06	3.249
Individual			1.692	1.22	0.579
Common			2.262	1.17	0.415

Table 10.4 dU/dt Specifications for 380–500 V Units

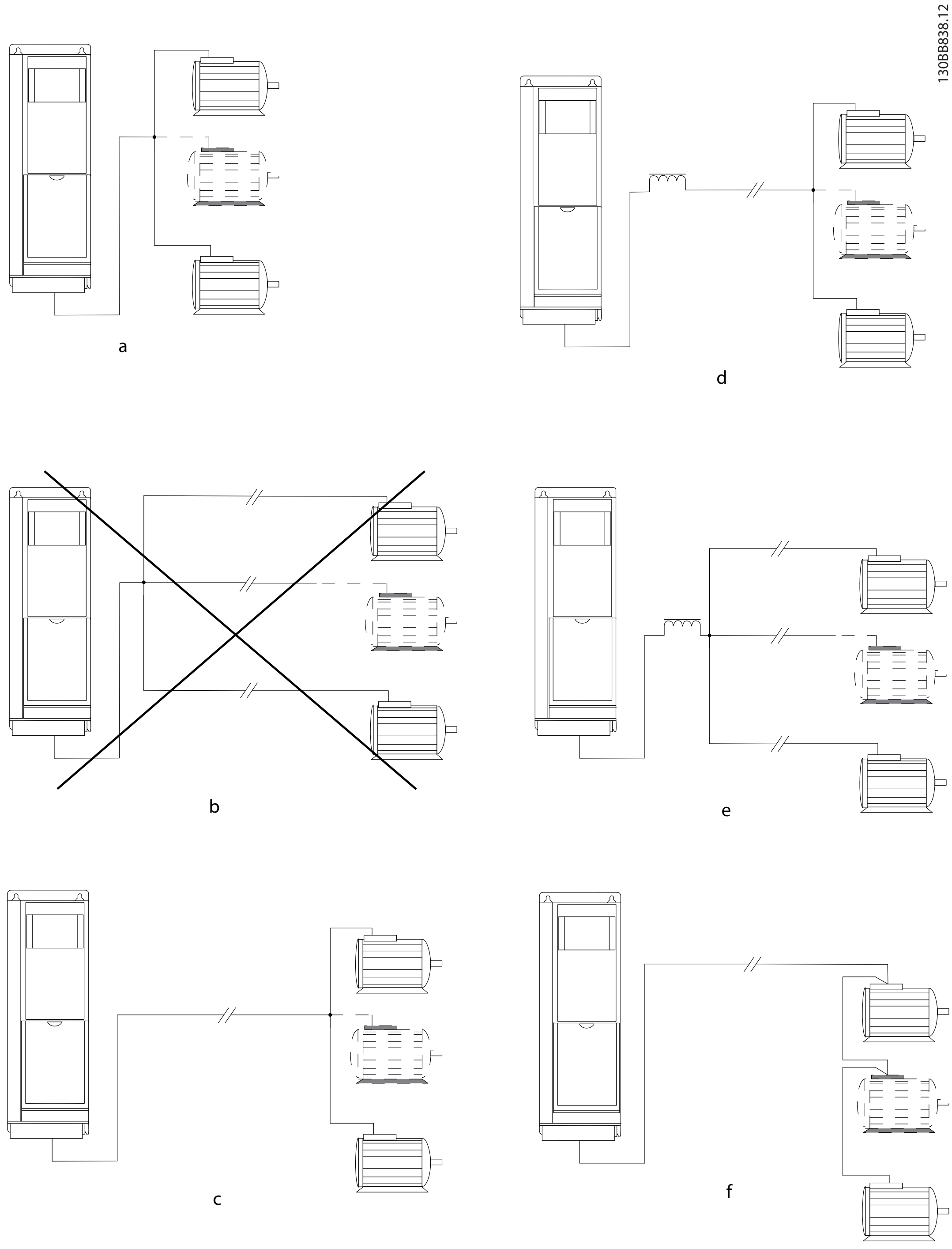
Filter	Cable length (m (ft))	Mains voltage (V)	Raise time (µs)	Vpeak (kV)	dU/dt (kV/µs)
None	150 (492)	690	0.65	1.79	2.184
Individual			1.76	2.2	0.909
Common			2.02	2.1	0.831

Table 10.5 dU/dt Specifications for 525–690 V Units

10.8 Parallel Connection of Motors

The frequency converter can control several parallel-connected motors. 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 frequency converter.
- 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 frequency converter cannot be used as motor protection. Provide further motor protection by including thermistors in each motor winding or individual thermal relays.
- When motors are connected in parallel, *parameter 1-02 Flux Motor Feedback Source* cannot be used, and *parameter 1-01 Motor Control Principle* must be set to *[0] U/f*.



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 *chapter 6.10 Cable Specifications*.
C	The total motor cable length specified in *chapter 6.10 Cable Specifications* is valid as long as the parallel cables are kept short less than 10 m (32 ft) each. See example 1.
D	Consider voltage drop across the motor cables. See example 1.
E	Consider voltage drop across the motor cables. See example 2.
F	The total motor cable length specified in *chapter 6.10 Cable Specifications* is valid as long as the parallel cables are kept less than 10 m (32 ft) each. See example 2.

Illustration 10.12 Different Parallel Connections of Motors

11 Mains

11.1 Mains Configurations

There are several types of AC mains systems for supplying power to frequency converters. Each affects the EMC characteristics of the system. The 5-wire TN-S systems are regarded as best regarding EMC, while the isolated IT system is the least preferred.

System type	Description
TN mains systems	There are 2 types of TN mains distribution systems: TN-S and TN-C.
TN-S	A 5-wire system with separate neutral (N) and protective earth (PE) conductors. It provides the best EMC properties and avoids transmitting interference.
TN-C	A 4-wire system with a common neutral and protective earth (PE) conductor throughout the system. The combined neutral and PE conductor results in poor EMC characteristics.
TT mains systems	A 4-wire system with a grounded neutral conductor and individual grounding of the drive system. It has good EMC characteristics when grounded properly.
IT grid system	An isolated 4-wire system with the neutral conductor either not grounded or grounded via an impedance.

Table 11.1 AC Mains Systems and EMC Characteristics

11.2 Mains Terminal Connections

When connecting the mains, observe the following:

- Size the wiring based on the input current of the frequency converter. For maximum wire sizes, see *chapter 6.5 Power-dependent Specifications*.
- Comply with local and national electrical codes for cable sizes.

NOTICE

MULTIPLE MAINS CABLES

If connecting more than 1 set of mains terminals, use the same number, size, and length of cables for each set of terminals. For example, do not use 1 cable on one mains terminal and 2 cables on another mains terminal.

2-drive module systems

Illustration 10.8 and *Illustration 10.9* show the mains terminal connections for 6-pulse and 12-pulse 2-drive systems, respectively.

- If a common terminal design is used with a 6-pulse, 2-drive system, there is 1 set of mains terminals.
- Common terminal design cannot be used with 12-pulse connection of mains in a 2-drive module systems. The mains cables are connected directly to the drive input terminals.
- There are individual brake terminals available in each drive module. Connect an equal number of recommended cables to the individual brake terminals.

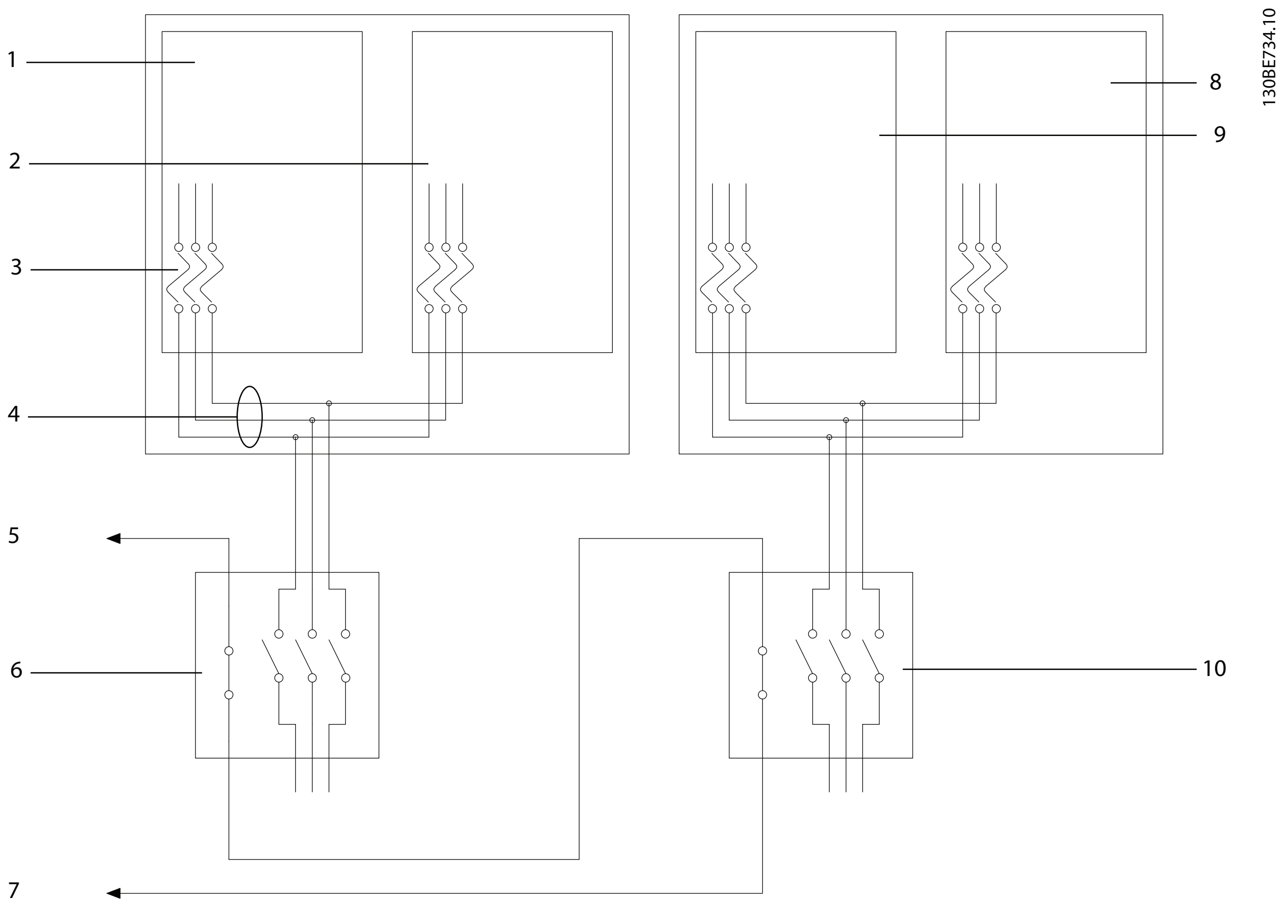
4-drive module systems

Illustration 10.10 shows the mains terminal connections for 4-drive systems. If a common terminal design is used, there is 1 set of mains terminals in each cabinet.

11.3 12-pulse Disconnector Configuration

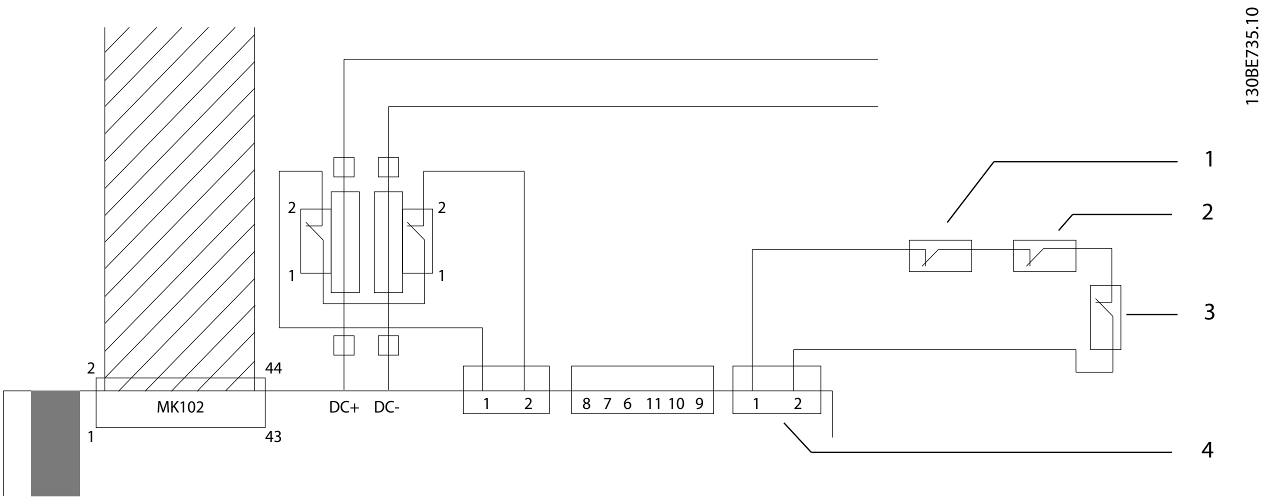
This section describes how to use a disconnector for a 12-pulse drive system. When using disconnectors or contactors, make sure to install an interlock. See *Illustration 11.1*. When installed, both contactors or disconnectors must close to avoid 1 set of rectifiers not working.

Use NC auxiliary contacts with contactors or mains disconnectors. Connect the interlock in series with the Klixon switch of the brake. If only 1 contactor/disconnector has closed, the LCP shows the error *Brake IGBT Fault* and does not allow the drive system to power the motor. *Illustration 11.2* shows a BRF connection with 12-pulse disconnector and interlock.



1	Drive module 1	6	Disconnector 1
2	Drive module 2	7	Brake fault
3	Supplementary fuses	8	Drive module 3
4	Mains input busbars	9	Drive module 4
5	Brake fault	10	Disconnector 2

Illustration 11.1 Connection of 12-Pulse Disconnector/Interlock



1	Auxiliary contact disconnector 1	3	Klixon switch
2	Auxiliary contact disconnector 2	4	BRF connector

Illustration 11.2 BRF Connection with 12-Pulse Disconnector/Interlock

NOTICE

If the brake option is not selected, the Klixon switch can be bypassed.

NOTICE

Danfoss is not responsible for any failure or malfunction in the disconnector/contactor switch.

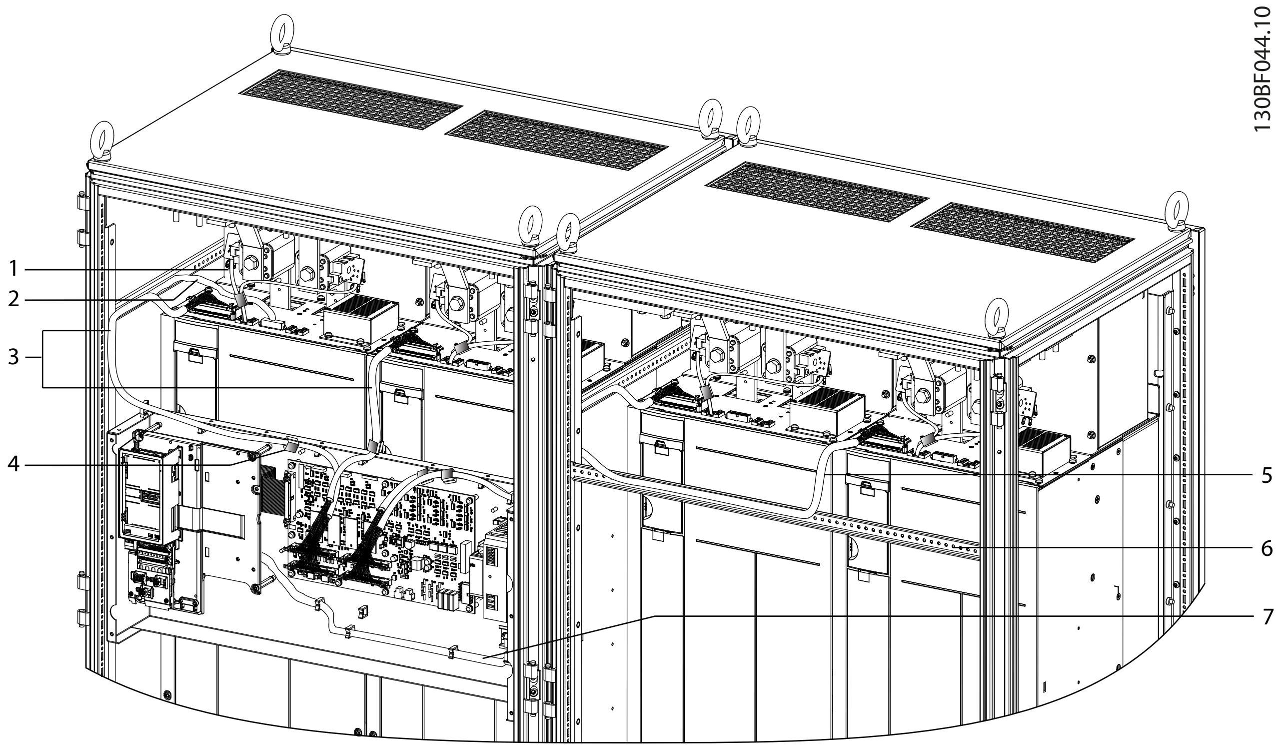
12 Control Wiring

12.1 Control Cable Routing

Cable routing

Route the cable inside the frequency converter cabinets as shown in *Illustration 12.1*. Wire routing for a 2-drive configuration is identical, except for the number of drive modules used.

- Isolate the control wiring from the high-power components in the drive modules.
- When the drive module 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. See *Illustration 12.2*.



1	Microswitch cable	5	44-pin ribbon cable from MDCIC to drive module 4
2	Relay cable (shown connected to terminal on top of module)	6	Bracket to support ribbon cable
3	44-pin ribbon cable from MDCIC to drive modules 1 and 2	7	Relay cable (shown connected to relay terminal on control shelf)
4	Ferrite core	–	–

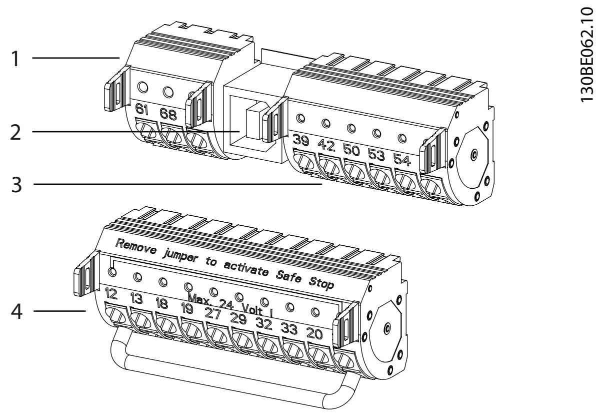
Illustration 12.1 Control Cable Routing for a 4-Drive System

12

12.2 Control Terminals

12.2.1 Control Terminal Types

Illustration 12.2 shows the removable frequency converter connectors. Terminal functions and default settings are summarized in *Table 12.1*. See *Illustration 12.2* for the location of the control terminals within the unit.



1	Terminals (+)68 and (-)69 are for an RS485 serial communication connection.
2	USB port available for use with the MCT 10 Set-up Software.
3	Two analog inputs, 1 analog output, 10 V DC supply voltage, and commons for the inputs and output.
4	Four programmable digital inputs terminals, 2 extra digital terminals programmable as either input or output, a 24 V DC terminal supply voltage, and a common for optional customer-supplied 24 V DC voltage.

