MAKING MODERN LIVING POSSIBLE

Design Guide

VLT® AutomationDrive FC 300
90-1200 kW

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THE REAL DRIVE

Contents

1 How to Read this Design Guide

1.1 How to Read This Design Guide - FC 300

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FC 300 **Design Guide** **Software version: 6.6x**
This Design Guide can be used for all FC 300 frequency converters with software version 6.6x. The software version number can be seen from *15-43 Software Version*.

Table 1.1 Software Version Label

1.2 Available Literature

- The *Operating Instructions* are shipped with the unit and include information on installation and startup.
- The *Design Guide* includes all technical information about the frequency converter, frames D, E, and F, and customer design and applications.
- The *Programming Guide* provides information on how to programme and includes complete parameter descriptions.
- The *Profibus Operating Instructions* provides information on how to control, monitor, and programme the frequency converter via a Profibus fieldbus.
- The *DeviceNet Operating Instructions* provides information on how to control, monitor, and programme the frequency converter via a DeviceNet fieldbus.

Danfoss technical literature is available in print from local Danfoss sales offices or online at:
www.danfoss.com/BusinessAreas/DrivesSolutions/Documentations/VLT+Technical+Documentation.htm

1.3 Approvals

Table 1.2 Compliance Marks: CE, UL, and C-Tick

The frequency converter complies with UL508C thermal memory retention requirements. For more information, refer to*3.11.1 Motor Thermal Protection*.

1.4 Symbols

The following symbols are used in this document.

WARNING

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

CAUTION

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

NOTICE

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

1.5 Abbreviations

Alternating current	AC
American wire gauge	AWG
Ampere/AMP	A
Automatic Motor Adaptation	AMA
Current limit	I_{LIM}
Degrees Celsius	°C
Direct current	DC
Drive Dependent	D-TYPE
Electro Magnetic Compatibility	EMC
Electronic Thermal Relay	ETR
Frequency converter	FC
Gram	g
Hertz	Hz
Horsepower	hp
Kilohertz	kHz
Local Control Panel	LCP
Meter	m
Millihenry Inductance	mH
Milliampere	mA
Millisecond	ms
Minute	min
Motion Control Tool	MCT
Nanofarad	nF
Newton Meters	Nm
Nominal motor current	$I_{M,N}$
Nominal motor frequency	$f_{M,N}$
Nominal motor power	$P_{M,N}$
Nominal motor voltage	$U_{M,N}$
Permanent Magnet motor	PM motor
Protective Extra Low Voltage	PELV
Printed Circuit Board	PCB
Rated Inverter Output Current	I_{INV}
Revolutions Per Minute	RPM
Regenerative terminals	Regen
Second	sec.
Synchronous Motor Speed	n_s
Torque limit	T_{LIM}
Volts	V
The maximum output current	$I_{VLT,MAX}$
The rated output current supplied by the frequency converter	$I_{VLT,N}$

Table 1.3 Abbreviations used in this Manual

1.6 Definitions

Drive:

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

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

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

Input:

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

Table 1.4 Input Functions

Motor:

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).

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

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

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

U_M
The instantaneous motor voltage.

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

Break-away torque:

$\underline{n_s}$
Synchronous motor speed.

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

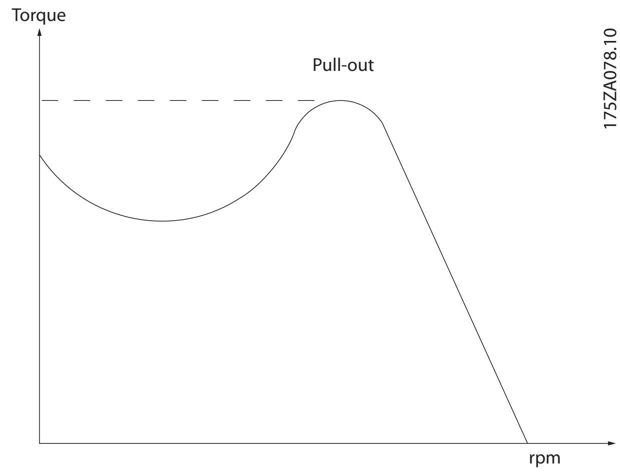


Illustration 1.1 Break-Away Torque Chart

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

Start-disable command
A stop command belonging to the group 1 control commands.

Stop command
See control commands parameter group.

References:

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 (FS-485 terminal 68-69).

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

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

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

Ref_{MAX}
Determines the relationship between the reference input at 100% full scale value (typically 10 V, 20 mA) and the resulting reference. The maximum reference value is set in *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 *3-02 Minimum Reference*.

Miscellaneous:

Analog Inputs
The analog inputs (current and voltage) are used for controlling functions of the frequency converter. 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.

Brake Resistor
The brake resistor is a module capable of absorbing the brake power generated in regenerative braking. This regenerative braking power increases the intermediate circuit voltage and a brake chopper ensures that the power is transmitted to the brake resistor.

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 two solid state outputs that can supply a 24 V DC (max. 40 mA) signal.

DSP
Digital Signal Processor.

Relay Outputs:
The frequency converter features two programmable relay outputs.

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 (LCP102)

Hiperface®
Hiperface® is a registered trademark by Stegmann.

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

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 none-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 metres from the frequency converter, in a front panel with the installation kit option.
The LCPI is available in two versions:

- Numerical LCP101 (NLCP)
- Graphical LCP102 (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 LCP101.

On-line/Off-line Parameters
Changes to on-line parameters are activated immediately after the data value is changed. Changes to off-line parameters are not activated until [OK] is entered on the LCP.

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.

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 MCB 102.

RCD
Residual Current Device. A device that disconnects a circuit in case of an imbalance between an energised conductor and ground. Also known as a ground fault circuit interrupter (GFCI).

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 **S**tator Flux oriented Asynchronous Vector **M**odulation (*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.

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 cancelled by activating Reset or, in some cases, by being programmed to reset automatically. Do not use trip for personal safety.

Trip Locked
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 will enter trip lock. A locked trip can only be cancelled 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^{plus}
If compared with standard voltage/frequency ratio control, Voltage Vector Control (VVC^{plus}) improves the dynamics and the stability, both when the speed reference is changed and in relation to the load torque.

60° AVM
Switching pattern called 60°**A**synchronous Vector Modulation (See *14-00 Switching Pattern*).

1.7 Power Factor

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

$$Power\ factor = \frac{\sqrt{3} \times U \times I_1 \times COS\varphi}{\sqrt{3} \times U \times I_{RMS}}$$

The power factor for 3-phase control:

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

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.

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

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.

2 Safety and Conformity

2.1 Safety Precautions

Frequency converters contain high-voltage components and have the potential for fatal injury if handled improperly. Only trained technicians should install and operate the equipment. No repair work should be attempted without first removing power from the frequency converter and waiting the designated amount of time for stored electrical energy to dissipate.

Strict adherence to safety precautions and notices is mandatory for safe operation of the frequency converter.

2.2 Caution

WARNING

DISCHARGE TIME

Frequency converters contain DC-link capacitors that can remain charged even when the frequency converter is not powered. To avoid electrical hazards, disconnect the following:

- **AC mains**
- **Permanent magnet type motors**
- **Remote DC-link power supplies, including battery backups, UPS and DC-link connections to other frequency converters**

Wait for the capacitors to fully discharge before performing any service or repair work. The amount of wait time is listed in the *Capacitor Discharge Time* table. Failure to wait the specified time after power has been removed before starting service or repair could result in death or serious injury.

Voltage [V]	Power [kW]	Minimum Waiting Time [Min]
380-500	90-250	20
	315-800 kW	40
525-690	55-315 (frame size D)	20
	355-1200	30

Table 2.1 Capacitor Discharge Times

2.2.1 Disposal Instruction

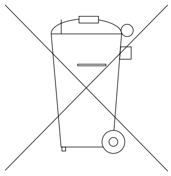
	Do not dispose of equipment containing electrical components together with domestic waste. Collect it separately in accordance with local and currently valid legislation.

Table 2.2 Disposal Instruction

2.3 CE Labelling

2.3.1 CE Conformity and Labelling

Machinery Directive (2006/42/EC)
Frequency converters do not fall under the machinery directive. However, if a frequency converter is supplied for use in a machine, Danfoss provides information on safety aspects relating to the frequency converter.
What is CE Conformity and Labelling?
The purpose of CE labelling is to avoid technical trade obstacles within EFTA and the EU. The EU has introduced the CE label as a simple way of showing whether a product complies with the relevant EU directives. The CE label says nothing about the specifications or quality of the product. Frequency converters are regulated by two EU directives:
Low-Voltage Directive (2006/95/EC)
Frequency converters must be CE labelled in accordance with the low-voltage directive of January 1, 1997. The directive applies to all electrical equipment and appliances used in the 50-1000 V AC and the 75-1500 V DC voltage ranges. Danfoss CE-labels in accordance with the directive and issues a declaration of conformity upon request.
EMC Directive (2004/108/EC)
EMC is short for electromagnetic compatibility. The presence of electromagnetic compatibility means that the mutual interference between different components/ appliances does not affect the way the appliances work. The EMC directive came into effect January 1, 1996. Danfoss CE-labels in accordance with the directive and issues a declaration of conformity upon request. To carry out EMC-correct installation, see *7.8 EMC-Correct Installation*. In addition, we specify which standards our products comply with. Danfossoffer the filters presented in the specifications and provide other types of assistance to ensure the optimum EMC result.

The frequency converter is most often used by trade professionals as a complex component forming part of a larger appliance, system or installation. It must be noted that the responsibility for the final EMC properties of the appliance, system or installation rests with the installer.

2.3.2 What Is Covered

The EU "*Guidelines on the Application of Council Directive 2004/108/EC*" outline three typical situations of using a frequency converter. See the following list for EMC coverage and CE labelling.

1. The frequency converter is sold directly to the end consumer, for example, to a DIY market. The end consumer is a layman who installs the frequency converter for use with a household appliance. For such applications, the frequency converter must be CE labelled in accordance with the EMC directive.
2. The frequency converter is sold for installation in a plant designed by trade professionals. The frequency converter and the finished plant do not have to be CE labelled under the EMC directive. However, the unit must comply with the basic EMC requirements of the directive. Compliance is ensured by using components, appliances, and systems that are CE labelled under the EMC directive.
3. The frequency converter is sold as part of a complete system, such as an air-conditioning system. The entire system must be CE labelled in accordance with the EMC directive. The manufacturer can ensure CE labelling under the EMC directive either by using CE labelled components or by testing the EMC of the system. If the manufacturer chooses to use only CE labelled components, there is no need to test the entire system.

2.3.3 Danfoss Frequency Converter and CE Labelling

CE labelling is a positive feature when used for its original purpose, which is to facilitate trade within the EU and EFTA.

CE labelling can cover many different specifications, so check the CE label to ensure that it covers the relevant applications.

Danfoss CE labels the frequency converters in accordance with the low-voltage directive, meaning that if the frequency converter is installed correctly, Danfoss guarantees compliance with the low-voltage directive. Danfoss issues a declaration of conformity that confirms our CE labelling in accordance with the low-voltage directive.

The CE label also applies if following the instructions for EMC-correct installation and filtering.

Detailed instructions for EMC-correct installation are found in *7.8 EMC-Correct Installation*. Furthermore, Danfoss specifies which standards our products comply with.

2.3.4 Compliance with EMC Directive 2004/108/EC

The primary users of the frequency converter are trade professionals, who use it as a complex component forming part of a larger appliance, system, or installation. The responsibility for the final EMC properties of the appliance, system, or installation rests with the installer. As an aid to the installer, Danfoss has prepared EMC installation guidelines for the power drive system. If the EMC-correct instructions for installation are followed, the standards and test levels stated for power drive systems are complied with. See *3.5.4 Immunity Requirements*.

2.4 Enclosure Types

The VLT Series frequency converters are available in various enclosure types to best accommodate the needs of the application. Enclosure ratings are provided based on 2 international standards:

- NEMA (National Electrical Manufacturers Association) in the United States
- IP (International Protection) ratings outlined by IEC (International Electrotechnical Commission) in the rest of the world

Standard Danfoss VLT frequency converters are available in various enclosure types to meet the requirements of IP00 (chassis), IP20, IP21 (NEMA 1), or IP54 (NEMA12).

UL and NEMA Standards
NEMA/UL Type 1 – Enclosures constructed for indoor use to provide a degree of protection to personnel against incidental contact with the enclosed units and to provide a degree of protection against falling dirt.

NEMA/UL Type 12 – General-purpose enclosures are intended for use indoors to protect the enclosed units against the following contaminants:

- fibres
- lint
- dust and dirt
- light splashing
- seepage
- dripping and external condensation of noncorrosive liquids

There can be no holes through the enclosure and no conduit knockouts or conduit openings, except when used with oil-resistant gaskets to mount oil-tight or dust-tight mechanisms. Doors are also provided with oil-resistant gaskets. In addition, enclosures for combination controllers have hinged doors, which swing horizontally and require a tool to open.

UL type validates that the enclosures meet NEMA standards. The construction and testing requirements for enclosures are provided in NEMA Standards Publication 250-2003 and UL 50, Eleventh Edition.

IP Codes
Table 2.4 provides a cross-reference between the 2 standards. *Table 2.3* demonstrates how to read the IP number code and defines the levels of protection. The frequency converters meet the requirements of both.

NEMA type	IP type
Chassis	IP00
Protected chassis	IP20
NEMA 1	IP21
NEMA 12	IP54

Table 2.3 IP Number Cross Reference

First digit (solid foreign objects)	
0	No protection
1	Protected to 50 mm (hands)
2	Protected to 12.5 mm (fingers)
3	Protected to 2.5 mm (tools)
4	Protected to 1.0 mm (wire)
5	Protected against dust – limited entry
6	Protected totally against dust
Second digit (water)	
0	No protection
1	Protected from vertical dripping water
2	Protected from dripping water at 15° angle
3	Protected from water at 60° angle
4	Protected from splashing water
5	Protected from water jets
6	Protected from strong water jets
7	Protected from temporary immersion
8	Protected from permanent immersion

Table 2.4 IP Number Code Definitions

2.5 Aggressive Environments

A frequency converter contains a large number of 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 may cause corrosion of components and metal parts. Steam, oil, and salt water may 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 may 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 very dusty environments, use equipment with enclosure rating IP54/IP55 or a cabinet for IP00/IP20/TYPE 1 equipment.

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

Such chemical reactions will 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 converter.

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

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

D and E enclosures have a stainless-steel back-channel option to provide additional protection in corrosive environments, such as salt air found near sea side applications. Proper ventilation is still required for the internal components of the frequency converter. Contact Danfoss for additional information.

2.5.1 Humidity

The frequency converter has been designed to meet the IEC/EN 60068-2-3 standard, EN 50178 § 9.4.2.2 at 50 °C.

2.5.2 Vibration

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

- IEC/EN 60068-2-6: Vibration (sinusoidal) - 1970
- IEC/EN 60068-2-64: Vibration, broad-band random

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

3 Product Introduction

3.1 Product Overview

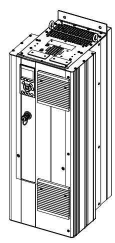
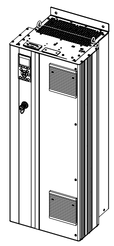
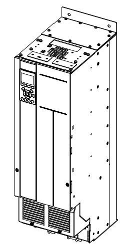
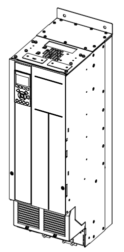
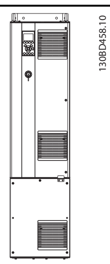
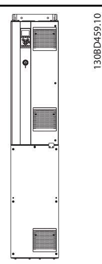
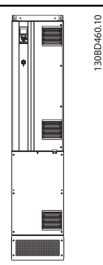
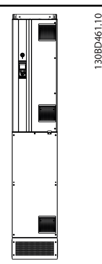
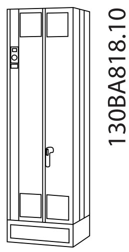
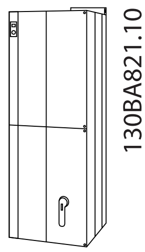
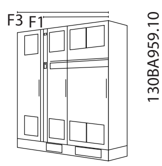
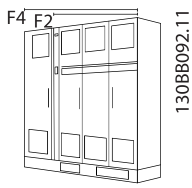
Frame size		D1h	D2h	D3h	D4h
					
Enclosure protection	IP	21/54	21/54	20	20
	NEMA	Type 1/Type 12	Type 1/Type 12	Chassis	Chassis
High overload rated power -160% overload torque		90-132 kW at 400 V (380-500 V) 55-132 kW at 690 V (525-690 V)	160-250 kW at 400 V (380-500 V) 160-315 kW at 690 V (525-690 V)	90-132 kW at 400 V (380-500 V) 55-132 kW at 690 V (525-690 V)	160-250 kW at 400 V (380-500 V) 160-315 kW at 690 V (525-690 V)
Frame size		**D5h**	**D6h**	**D7h**	**D8h**
					
Enclosure protection	IP	21/54	21/54	21/54	21/54
	NEMA	Type 1/Type 12	Type 1/Type 12	Type 1/Type 12	Type 1/Type 12
High overload rated power -160% overload torque		90-132 kW at 400 V (380-500 V) 55-132 kW at 690 V (525-690 V)	90-132 kW at 400 V (380-500 V) 55-132 kW at 690 V (525-690 V)	160-250 kW at 400 V (380-500 V) 160-315 kW at 690 V (525-690 V)	160-250 kW at 400 V (380-500 V) 160-315 kW at 690 V (525-690 V)
Frame size		**E1**	**E2**	**F1/F3**	**F2/ F4**
					
Enclosure protection	IP	21/54	00	21/54	21/54
	NEMA	Type 1/Type 12	Chassis	Type 1/Type 12	Type 1/Type 12
High overload rated power -160% overload torque		250-400 kW at 400 V (380-500 V) 355-560 kW at 690 V (525-690 V)	250-400 kW at 400 V (380-500 V) 355-560 kW at 690 V (525-690 V)	450-630 kW at 400 V (380-500 V) 630-800 kW at 690 V (525-690 V)	710-800 kW at 400 V (380-500 V) 900-1000 kW at 690 V (525-690 V)

Table 3.1 Product Overview, 6-Pulse Frequency Converters

NOTICE

The F-frames are available with or without an options cabinet. The F1 and F2 consist of a rectifier cabinet on the left and an inverter cabinet on the right. The F3/F4 are F1/F2 units with an additional options cabinet located left of the rectifier cabinet.

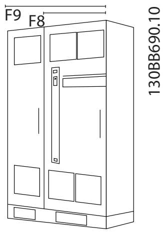
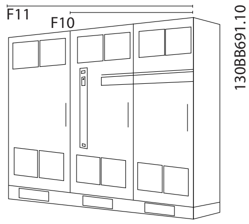
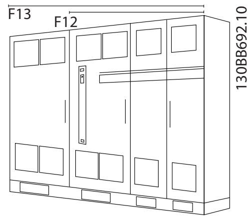
Frame size		F8	F9	F10	F11	F12	F13
							
Enclosure protection	IP	21/54	21/54	21/54	21/54	21/54	21/54
	NEMA	Type 1/Type 12	Type 1/Type 12	Type 1/Type 12	Type 1/Type 12	Type 1/Type 12	Type 1/Type 12
High overload rated power -160% overload torque		250-400 kW (380-500 V) 355-560 kW (525-690 V)	250-400 kW (380-500 V) 355-560 kW (525-690 V)	450-630 kW (380-500 V) 630-800 kW (525-690 V)	450-630 kW (380-500 V) 630-800 kW (525-690 V)	710-800 kW (380-500 V) 900-1200 kW (525-690 V)	710-800 kW (380-500V) 900-1200 kW (525-690 V)

Table 3.2 Product Overview, 12-Pulse Frequency Converters

NOTICE

The F-frames are available with or without an options cabinet. The F8, F10 and F12 consist of a rectifier cabinet on the left and an inverter cabinet on the right. The F9/F11/F13 are F8/F10/F12 units with an additional options cabinet located left of the rectifier cabinet.

3.2 Controls

The frequency converter is capable of controlling either the speed or the torque on the motor shaft. Setting *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 motor (sensorless).
- Closed loop PID requires a speed feedback to an input. A properly optimised 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 *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 *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 max speed limit factor is set in *4-21 Speed Limit Factor Source*. When running torque control, it is recommended to make 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 four quadrants and at all motor speeds.
- Open loop in VVC^{plus} mode. The function is used in mechanically robust applications, but its accuracy is limited. Open loop torque function works only in one speed direction. The torque is calculated on the basis of current measurement within the frequency converter. See *8 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 reference handling, see *3.3 Reference Handling*.

3.2.1 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 three-phased, standard AC motors and permanent magnet synchronous motors.

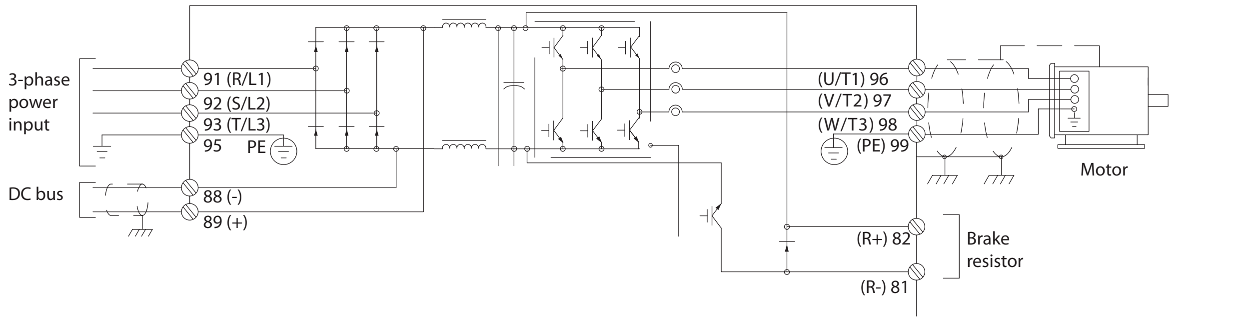


Illustration 3.1 Control Principle

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 power supply is also provided for use with the frequency converter control inputs and outputs. *Table 3.3* describes the functions of the control terminals. Many of these terminals have multiple functions determined by parameter settings. Some options provide more terminals. See *6.2 Mechanical Installation* for terminal locations.

Table 3.3 describes the functions of the control terminals. Many of these terminals have multiple functions determined by parameter settings. Some options provide more terminals. See *6.2 Mechanical Installation* for terminal locations.

Terminal no.	Function
01, 02, 03 and 04, 05, 06	Two 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 located on the power card.
12, 13	24 V DC power 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. Analog signal is 0/4 to 20 mA at a maximum of 500 Ω. 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	RS-485 common.
68, 69	RS-485 interface and serial communication.

Table 3.3 Terminal Control Functions (without Optional Equipment)

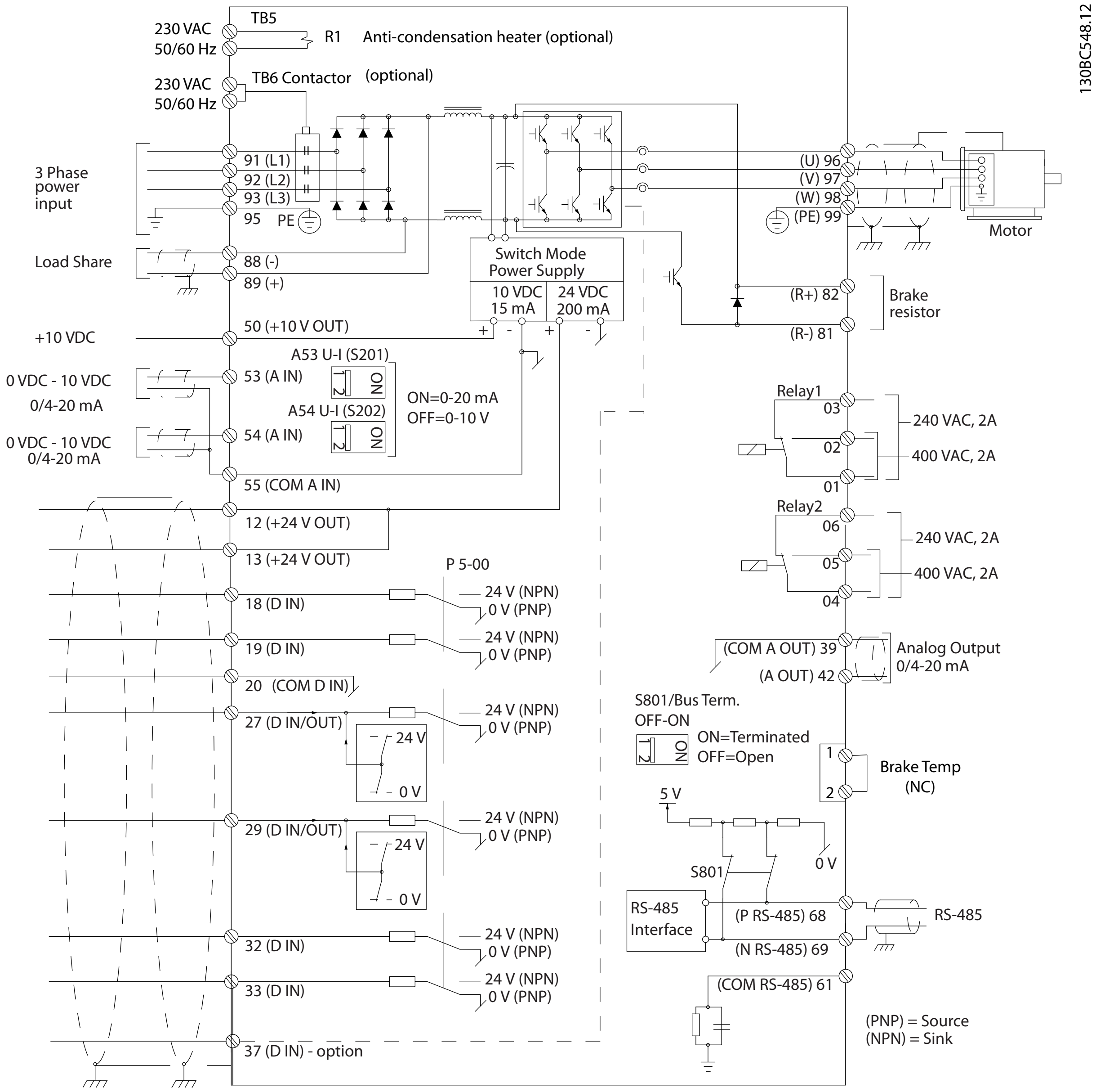


Illustration 3.2 D-frame Interconnect Diagram

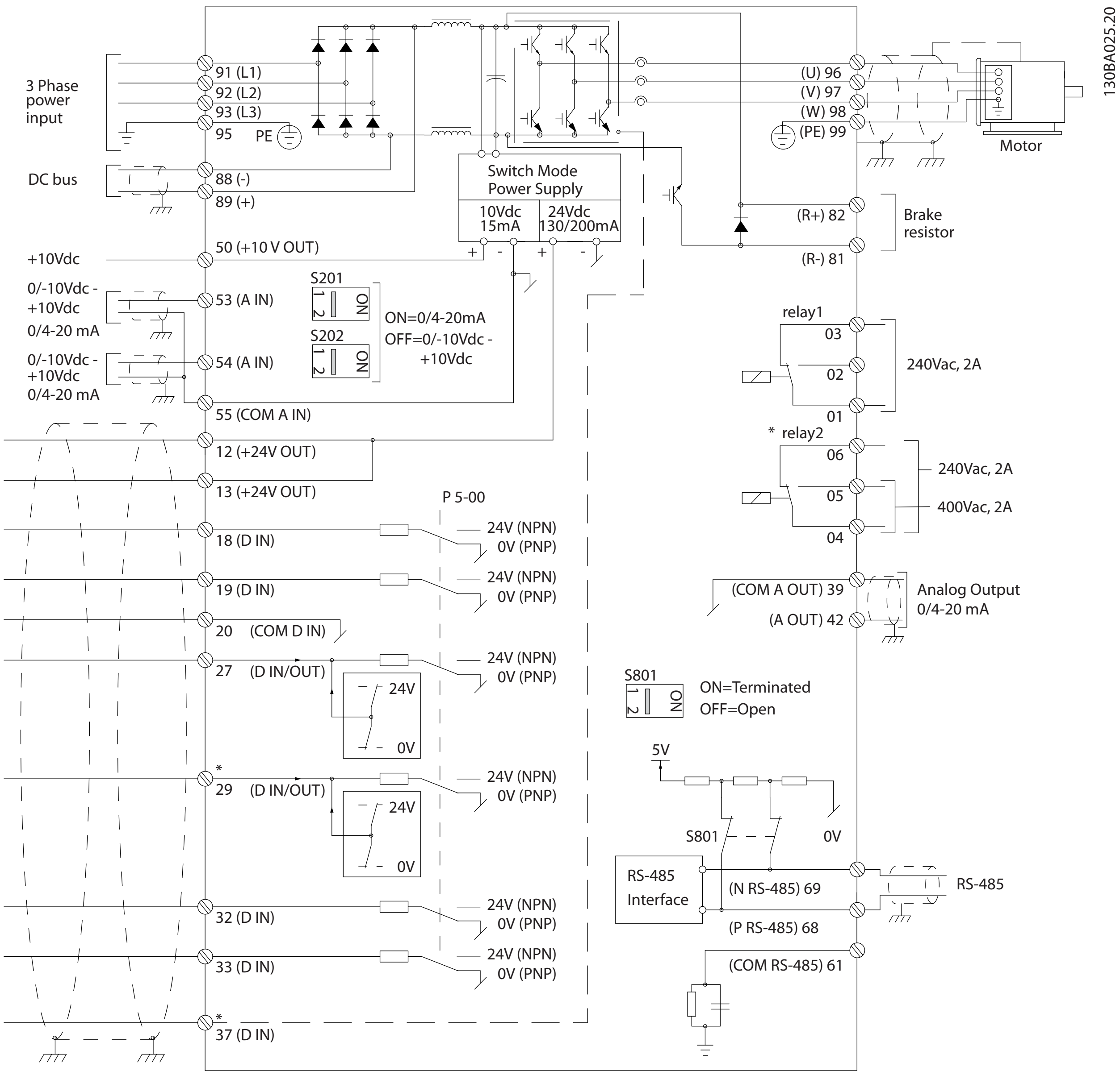


Illustration 3.3 E- and F-frame Interconnect Diagram

3.2.2 Control Structure in VVC^{plus} Advanced Vector Control

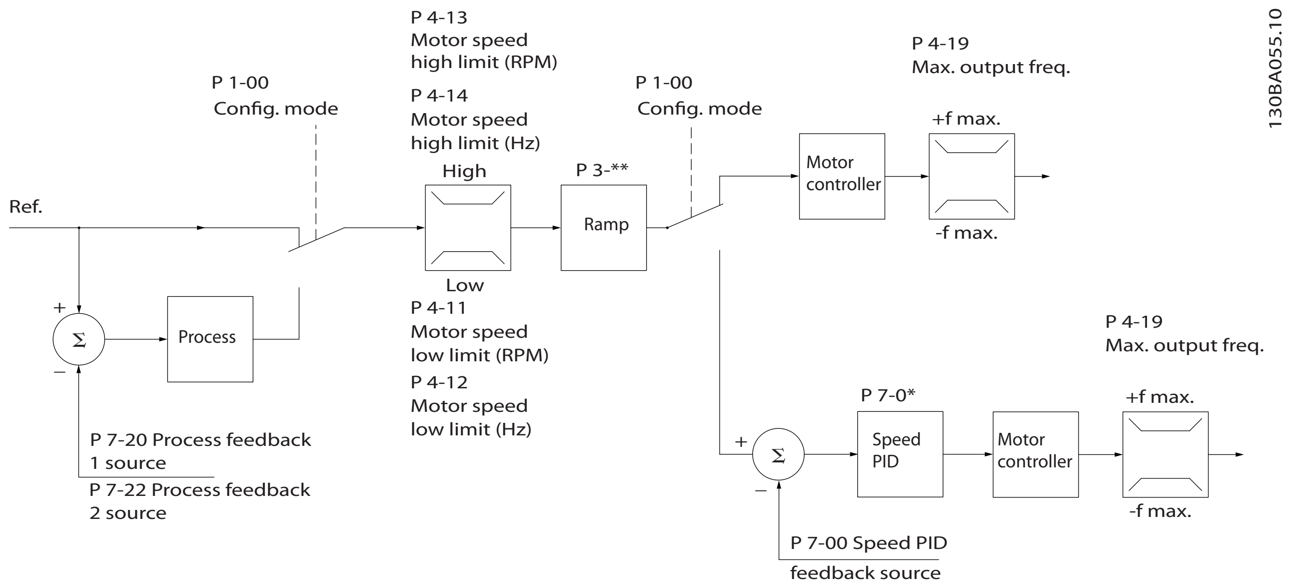


Illustration 3.4 Control Structure in VVC^{plus} Open Loop and Closed Loop Configurations

In *Illustration 3.4*, *1-01 Motor Control Principle* is set to *[1] VVC^{plus}* and *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 *1-00 Configuration Mode* is set to *[1] Speed closed loop*, the resulting reference is passed from the ramp limitation and speed limitation into a speed PID control. The speed PID control parameters are located in the 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 *1-00 Configuration Mode*. The Process PID parameters are located in parameter group *7-2* Process Ctrl, Feedback* and *7-3* Process PID Ctrl*.

3.2.3 Control Structure in Flux Sensorless

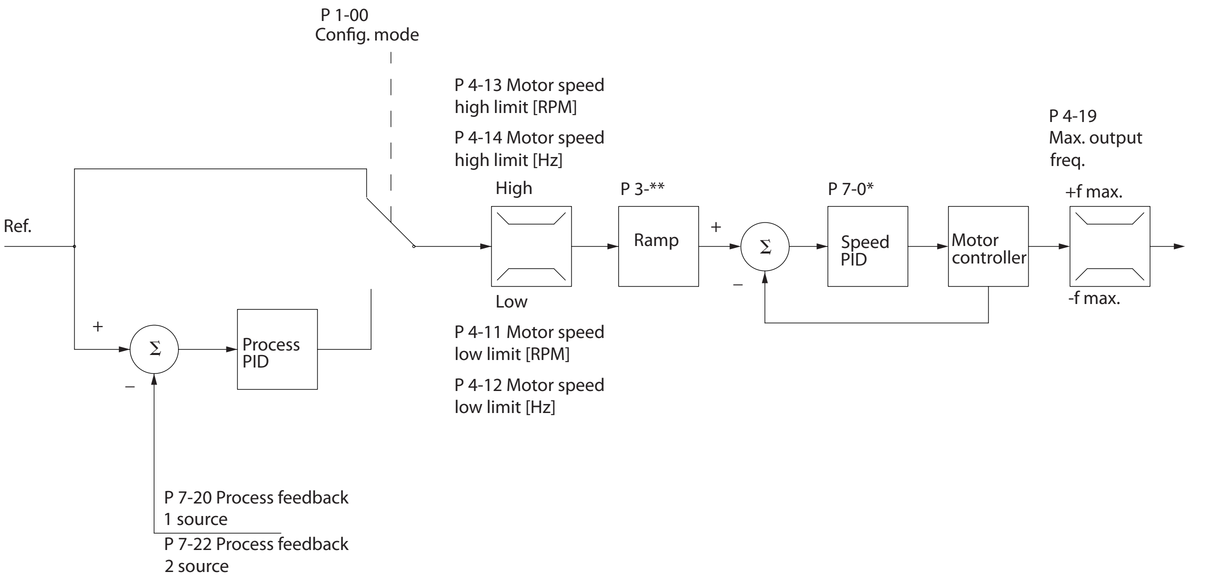


Illustration 3.5 Control Structure in Flux Sensorless Open Loop and Closed Loop Configurations

In *Illustration 3.5*, *1-01 Motor Control Principle* is set to *[2] Flux sensorless* and *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 closed loop control of speed or pressure in the controlled application, for example, select *[3] Process* in *1-00 Configuration Mode*. The Process PID parameters are found in parameter group *7-2* Process Ctrl. Feedback* and *7-3* Process PID Ctrl.*

3.2.4 Control Structure in Flux with Motor Feedback

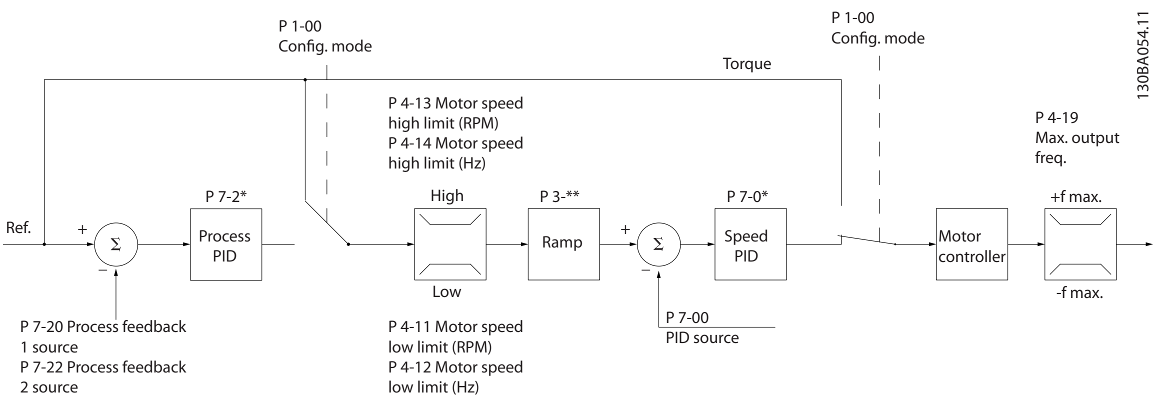


Illustration 3.6 Control Structure in Flux with Motor Feedback Configuration (Only Available in FC 302)

In *Illustration 3.6*, *1-01 Motor Control Principle* is set to *[3] Flux w motor feedb* and *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 *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 *1-00 Configuration Mode*. The Speed PID control parameters are located in parameter group *7-0* Speed PID Ctr.*

Select *[2] Torque* in *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* (*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 on the basis of 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 *1-00 Configuration Mode*.

3.2.5 Internal Current Control in VVC^{plus} Mode

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 *4-16 Torque Limit Motor Mode*, *4-17 Torque Limit Generator Mode*, and *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.

3.2.6 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 serial bus. If allowed in *0-40 [Hand on] Key on LCP*, *0-41 [Off] Key on LCP*, *0-42 [Auto on] Key on LCP*, and *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 H (manual) 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 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 (RS-485, USB, or an optional fieldbus). See more about starting, stopping, changing ramps and parameter set-ups etc. in parameter group *5-1* Digital Inputs* or parameter group *8-5* Serial Communication*.

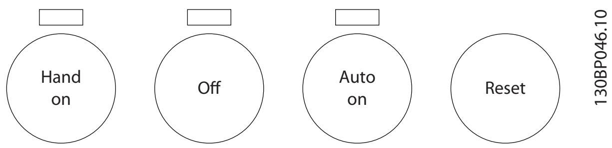


Illustration 3.7 LCP Control Keys

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 *3-13 Reference Site*.
To permanently select the remote reference, select *[1] Remote*. By selecting *[0] Linked to Hand/Auto* (default) the reference site will depend on whether Hand or Auto mode is active.

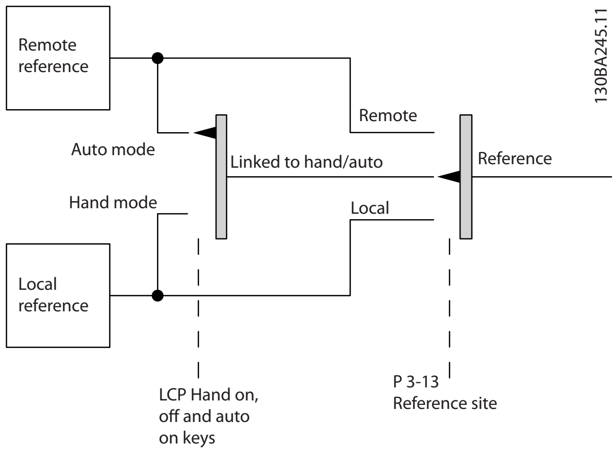


Illustration 3.8 Active Reference

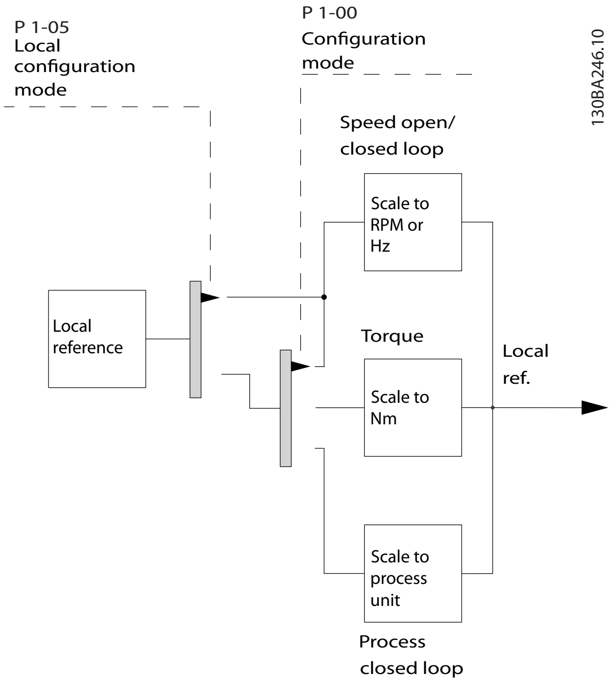


Illustration 3.9 Configuration Mode

Hand on	*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 3.4 Conditions for Local/Remote Reference Activation

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. *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.

3.3 Reference Handling

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 reference handling system for calculating the reference is shown in *Illustration 3.10*.

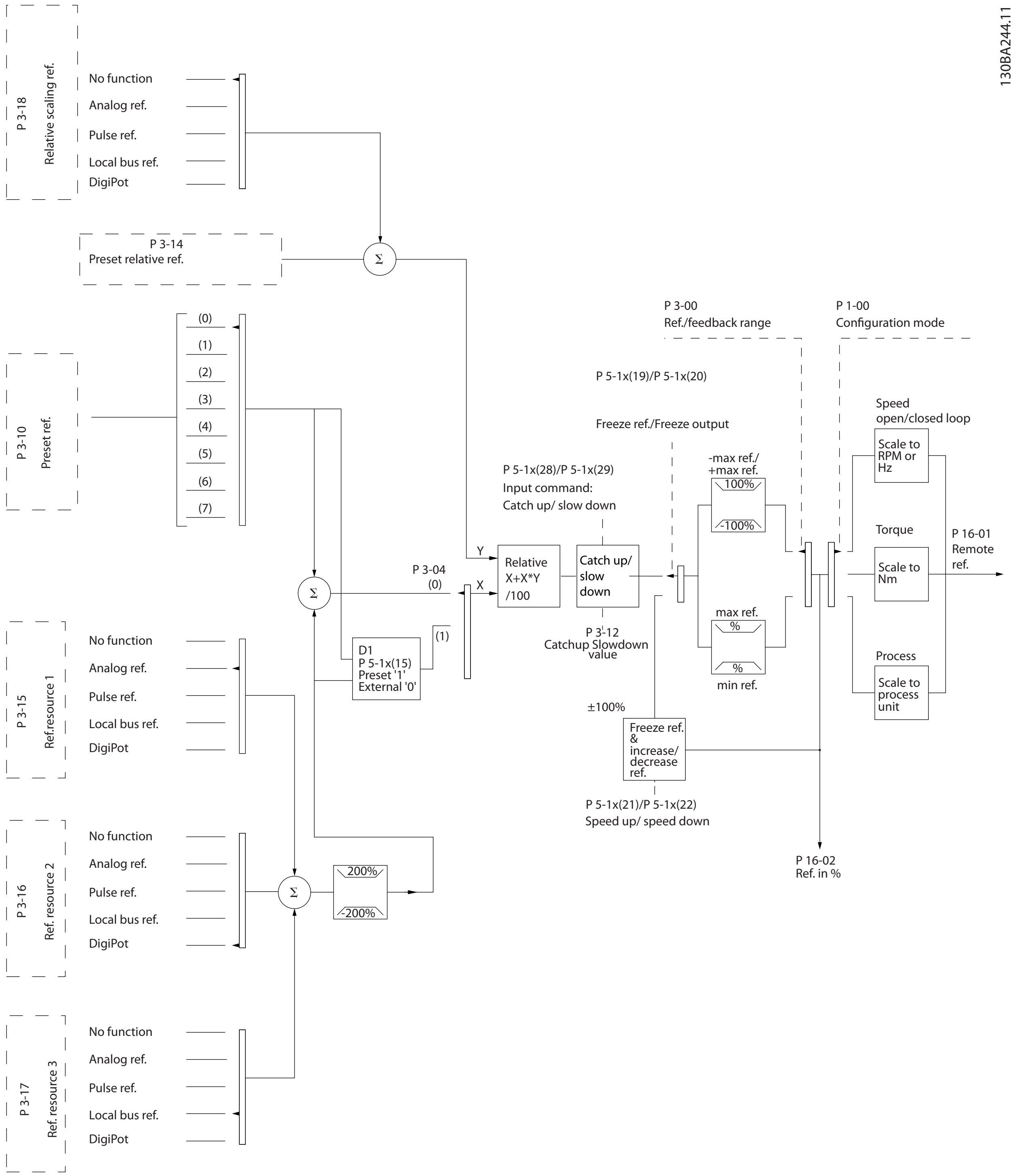


Illustration 3.10 Remote Reference

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

- X (External): A sum (see *3-04 Reference Function*) of up to 4 externally selected references, comprising any combination of a fixed preset reference (*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] etc). The combination is determined by the setting of *3-15 Reference Resource 1*, *3-16 Reference Resource 2* and *3-17 Reference Resource 3*.
- Y (Relative): A sum of one fixed preset reference (*3-14 Preset Relative Reference*) and one variable analog reference (*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, *3-18 Relative Scaling Reference Resource* must be set to *No function* and *3-14 Preset Relative Reference* to *0%*. The *catch up/slow down* function and the *freeze reference* function can both be activated by digital inputs on the frequency converter. 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*.

3.3.1 Reference Limits

3-00 Reference Range, *3-02 Minimum Reference*, and *3-03 Maximum Reference* together define the range of the sum of all references. The sum of all references are clamped when necessary. The relation between the resulting reference (after clamping) and the sum of all references is shown in *Illustration 3.11* and *Illustration 3.12*.

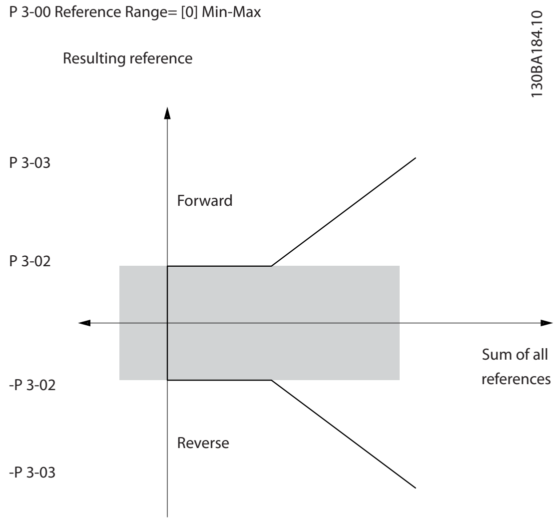


Illustration 3.11 Relation between Resulting Reference and the Sum of All References

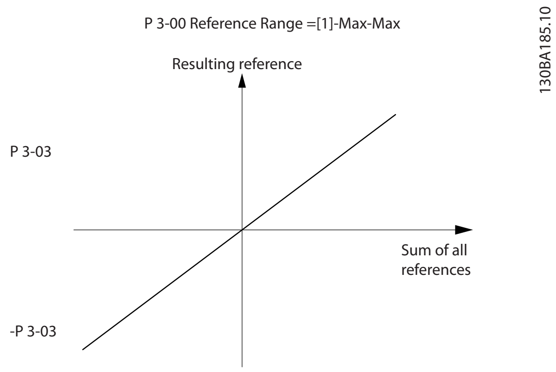


Illustration 3.12 Resulting Reference

The value of *3-02 Minimum Reference* can not be set to less than 0, unless *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 3.13*.

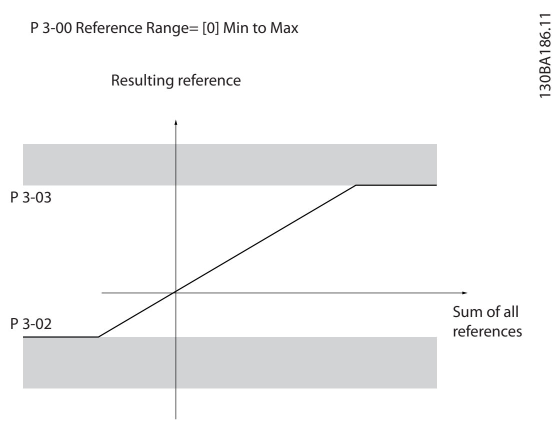


Illustration 3.13 Sum of All References

3.3.2 Scaling of Preset References and Bus References

Preset references

Preset references are scaled according to the following:

- When *3-00 Reference Range*: *[0] Min to Max* 0% reference equals 0 [unit], where unit can be any unit such as RPM, m/s, bar etc. 100% reference equals the Max abs (*3-03 Maximum Reference*), abs (*3-02 Minimum Reference*).
- When *3-00 Reference Range*: *[1] -Max to +Max* 0% reference equals 0 [unit] -100% reference equals - Max Reference 100% reference equals Max Reference.

Bus references

Bus references are scaled according to the following rules:

- When *3-00 Reference Range*: *[0] Min to Max*. To obtain max resolution on the bus reference, the scaling on the bus is: 0% reference equals Min Reference and 100% reference equals Max reference.
- When *3-00 Reference Range*: *[1] -Max to +Max* -100% reference equals -Max Reference 100% reference equals Max Reference.

3.3.3 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 3.14*) are clamped, whereas a feedback above or below is not.

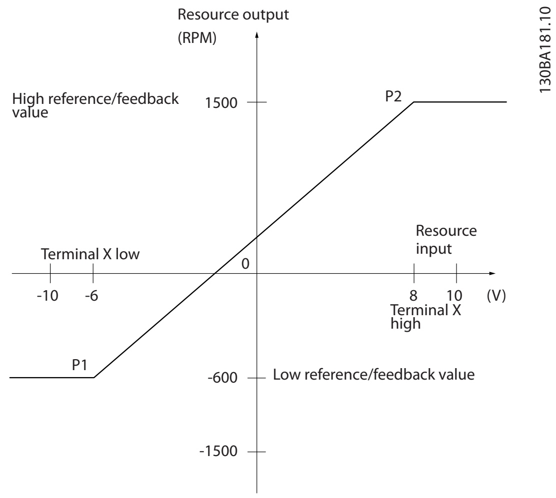


Illustration 3.14 Scaling of Analog and Pulse References

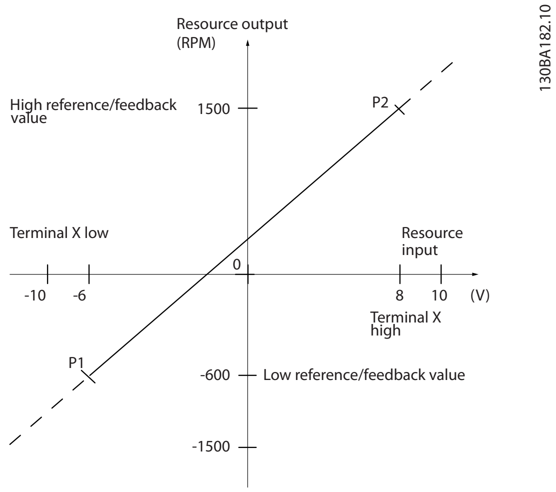


Illustration 3.15 Scaling of Analog and Pulse Feedback

The endpoints P1 and P2 are defined in *Table 3.5*, 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	6-14 Terminal 53 Low Ref./ Feedb. Value	6-14 Terminal 53 Low Ref./Feedb. Value	6-24 Terminal 54 Low Ref./ Feedb. Value	6-24 Terminal 54 Low Ref./Feedb. Value	5-52 Term. 29 Low Ref./Feedb. Value	5-57 Term. 33 Low Ref./Feedb. Value
Minimum input value	6-10 Terminal 53 Low Voltage [V]	6-12 Terminal 53 Low Current [mA]	6-20 Terminal 54 Low Voltage [V]	6-22 Terminal 54 Low Current [mA]	5-50 Term. 29 Low Frequency [Hz]	5-55 Term. 33 Low Frequency [Hz]
P2 =(Maximum input value, Maximum reference value)						
Maximum reference value	6-15 Terminal 53 High Ref./ Feedb. Value	6-15 Terminal 53 High Ref./Feedb. Value	6-25 Terminal 54 High Ref./ Feedb. Value	6-25 Terminal 54 High Ref./Feedb. Value	5-53 Term. 29 High Ref./ Feedb. Value	5-58 Term. 33 High Ref./Feedb. Value
Maximum input value	6-11 Terminal 53 High Voltage [V]	6-13 Terminal 53 High Current [mA]	6-21 Terminal 54 High Voltage [V]	6-23 Terminal 54 High Current [mA]	5-51 Term. 29 High Frequency [Hz]	5-56 Term. 33 High Frequency [Hz]

Table 3.5 P1 and P2 Parameters

3.3.4 Dead Band around Zero

In some cases, the reference and, in rare instances, the feedback needs a dead band around zero. This ensures the machine is stopped when the reference is “near zero”).

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

- Minimum reference value (see *Table 3.5* for relevant parameter) or maximum reference value must be zero. In other words; Either P1 or P2 must be on the X-axis in *Illustration 3.16*.
- Both points defining the scaling graph must be in the same quadrant.

The size of the dead band is defined by either P1 or P2 as shown in *Illustration 3.16*.

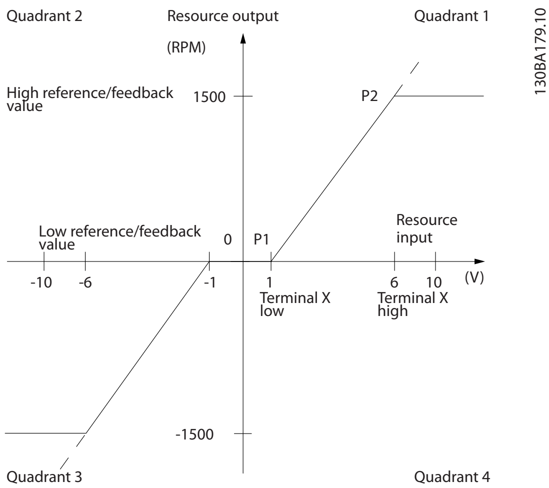


Illustration 3.16 Dead Band

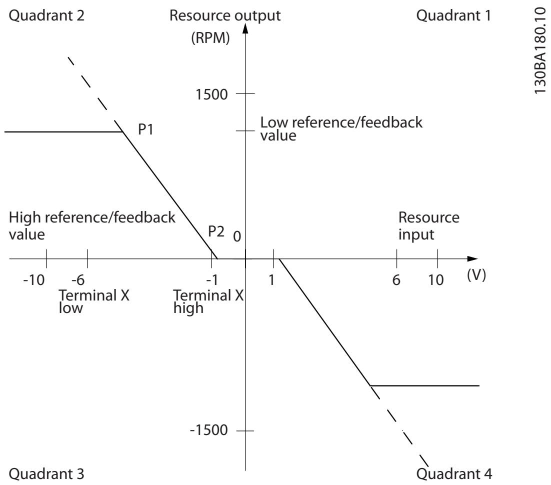


Illustration 3.17 Reverse Dead Band

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 provided that the end point P2 is placed in either Quadrant 1 or Quadrant 4.

Case 1. This case shows how reference input with limits inside Min to Max limits clamps.

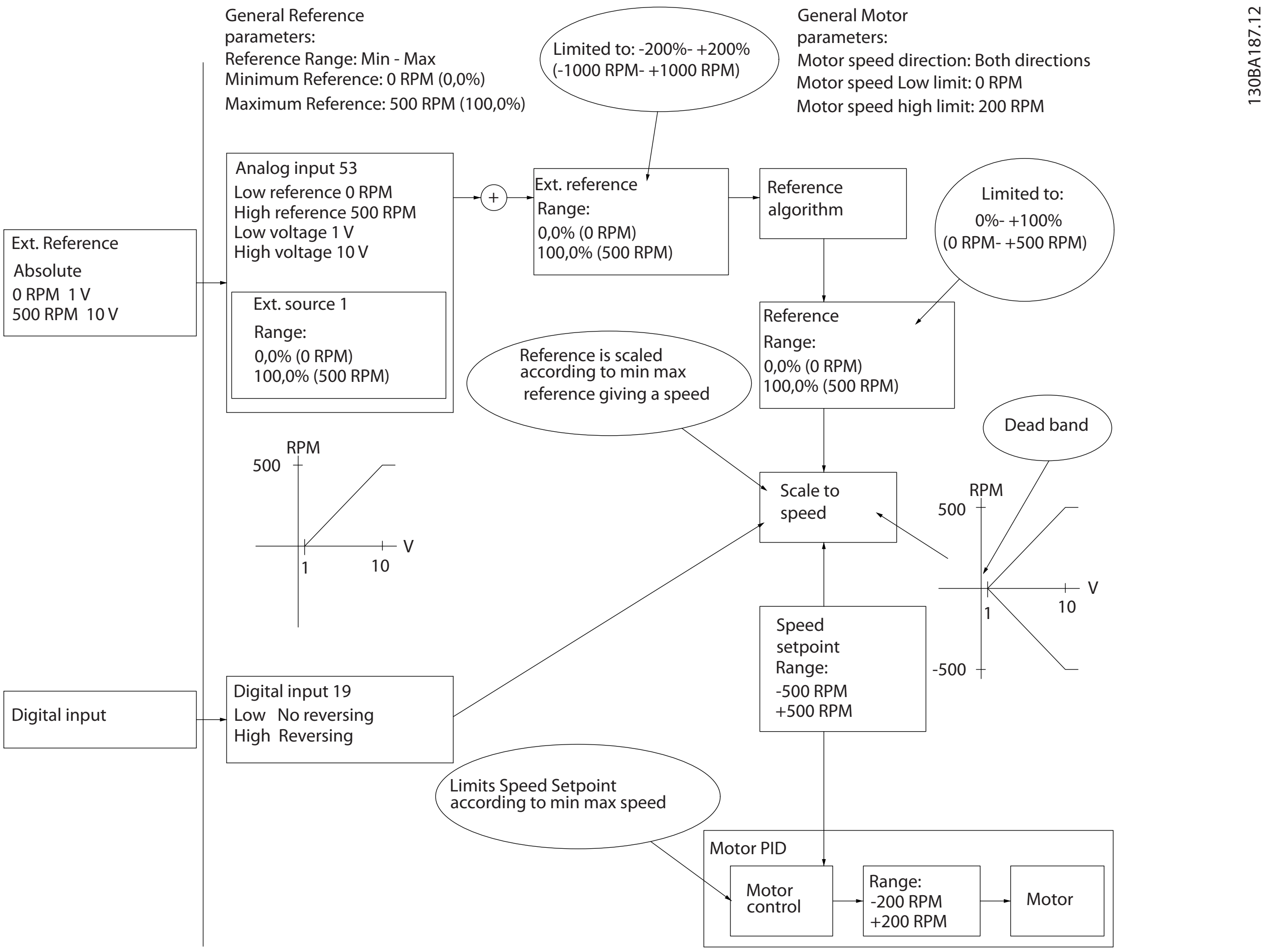


Illustration 3.18 Positive Reference with Dead Band, Digital Input to Trigger Reverse

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

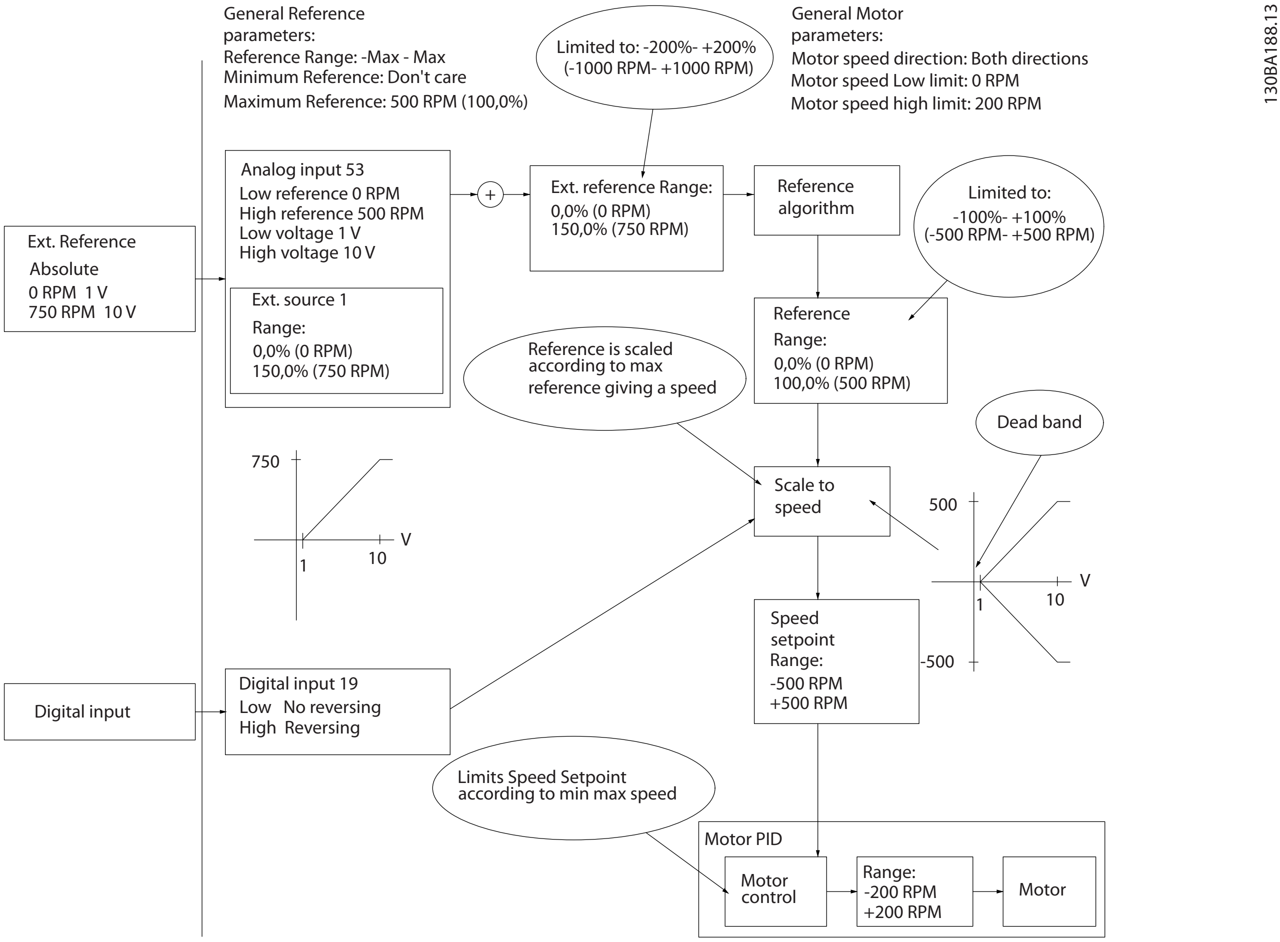


Illustration 3.19 Positive Reference with Dead Band, Digital Input to Trigger Reverse. Clamping Rules

Case 3.

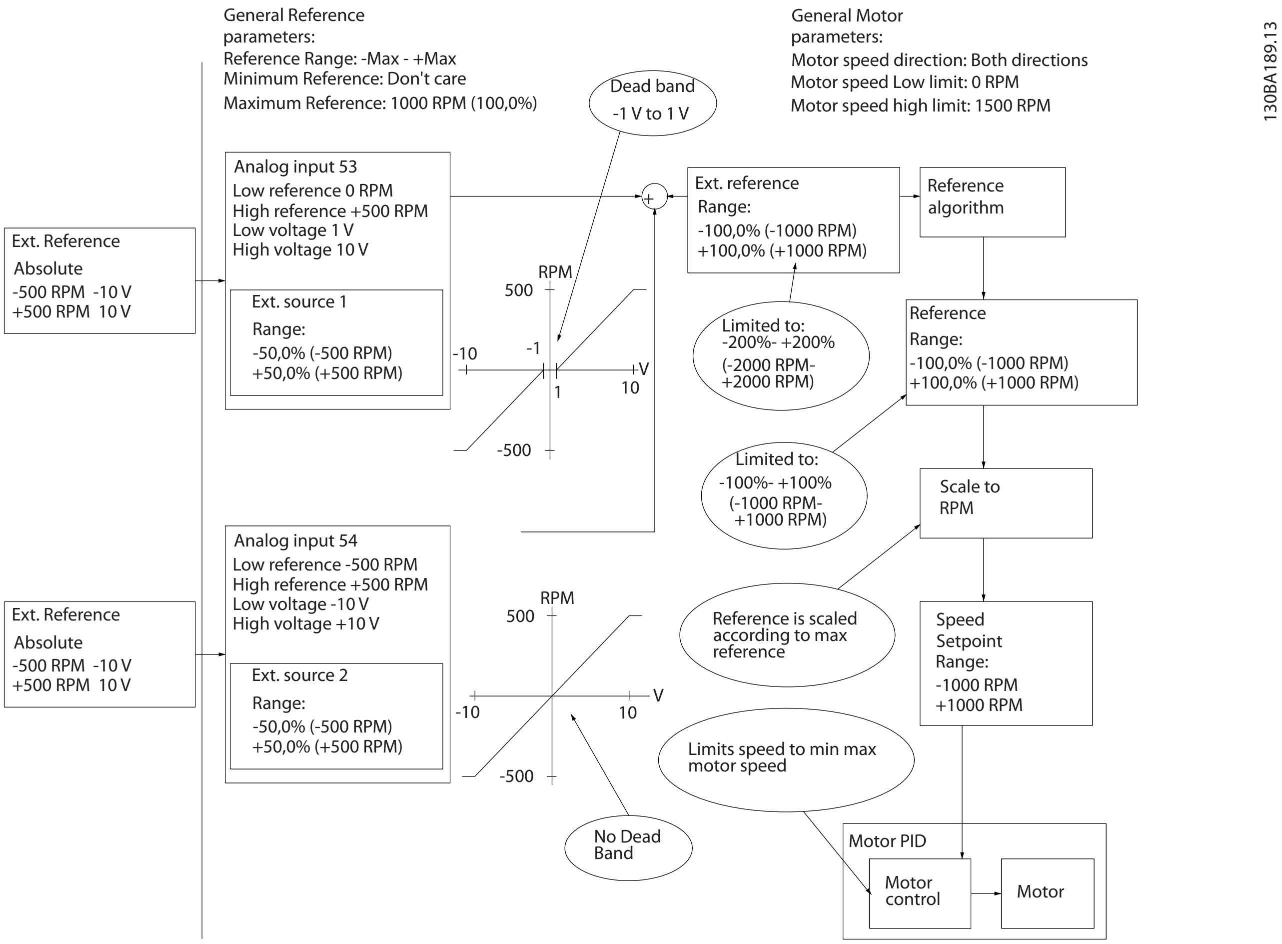


Illustration 3.20 Negative to Positive Reference with Dead Band, Sign Determines the Direction, -Max to +Max

3.4 PID Control

3.4.1 Speed PID Control

1-00 Configuration Mode	1-01 Motor Control Principle			
	U/f	VVC^{plus}	Flux sensorless	Flux w/ enc. feedb
[0] Speed open loop	Not Active	Not Active	Active	N.A.
[1] Speed closed loop	N.A.	Active	N.A.	Active
[2] Torque	N.A.	N.A.	N.A.	Not Active
[3] Process		Not Active	Active	Active

Table 3.6 Control Configurations Where the Speed Control is Active

"N.A." means that the specific mode is not available. "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 optimise the motor control performance. The 2 flux motor control principles are particularly dependent on proper tuning to yield their full potential.

3.4.2 Speed PID Control Parameters

<table>
<tr><th>Parameter</th><th colspan="2">Description of function</th></tr>
<tr><td>7-00 Speed PID Feedback Source</td><td colspan="2">Selects from which input the Speed PID should get its feedback.</td></tr>
<tr><td>30-83 Speed PID Proportional Gain</td><td colspan="2">The higher the value - the quicker the control. However, too high a value may lead to oscillations.</td></tr>
<tr><td>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 may lead to oscillations.</td></tr>
<tr><td>7-04 Speed PID Differentiation Time</td><td colspan="2">Provides a gain proportional to the rate of feedback change. A setting of zero disables the differentiator.</td></tr>
<tr><td>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 may soon become too dominant. This is because it reacts to changes in the error. 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">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 will deteriorate the dynamic performance of the speed PID control.
Practical settings of 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>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 3.7 Relevant Parameters for the Speed PID Control

3.4.3 Example of How to Programme 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. Starting and stopping is controlled by a switch connected to terminal 18.

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.

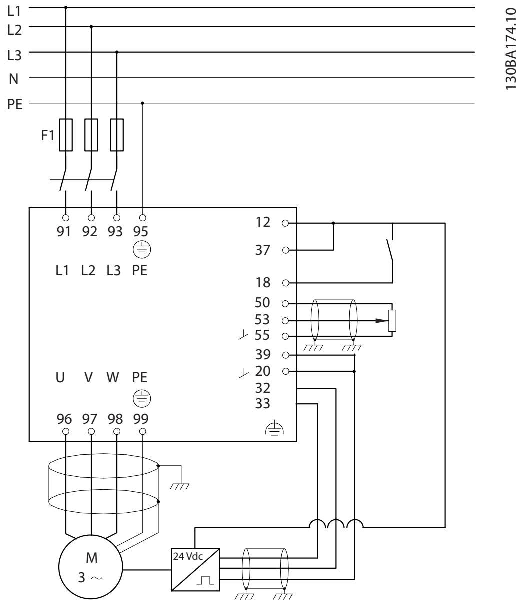


Illustration 3.21 Speed Control Connections

3.4.4 Speed PID Control Programming Order

The following must be programmed in the order shown (see explanation of settings in the *VLT® AutomationDrive Programming Guide*). In *Table 3.8* it is assumed that all other parameters and switches remain at their default settings.

Function	Parameter no.	Setting
1) To ensure the motor runs properly, do the following:		
Set the motor parameters according to the name plate data.	1-2* Motor Data	As specified by motor name plate
Perform Automatic Motor Adaptation (AMA).	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 (henceforth referred to as the “positive direction”).		Set a **positive** reference.
Go to *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 *16-20 Motor Angle* is increasing or decreasing.	16-20 Motor Angle	N.A. (read-only parameter) Note: An increasing value overflows at 65535 and starts again at 0.
If *16-20 Motor Angle* is decreasing, then change the encoder direction in *5-71 Term 32/33 Encoder Direction*.	5-71 Term 32/33 Encoder Direction	[1] Counter clockwise (if *16-20 Motor Angle* is decreasing)
3) Make sure the drive limits are set to safe values.		
Set acceptable limits for the references.	3-02 Minimum Reference 3-03 Maximum Reference	0 RPM (default) 1500 RPM (default)
Check that the ramp settings are within drive capabilities and allowed application operating specifications.	3-41 Ramp 1 Ramp Up Time 3-42 Ramp 1 Ramp Down Time	default setting default setting

Function	Parameter no.	Setting
Set acceptable limits for the motor speed and frequency.	4-11 Motor Speed Low Limit [RPM] 4-13 Motor Speed High Limit [RPM] 4-19 Max Output Frequency	0 RPM (default) 1500 RPM (default) 60 Hz (default 132 Hz)
4) Configure the speed control and select the motor control principle.		
Activation of Speed Control.	1-00 Configuration Mode	[1] Speed closed loop
Selection of Motor Control Principle.	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.	3-15 Reference Resource 1	Not necessary (default)
Scale analog Input 53 0 RPM (0 V) to 1500 RPM (10 V).	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 input 32 and 33 as encoder inputs.	5-14 Terminal 32 Digital Input 5-15 Terminal 33 Digital Input	[0] No operation (default)
Choose terminal 32/33 as motor feedback.	1-02 Flux Motor Feedback Source	Not necessary (default)
Choose terminal 32/33 as speed PID feedback.	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.	7-0* Speed PID Ctrl	See *3.4.5 Tuning Speed PID Control*
8) Finished.		
Save the parameter setting to the LCP.	0-50 LCP Copy	[1] All to LCP

Table 3.8 Programming Order

3.4.5 Tuning Speed PID Control

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

The value of *30-83 Speed PID Proportional Gain* is dependent on 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

***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 *30-83 Speed PID Proportional Gain* calculation against the following formula. This is not required if using a 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 *7-06 Speed PID Lowpass Filter Time* is 5 ms. A lower encoder resolution calls for a higher filter value. Typically a max torque ripple of 3% is acceptable. For incremental encoders, the Encoder Resolution is found in either *5-70 Term 32/33 Pulses Per Revolution* (24 V HTL on standard drive) or *17-11 Resolution (PPR)* (5 V TTL on MCB102 Option).

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

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

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

3

3.4.6 Process PID Control

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 through a pump or fan.

Table 3.9 shows the control configurations where the process control is possible. When a flux vector motor control principle is used, the speed control PID parameters should also be tuned. Refer to *3.2.2 Control Structure in VVC^{plus} Advanced Vector Control* to see where the speed control is active.

1-00 Configuration Mode	1-01 Motor Control Principle			
	U/f	VVC^{plus}	Flux Sensorless	Flux w/enc. feedb
[3] Process	N.A.	Process	Process & Speed	Process & Speed

Table 3.9 Process Control Configurations

NOTICE

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

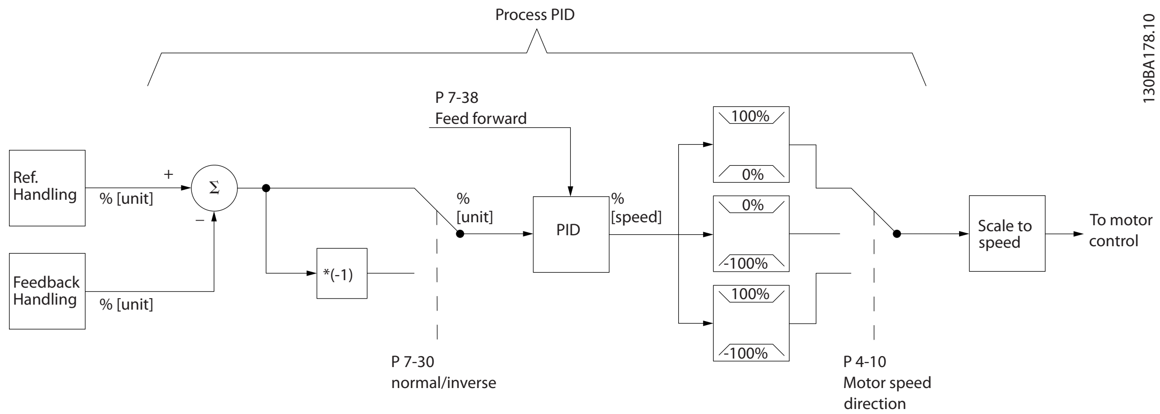


Illustration 3.22 Process PID Control Diagram

3.4.7 Process PID Control Parameters

The following parameters are relevant for the process control

Parameter	Description of function
7-20 Process CL Feedback 1 Resource	Selects from which input the Process PID should get its feedback.
7-22 Process CL Feedback 2 Resource	Optional: Determines if and from where the process PID should get an additional feedback signal. If an additional feedback source is selected, the 2 feedback signals are added together before being used in the process PID control.
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 lower than the reference. In the same situation, but under *[1] inverse operation*, the process control responds with a decreasing motor speed.
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 avoids integrating on an error that cannot be compensated for by means of a speed change. Disable this function by selecting *[0] Off*.
7-32 Process PID Start Speed	In some applications, reaching the required speed/set point 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. This is done by setting a process PID start value (speed) in *7-32 Process PID Start Speed*.
7-33 Process PID Proportional Gain	The higher the value, the quicker the control. However, too large a value may lead to oscillations.

Parameter	Description of function
7-34 Process PID Integral Time	Eliminates steady state speed error. Lower value means quick reaction. However, too small a value may lead to oscillations.
7-35 Process PID Differentiation Time	Provides a gain proportional to the rate of feedback change. A setting of zero disables the differentiator.
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.
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.
5-54 Pulse Filter Time Constant #29 (Pulse term. 29), 5-59 Pulse Filter Time Constant #33 (Pulse term. 33), 6-16 Terminal 53 Filter Time Constant (analog term 53), 6-26 Terminal 54 Filter Time Constant (analog term. 54)	If there are oscillations of the current/voltage feedback signal, these can be dampened by means of a low-pass filter. This time constant represents 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. This means that all currents/voltages that vary by more than 1.6 oscillations per s are damped by the filter. 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 3.10 Process Control Parameters

3.4.8 Example of Process PID Control

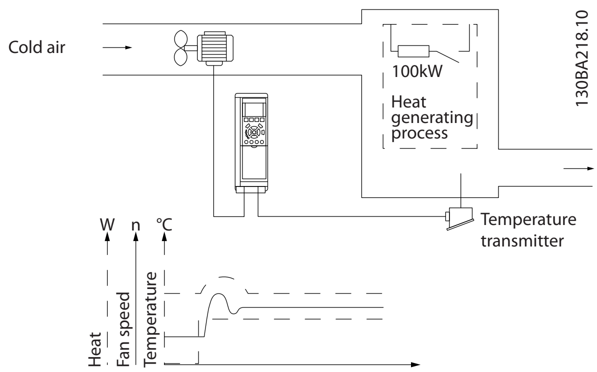


Illustration 3.23 Example of a Process PID Control Used in a Ventilation System

In this example using a ventilation system, the temperature must be adjustable from -5 to 35 °C 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 to 40 °C, 4–20 mA. Min./max. speed 300/1500 RPM.

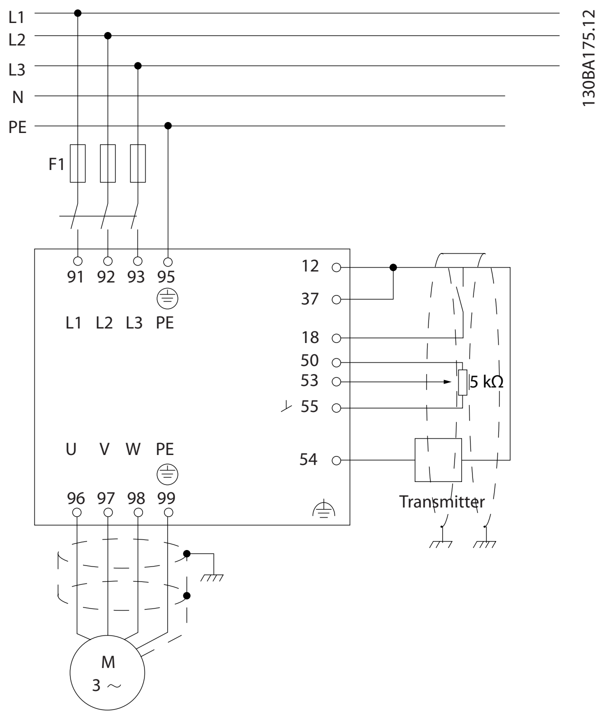


Illustration 3.24 Two-wire Transmitter

The following steps demonstrate how to set up the Process PID Control in *Illustration 3.24*.

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

3.4.9 Process PID Control Programming Order

Function	Par. no.	Setting
Initialise the frequency converter.	14-22	[2] Initialization - make a power cycling - press [Reset]
1) Set motor parameters:		
Set the motor parameters according to the name plate data.	1-2*	As stated on motor name plate
Perform a full **A**utomation **M**otor **A**daptation.	1-29	[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 *4-10 Motor Speed Direction* 2. Turn off mains - wait for DC link to discharge - switch two of the motor phases	4-10	Select correct motor shaft direction
Set configuration mode.	1-00	[3] Process
Set Local Mode Configuration.	1-05	[0] Speed Open Loop
3) Set reference configuration, *i.e.* the range for reference handling. Set scaling of analog input in parameter 6-**		
Set reference/feedback units: Set min. reference (10 °C): Set max. reference (80 °C): If set value is determined from a preset value (array parameter), set other reference sources to No Function.	3-01 3-02 3-03 3-10	[60] °C Unit shown on display -5 °C 35 °C [0] 35% $Ref = \frac{Par.\ 3-10_{(0)}}{100} \times ((Par.\ 3-03) - (par.\ 3-02)) = 24,5^{\circ} C$ *3-14 Preset Relative Reference* to *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.	3-41 3-42	20 s 20 s
Set min. speed limits: Set motor speed max. limit: Set max. output frequency:	4-11 4-13 4-19	300 RPM 1500 RPM 60 Hz
Set S201 or S202 to desired analog input function (Voltage (V) or milli-Amps (I)): **WARNING** **Switches are sensitive - Make a power cycling keeping default setting of V.**		
5) Scale analog inputs used for reference and feedback		
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:	6-10 6-11 6-24 6-25 7-20	0 V 10 V -5 °C 35 °C [2] analog input 54
6) Basic PID settings.		
Process PID normal/inverse.	7-30	[0] Normal
Process PID anti wind-up.	7-31	[1] On
Process PID start speed.	7-32	300 rpm
Save parameters to LCP.	0-50	[1] All to LCP

Table 3.11 Example of Process PID Control Set-up

3.4.10 Optimisation of the Process Regulator

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

- Proportional gain
- Integration time
- Differentiation time

In most processes, this can be done by following these steps:

1. Start the motor.
2. Set *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 stabilised. Now lower the proportional gain by 40-60%.
3. Set *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 stabilises, followed by an increase of 15-50%.
4. Only use *7-35 Process PID Differentiation Time* for very fast-acting systems only (differentiation time). The typical value is 4 times the set integration time. The differentiator should only be used when the setting of the proportional gain and the integration time has been fully optimised. Make sure that oscillations on the feedback signal are sufficiently dampened by the low-pass filter on the feedback signal.

NOTICE

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

3.4.11 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

The method described must not be used on applications that could be damaged by the oscillations created by marginally stable control settings.

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 via the feedback, meaning the system is marginally stable. The period of the oscillation (P_u) is determined as shown in *Illustration 3.25*.

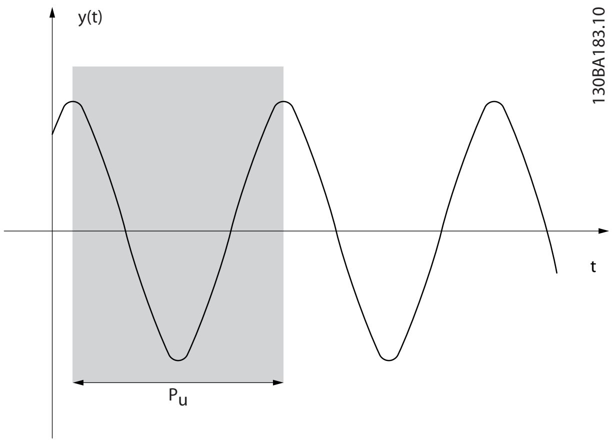


Illustration 3.25 Marginally Stable System

Measure P_u when the amplitude of oscillation is quite small. Then "back off" from this gain again, as shown in *Table 3.12*.

K_u is the gain at which the oscillation is obtained.

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

Table 3.12 Ziegler Nichols Tuning for Regulator, Based on a Stability Boundary

According to the Ziegler Nichols rule, experience has shown that the control setting described in the steps below provides a good closed loop response for many systems. The process operator can do the final tuning of the control repeatedly to yield satisfactory control.

Step-by-Step Description

1. Select only Proportional Control (Integral time is selected to the maximum value, while the differentiation time is selected to zero).
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. Measure the period of oscillation to obtain the critical time constant, P_u.
4. Use *Table 3.12* to calculate the necessary PID control parameters.

3

3.5 General Aspects of EMC

3.5.1 General Aspects of EMC Emissions

Electrical interference 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. Screened motor cables increase the leakage current (see *Illustration 3.26*) because they have higher capacitance to earth than unscreened 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 screen (I_3), there is only a small electromagnetic field (I_4) from the screened motor cable.

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

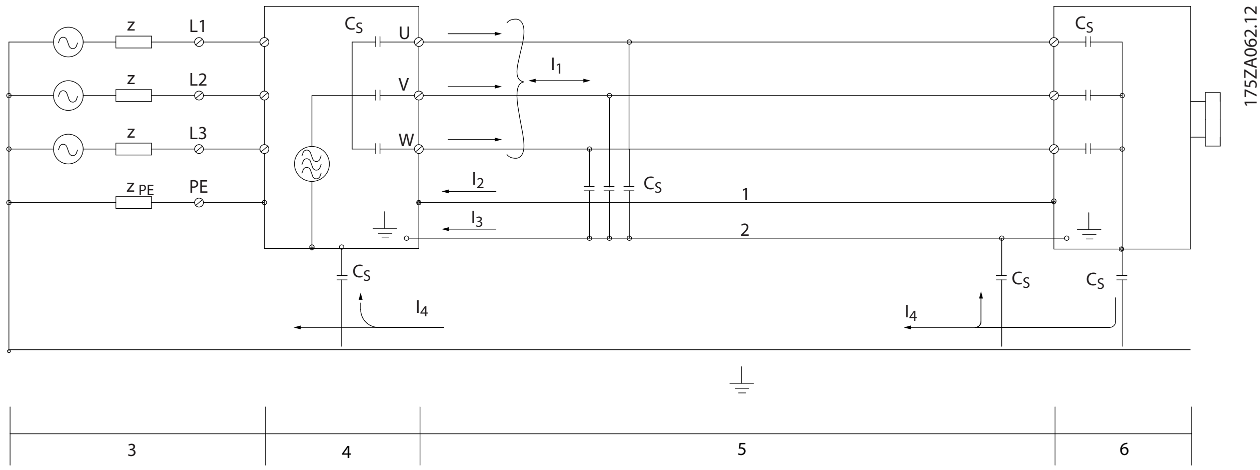


Illustration 3.26 Leakage Currents

1	Earth wire
2	Screen
3	AC mains supply
4	Frequency converter
5	Screened motor cable
6	Motor

Table 3.13 Legend to *Illustration 3.26*

Illustration 3.26 shows an example of a 6-pulse frequency converter, but could be applicable to a 12-pulse as well.

If placing the screen on a mounting plate, use a metal plate because the screen 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 unscreened 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 *7.8 EMC-Correct Installation*.

3.5.2 EMC Test Results

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

RFI filter type		**Conducted Emission**			**Radiated Emission**	
Standards and requirements	**EN 55011**	**Class B** Housing, trades and light industries	**Class A group 1** Industrial environment	**Class A group 2** Industrial environment	**Class B** Housing, trades and light industries	**Class A group 1** Industrial environment
	EN/IEC 61800-3	**Category C1** First environment Home and office	**Category C2** First environment Home and office	**Category C3** Second environment Industrial	**Category C1** First environment Home and office	**Category C2** First environment Home and office
H2						
FC 302	90-800 kW 380-500 V	No	No	150 m	No	No
	90-1200 kW 525-690 V	No	No	150 m	No	No
H4						
FC 302	90-800 kW 380-500 V	No	150 m	150 m	No	Yes
	90-315 kW 525-690 V	No	30 m	150 m	No	No

Table 3.14 EMC Test Results (Emission and Immunity)

⚠WARNING

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.

3.5.3 Emission Requirements

According to the EMC product standard for adjustable speed frequency converters EN/IEC 61800-3:2004, 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 3.15*.

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 1,000 V.	Class B
C2	Frequency converters installed in the home and office environment with a supply voltage less than 1,000 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 1,000 V.	Class A Group 2
C4	Frequency converters installed in an industrial environment with a supply voltage equal to or above 1,000 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 3.15 Emission Requirements

When the generic emission standards are used, the frequency converters are required to comply with *Table 3.16*

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

Table 3.16 Generic Emission Standard Limits

3.5.4 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 electrical interference, the following immunity tests have been performed on a frequency converter (with options if relevant), a screened 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 3.17*

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

Basic standard	Burst IEC 61000-4-4	Surge IEC 61000-4-5	ESD IEC 61000-4-2	Radiated 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 3.17 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

3.6 Galvanic Isolation (PELV)

3.6.1 PELV - Protective Extra Low Voltage

⚠WARNING

Installation at high altitude:
380-500 V, enclosure D, E, and F: At altitudes above 3 km, contact Danfoss regarding PELV.
525–690 V: At altitudes above 2 km, contact Danfoss regarding PELV.

⚠WARNING

Touching the electrical parts could be fatal - even after the equipment has been disconnected from mains.
Before touching any electrical parts, wait at least the amount of time indicated in *2.1 Safety Precautions*.
Shorter time is allowed only if indicated on the specific unit's nameplate.
Also make sure that other voltage inputs have been disconnected.

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 can be shown in 6 locations, as shown in *Illustration 3.27*.

1. Power supply (SMPS) including signal isolation of U_{DC}, indicating the intermediate current voltage.
2. Gate drive that runs the IGBTs (trigger transformers/opto-couplers).
3. Current transducers.
4. Optocoupler, brake module.
5. Internal inrush, RFI, and temperature measurement circuits.
6. Custom relays.

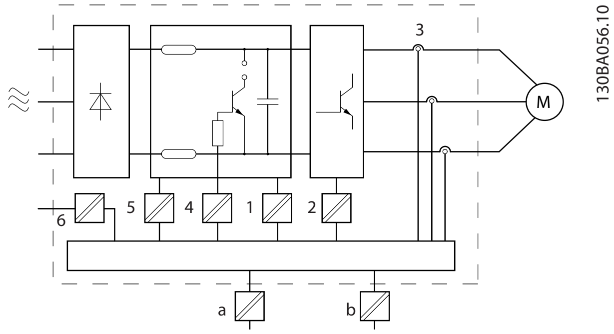


Illustration 3.27 Galvanic Isolation

The functional galvanic isolation - indicated by a and b in *Illustration 3.27* - is for the 24 V backup option and for the RS-485 standard bus interface.

3.7 Earth Leakage Current

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, which generates a leakage current in the earth connection. A fault current at the frequency converter's output power terminals could contain a DC component that can charge the filter capacitors and cause a transient earth current.
The earth leakage current is affected by the following:

- RFI filtering
- screened motor cables
- frequency converter power (see *Illustration 3.28*)
- line distortion (see *Illustration 3.29*)

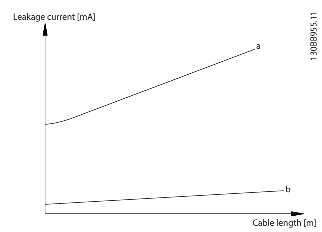


Illustration 3.28 Influence of the Cable Length and Power Size on the Leakage Current

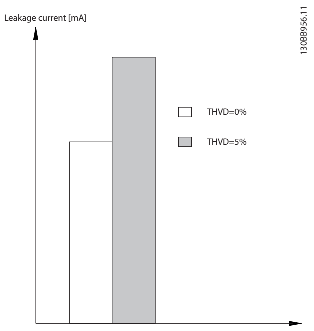


Illustration 3.29 Influence of Line Distortion on Leakage Current

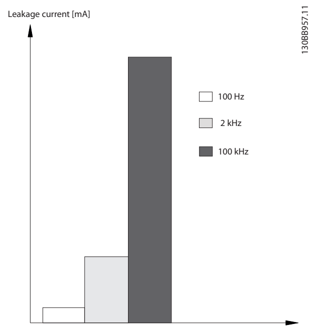


Illustration 3.31 Influence of the Cut-off Frequency of the RCD What is Responded to/Measured

NOTICE

When a filter is used, turn off *14-50 RFI Filter* when charging the filter to avoid a high leakage current making the RCD switch.

If the leakage current exceeds 3.5 mA, EN/IEC61800-5-1 (Power Drive System Product Standard) requires that earth grounding must be reinforced in one of the following ways:

- Earth ground wire (terminal 95) of at least 10 mm^2
- 2 separate earth ground wires both complying with the dimensioning rules

See EN/IEC61800-5-1 and EN50178 for further information.

Using RCDs

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

- Use RCDs of type B only, capable of detecting AC and DC currents
- Use RCDs with an inrush delay to prevent faults due to transient earth currents
- Dimension RCDs according to the system configuration and environmental considerations

See also *Protection Against Electrical Hazards*.

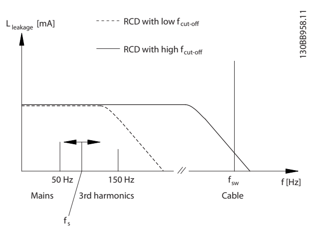


Illustration 3.30 Main Contributions to Leakage Current

3.8 Brake Functions

The braking function - either static or dynamic - is used for braking the load on the motor shaft.

3.8.1 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 either controlled by 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.

3.8.2 Dynamic Braking

Dynamic braking is accomplished internally within the frequency converter and is used to slow down the motor to an eventual stop. Dynamic braking is applied using of the following methods:

- 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 (*2-10 Brake Function*=[1])
- 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 will overheat the motor (*2-10 Brake Function*=[2])
- DC brake: An over-modulated DC current added to the AC current works as an eddy current brake (*2-02 DC Braking Time*≠0 s)

3.8.3 Selection of Brake Resistor

To handle higher demands by generatoric braking, a brake resistor is necessary. Using a brake resistor ensures the energy is absorbed in the brake resistor and not in the frequency converter. For more information see *Brake Resistor 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 3.32* shows a typical braking cycle.

NOTICE

Motor suppliers often use S5 when stating the permissible 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)

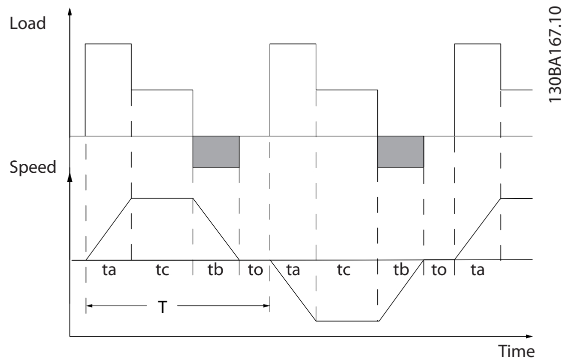


Illustration 3.32 Typical Braking Cycle

	Cycle time (s)	Braking duty cycle at 100% torque	Braking duty cycle at over torque (150/160%)
380-500 V			
N90K-N160	600	Continuous	10%
N200-N250	600	Continuous	10%
P315-P800	600	40%	10%
525-690 V			
N55K-N315, P355-P400	600	40%	10%
P500-P560	600	40%	10%
P630-P1M0	600	40%	10%

Table 3.18 Braking at High Overload Torque Level

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% is used on dissipating excess heat. Make sure the resistor is designed to handle the required braking time. The maximum permissible load on the brake resistor is stated as a peak power at a given intermittent duty cycle. The brake resistance is calculated as shown:

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

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

As can be seen, the brake resistance depends on the intermediate circuit voltage (U_{dc}).

Size	Brake active	Warning before cut out	Cut out (trip)
FC 302 3x380-500 V*	810 V/795 V	84 V/828 V	850 V/855 V
FC 302 3x525-690 V	1084 V	1109 V	1130 V

Table 3.19 Brake Limits

** Power size dependent*

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}. This guarantees that the frequency converter is able to brake at the highest braking torque ($M_{br(\%)}$) of 160%. The formula can be written as:

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

η_{motor} is typically at 0.90
η_{VLT} is typically at 0.98

For 200 V, 480 V, 500 V, and 600 V frequency converters, R_{rec} at 160% braking torque is written as:

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

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

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

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

NOTICE

The resistor brake circuit resistance selected should not be higher than that recommended by Danfoss. D-F size frequency converters contain more than one brake chopper and must use 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 contactor can be controlled by the frequency converter.

⚠WARNING

FIRE HAZARD

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

3.8.4 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 limit selected in *2-12 Brake Power Limit (kW)*. Use *2-13 Brake Power Monitoring* to select what function occurs when the power transmitted to the brake resistor exceeds the limit set in *2-12 Brake Power Limit (kW)*.

⚠CAUTION

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

Over voltage control (OVC) can be selected as an alternative brake function in *2-17 Over-voltage Control*. This function is active for all units and ensures that if the DC link voltage increases, the output frequency also increases to limit the voltage from the DC link, thereby avoiding a trip.

NOTICE

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

3.9 Mechanical Brake Control

For hoisting applications, controlling an electro-magnetic brake is necessary. For controlling the brake, a relay output (relay1 or relay2) 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. In *5-40 Function Relay* (array parameter), *5-30 Terminal 27 Digital Output*, or *5-31 Terminal 29 Digital Output*, select *[32] mechanical brake control* for applications with an electro-magnetic brake.

When *[32] mechanical brake control* is selected, the mechanical brake relay remains closed during start until the output current is above the level selected in *2-20 Release Brake Current*. During stop, the mechanical brake will close when the speed is below the level selected in *2-21 Activate Brake Speed [RPM]*. If the frequency converter is brought into an alarm condition, such as an over-voltage situation, the mechanical brake immediately cuts in. This is also the case during Safe Torque Off.