Illustration 12.2 Control Terminal Locations

Terminal	Parameter	Default setting	Description
Digital inputs/outputs			
12, 13	–	+24 V DC	Digital inputs. 24 V DC supply voltage. Maximum output current is 200 mA total for all 24 V loads. Usable for digital inputs and external transducers.
18	*Parameter 5-10 Terminal 18 Digital Input*	*[8] Start*	
19	*Parameter 5-11 Terminal 19 Digital Input*	*[10] Reversing*	
32	*Parameter 5-14 Terminal 32 Digital Input*	*[0] No operation*	
33	*Parameter 5-15 Terminal 33 Digital Input*	*[0] No operation*	
27	*Parameter 5-12 Terminal 27 Digital Input*	*[2] Coast inverse*	Selectable for digital input and output. Default setting is input.
29	*Parameter 5-13 Terminal 29 Digital Input*	*[14] Jog*	
20	–	–	Common for digital inputs and 0 V potential for 24 V supply.
37	–	Safe Torque Off (STO)	Safe input (optional). Used for STO.
Analog inputs/outputs			
39	–	–	Common for analog output.
42	*Parameter 6-50 Terminal 42 Output*	Speed 0 – high limit	Programmable analog output. The analog signal is 0–20 mA or 4–20 mA at a maximum of 500 Ω
50	–	+10 V DC	10 V DC analog supply voltage. 15 mA maximum commonly used for potentiometer or thermistor.
53	*Parameter group 6-1* Analog Input 1*	Reference	Analog input. Selectable for voltage or current. Switches A53 and A54 select mA or V.
54	*Parameter group 6-2* Analog Input 2*	Feedback	
55	–	–	Common for analog input
Serial communication			
61	–	–	Integrated RC-filter for cable shield. ONLY for connecting the shield when experiencing EMC problems.
68 (+)	*Parameter group 8-3* FC Port Settings*	–	RS485 interface. A control card switch is provided for termination resistance.
69 (-)	*Parameter group 8-3* FC Port Settings*	–	
Relays			
01, 02, 03	*Parameter 5-40 Function Relay* [0]	*[9] Alarm*	Form C relay output. Usable for AC or DC voltage and resistive or inductive loads.
04, 05, 06	*Parameter 5-40 Function Relay* [1]	*[5] Running*	

Table 12.1 Terminal Description

Extra terminals:

- 2 form C relay outputs. Location of the outputs depends on the frequency converter configuration.
- Terminals on built-in optional equipment. See the manual provided with the equipment option.

12.2.2 Wiring to Control Terminals

Terminal plugs can be removed for easy access.

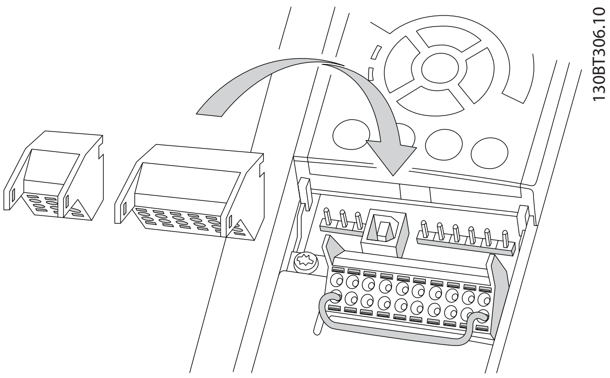


Illustration 12.3 Removal of Control Terminals

12.2.3 Enabling Motor Operation

A jumper wire is required between terminal 12 (or 13) and terminal 27 for the frequency converter to operate when using factory default programming values.

- Digital input terminal 27 is designed to receive 24 V DC external interlock command.
- When no interlock device is used, wire a jumper between control terminal 12 (recommended) or 13 to terminal 27. The jumper provides an internal 24 V signal on terminal 27.
- When the status line at the bottom of the LCP reads *AUTO REMOTE COAST*, it indicates that the unit is ready to operate but is missing an input signal on terminal 27.
- When factory installed optional equipment is wired to terminal 27, do not remove that wiring.

12.2.4 Voltage/Current Input Selection

The analog mains terminals 53 and 54 allow the setting of the input signal to voltage (0–10 V) or current (0/4–20 mA). See *Illustration 12.2* for the location of the control terminals within the drive system.

Default parameter settings:

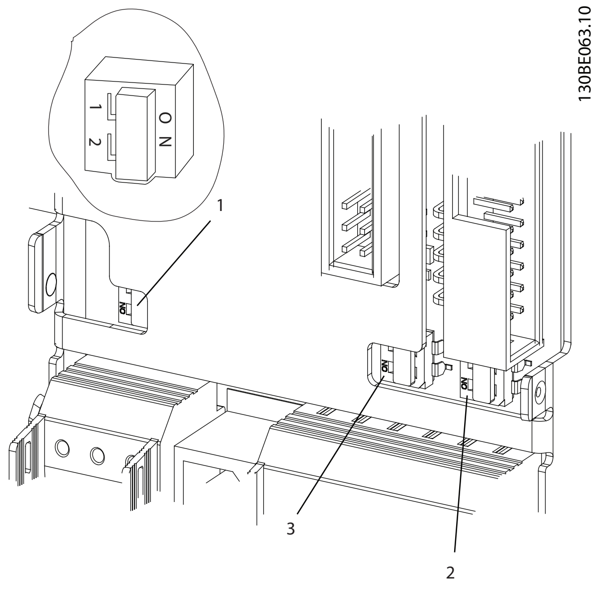
- Terminal 53: Speed reference signal in open loop (see *parameter 16-61 Terminal 53 Switch Setting*).
- Terminal 54: Feedback signal in closed loop (see *parameter 16-63 Terminal 54 Switch Setting*).

NOTICE

REMOVE POWER

Remove power to the frequency converter before changing switch positions.

1. Remove the LCP (see *Illustration 12.4*).
2. Remove any optional equipment covering the switches.
3. Set switches A53 and A54 to select the signal type. U selects voltage, I selects current.



1	Bus termination switch
2	A54 switch
3	A53 switch

Illustration 12.4 Locations of Bus Termination Switch and Switches A53 and A54

12.2.5 RS485 Serial Communication

An RS485 serial communications bus can be used with the drive system. Up to 32 nodes can be connected as a bus, or via drop cables from a common trunk line to 1 network segment. Repeaters can be used to divide network segments. Each repeater functions as a node within the segment in which it is installed. Each node connected within a given network must have a unique node address, across all segments.

- Connect RS485 serial communication wiring to terminals (+)68 and (-)69.
- Terminate each segment at both ends, using either the termination switch (bus term on/off, see *Illustration 12.4*) on the drive module, or a biased network termination resistor.
- Connect a large surface of the shield to ground, for example with a cable clamp or a conductive cable gland.
- Maintain the same ground potential throughout the network by applying potential-equalizing cables.
- Prevent impedance mismatch by using the same type of cable throughout the entire network.

Cable	**Shielded twisted pair (STP)**
Impedance	120 Ω
Maximum cable length	
Station-to-station [m (ft)]	500 (1640)
Total including drop lines [m (ft)]	1200 (3937)

Table 12.2 Cable Information

12.3 Relay Output

The relay terminal is on the top plate of the drive module. Connect the relay terminal of drive module 1 (the drive module on the far left) to the terminal blocks on the control shelf using an extended wiring harness.

NOTICE

For reference, drive modules are numbered from left to right.

Relay 1
- Terminal 01: Common
- Terminal 02: Normally open 400 V AC
- Terminal 03: Normally closed 240 V AC

Relay 2
- Terminal 04: Common
- Terminal 05: Normally open 400 V AC
- Terminal 06: Normally closed 240 V AC

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

Use VLT® Relay Card MCB 105 option module for extra relay outputs.

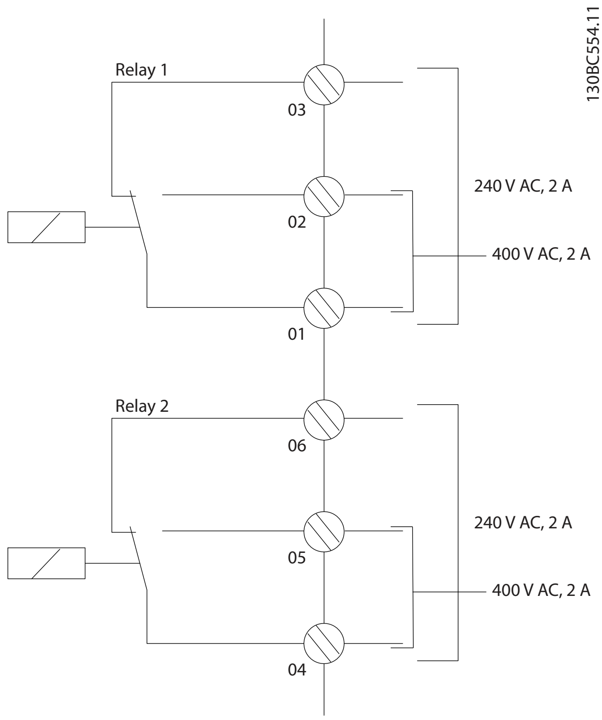


Illustration 12.5 Extra Relay Outputs

12

13 Braking

13.1 Types of Braking

The frequency converter utilizes 3 types of braking:

- Mechanical holding brake
- Dynamic brake
- Mechanical brake control

Mechanical holding brake
A mechanical holding brake is an external piece of equipment mounted directly on the motor shaft that performs static braking. Static braking is when a brake is used to clamp down on the motor after the load has been stopped. A holding brake is controlled by either a PLC or directly by a digital output from the frequency converter.

NOTICE

A frequency converter cannot provide a safe control of a mechanical brake. A redundancy circuitry for the brake control must be included in the installation.

Dynamic brake
Dynamic brake is accomplished internally within the frequency converter and is used to slow down the motor to an eventual stop. Use the following methods to apply dynamic brake:

- Resistor brake: A brake IGBT keeps the overvoltage under a certain threshold by directing the brake energy from the motor to the connected brake resistor.
- AC brake: The brake energy is distributed in the motor by changing the loss conditions in the motor. The AC brake function cannot be used in applications with high cycling frequency since this function overheats the motor.
- DC brake: An overmodulated DC current added to the AC current works as an eddy current brake.

Mechanical brake control
For hoisting applications, controlling an electro-magnetic brake is necessary. For controlling the brake, a relay output (relay 1 or relay 2) or a programmed digital output (terminal 27 or 29) is required. Normally, this output must be closed for as long as the frequency converter is unable to hold the motor.

If the frequency converter is brought into an alarm condition, such as an overvoltage situation, the mechanical brake immediately cuts in. The mechanical brake also cuts in during Safe Torque Off.

NOTICE

For vertical lifting or hoisting applications, it is strongly recommended to ensure that the load can be stopped if there is an emergency or a malfunction. If the frequency converter is in alarm mode or in an overvoltage situation, the mechanical brake cuts in.

13.2 Brake Resistor

13.2.1 Selection of Brake Resistor

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

If the amount of kinetic energy transferred to the resistor in each braking period is not known, the average power can be calculated based on the cycle time and braking time (intermittent duty cycle). The resistor intermittent duty cycle is an indication of the duty cycle at which the resistor is active. *Illustration 13.1* shows a typical braking cycle.

NOTICE

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

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

Duty cycle=t_b/T

T=cycle time in s
t_b is the braking time in s (of the cycle time)

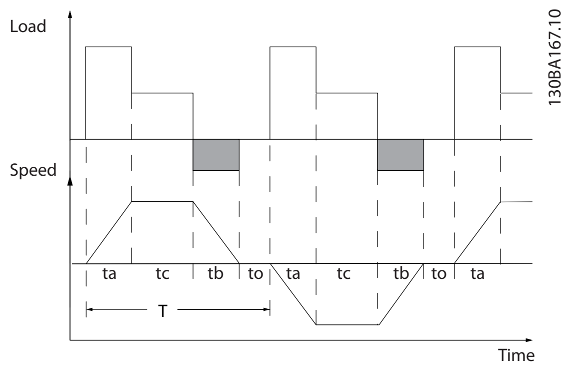


Illustration 13.1 Typical Braking Cycle

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Brake power levels

The following brake power levels apply to the VLT® Parallel Drive Modules.

Power size kW (hp)	Cycle time (s)	Braking duty cycle at 100% torque	Braking duty cycle at over torque (150%)
VLT® HVAC Drive FC 102 and VLT® AQUA Drive FC 202 (380–480 V)			
315 (450)	600	Continuous	10%
355–1000 (500–1350)	600	40%	10%
VLT® HVAC Drive FC 102 and VLT® AQUA Drive FC 202 (525–690 V)			
315–355 (450–500)	600	Continuous	10%
400–1200 (400–1350)	600	40%	10%
VLT® AutomationDrive FC 302 (380–480 V)			
250 (350)	600	Continuous	10%
315–800 (450–1200)	600	40%	10%
VLT® AutomationDrive FC 302 (525–690 V)			
250–315 (300–350)	600	Continuous	10%
355–1000 (450–1150)	600	40%	10%

Table 13.1 Brake Cycle for Parallel Drive Modules

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

Make sure that the resistor is designed to handle the required braking time. The maximum allowable load on the brake resistor is stated as a peak power at a given intermittent duty cycle. The brake resistance is calculated:

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

where

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

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

Voltage	Brake active	Warning before cut out	Cut out (trip)
380–480 V	769 V	810 V	820 V
525–690 V	1084 V	1109 V	1130 V

Table 13.2 Brake Limits for VLT® HVAC Drive FC 102 and VLT® AQUA Drive FC 202 Parallel Drive Modules

Voltage	Brake active	Warning before cut out	Cut out (trip)
380–500 V	795 V	828 V	855 V
525–690 V	1084 V	1109 V	1130 V

Table 13.3 Brake Limits for VLT® AutomationDrive FC 302 Parallel Drive Modules

NOTICE

Check that the brake resistor can handle a voltage of 410 V, 820 V, 850 V, 975 V, or 1130 V - unless Danfoss brake resistors are used.

Danfoss recommends the brake resistance R_{rec}. Using the R_{rec} formula guarantees that the frequency converter is able to brake at the highest brake power ($M_{br(\%)}$) of 160%. The formula can be written as:

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

η_{motor} is typically at 0.90

η_{VLT} is typically at 0.98

For 480 V, 500 V, and 600 V frequency converters, R_{rec} at 160% brake power is written as:

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

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

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

NOTICE

Do not select a resistor brake circuit resistance that is higher than what is recommended by Danfoss. One brake resistor per brake chopper.

NOTICE

If a short circuit occurs in the brake transistor, power dissipation in the brake resistor is only prevented by using a mains switch or contactor to disconnect the mains from the frequency converter. The frequency converter can control the contactor.

⚠WARNING

FIRE HAZARD

Brake resistors can get hot while/after braking and must be placed in a secure environment to avoid fire risk.

13.2.2 Control with Brake Function

The brake is protected against short-circuiting of the brake resistor, and the brake transistor is monitored to ensure that short-circuiting of the transistor is detected. A relay/ digital output can be used to protect the brake resistor against overloading by generating a fault in the frequency converter.

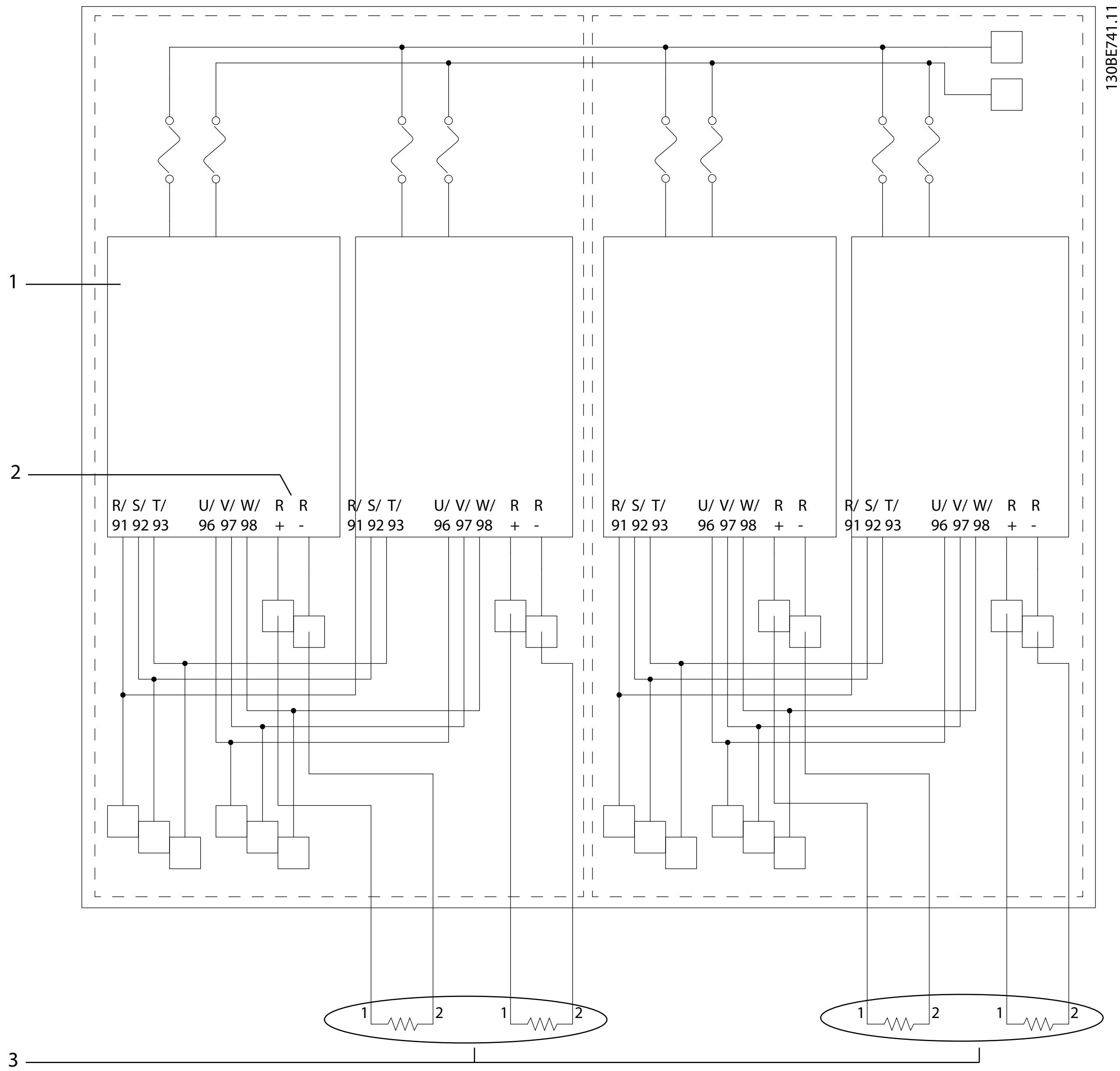
In addition, the brake makes it possible to read out the momentary power and the mean power for the latest 120 s. The brake can also monitor the power energizing and make sure that it does not exceed the programmable limit set in the LCP.

NOTICE

Monitoring the brake power is not a safety function; a thermal switch is required for that purpose. The brake resistor circuit is not ground leakage protected.