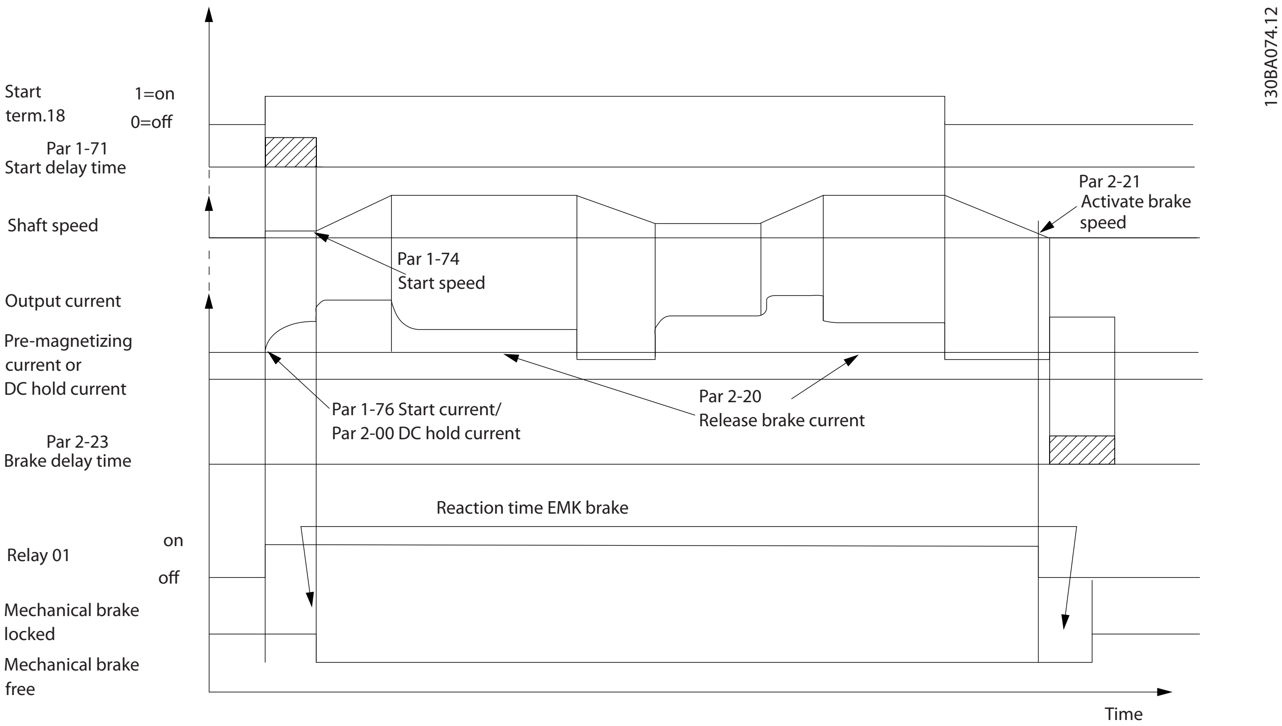


Illustration 3.33 Mechanical Brake Control in Open Loop

To control the electro-magnetic brake, use the following steps:

1. Use any relay output or digital output (terminal 27 or 29). If necessary, use a contactor.
2. Ensure that the output is switched off as long as the frequency converter is unable to drive the motor. Examples include the load being too heavy or the motor not being mounted.
3. Before connecting the mechanical brake, select *[32] Mechanical brake control* in parameter group *5-4* Relays* (or in group *5-3* Digital Outputs*).
4. The brake is released when the motor current exceeds the preset value in *2-20 Release Brake Current*.
5. The brake is engaged when the output frequency is less than the frequency set in *2-21 Activate Brake Speed [RPM]* or *2-22 Activate Brake Speed [Hz]* and only if the frequency converter carries out a stop command.

NOTICE

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

For hoisting applications, make sure that the torque limits in *4-16 Torque Limit Motor Mode* and *4-17 Torque Limit Generator Mode* are set lower than the current limit in *4-18 Current Limit*. It is also recommended to set *14-25 Trip Delay at Torque Limit* to "0", *14-26 Trip Delay at Inverter Fault* to "0" and *14-10 Mains Failure* to *[3] Coasting*.

3.9.1 Hoist Mechanical Brake

The VLT® AutomationDrive features a mechanical brake control specifically designed for hoisting applications. The hoist mechanical brake is activated by *1-72 Start Function* [6]. The main difference compared to the regular mechanical brake control is that the hoist mechanical brake function has direct control over the brake relay. Instead of setting a current to release the brake, the torque applied against the closed brake before release is defined. Because the torque is defined directly, the setup is more straightforward for hoisting applications.
Use *2-28 Gain Boost Factor*, to obtain quicker control when releasing the brake. The hoist mechanical brake strategy is based on the following three-step sequence, where motor control and brake release are synchronized to obtain the smoothest possible brake release.

1. **Pre-magnetize the motor**
   To ensure that there is a hold on the motor and to verify that it is mounted correctly, the motor is first pre-magnetized.
2. **Apply torque against the closed brake**
   When the load is held by the mechanical brake, its size cannot be determined, only its direction. The moment the brake opens, the load must be taken over by the motor. To facilitate the takeover, a user-defined torque that is set in *2-26 Torque Ref* is applied in the hoisting direction. This is used to initialize the speed controller that finally takes over the load. To reduce wear on the gearbox due to backlash, the torque is ramped up.
3. **Release brake**
   When the torque reaches the value set in *2-26 Torque Ref*, the brake is released. The value set in *2-25 Brake Release Time* determines the delay before the load is released. To react as quickly as possible on the load-step that follows upon brake release, the speed-PID control can be boosted by increasing the proportional gain.

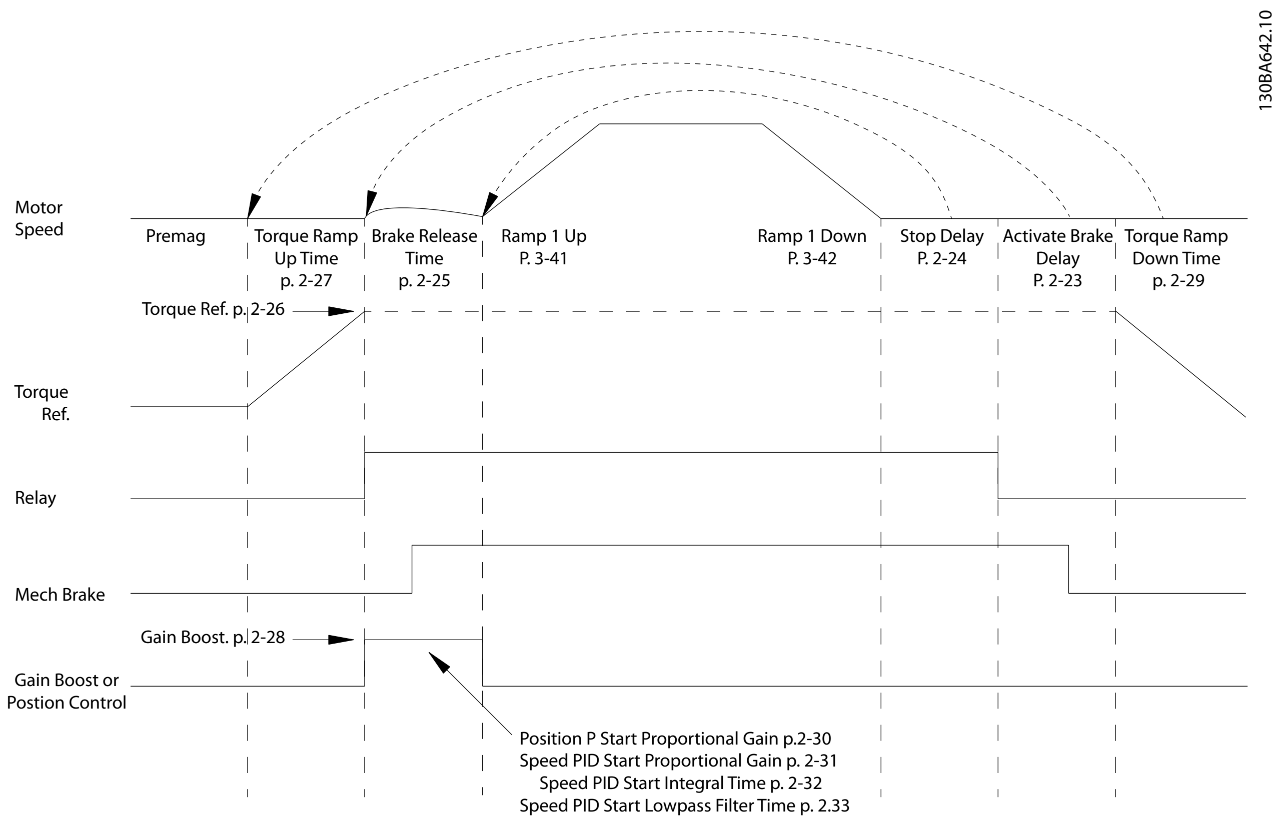


Illustration 3.34 Brake Release Sequence for Hoist Mechanical Brake Control

I) **Activate brake delay:** The frequency converter starts again from the mechanical brake engaged position.
II) **Stop delay:** When the time between successive starts is shorter than the setting in *2-24 Stop Delay*, the frequency converter starts without applying the mechanical brake.

For an example of advanced mechanical brake control for hoisting applications, see *8.10 Mechanical Brake Control*.

3.9.2 Brake Resistor Cabling

EMC (Twisted Cables/Shielding)
Twist the wires to reduce electrical noise between the brake resistor and the frequency converter. For enhanced EMC performance, use a metal screen.

3.10 Smart Logic Controller

Smart Logic Control (SLC) is a sequence of user-defined actions (see *13-52 SL Controller Action* [x]) executed by the SLC when the associated user-defined event (see *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 leads to an associated action as shown in *Illustration 3.35*.

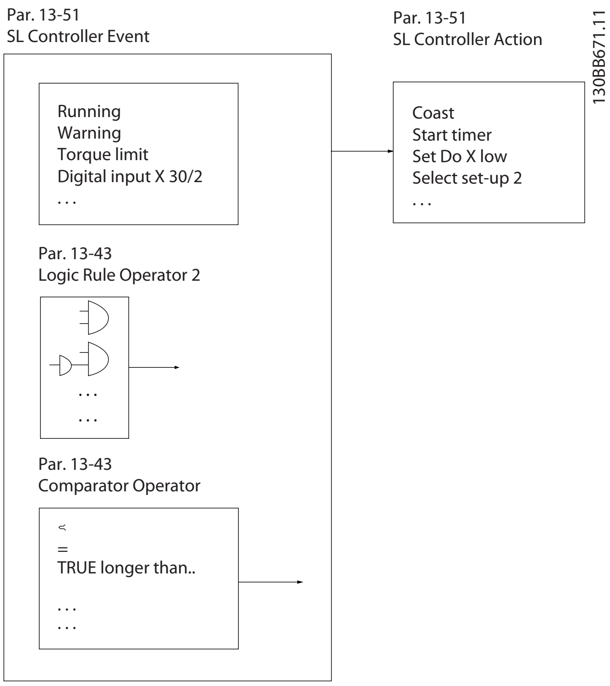


Illustration 3.35 Current Control Status/Event and Action

Events and actions are each numbered and linked together in pairs (states). This means that when *[0] event* is fulfilled (attains the value TRUE), *[0] action* is executed. After this, the conditions of *[1] event* are evaluated and if evaluated TRUE, *[1] action* will be executed and so on. Only one 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 will be evaluated. This means that when the SLC starts, it evaluates only *[0] event* each scan interval. Only when *[0] event* is evaluated TRUE, will the SLC execute *[0] action* and start evaluating *[1] event*. It is possible to programme from 1 to 20 *events* and *actions*. When the last *event/action* has been executed, the sequence starts over again from *[0] event*/*[0] action*. *Illustration 3.36* shows an example with 3 event/actions:

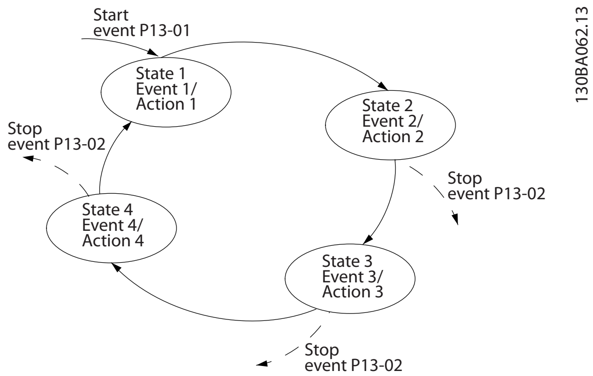


Illustration 3.36 Internal Current Control Example

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

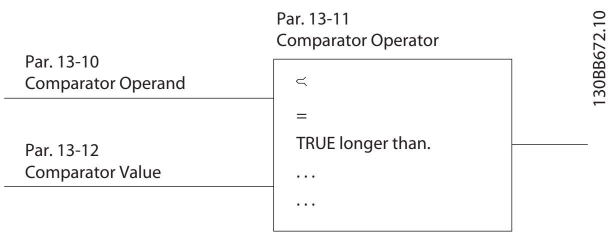


Illustration 3.37 Comparators

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.

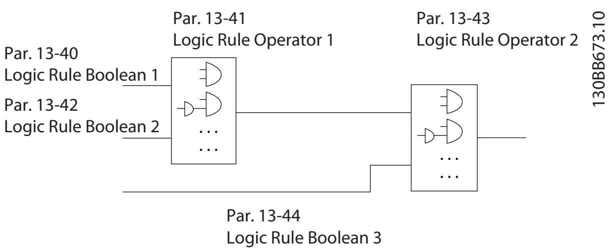
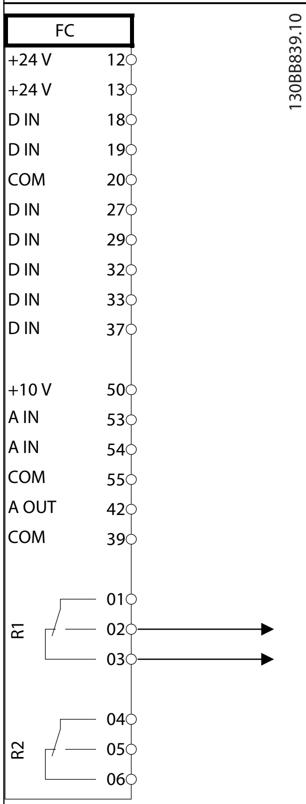


Illustration 3.38 Logic Rules

Application example



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

Notes/Comments:
If the limit in the feedback monitor is exceeded, Warning 90 will be issued. The SLC monitors Warning 90 and in the case that Warning 90 becomes TRUE, then 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 drive continues and the warning disappears. But Relay 1 will still be triggered until [Reset] on the LCP.

Table 3.20 Using SLC to Set a Relay

3.11 Extreme Running Conditions

Short Circuit (Motor Phase – Phase)
The frequency converter is protected against short circuits by means of 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 permitted 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 .

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

Motor-Generated Over-Voltage
The voltage in the intermediate circuit is increased when the motor acts as a generator. This occurs 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 moment of inertia is high, the friction is low, and the ramp-down time is too short for the energy to be dissipated as a loss in the frequency converter or motor.
- Incorrect slip compensation setting may cause higher DC link voltage.
- Back-EMF from PM motor operation. If coasted at high RPM, the PM motor back-EMF may potentially exceed the maximum voltage tolerance of the frequency converter and cause damage. To help prevent this, the value of *4-19 Max Output Frequency* is automatically limited based on an internal calculation based on the value of *1-40 Back EMF at 1000 RPM*, *1-25 Motor Nominal Speed* and *1-39 Motor Poles*. If it is possible that the motor may over-speed, Danfoss recommends a brake resistor be equipped to the frequency converter.

NOTICE

The frequency converter must be equipped with a brake chopper.

The control unit may attempt to correct the ramp if possible (*2-17 Over-voltage Control*). The inverter turns off to protect the transistors and the intermediate circuit capacitors when a certain voltage level is reached. See *2-10 Brake Function* and *2-17 Over-voltage Control* to select the method used for controlling the intermediate circuit voltage level.

NOTICE

OVC cannot be activated when running a PM motor (when*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 intermediate circuit voltage drops below the minimum stop level. Minimum stop level typically is 15% below the frequency converter's lowest rated supply voltage. The mains voltage before the drop-out and the motor load determines how long it takes for the inverter to coast.

Static overload in VVC^{plus} mode
An overload occurs when the torque limit in *4-16 Torque Limit Motor Mode*/*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 may occur that makes the frequency converter cut out after approximately 5-10 s.
Operation within the torque limit is limited in time (0-60 s) in *14-25 Trip Delay at Torque Limit*.

3.11.1 Motor Thermal Protection

To protect the application from serious damages, VLT® AutomationDrive offers several dedicated features.

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

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

Minimum speed limit
4-11 Motor Speed Low Limit [RPM] or *4-12 Motor Speed Low Limit [Hz]* limit the operating speed range to between 30 and 50/60 Hz. *4-13 Motor Speed High Limit [RPM]* or *4-19 Max Output Frequency* limit the max 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 3.39* 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 cut of 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 speed the ETR cuts of at lower heat due to less cooling of the motor. In that way the motor is protected from being over heated 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 read out parameter in *16-18 Motor Thermal* in the FC 300.

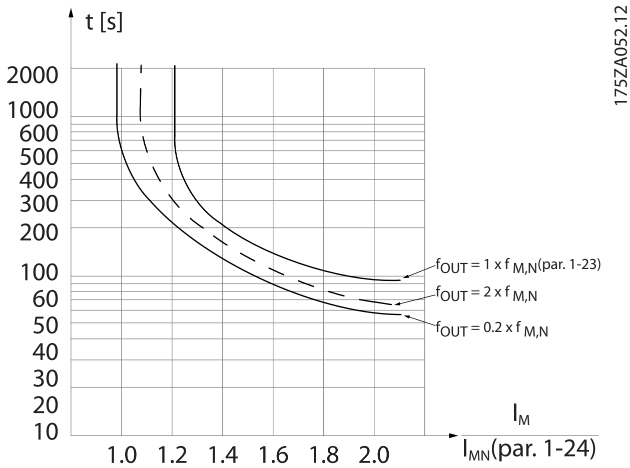


Illustration 3.39 ETR Example

3.12 Safe Torque Off

3.12.1 Safe Torque Off Operation

The FC 302 is available with Safe Torque Off (STO) functionality via control terminal 37. 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 frequency converter's regular stop function instead. When automatic restart is used, the requirements according to ISO 12100-2 paragraph 5.3.2.5 must be fulfilled.

3.12.2 Safe Torque Off Operation (FC 302 only)

The Safe Torque Off function of FC 302 can be used for asynchronous, synchronous, and permanent magnet motors. It may happen that 2 faults occur in the frequency converter's power semiconductor. When using synchronous or permanent magnet motors, this may cause a residual rotation. The rotation can be calculated to Angle=360/(Number of Poles). The application using synchronous or permanent magnet motors must take this into consideration and ensure that this is not a critical safety issue. This situation is not relevant for asynchronous motors.

3.12.3 Liability Conditions

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 and safety/accident prevention
- Understanding the generic and safety guidelines given in this description and the extended description in the *Operating Instructions VLT® Frequency Converters – Safe Torque Off*.
- 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.

3.12.4 Additional Information

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

3.12.5 Installation of External Safety Device in Combination with 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 button or safety-guard switch) that activates Safe Torque Off. This means that 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 is 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 output connection of the safety device with safe AND logic to Safe Torque Off terminal 37 must be short-circuit protected. *Illustration 3.40* shows a Restart input for the external Safety Device. This means that in this installation, set [7] or [8] *5-19 Terminal 37 Safe Stop*. Refer to the *MCB 112 Operating Instructions for further details*.

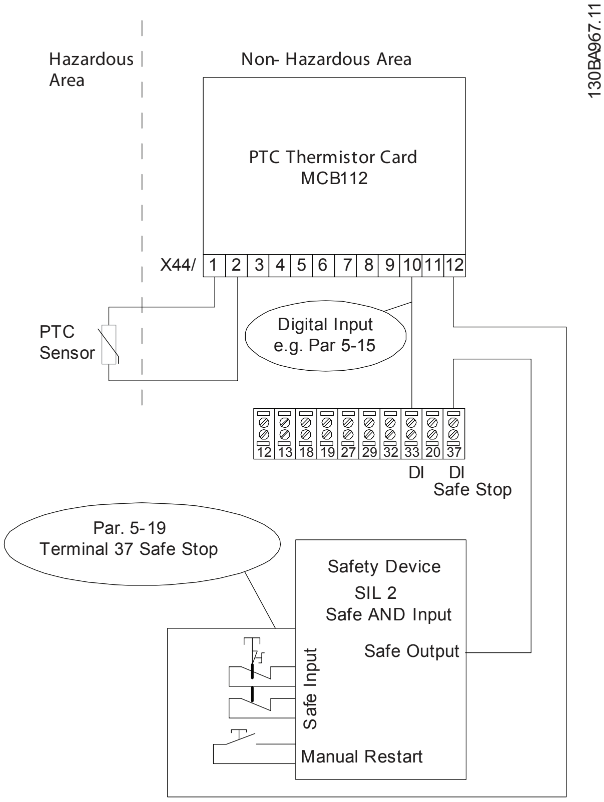


Illustration 3.40 Illustration of the Essential Aspects for Installing a Combination of a Safe Torque Off Application and an MCB 112 Application

Parameter settings for external safety device in combination with MCB 112
If MCB 112 is connected, then additional selections ([4]–[9]) become possible for *5-19 Terminal 37 Safe Stop* (Terminal 37 Safe Torque Off).
Selections [1]* and [3] *5-19 Terminal 37 Safe Stop* are still available but are not to be used as those are for installations without MCB 112 or any external safety devices. If [1]* or [3] *5-19 Terminal 37 Safe Stop* should be selected by mistake and MCB 112 is triggered, then the frequency converter will react with an alarm "Dangerous Failure [A72]" and coast the frequency converter safely without automatic restart.
Selections [4] and [5] *5-19 Terminal 37 Safe Stop* are only selected when MCB 112 uses the Safe Torque Off. If selections [4] or [5] *5-19 Terminal 37 Safe Stop* are selected by mistake and the external safety device triggers Safe Torque Off, the frequency converter reacts with an alarm "Dangerous Failure [A72]" and coasts the frequency converter safely without automatic restart.

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

NOTICE

Note that [7] and [8] *5-19 Terminal 37 Safe Stop* open up for Automatic restart when the external safety device is de-activated again.

This 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 *9.7 PTC Thermistor Card MCB 112* and the operating instructions for more information about MCB 112.

4 Selection

4.1 Electrical Data, 380-500 V

FC 302	N90K		N110		N132		N160		N200		N250	
High/Normal load*	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**
Typical shaft output at 400 V [kW]	90	110	110	132	132	160	160	200	200	250	250	315
Typical shaft output at 460 V [hp]	125	150	150	200	200	250	250	300	300	350	350	450
Typical shaft ouptut at 500 V [kW]	110	132	132	160	160	200	200	250	250	315	315	355
Enclosure IP21	D1h		D1h		D1h		D2h		D2h		D2h	
Enclosure IP54	D1h		D1h		D1h		D2h		D2h		D2h	
Enclosure IP20	D3h		D3h		D3h		D4h		D4h		D4h	
Output current												
Continuous (at 400 V) [A]	177	212	212	260	260	315	315	395	395	480	480	588
Intermittent (60 s overload) (at 400 V)[A]	266	233	318	286	390	347	473	435	593	528	720	647
Continuous (at 460/500 V) [A]	160	190	190	240	240	302	302	361	361	443	443	535
Intermittent (60 s overload) (at 460/500 V) [kVA]	240	209	285	264	360	332	453	397	542	487	665	588
Continuous kVA (at 400 V) [kVA]	123	147	147	180	180	218	218	274	274	333	333	407
Continuous kVA (at 460 V) [kVA]	127	151	151	191	191	241	241	288	288	353	353	426
Continuous kVA (at 500 V) [kVA]	139	165	165	208	208	262	262	313	313	384	384	463
Maximum input current												
Continuous (at 400 V) [A]	171	204	204	251	251	304	304	381	381	463	463	567
Continuous (at 460/500 V) [A]	154	183	183	231	231	291	291	348	348	427	427	516
Max. cable size: mains, motor, brake and load share [mm² (AWG)][1)2)]	2x95 (2x3/0)						2x185 (2x350 mcm)					
Max. external mains fuses [A][3]	315		350		400		550		630		800	
Estimated power loss at 400 V [W][4) 5)]	2031	2559	2289	2954	2923	3770	3093	4116	4039	5137	5005	6674
Estimated power loss at 460 V [W] [4) 5)]	1828	2261	2051	2724	2089	3628	2872	3569	3575	4566	4458	5714
Weight, enclosure IP21, IP54 kg (lbs.) [6)]	62 (135)						125 (275)					
Weight, enclosure IP20 kg (lbs.) [6)]	62 (135)						125 (275)					
Efficiency[5)]	0.98											
Output frequency	0-590 Hz											
Heatsink overtemp trip	110 °C											
Control card ambient trip	75 °C						80 °C					
*High overload=150% current for 60 s, Normal overload=110% current for 60 s												

Table 4.1 Technical Specifications, D-frame 380-500 V Mains Supply 3x380-500 V AC

1) American Wire Gauge.

2) Wiring terminals on N132, N160, and N315 frequency converters cannot receive cables one size larger.

3) For fuse ratings, see 7.2.1 Fuses.

4) Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the frequency converter. If the switching frequency is raised from nominal, the power losses rise significantly. LCP and typical control card power consumptions are included. Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.

5) Measured using 5 m screened motor cables at rated load and rated frequency.

6) Additional frame size weights are as follows: D5h - 166 (255) / D6h - 129 (285) / D7h - 200 (440) / D8h - 225 (496). Weights are in kg (lbs).

FC 302	P315		P355		P400	
High/Normal load*	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**
Typical shaft output at 400 V [kW]	315	355	355	400	400	450
Typical shaft output at 460 V [HP]	450	500	500	600	550	600
Typical shaft output at 500 V [kW]	355	400	400	500	500	530
Enclosure IP21	E1		E1		E1	
Enclosure IP54	E1		E1		E1	
Enclosure IP00	E2		E2		E2	
Output current						
Continuous (at 400 V) [A]	600	658	658	745	695	800
Intermittent (60 s overload) (at 400 V) [A]	900	724	987	820	1043	880
Continuous (at 460/500 V) [A]	540	590	590	678	678	730
Intermittent (60 s overload) (at 460/500 V) [A]	810	649	885	746	1017	803
Continuous kVA (at 400 V) [kVA]	416	456	456	516	482	554
Continuous kVA (at 460 V) [kVA]	430	470	470	540	540	582
Continuous kVA (at 500 V) [kVA]	468	511	511	587	587	632
Maximum input current						
Continuous (at 400 V) [A]	590	647	647	733	684	787
Continuous (at 460/500 V) [A]	531	580	580	667	667	718
Max. cable size, mains, motor and load share [mm^2 (AWG)] [1)2)]	4x240 (4x500 mcm)		4x240 (4x500 mcm)		4x240 (4x500 mcm)	
Max. cable size, brake [mm^2 (AWG)[1)]	2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)	
Max. external mains fuses [A][3)]	900		900		900	
Estimated power loss at 400 V [W][4) 5)]	6794	7532	7498	8677	7976	9473
Estimated power loss at 460 V [W] [4)5)]	6118	6724	6672	7819	7814	8527
Weight, enclosure IP21, IP54 [kg]	270		272		313	
Weight, enclosure IP00 [kg]	234		236		277	
Efficiency[5)]	0.98					
Output frequency	0-590 Hz					
Heatsink overtemp. trip	110 °C					
Control card ambient trip	85 °C					
* High overload=160% torque during 60 s, Normal overload=110% torque during 60 s.						

Table 4.2 Technical Specifications, E-frame 380-500 V Mains Supply 3x380-500 V AC

1) American Wire Gauge.

2) Wiring terminals on N132, N160, and P315 frequency converters cannot receive cables one size larger.

3) For fuse ratings, see 7.2.1 Fuses.

4) Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the frequency converter. If the switching frequency is raised from nominal, the power losses rise significantly. LCP and typical control card power consumptions are included. Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.

5) Measured using 5 m screened motor cables at rated load and rated frequency.

FC 302	P450		P500		P560		P630		P710		P800	
High/Normal load*	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**
Typical shaft output at 400 V [kW]	450	500	500	560	560	630	630	710	710	800	800	1000
Typical shaft output at 460 V [HP]	600	650	650	750	750	900	900	1000	1000	1200	1200	1350
Typical shaft output at 500 V [kW]	530	560	560	630	630	710	710	800	800	1000	1000	1100
Enclosure IP21, IP54 without/with options cabinet	F1/ F3		F1/ F3		F1/ F3		F1/ F3		F2/ F4		F2/ F4	
Output current												
Continuous (at 400 V) [A]	800	880	880	990	990	1120	1120	1260	1260	1460	1460	1720
Intermittent (60 s overload) (at 400 V) [A]	1200	968	1320	1089	1485	1232	1680	1386	1890	1606	2190	1892
Continuous (at 460/500 V) [A]	730	780	780	890	890	1050	1050	1160	1160	1380	1380	1530
Intermittent (60 s overload) (at 460/500 V) [A]	1095	858	1170	979	1335	1155	1575	1276	1740	1518	2070	1683
Continuous kVA (at 400 V) [kVA]	554	610	610	686	686	776	776	873	873	1012	1012	1192
Continuous kVA (at 460 V) [kVA]	582	621	621	709	709	837	837	924	924	1100	1100	1219
Continuous kVA (at 500 V) [kVA]	632	675	675	771	771	909	909	1005	1005	1195	1195	1325
Maximum input current												
Continuous (at 400 V) [A]	779	857	857	964	964	1090	1090	1227	1227	1422	1422	1675
Continuous (at 460/500 V) [A]	711	759	759	867	867	1022	1022	1129	1129	1344	1344	1490
Max. cable size,motor [mm^2 (AWG)[1)]]	8x150 (8x300 mcm)								12x150 (12x300 mcm)			
Max. cable size,mains F1/F2 [mm^2 (AWG)[1)]]	8x240 (8x500 mcm)											
Max. cable size,mains F3/F4 [mm^2 (AWG)[1)]]	8x456 (8x900 mcm)											
Max. cable size, loadsharing [mm^2 (AWG)[1)]]	4x120 (4x250 mcm)											
Max. cable size, brake [mm^2 (AWG)[1)]	4x185 (4x350 mcm)								6x185 (6x350 mcm)			
Max. external mains fuses [A][2)]	1600				2000				2500			
Estimated power loss at 400 V [W][3)4)]	9031	10162	10146	11822	10649	12512	12490	14674	14244	17293	15466	19278
Estimated power loss at 460 V [W] [3) 4)]	8212	8876	8860	10424	9414	11595	11581	13213	13005	16229	14556	16624
F3/F4 max. added losses A1 RFI, CB or Disconnect, & contactor F3/F4	893	963	951	1054	978	1093	1092	1230	2067	2280	2236	2541
Max. panel options losses	400											
Weight, enclosure IP21, IP54 [kg]	1017/1318								1260/1561			
Weight, rectifier module [kg]	102		102		102		102		136		136	
Weight, inverter module [kg]	102		102		102		136		102		102	
Efficiency[4)]	0.98											
Output frequency	0-590 Hz											
Heatsink overtemp. trip	110 °C											
Control card ambient trip	85 °C											
* High overload=160% torque during 60 s, Normal overload=110% torque during 60 s.												

Table 4.3 Technical Specifications, F-frames, 380-500 V Mains Supply 3x380-500 V AC

1) American Wire Gauge.

2) For fuse ratings, see 7.2.1 Fuses.

3) Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the frequency converter. If the switching frequency is raised from nominal, the power losses rise significantly. LCP and typical control card power consumptions are included. Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.

4) Measured using 5 m screened motor cables at rated load and rated frequency.

FC 302	P250		P315		P355		P400	
High/Normal load*	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**
Typical shaft output at 400 V [kW]	250	315	315	355	355	400	400	450
Typical shaft output at 460 V [HP]	350	450	450	500	500	600	550	600
Typical shaft output at 500 V [kW]	315	355	355	400	400	500	500	530
Enclosure IP21	F8/F9		F8/F9		F8/F9		F8/F9	
Enclosure IP54	F8/F9		F8/F9		F8/F9		F8/F9	
Output current								
Continuous (at 400 V) [A]	480	600	600	658	658	745	695	800
Intermittent (60 s overload) (at 400 V) [A]	720	660	900	724	987	820	1043	880
Continuous (at 460/500 V) [A]	443	540	540	590	590	678	678	730
Intermittent (60 s overload) (at 460/500 V) [A]	665	594	810	649	885	746	1017	803
Continuous KVA (at 400 V) [KVA]	333	416	416	456	456	516	482	554
Continuous KVA (at 460 V) [KVA]	353	430	430	470	470	540	540	582
Continuous KVA (at 500 V) [KVA]	384	468	468	511	511	587	587	632
Maximum input current								
Continuous (at 400 V) [A]	472	590	590	647	647	733	684	787
Continuous (at 460/500 V) [A]	436	531	531	580	580	667	667	718
Max. cable size, mains [mm^2 (AWG)[1)]]	4x90 (3/0)		4x90 (3/0)		4x240 (500 mcm)		4x240 (500 mcm)	
Max. cable size, motor [mm^2 (AWG)[1)]]	4x240 (4x500 mcm)		4x240 (4x500 mcm)		4x240 (4x500 mcm)		4x240 (4x500 mcm)	
Max. cable size, brake [mm^2 (AWG)[1)]]	2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)	
Max. external mains fuses [A][2)]	700							
Estimated power loss at 400 V [W] [3) 4)]	5164	6790	6960	7701	7691	8879	8178	9670
Estimated power loss at 460 V [W] [3) 4)]	4822	6082	6345	6953	6944	8089	8085	8803
Weight,enclosure IP21, IP54 [kg]	447/669							
Efficiency[4)]	0.98							
Output frequency	0-590 Hz							
Heatsink overtemp. trip	110 °C							
Control card ambient trip	85 °C							
* High overload=160% torque during 60 s, Normal overload=110% torque during 60 s.								

Table 4.4 Technical Specifications F8/F9 Frames, 380-500 Mains Supply 6x380-500 V AC, 12-Pulse

1) American Wire Gauge.

2) For fuse ratings, see 7.2.1 Fuses.

3) Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the frequency converter. If the switching frequency is raised from nominal, the power losses rise significantly. LCP and typical control card power consumptions are included. Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.

4) Measured using 5 m screened motor cables at rated load and rated frequency.

FC 302	P450		P500		P560		P630		P710		P800	
High/Normal load *	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**
Typical shaft output at 400 V [kW]	450	500	500	560	560	630	630	710	710	800	800	1000
Typical shaft output at 460 V [HP]	600	650	650	750	750	900	900	1000	1000	1200	1200	1350
Typical shaft output at 500 V [kW]	530	560	560	630	630	710	710	800	800	1000	1000	1100
Enclosure IP21, IP54 without/with options cabinet	F10/F11		F10/F11		F10/F11		F10/F11		F12/F13		F12/F13	
Output current												
Continuous (at 400 V) [A]	800	880	880	990	990	1120	1120	1260	1260	1460	1460	1720
Intermittent (60 s overload) (at 400 V) [A]	1200	968	1320	1089	1485	1232	1680	1386	1890	1606	2190	1892
Continuous (at 460/500 V) [A]	730	780	780	890	890	1050	1050	1160	1160	1380	1380	1530
Intermittent (60 s overload) (at 460/500 V) [A]	1095	858	1170	979	1335	1155	1575	1276	1740	1518	2070	1683
Continuous KVA (at 400 V) [KVA]	554	610	610	686	686	776	776	873	873	1012	1012	1192
Continuous KVA (at 460 V) [KVA]	582	621	621	709	709	837	837	924	924	1100	1100	1219
Continuous KVA (at 500 V) [KVA]	632	675	675	771	771	909	909	1005	1005	1195	1195	1325
Maximum input current												
Continuous (at 400 V) [A]	779	857	857	964	964	1090	1090	1227	1227	1422	1422	1675
Continuous (at 460/500 V) [A]	711	759	759	867	867	1022	1022	1129	1129	1344	1344	1490
Max. cable size, motor [mm^2 (AWG)[1)]]	8x150 (8x300 mcm)								12x150 (12x300 mcm)			
Max. cable size, mains [mm^2 (AWG)[1)]]	6x120 (6x250 mcm)											
Max. cable size, brake [mm^2 (AWG)[1)]]	4x185 (4x350 mcm)								6x185 (6x350 mcm)			
Max. external mains fuses [A][2)]	900						1500					
Estimated power loss at 400 V [W][3) 4)]	9492	10647	10631	12338	11263	13201	13172	15436	14967	18084	16392	20358
Estimated power loss at 460 V [W][3) 4)]	8730	9414	9398	11006	10063	12353	12332	14041	13819	17137	15577	17752
F9/F11/F13 max. added losses A1 RFI, CB or disconnect, & contactor F9/F11/F13	893	963	951	1054	978	1093	1092	1230	2067	2280	2236	2541
Max. panel options losses	400											
Weight,enclosure IP21, IP54 [kg]	1017/ 1319								1261/ 1562			
Weight, rectifier module [kg]	102		102		102		102		136		136	
Weight, inverter module [kg]	102		102		102		136		102		102	
Efficiency[4)]	0.98											
Output frequency	0-590 Hz											
Heatsink overtemp. trip	95 °C											
Power card ambient trip	85 °C											
* High overload=160% torque during 60 s, Normal overload=110% torque during 60 s.												

Table 4.5 Technical Specifications, F10-F13 frames, 380-500 V Mains Supply 6x380-500 V AC, 12-Pulse

1) American Wire Gauge.

2) For fuse ratings, see 7.2.1 Fuses.

3) Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the frequency converter. If the switching frequency is raised from nominal, the power losses rise significantly. LCP and typical control card power consumptions are included. Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.

4) Measured using 5 m screened motor cables at rated load and rated frequency.

4.2 Electrical Data, 525-690 V

FC 302	N55K		N75K		N90K		N110		N132	
High/Normal load*	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**
Typical shaft output at 550 V [kW]	45	55	55	75	75	90	90	110	110	132
Typical shaft output at 575 V [hp]	60	75	75	100	100	125	125	150	150	200
Typical shaft output at 690 V [kW]	55	75	75	90	90	110	110	132	132	160
Enclosure IP21	D1h		D1h		D1h		D1h		D1h	
Enclosure IP54	D1h		D1h		D1h		D1h		D1h	
Enclosure IP20	D3h		D3h		D3h		D3h		D3h	
Output current										
Continuous (at 550 V) [A]	76	90	90	113	113	137	137	162	162	201
Intermittent (60 s overload) (at 550 V) [A]	122	99	135	124	170	151	206	178	243	221
Continuous (at 575/690 V) [A]	73	86	86	108	108	131	131	155	155	192
Intermittent (60 s overload) (at 575/690 V) [kVA]	117	95	129	119	162	144	197	171	233	211
Continuous kVA (at 550 V) [kVA]	72	86	86	108	108	131	131	154	154	191
Continuous kVA (at 575 V) [kVA]	73	86	86	108	108	130	130	154	154	191
Continuous kVA (at 690 V) [kVA]	87	103	103	129	129	157	157	185	185	229
Maximum input current										
Continuous (at 550 V) [A]	77	89	89	110	110	130	130	158	158	198
Continuous (at 575 V) [A]	74	85	85	106	106	124	124	151	151	189
Continuous (at 690 V)	77	87	87	109	109	128	128	155	155	197
Max. cable size: mains, motor, brake and load share mm^2 (AWG)[1]	2x95 (2x3/0)									
Max. external mains fuses [A] [2]	160		315		315		315		315	
Estimated power loss at 575 V [W] [3) 4)]	1098	1162	1162	1428	1430	1740	1742	2101	2080	2649
Estimated power loss at 690 V [W] [3) 4)]	1057	1204	1205	1477	1480	1798	1800	2167	2159	2740
Weight, enclosure IP21, IP54 kg (lbs.)	62 (135)									
Weight, enclosure IP20 kg (lbs.)	125 (275)									
Efficiency [4]	0.98									
Output frequency	0–590 Hz									
Heatsink overtemperature trip	110 °C									
Control card ambient trip	75 °C									
*High overload=150% current for 60 s, Normal overload=110% current for 60 s.										

Table 4.6 Technical Specifications, D-frame, 525-690 V Mains Supply 3x525-690 V AC

1) American Wire Gauge.

2) For fuse ratings, see 7.2.1 Fuses.

3) Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the frequency converter. If the switching frequency is raised from nominal, the power losses rise significantly. LCP and typical control card power consumptions are included. Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.

4) Measured using 5 m screened motor cables at rated load and rated frequency.

4

FC 302 High/Normal load*	N160		N200		N250		N315	
	HO	NO	HO	NO	HO	NO	HO	NO
Typical Shaft output at 550 V [kW]	132	160	160	200	200	250	250	315
Typical Shaft output at 575 V [hp]	200	250	250	300	300	350	350	400
Typical Shaft output at 690 V [kW]	160	200	200	250	250	315	315	400
Enclosure IP21	D2h		D2h		D2h		D2h	
Enclosure IP54	D2h		D2h		D2h		D2h	
Enclosure IP20	D4h		D4h		D4h		D4h	
Output current								
Continuous (at 550 V) [A]	201	253	253	303	303	360	360	418
Intermittent (60 s overload) (at 550 V)[A]	302	278	380	333	455	396	540	460
Continuous (at 575/690 V) [A]	192	242	242	290	290	344	344	400
Intermittent (60 s overload) (at 575/690 V) [kVA]	288	266	363	319	435	378	516	440
Continuous kVA (at 550 V) [kVA]	191	241	241	289	289	343	343	398
Continuous kVA (at 575 V) [kVA]	191	241	241	289	289	343	343	398
Continuous kVA (at 690 V) [kVA]	229	289	289	347	347	411	411	478
Maximum input current								
Continuous (at 550 V) [A]	198	245	245	299	299	355	355	408
Continuous (at 575 V) [A]	189	234	234	286	286	339	339	390
Continuous (at 690 V)	197	240	240	296	296	352	352	400
Max. cable size: mains, motor, brake and load share mm^2 (AWG)[1]	2x185 (2x350)							
Max. external mains fuses [A] [2]	550							
Estimated power loss at 575 V [W] [3) 4)]	2361	3074	3012	3723	3642	4465	4146	5028
Estimated power loss at 690 V [W] [3) 4)]	2446	3175	3123	3851	3771	4614	4258	5155
Weight, enclosure IP21, IP54 kg (lbs.)	125 (275)							
Weight, enclosure IP20 kg (lbs.)	125 (275)							
Efficiency [4]	0.98							
Output frequency	0–590 Hz							
Heatsink overtemperature trip	110 °C							
Control card ambient trip	80 °C							
*High overload=150% current for 60 s, Normal overload=110% current for 60 s.								

Table 4.7 Technical Specifications, D-frame, 525-690 V Mains Supply 3x525-690 V AC

1) American Wire Gauge.

2) For fuse ratings, see 7.2.1 Fuses.

3) Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the frequency converter. If the switching frequency is raised from nominal, the power losses rise significantly. LCP and typical control card power consumptions are included. Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.

4) Measured using 5 m screened motor cables at rated load and rated frequency.

FC 302	P355	
High/Normal load*	**HO**	**NO**
Typical shaft output at 550 V [kW]	315	355
Typical shaft output at 575 V [HP]	400	450
Typical shaft output at 690 V [kW]	355	450
Enclosure IP21	E1	
Enclosure IP54	E1	
Enclosure IP00	E2	
Output current		
Continuous (at 550 V) [A]	395	470
Intermittent (60 s overload) (at 550 V) [A]	593	517
Continuous (at 575/690 V) [A]	380	450
Intermittent (60 s overload) (at 575/690 V) [A]	570	495
Continuous KVA (at 550 V) [KVA]	376	448
Continuous KVA (at 575 V) [KVA]	378	448
Continuous KVA (at 690 V) [KVA]	454	538
Maximum input current		
Continuous (at 550 V) [A]	381	453
Continuous (at 575 V) [A]	366	434
Continuous (at 690 V) [A]	366	434
Max. cable size, mains, motor and load share [mm^2 (AWG)[1)]]	4x240 (4x500 mcm)	
Max. cable size, brake [mm^2 (AWG)[1)]]	2x185 (2x350 mcm)	
Max. external mains fuses [A][2)]	700	
Estimated power loss at 600 V [W][3)4)]	4424	5323
Estimated power loss at 690 V [W][3) 4)]	4589	5529
Weight, enclosure IP21, IP54 [kg]	263	
Weight, enclosure IP00 [kg]	221	
Efficiency[4) 4)]	0.98	
Output frequency	0-500 Hz	
Heatsink overtemp. trip	110 °C	
Power card ambient trip	85 °C	
* High overload=160% torque during 60 s, Normal overload=110% torque during 60 s.		

Table 4.8 Technical Specifications, E-frame, 525-690 V Mains Supply 3x525-690 V AC

1) American Wire Gauge.

2) For fuse ratings, see 7.2.1 Fuses.

3) Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the frequency converter. If the switching frequency is raised from nominal, the power losses rise significantly. LCP and typical control card power consumptions are included. Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.

4) Measured using 5 m screened motor cables at rated load and rated frequency.

FC 302	P400		P500		P560	
High/Normal load*	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**
Typical shaft output at 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
Enclosure IP21	E1		E1		E1	
Enclosure IP54	E1		E1		E1	
Enclosure IP00	E2		E2		E2	
Output current						
Continuous (at 550 V) [A]	429	523	523	596	596	630
Intermittent (60 s overload) (at 550 V) [A]	644	575	785	656	894	693
Continuous (at 575/690 V) [A]	410	500	500	570	570	630
Intermittent (60 s overload) (at 575/690 V) [A]	615	550	750	627	855	693
Continuous KVA (at 550 V) [KVA]	409	498	498	568	568	600
Continuous KVA (at 575 V) [KVA]	408	498	498	568	568	627
Continuous KVA (at 690 V) [KVA]	490	598	598	681	681	753
Maximum input current						
Continuous (at 550 V) [A]	413	504	504	574	574	607
Continuous (at 575 V) [A]	395	482	482	549	549	607
Continuous (at 690 V) [A]	395	482	482	549	549	607
Max. cable size, mains, motor and load share [mm^2 (AWG)[1)]]	4x240 (4x500 mcm)		4x240 (4x500 mcm)		4x240 (4x500 mcm)	
Max. cable size, brake [mm^2 (AWG)[1)]]	2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)	
Max. external mains fuses [A][2)]	700		900		900	
Estimated power loss at 600 V [W][3)4)]	4795	6010	6493	7395	7383	8209
Estimated power loss at 690 V [W][3)4)]	4970	6239	6707	7653	7633	8495
Weight, enclosure IP21, IP54 [kg]	263		272		313	
Weight, enclosure IP00 [kg]	221		236		277	
Efficiency[4)]	0.98					
Output frequency	0-500 Hz					
Heatsink overtemp. trip	110 °C					
Power card ambient trip	85 °C					
* High overload=160% torque during 60 s, Normal overload=110% torque during 60 s.						

Table 4.9 Technical Specifications, E-frame 525-690 V Mains Supply 3x525-690 V AC

1) American Wire Gauge.

2) For fuse ratings, see 7.2.1 Fuses.

3) Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the frequency converter. If the switching frequency is raised from nominal, the power losses rise significantly. LCP and typical control card power consumptions are included. Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.

4) Measured using 5 m screened motor cables at rated load and rated frequency.

FC 302	P630		P710		P800	
High/Normal load*	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**
Typical shaft output at 550 V [kW]	500	560	560	670	670	750
Typical shaft output at 575 V [HP]	650	750	750	950	950	1050
Typical shaft output at 690 V [kW]	630	710	710	800	800	900
Enclosure IP21, IP54 without/with options cabinet	F1/ F3		F1/ F3		F1/ F3	
Output current						
Continuous (at 550 V) [A]	659	763	763	889	889	988
Intermittent (60 s overload) (at 550 V) [A]	989	839	1145	978	1334	1087
Continuous (at 575/690 V) [A]	630	730	730	850	850	945
Intermittent (60 s overload) (at 575/690 V) [A]	945	803	1095	935	1275	1040
Continuous KVA (at 550 V) [KVA]	628	727	727	847	847	941
Continuous KVA (at 575 V) [KVA]	627	727	727	847	847	941
Continuous KVA (at 690 V) [KVA]	753	872	872	1016	1016	1129
Maximum input current						
Continuous (at 550 V) [A]	642	743	743	866	866	962
Continuous (at 575 V) [A]	613	711	711	828	828	920
Continuous (at 690 V) [A]	613	711	711	828	828	920
Max. cable size, motor [mm^2 (AWG)[1)]]	8x150 (8x300 mcm)					
Max. cable size,mains F1 [mm^2 (AWG)[1)]]	8x240 (8x500 mcm)					
Max. cable size,mains F3 [mm^2 (AWG)[1)]]	8x456 (8x900 mcm)					
Max. cable size, loadsharing [mm^2 (AWG)[1)]]	4x120 (4x250 mcm)					
Max. cable size, brake [mm^2 (AWG)[1)]]	4x185 (4x350 mcm)					
Max. external mains fuses [A][2)]	1600					
Estimated power loss at 600 V [W][3) 4)]	8075	9500	9165	10872	10860	12316
Estimated power loss at 690 V [W][3) 4)]	8388	9863	9537	11304	11291	12798
F3/F4 Max added losses CB or disconnect & contactor	342	427	419	532	519	615
Max panel options losses	400					
Weight, enclosure IP21, IP54 [kg]	1017/1318					
Weight, rectifier module [kg]	102		102		102	
Weight, inverter module [kg]	102		102		136	
Efficiency[4)]	0.98					
Output frequency	0-500 Hz					
Heatsink overtemp. trip	95 °C		105 °C		95 °C	
Power card ambient trip	85 °C					
* High overload=160% torque during 60 s, Normal overload=110% torque during 60 s.						

Table 4.10 Technical Specifications, F1/F3 frames, 525-690 V Mains Supply 3x525-690 V AC

1) American Wire Gauge.

2) For fuse ratings, see 7.2.1 Fuses.

3) Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the frequency converter. If the switching frequency is raised from nominal, the power losses rise significantly. LCP and typical control card power consumptions are included. Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.

4) Measured using 5 m screened motor cables at rated load and rated frequency.

FC 302	P900		P1M0		P1M2	
High/Normal load*	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**
Typical shaft output at 550 V [kW]	750	850	850	1000	1000	1100
Typical shaft output at 575 V [HP]	1050	1150	1150	1350	1350	1550
Typical shaft output at 690 V [kW]	900	1000	1000	1200	1200	1400
Enclosure IP21, IP54 without/with options cabinet	F2/F4		F2/F4		F2/F4	
Output current						
Continuous (at 550 V) [A]	988	1108	1108	1317	1317	1479
Intermittent (60 s overload) (at 550 V) [A]	1482	1219	1662	1449	1976	1627
Continuous (at 575/690 V) [A]	945	1060	1060	1260	1260	1415
Intermittent (60 s overload) (at 575/690 V) [A]	1418	1166	1590	1386	1890	1557
Continuous KVA (at 550 V) [KVA]	941	1056	1056	1255	1255	1409
Continuous KVA (at 575 V) [KVA]	941	1056	1056	1255	1255	1409
Continuous KVA (at 690 V) [KVA]	1129	1267	1267	1506	1506	1691
Maximum input current						
Continuous (at 550 V) [A]	962	1079	1079	1282	1282	1440
Continuous (at 575 V) [A]	920	1032	1032	1227	1227	1378
Continuous (at 690 V) [A]	920	1032	1032	1227	1227	1378
Max. cable size, motor [mm^2 (AWG)[1)]]	12x150 (12x300 mcm)					
Max. cable size, mains F2 [mm^2 (AWG)[1)]]	8x240 (8x500 mcm)					
Max. cable size, mains F4 [mm^2 (AWG)[1)]]	8x456 (8x900 mcm)					
Max. cable size, loadsharing [mm^2 (AWG)[1)]]	4x120 (4x250 mcm)					
Max. cable size, brake [mm^2 (AWG)[1)]]	6x185 (6x350 mcm)					
Max. external mains fuses [A][2)]	1600		2000		2500	
Estimated power loss at 600 V [W][3)] [4)]	12062	13731	13269	16190	16089	18536
Estimated power loss at 690 V [W][3)] [4)]	12524	14250	13801	16821	16719	19247
F3/F4 Max added losses CB or disconnect & contactor	556	665	634	863	861	1044
Max panel options losses	400					
Weight, enclosure IP21, IP54 [kg]	1260/1561				1294/1595	
Weight, rectifier module [kg]	136		136		136	
Weight, inverter module [kg]	102		102		136	
Efficiency[4)]	0.98					
Output frequency	0-500 Hz					
Heatsink overtemp. trip	95 °C		105 °C		95 °C	
Power card ambient trip	85 °C					
* High overload=160% torque during 60 s, Normal overload=110% torque during 60 s.						

Table 4.11 Technical Specifications, F2/F4 frames, 525-690 V Mains Supply 3x525-690 V AC

1) American Wire Gauge.

2) For fuse ratings, see 7.2.1 Fuses.

3) Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the frequency converter. If the switching frequency is raised from nominal, the power losses rise significantly. LCP and typical control card power consumptions are included. Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.

4) Measured using 5 m screened motor cables at rated load and rated frequency.

4.2.1 Electrical Data, 525-690 V AC, 12-Pulse

FC 302	P355		P400		P500		P560	
High/Normal load	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**
Typical shaft output at 550 V [kW]	315	355	315	400	400	450	450	500
Typical shaft output at 575 V [HP]	400	450	400	500	500	600	600	650
Typical shaft output at 690 V [kW]	355	450	400	500	500	560	560	630
Enclosure IP21	F8/F9		F8/F9		F8/F9		F8/F9	
Enclosure IP54	F8/F9		F8/F9		F8/F9		F8/F9	
Output current								
Continuous (at 550 V) [A]	395	470	429	523	523	596	596	630
Intermittent (60 s overload) (at 550 V) [A]	593	517	644	575	785	656	894	693
Continuous (at 575/690 V) [A]	380	450	410	500	500	570	570	630
Intermittent (60 s overload) (at 575/690 V) [A]	570	495	615	550	750	627	855	693
Continuous KVA (at 550 V) [KVA]	376	448	409	498	498	568	568	600
Continuous KVA (at 575 V) [KVA]	378	448	408	498	498	568	568	627
Continuous KVA (at 690 V) [KVA]	454	538	490	598	598	681	681	753
Maximum input current								
Continuous (at 550 V) [A]	381	453	413	504	504	574	574	607
Continuous (at 575 V) [A]	366	434	395	482	482	549	549	607
Continuous (at 690 V) [A]	366	434	395	482	482	549	549	607
Max. cable size, mains [mm^2 (AWG)[1)]]	4x85 (3/0)							
Max. cable size, motor [mm^2 (AWG)[1)]]	4x250 (500 mcm)							
Max. cable size, brake [mm^2 (AWG)[1)]]	2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)	
Max. external mains fuses [A][2)]	630							
Estimated power loss at 600 V [W][3) 4)]	4424	5323	4795	6010	6493	7395	7383	8209
Estimated power loss at 690 V [W][3) 4)]	4589	5529	4970	6239	6707	7653	7633	8495
Weight, enclosure IP21, IP54 [kg]	447/669							
Efficiency[4)]	0.98							
Output frequency	0-500 Hz							
Heatsink overtemp. trip	110 °C							
Power card ambient trip	85 °C							
* High overload=160% torque during 60 s, Normal overload=110% torque during 60 s.								

Table 4.12 Technical Specifications F8/F9 frames, 525-690 V Mains Supply 6x525-690 V AC, 12-Pulse

1) American Wire Gauge.

2) For fuse ratings, see 7.2.1 Fuses.

3) Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the frequency converter. If the switching frequency is raised from nominal, the power losses rise significantly. LCP and typical control card power consumptions are included. Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.

4) Measured using 5 m screened motor cables at rated load and rated frequency.

FC 302	P630		P710		P800	
High/Normal load	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**
Typical shaft output at 550 V [kW]	500	560	560	670	670	750
Typical shaft output at 575 V [HP]	650	750	750	950	950	1050
Typical shaft output at 690 V [kW]	630	710	710	800	800	900
Enclosure IP21, IP54 without/with options cabinet	F10/F11		F10/F11		F10/F11	
Output current						
Continuous (at 550 V) [A]	659	763	763	889	889	988
Intermittent (60 s overload) (at 550 V) [A]	989	839	1145	978	1334	1087
Continuous (at 575/690 V) [A]	630	730	730	850	850	945
Intermittent (60 s overload) (at 575/690 V) [A]	945	803	1095	935	1275	1040
Continuous KVA (at 550 V) [KVA]	628	727	727	847	847	941
Continuous KVA (at 575 V) [KVA]	627	727	727	847	847	941
Continuous KVA (at 690 V) [KVA]	753	872	872	1016	1016	1129
Maximum input current						
Continuous (at 550 V) [A]	642	743	743	866	866	962
Continuous (at 575 V) [A]	613	711	711	828	828	920
Continuous (at 690 V) [A]	613	711	711	828	828	920
Max. cable size, motor [mm^2 (AWG)[1)]]	8x150 (8x300 mcm)					
Max. cable size, mains [mm^2 (AWG)[1)]]	6x120 (6x250 mcm)					
Max. cable size, brake [mm^2 (AWG)[1)]]	4x185 (4x350 mcm)					
Max. external mains fuses [A][2)]	900					
Estimated power loss at 600 V [W][3) 4)]	8075	9500	9165	10872	10860	12316
Estimated power loss at 690 V [W][3) 4)]	8388	9863	9537	11304	11291	12798
F3/F4 Max added losses CB or disconnect & contactor	342	427	419	532	519	615
Max panel options losses	400					
Weight, enclosure IP21, IP54 [kg]	1017/1319					
Weight, rectifier module [kg]	102		102		102	
Weight, inverter module [kg]	102		102		136	
Efficiency[4)]	0.98					
Output frequency	0-500 Hz					
Power heatsink overtemp. trip	95 °C		105 °C		95 °C	
Power card ambient trip	85 °C					
* High overload=160% torque during 60 s, Normal overload=110% torque during 60 s						

Table 4.13 Technical Specifications, F10/F11 frames, 525-690 V Mains Supply 6x525-690 V AC, 12-Pulse

1) American Wire Gauge.

2) For fuse ratings, see 7.2.1 Fuses.

3) Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the frequency converter. If the switching frequency is raised from nominal, the power losses rise significantly. LCP and typical control card power consumptions are included. Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.

4) Measured using 5 m screened motor cables at rated load and rated frequency.

FC 302	P900		P1M0		P1M2	
High/ Normal load*	**HO**	**NO**	**HO**	**NO**	**HO**	**NO**
Typical shaft output at 550 V [kW]	750	850	850	1000	1000	1100
Typical shaft output at 575 V [HP]	1050	1150	1150	1350	1350	1550
Typical shaft output at 690 V [kW]	900	1000	1000	1200	1200	1400
Enclosure IP21, IP54 without/with options cabinet	F12/F13		F12/F13		F12/F13	
Output current						
Continuous (at 550 V) [A]	988	1108	1108	1317	1317	1479
Intermittent (60 s overload) (at 550 V) [A]	1482	1219	1662	1449	1976	1627
Continuous (at 575/690 V) [A]	945	1060	1060	1260	1260	1415
Intermittent (60 s overload) (at 575/690 V) [A]	1418	1166	1590	1386	1890	1557
Continuous KVA (at 550 V) [KVA]	941	1056	1056	1255	1255	1409
Continuous KVA (at 575 V) [KVA]	941	1056	1056	1255	1255	1409
Continuous KVA (at 690 V) [KVA]	1129	1267	1267	1506	1506	1691
Maximum input current						
Continuous (at 550 V) [A]	962	1079	1079	1282	1282	1440
Continuous (at 575 V) [A]	920	1032	1032	1227	1227	1378
Continuous (at 690 V) [A]	920	1032	1032	1227	1227	1378
Max. cable size, motor [mm^2 (AWG)[1)]]	12x150 (12x300 mcm)					
Max. cable size, mains F12 [mm^2 (AWG)[1)]]	8x240 (8x500 mcm)					
Max. cable size, mains F13 [mm^2 (AWG)[1)]]	8x400 (8x900 mcm)					
Max. cable size, brake [mm^2 (AWG[1)])]	6x185 (6x350 mcm)					
Max. external mains fuses [A][2)]	1600		2000		2500	
Estimated power loss at 600 V [W][3) 4)]	12062	13731	13269	16190	16089	18536
Estimated power loss at 690 V [W][3)4)]	12524	14250	13801	16821	16719	19247
F3/F4 Max added losses CB or disconnect & contactor	556	665	634	863	861	1044
Max panel options losses	400					
Weight, enclosure IP21, IP 54 [kg]	1261/1562				1295/1596	
Weight, rectifier module [kg]	136		136		136	
Weight, inverter module [kg]	102		102		136	
Efficiency[4)]	0.98					
Output frequency	0-500 Hz					
Power heatsink overtemp. trip	95 °C		105 °C		95 °C	
Power card ambient trip	85 °C					
* High overload=160% torque during 60 s, Normal overload=110% torque during 60 s.						

Table 4.14 Technical Specifications, F12/F13 frames, 525-690 V Mains Supply 6x525-690 V AC, 12-Pulse

1) American Wire Gauge.

2) For fuse ratings, see 7.2.1 Fuses.

3) Typical power loss is at normal conditions and expected to be within ±15% (tolerance relates to variety in voltage and cable conditions.) These values are based on a typical motor efficiency (IE/IE3 border line). Lower efficiency motors add to the power loss in the frequency converter. If the switching frequency is raised from nominal, the power losses rise significantly. LCP and typical control card power consumptions are included. Options and customer load can add up to 30 W to the losses, though usually a fully loaded control card and options for slots A and B each add only 4 W.

4) Measured using 5 m screened motor cables at rated load and rated frequency.

4.3 General Specifications

Mains Supply

Supply terminals (6-Pulse)	L1, L2, L3
Supply terminals (12-Pulse)	L1-1, L2-1, L3-1, L1-2, L2-2, L3-2
Supply voltage	380-500 V ±10%
Supply voltage	FC 302: 525-690 V ±10%

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

Supply frequency	50/60 Hz ±5%
Max. imbalance temporary between mains phases	3.0% of rated supply voltage
True power factor (λ)	≥0.9 nominal at rated load
Displacement Power Factor (cos ϕ)	near unity (>0.98)
Switching on input supply L1, L2, L3 (power-ups) ≥ 90 kW	maximum 1 time/2 min.
Environment according to EN60664-1	overvoltage category III/pollution degree 2

The unit is suitable for use on a circuit capable of delivering not more than 100,000 RMS symmetrical Amperes, 240/500/600/690 V maximum.

Motor Output (U, V, W)

Output voltage	0-100% of supply voltage
Output frequency (90-1000 kW)	0-590[1)] Hz
Output frequency in flux mode (FC 302 only)	0-300 Hz
Switching on output	Unlimited
Ramp times	0.01-3600 s

1) Voltage and power dependent.

Torque Characteristics

Starting torque (Constant torque)	maximum 160% for 60 s[1)]
Starting torque	maximum 180% up to 0.5 s[1)]
Overload torque (Constant torque)	maximum 160% for 60 s[1)]
Starting torque (Variable torque)	maximum 110% for 60 s[1)]
Torque rise time in VVC^{plus} (independent of fsw)	10 ms
Torque rise time in FLUX (for 5 kHz fsw)	1 ms

1) Percentage relates to the nominal torque.
2) The torque response time depends on application and load but as a general rule, the torque step from 0 to reference is 4-5 x torque rise time.

Cable Lengths and Cross Sections for Control Cables[1)]

Max. motor cable length, screened	150 m
Max. motor cable length, unscreened	300 m
Maximum cross section to control terminals, flexible/rigid wire without cable end sleeves	1.5 mm²/16 AWG
Maximum cross section to control terminals, flexible wire with cable end sleeves	1 mm²/18 AWG
Maximum cross section to control terminals, flexible wire with cable end sleeves with collar	0.5 mm²/20 AWG
Minimum cross section to control terminals	0.25 mm²/24 AWG

1)For power cables, see 4.1 Electrical Data, 380-500 V.

Protection and Features

- Electronic thermal motor protection against overload.

- Temperature monitoring of the heatsink ensures that the frequency converter trips if the temperature reaches a pre-defined level. An overload temperature cannot be reset until the temperature of the heatsink is below the values stated in the tables on the following pages. Note that these temperatures may vary for different power sizes, frame sizes, enclosure ratings etc.
- The frequency converter is protected against short-circuits on motor terminals U, V, W.
- If a mains phase is missing, the frequency converter trips or issues a warning depending on the load.
- Monitoring of the intermediate circuit voltage ensures that the frequency converter trips if the intermediate circuit voltage is too low or too high.
- The frequency converter constantly checks for critical levels of internal temperature, load current, high voltage on the intermediate circuit and low motor speeds. As a response to a critical level, the frequency converter can adjust the switching frequency and/or change the switching pattern in order to ensure the performance of the frequency converter.

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) Min. pulse width	4.5 ms
Input resistance, R_i	approx. 4 kΩ

Safe Torque Off Terminal 37[3, 4] (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] Terminals 27 and 29 can also be programmed as output.

[2] Except Safe Torque Off input Terminal 37.

[3] For more information on terminal 37 and Safe Torque Off, see 3.12 Safe Torque Off.

[4] When using a contactor with a DC coil inside in combination with Safe Torque Off, it is important to make a return way for the current from the coil when turning it off. This can be done by using a freewheel diode (or, alternatively, a 30 or 50 V MOV for quicker response time) across the coil. 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 A53 and A54 (D-Frame) S201 and S202 (E & F-Frames)
Voltage mode	Switch A53 and A54 (D-Frame) S201 and S202 (E & F-Frames)=OFF (U)
Voltage level	-10 to +10 V (scaleable)
Input resistance, R_i	approx. 10 kΩ
Max. voltage	± 20 V
Current mode	Switch A53 and A54 (D-Frame) S201 and S202 (E & F-Frames)=ON (I)
Current level	0/4 to 20 mA (scaleable)
Input resistance, R_i	approx. 200 Ω

Max. current	30 mA
Resolution for analog inputs	10 bit (+sign)
Accuracy of analog inputs	Max. error 0.5% of full scale
Bandwidth	100 Hz

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

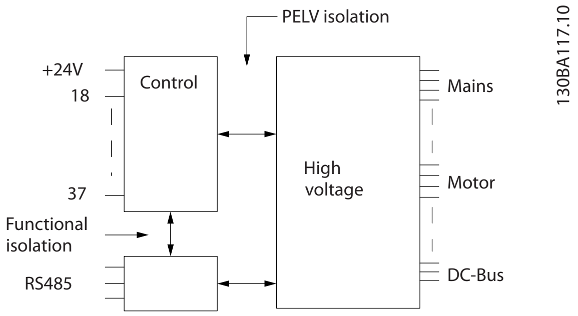


Illustration 4.1 PELV Isolation

Pulse/Encoder Inputs

Programmable pulse/encoder inputs	2/1
Terminal number pulse/encoder	29 [1)], 33 [2)]/32 [3)], 33 [3)]
Max. frequency at terminal 29, 32, 33	110 kHz (Push-pull driven)
Max. frequency at terminal 29, 32, 33	5 kHz (open collector)
Min. frequency at terminal 29, 32, 33	4 Hz
Voltage level	see *9.2.2 Digital Inputs - Terminal X30/1-4*
Maximum voltage on input	28 V DC
Input resistance, R_i	approx. 4 kΩ
Pulse input accuracy (0.1-1 kHz)	Max. error: 0.1% of full scale
Encoder input accuracy (1-11 kHz)	Max. 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) FC 302 only

2) Pulse inputs are 29 and 33

3) Encoder inputs: 32=A, and 33=B

Analog Output

Number of programmable analog outputs	1
Terminal number	42
Current range at analog output	0/4-20 mA
Max. load GND - analog output	500 Ω
Accuracy on analog output	Max. 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, RS-485 Serial Communication

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

The RS-485 serial communication circuit is 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
Max. output current (sink or source)	40 mA
Max. load at frequency output	1 kΩ

Max. 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	Max. error: 0.1 % of full scale
Resolution of frequency outputs	12 bit

[1] Terminal 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
Max. 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)
Max. terminal load (AC-1)[1] on 1-3 (NC), 1-2 (NO) (Resistive load)	240 V AC, 2 A
Max. terminal load (AC-15)[1] (Inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Max. terminal load (DC-1)[1] on 1-2 (NO), 1-3 (NC) (Resistive load)	60 V DC, 1 A
Max. terminal load (DC-13)[1] (Inductive load)	24 V DC, 0.1 A
Relay 02 (FC 302 only) Terminal number	4-6 (break), 4-5 (make)
Max. terminal load (AC-1)[1] on 4-5 (NO) (Resistive load)[2][3] Overvoltage cat. II	400 V AC, 2 A
Max. terminal load (AC-15)[1] on 4-5 (NO) (Inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Max. terminal load (DC-1)[1] on 4-5 (NO) (Resistive load)	80 V DC, 2 A
Max. terminal load (DC-13)[1] on 4-5 (NO) (Inductive load)	24 V DC, 0.1 A
Max. terminal load (AC-1)[1] on 4-6 (NC) (Resistive load)	240 V AC, 2 A
Max. terminal load (AC-15)[1] on 4-6 (NC) (Inductive load @ cosφ 0.4)	240 V AC, 0.2 A
Max. terminal load (DC-1)[1] on 4-6 (NC) (Resistive load)	50 V DC, 2 A
Max. terminal load (DC-13)[1] on 4-6 (NC) (Inductive load)	24 V DC, 0.1 A
Min. 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 AC2A.

Control Card, 10 V DC Output

Terminal number	50
Output voltage	10.5 V ±0.5 V
Max. load	15 mA

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

Control Characteristics

Resolution of output frequency at 0-1000 Hz	± 0.003 Hz
Repeat accuracy of precise start/stop (terminals 18, 19)	≤±0.1 ms
System response time (terminals 18, 19, 27, 29, 32, 33)	≤2 ms
Speed control range (open loop)	1:100 of synchronous speed
Speed control range (closed loop)	1:1000 of synchronous speed
Speed accuracy (open loop)	30-4000 rpm: error ±8 rpm
Speed accuracy (closed loop), depending on resolution of feedback device	0-6000 rpm: error ±0.15 rpm

Torque control accuracy (speed feedback)	max error ±5% of rated torque

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

Control Card Performance

Scan interval	1 ms

Surroundings

Frame size D1h, D2h , E1, F1, F2, F3 and F4	IP21, IP54
Frame size D3h, D4h	IP20
E2	IP00
Vibration test, frame size D, E and F	1 g
Max. relative humidity	5%-95%(IEC 60 721-3-3; Class 3K3 (non-condensing) during operation
Aggressive environment (IEC 60068-2-43) H_2S test	class Kd
Test method according to IEC 60068-2-43 H2S (10 days)	
Aggressive environment (IEC 721-3-3), coated	Class 3C3
Ambient temperature (full rating with default parameter settings)	Max. 45 °C
Ambient temperature with derating	Max. 55 °C

For more information on derating for high ambient temperature, see 4.7 Special Conditions.

Minimum ambient temperature during full-scale operation	0 °C
Minimum ambient temperature at reduced performance	-10 °C
Temperature during storage/transport	-25 to +65/70 °C
Maximum altitude above sea level	1000 m

Derating for high altitude, see 4.7 Special Conditions

EMC standards, Emission	EN 61800-3, EN 61000-6-3/4, EN 55011
EMC standards, Immunity	EN 61800-3, EN 61000-6-1/2, EN 61000-4-2, EN 61000-4-3, EN 61000-4-4, EN 61000-4-5, EN 61000-4-6

See 4.7 Special Conditions.

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 protection earth. Use only an isolated laptop as PC connection to the USB connector on the frequency converter.

4.4 Efficiency

Efficiency of the Frequency Converter (η_{VLT})
The load on the frequency converter has little effect on its efficiency. In general, the efficiency is the same at the rated motor frequency $f_{M,N}$, whether the motor supplies 100% of the rated shaft torque or only 75%, in case of partial loads.

The efficiency of the frequency converter does not change even if other U/f characteristics are chosen. However, the U/f characteristics influence the efficiency of the motor.

The efficiency declines slightly when the switching frequency is set to a value of above 5 kHz. The efficiency is slightly reduced when the mains voltage is 480 V, or if the motor cable is longer than 30 m.

Frequency Converter Efficiency Calculation
Calculate the efficiency of the frequency converter at different speeds and loads based on *Illustration 4.2*. The factor in this graph must be multiplied with the specific efficiency factor listed in the specification tables in *4.1 Electrical Data, 380-500 V* and *4.2 Electrical Data, 525-690 V*.

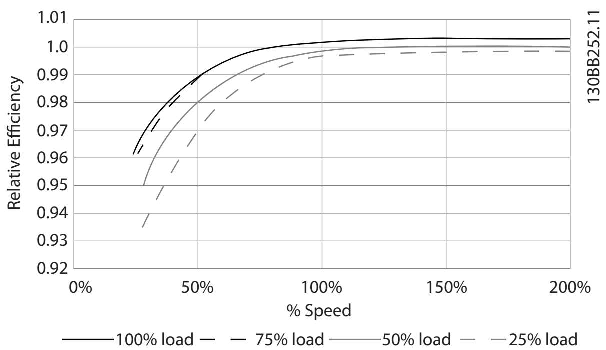


Illustration 4.2 Typical Efficiency Curves

Example: Assume a 160 kW, 380–480 V AC frequency converter at 25% load at 50% speed. *Illustration 4.2* shows 0.97 - rated efficiency for a 160 kW frequency converter is 0.98. The actual efficiency is then: 0.97x 0.98=0.95.

Efficiency of the Motor (η_{MOTOR})
The efficiency of a motor connected to the frequency converter depends on magnetizing level. In general, the efficiency is as good as with mains operation. The efficiency of the motor depends on the type of motor.

In the range of 75–100% of the rated torque, the efficiency of the motor is practically constant, both when the frequency converter controls it and when it runs directly on mains.

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

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

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

4.5 Acoustic Noise

The acoustic noise from the frequency converter comes from three sources:

1. DC intermediate circuit coils
2. Integral fan
3. RFI filter choke

Table 4.15 lists the typical acoustic noise values measured at a distance of 1 m from the unit.

Frame size	dBA at full fan speed
N90k	71
N110	71
N132	72
N160	74
N200	75
N250	73
E1/E2-Frames 1)	74
E1/E2-Frames 2)	83
F-Frames	80

Table 4.15 Acoustic Noise

1) *250 kW, 380-500 V and 355/400 kW, 525-690 V only.*

2) *All other E-frame units.*

4

4.6 dU/dt Conditions

NOTICE

To avoid the premature ageing 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 *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 screened or unscreened)
- inductance

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

Peak voltage on the motor terminals is caused by the switching of the IGBTs. The frequency converter complies with the demands of IEC 60034-25 regarding motors designed to be controlled by 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 4.16* and *Table 4.17* 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 to be controlled by frequency converters, and NEMA MG 1-1998 Part 31.4.4.2 for inverter fed motors. The power sizes below do not comply with NEMA MG 1-1998 Part 30.2.2.8 for general purpose motors.

Power size	Cable length [m]	Mains voltage [V]	Rise time [µs]	Peak voltage [V]	dU/dt [V/µs]
90-250 kW/ 380-500 V	30	400	0.26	1180	2109`

Table 4.16 dU/dt, D-frame, 380-500 V

Power size	Cable length [m]	Mains voltage [V]	Rise time [µs]	Peak voltage [V]	dU/dt [V/µs]
315-800 kW/380-500 V	30	500	0.71	1165	1389
	30	500 [1)]	0.80	906	904
	30	400	0.61	942	1233
	30	400[1)]	0.82	760	743

Table 4.17 dU/dt E-frame, 380-500 V

[1)] With Danfoss dU/dt filter

Power size	Cable length [m]	Mains voltage [V]	Rise time [µs]	Peak voltage [V]	dU/dt [V/µs]
90-132 kW/ 525-690 V	150	690	0.36	2135	2.197
160-315 kW/525-690 V	150	690[1)]	0.46	2210	1.744

Table 4.18 dU/dt D-frame 525-690 V

[1)] With Danfoss dU/dt filter

Power size	Cable length [m]	Mains voltage [V]	Rise time [µs]	Peak voltage [V]	dU/dt [V/µs]
355-1200 kW/525-690 V	30	690	0.57	1611	2261
	30	575	0.25		2510
	30	690[1)]	1.13	1629	1150

Table 4.19 dU/dt E- and F-frames 525-690 V

[1)] With Danfoss dU/dt filter.

4.7 Special Conditions

This section provides detailed data regarding the operating of the frequency converter in conditions that require derating. In some conditions, derating must be done manually. In other conditions, the frequency converter performs a degree of automatic derating when necessary. This is done to ensure proper performance at critical stages where the alternative could be a trip.

4.7.1 Manual Derating

Manual derating must be considered for:

- Air pressure – relevant for installation at altitudes above 1 km
- Motor speed – at continuous operation at low RPM in constant torque applications
- Ambient temperature – relevant for ambient temperatures above 50 °C

4.7.2 Derating for Ambient Temperature

Graphs are presented individually for 60° AVM and SFAVM. 60° AVM only switches 2/3 of the time, whereas SFAVM switches throughout the whole period. The maximum switching frequency is 16 kHz for 60° AVM and 10 kHz for SFAVM. The discrete switching frequencies are presented in *Table 4.20* and *Table 4.21*.

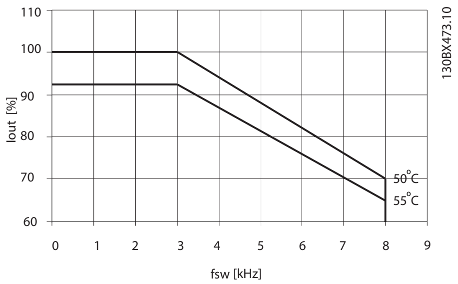
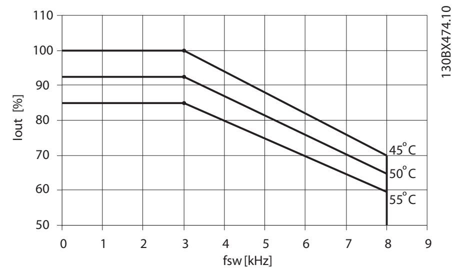
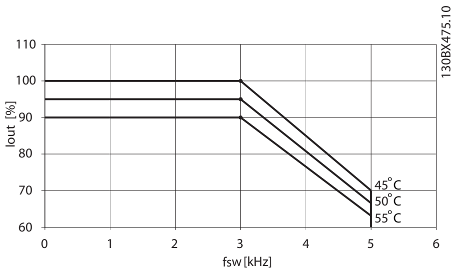
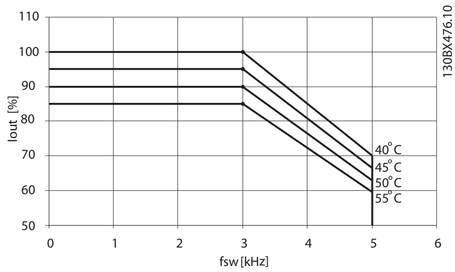
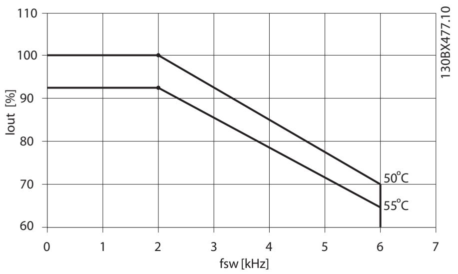
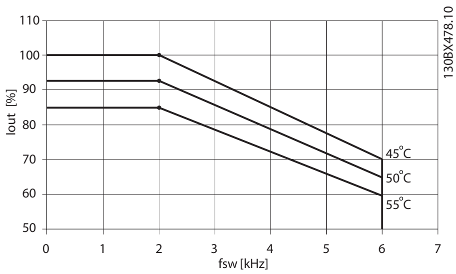
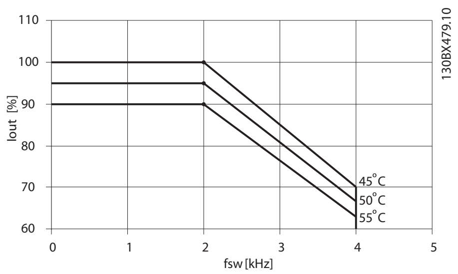
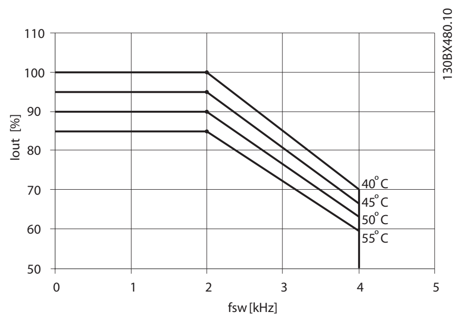
Frame model	Switching pattern	High overload HO, 150%	Normal overload NO, 110%
D-frame N90 to N250 380-500 V	60 AVM		
	SFAVM		
E & F-frame P315 to P1M0 380-500 V	60 AVM		
	SFAVM		

Table 4.20 Derating Tables for Frequency Converters Rated 380-500 V (T5)

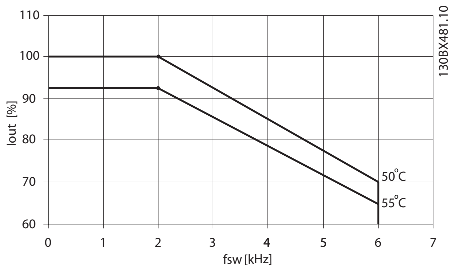
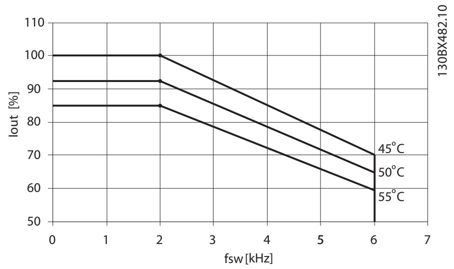
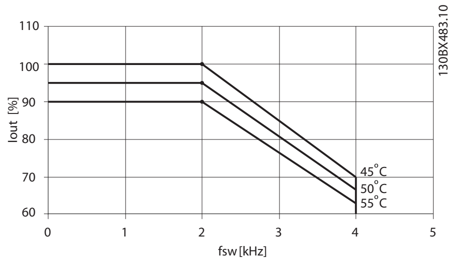
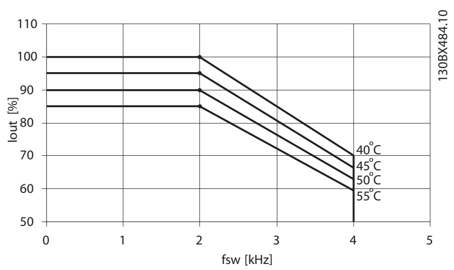
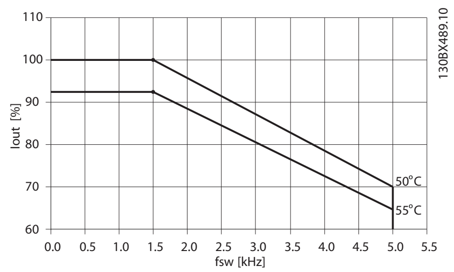
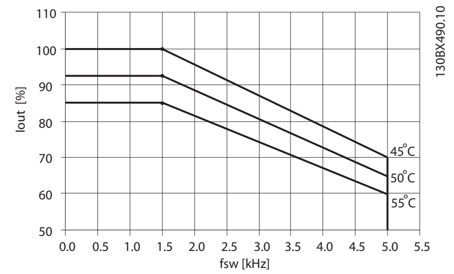
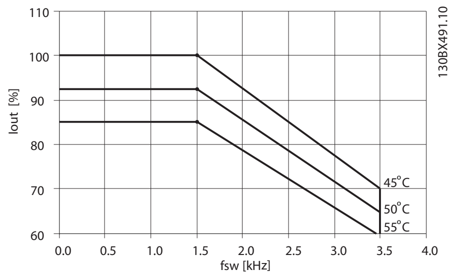
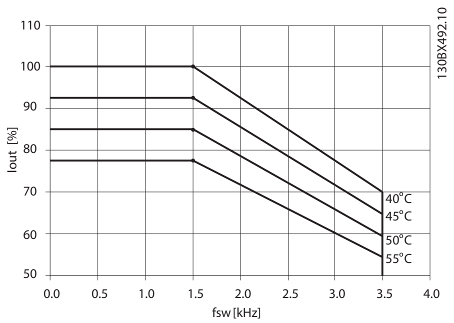
Frame model	Switching pattern	High overload HO, 150%	Normal overload NO, 110%
D-frame N55K to N315 525-690 V	60 AVM		
	SFAVM		
E & F-frame P355 to P1M0 525-690 V	60 AVM		
	SFAVM		

Table 4.21 Derating Tables for Frequency Converters Rated 525-690 V (T7)

4.7.3 Automatic Derating

The frequency converter constantly checks for critical levels:

- Critical high temperature on the control card or heatsink
- High motor load or low motor speed
- High DC link voltage

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

NOTICE

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

5 How to Order

5.1 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 5.1 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 type 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 5.2 Type Code Example for Ordering a Frequency Converter

Not all choices/options are available for each FC 302 variant. To verify if the appropriate version is available, consult the drive configurator on the Internet.

5.1.1 Drive Configurator

It is possible to design an FC 300 frequency converter according to the application requirements by using the ordering number system shown in *Table 5.1* and *Table 5.2*.

For the FC 300 series, 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-302N132T5E20H4BGCXXXSXXXXA0BXCXXXXD0

The meaning of the characters in the string are defined in *Table 5.3*. Additional detail is provided for each frequency converter in the can be located in the pages containing the ordering numbers in this chapter. In the example above, a Profibus DP V1 and a 24 V back-up option is included in the frequency converter.

Use the drive configurator to configure the appropriate drive for the right application. 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 drives with a different language package, contact the local Danfoss sales office.

Description	Pos	Possible choice
Product group	1-6	302: FC 302
Generation Code	7	N
Power rating	8-10	55-315 kW
Phases	11	Three phases (T)
Mains voltage	11-12	T 5: 380-500 V AC T 7: 525-690 V AC
Enclosure	13-15	E20: IP20 (chassis - for installation in an external enclosure) E2S: IP20/chassis - D3h Frame E21: IP21 (NEMA 1) E2D: IP21/Type-1 D1h Frame E54: IP54 (NEMA 12) E5D: IP54/Type-12 D1h Frame E2M: IP21 (NEMA 1) with mains shield E5M: IP54 (NEMA 12) with mains shield C20: IP20 (chassis) + stainless steel back channel C2S: IP20/chassis with stainless steel back channel - D3h Frame H21: IP21 (NEMA 1) + heater H54: IP54 (NEMA 12) + heater
RFI filter	16-17	H2: RFI filter, class A2 (standard) H4: RFI filter class A1[1)]
Brake	18	X: No brake IGBT B: Brake IGBT mounted R: Regeneration terminals S: Brake + regeneration (IP20 only)
Display	19	G: Graphical Local Control Panel LCP N: Numerical Local Control Panel (LCP) X: No Local Control Panel
Coating PCB	20	C: Coated PCB R: Coated PCB + ruggedized
Mains option	21	X: No mains option 3: Mains disconnect and fuse 4: Mains contactor + fuses 7: Fuse A: Fuse and load sharing (IP20 only) D: Load share terminals (IP20 only) E: Mains disconnect + contactor + fuses J: Circuit breaker + fuses
Adaptation	22	X: Standard cable entries
Adaptation	23	X: No adaptation Q: Heat sink access panel
Software release	24-27	Actual software
Software language	28	

Table 5.3 Ordering Type Code for D-frame Frequency Converters

1) Available for all D-frames.

Description	Pos	Possible choice
Product group	1-3	302: FC 302
Drive series	4-6	FC 302
Power rating	8-10	250-560 kW
Phases	11	Three phases (T)
Mains voltage	11-12	T 5: 380-500 V AC T 7: 525-690 V AC
Enclosure	13-15	E00: IP00 (chassis - for installation in an external enclosure) C00: IP00/Chassis w/ stainless steel back channel E21: IP21 (NEMA 1) E54: IP54 (NEMA 12) E2M: IP21 (NEMA 1) with mains shield E5M: IP54 (NEMA 12) with mains shield
RFI filter	16-17	H2: RFI filter, class A2 (standard) H4: RFI filter class A1[1)] B2: 12-pulse drive with RFI filter, class A2 B4: 12-pulse drive with RFI filter, class A1 N2: LHD with RFI filter, class A2 N4: LHD with RFI filter, class A1
Brake	18	B: Brake IGBT mounted X: No brake IGBT R: Regeneration terminals S: Brake + regeneration
Display	19	G: Graphical Local Control Panel LCP N: Numerical Local Control Panel (LCP) X: No Local Control Pane
Coating PCB	20	C: Coated PCB
Mains option	21	X: No mains option 3: Mains disconnect and Fuse 5: Mains disconnect, Fuse and Load sharing 7: Fuse A: Fuse and Load sharing D: Load sharing
Adaptation	22	X: Standard cable entries
Adaptation	23	X: No adaptation
Software release	24-27	Actual software
Software language	28	

Table 5.4 Ordering Type Code for E-frame Frequency Converters

1) Available for 380-480/500 V only.

2) Consult the factory for applications requiring maritime certification.

Description	Pos	Possible choice
Product group	1-6	FC 302
Power rating	8-10	450-1200 kW
Phases	11	Three phases (T)
Mains voltage	11-12	T 5: 380-500 V AC T 7: 525-690 V AC
Enclosure	13-15	C21: IP21/NEMA Type 1 with stainless steel back channel C54: IP54/Type 12 Stainless steel back channel E21: IP 21/ NEMA Type 1 E54: IP 54/ NEMA Type 12 L2X: IP21/NEMA 1 with cabinet light & IEC 230 V power outlet L5X: IP54/NEMA 12 with cabinet light & IEC 230 V power outlet L2A: IP21/NEMA 1 with cabinet light & NAM 115 V power outlet L5A: IP54/NEMA 12 with cabinet light & NAM 115 V power outlet H21: IP21 with space heater and thermostat H54: IP54 with space heater and thermostat R2X: IP21/NEMA1 with space heater, thermostat, light & IEC 230 V outlet R5X: IP54/NEMA12 with space heater, thermostat, light & IEC 230 V outlet R2A: IP21/NEMA1 with space heater, thermostat, light, & NAM 115 V outlet R5A: IP54/NEMA12 with space heater, thermostat, light, & NAM 115 V outlet

Description	Pos	Possible choice
RFI filter	16-17	H2: RFI filter, class A2 (standard) H4: RFI filter, class A1 HE: RCD with Class A2 RFI filter HF: RCD with class A1 RFI filter HG: IRM with Class A2 RFI filter HH: IRM with class A1 RFI filter HJ: NAMUR terminals and class A2 RFI filter HK: NAMUR terminals with class A1 RFI filter HL: RCD with NAMUR terminals and class A2 RFI filter HM: RCD with NAMUR terminals and class A1 RFI filter HN: IRM with NAMUR terminals and class A2 RFI filter HP: IRM with NAMUR terminals and class A1 RFI filter N2: Low Harmonic Drive with RFI filter, class A2 N4: Low Harmonic Drive with RFI filter, class A1 B2: 12-pulse drive with RFI filter, class A2 B4: 12-pulse drive with RFI filter, class A1 BE: 12-pulse + RCD for TN/TT Mains + Class A2 RFI BF: 12-pulse + RCD for TN/TT Mains + Class A1 RFI BG: 12-pulse + IRM for IT Mains + Class A2 RFI BH: 12-pulse + IRM for IT Mains + Class A1 RFI BM: 12-pulse + RCD for TN/TT Mains + NAMUR Terminals + Class A1 RFI*
Brake	18	B: Brake IGBT mounted X: No brake IGBT C: Safe Stop with Pilz Relay D : Safe Stop with Pilz Safety Relay & Brake IGBT R: Regeneration terminals M: IEC Emergency stop pushbutton (with Pilz safety relay) N: IEC Emergency stop pushbutton with brake IGBT and brake terminals P: IEC Emergency stop pushbutton with regeneration terminals
Display	19	G: Graphical Local Control Panel LCP
Coating PCB	20	C: Coated PCB

Description	Pos	Possible choice
Mains option	21	X: No mains option 3: Mains disconnect and Fuse 5: Mains disconnect, Fuse and Load sharing 7: Fuse A: Fuse and Load sharing D: Load sharing E: Mains disconnect, contactor & fuses F: Mains circuit breaker, contactor & fuses G: Mains disconnect, contactor, loadsharing terminals & fuse[2)] H: Mains circuit breaker, contactor, loadsharing terminals & fuses J: Mains circuit breaker & fuses K: Mains circuit breaker, loadsharing terminals & fuses
Power Terminals & Motor Starters	22	X: No option E 30 A, fuse-protected power terminals F: 30 A, fuse-protected power terminals & 2.5-4 A manual motor starter G: 30 A, fuse-protected power terminals & 4-6.3 A manual motor starter H: 30 A, fuse-protected power terminals & 6.3-10 A manual motor starter J: 30 A, fuse-protected power terminals & 10-16 A manual motor starter K: Two 2.5-4 A manual motor starters L: Two 4-6.3 A manual motor starters M: Two 6.3-10 A manual motor starters N: Two 10-16 A manual motor starters
Auxiliary 24V Supply & External Temperature Monitoring	23	X: No option H: 5 A, 24 V power supply (customer use) J: External temperature monitoring G: 5 A, 24 V power supply (customer use) & external temperature monitoring
Software release	24-27	Actual software
	24-28	S023: 316 Stainless Steel Backchannel - high power drives only
Software language	28	
* Requires MCB 112 and MCB 113		

Table 5.5 Ordering Type Code for F-frame Frequency Converters

Description	Pos	Possible choice
A options	29-30	AX: No A option A0: MCA 101 Profibus DP V1 (standard) A4: MCA 104 DeviceNet (standard) A6: MCA 105 CANOpen (standard) AN: MCA 121 Ethernet IP AL: MCA-120 ProfiNet AQ: MCA-122 Modbus TCP AT: MCA 113 Profibus converter VLT3000 AU: MCA-114 Profibus Converter VLT5000
B options	31-32	BX: No option BK: MCB 101 General purpose I/O option BR: MCB 102 Encoder option BU: MCB 103 Resolver option BP: MCB 105 Relay option BZ: MCB 108 Safety PLC Interface B2: MCB 112 PTC Thermistor Card B4: MCB-114 VLT Sensor Input
C0/ E0 options	33-34	CX: No option C4: MCO 305, Programmable Motion Controller BK: MCB 101 General purpose I/O in E0 BZ: MCB 108 Safety PLC Interface in E0
C1 options/ A/B in C Option Adaptor	35	X: No option R: MCB 113 Ext. Relay Card Z: MCA 140 Modbus RTU OEM option E: MCF 106 A/B in C Option Adaptor
C option software/ E1 options	36-37	XX: Standard controller 10: MCO 350 Synchronizing control 11: MCO 351 Positioning control 12: MCO 352 Center winder AN: MCA 121 Ethernet IP in E1 BK: MCB 101General purpose I/O in E1 BZ: MCB 108 Safety PLC Interface in E1
D options	38-39	DX: No option D0: MCB 107 Ext. 24 V DC back-up

Table 5.6 Ordering Options for All Frame Sizes

5.2 Ordering Numbers

5.2.1 Options and Accessories

Type	Description	Ordering no.	
Miscellaneous hardware			
Profibus top entry	Top entry for D and E-frame, enclosure type IP00, IP20, IP21, and IP54	176F1742	
Terminal blocks	Screw terminal blocks for replacing spring loaded terminals 1 pc 10 pin 1 pc 6 pin and 1 pc 3 pin connectors	130B1116	
Ordering numbers for Duct Cooling kits, NEMA 3R kits, Pedestal kits, Input Plate Option kits and Mains Shield can be found in *9.12 High Power Options*			
LCP			
LCP 101	Numerical Local Control Panel (NLCP)	130B1124	
LCP 102	Graphical Local Control Panel (GLCP)	130B1107	
LCP cable	Separate LCP cable, 3 m	175Z0929	
LCP kit, IP21	Panel mounting kit including graphical LCP, fasteners, 3 m cable and gasket	130B1113	
LCP kit, IP21	Panel mounting kit including numerical LCP, fasteners and gasket	130B1114	
LCP kit, IP21	Panel mounting kit for all LCPs including fasteners, 3 m cable and gasket	130B1117	
Options for slot A		**Uncoated**	**Coated**
MCA 101	Profibus option DP V0/V1	130B1100	130B1200
MCA 104	DeviceNet option	130B1102	130B1202
MCA 105	CANopen	130B1103	130B1205
MCA 113	Profibus VLT 3000 protocol converter	130B1245	
Options for slot B			
MCB 101	General purpose Input Output option	130B1125	130B1212
MCB 103	Encoder option	130B1115	130B1203
MCB 103	Resolver option	130B1127	130B1227
MCB 105	Relay option	130B1110	130B1210
MCB 108	Safety PLC interface (DC/DC Converter)	130B1120	130B1220
MCB 112	ATEX PTC Thermistor Card		130B1137
Options for slot C			
MCO 305	Programmable Motion Controller	130B1134	130B1234
MCO 350	Synchronizing controller	130B1152	130B1252
MCO 351	Positioning controller	130B1153	120B1253
MCO 352	Center Winder Controller	130B1165	130B1166
MCB 113	Extended Relay Card	130B1164	130B1264
Option for slot D		**Uncoated**	**Coated**
MCB 107	24 V DC back-up	130B1108	130B1208
External options			
Ethernet IP	Ethernet master	175N2584	

Table 5.7 Options and Accessories

Type	Description	Ordering no.
PC software		
MCT 10	MCT 10 Set-up Software - 1 user	130B1000
MCT 10	MCT 10 Set-up Software - 5 users	130B1001
MCT 10	MCT 10 Set-up Software - 10 users	130B1002
MCT 10	MCT 10 Set-up Software - 25 users	130B1003
MCT 10	MCT 10 Set-up Software - 50 users	130B1004
MCT 10	MCT 10 Set-up Software - 100 users	130B1005
MCT 10	MCT 10 Set-up Software - unlimited users	130B1006

Table 5.8 Software Options

Options can be ordered as factory built-in options. For information on fieldbus and application option compatibility with older software versions, contact the Danfoss supplier.