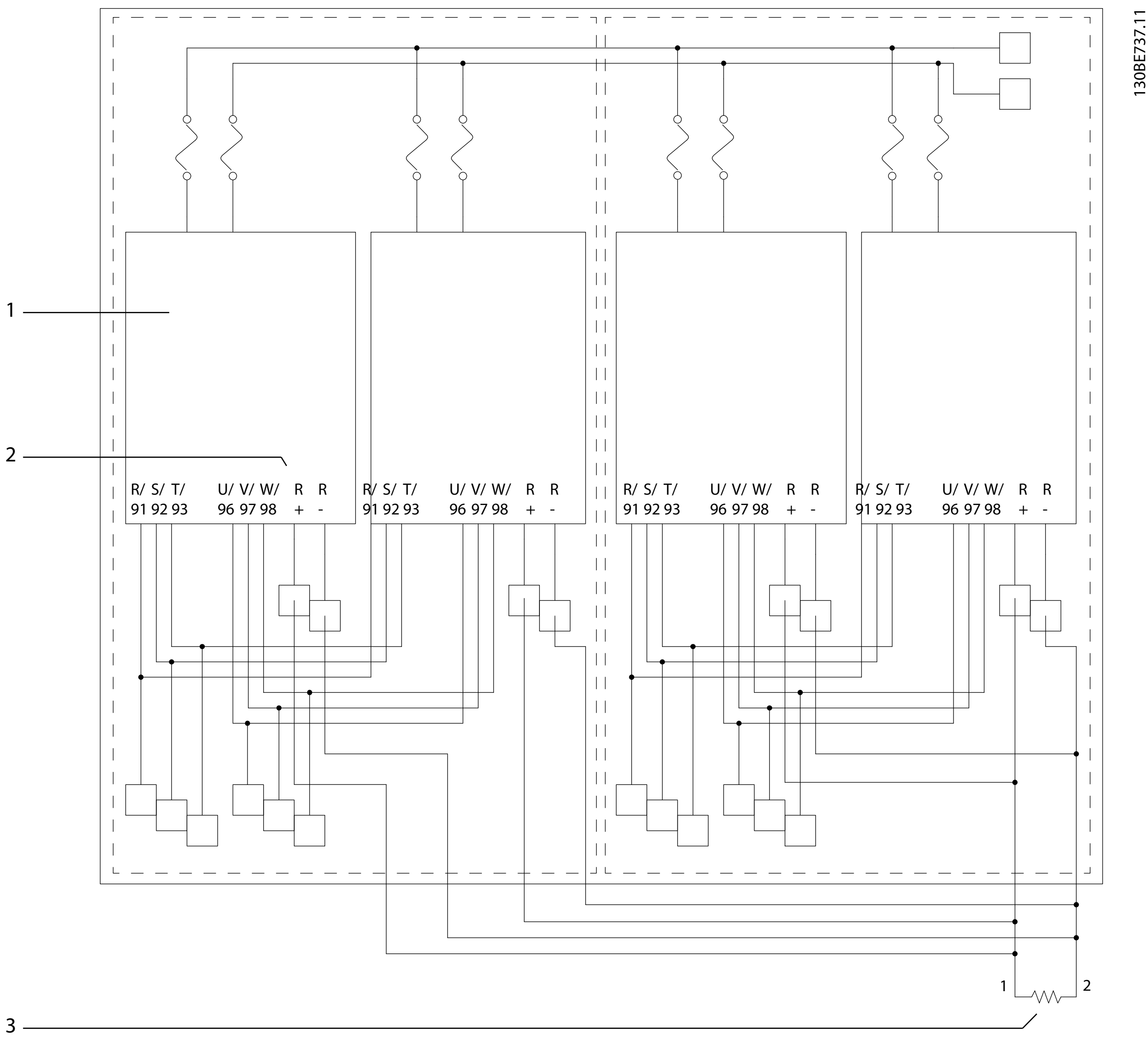
Overvoltage control (OVC) can be selected as an alternative brake function. This function is active for all units and ensures that if the DC-link voltage increases, the output frequency also increases to limit the voltage from the DC link, thereby avoiding a trip.

13.2.3 Brake Resistor Connection



1	Drive module	3	Individual brake resistors
2	Brake terminals	–	–

Illustration 13.2 Connection of Individual Brake Resistor to Each Drive Module



1	Drive module	3	Common brake resistor
2	Brake terminals	–	–

Illustration 13.3 Connection of Common Brake Resistor to Each Drive Module

14 Controls

14.1 Overview of Speed and Torque Control

The frequency converter can control either the speed or the torque on the motor shaft. Setting *parameter 1-00 Configuration Mode* determines the type of control.

Speed control

There are 2 types of speed control:

- Open loop does not require any feedback from the motor (sensorless).
- Closed loop PID requires a speed feedback to an input. A properly optimized speed closed-loop control has higher accuracy than a speed open-loop control. The speed control selects which input to use as speed PID feedback in *parameter 7-00 Speed PID Feedback Source*.

Torque control

The torque control function is used in applications where the torque on the motor output shaft is controlling the application as tension control. Torque control is selected in *parameter 1-00 Configuration Mode*, either in *[4] VVC+ open loop* or *[2] Flux control closed loop with motor speed feedback*. Torque setting is done by setting an analog, digital, or bus-controlled reference. The maximum speed limit factor is set in *parameter 4-21 Speed Limit Factor Source*. When running torque control, Danfoss recommends making a full AMA procedure since the correct motor data is essential for optimal performance.

- Closed loop in flux mode with encoder feedback offers superior performance in all 4 quadrants and at all motor speeds.
- Open loop 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 from the current measurement within the frequency converter. See *chapter 17 Application Examples*.

Speed/torque reference

The reference to these controls can either be a single reference or be the sum of various references including relatively scaled references. For more information on handling of reference, see *chapter 15 Handling of References*.

14.2 Control Principle

A frequency converter rectifies AC voltage from mains into DC voltage, after which this DC voltage is converted into AC power with a variable amplitude and frequency.

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

The control terminals provide for wiring feedback, reference, and other input signals to the following:

- Frequency converter
- Output of frequency converter status and fault conditions
- Relays to operate auxiliary equipment
- Serial communication interface

Control terminals are programmable for various functions by selecting parameter options described in the main or quick menus. Most control wiring is customer supplied unless factory ordered. A 24 V DC supply is also provided for use with the frequency converter control inputs and outputs.

Table 14.1 describes the functions of the control terminals. Many of these terminals have multiple functions determined by parameter settings. Some options provide more terminals. See *chapter 10.5 Motor Terminal Connections* for terminal locations.

Terminal number	Function
01, 02, 03 and 04, 05, 06	2 form C output relays. Maximum 240 V AC, 2 A. Minimum 24 V DC, 10 mA, or 24 V AC, 100 mA. Can be used for indicating status and warnings. Physically on the power card.
12, 13	24 V DC supply to digital inputs and external transducers. The maximum output current is 200 mA.
18, 19, 27, 29, 32, 33	Digital inputs for controlling the frequency converter. R=2 kΩ. Less than 5 V=logic 0 (open). Greater than 10 V=logic 1 (closed). Terminals 27 and 29 are programmable as digital/pulse outputs.
20	Common for digital inputs.
37	0–24 V DC input for safety stop (some units).
39	Common for analog and digital outputs.
42	Analog and digital outputs for indicating values such as frequency, reference, current, and torque. The analog signal is 0/4 to 20 mA at a maximum of 500 Ω. The digital signal is 24 V DC at a minimum of 500 Ω.
50	10 V DC, 15 mA maximum analog supply voltage for potentiometer or thermistor.
53, 54	Selectable for 0–10 V DC voltage input, R=10 kΩ, or analog signals 0/4 to 20 mA at a maximum of 200 Ω. Used for reference or feedback signals. A thermistor can be connected here.
55	Common for terminals 53 and 54.
61	RS485 common.
68, 69	RS485 interface and serial communication.

Table 14.1 Terminal Control Functions (without Optional Equipment)

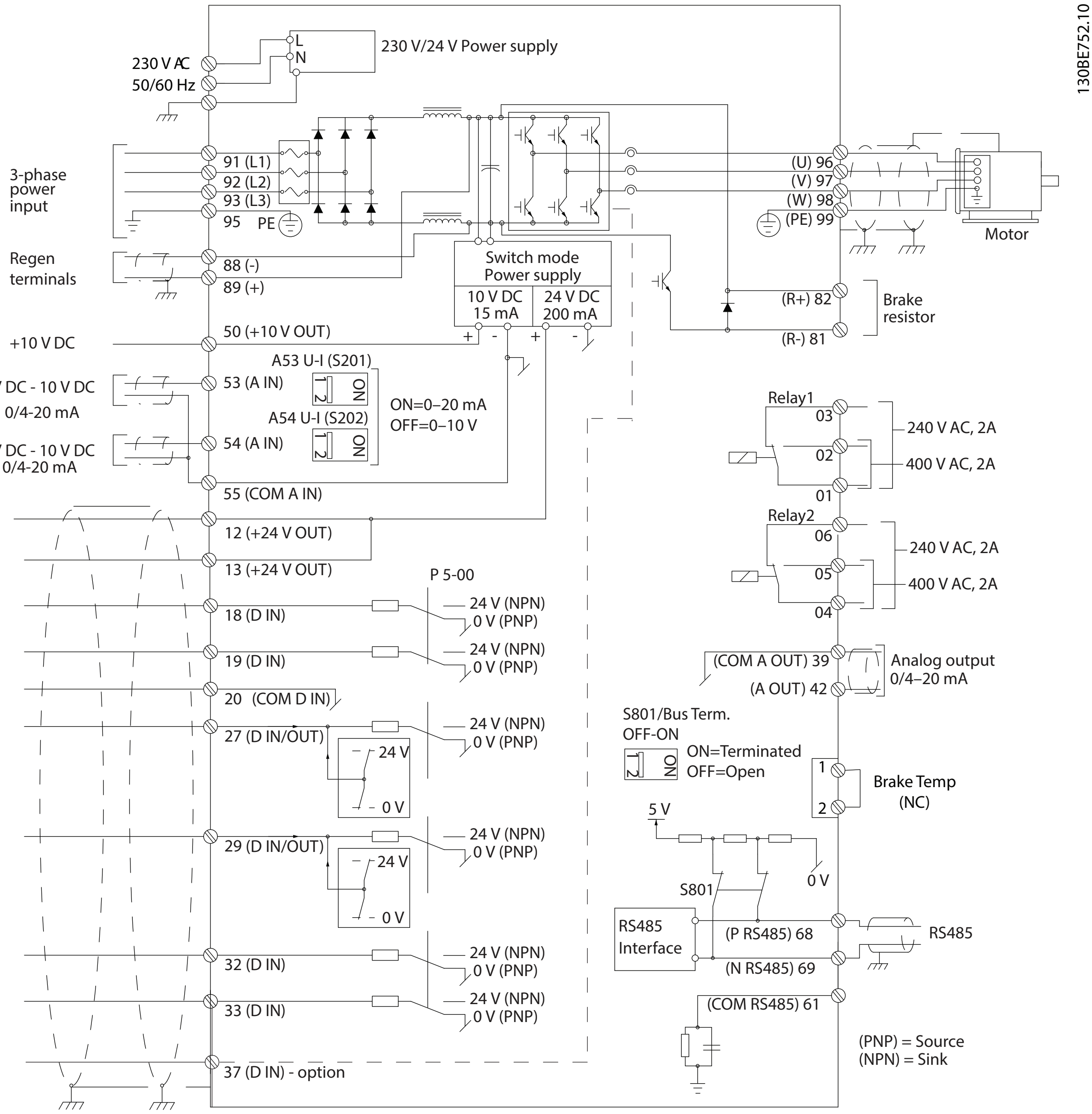


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Illustration 14.1 Wiring Diagram

14.3 Control Structure in VVC+ Advanced Vector Control

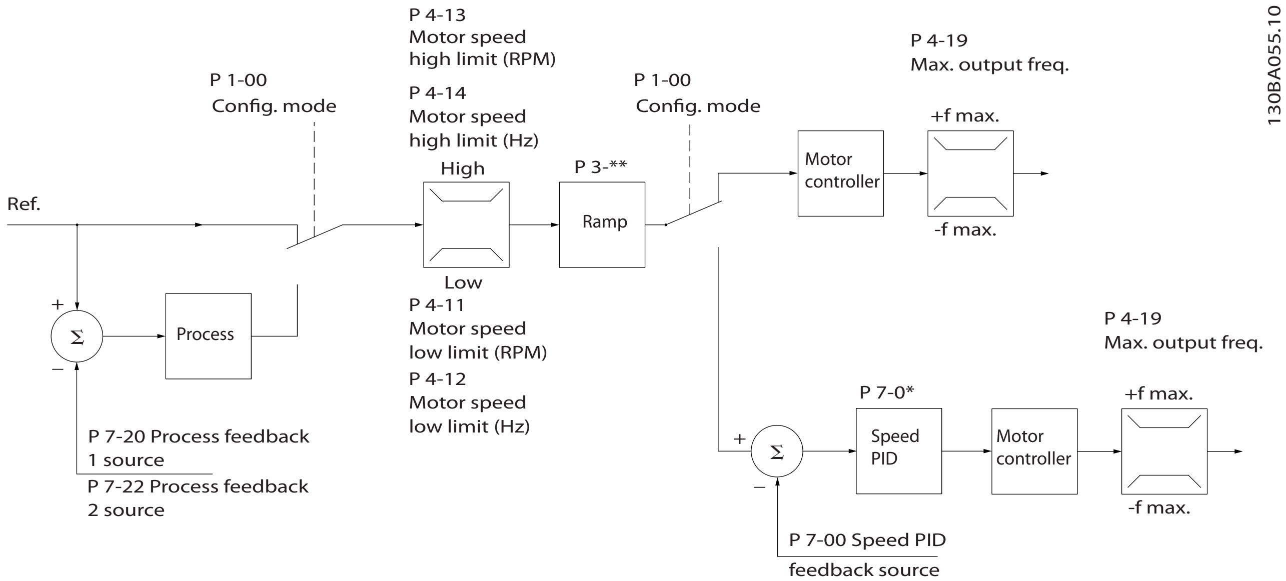

Illustration 14.2 Control Structure in VVC+ Open-loop and Closed-loop Configurations

In *Illustration 14.2*, *parameter 1-01 Motor Control Principle* is set to *[1] VVC+* and *parameter 1-00 Configuration Mode* is set to *[0] Speed open loop*. The resulting reference from the reference handling system is received and fed through the ramp limitation and speed limitation before being sent to the motor control. The output of the motor control is then limited by the maximum frequency limit.

If *parameter 1-00 Configuration Mode* is set to *[1] Speed closed loop*, the resulting reference is passed from the ramp limitation and speed limitation into a speed PID control. The speed PID control parameters are in *parameter group 7-0* Speed PID Ctrl*. The resulting reference from the speed PID control is sent to the motor control limited by the frequency limit.

To use the process PID control for closed-loop control of speed or pressure in the controlled application, for example, select *[3] Process* in *parameter 1-00 Configuration Mode*. The process PID parameters are located in *parameter group 7-2* Process Ctrl. Feedback* and *parameter group 7-3* Process PID Ctrl*.

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14.4 Control Structure in Flux Sensorless

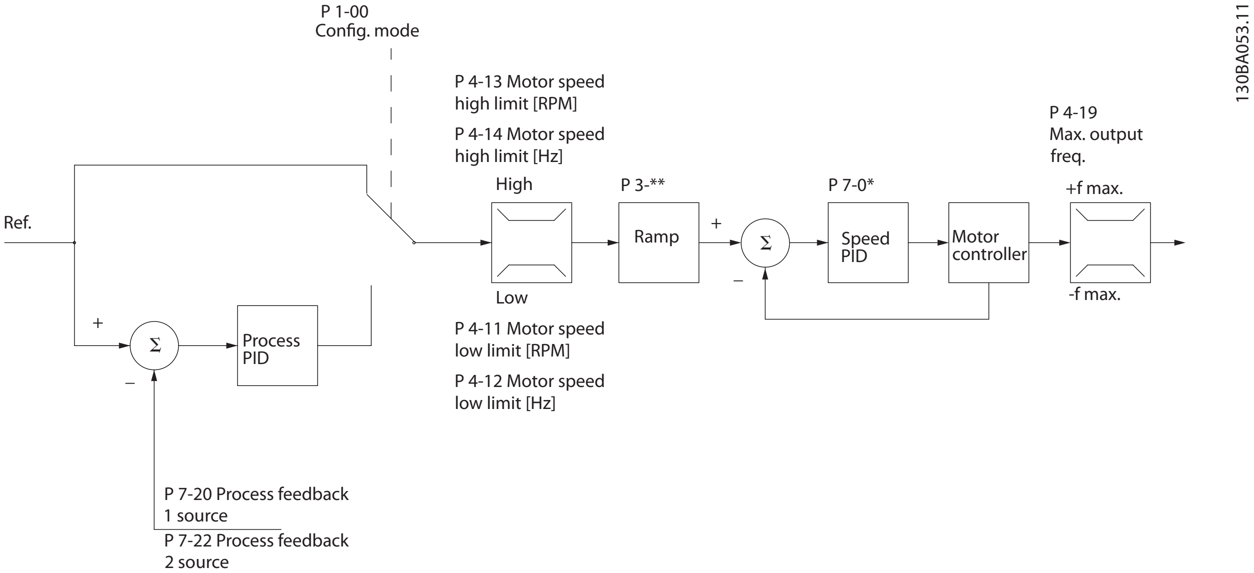

Illustration 14.3 Control Structure in Flux Sensorless Open-loop and Closed-loop Configurations

In *Illustration 14.3*, *parameter 1-01 Motor Control Principle* is set to *[2] Flux Sensorless* and *parameter 1-00 Configuration Mode* is set to *[0] Speed open loop*. The resulting reference from the reference handling system is fed through the ramp and speed limitations as determined by the parameter settings indicated.

An estimated speed feedback is generated to the speed PID to control the output frequency. The speed PID must be set with its P, I, and D parameters (*parameter group 7-0* Speed PID Ctrl*).

To use the process PID control for control of speed or pressure in the controlled application, for example, select *[3] Process* in *parameter 1-00 Configuration Mode*. The process PID parameters are found in *parameter group 7-2* Process Ctrl. Feedback* and *parameter group 7-3* Process PID Ctrl.*

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14.5 Control Structure in Flux with Motor Feedback

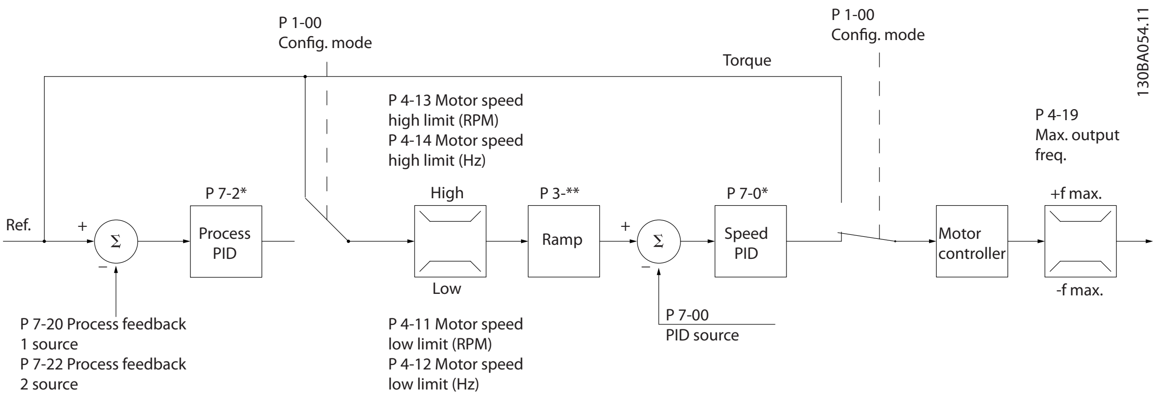

Illustration 14.4 Control Structure in Flux with Motor Feedback Configuration (only Available in VLT® AutomationDrive FC 302)

In *Illustration 14.4*, *parameter 1-01 Motor Control Principle* is set to *[3] Flux w motor feedb* and *parameter 1-00 Configuration Mode* is set to *[1] Speed closed loop*.

The motor control in this configuration relies on a feedback signal from an encoder mounted directly on the motor (set in *parameter 1-02 Flux Motor Feedback Source*).