5.2.2 Brake Resistors

The requirements for brake resistors vary in different applications. Always consult the VLT FC Series Brake Resistor Design Guide before selecting brake resistors. Critical data includes:

- Brake duty cycle, resistance and brake resistor power capability
- Frequency converter minimum resistance

The tables below present typical data for 2 common application types. 10% is typically used for occasional braking of horizontal loads. 40% is typically used in lifting applications where the load must be stopped every time it is lowered.

380-500 V AC				
FC 302 [T5]	**Pm (HO) [kW]**	**Number of brake choppers(1)**	**Rmin**	**Rbr, nom**
N90K	90	1	3.6	3.8
N110	110	1	3.0	3.2
N132	132	1	2.5	2.5
N160	160	1	2.0	2.0
N200	200	1	1.6	1.7
N250	250	1	1.2	1.4
P315	315	1	1.2	1.5
P355	355	1	1.2	1.3
P400	400	1	1.1	1.1
P450	450	2	0.9	1.0
P500	500	2	0.9	0.91
P560	560	2	0.8	0.82
P630	630	2	0.7	0.72
P710	710	3	0.6	0.64
P800	800	3	0.5	0.57

Table 5.9 Brake Chopper Data, 380-500 V

R_{min}=*Minimum brake resistance that can be used with this frequency converter. If the frequency converter includes multiple brake choppers, the resistance value is the sum of all resisters in parallel.*

$R_{br, nom}$=*Nominal resistance required to achieve 150% braking torque.*

R_{rec}=*Resistance value of the recommended Danfoss brake resistor.*

1) Larger frequency converters include multiple inverter modules with a brake chopper in each inverter. Equal resistors should be connected to each brake chopper.

5

525-690 V AC				
FC 302 [T7]	**Pm (HO) [kW]**	**Number of brake choppers(1)**	**Rmin**	**Rbr, nom**
N55K	55	1	13.5	11.0
N75K	75	1	8.8	9.4
N90K	90	1	8.2	7.5
N110	110	1	6.6	6.2
N132	132	1	4.2	5.2
N160	160	1	4.2	4.2
N200	200	1	3.4	3.3
N250	250	1	2.3	2.8
N315	315	1	2.3	2.4
P355	355	1	2.3	2.4
P400	400	1	2.1	2.1
P500	500	1	2.0	2.0
P560	560	1	2.0	2.0
P630	630	2	1.3	1.3
P710	710	2	1.1	1.2
P800	800	2	1.1	1.1
P900	900	3	1.0	1.0
P1M0	1000	3	0.8	0.84
P1M2	1200	3	0.7	0.70
P1M4	1400	4	0.55	0.60

Table 5.10 Brake Chopper Data 525-690 V

R_{min}=Minimum brake resistance that can be used with this frequency converter . If the frequency converter includes multiple brake choppers, the resistance value is the sum of all resisters in parallel.
$R_{br, nom}$=Nominal resistance required to achieve 150% braking torque.
R_{rec}=Resistance value of the recommended Danfoss brake resistor.

1) Larger frequency converters include multiple inverter modules with a brake chopper in each inverter. Equal resistors should be connected to each brake chopper.

5.2.3 Advanced Harmonic Filters

Harmonic filters are used to reduce mains harmonics:

- AHF 010: 10% current distortion
- AHF 005: 5% current distortion

For detailed information on advanced harmonic filters, see the *Advanced Harmonic Filters Design Guide*.

Code number AHF005 IP00 IP20	Code number AHF010 IP00 IP20	Filter current rating	Typical motor	VLT model and current ratings		Losses		Acoustic noise	Frame size	
						AHF005	AHF010			
		[A]	[kW]	[kW]	[A]	[W]	[W]	[dBA]	AHF005	AHF010
130B1446 130B1251	130B1295 130B1214	204	110	N110	204	1080	742	<75	X6	X6
130B1447 130B1258	130B1369 130B1215	251	132	N132	251	1195	864	<75	X7	X7
130B1448 130B1259	130B1370 130B1216	304	160	N160	304	1288	905	<75	X7	X7
130B3153 130B3152	130B3151 130B3136	325	Paralleling for 355 kW			1406	952	<75	X8	X7
130B1449 130B1260	130B1389 130B1217	381	200	N200	381	1510	1175	<77	X8	X7
130B1469 130B1261	130B1391 130B1228	480	250	N250	472	1852	1542	<77	X8	X8
2x130B1448 2x130B1259	2x130B1370 2x130B1216	608	315	N315	590	2576	1810	<80		

Table 5.11 Advanced Harmonic Filters 380-415 V, 50 Hz, D-frame

Code number AHF005 IP00 IP20	Code number AHF010 IP00 IP20	Filter current rating	Typical motor	VLT model and current ratings		Losses		Acoustic noise	Frame size	
						AHF005	AHF010			
		[A]	[kW]	[kW]	[A]	[W]	[W]	[dBA]	AHF005	AHF010
2x130B3153 2x130B3152	2x130B3151 2x130B3136	650	355	P355	647	2812	1904	<80		
130B1448+130B1449 130B1259+130B1260	130B1370+130B1389 130B1216+130B1217	685	400	P400	684	2798	2080	<80		
2x130B1449 2x130B1260	2x130B1389 2x130B1217	762	450	P450	779	3020	2350	<80		
130B1449+130B1469 130B1260+130B1261	130B1389+130B1391 130B1217+130B1228	861	500	P500	857	3362	2717	<80		
2x130B1469 2x130B1261	2x130B1391 2x130B1228	960	560	P560	964	3704	3084	<80		
3x130B1449 3x130B1260	3x130B1389 3x130B1217	1140	630	P630	1090	4530	3525	<80		
2x130B1449+130B1469 2x130B1260+130B1261	2x130B1389+130B1391 2x130B1217+130B1228	1240	710	P710	1227	4872	3892	<80		
3x130B1469 3x1301261	3x130B1391 3x130B1228	1440	800	P800	1422	5556	4626	<80		
2x130B1449+2x130B1469 2x130B1260+2x130B1261	2x130B1389+2x130B1391 2x130B1217+2x130B1228	1720	1000	P1000	1675	6724	5434	<80		

Table 5.12 Advanced Harmonic Filters 380-415 V, 50 Hz, E- and F-frames

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Code number AHF005 IP00 IP20	Code number AHF010 IP00 IP20	Filter current rating	Typical motor	VLT model and current ratings		Losses		Acoustic noise	Frame size	
						AHF005	AHF010			
		[A]	[kW]	[kW]	[A]	[W]	[W]	[dBA]	AHF005	AHF010
130B3131 130B2869	130B3090 130B2500	204	110	N110	204	1080	743	<75	X6	X6
130B3132 130B2870	130B3091 130B2700	251	132	N132	251	1194	864	<75	X7	X7
130B3133 130B2871	130B3092 130B2819	304	160	N160	304	1288	905	<75	X8	X7
130B3157 130B3156	130B3155 130B3154	325	Paralleling for 355 kW			1406	952	<75	X8	X7
130B3134 130B2872	130B3093 130B2855	381	200	N200	381	1510	1175	<77	X8	X7
130B3135 130B2873	130B3094 130B2856	480	250	N250	472	1850	1542	<77	X8	X8
2x130B3133 2x130B2871	2x130B3092 2x130B2819	608	315	N315	590	2576	1810	<80		

Table 5.13 Advanced Harmonic Filters, 380-415 V, 60 Hz, D-frame

Code number AHF005 IP00 IP20	Code number AHF010 IP00 IP20	Filter current rating	Typical motor	VLT model/ current ratings		Losses		Acoustic noise	Frame size	
						AHF005	AHF010			
		[A]	[kW]	[kW]	[A]	[W]	[W]	[dBA]	AHF005	AHF010
2x130B3157 2x130B3156	2x130B3155 2x130B3154	650	315	P355	647	2812	1904	<80		
130B3133+130B3134 130B2871+130B2872	130B3092+130B3093 130B2819+130B2855	685	355	P400	684	2798	2080	<80		
2x130B3134 2x130B2872	2x130B3093 2x130B2855	762	400	P450	779	3020	2350	<80		
130B3134+130B3135 130B2872+130B3135	130B3093+130B3094 130B2855+130B2856	861	450	P500	857	3362	2717	<80		
2x130B3135 2x130B2873	2x130B3094 2x130B2856	960	500	P560	964	3704	3084	<80		
3x130B3134 3x130B2872	3x130B3093 3x130B2855	1140	560	P630	1090	4530	3525	<80		
2x130B3134+130B3135 2x130B2872+130B2873	2x130B3093+130B3094 2x130B2855+130B2856	1240	630	P710	1227	4872	3892	<80		
3x130B3135 3x130B2873	3x130B3094 3x130B2856	1440	710	P800	1422	5556	4626	<80		
2x130B3134+2x130B3135 2x130B2872+2x130B2873	2x130B3093+2x130B3094 2x130B2855+2x130B2856	1722	800	P1M0	1675	6724	5434	<80		

Table 5.14 Advanced Harmonic Filters, 380-415 V, 60 Hz, E- and F-frames

Code number AHF005 IP00 IP20	Code number AHF010 IP00 IP20	Filter current rating	Typical motor	VLT model and current ratings		Losses		Acoustic noise	Frame size	
						AHF005	AHF010			
		[A]	[HP]	[HP]	[A]	[W]	[W]	[dBA]	AHF005	AHF010
130B1799 130B1764	130B1782 130B1496	183	150	N110	183	1080	743	<75	X6	X6
130B1900 130B1765	130B1783 130B1497	231	200	N132	231	1194	864	<75	X7	X7
130B2200 130B1766	130B1784 130B1498	291	250	N160	291	1288	905	<75	X8	X7
130B2257 130B1768	130B1785 130B1499	355	300	N200	348	1406	952	<75	X8	X7
130B3168 130B3167	130B3166 130B3165	380	Used for paralleling at 355 kW			1510	1175	<77	X8	X7
130B2259 130B1769	130B1786 130B1751	436	350	N250	436	1852	1542	<77	X8	X8
130B1900+ 130B2200 130B1765+ 130B1766	130B1783+ 130B1784 130B1497+ 130B1498	522	450	N315	531	2482	1769	<80		

Table 5.15 Advanced Harmonic Filters 440-480 V, 60 Hz, D-frame

Code number AHF005 IP00/IP20	Code number AHF010 IP00/IP20	Filter current rating	Typical motor	VLT model/ current ratings		Losses		Acoustic noise	Frame size	
						AHF005	AHF010			
		[A]	[HP]	[kW]	[A]	[W]	[W]	[dBA]	AHF005	AHF010
2x130B2200 2x130B1766	2x130B1784 2x130B1498	582	500	P355	580	2576	1810	<80		
130B2200+130B3166 130B1766+130B3167	130B1784+130B3166 130B1498+130B3165	671	550	P400	667	2798	2080	<80		
2x130B2257 2x130B1768	2x130B1785 2x130B1499	710	600	P450	711	2812	1904	<80		
2x130B3168 2x130B3167	2x130B3166 2x130B3165	760	650	P500	759	3020	2350	<80		
2x130B2259 2x130B1769	2x130B1786 2x130B1751	872	750	P560	867	3704	3084	<80		
3x130B2257 3x130B1768	3x130B1785 3x130B1499	1065	900	P630	1022	4218	2856	<80		
3x130B3168 3x130B3167	3x130B3166 3x130B3165	1140	1000	P710	1129	4530	3525	<80		
3x130B2259 3x130B1769	3x130B1786 3x130B1751	1308	1200	P800	1344	5556	4626	<80		
2x130B2257+2x130B2259 2x130B1768+2x130B1768	2x130B17852x130B1785 +2x130B1786 2x130B1499+2x130B1751	1582	1350	P1M0	1490	6516	5988	<80		

Table 5.16 Advanced Harmonic Filters, 440-480 V, 60 Hz, E- and F-frames

Code number AHF005 IP00/ IP20	Code number AHF010 IP00/ IP20	Filter current rating 50 Hz	Typical motor	VLT model and current ratings		Losses AHF005	Losses AHF010	Acoustic noise	Frame size AHF005	Frame size AHF010
		[A]	[HP]	[kW]	[A]	[W]	[W]	[dBa]	AHF005	AHF010
130B5269 130B5254	130B5237 130B5220	87	75	N75K	85	962	692	<72	X6	X6
130B5270 130B5255	130B5238 130B5221	109	100	N90K	106	1080	743	<72	X6	X6
130B5271 130B5256	130B5239 130B5222	128	125	N110	124	1194	864	<72	X6	X6
130B5272 130B5257	130B5240 130B5223	155	150	N132	151	1288	905	<72	X7	X7
130B5273 130B5258	130B5241 130B5224	197	200	N160	189	1406	952	<72	X7	X7
130B5274 130B5259	130B5242 130B5225	240	250	N200	234	1510	1175	<75	X8	X8
130B5275 130B5260	130B5243 130B5226	296	300	N250	286	1852	1288	<75	X8	X8
2x130B5273 2x130B5258	130B5244 130B5227	366	350	N315	339	2812	1542	<75		X8
2x130B5273 2x130B5258	130B5245 130B5228	395	400	N400	395	2812	1852	<75		X8

Table 5.17 Advanced Harmonic Filters, 600 V, 60 Hz

Code number AHF005 IP00/ IP20	Code number AHF010 IP00/ IP20	Filter current rating 50 Hz	Typical motor	VLT model and current ratings		Losses AHF005	Losses AHF010	Acoustic noise	Frame size AHF005	Frame size AHF010
		[A]	[HP]	[kW]	[A]	[W]	[W]	[dBa]	AHF005	AHF010
2x130B5274 2x130B5259	2x130B5242 2x130B5225	480	500	P500	482	3020	2350			
2x130B5275 2x130B5260	2x130B5243 2x130B5226	592	600	P560	549	3704	2576			
3x130B5274 3x130B5259	2x130B5244 2x130B5227	732	650	P630	613	4530	3084			
3x130B5274 3x130B5259	2x130B5244 2x130B5227	732	750	P710	711	4530	3084			
3x130B5275 3x130B5260	3x130B5243 3x139B5226	888	950	P800	828	5556	3864			
4x130B5274 4x130B5259	3x130B5244 3x130B5227	960	1050	P900	920	6040	4626			
4x130B5275 4x130B5260	3x130B5244 3x130B5227	1098	1150	P1M0	1032	7408	4626			
	4x130B5244 4x130B5227	1580	1350	P1M2	1227		6168			

Table 5.18 Advanced Harmonic Filters, 600 V, 60 Hz

Code number AHF005 IP00/ IP20	Code number AHF010 IP00/ IP20	Filter current rating	VLT model and current ratings						Losses		Acoustic noise	Frame size	
		50 Hz	Typical motor size	500-550 V		Typical motor size	551-690 V		AHF005	AHF010			
		[A]	[kW]	[kW]	[A]	[kW]	[kW]	[A]	[W]	[W]	[dBa]	AHF005	AHF010
130B5024	130B5325	77	45	N55K	71	75	N75K	76	841	488	<72	X6	X6
130B5169	130B5287												
130B5025	130B5326	87	55	N75K	89				962	692	<72	X6	X6
130B5170	130B5288												
130B5026	130B5327	109	75	N90K	110	90	N90K	104	1080	743	<72	X6	X6
130B5172	130B5289												
130B5028	130B5328	128	90	N110	130	110	N110	126	1194	864	<72	X6	X6
130B5195	130B5290												
130B5029	130B5329	155	110	N132	158	132	N132	150	1288	905	<72	X7	X7
130B5196	130B5291												
130B5042	130B5330	197	132	N160	198	160	N160	186	1406	952	<72	X7	X7
130B5197	130B5292												
130B5066	130B5331	240	160	N200	245	200	N200	234	1510	1175	<75	X8	X7
130B5198	130B5293												
130B5076	130B5332	296	200	N250	299	250	N250	280	1852	1288	<75	X8	X8
130B5199	130B5294												
2x130B5042	130B5333	366	250	N315	355	315	N315	333	2812	1542			X8
2x130B5197	130B5295												
2x130B5042	130B5334	395	315	N355	381	400			2812	1852			X8
130B5042 +130B5066	130B5330 +130B5331	437	355	N400	413	500	N400	395	2916	2127			
130B5197 +130B5198	130B5292 +130B5293												

Table 5.19 Advanced Harmonic Filters, 500-690 V, 50 Hz

Code number AHF005 IP00/ IP20	Code number AHF010 IP00/ IP20	Filter current rating	VLT model and current ratings						Losses		Acoustic noise	Frame size	
		50 Hz	Typical motor size	500-550 V		Typical motor size	551-690 V		AHF005	AHF010			
		[A]	[kW]	[kW]	[A]	[kW]	[kW]	[A]	[W]	[W]	[dBa]	AHF005	AHF010
130B5066 +130B5076	130B5331 +130B5332	536	400	P450	504	560	P500	482	3362	2463			
130B5198 +130B5199	130B5292 +130B5294												
2 x130B5076	2x130B5332	592	450	P500	574	630	P560	549	3704	2576			
2 x130B5199	2x130B5294												
130B5076 +2x130B5042	130B5332 +130B5333	662	500	P560	642	710	P630	613	4664	2830			
130B5199 +2x130B5197	130B5294 +130B5295												
4x130B5042	2x130B5333	732	560	P630	743	800	P710	711	5624	3084			
4x130B5197	2x130B5295												
3x130B5076	3x130B5332	888	670	P710	866	900	P800	828	5556	3864			
3x130B5199	3x130B5294												
2x130B5076 +2x130B5042	2x130B5332 +130B5333	958	750	P800	962	1000	P900	920	6516	4118			
2x130B5199 +2x130B5197	2x130B5294 +130B5295												
6x130B5042	3x130B5333	1098	850	P1M0	1079		P1M0	1032	8436	4626			
6x130B5197	3x130B5295												

Table 5.20 Advanced Harmonic Filters, 500-690 V, 50 Hz

5.2.4 Sine-Wave Filter Modules, 380-690 V AC

400 V, 50 Hz		460 V, 60 Hz		500 V, 50 Hz		Frame size	Filter ordering number	
[kW]	[A]	[HP]	[A]	[kW]	[A]		IP00	IP23
90	177	125	160	110	160	D1h/D3h/D5h/D6h	130B3182	130B3183
110	212	150	190	132	190	D1h/D3h/D5h/D6h	130B3184	130B3185
132	260	200	240	160	240	D1h/D3h/D5h/D6h, D13		
160	315	250	302	200	302	D2h/D4h, D7h/D8h, D13	130B3186	130B3187
200	395	300	361	250	361	D2h/D4h,D7h/D8h, D13		
250	480	350	443	315	443	D2h/D4h, D7h, D8h, D13, E9, F8/F9	130B3188	130B3189
315	600	450	540	355	540	E1/E2, E9, F8/F9	130B3191	130B3192
355	658	500	590	400	590	E1/E2, E9, F8/F9		
400	745	600	678	500	678	E1/E2, E9, F8/F9	130B3193	130B3194
450	800	600	730	530	730	E1/E2, E9, F8/F9		
450	800	600	730	530	730	F1/F3, F10/F11, F18	2X130B3186	2X130B3187
500	880	650	780	560	780	F1/F3, F10/F11, F18	2X130B3188	2X130B3189
560	990	750	890	630	890	F1/F3, F10/F11, F18		
630	1120	900	1050	710	1050	F1/F3, F10/F11, F18	2X130B3191	2X130B3192
710	1260	1000	1160	800	1160	F1/F3, F10/F11, F18		
710	1260	1000	1160	800	1160	F2/F4, F12/F13	3X130B3188	3X130B3189
800	1460					F2/F4, F12/F13		
		1200	1380	1000	1380	F2/F4, F12/F13	3X130B3191	3X130B3192
1000	1720	1350	1530	1100	1530	F2/F4, F12/F13		

Table 5.21 Sine Wave Filter Modules, 380-500 V

5

525 V, 50 Hz		575 V, 60 Hz		690 V, 50 Hz		Frame size	Filter ordering number	
[kW]	[A]	[HP]	[A]	[kW]	[A]		IP00	IP23
45	76	60	73	55	73	D1h/D3h/D5h/D6h	130B4116	130B4117
55	90	75	86	75	86	D1h/D3h/D5h/D6h	130B4118	130B4119
75	113	100	108	90	108	D1h/D3h/D5h/D6h	130B4118	130B4119
90	137	125	131	110	131	D1h/D3h/D5h/D6h	130B4121	130B4124
110	162	150	155	132	155	D1h/D3h/D5h/D6h		
132	201	200	192	160	192	D2h/D4h, D7h/D8h	130B4125	130B4126
160	253	250	242	200	242	D2h/D4h, D7h/D8h		
200	303	300	290	250	290	D2h/D4h, D7h/D8h	130B4129	130B4151
250	360	350	344	315	344	D2h/D4h, D7h/D8h, F8/F9		
		350	344	355	380	F8/F9	130B4152	130B4153
315	429	400	400	400	410	F8/F9		
		400	410			E1/E2, F8/F9	130B4154	130B4155
355	470	450	450	450	450	E1/E2, F8/F9		
400	523	500	500	500	500	E1/E2, F8/F9		
450	596	600	570	560	570	E1/E2, F8/F9	130B4156	130B4157
500	630	650	630	630	630	E1/E2, F8/F9		
500	659			630	630	F1/F3, F10/F11	2X130B4129	2X130B4151
		650	630			F1/F3, F10/F11	2X130B4152	2X130B4153
560	763	750	730	710	730	F1/F3, F10/F11		
670	889	950	850	800	850	F1/F3, F10/F11	2X130B4154	2X130B4155
750	988	1050	945	900	945	F1/F3, F10/F11		
750	988	1050	945	900	945	F2/F4, F12/F13	3X130B4152	3X130B4153
850	1108	1150	1060	1000	1060	F2/F4, F12/F13		
1000	1317	1350	1260	1200	1260	F2/F4, F12/F13	3X130B4154	3X130B4155

Table 5.22 Sine Wave Filter Modules 525-690 V

NOTICE

When using sine-wave filters, ensure that the switching frequency complies with filter specifications in *14-01 Switching Frequency*.

See also *Advanced Harmonic Filters Design Guide*.

5.2.5 dU/dt Filters

Typical application ratings						Frame size	Filter ordering number	
380-500 V [T5]								
400 V, 50 Hz		460 V, 60 Hz		500 V, 50 Hz				
kW	A	HP	A	kW	A		IP00	IP23
90	177	125	160	110	160	D1h/D3h/D5h/D6h	130B2847	130B2848
110	212	150	190	132	190	D1h/D3h/D5h/D6h		
132	260	200	240	160	240	D1h/D3h, D2h/D4h, D13		
160	315	250	302	200	302	D2h/D4h, D7h/D8h, D13		
200	395	300	361	250	361	D2h/D4h, D7h/D8h, D13	130B2849	130B3850
250	480	350	443	315	443	D2h/D4h, D7h/D8h, D11 E1/E2, E9, F8/F9		
315	600	450	540	355	540	E1/E2, E9, F8/F9	130B2851	130B2852
355	658	500	590	400	590	E1/E2, E9, F8/F9		
						E1/E2, F8/F9		
						E1/E2, F8/F9	130B2853	130B2854
400	745	600	678	500	678	E1/E2, E9, F8/F9		
450	800	600	730	530	730	E1/E2, E9, F8/F9		
						E1/E2, F8/F9		
450	800	600	730	530	730	F1/F3, F10/F11, F18	2x130B28492	2x130B28502
500	880	650	780	560	780	F1/F3, F10/F11, F18		
						F1/F3, F10/F11	2x130B2851	2x130B2852
560	990	750	890	630	890	F1/F3, F10/F11, F18		
630	1120	900	1050	710	1050	F1/F3, F10/F11, F18		
710	1260	1000	1160	800	1160	F1/F3, F10/F11, F18	2x130B2851	2x130B2852
						F1/F3, F10/F11	2x130B2853	2x130B2854
710	1260	1000	1160	800	1160	F2/F4, F12/F13	3x130B2849	3x130B2850
						F2/F4, F12/F13	3x130B2851	3x130B2852
800	1460	1200	1380	1000	1380	F2/F4, F12/F13		
1000	1720	1350	1530	1100	1530	F2/F4, F12/F13		
						F2/F4, F12/F13	3x130B2853	3x130B2854

Table 5.23 dU/dt Filter Ordering Numbers for 380-500 V

Typical application ratings						Frame size	Filter ordering number	
525-690 V [T7]								
525 V, 50 Hz		575 V, 60 Hz		690 V, 50 Hz				
kW	A	HP	A	kW	A		IP00	IP23
45	76	60	73	55	73	D1h/D3h, D5h/D6h	130B2841	130B2842 (IP20)
55	90	75	86	75	86	D1h/D3h, D5h/D6h		
75	113	100	108	90	108	D1h/D3h, D5h/D6h	130B2844	130B2845 (IP20)
90	137	125	131			D1h/D3h, D5h/D6h		
110	162	150	155	110	131	D1h/D3h, D5h/D6h	130B2847	130B2848
132	201	200	192	132	155	D1h/D3h, D2h/D4h, D13		
		250	242	160	192	D2h/D4h, D7h/D8h, D13		
160	253			200	242	D2h/D4h, D7h/D8h, D13	130B2849	130B3850
200	303	300	290	250	290	D2h/D4h, D7h/D8h, D11 E9, F8/F9		
250	360	350	344	315	344	D2h/D4h, D7h/D8h, E9, F8/F9	130B2851	130B2852
300	395	400	410	355	380	D2h/D4h, D7h/D8h, E9, F8/F9		
315	429	450	450	400	410	D2h/D4h, D7h/D8h, E1/E2, F8/F9		
				450	450	E1/E2, F8/F9	130B2853	130B2854
400	523	500	500	500	500	E1/E2, E9, F8/F9		
450	596	600	570	560	570	E1/E2, E9, F8/F9		
500	630	650	630	630	630	E1/E2, F8/F9		
						F1/F3, F10/F11, F18	2x130B28492	2x130B28502
500	659	650	630			F1/F3, F10/F11, F18		
				630[2]	630[2]	F1/F3, F10/F11	2x130B2851	2x130B2852
560	763	750	730	710	730	F1/F3, F10/F11, F18		
670	889	950	850	800	850	F1/F3, F10/F11, F18		
750	988	1050	945			F1/F3, F10/F11, F18	2x130B2851	2x130B2852
				900	945	F1/F3, F10/F11	2x130B2853	2x130B2854
750	988	1050	945			F2/F4, F12/F13	3x130B2849	3x130B2850
				900	945	F2/F4, F12/F13	3x130B2851	3x130B2852
850	1108	1150	1060	1000	1060	F2/F4, F12/F13		
1000	1317	1350	1260	1200	1260	F2/F4, F12/F13		
1100	1479	1550	1415	1400	1415	F2/F4, F12/F13	3x130B2853	3x130B2854

Table 5.24 dU/dt Filter Ordering Numbers for 525-690 V

NOTICE

See also *Advanced Harmonic Filters Design Guide*.

6 Mechanical Installation

6.1 Pre-installation

NOTICE

It is important to plan the installation of the frequency converter. Neglecting this may result in extra work during and after installation.

Select the best possible operation site by considering the following criteria:

- Ambient operating temperature
- Installation method
- How to cool the unit
- Position of the frequency converter
- Cable routing
- Ensure the power source supplies the correct voltage and necessary current
- Ensure that the motor current rating is within the maximum current from the frequency converter
- If the frequency converter is without built-in fuses, ensure that the external fuses are rated correctly

For more detail, see the following pages in this chapter.

6.1.1 Receiving the Frequency Converter

When receiving the frequency converter, make sure that the packaging is intact, and be aware of any potential damage to the unit during transport. If damage has occurred, contact the shipping company immediately to claim the damage.

Also, look at the nameplate as shown in *Illustration 6.1* and verify the order matches the information found on the nameplate.

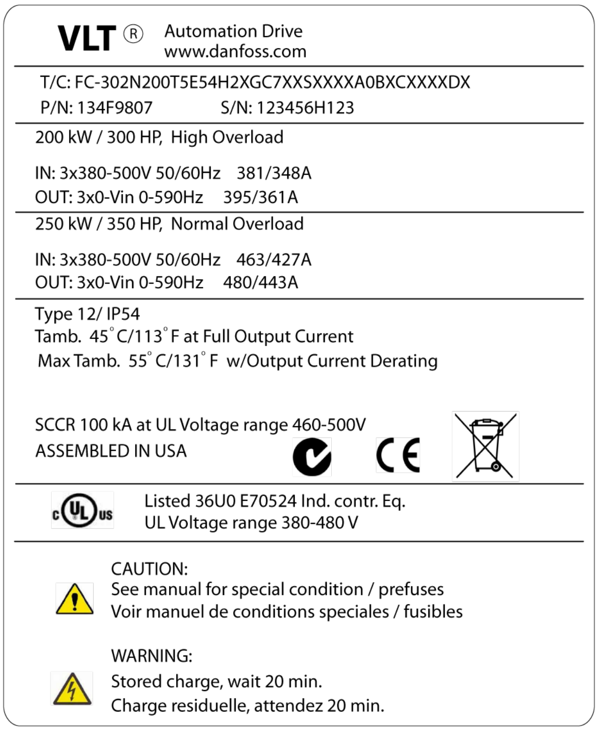


Illustration 6.1 Nameplate Label

6.1.2 Transportation and Unpacking

Before unpacking the frequency converter, position it as close as possible to the final installation site. Remove the box and leave the frequency converter on the pallet until ready for installation.

6.1.3 Lifting

Lift the frequency converter using the dedicated lifting eyes. For all E2 (IP00) enclosures, use a bar to avoid bending the lifting holes of the frequency converter.

The following illustrations demonstrate the recommended lifting methods for the different frame sizes. In addition to *Illustration 6.4*, *Illustration 6.5*, and *Illustration 6.6*, a spreader bar is an acceptable way to lift the F-frame.

WARNING

The lifting bar must be able to handle the weight of the frequency converter. See *6.1.4 Mechanical Dimensions* for the weight of each frame size. Maximum diameter for the bar is 2.5 cm (1 inch). The angle from the top of the drive to the lifting cable should be 60° or greater.

6

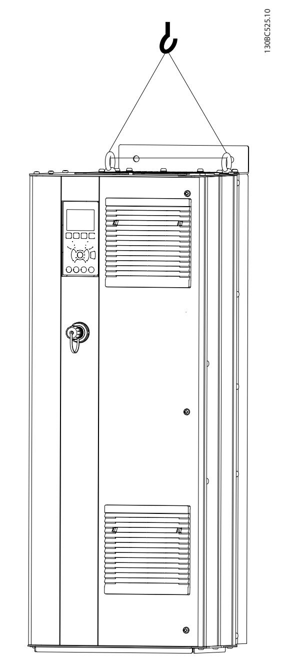


Illustration 6.2 Recommended Lifting Method, D-frame Size

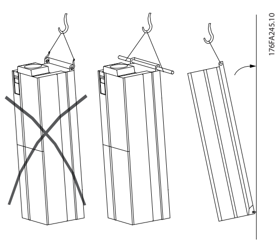


Illustration 6.3 Recommended Lifting Method, E-frame Size

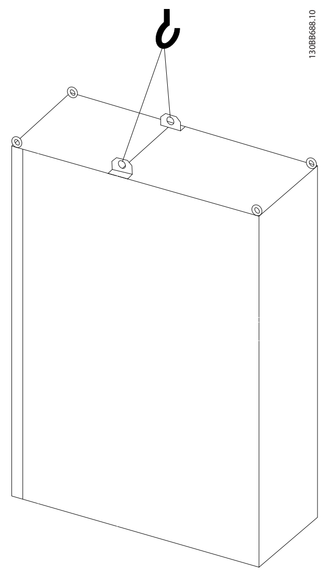


Illustration 6.4 Recommended Lifting Method, Frame Sizes F1, F2, F9 and F10

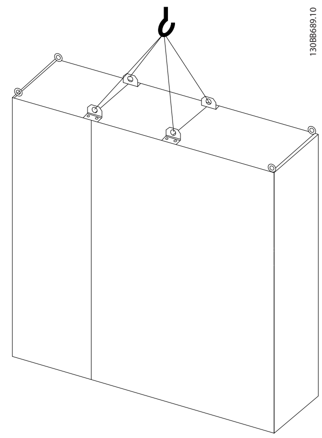


Illustration 6.5 Recommended Lifting Method, Frame Sizes F3, F4, F11, F12 and F13

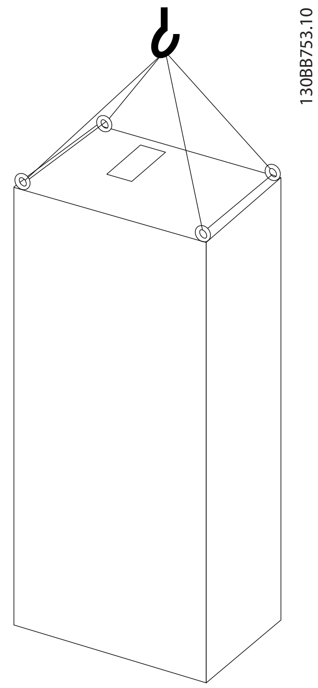


Illustration 6.6 Recommended Lifting Method, Frame Size F8

NOTICE

The pedestal is packaged separately and included in the shipment. Mount the frequency converter on the pedestal in its final location. The pedestal allows proper airflow and cooling to the frequency converter. See *6.2.13 Pedestal Installation of F-frames*.

6.1.4 Mechanical Dimensions

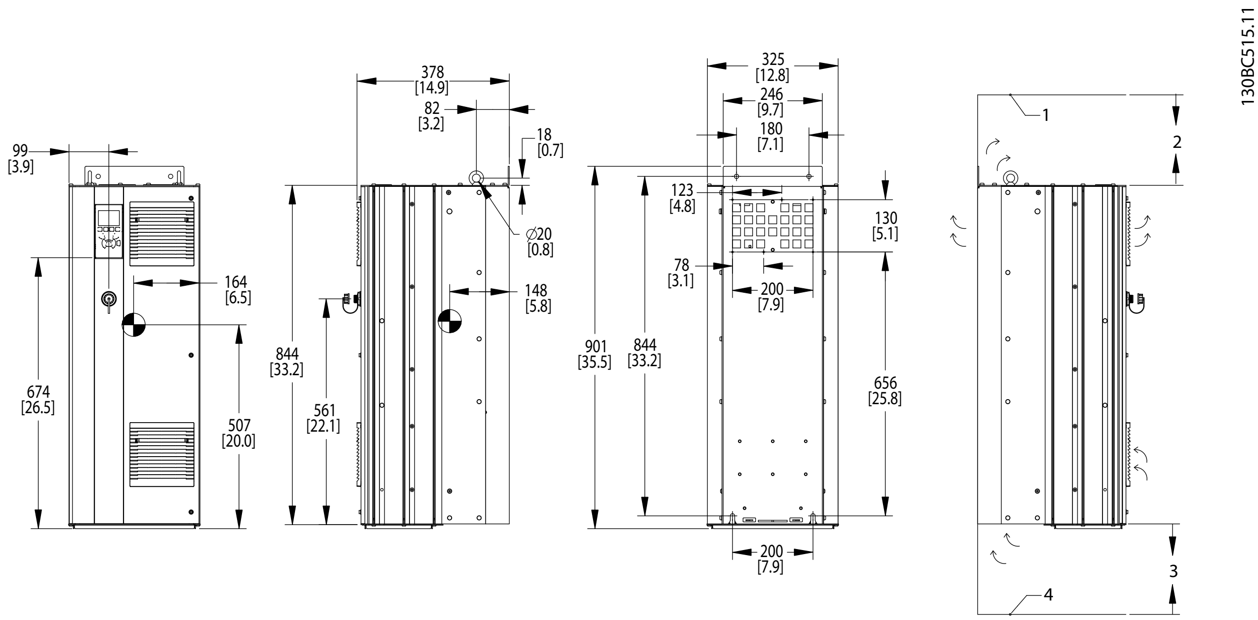


Illustration 6.7 Mechanical Dimensions, D1h

1	Ceiling
2	Air space outlet minimum 225 mm [8.9 in]
3	Air space inlet minimum 225 mm [8.9 in]
4	Floor

Table 6.1 Legend to *Illustration 6.7*

NOTICE

If using a kit to direct the airflow from the heat sink to the outside vent on the back of the frequency converter, the required ceiling clearance is 100 mm.

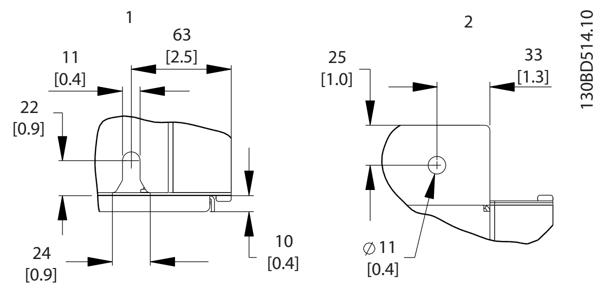


Illustration 6.8 Detail Dimensions, D1h

1	Bottom mounting slot detail
2	Top mounting hole detail

Table 6.2 Legend to *Illustration 6.8*

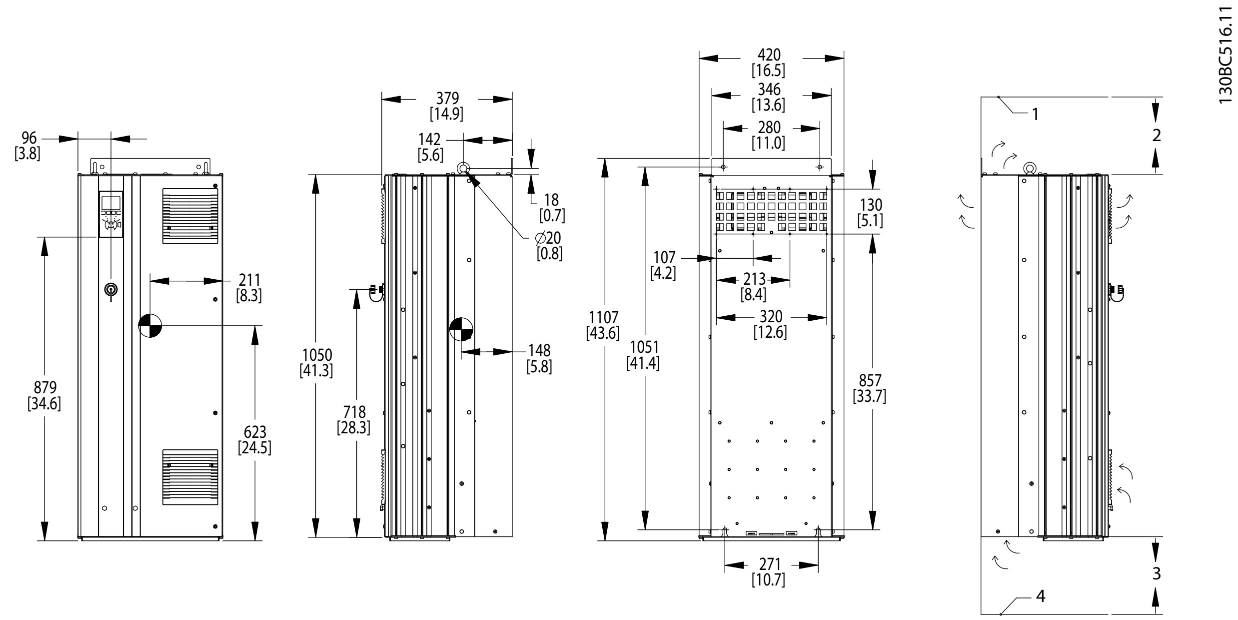


Illustration 6.9 Mechanical Dimensions, D2h

1	Ceiling
2	Air space outlet minimum 225 mm [8.9 in]
3	Air space inlet minimum 225 mm [8.9 in]
4	Floor

Table 6.3 Legend to *Illustration 6.9*

NOTICE

If using a kit to direct the airflow from the heat sink to the outside vent on the back of the frequency converter, the required ceiling clearance is 100 mm.

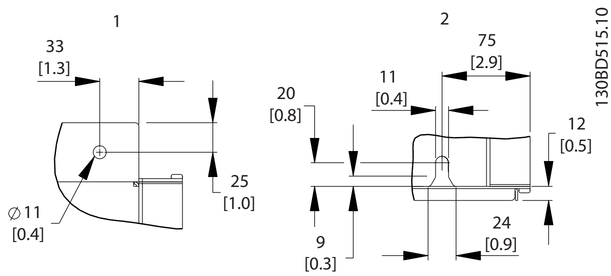


Illustration 6.10 Detail Dimensions, D2h

1	Top mounting hole detail
2	Bottom mounting slot detail

Table 6.4 Legend to *Illustration 6.10*

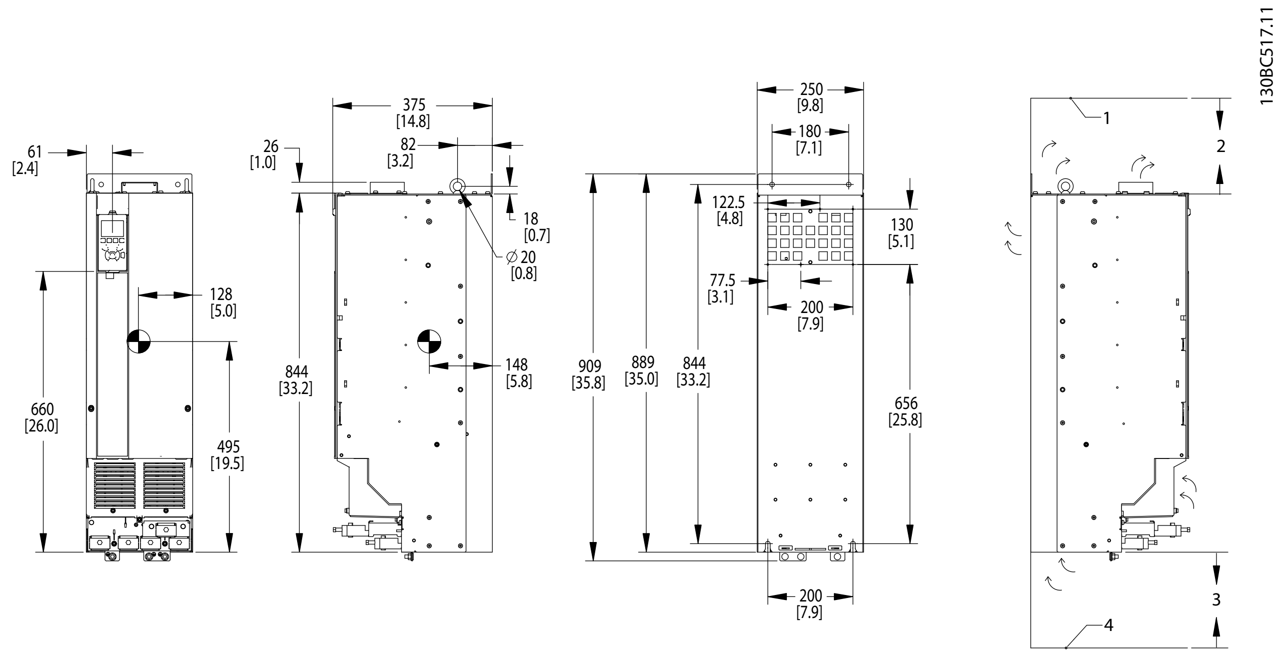


Illustration 6.11 Mechanical Dimensions, D3h

1	Ceiling
2	Air space outlet minimum 225 mm [8.9 in]
3	Air space inlet minimum 225 mm [8.9 in]
4	Floor

Table 6.5 Legend to *Illustration 6.11*

NOTICE

If using a kit to direct the airflow from the heat sink to the outside vent on the back of the frequency converter, the required ceiling clearance is 100 mm.

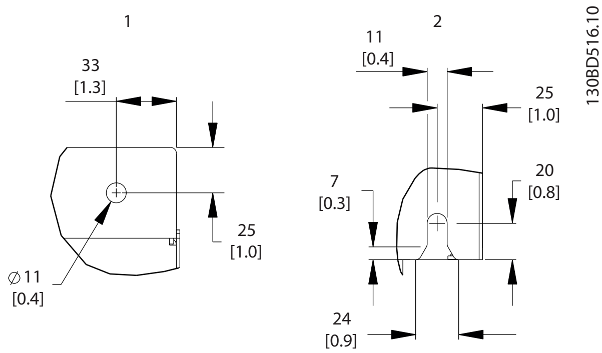


Illustration 6.12 Detail Dimensions, D3h

1	Top mounting hole detail
2	Bottom mounting slot detail

Table 6.6

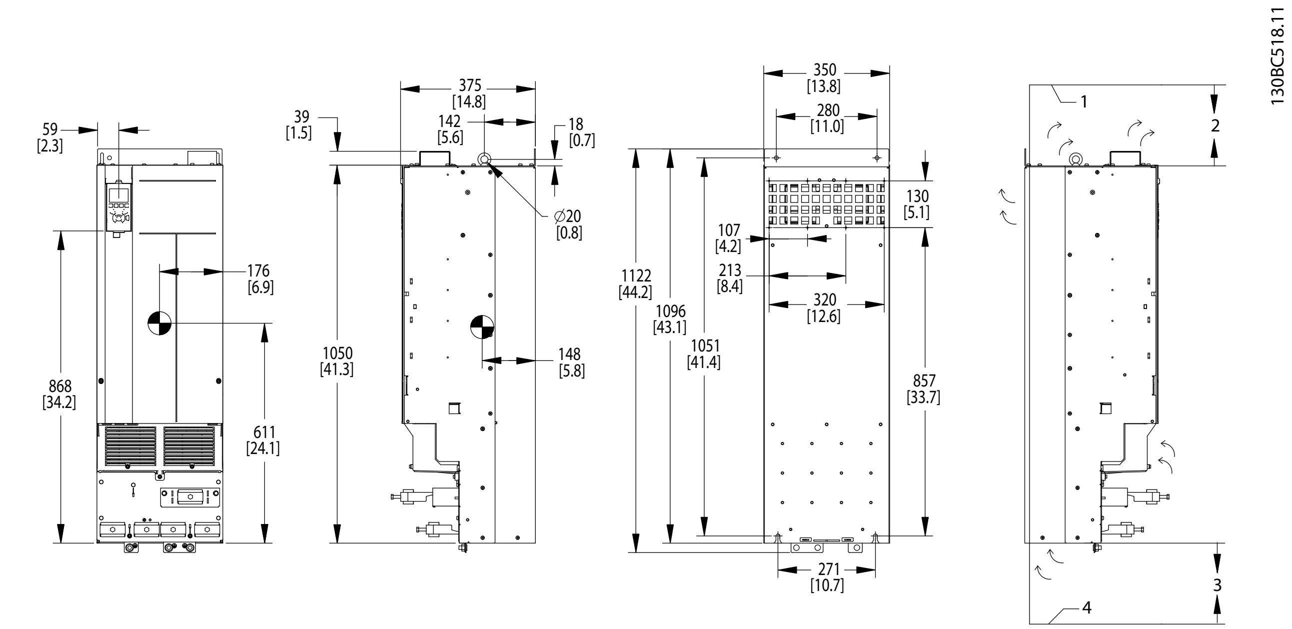


Illustration 6.13 Mechanical Dimensions, D4h

1	Ceiling
2	Air space outlet minimum 225 mm [8.9 in]
3	Air space inlet minimum 225 mm [8.9 in]
4	Floor

Table 6.7 Legend to *Illustration 6.13*

NOTICE

If using a kit to direct the airflow from the heat sink to the outside vent on the back of the frequency converter, the required ceiling clearance is 100 mm.

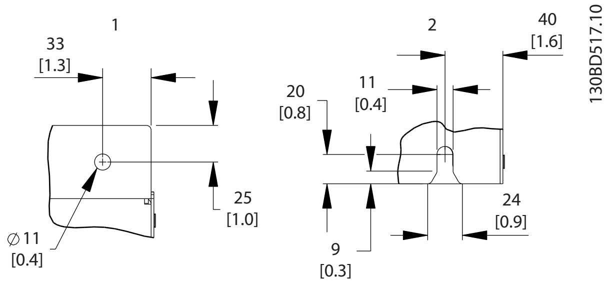


Illustration 6.14 Detail Dimensions, D4h

1	Top mounting hole detail
2	Bottom mounting slot detail

Table 6.8 Legend to *Illustration 6.14*

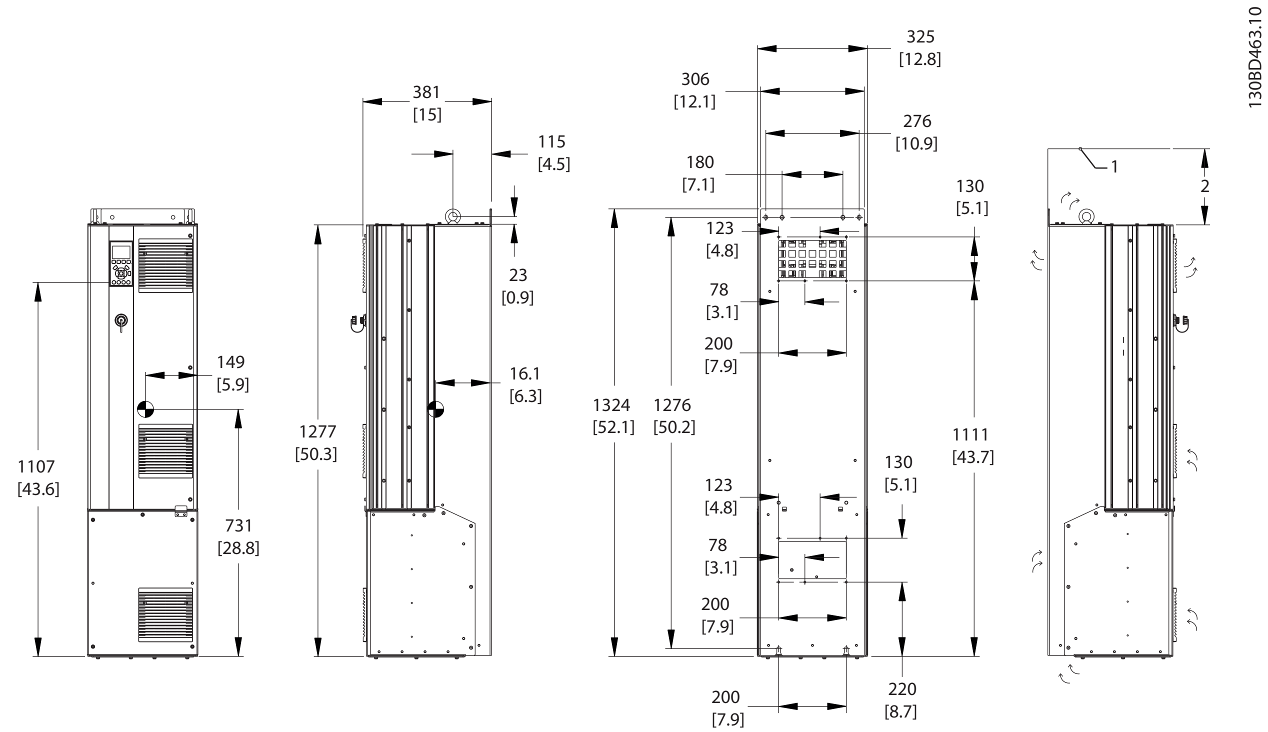


Illustration 6.15 Mechanical Dimensions, D5h

1	Ceiling
2	Air space outlet minimum 225 mm [8.9 in]

Table 6.9 Legend to *Illustration 6.15*

NOTICE

If using a kit to direct the airflow from the heat sink to the outside vent on the back of the frequency converter, the required ceiling clearance is 100 mm.

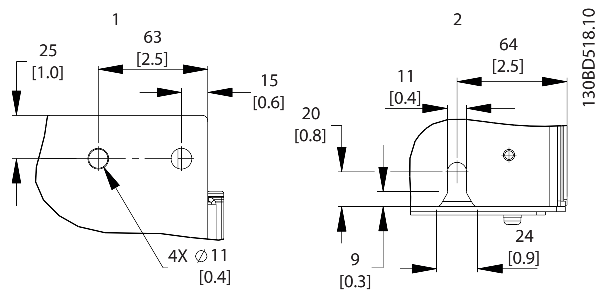


Illustration 6.16 Detail Dimensions, D5h

1	Top mounting hole detail
2	Bottom mounting slot detail

Table 6.10 Legend to *Illustration 6.16*

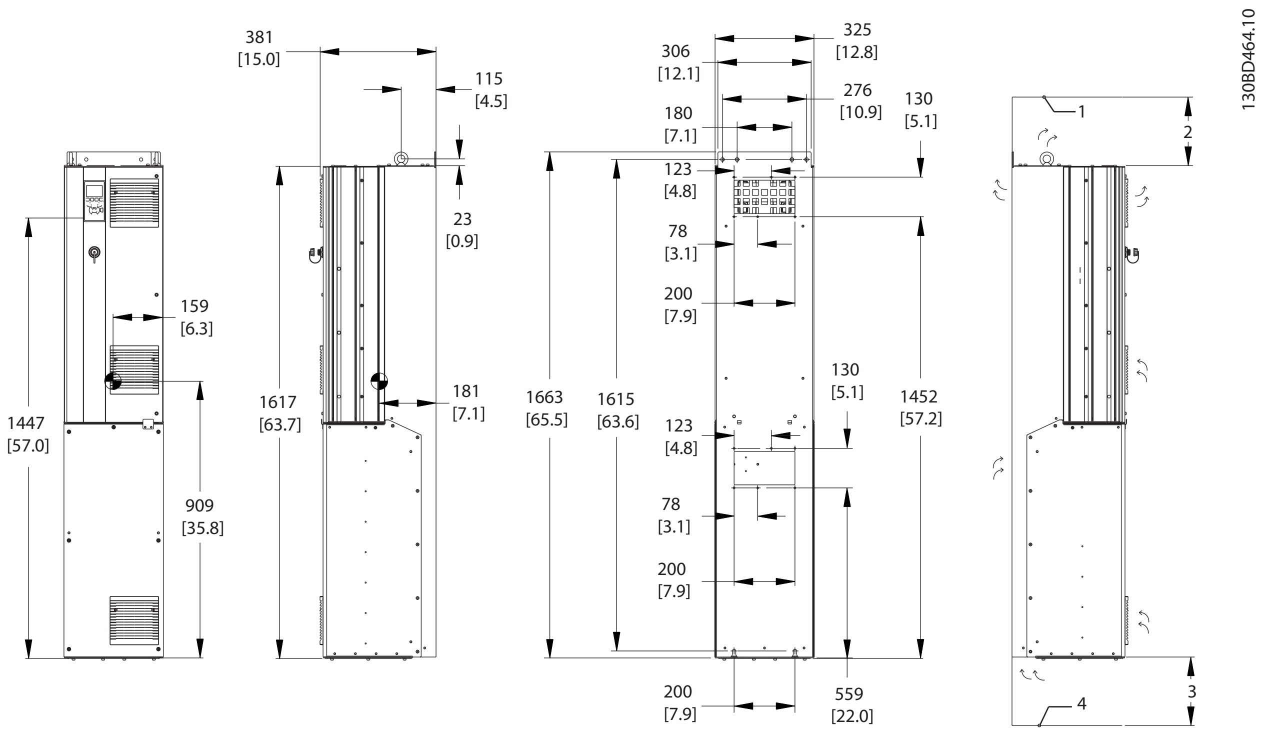


Illustration 6.17 Mechanical Dimensions, D6h

1	Ceiling
2	Air space outlet minimum 225 mm [8.9 in]
3	Air space intlet minimum 225 mm [8.9 in]
4	Floor

Table 6.11 Legend to *Illustration 6.17*

NOTICE

If using a kit to direct the airflow from the heat sink to the outside vent on the back of the frequency converter, the required ceiling clearance is 100 mm.

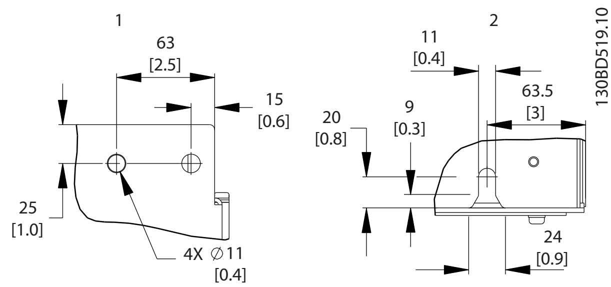


Illustration 6.18 Detail Dimensions, D6h

1	Top mounting hole detail
2	Bottom mounting slot detail

Table 6.12 Legend to *Illustration 6.18*

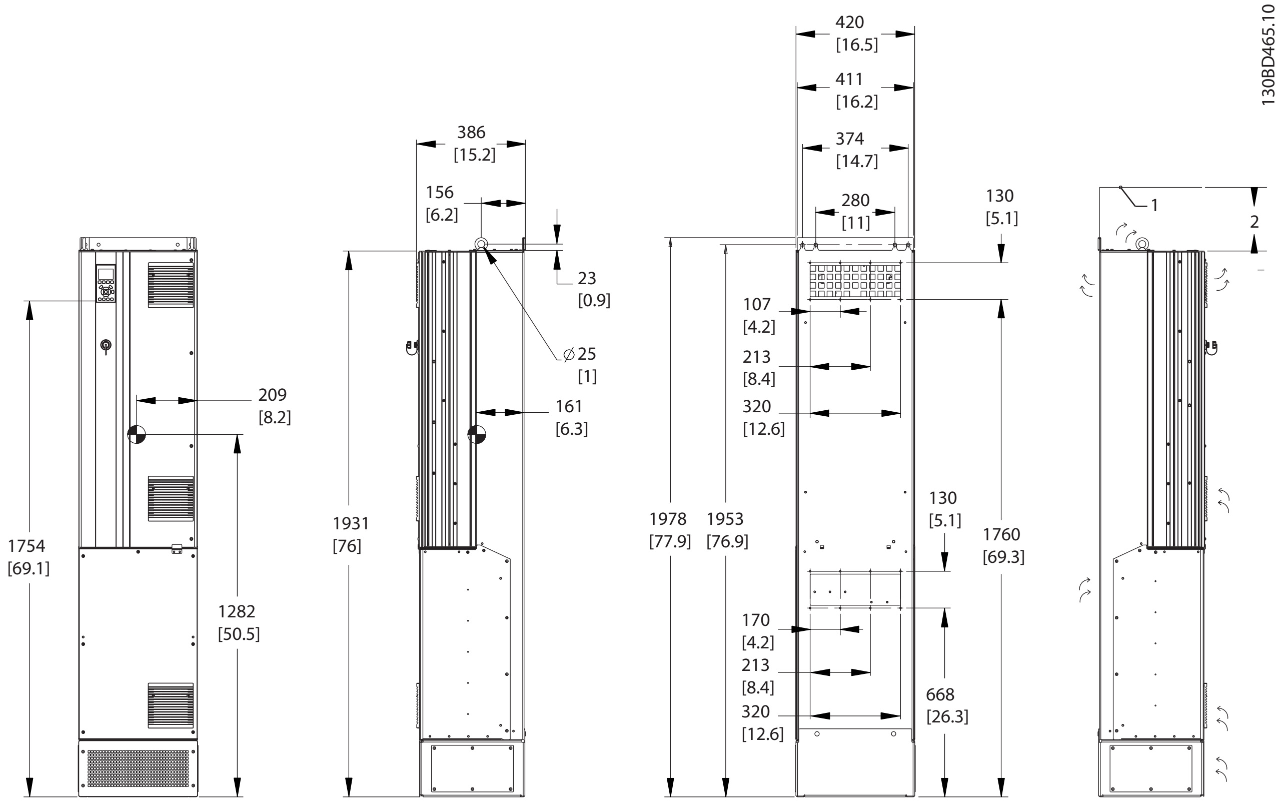


Illustration 6.19 Mechanical Dimensions, D7h

1	Ceiling
2	Air space outlet minimum 225 mm [8.9 in]

Table 6.13 Legend to ***Illustration 6.19***

NOTICE

If using a kit to direct the airflow from the heat sink to the outside vent on the back of the frequency converter, the required ceiling clearance is 100 mm.

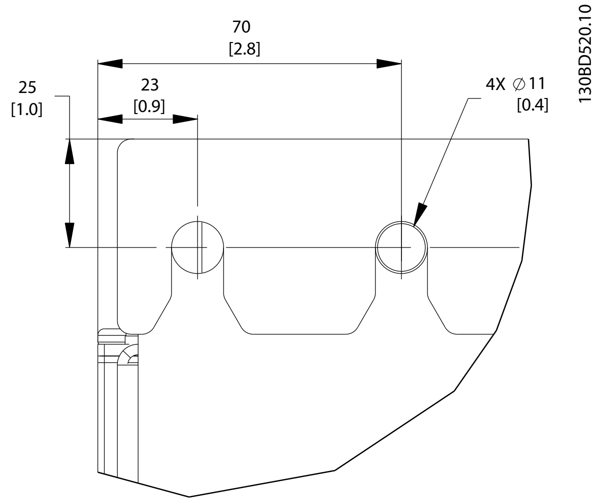


Illustration 6.20 Top Mounting Hole Dimension Detail, D7h

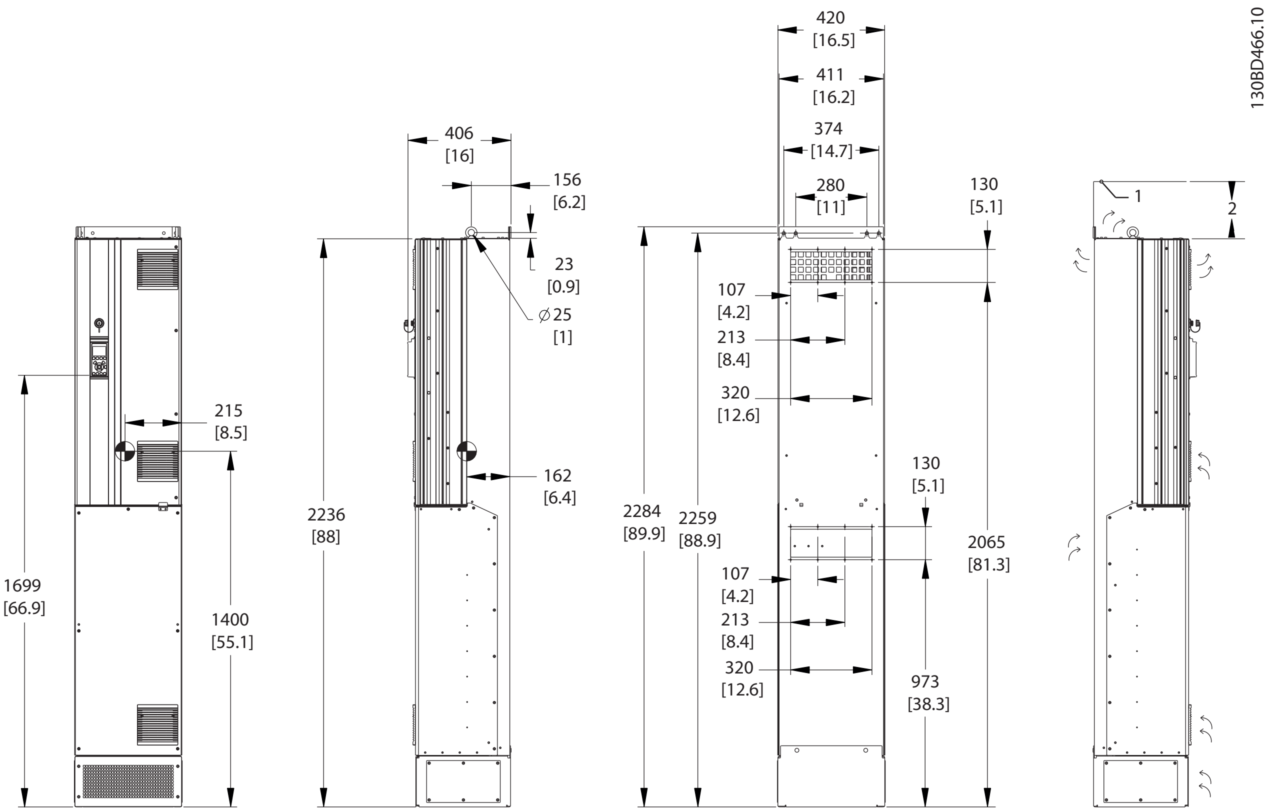


Illustration 6.21 Mechanical Dimensions, D8h

1	Ceiling
2	Air space outlet minimum 225 mm [8.9 in]

Table 6.14 Legend to *Illustration 6.21*

NOTICE

If using a kit to direct the airflow from the heat sink to the outside vent on the back of the frequency converter, the required ceiling clearance is 100 mm.

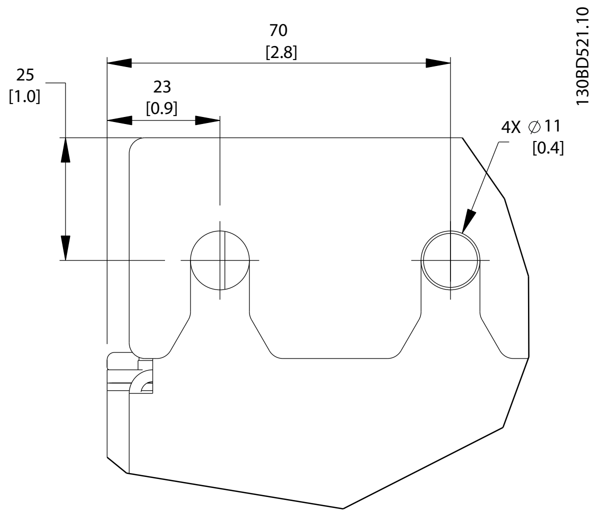


Illustration 6.22 Top Mounting Hole Dimension Detail, D8h

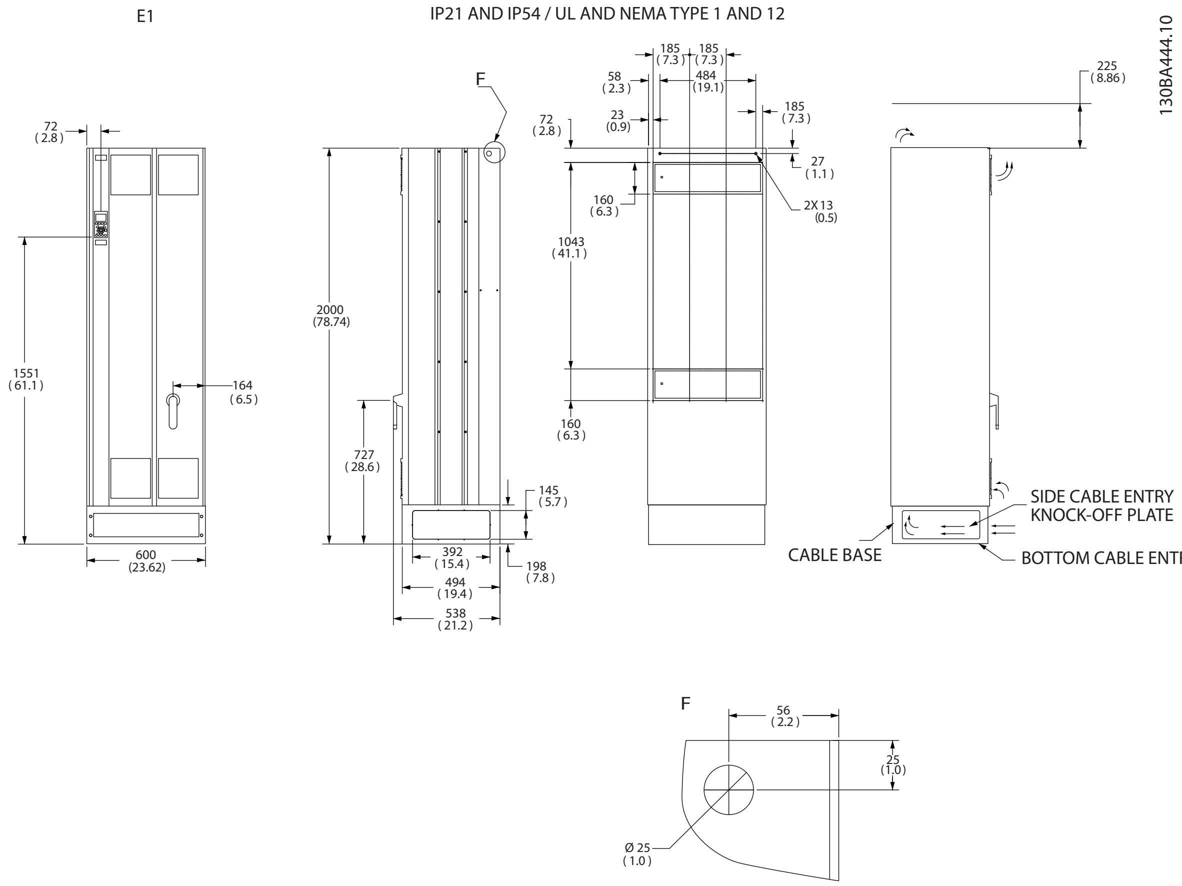


Illustration 6.23 Mechanical Dimensions, E1

F	Lifting eye detail

Table 6.15 Legend to *Illustration 6.23*

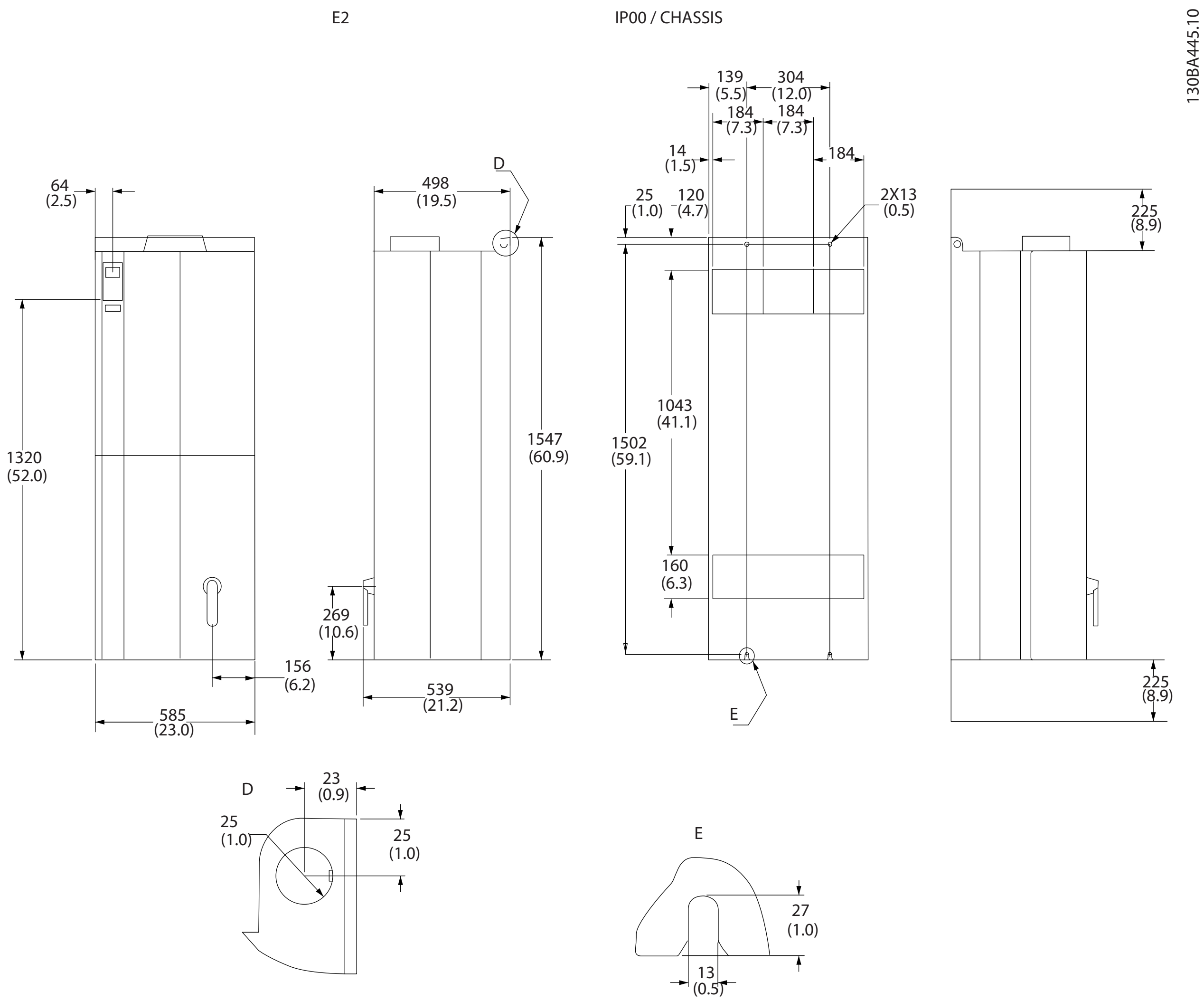


Illustration 6.24 Mechanical Dimensions, E2

D	Lifting eye detail
E	Rear mounting slots

Table 6.16 Legend to *Illustration 6.24*

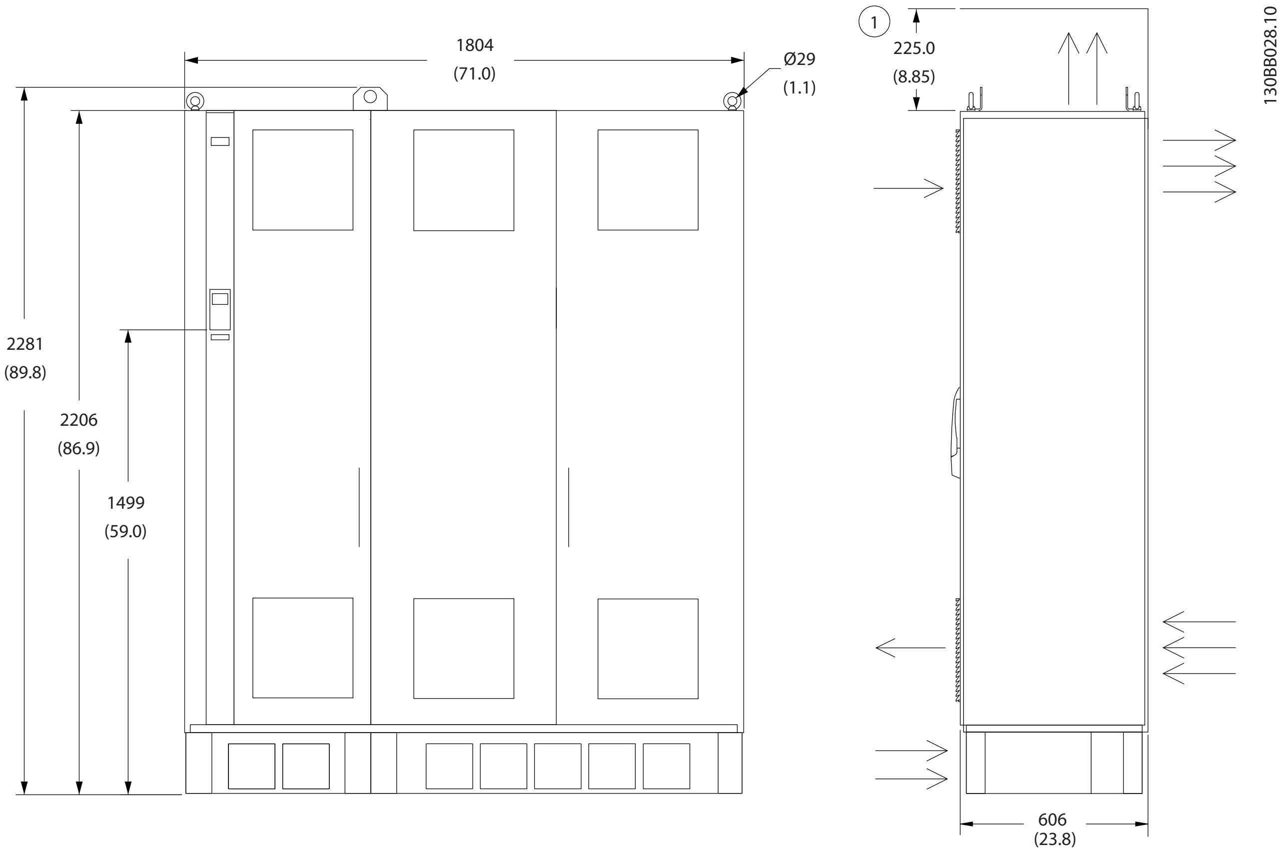


Illustration 6.25 Mechanical Dimensions, F2

1	Minimum clearance from ceiling

Table 6.17 Legend to *Illustration 6.25*

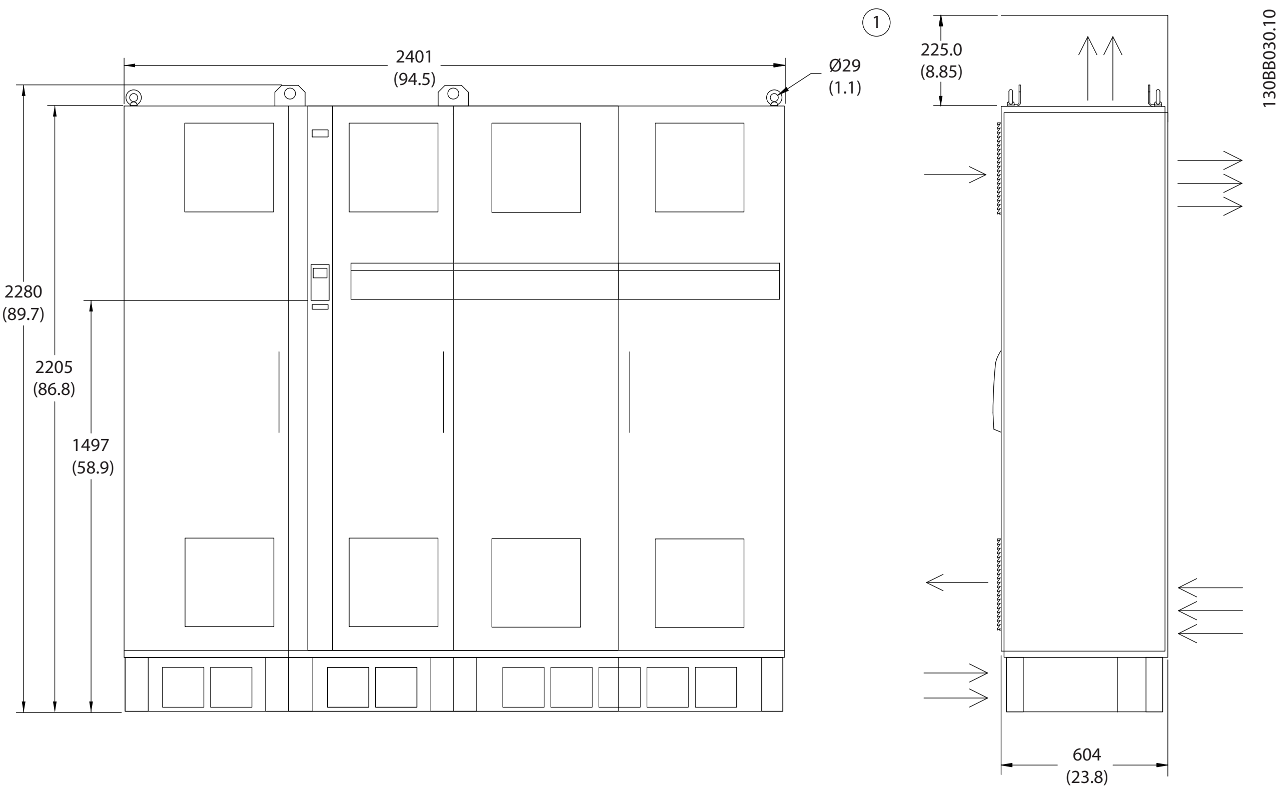


Illustration 6.26 Mechanical Dimensions, F4

1	Minimum clearance from ceiling

Table 6.18 Legend to *Illustration 6.26*

Frame size		D1h	D2h	D3h	D4h	D3h	D4h
		90-132 kW (380-500 V) 90-132 kW (525-690 V)	**160-250 kW (380-500 V) 160-315 kW (525-690 V)**	**90-132 kW (380-500 V) 37-132 kW (525-690 V)**	**160-250 kW (380-500 V) 160-315 kW (525-690 V)**	**With Regeneration or Load Share Terminals**	
IP NEMA		21/54 Type 1/12	21/54 Type 1/12	20 Chassis	20 Chassis	20 Chassis	20 Chassis
Shipping dimensions [mm]	Height	587	587	587	587	587	587
	Width	997	1170	997	1170	1230	1430
	Depth	460	535	460	535	460	535
Drive dimensions [mm]	Height	901	1060	909	1122	1004	1268
	Width	325	420	250	350	250	350
	Depth	378	378	375	375	375	375
Max weight [kg]		98	164	98	164	108	179

Table 6.19 Mechanical Dimensions, Frame Size D1h-D4h

Frame size		D5h	D6h	D7h	D8h
		90-132 kW (380-500 V) 90-132 kW (525-690 V)	**90-132 kW (380-500 V) 90-132 kW (525-690 V)**	**160-250 kW (380-500 V) 160-315 kW (525-690 V)**	**160-250 kW (380-500 V) 160-315 kW (525-690 V)**
IP NEMA		21/54 Type 1/12	21/54 Type 1/12	21/54 Type 1/12	21/54 Type 1/12
Shipping dimensions [mm]	Height	660	660	660	660
	Width	1820	1820	2470	2470
	Depth	510	510	590	590
Drive dimensions [mm]	Height	1324	1663	1978	2284
	Width	325	325	420	420
	Depth	381	381	386	406
Max weight [kg]		116	129	200	225

Table 6.20 Mechanical Dimensions, Frame Size D5h-D8h

Frame size		E1	E2	F1	F2	F3	F4
		250-400 kW (380-500 V) 355-560 kW (525-690 V)	**250-400 kW (380-500 V) 355-560 kW (525-690 V)**	**450-630 kW (380-500 V) 630-800 kW (525-690 V)**	**710-800 kW (380-500 V) 900-1200 kW (525-690 V)**	**450-630 kW (380-500 V) 630-800 kW (525-690 V)**	**710-800 kW (380-500 V) 900-1200 kW (525-690 V)**
IP NEMA		21, 54 Type 12	00 Chassis	21, 54 Type 12	21, 54 Type 12	21, 54 Type 12	21, 54 Type 12
Shipping dimensions [mm]	Height	840	831	2324	2324	2324	2324
	Width	2197	1705	1569	1962	2159	2559
	Depth	736	736	1130	1130	1130	1130
Drive dimensions [mm]	Height	2000	1547	2204	2204	2204	2204
	Width	600	585	1400	1800	2000	2400
	Depth	494	498	606	606	606	606
Max weight [kg]		313	277	1017	1260	1318	1561

Table 6.21 Mechanical Dimensions, Frame Size E1-E2, F1-F4

6

6.1.5 Mechanical Dimensions, 12-Pulse Units

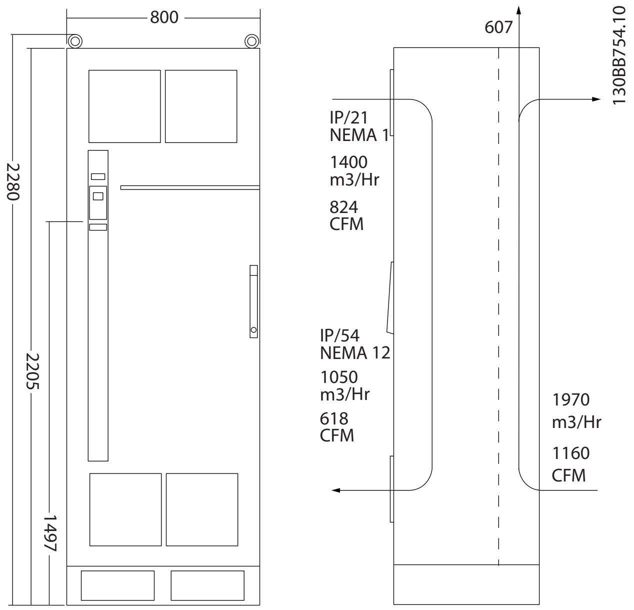


Illustration 6.27 Mechanical Dimensions (mm), F8

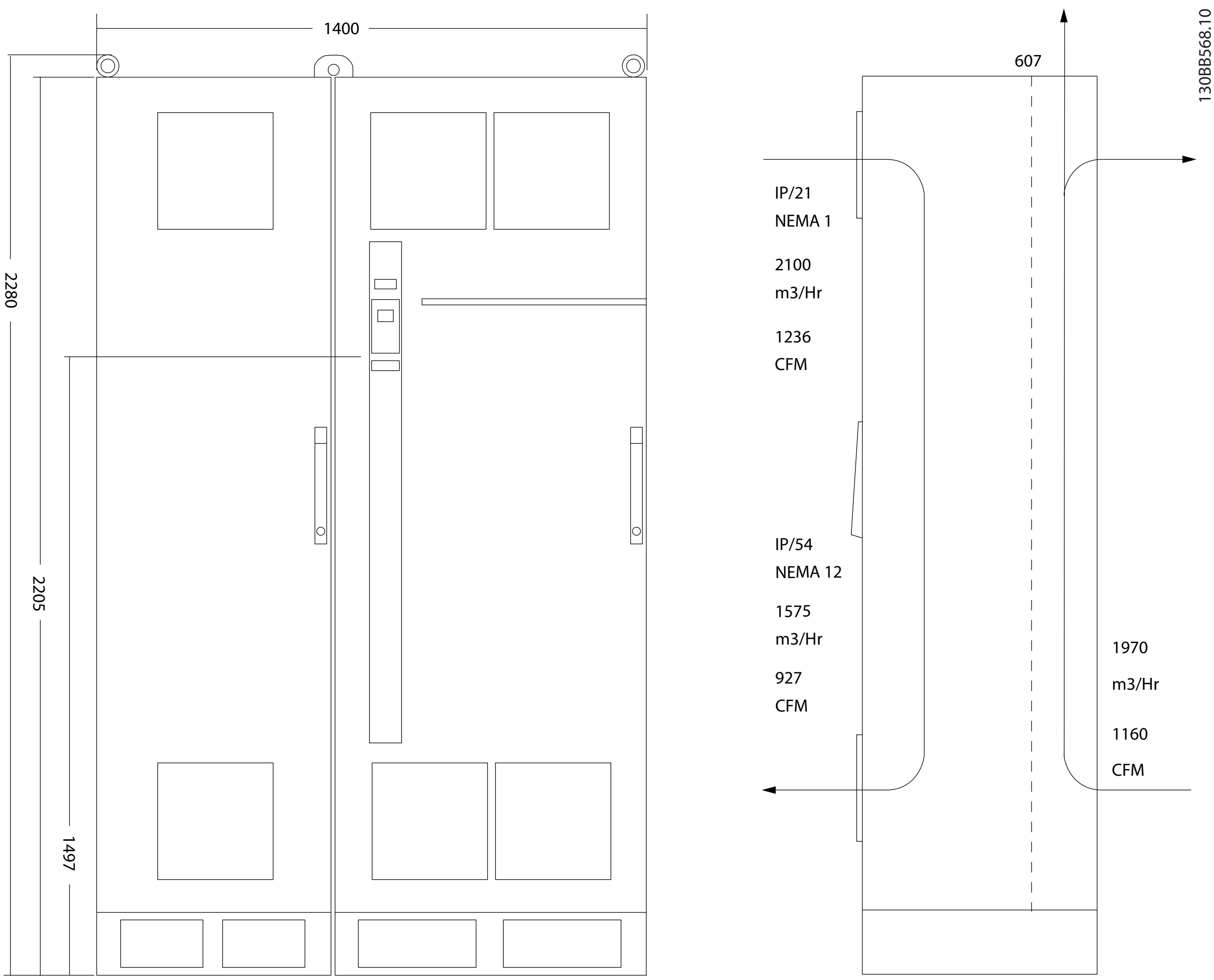


Illustration 6.28 Mechanical Dimensions (mm), F9

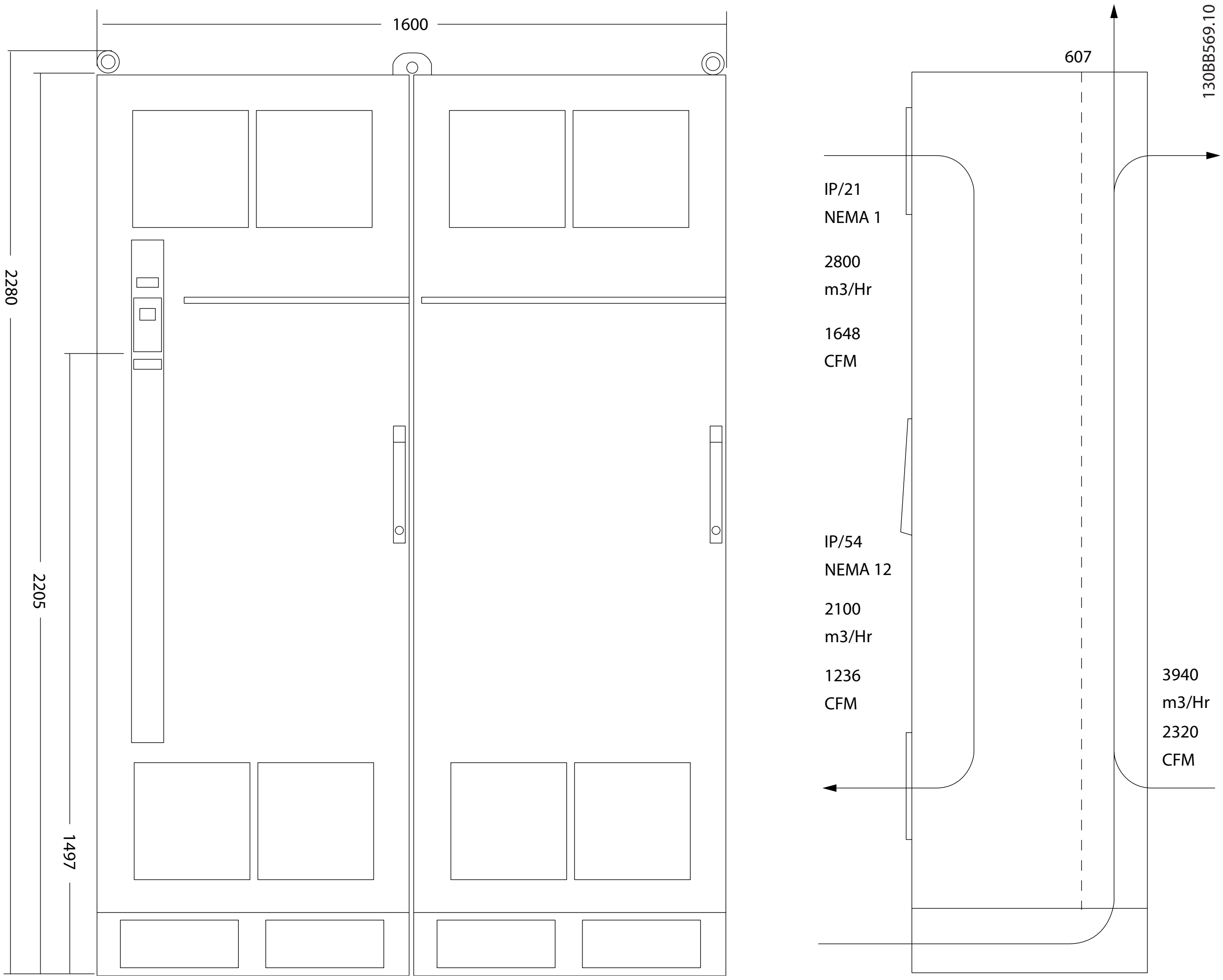


Illustration 6.29 Mechanical Dimensions (mm), F10

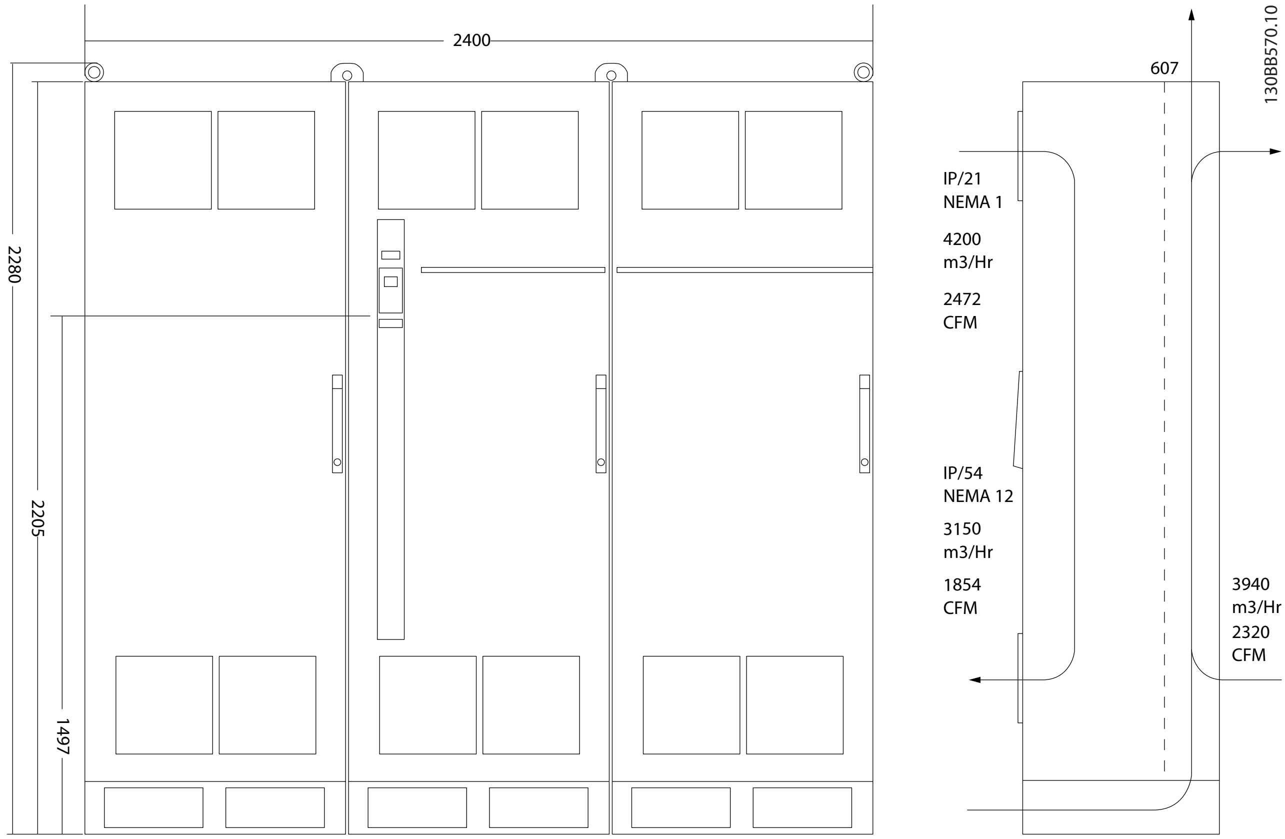


Illustration 6.30 Mechanical Dimensions (mm), F11

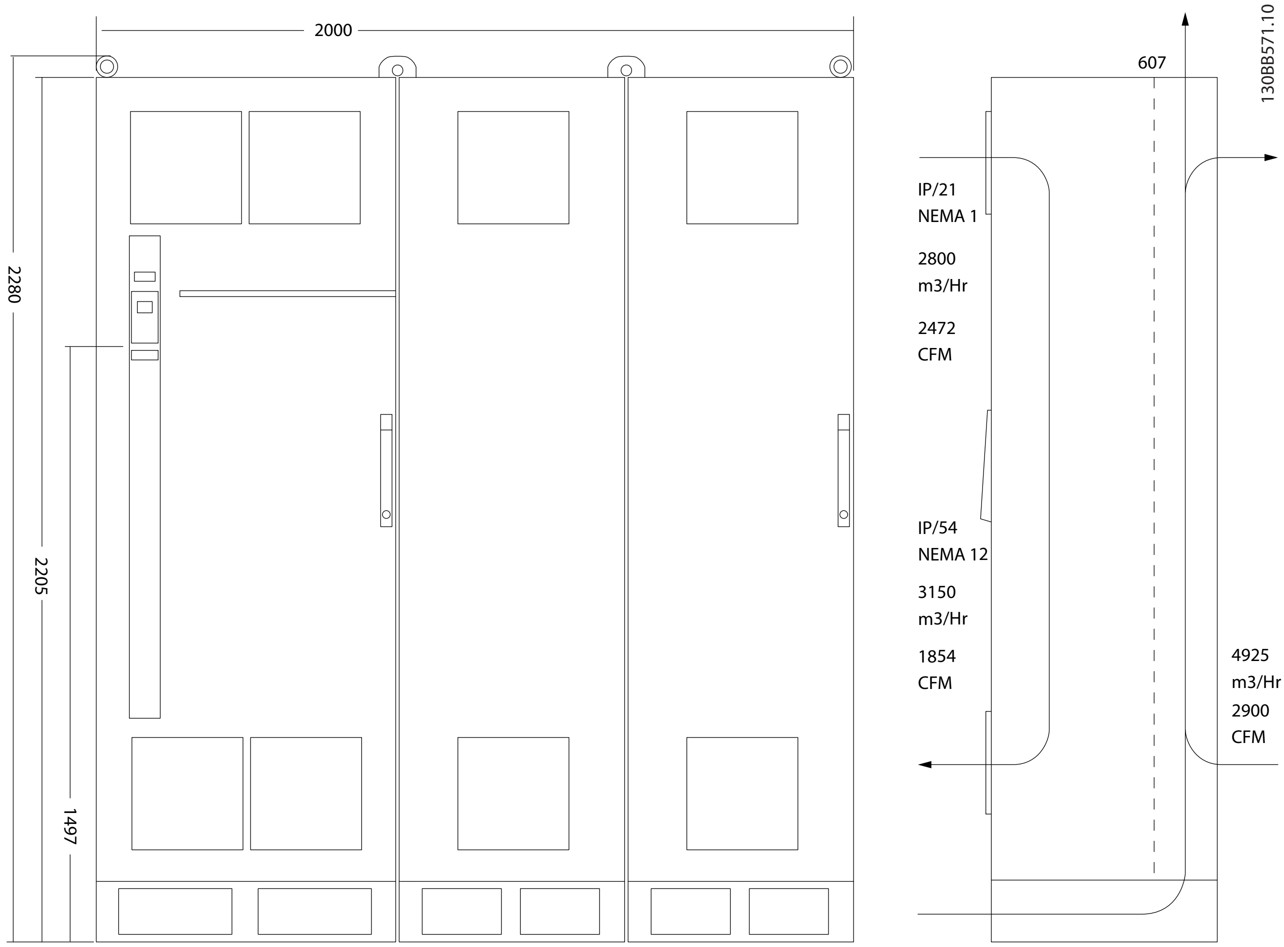


Illustration 6.31 Mechanical Dimensions (mm), F12

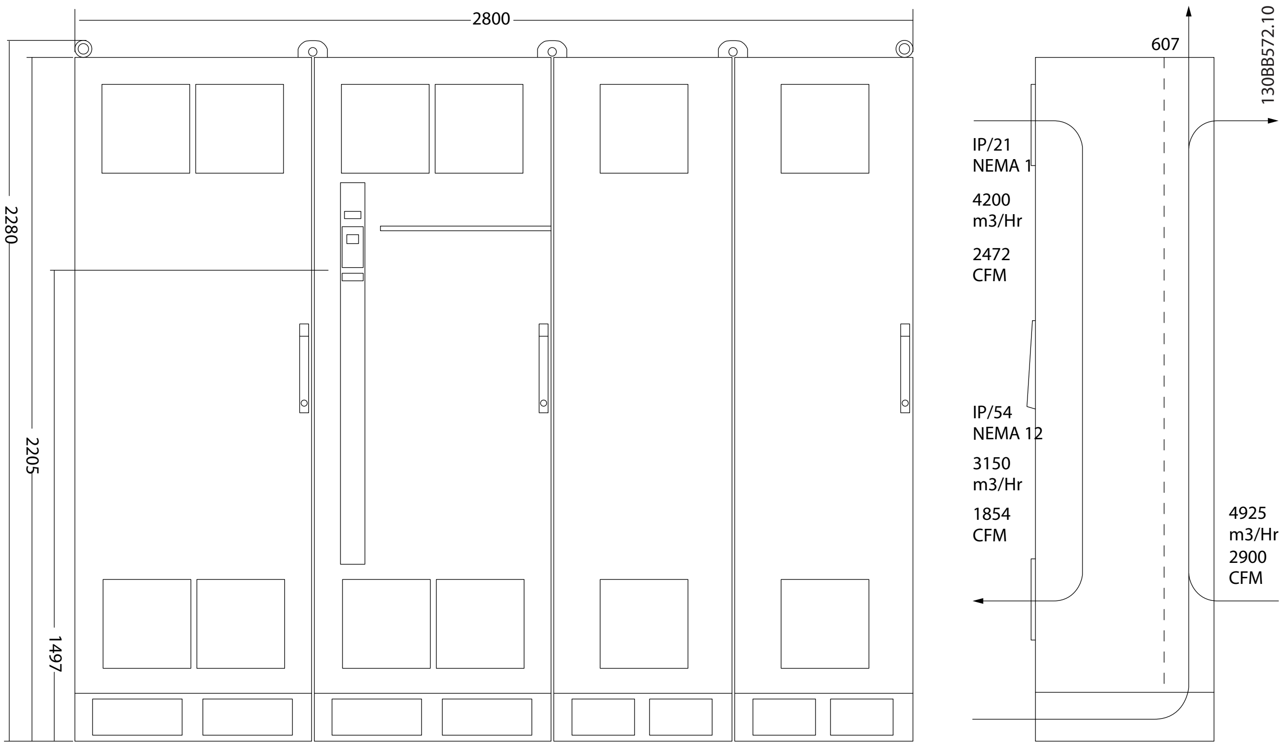


Illustration 6.32 Mechanical Dimensions (mm), F13

Frame size		**F8**	**F9**	**F10**	**F11**	**F12**	**F13**
High overload rated power - 160% overload torque		**250-400 kW (380-500 V) 355-560 kW (525-690 V)**	**250-400 kW (380-500 V) 355-560 kW (525-690 V)**	**450-630 kW (380-500 V) 630-800 kW (525-690 V)**	**450-630 kW (380-500 V) 630-800 kW (525-690 V)**	**710-800 kW (380-500 V) 900-1200 kW (525-690 V)**	**710-800 kW (380-500 V) 900-1200 kW (525-690 V)**
IP **NEMA**		21, 54 Type 1/Type 12	21, 54 Type 1/Type 12	21, 54 Type 1/Type 12	21, 54 Type 1/Type 12	21, 54 Type 1/Type 12	21, 54 Type 1/Type 12
Shipping dimensions [mm]	Height	2324					
	Width	970	1568	1760	2559	2160	2960
	Depth	1130					
Drive dimensions [mm]	Height	2204					
	Width	800	1400	1600	2200	2000	2600
	Depth	606					
Max weight [kg]		447	669	893	1116	1037	1259

Table 6.22 Mechanical Dimensions, 12-Pulse Units, Frame Sizes F8-F13

6.2 Mechanical Installation

Preparation for the mechanical installation of the frequency converter must be done carefully to ensure a proper fit and to avoid additional work during installation. The mechanical drawings in *6.1.4 Mechanical Dimensions* provide more information about the space requirements.