To use the resulting reference as an input for the speed PID control, select *[1] Speed closed loop* in *parameter 1-00 Configuration Mode*. The speed PID control parameters are located in *parameter group 7-0* Speed PID Ctr.*

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

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

14.6 Internal Current Control in VVC+

The frequency converter features an integral current limit control which is activated when the motor current, and thus the torque, is higher than 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*.
When the frequency converter 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.

14.7 Local and Remote Control

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

The frequency converter can be operated manually via the LCP or remotely via analog and digital inputs and fieldbus. If allowed in *parameter 0-40 [Hand on] Key on LCP*, *parameter 0-41 [Off] Key on LCP*, *parameter 0-42 [Auto on] Key on LCP*, and *parameter 0-43 [Reset] Key on LCP*, it is possible to start and stop the frequency converter via the LCP [Hand On] and [Off]. Press [Reset] to reset the alarms. After pressing [Hand On], the frequency converter goes into hand-on mode and follows (as default) the local reference that can be set using the arrow keys on the LCP.

After pressing [Auto On], the frequency converter goes into auto-on mode and follows (as default) the remote reference. In this mode, it is possible to control the frequency converter via the digital inputs and various serial interfaces (RS485, USB, or an optional fieldbus). For information about starting, stopping, changing ramps and parameter set-ups, see *parameter group 5-1* Digital Inputs* or *parameter group 8-5* Serial Communication*.

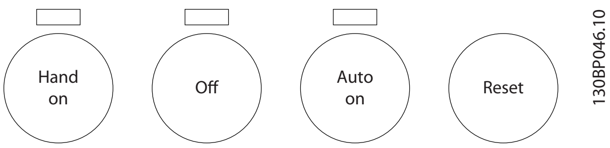

Illustration 14.5 LCP Control Keys

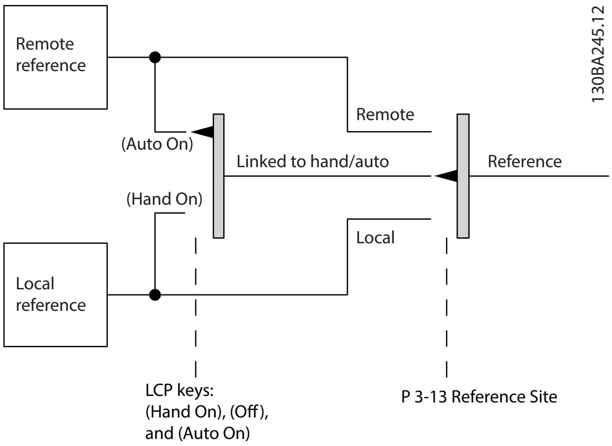

Illustration 14.6 Active Reference

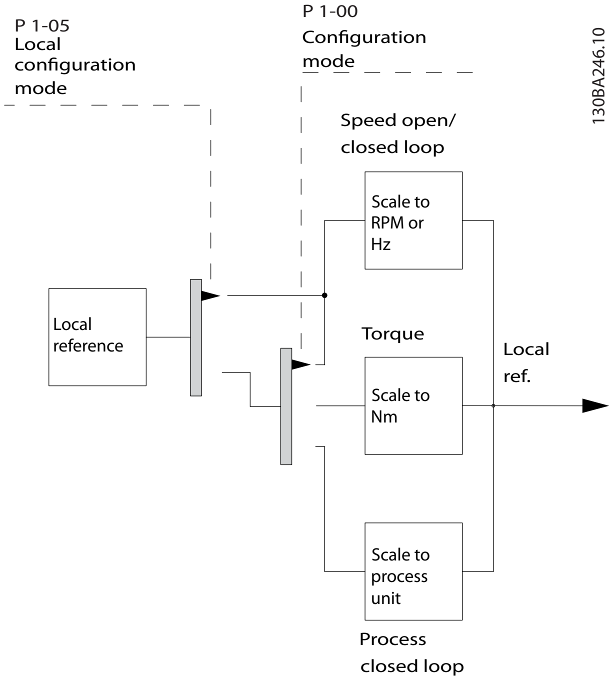

Illustration 14.7 Configuration Mode

Active reference and configuration mode

The active reference can be either the local reference or the remote reference.

The local reference can be permanently selected by selecting *[2] Local* in *parameter 3-13 Reference Site*.
To permanently select the remote reference, select *[1] Remote*. By selecting *[0] Linked to Hand/Auto* (default), the reference site depends on whether hand-on mode or auto-on mode is active.

[Hand On]	*Parameter 3-13 Reference Site*	Active reference
Hand	Linked to Hand/Auto	Local
Hand⇒Off	Linked to Hand/Auto	Local
Auto	Linked to Hand/Auto	Remote
Auto⇒Off	Linked to Hand/Auto	Remote
All keys	Local	Local
All keys	Remote	Remote

Table 14.2 Conditions for Local/Remote Reference Activation

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Parameter 1-00 Configuration Mode determines what kind of application control principle (for example, speed, torque, or process control) is used when the remote reference is active. *Parameter 1-05 Local Mode Configuration* determines the kind of application control principle that is used when the local reference is active. One of them is always active, but both cannot be active at the same time.

14.8 Smart Logic Controller

Smart logic control (SLC) is a sequence of user-defined actions (see *parameter 13-52 SL Controller Action* [x]) executed by the SLC when the associated user-defined event (see *parameter 13-51 SL Controller Event* [x]) is evaluated as true by the SLC.
The condition for an event can be a particular status or when the output from a logic rule or a comparator operand becomes true. This condition leads to an associated action as shown in *Illustration 14.8*.

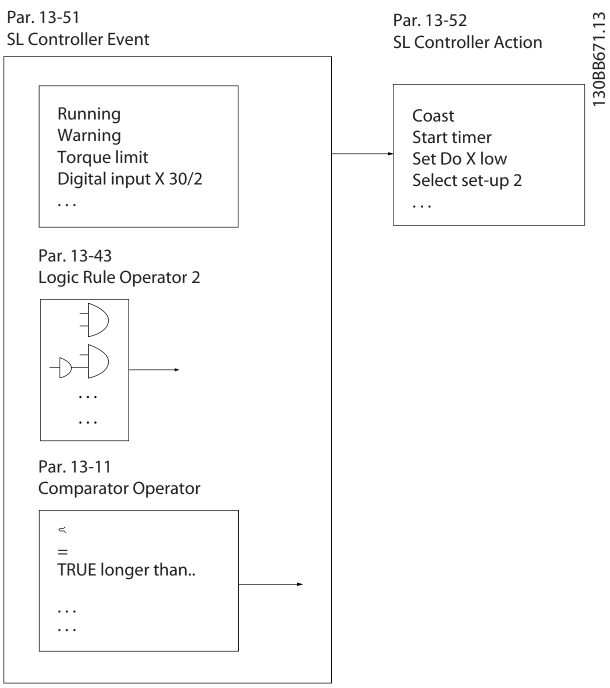

Illustration 14.8 Current Control Status/Event and Action

Events and actions are each numbered and linked together in pairs (states). For example, when *[0] event* is fulfilled (attains the value true), *[0] action* is executed. Afterwards, the conditions of *[1] event* are evaluated and if evaluated true, *[1] action* is executed, and so on. Only 1 event is evaluated at any time. If an event is evaluated as false, nothing happens in the SLC during the current scan interval and no other events are evaluated. When the SLC starts, it evaluates only *[0] event* each scan interval. Only when *[0] event* is evaluated true, the SLC executes *[0] action* and starts evaluating *[1] 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 *[0] event/[0] action*. *Illustration 14.9* shows an example with 3 event/actions:

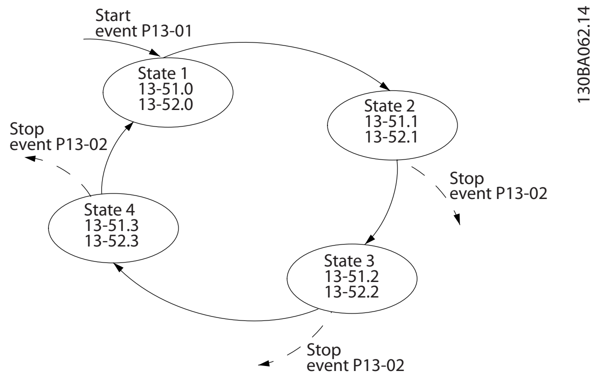

Illustration 14.9 Internal Current Control Example

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

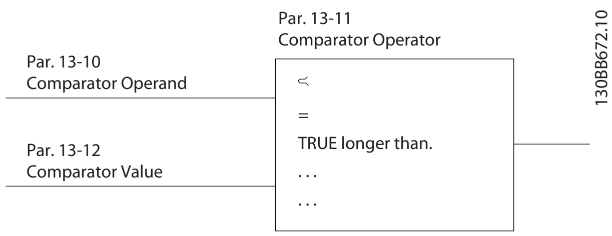

Illustration 14.10 Comparators

Logic rules
Combine up to 3 boolean (true/false) inputs from timers, comparators, digital inputs, status bits, and events using the logical operators AND, OR, and NOT.

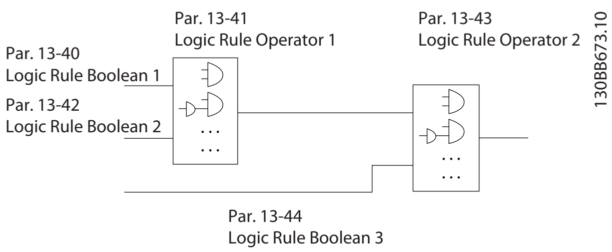

Illustration 14.11 Logic Rules

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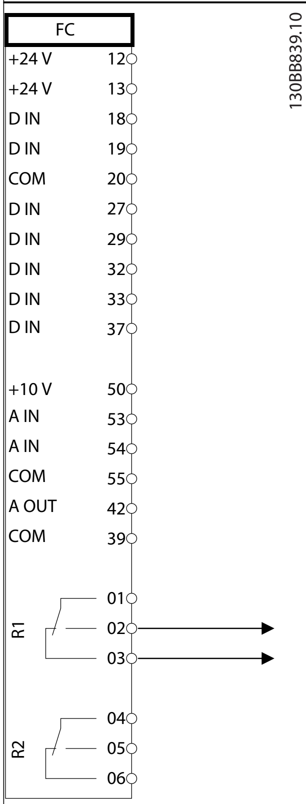
Application example



Parameters	
Function	**Setting**
Parameter 4-30 Motor Feedback Loss Function	*[1] Warning*
Parameter 4-31 Motor Feedback Speed Error	100 RPM
Parameter 4-32 Motor Feedback Loss Timeout	5 s
Parameter 7-00 S peed PID Feedback Source	*[2] MCB 102*
Parameter 17-11 Resolution (PPR)	1024*
Parameter 13-00 SL Controller Mode	*[1] On*
Parameter 13-01 Start Event	*[19] Warning*
Parameter 13-02 Stop Event	*[44] Reset key*
Parameter 13-10 Comparator Operand	*[21] Warning no.*
Parameter 13-11 Comparator Operator	[1] ≈*
Parameter 13-12 Comparator Value	90
Parameter 13-51 SL Controller Event	*[22] Comparator 0*
Parameter 13-52 SL Controller Action	*[32] Set digital out A low*
Parameter 5-40 F unction Relay	*[80] SL digital output A*
*=Default Value	

Notes/Comments:

If the limit in the feedback monitor is exceeded, *warning 90, Feedback Monitor* is issued. The SLC monitors *warning 90, Feedback Monitor*. If *warning 90, Feedback Monitor* becomes true, relay 1 is triggered.

External equipment may then indicate that service may be required. If the feedback error goes below the limit again within 5 s, the frequency converter continues and the warning disappears. Press [Reset] on the LCP to reset relay 1.

Table 14.3 Using SLC to Set a Relay

15 Handling of References

Local reference
The local reference is active when the frequency converter is operated with the [Hand On] key active. Adjust the reference by using the [▲/▼] and [◄/►] keys.

Remote reference
The system for calculating the reference is shown in *Illustration 15.1*.

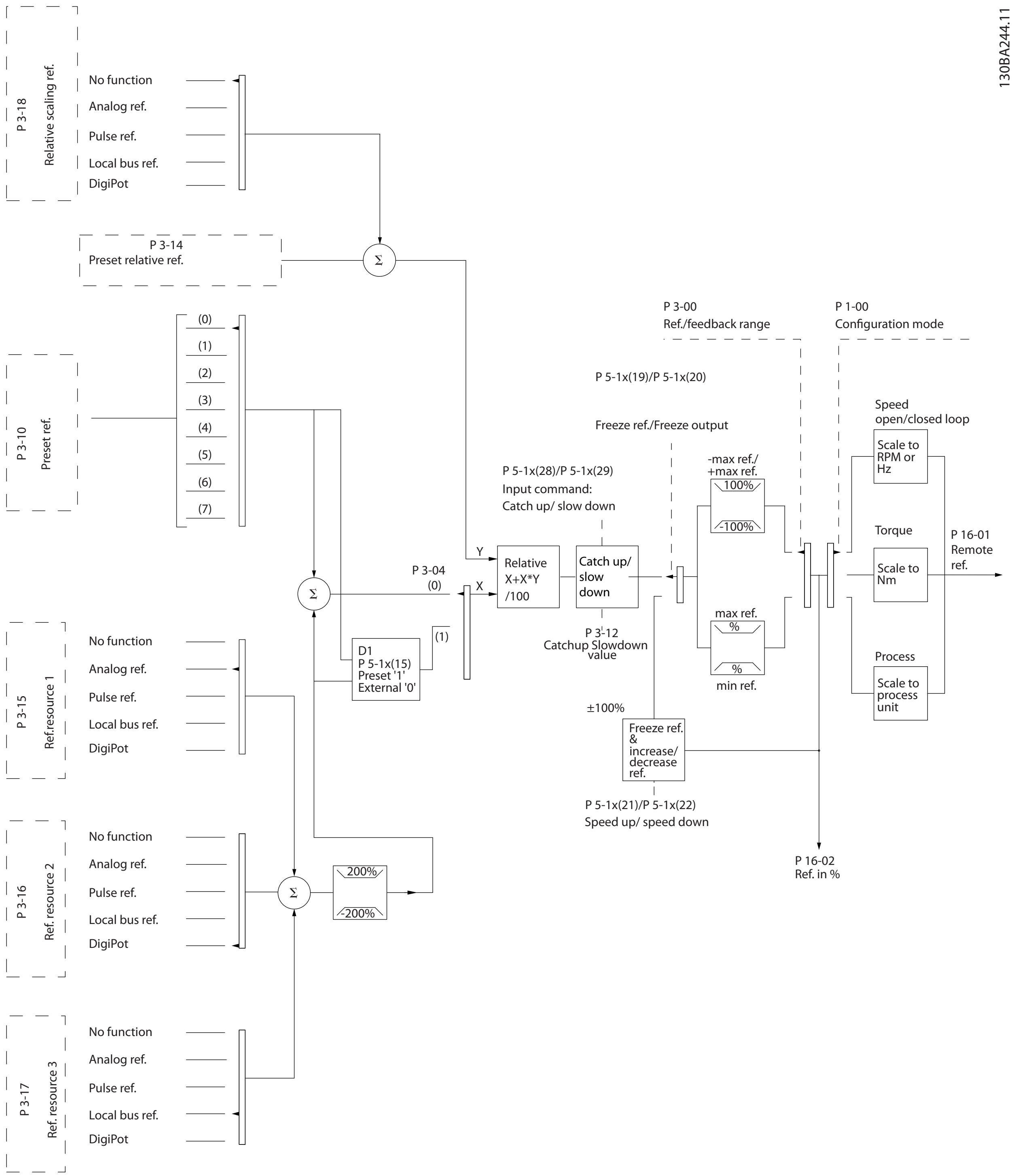


Illustration 15.1 Remote Reference

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The remote reference is calculated once every scan interval and initially consists of the following reference inputs:

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

The 2 types of reference inputs are combined in the following formula: Remote reference =X+X*Y/100%. If the relative reference is not used, *parameter 3-18 Relative Scaling Reference Resource* must be set to *[0] No function* and *parameter 3-14 Preset Relative Reference* to *0%*. The frequency converter can activate the *catch up/slow down* function and the *freeze reference* function. The functions and parameters are described in the *programming guide*. The scaling of analog references is described in *parameter groups 6-1* Analog Input 1* and *6-2* Analog Input 2*, and the scaling of digital pulse references is described in *parameter group 5-5* Pulse Input 2*.
Reference limits and ranges are set in *parameter group 3-0* Reference Limits*.

15.1 Reference Limits

Parameter 3-00 Reference Range, *parameter 3-02 Minimum Reference*, and *parameter 3-03 Maximum Reference* together define the range of the sum of all references. The sum of all references is clamped when necessary. The relation between the resulting reference (after clamping) and the sum of all references is shown in *Illustration 15.2* and *Illustration 15.3*.

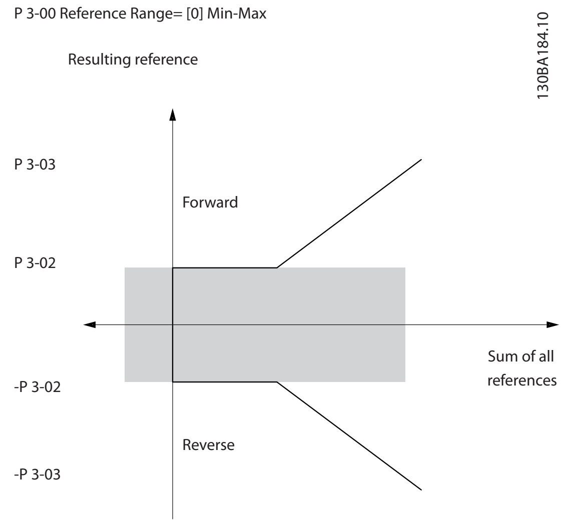

Illustration 15.2 Relation between Resulting Reference and the Sum of All References

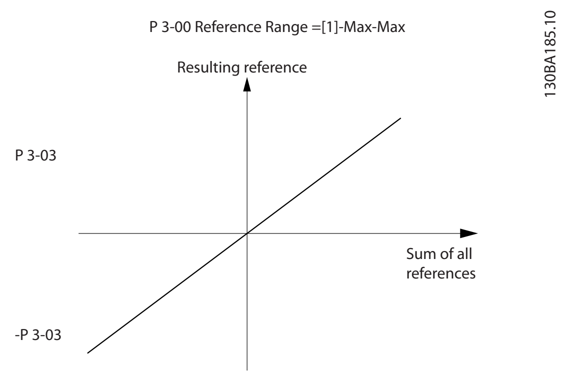

Illustration 15.3 Resulting Reference

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The value of *parameter 3-02 Minimum Reference* cannot be set to less than 0, unless *parameter 1-00 Configuration Mode* is set to *[3] Process*. In that case, the following relations between the resulting reference (after clamping) and the sum of all references is as shown in *Illustration 15.4*.

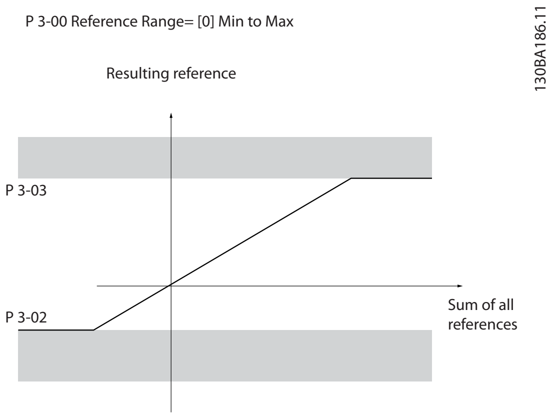

Illustration 15.4 Sum of All References

15.2 Scaling of Preset References

Preset references are indicated by units, which can be RPM, m/s, bar, and so on. The preset references are scaled according to the following rules:

- When *parameter 3-00 Reference Range= [0] Min to Max* , *parameter 3-02 Minimum Reference* is the minimum reference (0%), and *parameter 3-03 Maximum Reference* is the maximum reference (100%). 50% reference is found halfway between these 2 values.
- When *parameter 3-00 Reference Range=[1] -Max to +Max* , *parameter 3-02 Minimum Reference* is ignored. *Parameter 3-03 Maximum Reference* is the maximum reference (100%), which is used for the +Max value (+100%) and the -Max value (-100%). 50% reference is found halfway between these 2 values.