6.2.1 Tools Needed

To perform the mechanical installation, the following tools are needed:

- Drill with 10 mm or 12 mm drill bits.
- Tape measurer.
- Wrench with relevant metric sockets (7–17 mm).
- Wrench extensions.
- Sheet metal punch for conduits or cable glands in IP21 (NEMA 1) and IP54 (NEMA 12) units.
- Lifting bar to lift the unit (rod or tube max. Ø 25 mm (1 inch), able to lift minimum 400 kg (880 lbs)).
- Crane or other lifting aid to place the frequency converter in position.
- Use a Torx T50 tool to install the E1 in IP21 and IP54 enclosure types.

6.2.2 General Considerations

Wire Access
Ensure that proper cable access is present including necessary bending allowance. As the IP00 enclosure is open to the bottom, cables must be fixed to the back panel of the enclosure where the frequency converter is mounted.

NOTICE

All cable lugs/shoes must mount within the width of the terminal bus bar.

Space
Ensure proper space above and below the frequency converter to allow airflow and cable access. In addition, space in front of the unit must be considered to enable opening of the door of the panel.

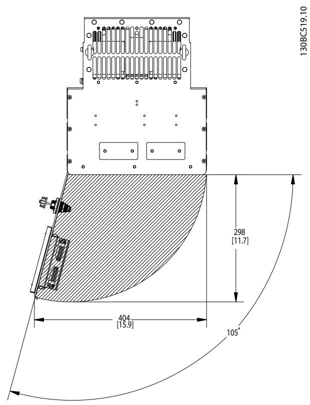


Illustration 6.33 Front Clearance of IP21/IP54 Enclosure Type, Frame Size D1h, D5h, and D6h

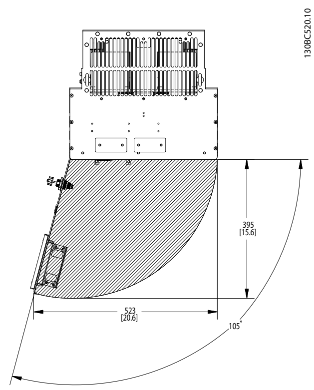


Illustration 6.34 Front Clearance of IP21/IP54 Enclosure Type, Frame Size D2h, D7h, and D8h

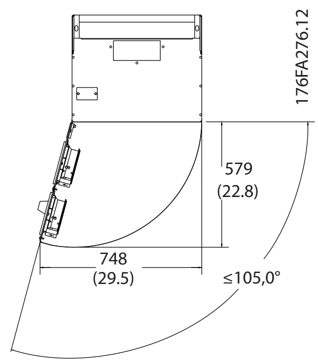


Illustration 6.35 Front Clearance of IP21/IP54 Enclosure Type, Frame Size E1.

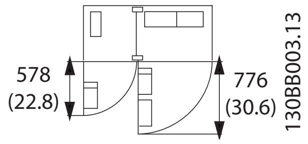


Illustration 6.36 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F1

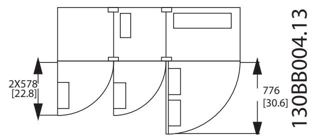


Illustration 6.37 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F3

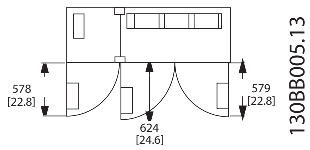


Illustration 6.38 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F2

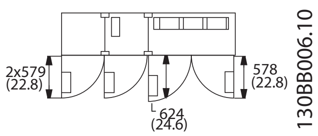


Illustration 6.39 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F4

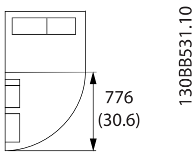


Illustration 6.40 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F8

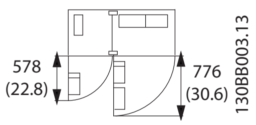


Illustration 6.41 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F9

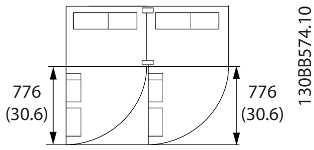


Illustration 6.42 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F10

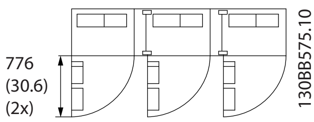


Illustration 6.43 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F11

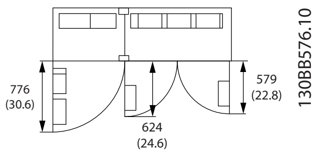


Illustration 6.44 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F12

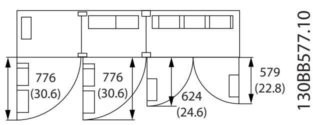


Illustration 6.45 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F13

6

6.2.3 Terminal Locations - Frame Size D

Take the following terminal positions into consideration when designing for cables access.
Dimensions are shown in mm [in].

NOTICE

Power cables are heavy and hard to bend. Consider the optimum position of the frequency converter to ensure easy installation of the cables.