15.3 Scaling of Analog and Pulse References, and Feedback

References and feedback are scaled from analog and pulse inputs in the same way. The only difference is that a reference above or below the specified minimum and maximum endpoints (P1 and P2 in *Illustration 15.5*) are clamped, whereas feedback above or below is not.

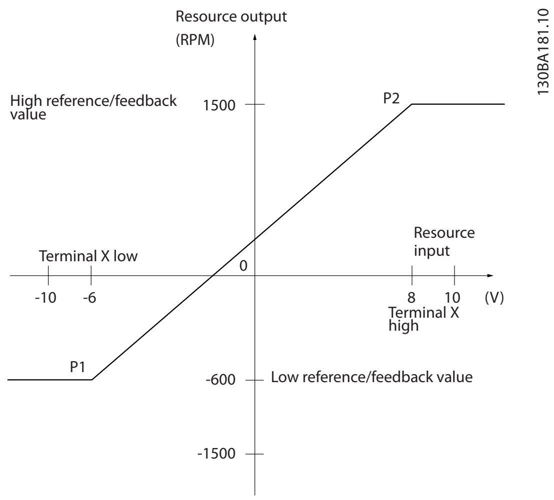

Illustration 15.5 Scaling of Analog and Pulse References

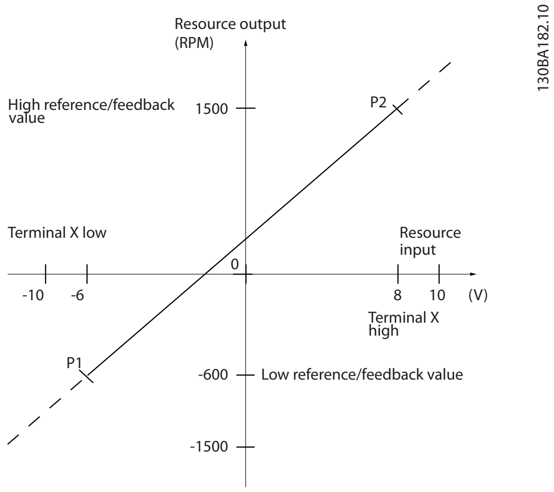

Illustration 15.6 Scaling of Analog and Pulse Feedback

The following parameters define the endpoints P1 and P2, depending on which analog or pulse input is used.

	Analog 53 S201=OFF	Analog 53 S201=ON	Analog 54 S202=OFF	Analog 54 S202=ON	Pulse input 29	Pulse input 33
P1=(Minimum input value, minimum reference value)						
Minimum reference value	*Parameter 6-14 Terminal 53 Low Ref./Feedb. Value*	*Parameter 6-14 Terminal 53 Low Ref./Feedb. Value*	*Parameter 6-24 Terminal 54 Low Ref./Feedb. Value*	*Parameter 6-24 Terminal 54 Low Ref./Feedb. Value*	*Parameter 5-52 Term. 29 Low Ref./Feedb. Value*	*Parameter 5-57 Term. 33 Low Ref./Feedb. Value*
Minimum input value	*Parameter 6-10 Terminal 53 Low Voltage* [V]	*Parameter 6-12 Terminal 53 Low Current* [mA]	*Parameter 6-20 Terminal 54 Low Voltage* [V]	*Parameter 6-22 Terminal 54 Low Current* [mA]	*Parameter 5-50 Term. 29 Low Frequency* [Hz]	*Parameter 5-55 Term. 33 Low Frequency* [Hz]
P2 =(Maximum input value, maximum reference value)						
Maximum reference value	*Parameter 6-15 Terminal 53 High Ref./Feedb. Value*	*Parameter 6-15 Terminal 53 High Ref./Feedb. Value*	*Parameter 6-25 Terminal 54 High Ref./Feedb. Value*	*Parameter 6-25 Terminal 54 High Ref./Feedb. Value*	*Parameter 5-53 Term. 29 High Ref./Feedb. Value*	*Parameter 5-58 Term. 33 High Ref./Feedb. Value*
Maximum input value	*Parameter 6-11 Terminal 53 High Voltage* [V]	*Parameter 6-13 Terminal 53 High Current* [mA]	*Parameter 6-21 Terminal 54 High Voltage* [V]	*Parameter 6-23 Terminal 54 High Current* [mA]	*Parameter 5-51 Term. 29 High Frequency* [Hz]	*Parameter 5-56 Term. 33 High Frequency* [Hz]

Table 15.1 P1 and P2 Parameters

15.4 Dead Band Around Zero

Sometimes the reference and, in rare instances, the feedback need a dead band around zero. The dead band is used to ensure that the machine is stopped when the reference is near 0).

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

- Minimum reference value (see *Table 15.1* for relevant parameter) or maximum reference value must be 0. In other words; Either P1 or P2 must be on the X-axis in *Illustration 15.7*.
- Both points defining the scaling graph must be in the same quadrant.

P1 or P2 defines the size of the dead band. See *Illustration 15.7*.

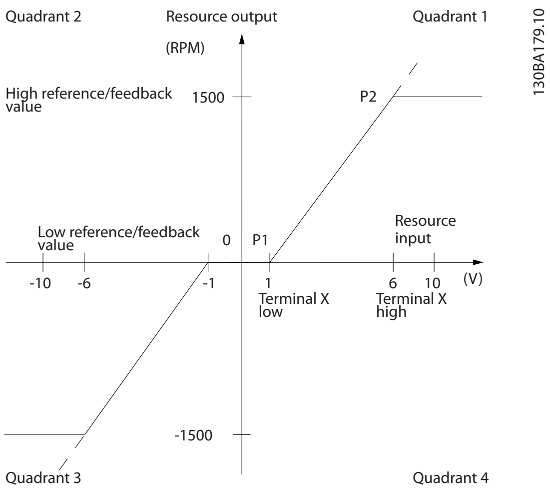

Illustration 15.7 Dead Band

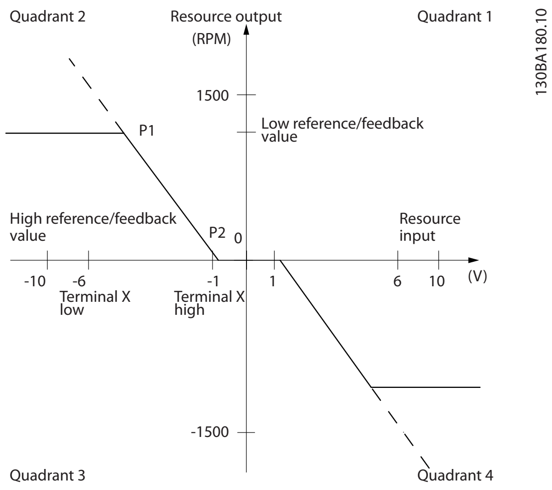

Illustration 15.8 Reverse Dead Band

Thus a reference endpoint of P1=(0 V, 0 RPM) does not result in any dead band, but a reference endpoint of P1=(1 V, 0 RPM), results in a -1 V to +1 V dead band if the P2 endpoint is placed in either Quadrant 1 or Quadrant 4.

Case 1. This case shows how reference input with limits inside minimum to maximum limits clamps.

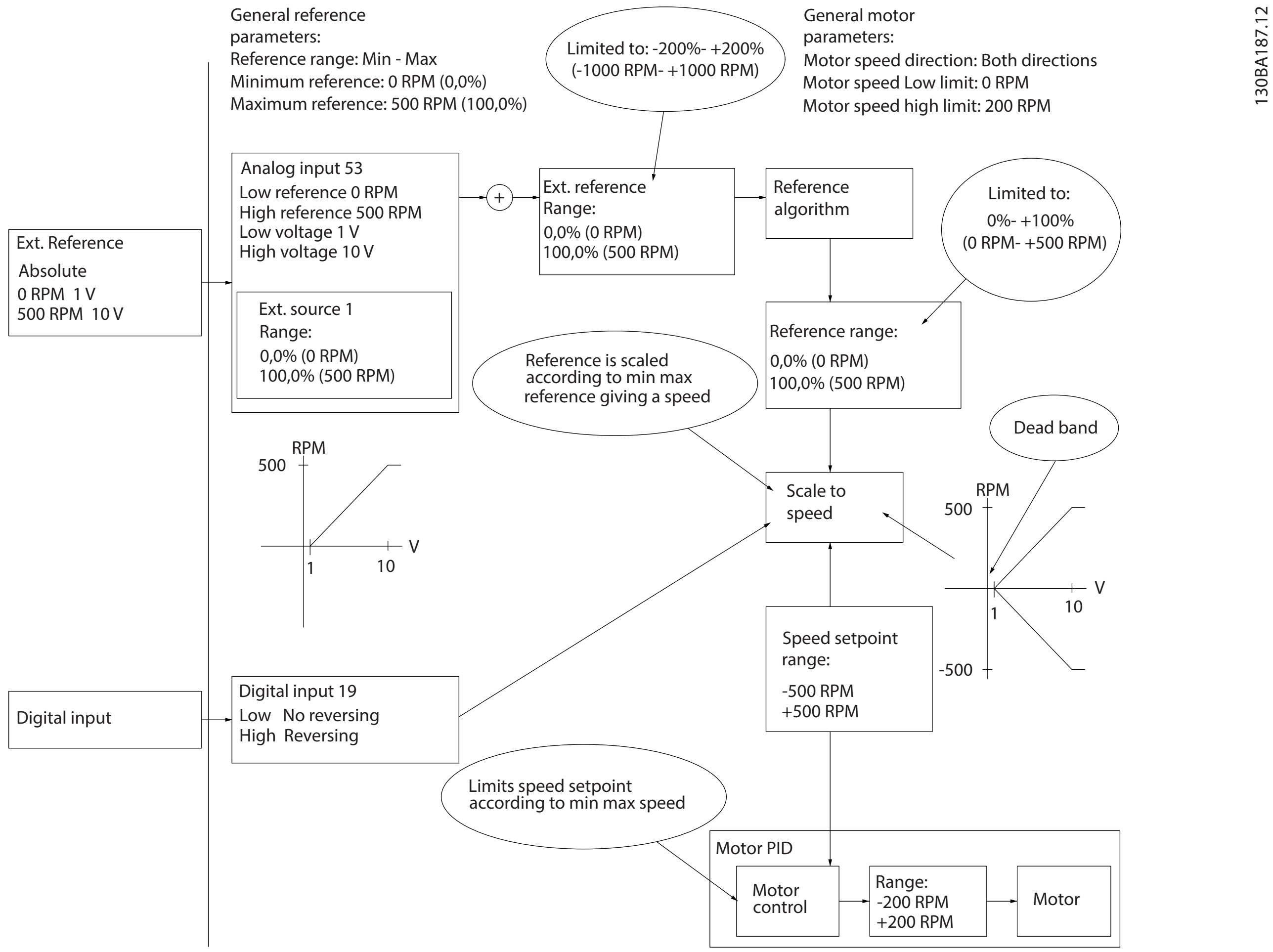

Illustration 15.9 Positive Reference with Dead Band, Digital Input to Trigger Reverse

Case 2. This case shows how reference input with limits outside -maximum to +maximum limits clamps to the inputs low and high limits before addition to external reference, as well as how the external reference is clamped to -maximum to +maximum by the reference algorithm.

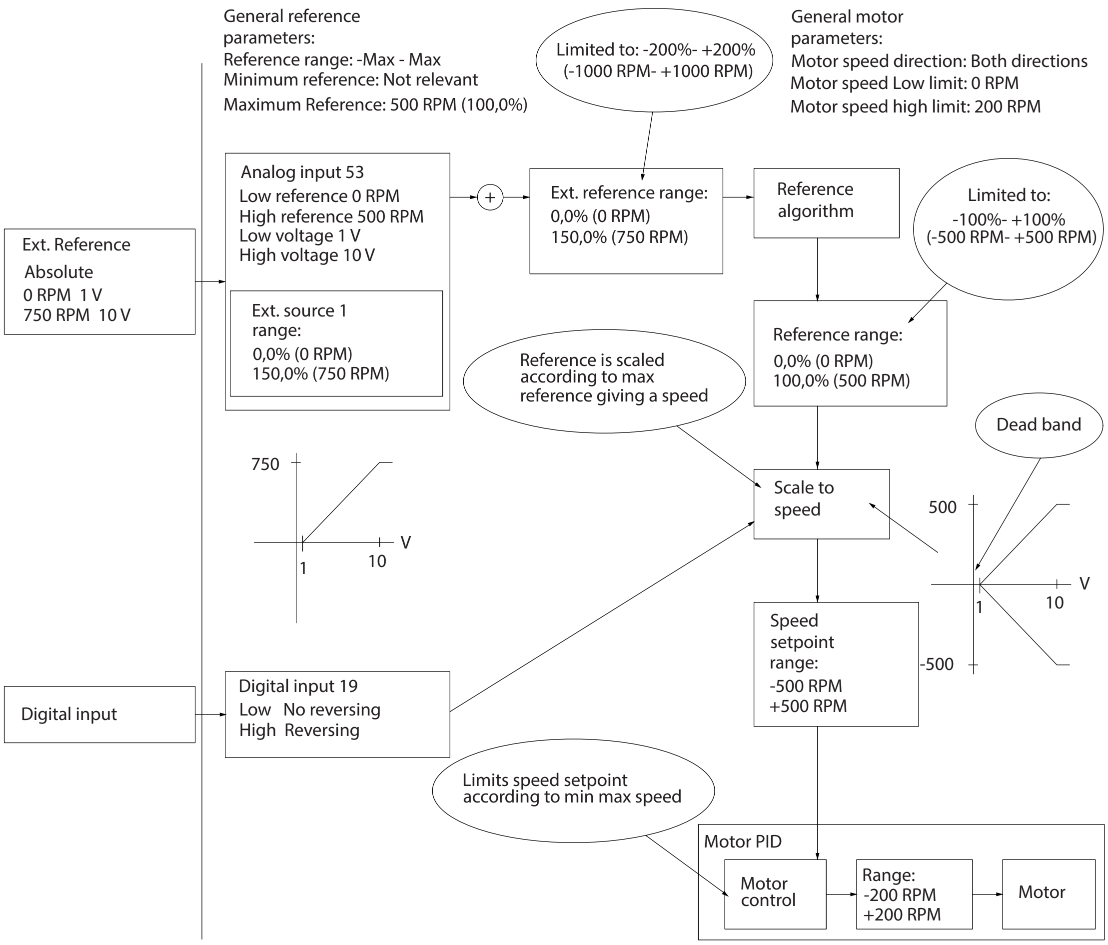

Illustration 15.10 Positive Reference with Dead Band, Digital Input to Trigger Reverse. Clamping Rules

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Case 3.

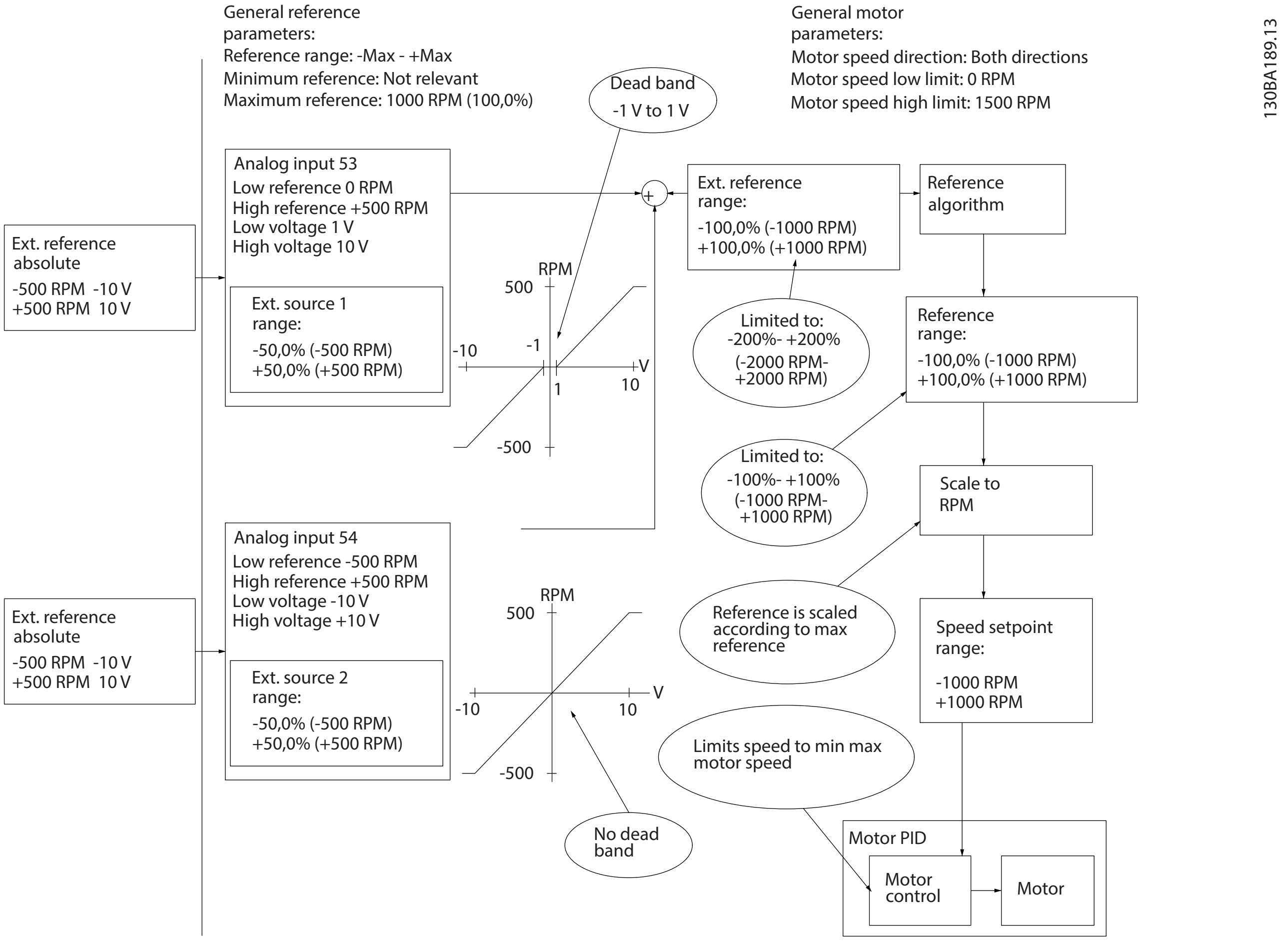

Illustration 15.11 Negative to Positive Reference with Dead Band, Sign Determines the Direction, -Maximum to +Maximum

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16 PID Controls

16.1 Speed PID Controls

Parameter 1-00 Configuration Mode	*Parameter 1-01 Motor Control Principle*			
	U/f	**VVC+**	**Flux sensorless**	**Flux w/encoder feedback**
[0] Speed open loop	Not active	Not active	Active	–
[1] Speed closed loop	–	Active	–	Active
[2] Torque	–	–	–	Not active
[3] Process	–	Not active	Active	Active

Table 16.1 Control Configurations Where the Speed Control is Active

"Not Active" means that the specific mode is available but the speed control is not active in that mode.

NOTICE

The speed control PID works under the default parameter setting, but tuning the parameters is highly recommended to optimize the motor control performance. The 2 flux motor control principles depend on proper tuning to yield their full potential.

16.1.1 Speed PID Control Parameters

<table>
<tr><th>Parameter</th><th colspan="2">Description of function</th></tr>
<tr><td>Parameter 7-00 Speed PID Feedback Source</td><td colspan="2">Selects from which input the speed PID gets its feedback.</td></tr>
<tr><td>Parameter 30-83 Speed PID Proportional Gain</td><td colspan="2">The higher the value - the quicker the control. However, too high a value can lead to oscillations.</td></tr>
<tr><td>Parameter 7-03 Speed PID Integral Time</td><td colspan="2">Eliminates steady state speed error. Lower value means quick reaction. However, too low a value can lead to oscillations.</td></tr>
<tr><td>Parameter 7-04 Speed PID Differentiation Time</td><td colspan="2">Provides a gain proportional to the rate of feedback change. A setting of 0 disables the differentiator.</td></tr>
<tr><td>Parameter 7-05 Speed PID Diff. Gain Limit</td><td colspan="2">If there are quick changes in reference or feedback in a given application - which means that the error changes swiftly - the differentiator can become too dominant. The quicker the error changes, the stronger the differentiator gain is. The differentiator gain can thus be limited to allow setting of the reasonable differentiation time for slow changes and a suitably quick gain for quick changes.</td></tr>
<tr><td rowspan="6">Parameter 7-06 Speed PID Lowpass Filter Time</td><td colspan="2">A low-pass filter dampens oscillations to the feedback signal and improves steady state performance. However, too large a filter time deteriorates the dynamic performance of the speed PID control.
Practical settings of parameter 7-06 Speed PID Lowpass Filter Time taken from the number of pulses per revolution from encoder (PPR):</td></tr>
<tr><td>Encoder PPR</td><td>Parameter 7-06 Speed PID Lowpass Filter Time</td></tr>
<tr><td>512</td><td>10 ms</td></tr>
<tr><td>1024</td><td>5 ms</td></tr>
<tr><td>2048</td><td>2 ms</td></tr>
<tr><td>4096</td><td>1 ms</td></tr>
</table>

Table 16.2 Relevant Parameters for the Speed PID Control

16.1.2 Example of How to Program the Speed Control

In this case, the speed PID control is used to maintain a constant motor speed regardless of the changing load on the motor. The required motor speed is set via a potentiometer connected to terminal 53. The speed range is 0–1500 RPM corresponding to 0–10 V over the potentiometer. A switch connected to terminal 18 controls the starting and stopping. The speed PID monitors the actual RPM of the motor by using a 24 V (HTL) incremental encoder as feedback. The feedback sensor is an encoder (1024 pulses per revolution) connected to terminals 32 and 33.

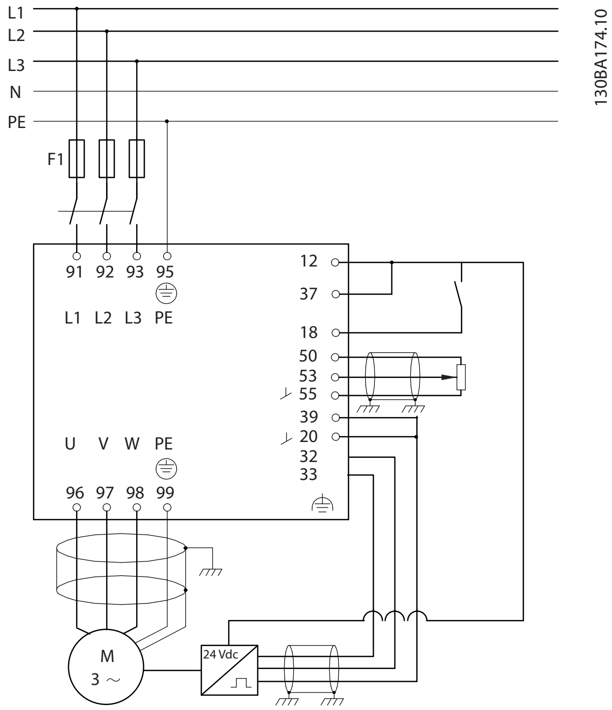

Illustration 16.1 Speed Control Connections

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16.1.3 Speed PID Control Programming Order

The following must be programmed in the order shown (see explanation of settings in the *programming guide*). In *Table 16.3* it is assumed that all other parameters and switches remain at their default settings.

Function	Parameter number	Setting
1) To ensure that the motor runs properly, perform the following:		
Set the motor parameters according to the nameplate data.	*Parameter group 1-2* Motor Data*	As specified by motor nameplate
Perform automatic motor adaptation (AMA).	*Parameter 1-29 Automatic Motor Adaptation (AMA)*	*[1] Enable complete* AMA
2) Check that the motor is running and that the encoder is attached properly. Do the following:		
Press [Hand On]. Check that the motor is running and note in which direction it is turning (positive direction).		Set a positive reference.
Go to *parameter 16-20 Motor Angle*. Turn the motor slowly in the positive direction. It must be turned so slowly (only a few RPM) that it can be determined if the value in *parameter 16-20 Motor Angle* is increasing or decreasing.	*Parameter 16-20 Motor Angle*	N/A Read-only parameter. Note: An increasing value overflows at 65535 and starts again at 0.
If *parameter 16-20 Motor Angle* is decreasing, then change the encoder direction in *parameter 5-71 Term 32/33 Encoder Direction*.	*Parameter 5-71 Term 32/33 Encoder Direction*	*[1] Counterclockwise* (if *parameter 16-20 Motor Angle* is decreasing)
3) Make sure that the frequency converter limits are set to safe values.		
Set acceptable limits for the references.	*Parameter 3-02 Minimum Reference*	0 RPM (default)
	Parameter 3-03 Maximum Reference	1500 RPM (default)
Check that the ramp settings are within unit capabilities and allowed application operating specifications.	*Parameter 3-41 Ramp 1 Ramp Up Time*	Default setting
	Parameter 3-42 Ramp 1 Ramp Down Time	
Set acceptable limits for the motor speed and frequency.	*Parameter 4-11 Motor Speed Low Limit [RPM]*	0 RPM (default)
	Parameter 4-13 Motor Speed High Limit [RPM]	1500 RPM (default)
	Parameter 4-19 Max Output Frequency	60 Hz (default 132 Hz)
4) Configure the speed control and select the motor control principle.		
Activation of speed control.	*Parameter 1-00 Configuration Mode*	*[1] Speed closed loop*
Selection of motor control principle.	*Parameter 1-01 Motor Control Principle*	*[3] Flux w motor feedb*
5) Configure and scale the reference to the speed control.		
Set up analog input 53 as a reference source.	*Parameter 3-15 Reference Resource 1*	Not necessary (default)
Scale analog input 53 from 0 RPM (0 V) to 1500 RPM (10 V).	*Parameter group 6-1* Analog Input 1*	Not necessary (default)
6) Configure the 24 V HTL encoder signal as feedback for the motor control and the speed control.		
Set up digital inputs 32 and 33 as encoder inputs.	*Parameter 5-14 Terminal 32 Digital Input*	*[0] No operation* (default)
	Parameter 5-15 Terminal 33 Digital Input	

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Function	Parameter number	Setting
Select terminal 32/33 as motor feedback.	*Parameter 1-02 Flux Motor Feedback Source*	Not necessary (default)
Select terminal 32/33 as speed PID feedback.	*Parameter 7-00 Speed PID Feedback Source*	Not necessary (default)
7) Tune the speed control PID parameters.		
Use the tuning guidelines when relevant, or tune manually.	*Parameter group 7-0* Speed PID Ctrl*	See *chapter 16.1.4 Tuning Speed PID Control*
8) Finished.		
Save the parameter setting to the LCP.	*Parameter 0-50 LCP Copy*	*[1] All to LCP*

Table 16.3 Programming Order

16.1.4 Tuning Speed PID Control

The following tuning guidelines are relevant when using one of the flux motor control principles in applications where the load is inertial (with a low amount of friction).

The value of *parameter 30-83 Speed PID Proportional Gain* depends the combined inertia of the motor and load. The selected bandwidth can be calculated using the following formula:

$$Par.\ 7-02\ =$$
$$\frac{Total\ inertia\ \left[kgm^2\right]\ x\ par.\ 1-25}{Par.\ 1-20\ x\ 9550}\ x\ Bandwidth\ \left[rad/s\right]$$

NOTICE

***Parameter 1-20 Motor Power [kW]* is the motor power in kilowatts. For example, enter 4 kW instead of 4000 W in the formula.**

A practical value for the bandwidth is 20 rad/s. Check the result of the *parameter 30-83 Speed PID Proportional Gain* calculation against the following formula. This function is not required if using high-resolution feedback such as a SinCos feedback.

$$Par.\ 7-02_{MAX}\ =$$
$$\frac{0.01\ x\ 4\ x\ Encoder\ Resolution\ x\ Par.\ 7-06}{2\ x\ \pi}$$
$$x\ Max\ torque\ ripple\ [\%]$$

A good starting value for *parameter 7-06 Speed PID Lowpass Filter Time* is 5 ms. A lower encoder resolution calls for a higher filter value. Typically, a maximum torque ripple of 3% is acceptable. For incremental encoders, the encoder resolution is found in either *parameter 5-70 Term 32/33 Pulses Per Revolution* (24 V HTL on standard drive) or *parameter 17-11 Resolution (PPR)* (5 V TTL on VLT® Encoder Input MCB 102 option).

Generally, the encoder resolution and the feedback filter time set the practical maximum limit of *parameter 30-83 Speed PID Proportional Gain*, but other factors in the application can limit the *parameter 30-83 Speed PID Proportional Gain* to a lower value.

To minimize the overshoot, *parameter 7-03 Speed PID Integral Time* could be set to approximately 2.5 s. Time varies with the application.

Set the *parameter 7-04 Speed PID Differentiation Time* to 0 until everything else is tuned. If necessary, finish the tuning by adjusting this setting in small increments.

16.2 Process PID Controls

The process PID control can be used to control application parameters that can be measured by different sensors (pressure, temperature, and flow) and be affected by the connected motor via a pump or fan.

Table 16.4 shows the control configurations where the process control is possible. Tune the speed control PID parameters when a flux vector motor control principle is used. To see where the speed control is active, refer to *chapter 14.3.1 Control Structure in VVC+ Advanced Vector Control*.

Parameter 1-00 Configuration Mode	*Parameter 1-01 Motor Control Principle*			
	U/f	VVC+	Flux sensorless	Flux with encoder feedback
[3] Process	–	Process	Process & speed	Process & speed

Table 16.4 Process Control Configurations

NOTICE

The process control PID works under the default parameter setting, but tuning the parameters is highly recommended to optimize the application control performance. The 2 flux motor control principles depend on proper speed control PID tuning to yield their full potential. The speed control PID tuning occurs before tuning the process control PID.

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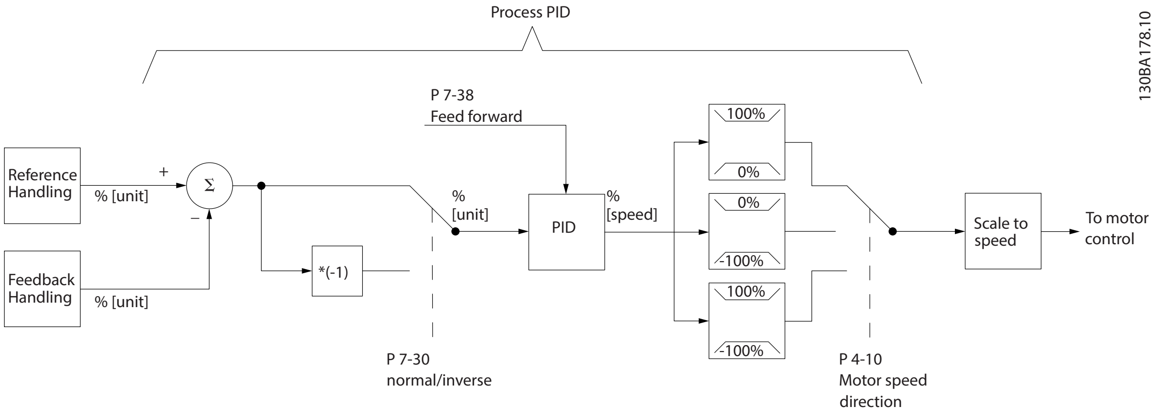

Illustration 16.2 Process PID Control Diagram

16.2.1 Process PID Control Parameters

The following parameters are relevant for the process control

Parameter	Description of function
Parameter 7-20 Process CL Feedback 1 Resource	Selects from which input the process PID gets its feedback.
Parameter 7-22 Process CL Feedback 2 Resource	Optional: Determines if and from where the process PID gets an additional feedback signal. If an additional feedback source is selected, the 2 feedback signals are added before being used in the process PID control.
Parameter 7-30 Process PID Normal/ Inverse Control	Under *[0] Normal operation*, the process control responds with an increase of the motor speed if the feedback is lower than the reference. In the same situation, but under *[1] Inverse operation*, the process control responds with a decreasing motor speed.
Parameter 7-31 Process PID Anti Windup	The anti-windup function ensures that when either a frequency limit or a torque limit is reached, the integrator is set to a gain that corresponds to the actual frequency. This function avoids integrating on an error that cannot be compensated with a speed change. Disable this function by selecting *[0] Off*.
Parameter 7-32 Process PID Start Speed	In some applications, reaching the required speed/setpoint can take a long time. In such cases, it is beneficial to set a fixed motor speed from the frequency converter before the process control is activated. Set the fixed motor speed by setting a process PID start value (speed) in *parameter 7-32 Process PID Start Speed*.
Parameter 7-33 Process PID Proportional Gain	The higher the value, the quicker the control. However, too large a value can lead to oscillations.
Parameter 7-34 Process PID Integral Time	Eliminates steady state speed error. Lower value means quick reaction. However, too small a value can lead to oscillations.
Parameter 7-35 Process PID Differentiation Time	Provides a gain proportional to the rate of feedback change. A setting of 0 disables the differentiator.
Parameter 7-36 Process PID Diff. Gain Limit	If there are quick changes in reference or feedback in a given application, the differentiator gain can be limited to allow setting of a reasonable differentiation time for slow error changes.
Parameter 7-38 Process PID Feed Forward Factor	In applications where there is a good and approximately linear correlation between the process reference and the motor speed necessary for obtaining that reference, the feed forward factor can be used to achieve better dynamic performance of the process PID control.

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Parameter	Description of function
Parameter 5-54 Pulse Filter Time Constant #29 (Pulse term. 29), *Parameter 5-59 Pulse Filter Time Constant #33* (Pulse term. 33), *Parameter 6-16 Terminal 53 Filter Time Constant* (analog term 53), *Parameter 6-26 Terminal 54 Filter Time Constant* (analog term. 54)	If there are oscillations of the current/voltage feedback signal, these oscillations can be dampened with a low-pass filter. This time constant shows the speed limit of the ripples occurring on the feedback signal. Example: If the low-pass filter has been set to 0.1 s, the limit speed is 10 RAD/s (the reciprocal of 0.1 s), corresponding to (10/(2 x π))=1.6 Hz. The example shows that the filter dampens all currents/voltages that vary by more than 1.6 oscillations per s. The control is only carried out on a feedback signal that varies by a frequency (speed) of less than 1.6 Hz. The low-pass filter improves steady state performance, but selecting too large a filter time deteriorates the dynamic performance of the process PID control.

Table 16.5 Process Control Parameters

16.2.2 Example of Process PID Control

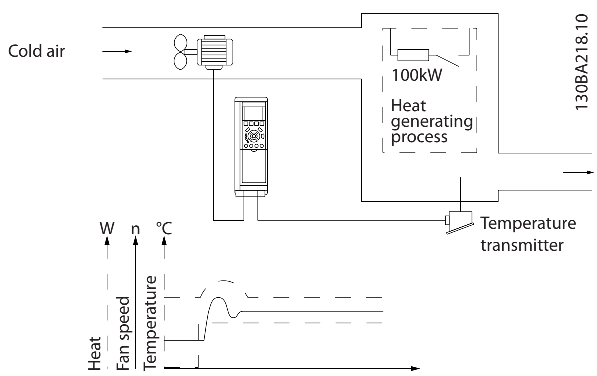

Illustration 16.3 Example of a Process PID Control Used in a Ventilation System

In this example using a ventilation system, the temperature must be adjustable from -5 °C (23 °F) to 35 °C (95 °F) with a potentiometer of 0–10 V. The process control is used to keep the set temperature constant.

When the temperature increases, the process PID control increases the ventilation speed so more airflow is generated. When the temperature drops, the speed is reduced. The transmitter used is a temperature sensor with a working range of -10 °C (14 °F) to 40 °C (104 °F), 4–20 mA. Minimum/maximum speed 300/1500 RPM.

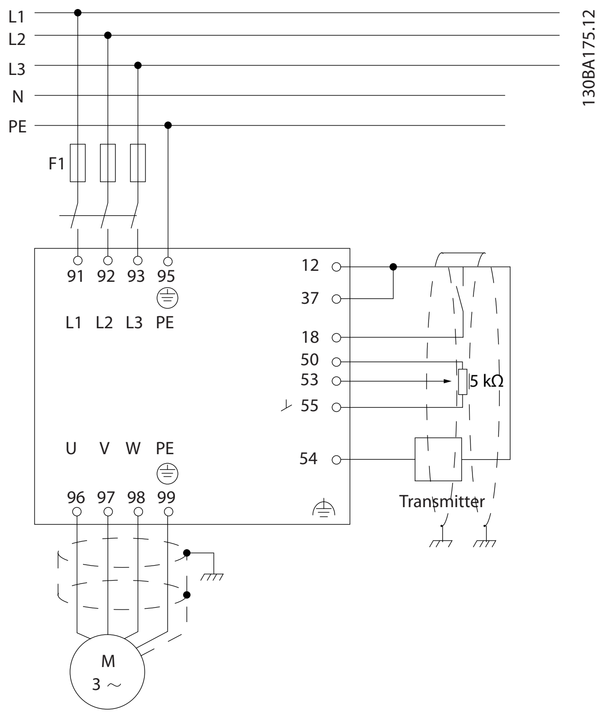

Illustration 16.4 Two-wire Transmitter

The following steps demonstrate how to set up the process PID control in *Illustration 16.4*.

1. Start/Stop via switch connected to terminal 18.
2. Temperature reference via potentiometer (-5 to 35 °C (23 to 95 °F), 0–10 V DC) connected to terminal 53.
3. Temperature feedback via transmitter (-10 to 40 °C (14 to 104 °F), 4–20 mA) connected to terminal 54. Switch S202 set to ON (current input).

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16.2.3 Process PID Control Programming Order

Function	Parameter	Setting
Initialize the frequency converter.	*Parameter 14-22 Operation Mode*	*[2] Initialization* 1. Perform a power cycling. 2. Press [Reset].
1) Set motor parameters:		
Set the motor parameters according to the nameplate data.	*Parameter group 1-2* Motor Data*	As stated on motor nameplate.
Perform automatic motor adaptation (AMA).	*Parameter 1-29 Automatic Motor Adaptation (AMA)*	[1] Enable complete AMA
2) Check that motor is running in the right direction: When the motor is connected to frequency converter with straight forward phase order as U - U; V- V; W - W, the motor shaft usually turns clockwise as viewed from the shaft end.		
Press the [Hand On] LCP key. Check the shaft direction by applying a manual reference.		
If the motor turns opposite of the required direction: 1. Change motor direction in *parameter 4-10 Motor Speed Direction*. 2. Turn off mains - wait for DC link to discharge - switch 2 of the motor phases.	*Parameter 4-10 Motor Speed Direction*	Select correct motor shaft direction.
Set configuration mode.	*Parameter 1-00 Configuration Mode*	*[3] Process*
Set local mode configuration.	*Parameter 1-05 Local Mode Configuration*	*[0] Speed Open Loop*
3) Set reference configuration, that is the range for handling of references. Set scaling of analog input in *parameter group 6- Analog In/Out:***		
Set reference/feedback units: Set minimum reference (10 °C (50 °F)): Set maximum reference (80 °C (176 °F)): If set value is determined from a preset value (array parameter), set other reference sources to No function.	*Parameter 3-01 Reference/Feedback Unit* *Parameter 3-02 Minimum Reference* *Parameter 3-03 Maximum Reference* *Parameter 3-10 Preset Reference*	[60] °C Unit shown on display -5 °C (23 °F) 35 °C (95 °F) [0] 35% $Ref = \frac{Par.\ 3-10_{(0)}}{100} \times ((Par.\ 3-03) - (par.\ 3-02)) = 24,5° C$ *Parameter 3-14 Preset Relative Reference* to *parameter 3-18 Relative Scaling Reference Resource [0]=No Function*
4) Adjust limits for the frequency converter:		
Set ramp times to an appropriate value as 20 s.	*Parameter 3-41 Ramp 1 Ramp Up Time* *Parameter 3-42 Ramp 1 Ramp Down Time*	20 s 20 s
Set minimum speed limits: Set motor speed max. limit: Set maximum output frequency:	*Parameter 4-11 Motor Speed Low Limit [RPM]* *Parameter 4-13 Motor Speed High Limit [RPM]* *Parameter 4-19 Max Output Frequency*	300 RPM 1500 RPM 60 Hz
Set S201 or S202 to desired analog input function (Voltage (V) or milliamps (I)): ***NOTICE*** **Turn off the frequency converter before moving the switches from one setting to another. Use finger to gently move the switches.**		
5) Scale analog inputs used for reference and feedback:		

Function	Parameter	Setting
Set terminal 53 low voltage: Set terminal 53 high voltage: Set terminal 54 low feedback value: Set terminal 54 high feedback value: Set feedback source:	*Parameter 6-10 Terminal 53 Low Voltage* *Parameter 6-11 Terminal 53 High Voltage* *Parameter 6-24 Terminal 54 Low Ref./Feedb. Value* *Parameter 6-25 Terminal 54 High Ref./Feedb. Value* *Parameter 7-20 Process CL Feedback 1 Resource*	0 V 10 V -5 °C (23 °F) 35 °C (95 °F) *[2] analog input 54*
6) Basic PID settings:		
Process PID normal/inverse.	*Parameter 7-30 Process PID Normal/ Inverse Control*	*[0] Normal*
Process PID anti wind-up.	*Parameter 7-31 Process PID Anti Windup*	*[1] On*
Process PID start speed.	*Parameter 7-32 Process PID Start Speed*	300 RPM
Save parameters to LCP.	*Parameter 0-50 LCP Copy*	*[1] All to LCP*

Table 16.6 Example of Process PID Control Set-up

16.2.4 Process Controller Optimization

After the basic settings have been made, optimize the following:

- Proportional gain
- Integration time
- Differentiation time

In most processes, the basic settings can be done by following these steps:

1. Start the motor.
2. Set *parameter 7-33 Process PID Proportional Gain* to 0.3 and increase it until the feedback signal begins to vary continuously. Then reduce the value until the feedback signal has stabilized. Now lower the proportional gain by 40–60%.
3. Set *parameter 7-34 Process PID Integral Time* to 20 s and reduce the value until the feedback signal begins to vary continuously. Increase the integration time until the feedback signal stabilizes, followed by an increase of 15–50%.
4. Only use *parameter 7-35 Process PID Differentiation Time* for very fast-acting systems only (differentiation time). The typical value is 4 times the set integration time. Only use the differentiator when the setting of the proportional gain and the integration time are fully optimized. Make sure that the low-pass filter sufficiently dampens the oscillations on the feedback signal.

NOTICE

If necessary, start/stop can be activated several times to provoke a variation of the feedback signal.

16.3 Optimization of PID Controls

16.3.1 Ziegler Nichols Tuning Method

Several tuning methods can be used to tune the PID controls of the frequency converter. One approach is to use the Ziegler Nichols tuning method.

NOTICE

Do not use the method described in cases where oscillations created by marginally stable control settings can damage applications.

The criteria for adjusting the parameters are based on evaluating the system at the limit of stability rather than on taking a step response. The proportional gain is increased until continuous oscillations are observed (as measured on the feedback), that is, until the system becomes marginally stable. The corresponding gain (K_u) is called the ultimate gain. The period of the oscillation (P_u) (called the ultimate period) is determined as shown in *Illustration 16.5*.

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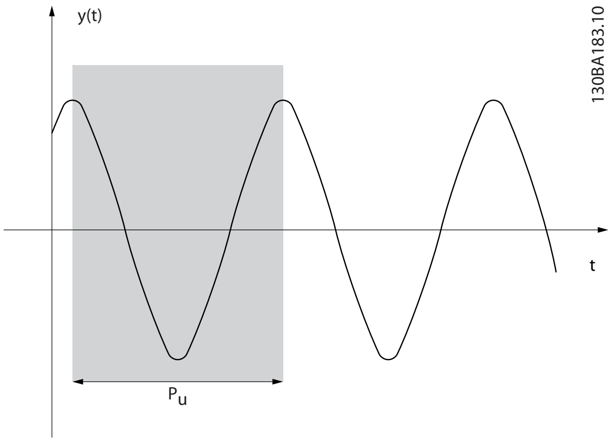

Illustration 16.5 Marginally Stable System

Measure P_u when the amplitude of oscillation is quite small. Then back off from this gain again, as shown in *Table 16.7*.

K_u is the gain at which the oscillation is obtained.

Type of control	Proportional gain	Integral time	Differentiation time
PI-control	0.45 x K_u	0.833 x P_u	–
PID tight control	0.6 x K_u	0.5 x P_u	0.125 x P_u
PID some overshoot	0.33 x K_u	0.5 x P_u	0.33 x P_u

Table 16.7 Ziegler Nichols Tuning for Regulator, Based on a Stability Boundary

Use the control settings described below for initial tuning. The process operator can then fine-tune the control as necessary.

Step-by-step description:

1. Select only proportional control (integral time is selected to the maximum value, while the differentiation time is selected to 0).
2. Increase the value of the proportional gain until the point of instability is reached (sustained oscillations) and the critical value of gain, K_u, is reached.
3. To obtain the critical time constant, measure the period of oscillation: P_u.
4. To calculate the necessary PID control parameters, use *Table 16.7*.

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17 Application Examples

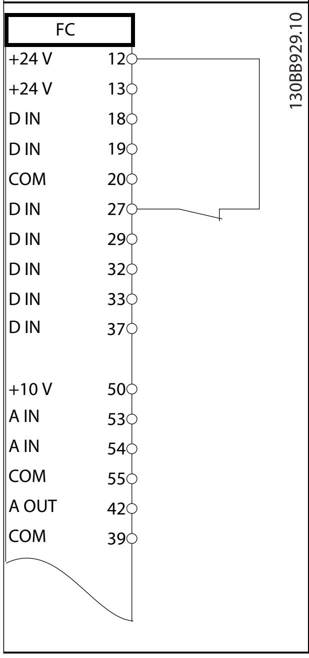
This section lists the various application examples, and gives the parameter settings and special notes, as needed, for each example.

NOTICE

PELV COMPLIANCE

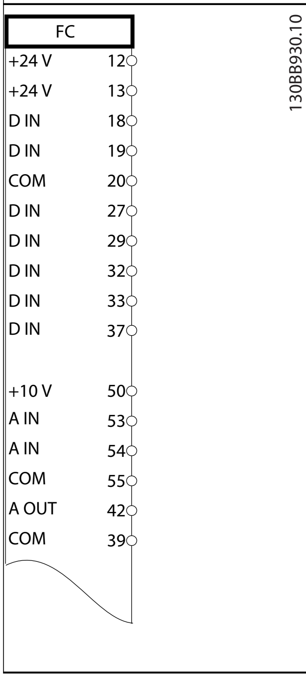
If short circuits occur between the motor windings and the sensor when the motor temperature is monitored via a thermistor or KTY sensor, PELV compliance is not achieved. Ensure PELV compliance by using reinforced or double insulation.

17.1 Automatic Motor Adaptation (AMA)



Parameters	
Function	**Setting**
Parameter 1-29 Automatic Motor Adaptation (AMA)	*[1] Enable complete AMA*
Parameter 5-12 Terminal 27 Digital Input	*[2]* Coast inverse*
*=Default value	
Notes/comments: Set *parameter group 1-2* Motor Data* according to motor nameplate.	

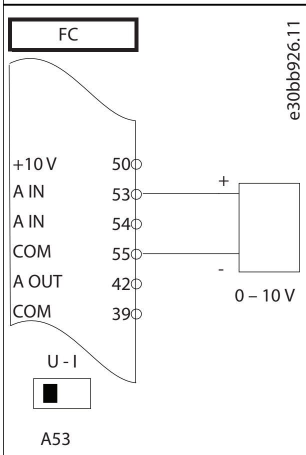
Table 17.1 AMA with T27 Connected



Parameters	
Function	**Setting**
Parameter 1-29 Automatic Motor Adaptation (AMA)	*[1] Enable complete AMA*
Parameter 5-12 Terminal 27 Digital Input	*[0] No operation*
*=Default value	
Notes/comments: Set *parameter group 1-2* Motor Data* according to motor nameplate.	

Table 17.2 AMA without T27 Connected

17.2 Analog Speed Reference



Parameters	
Function	**Setting**
Parameter 6-10 Terminal 53 Low Voltage	0.07 V*
Parameter 6-11 Terminal 53 High Voltage	10 V*
Parameter 6-14 Terminal 53 Low Ref./Feedb. Value	0 RPM
Parameter 6-15 Terminal 53 High Ref./Feedb. Value	1500 RPM
*=Default value	
Notes/comments:	

Table 17.3 Analog Speed Reference (Voltage)

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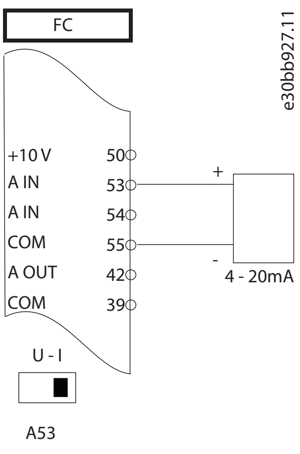
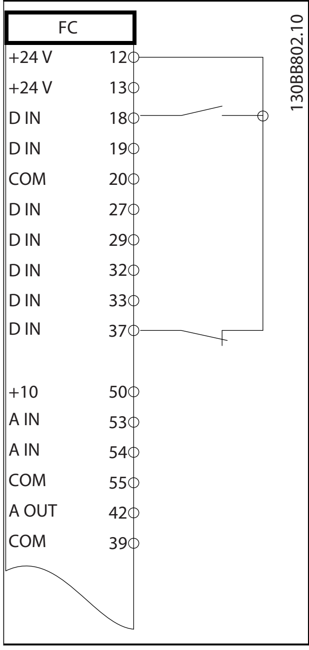


	Parameters	
	Function	Setting
	Parameter 6-12 Terminal 53 Low Current	4 mA*
	Parameter 6-13 Terminal 53 High Current	20 mA*
	Parameter 6-14 Terminal 53 Low Ref./Feedb. Value	0 RPM
	Parameter 6-15 Terminal 53 High Ref./Feedb. Value	1500 RPM
	*=Default value	
	Notes/comments:	

Table 17.4 Analog Speed Reference (Current)

17.3 Start/Stop



	Parameters	
	Function	Setting
	Parameter 5-10 Terminal 18 Digital Input	*[8] Start**
	Parameter 5-12 Terminal 27 Digital Input	*[0] No operation*
	Parameter 5-19 Terminal 37 Safe Stop	*[1] Safe Torque Off Alarm*
	*=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 17.5 Start/Stop Command with Safe Torque Off

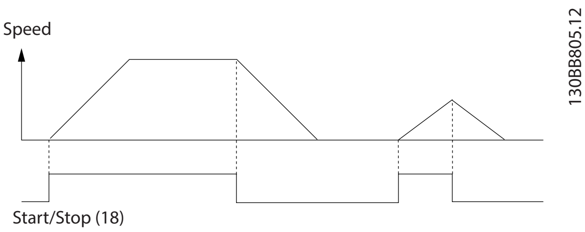
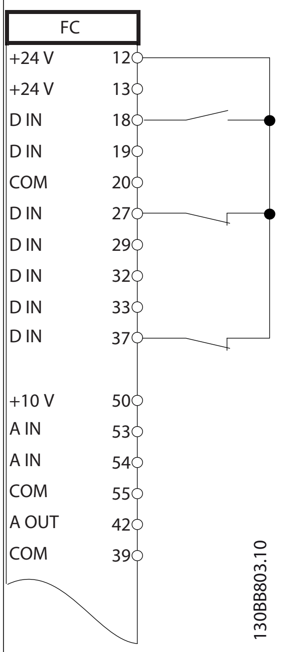


Illustration 17.1 Start/Stop with Safe Torque Off



	Parameters	
	Function	Setting
	Parameter 5-10 Terminal 18 Digital Input	*[9] Latched Start*
	Parameter 5-12 Terminal 27 Digital Input	*[6] Stop Inverse*
	*=Default value	
	Notes/comments: If *parameter 5-12 Terminal 27 Digital Input* is set to *[0] No operation*, a jumper wire to terminal 27 is not needed.	

Table 17.6 Pulse Start/Stop

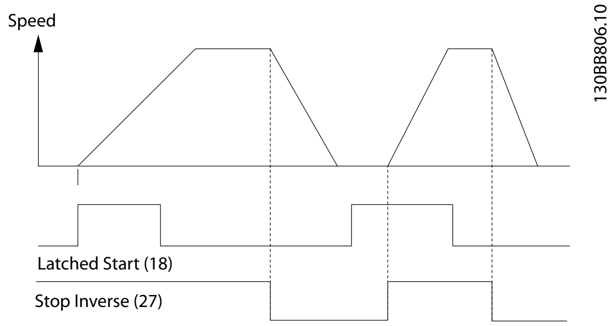
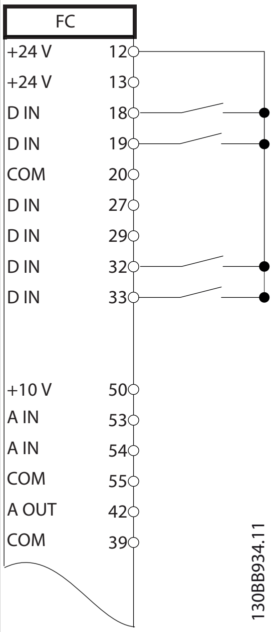


Illustration 17.2 Latched Start/Stop Inverse

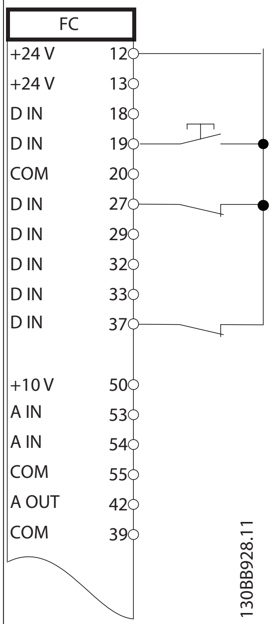
17



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

Table 17.7 Start/Stop with Reversing and 4 Preset Speeds

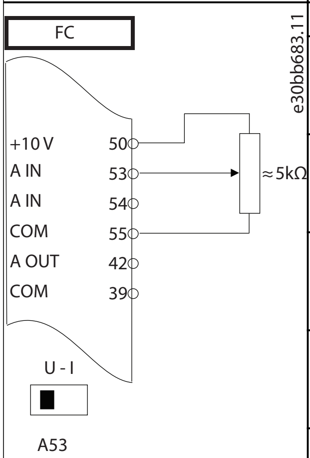
17.4 External Alarm Reset



Parameters	
Function	**Setting**
Parameter 5-11 Terminal 19 Digital Input	*[1] Reset*
*=Default value	
Notes/comments:	

Table 17.8 External Alarm Reset

17.5 Speed Reference with Manual Potentiometer



Parameters	
Function	**Setting**
Parameter 6-10 Terminal 53 Low Voltage	0.07 V*
Parameter 6-11 Terminal 53 High Voltage	10 V*
Parameter 6-14 Terminal 53 Low Ref./Feedb. Value	0 RPM
Parameter 6-15 Terminal 53 High Ref./Feedb. Value	1500 RPM
*=Default value	
Notes/comments:	

Table 17.9 Speed Reference (Using a Manual Potentiometer)

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17.6 Speed Up/Speed Down

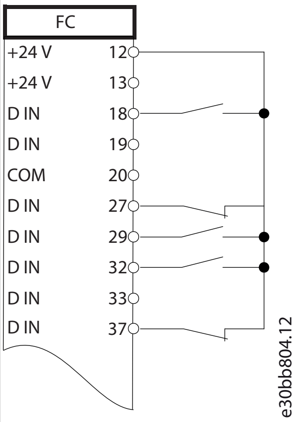
	Parameters	
	**Function**	**Setting**
	Parameter 5-10 Terminal 18 Digital Input	*[8] Start**
	Parameter 5-12 Terminal 27 Digital Input	*[19] Freeze Reference*
	Parameter 5-13 Terminal 29 Digital Input	*[21] Speed Up*
	Parameter 5-14 Terminal 32 Digital Input	*[22] Speed Down*
	*=Default value	
	Notes/comments:	

Table 17.10 Speed Up/Speed Down

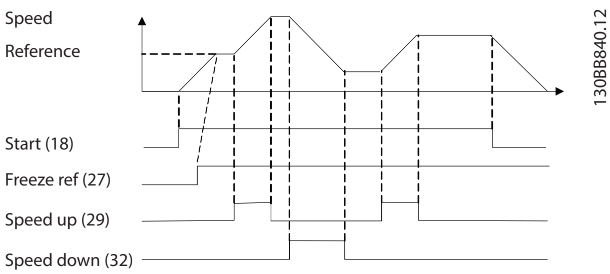


Illustration 17.3 Speed Up/Speed Down

17.7 RS485 Network Connection

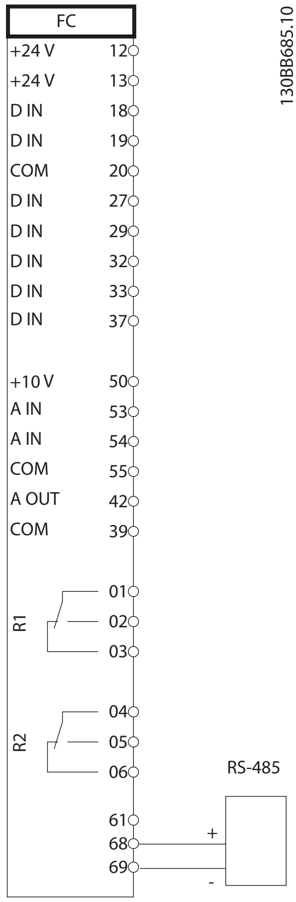
	Parameters	
	**Function**	**Setting**
	Parameter 8-30 Protocol	FC*
	Parameter 8-31 Address	1*
	Parameter 8-32 Baud Rate	9600*
	*=Default value	
	Notes/comments: Select protocol, address, and baud rate in the parameters.	

Table 17.11 RS485 Network Connection

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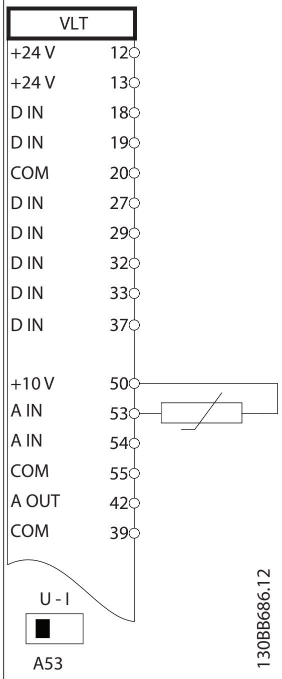
17.8 Motor Thermistor

NOTICE

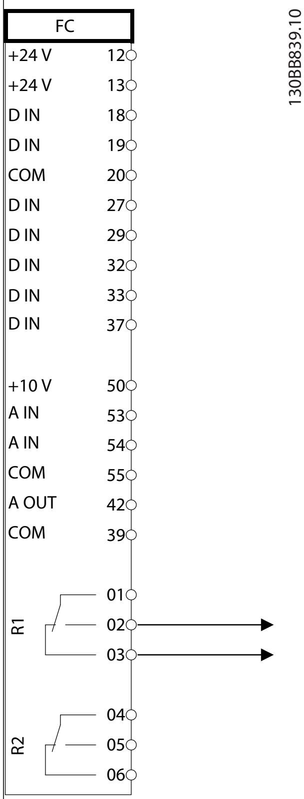
Thermistors must use reinforced or double insulation to meet PELV insulation requirements.



Function	Setting
Parameters	
Parameter 1-90 Motor Thermal Protection	*[2] Thermistor trip*
Parameter 1-93 T hermistor Source	*[1] analog input 53*
*=Default value	
Notes/comments: If only a warning is wanted, set *parameter 1-90 Motor Thermal Protection* to *[1] Thermistor warning.*	

Table 17.12 Motor Thermistor

17.9 Relay Set-up with Smart Logic Control

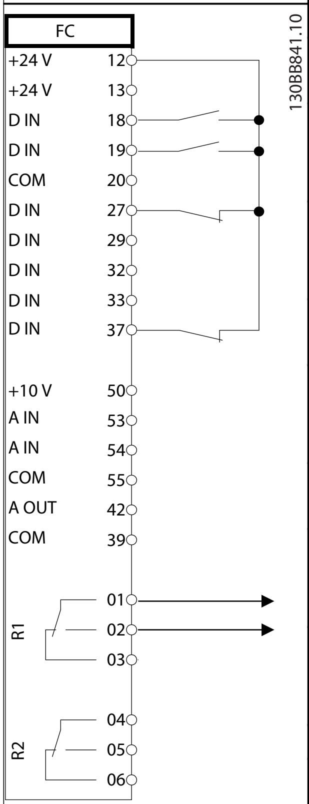


Function	Setting
Parameters	
Parameter 4-30 Motor Feedback Loss Function	*[1] Warning*
Parameter 4-31 Motor Feedback Speed Error	100 RPM
Parameter 4-32 Motor Feedback Loss Timeout	5 s
Parameter 7-00 S peed PID Feedback Source	*[2] MCB 102*
Parameter 17-11 Resolution (PPR)	1024*
Parameter 13-00 SL Controller Mode	*[1] On*
Parameter 13-01 Start Event	*[19] Warning*
Parameter 13-02 Stop Event	*[44] Reset key*
Parameter 13-10 Comparator Operand	*[21] Warning no.*
Parameter 13-11 Comparator Operator	*[1] ≈ (equal)**
Parameter 13-12 Comparator Value	90
Parameter 13-51 SL Controller Event	*[22] Comparator 0*
Parameter 13-52 SL Controller Action	*[32] Set digital out A low*
Parameter 5-40 F unction Relay	*[80] SL digital output A*
*=Default value	

Notes/comments:
If the limit in the feedback monitor is exceeded, *warning 90 Feedback Mon.* is issued. The SLC monitors *warning 90 Feedback Mon.* and if the warning becomes true, relay 1 is triggered. External equipment may require service. If the feedback error goes below the limit again within 5 s, the frequency converter continues and the warning disappears. Reset relay 1 by pressing [Reset] on the LCP.

Table 17.13 Using SLC to Set a Relay

17.10 Mechanical Brake Control



Parameters	
Function	**Setting**
Parameter 5-40 Function Relay	*[32] Mech. brake ctrl.*
Parameter 5-10 Terminal 18 Digital Input	*[8] Start**
Parameter 5-11 Terminal 19 Digital Input	*[11] Start reversing*
Parameter 1-71 Start Delay	0.2
Parameter 1-72 Start Function	*[5] VVC+/ FLUX Clockwise*
Parameter 1-76 Start Current	Im,n
Parameter 2-20 Release Brake Current	App. dependent
Parameter 2-21 Activate Brake Speed [RPM]	Half of nominal slip of the motor
*=Default value	
Notes/comments:	

Table 17.14 Wiring Configuration for Mechanical Brake Control

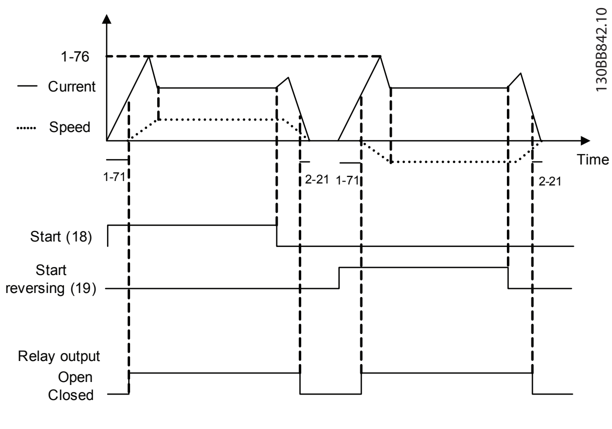


Illustration 17.4 Mechanical Brake Control

17.11 Encoder Connection

Before setting up the encoder, the basic settings for a closed-loop speed control system are shown.
See also *chapter 7.3.7 VLT® Encoder Input MCB 102*.

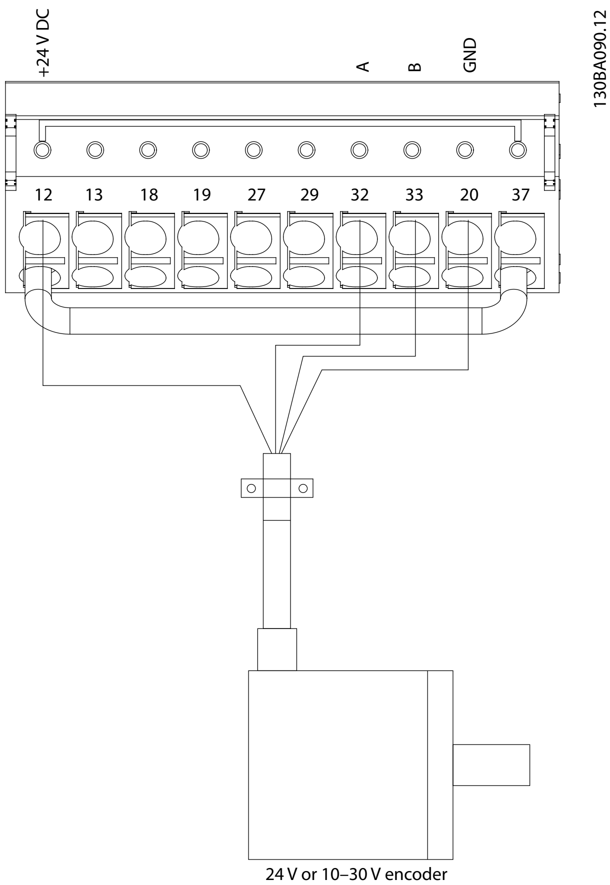


Illustration 17.5 Encoder Connection to the Frequency Converter

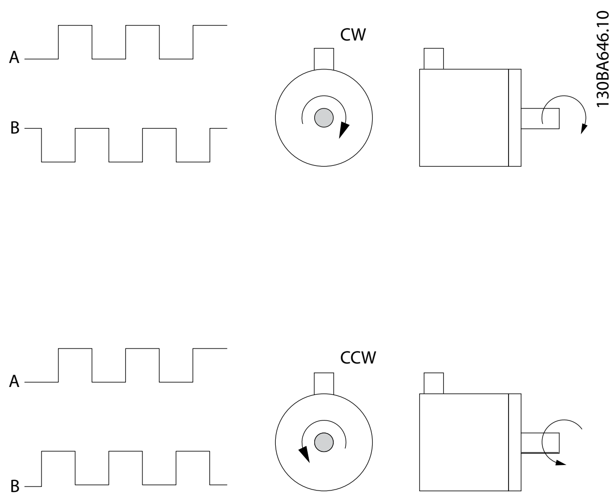


Illustration 17.6 24 V Incremental Encoder. Maximum Cable Length 5 m (16 ft)

17.12 Encoder Direction

The direction of the encoder, identified by looking into the shaft end, is determined by which order the pulses enter the frequency converter.

- 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.

17.13 Closed Loop Drive System

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

- Motor
- Frequency converter
- Encoder as feedback system
- Mechanical brake
- Brake resistor for dynamic braking
- Transmission
- Gear box
- Load

Applications demanding mechanical brake control typically needs a brake resistor.

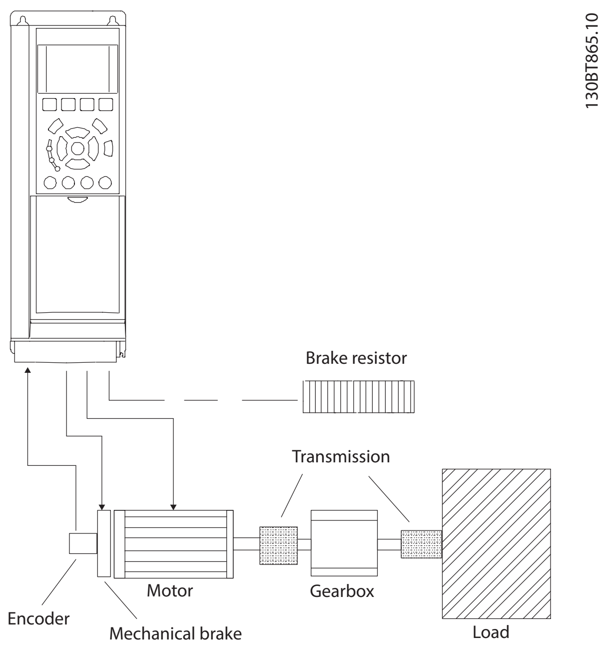


Illustration 17.7 Basic Set-up for FC 302 closed-loop Speed Control

17.14 Programming of Torque Limit and Stop

In applications with an external electro-mechanical brake, such as hoisting applications, it is possible to stop the frequency converter via a standard stop command and simultaneously activate the external electro-mechanical brake.
Illustration 17.8 shows the programming of these frequency converter connections.

If a stop command is active via terminal 18 and the frequency converter is not at the torque limit, the motor ramps down to 0 Hz.
If the frequency converter is at the torque limit and a stop command is activated, the system activates terminal 29 Output (programmed to *[27] Torque limit & stop*). The signal to terminal 27 changes from logic 1 to logic 0 and the motor starts to coast, ensuring that the hoist stops even if the frequency converter itself cannot handle the required torque, for example due to excessive overload.

To program the stop and torque limit, connect to the following terminals:

- Start/stop via terminal 18
  parameter 5-10 Terminal 18 Digital Input [8] Start
- Quick stop via terminal 27
  parameter 5-12 Terminal 27 Digital Input [2] Coasting Stop, Inverse
- Terminal 29 Output
  parameter 5-02 Terminal 29 Mode [1] Terminal 29 Mode Output
  parameter 5-31 Terminal 29 Digital Output [27] Torque limit & stop
- Relay output [0] (Relay 1)
  parameter 5-40 Function Relay [32] Mechanical Brake Control

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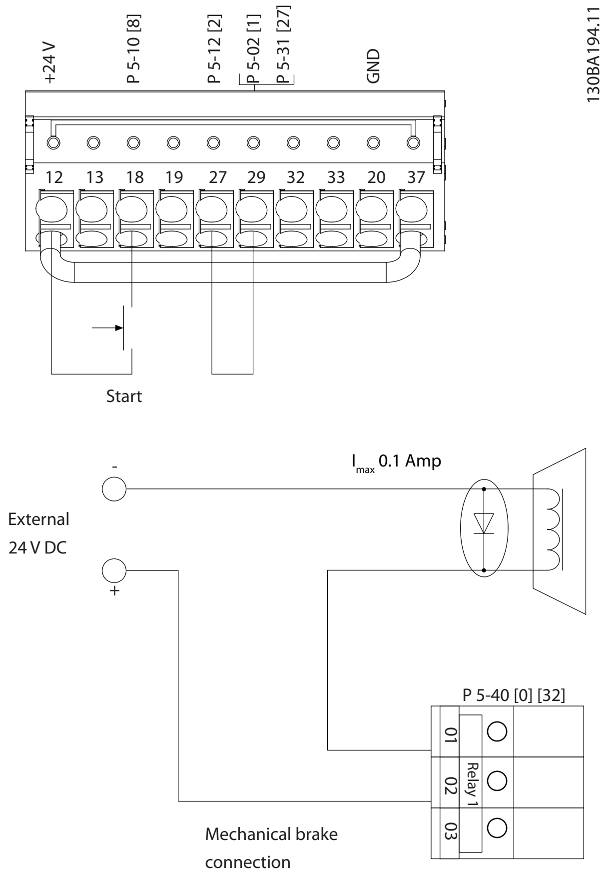

Illustration 17.8 Stop and Torque Limit Terminal Connections

18 Appendix

18.1 Disclaimer

Danfoss shall have no obligation with respect to any product that

- is not installed according to the standard configuration as specified in the installation guide.
- is improperly repaired or altered.
- is subjected to misuse, negligence, and improper installation where the guidelines were not followed.
- is used in a contradictory manner to the instructions provided.
- is a result of normal wear and tear.

18.2 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 (inch).

18.3 Glossary

Variables used in calculations:

f_{JOG}
The motor frequency when the jog function is activated (via digital terminals).

f_M
The motor frequency.

f_{MAX}
The maximum motor frequency.

f_{MIN}
The minimum motor frequency.

$f_{M,N}$
The rated motor frequency (nameplate data).

I_M
The motor current.

$I_{M,N}$
The rated motor current (nameplate data).

$I_{VLT,MAX}$
The maximum output current.

$I_{VLT,N}$
The rated output current supplied by the frequency converter.

$n_{M,N}$
The nominal motor speed (nameplate data).

$P_{M,N}$
The rated motor power (nameplate data).

$T_{M,N}$
The rated torque (motor).

U_M
The instant motor voltage.

$U_{M,N}$
The rated motor voltage (nameplate data).

$U_{VLT,\ MAX}$
The maximum output voltage.

η_{VLT}
The efficiency of the frequency converter is defined as the ratio between the power output and the power input.

Break-away torque

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

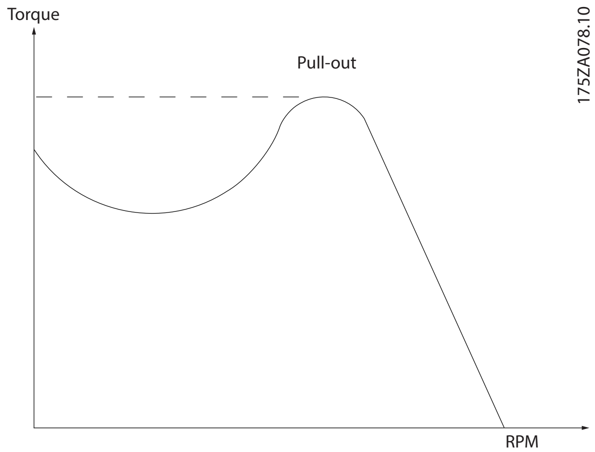

Illustration 18.1 Break-away Torque Chart

General terms and abbreviations:

60° AVM
Switching pattern called 60° asynchronous vector modulation (See *parameter 14-00 Switching Pattern*).

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Advanced Vector Control
If compared with standard voltage/frequency ratio control, advanced vector control improves the dynamics and the stability, both when the speed reference is changed and in relation to the load torque.

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

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

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

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

Analog reference
A signal transmitted to the 53 or 54, can be voltage or current.

Binary reference
A signal applied to the serial communication port (RS485 terminal 68–69).

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.

Bus reference
A signal transmitted to the serial communication port (FC port).

CT characteristics
Constant torque characteristics used for screw and scroll refrigeration compressors.

Digital inputs
The digital inputs can be used for controlling various functions of the frequency converter.

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

DSP
Digital signal processor.

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

GLCP
Graphical local control panel (LCP 102)

HIPERFACE®
HIPERFACE® is a registered trademark by Stegmann.

Initializing
If initializing is carried out (*parameter 14-22 Operation Mode*), the programmable parameters of the frequency converter return to their default settings.

Input functions

Control command Start and stop the connected motor with the LCP or the digital inputs. Functions are divided into 2 groups. Functions in group 1 have higher priority than functions in group 2.	Group 1	Reset, coast stop, reset and coast stop, quick stop, DC brake, stop and the [Off] key.
	Group 2	Start, pulse start, reversing, start reversing, jog, and freeze output.

Table 18.1 Input Functions

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

LCP
The local control panel (LCP) makes up a complete interface for control and programming of the frequency converter. The LCP is detachable and can be installed up to 3 m (10 ft) from the frequency converter, in a front panel with the installation kit option.
The LCP is available in 2 versions:

- Numerical LCP 101 (NLCP)
- Graphical LCP 102 (GLCP)

lsb
Least significant bit.

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

msb
Most significant bit.

NLCP
Numerical local control panel LCP 101.

Online/offline parameters
Changes to online parameters are activated immediately after the data value is changed. Press [OK] on the LCP to activate changes to offline parameters.

PID controller
The PID controller maintains the desired speed, pressure, and temperature by adjusting the output frequency to match the varying load.

PCD
Process data.

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

$$Power\ factor = \frac{\sqrt{3} \times U \times I_{1} \times cos\phi}{\sqrt{3} \times U \times I_{RMS}}$$

The power factor for 3-phase control:

$$= \frac{I_1 \times cos\phi 1}{I_{RMS}} = \frac{I_1}{I_{RMS}}\ since\ cos\phi 1 = 1$$

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

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

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

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

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. The encoder connection is either via terminal 32 or encoder option.

Pulse reference
A pulse frequency signal transmitted to the digital inputs (terminal 29 or 33).

RCD
Residual current device. A device that disconnects a circuit if there is an imbalance between an energized conductor and ground. Also known as a ground fault circuit interrupter (GFCI).

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

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

Set-up
Parameter settings can be saved in 4 set-ups. Change between the 4 parameter set-ups and edit 1 set-up, while another set-up is active.

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

Slip compensation
The frequency converter 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.

STW
Status word.

Start-disable command
A stop command belonging to the group 1 control commands. See *Table 18.1*.

Stop command
See control commands parameter group.

Thermistor
A temperature-dependent resistor placed where the temperature is monitored (frequency converter or motor).

THD
Total harmonic distortion. A state of full harmonic distortion.

Trip
A state entered in fault situations. For example, if the frequency converter is subject to an overtemperature or when it is protecting the motor, process, or mechanism. Restart is prevented until the cause of the fault has disappeared and the trip state is canceled by pressing [Reset] or, sometimes, by being programmed to reset automatically. Do not use trip for personal safety.

Trip lock
A state entered in fault situations when the frequency converter is protecting itself and requires physical intervention. For example, if the frequency converter is subject to a short circuit on the output, it enters trip lock. A locked trip can only be canceled by cutting off mains, removing the cause of the fault, and reconnecting the frequency converter.

VT characteristics
Variable torque characteristics used for pumps and fans.

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

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