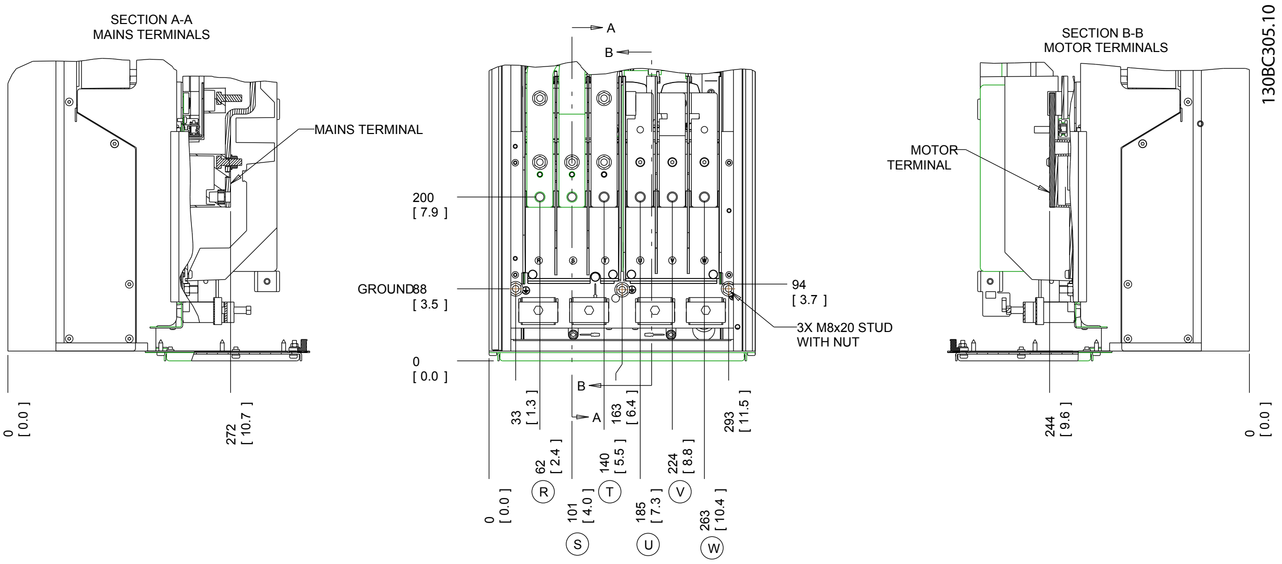


Illustration 6.46 Position of Power Connections, Frame Size D1h

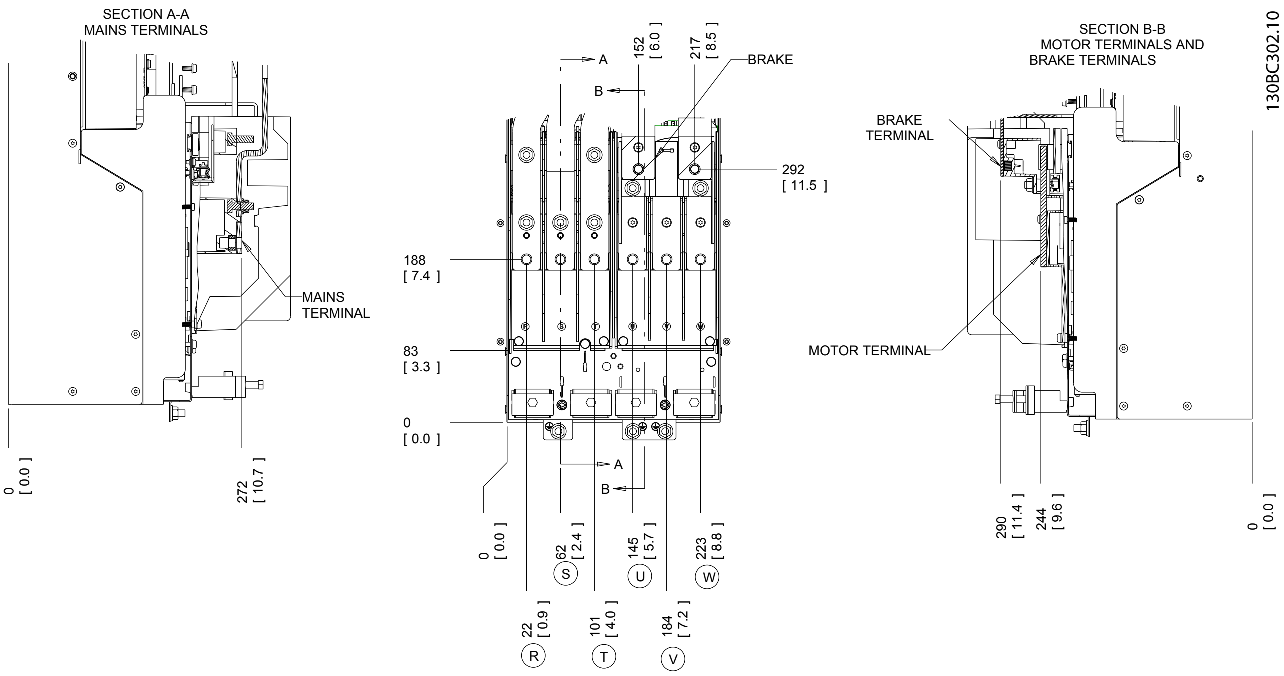


Illustration 6.47 Position of Power Connections, Frame Size D3h

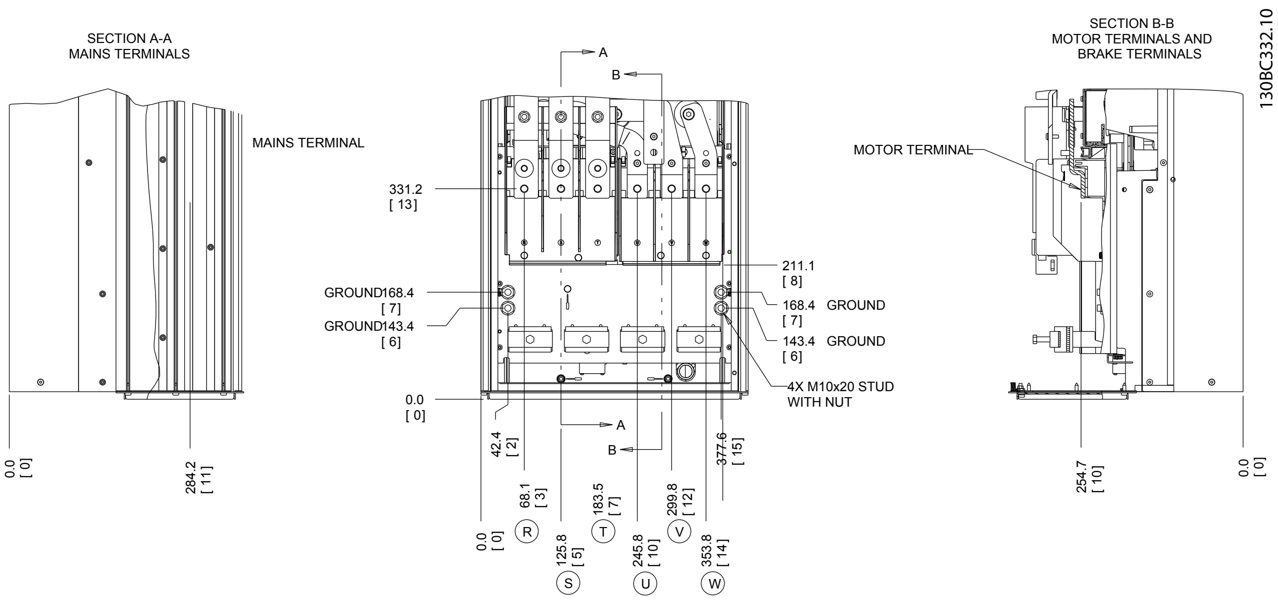


Illustration 6.48 Position of Power Connections, Frame Size D2h

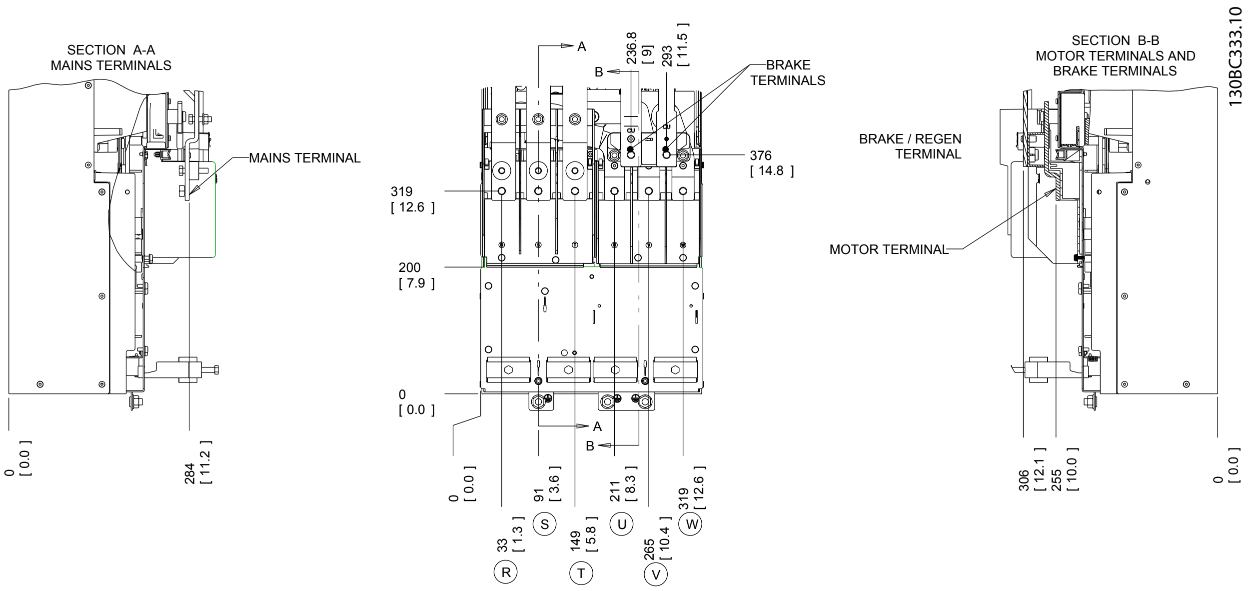


Illustration 6.49 Position of Power Connections, Frame Size D4h

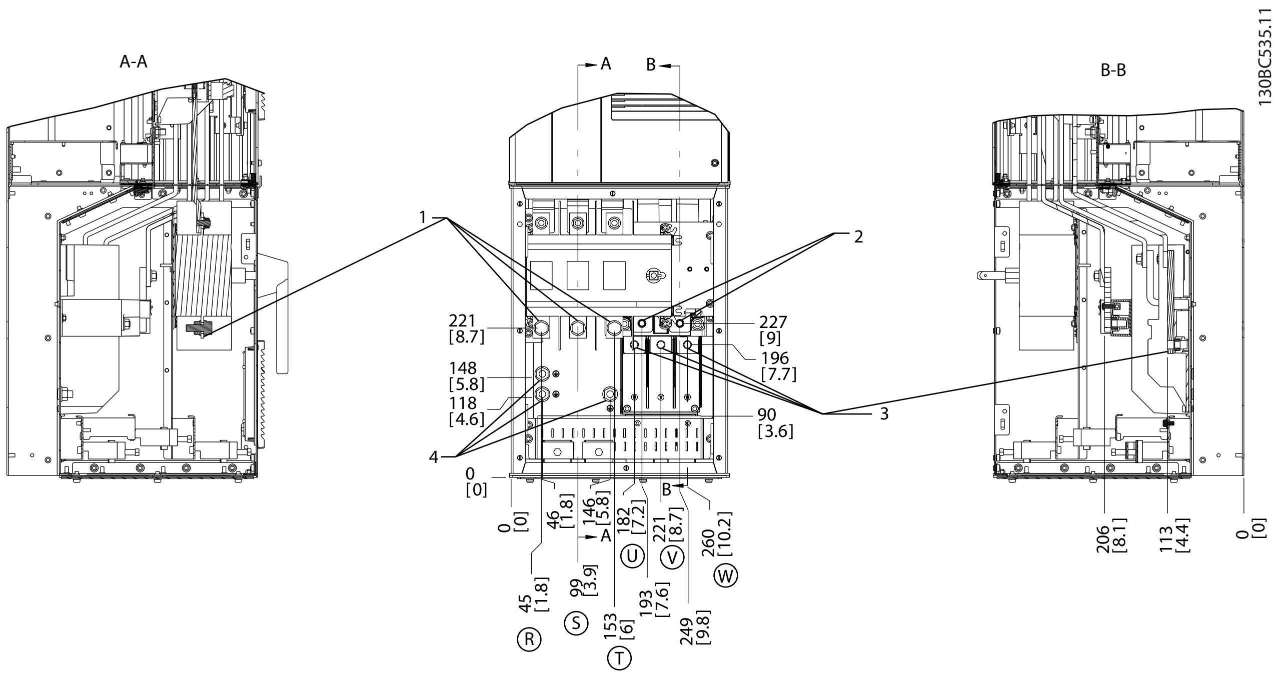


Illustration 6.50 Terminal Locations, D5h with Disconnect Option

1	Mains Terminals
2	Brake Terminals
3	Motor Terminals
4	Earth/Ground Terminals

Table 6.23 Legend to *Illustration 6.50*

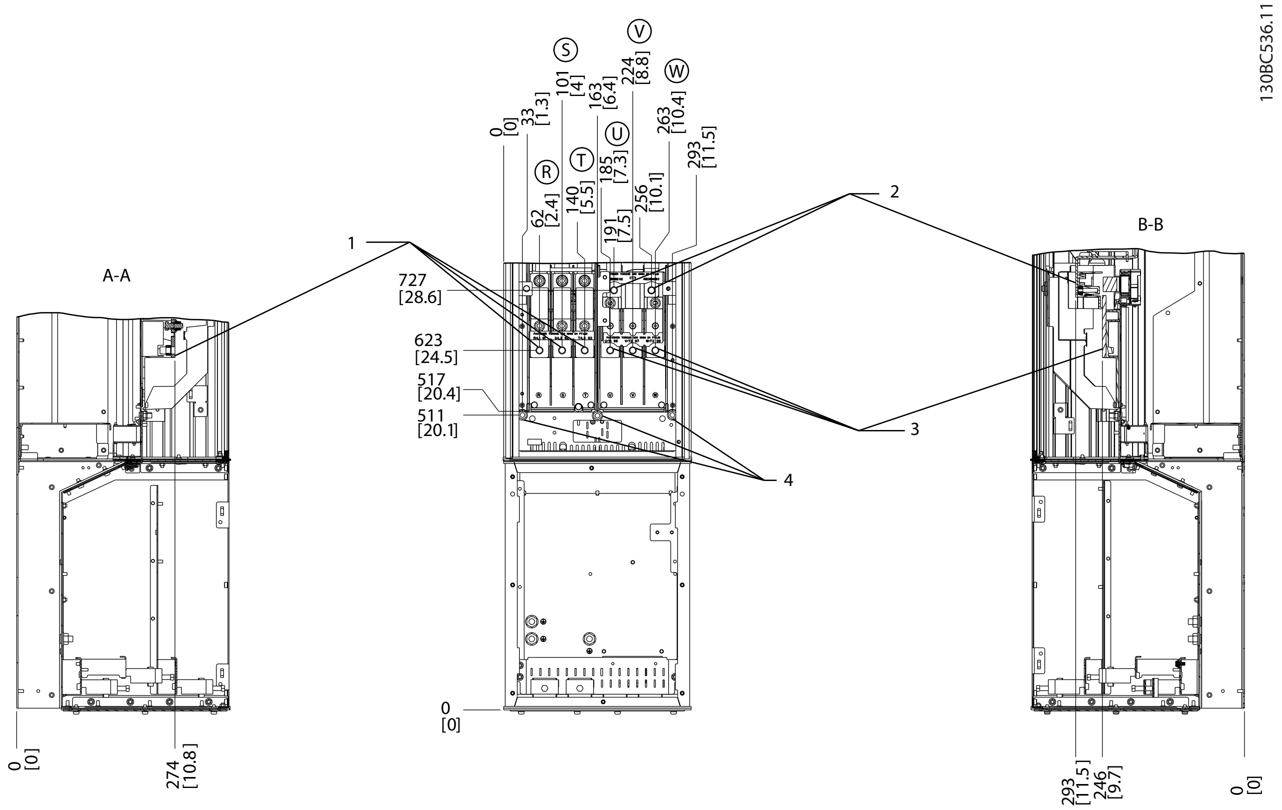


Illustration 6.51 Terminal Locations, D5h with Brake Option

1	Mains Terminals
2	Brake Terminals
3	Motor Terminals
4	Earth/Ground Terminals

Table 6.24 Legend to *Illustration 6.51*

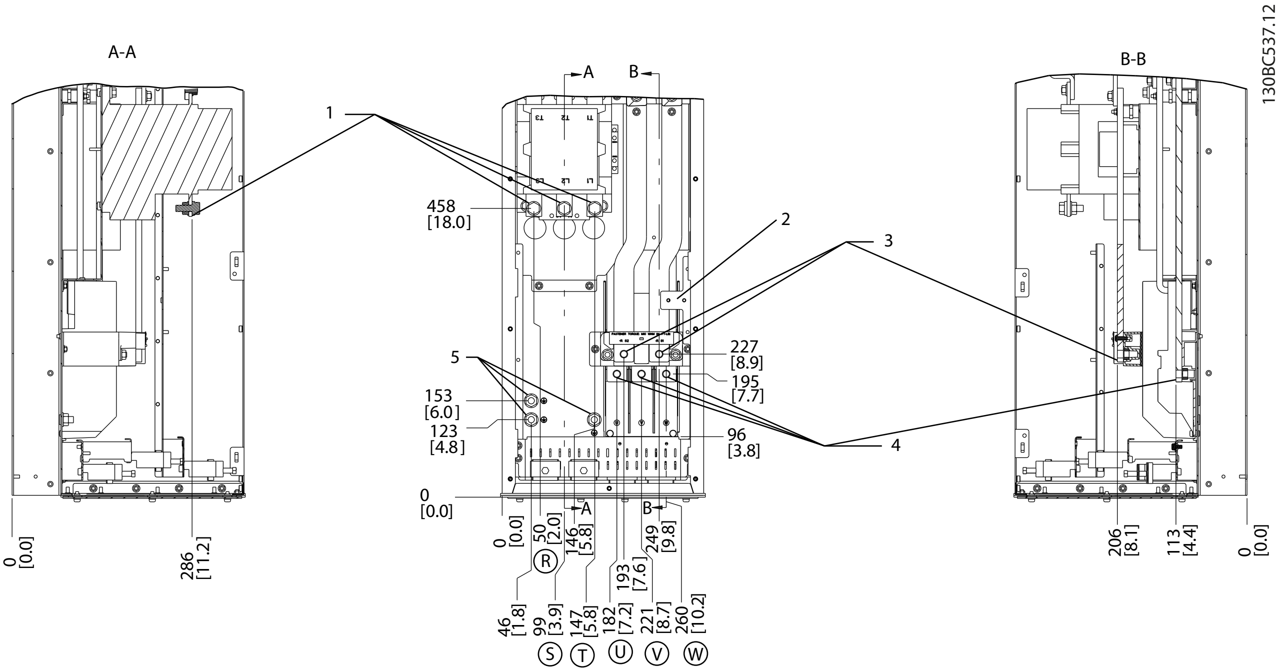


Illustration 6.52 Terminal Locations, D6h with Contactor Option

1	Mains Terminals
2	TB6 Terminal block for contactor
3	Brake Terminals
4	Motor Terminals
5	Earth/Ground Terminals

Table 6.25 Legend to *Illustration 6.52*

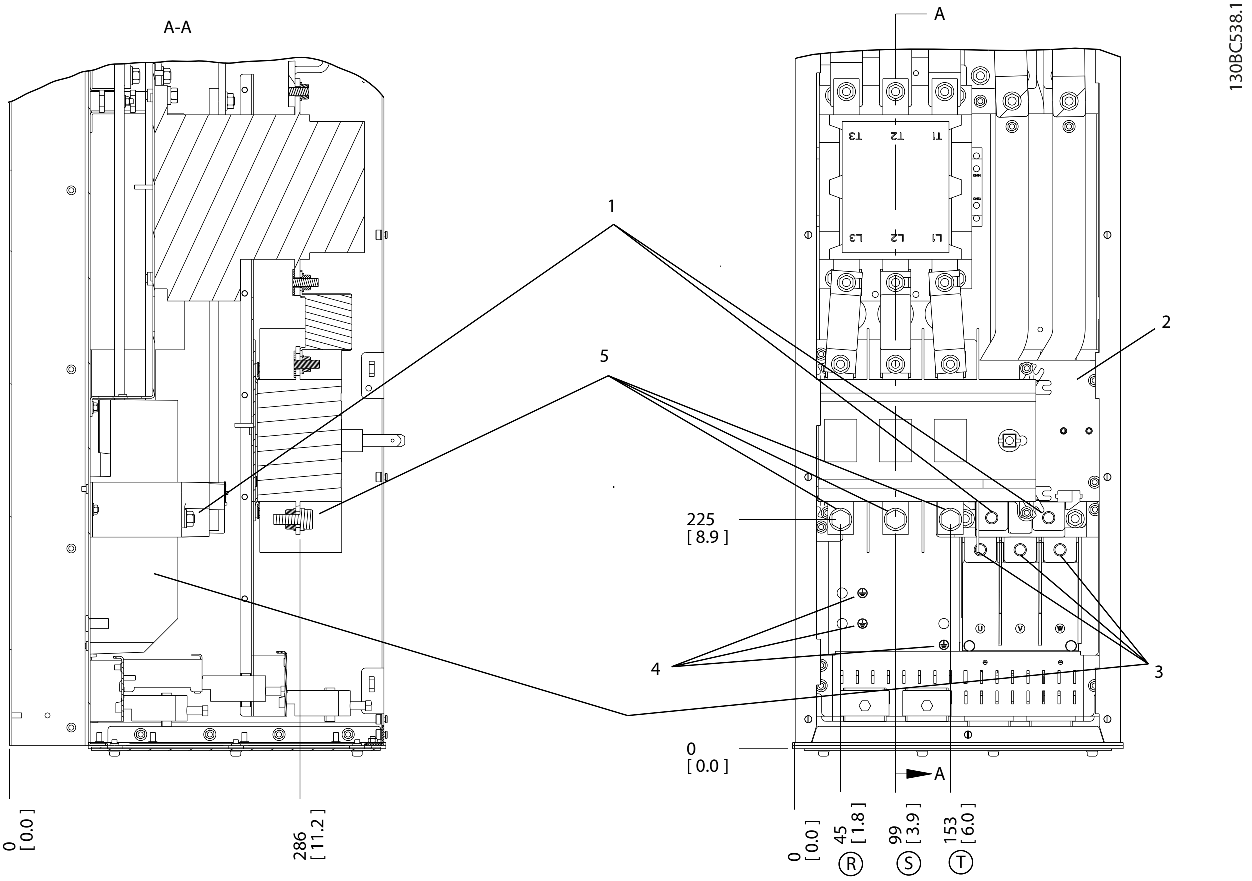


Illustration 6.53 Terminal Locations, D6h with Contactor and Disconnect Options

1	Brake Terminals
2	TB6 Terminal block for contactor
3	Motor Terminals
4	Earth/Ground Terminals
5	Mains Terminals

Table 6.26 Legend to *Illustration 6.53*

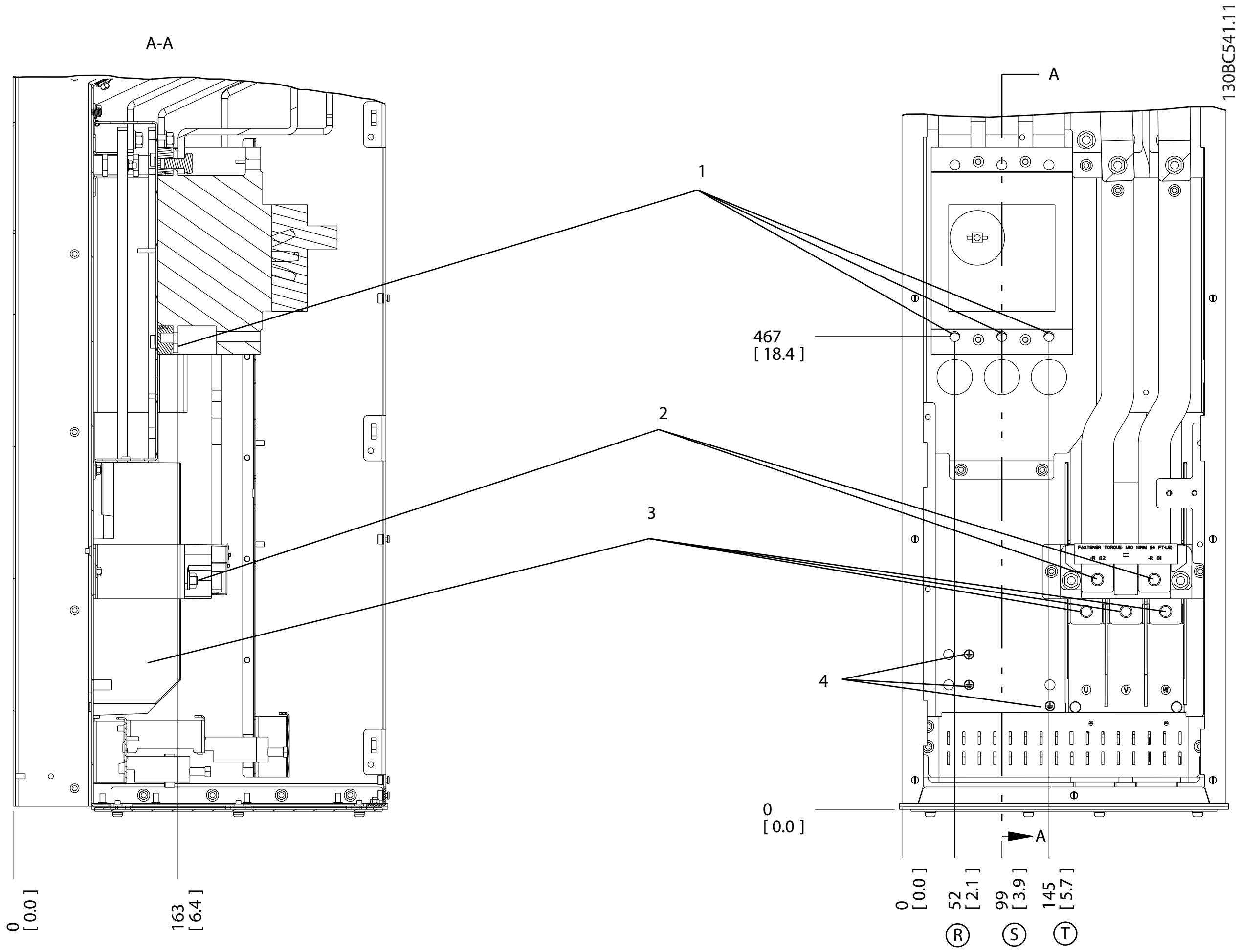


Illustration 6.54 Terminal Locations, D6h with Circuit Breaker Option

1	Mains Terminals
2	Brake Terminals
3	Motor Terminals
4	Earth/Ground Terminals

Table 6.27 Legend to *Illustration 6.54*

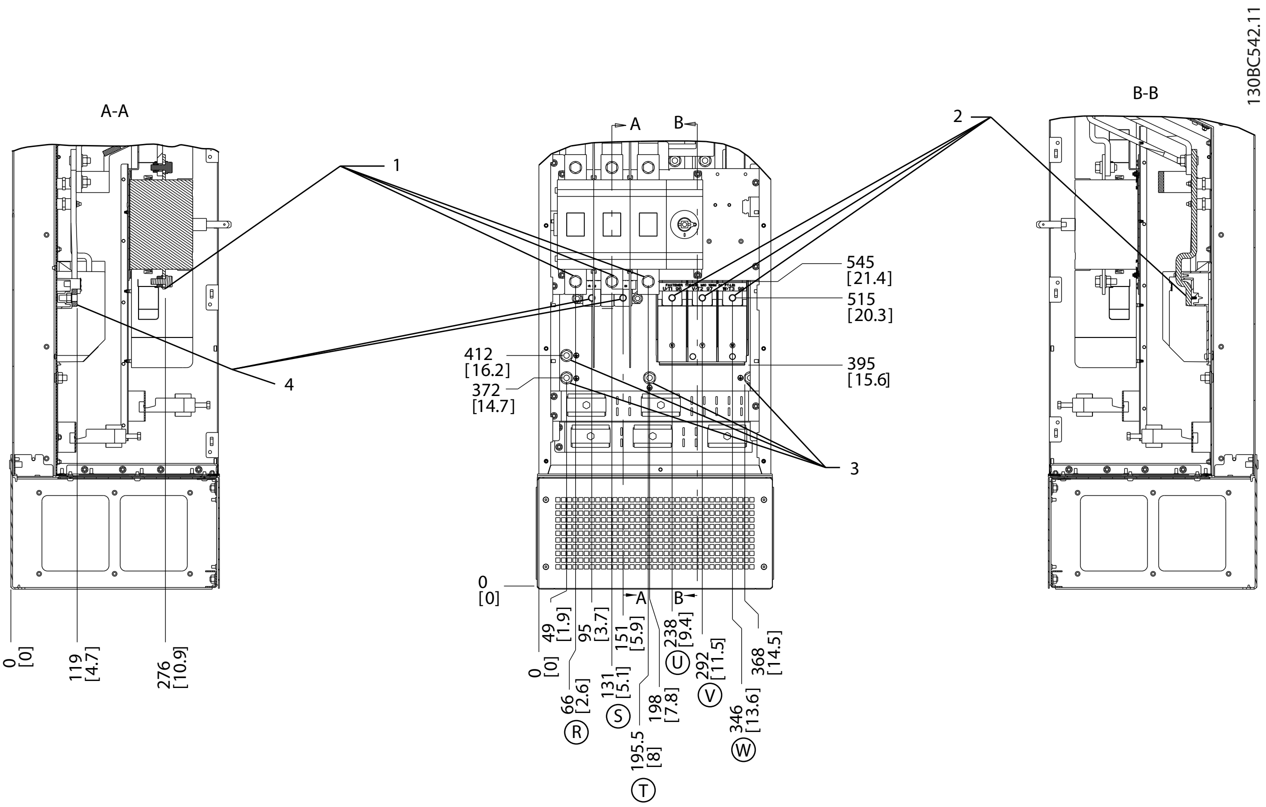


Illustration 6.55 Terminal Locations, D7h with Disconnect Option

1	Mains Terminals
2	Motor Terminals
3	Earth/Ground Terminals
4	Brake Terminals

Table 6.28 Legend to *Illustration 6.55*

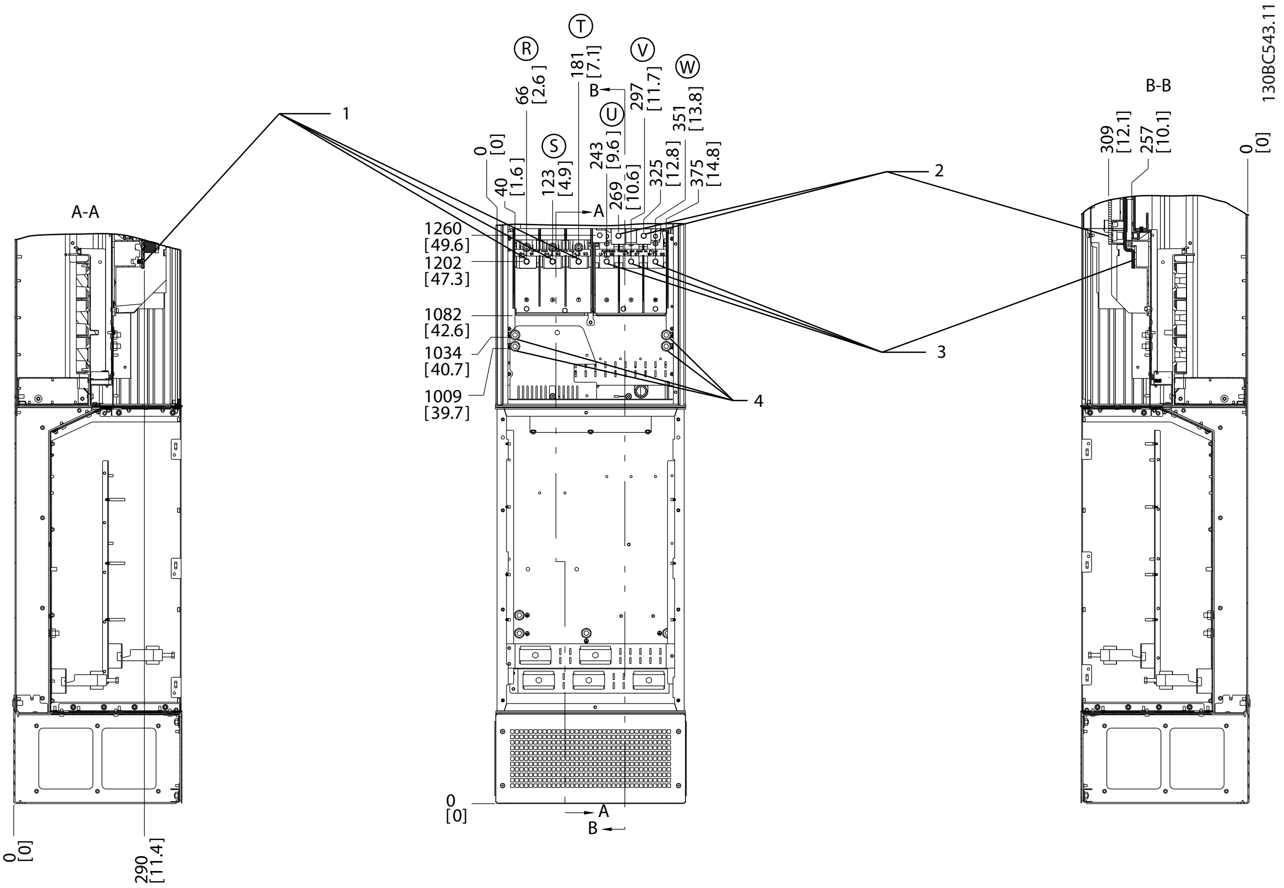


Illustration 6.56 Terminal Locations, D7h with Brake Option

1	Mains Terminals
2	Brake Terminals
3	Motor Terminals
4	Earth/Ground Terminals

Table 6.29 Legend to *Illustration 6.56*

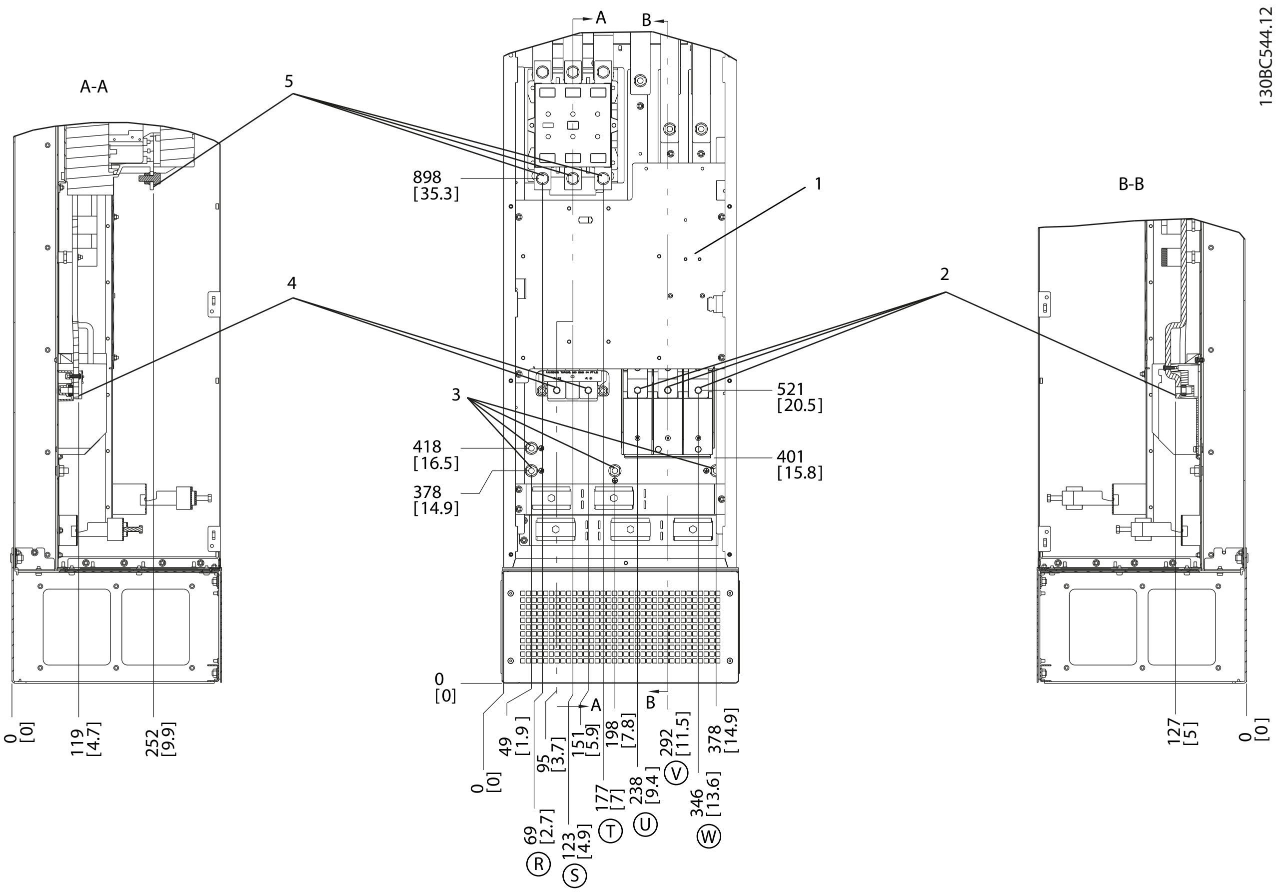


Illustration 6.57 Terminal Locations, D8h with Contactor Option

1	TB6 Terminal block for contactor
2	Motor Terminals
3	Earth/Ground Terminals
4	Brake Terminals
5	Mains Terminals

Table 6.30 Legend to *Illustration 6.57*

6

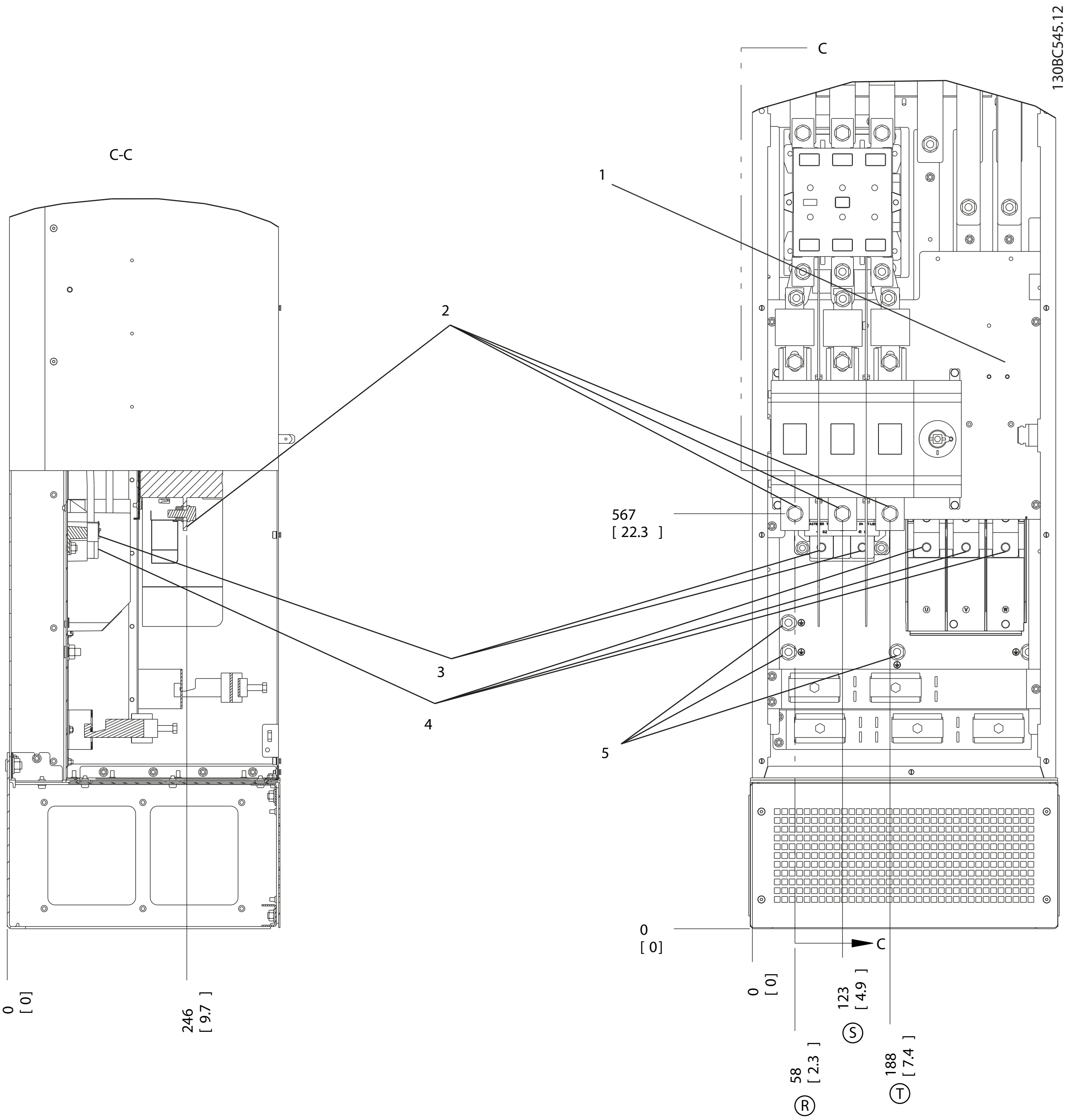


Illustration 6.58 Terminal Locations, D8h with Contactor and Disconnect Options

1	TB6 Terminal block for contactor
2	Mains Terminals
3	Brake Terminals
4	Motor Terminals
5	Earth/Ground Terminals

Table 6.31 Legend to *Illustration 6.58*

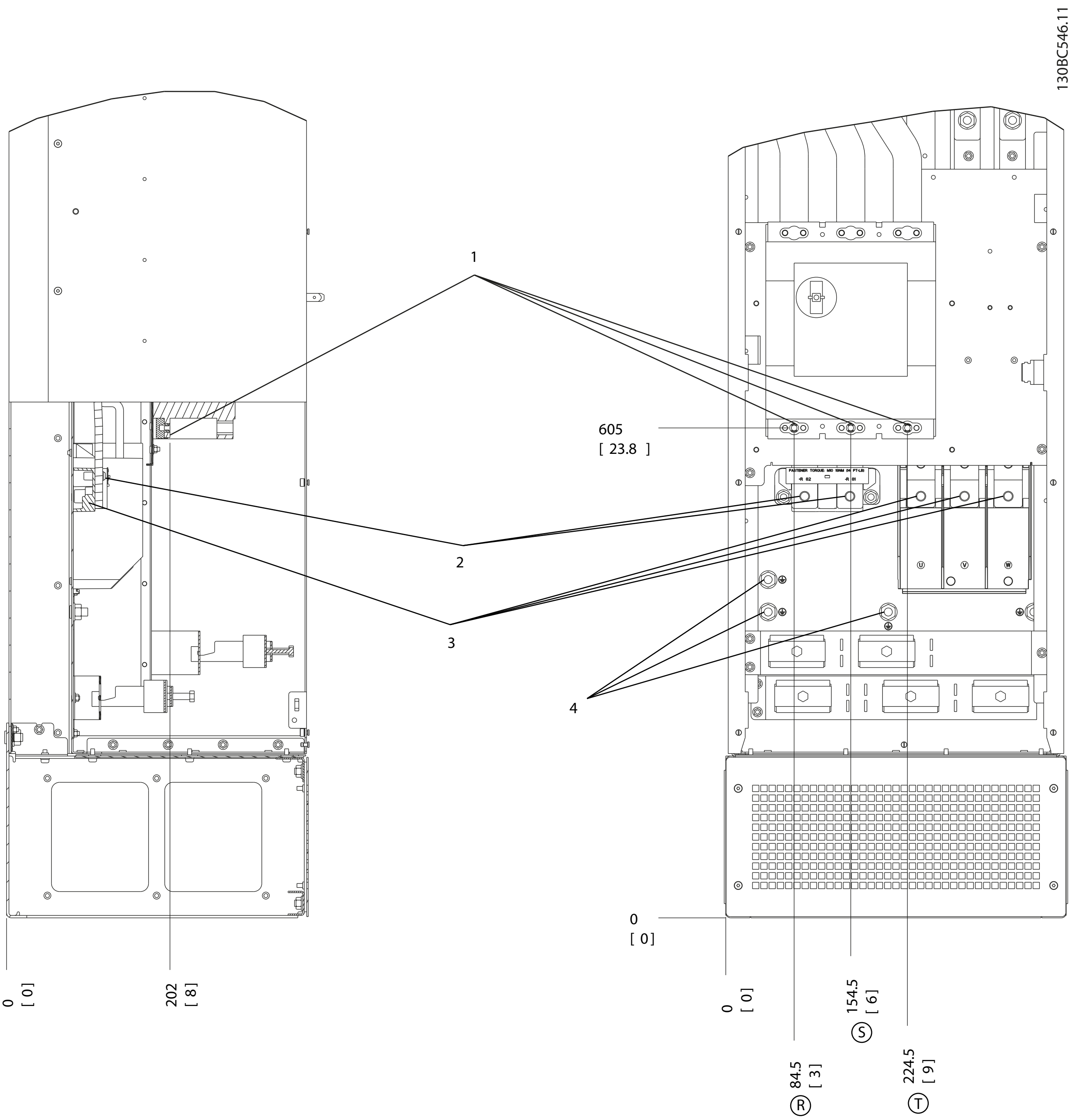


Illustration 6.59 Terminal Locations, D8h with Circuit Breaker Option

1	Mains Terminals
2	Brake Terminals
3	Motor Terminals
4	Earth/Ground Terminals

Table 6.32 Legend to *Illustration 6.59*

6

6.2.4 Terminal Locations - Frame Size E

Terminal Locations - Frame Size E1

Take the following position of the terminals into consideration when designing the cable access.

Dimensions are shown in mm [in].

NOTICE

Power cables are heavy and hard to bend. Consider the optimum position of the frequency converter to ensure easy installation of the cables. Each terminal allows the use of up to 4 cables with cable lugs or the use of a standard box lug. Earth is connected to a relevant termination point in the frequency converter.

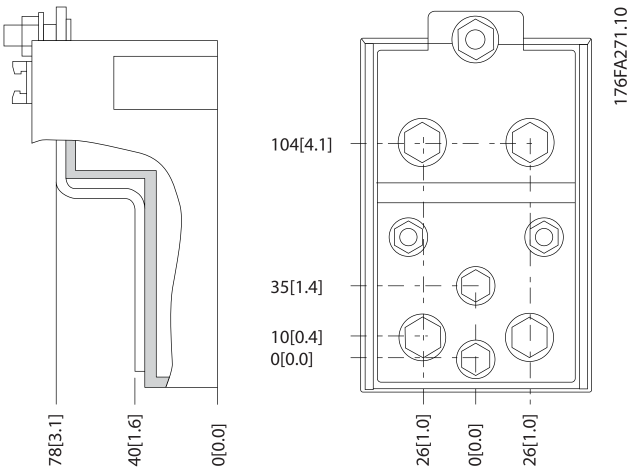


Illustration 6.60 Terminal in Detail

NOTICE

Power connections can be made to positions A or B.

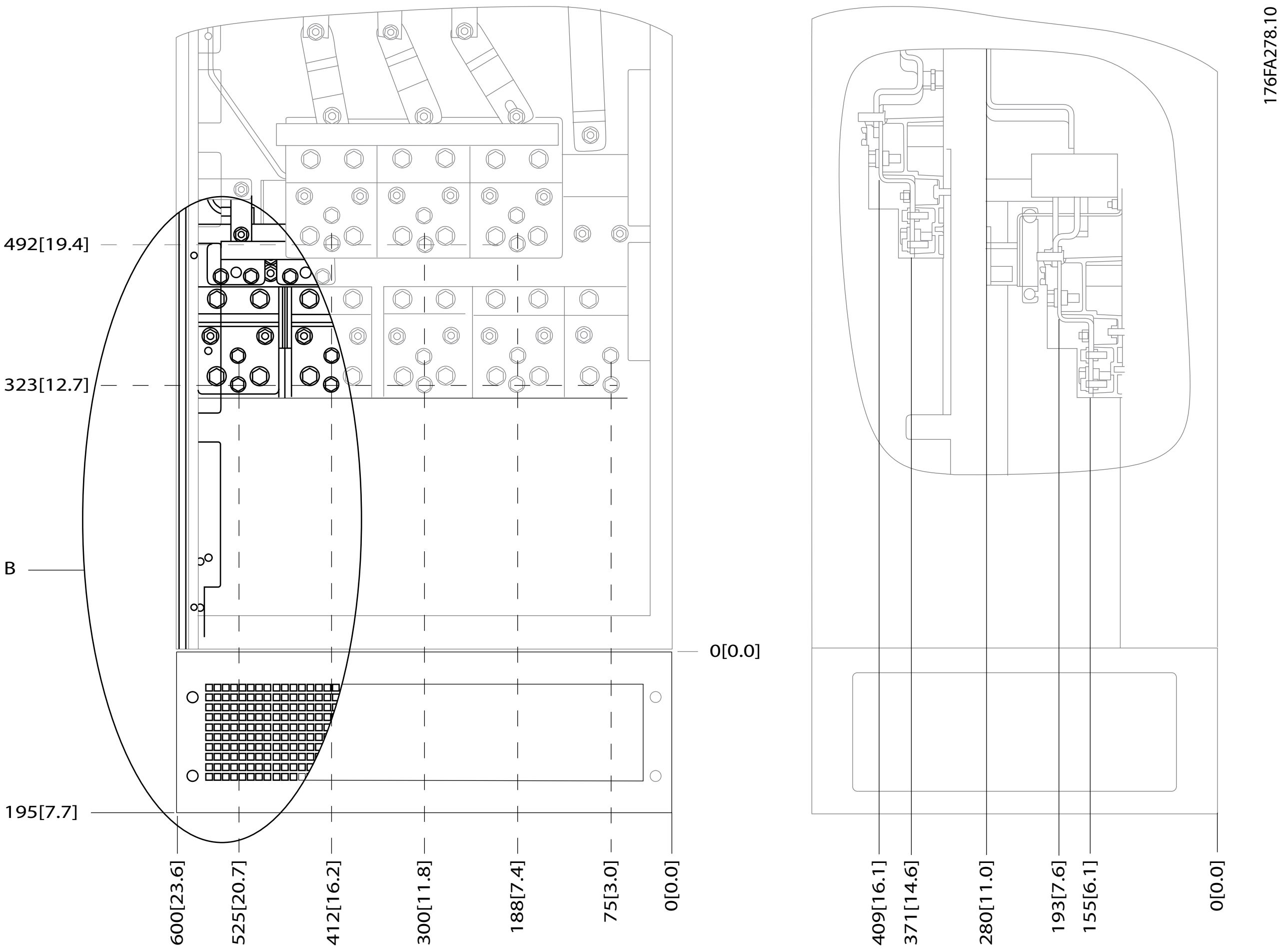


Illustration 6.61 IP21 (NEMA Type 1) and IP54 (NEMA Type 12) Enclosure Power Connection Positions

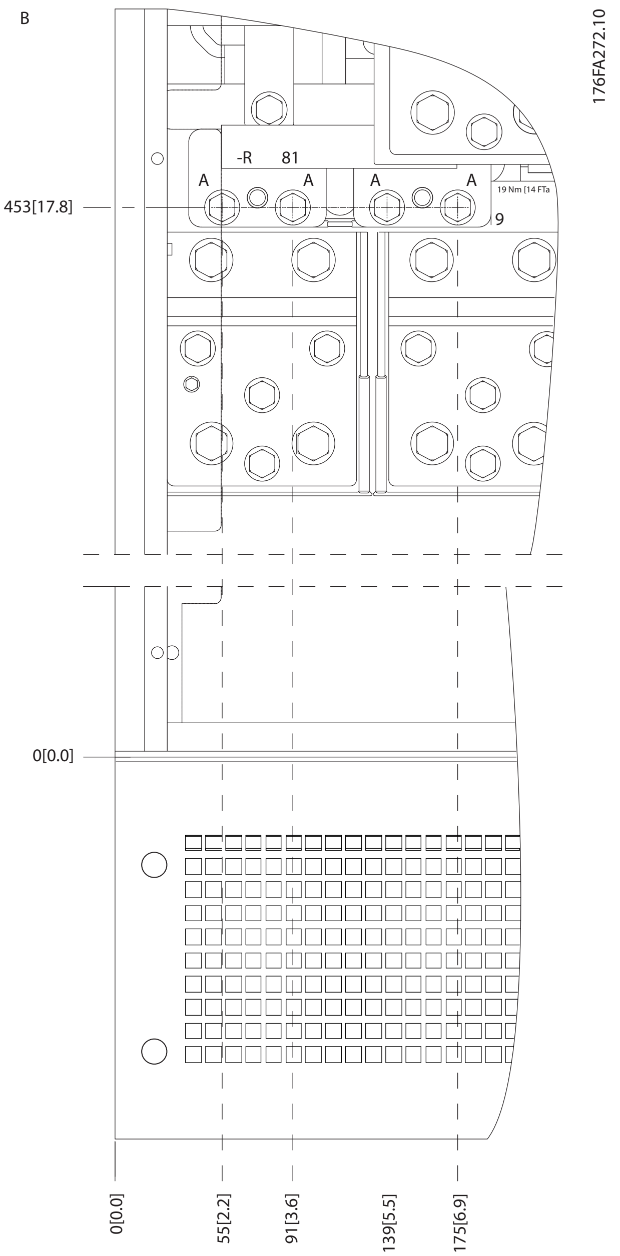


Illustration 6.62 IP21 (NEMA type 1) and IP54 (NEMA type 12) Enclosure Power Connection Positions (Detail B)

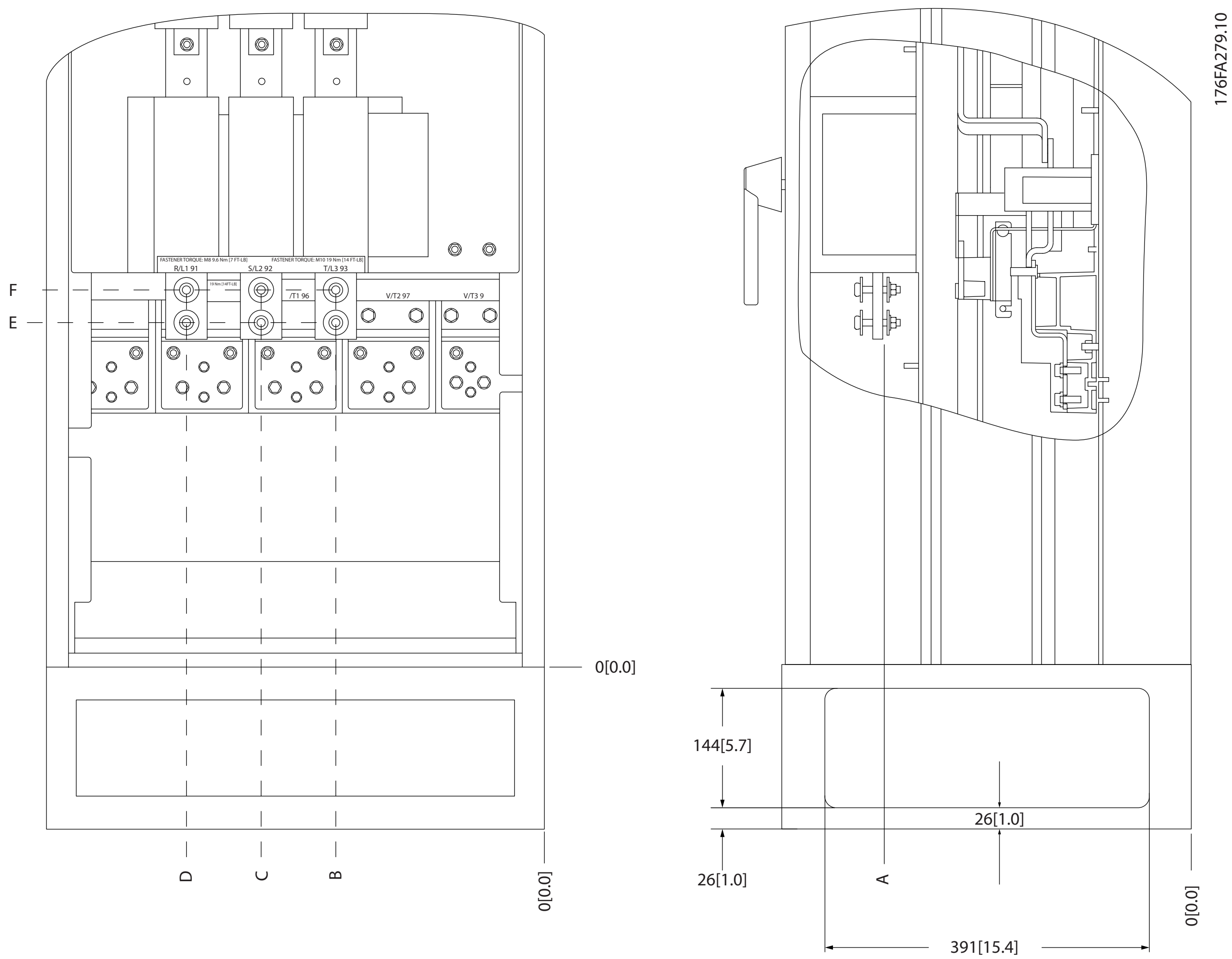


Illustration 6.63 IP21 (NEMA type 1) and IP54 (NEMA type 12) Enclosure Power Connection Position of Disconnect Switch

Frame size	Unit type	Dimension for disconnect terminal, mm (in)					
E1	IP54/IP21 UL and NEMA1/NEMA12	A	B	C	D	E	F
	250/315 kW (400 V) and 355/450-500/630 KW (690 V)	381 (15.0)	253 (9.9)	342 (13.5)	431 (17.0)	562 (22.1)	N/A
	315/355-400/450 kW (400 V)	371 (14.6)	251 (9.9)	341 (13.4)	431 (17.0)	416 (16.4)	455 (17.9)

Table 6.33 Legend to *Illustration 6.63*

Terminal Locations - Frame Size E2

Take the following position of the terminals into consideration when designing the cable access.

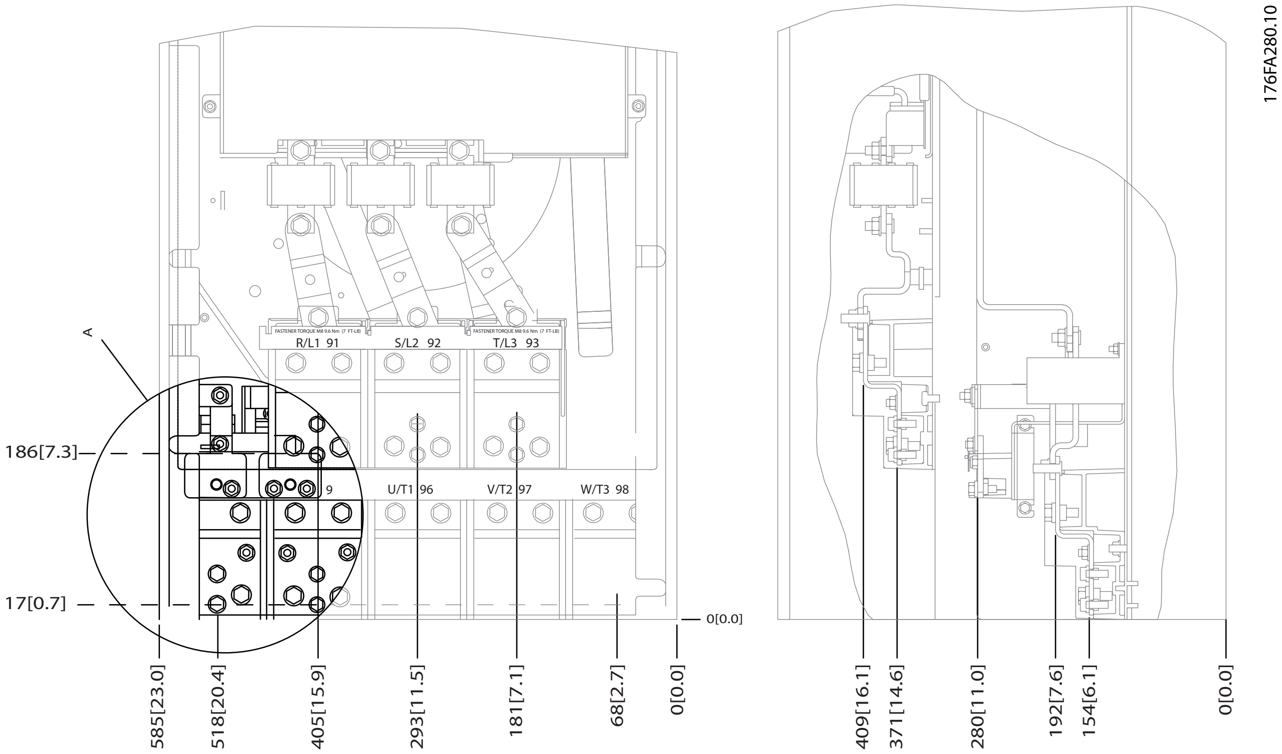


Illustration 6.64 IP00 Enclosure Power Connection Positions

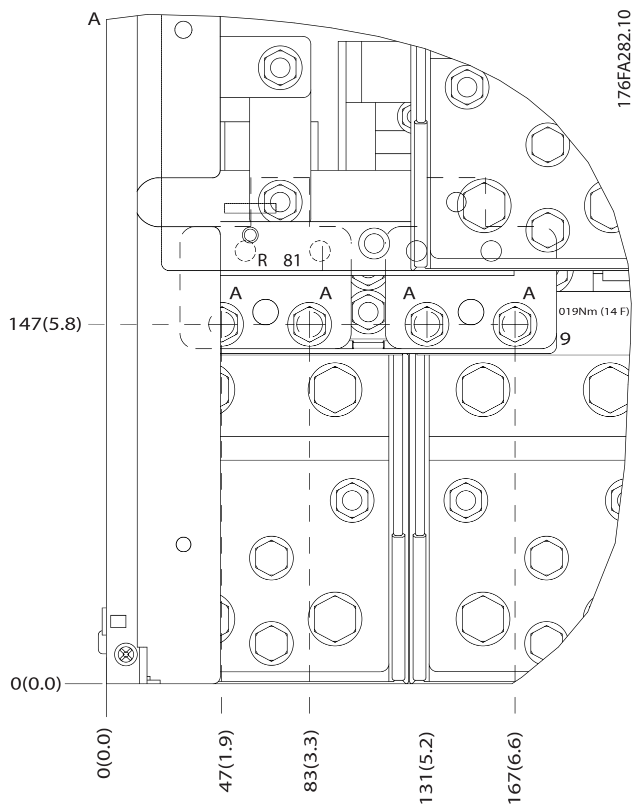


Illustration 6.65 IP00 Enclosure Power Connection Positions

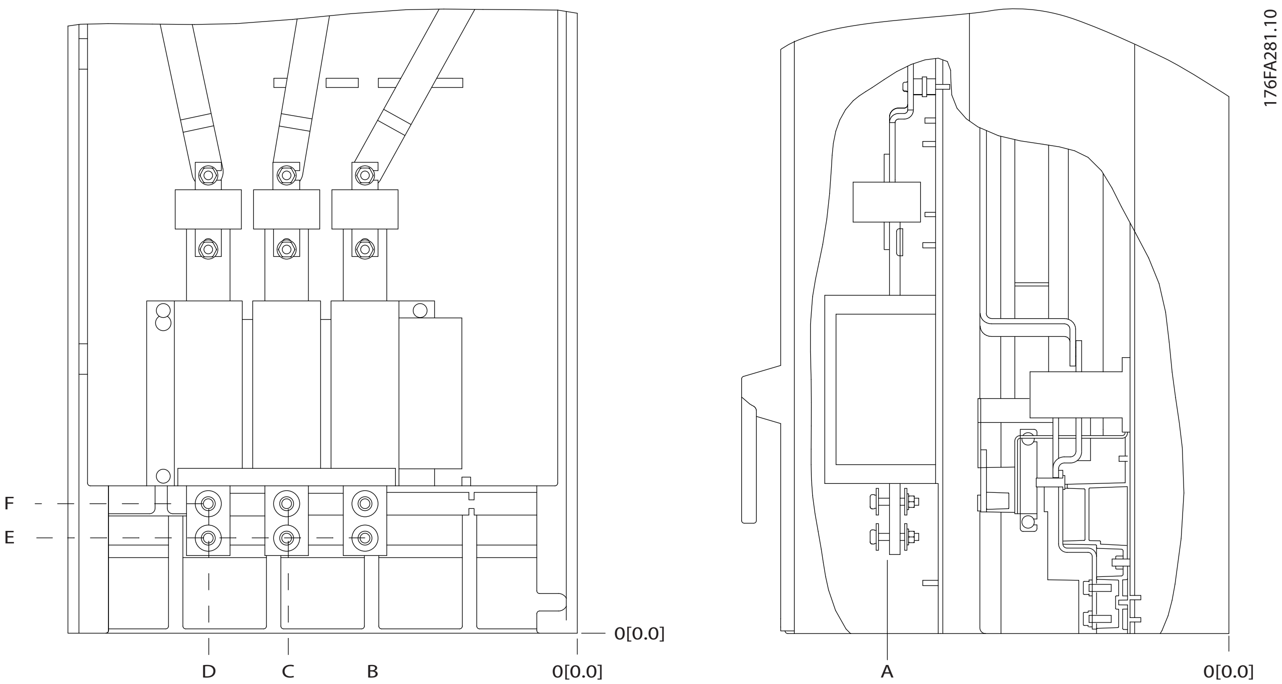


Illustration 6.66 IP00 Enclosure Power Connections, Position of Disconnect Switch

Frame size	Unit type	Dimension for disconnect terminal, mm (in)					
E2	IP00/CHASSIS	A	B	C	D	E	F
	250/315 kW (400 V) and 355/450-500/630 KW (690 V)	381 (15.0)	245 (9.6)	334 (13.1)	423 (16.7)	256 (10.1)	N/A
	315/355-400/450 kW (400 V)	383 (15.1)	244 (9.6)	334 (13.1)	424 (16.7)	109 (4.3)	149 (5.8)

Table 6.34 Disconnect Terminal Locations - Frame Size E2

6.2.5 Terminal Locations - Frame Size F

The F-frames have 4 different sizes, F1, F2, F3, and F4. The F1 and F2 consist of an inverter cabinet on the right and rectifier cabinet on the left. The F3 and F4 are F1/F2 units with an additional options cabinet to the left of the rectifier cabinet.

Terminal Locations - Frame Size F1 and F3

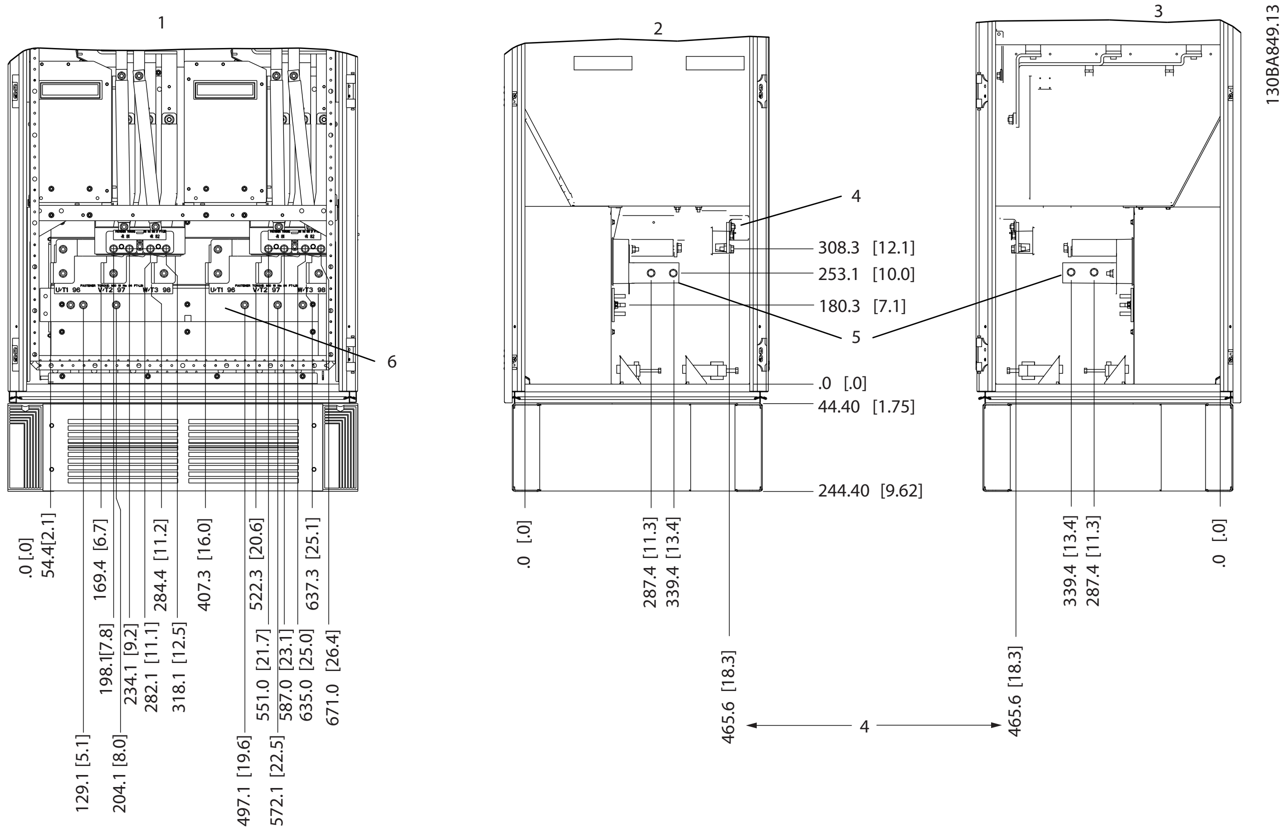


Illustration 6.67 Terminal Locations - Inverter Cabinet. Gland Plate is 42 mm below .0 Level.

1	Front View
2	Left Side View
3	Right Side View
4	Brake Terminals
5	Earth ground bar

Table 6.35 Legend to *Illustration 6.67*

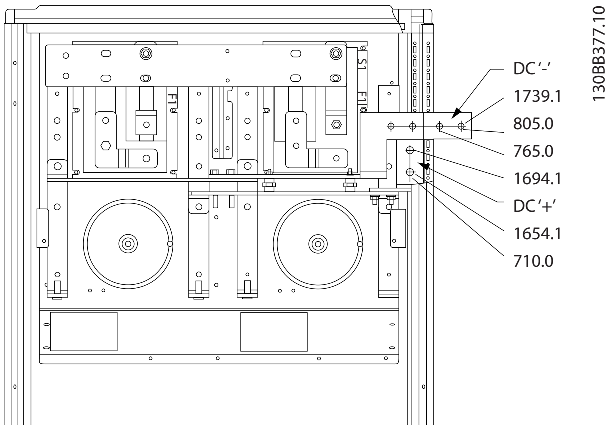


Illustration 6.68 Terminal Locations - Regeneration Terminals for F1 and F3

Terminal Locations - Frame Size F2 and F4

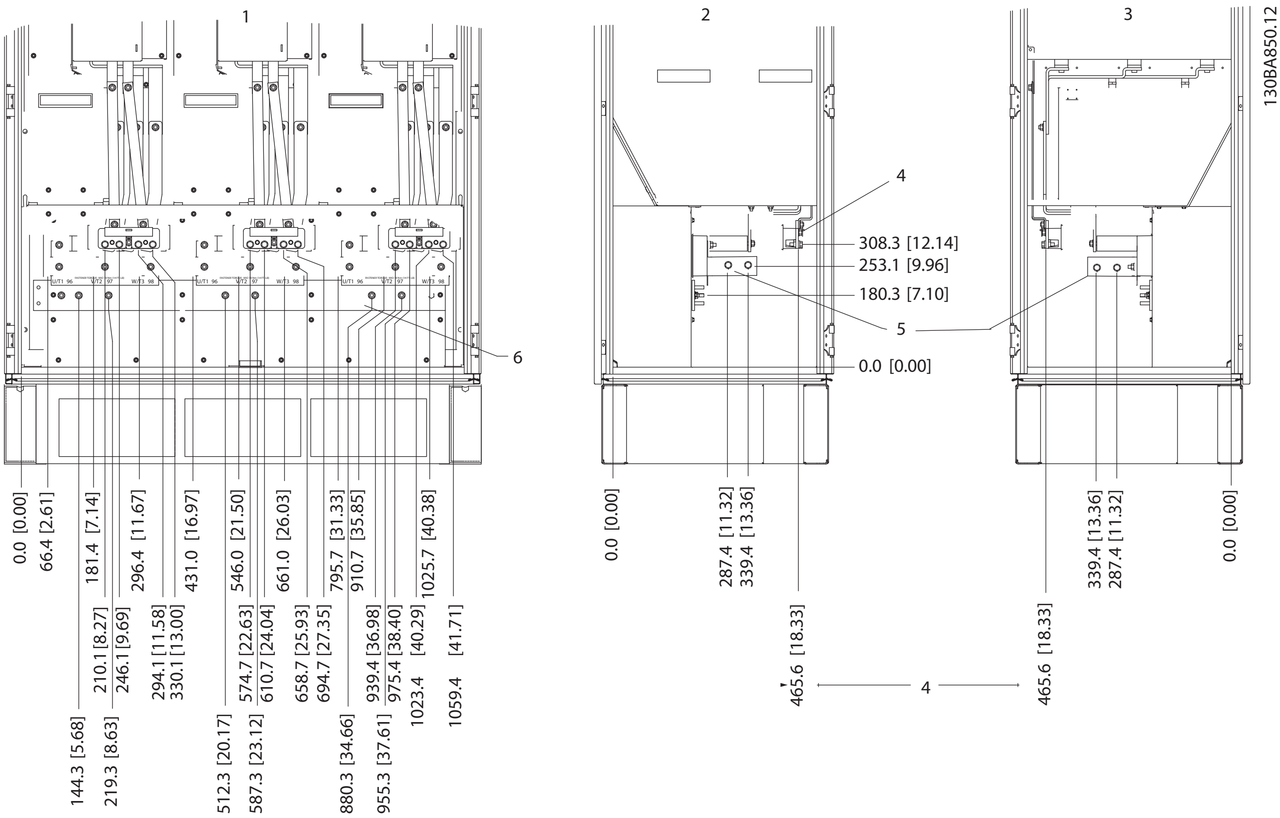


Illustration 6.69 Terminal Locations - Inverter Cabinet. Gland Plate is 42 mm below .0 Level.

1	Front View
2	Left Side View
3	Right Side View
4	Brake Terminals
5	Earth/Ground bar

Table 6.36 Legend to *Illustration 6.69*

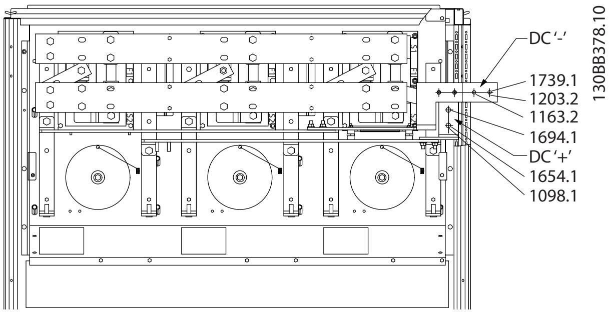
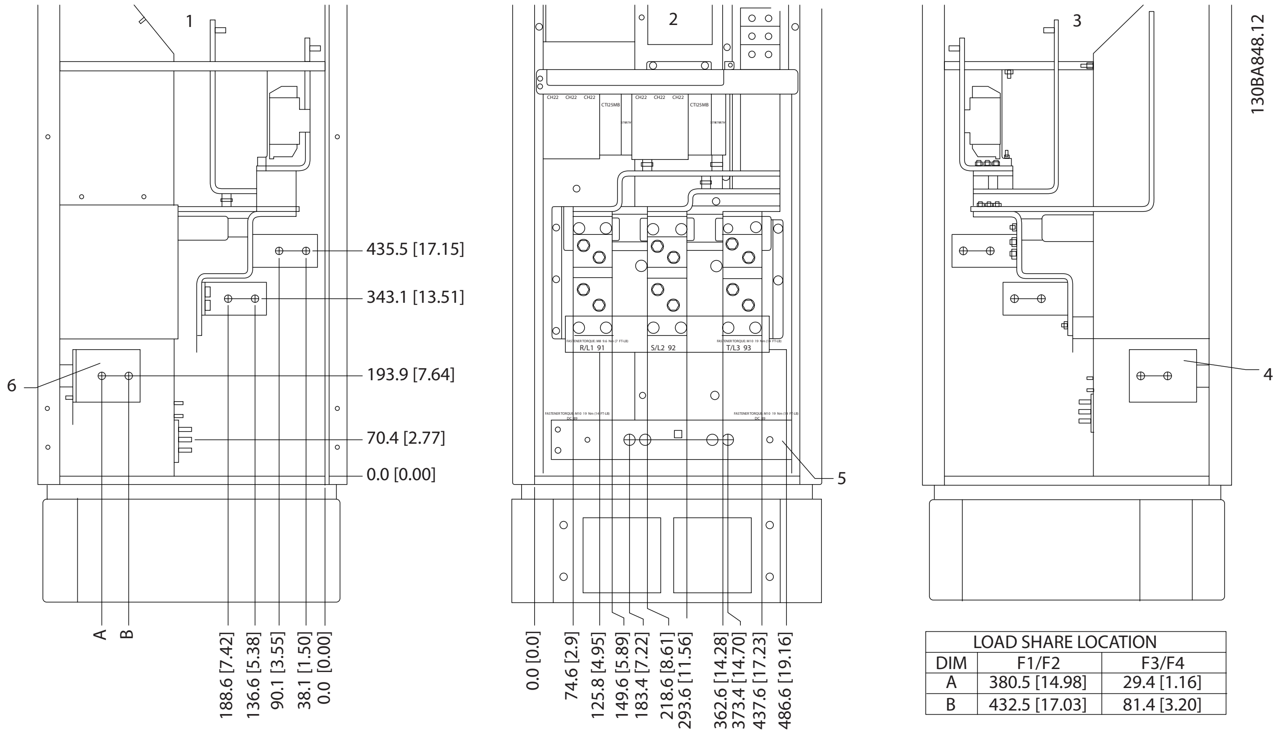


Illustration 6.70 Terminal Locations - Regeneration Terminals for F2 and F4

Terminal Locations - Rectifier (F1, F2, F3 and F4)



LOAD SHARE LOCATION		
DIM	F1/F2	F3/F4
A	380.5 [14.98]	29.4 [1.16]
B	432.5 [17.03]	81.4 [3.20]

Illustration 6.71 Terminal Locations - Rectifier. Gland Plate is 42 mm below .0 Level.

1	Left Side View
2	Front View
3	Right Side View
4	Loadshare Terminal (-)
5	Earth/Ground Bar
6	Loadshare Terminal (+)

Table 6.37 Legend to *Illustration 6.71*

Terminal Locations - Options Cabinet (F3 and F4)

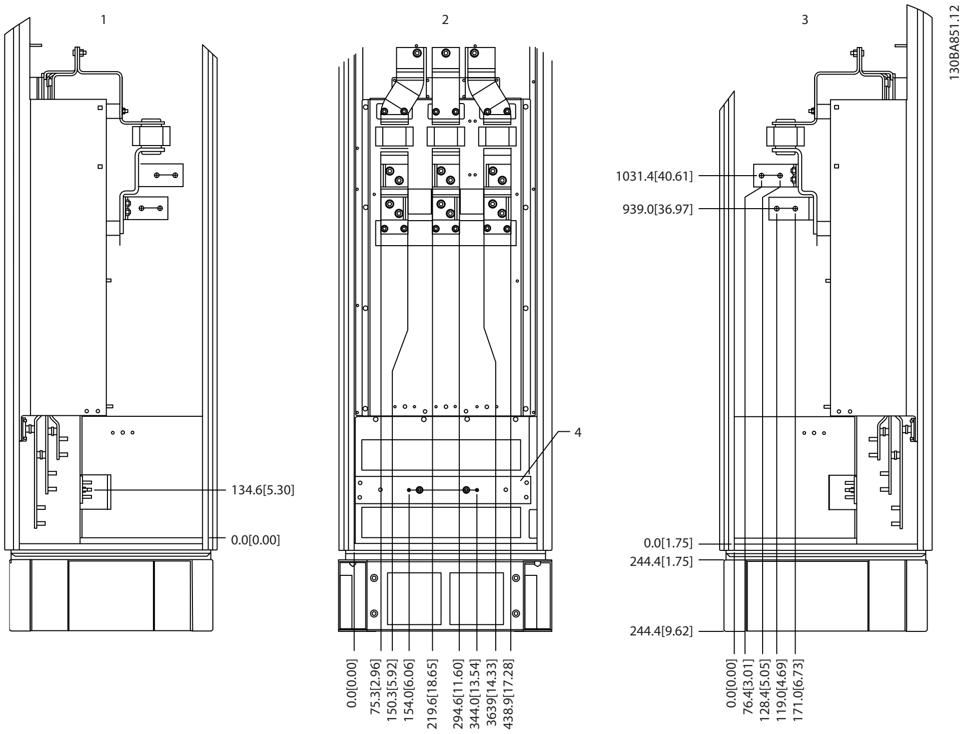


Illustration 6.72 Terminal Locations - Options Cabinet (Left, Front and Right Side View). Gland Plate is 42 mm below .0 Level.

1	Earth/Ground bar

Table 6.38 Legend to *Illustration 6.72*

Terminal Locations - Options Cabinet with Circuit Breaker/Molded Case Switch (F3 and F4)

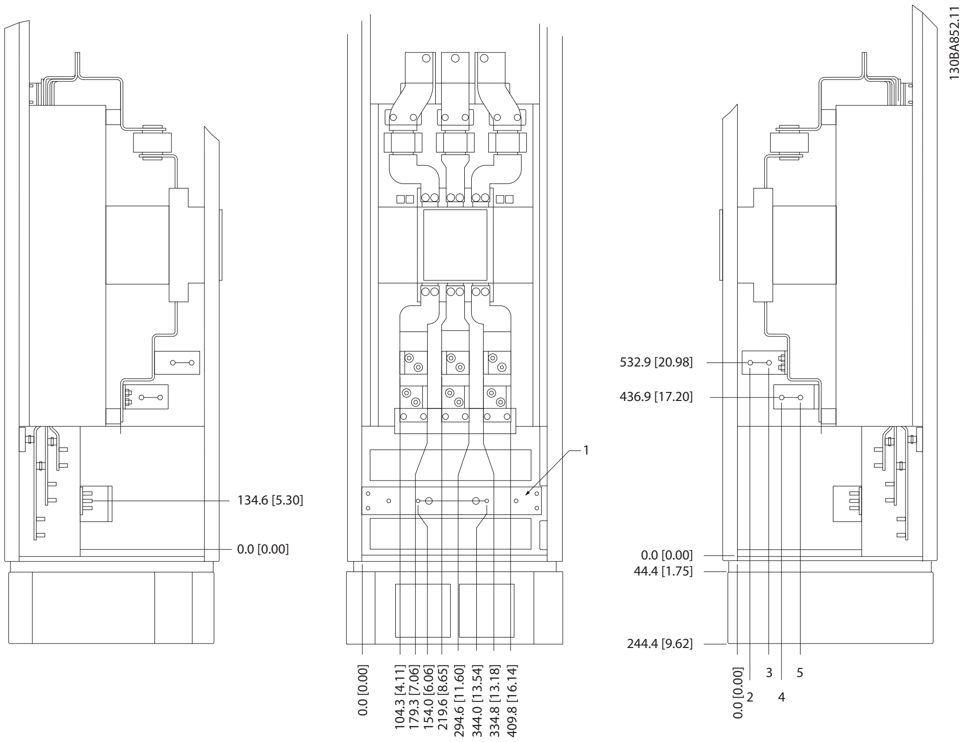


Illustration 6.73 Terminal Locations - Options Cabinet with Circuit Breaker/Molded Case Switch (Left, Front and Right Side View). Gland Plate is 42 mm below .0 Level.

1	Earth/Ground bar

Table 6.39 Legend to *Illustration 6.73*

Power size	2	3	4	5
450 kW (480 V), 630-710 kW (690 V)	34.9	86.9	122.2	174.2
500-800 kW (480 V), 800-1000 kW (690 V)	46.3	98.3	119.0	171.0

Table 6.40 Dimension for Terminal

6.2.6 Terminal Locations - Frame Size F, 12-Pulse

The 12-Pulse F-frame enclosures have 6 different sizes. The F8, F10, and F12 consist of an inverter cabinet on the right and a rectifier cabinet on the left. The F9, F11, and F13 are F8, F10, and F12 units with an additional options cabinet to the left of the rectifier.

Terminal Locations - Inverter and Rectifier Frame Size F8 and F9

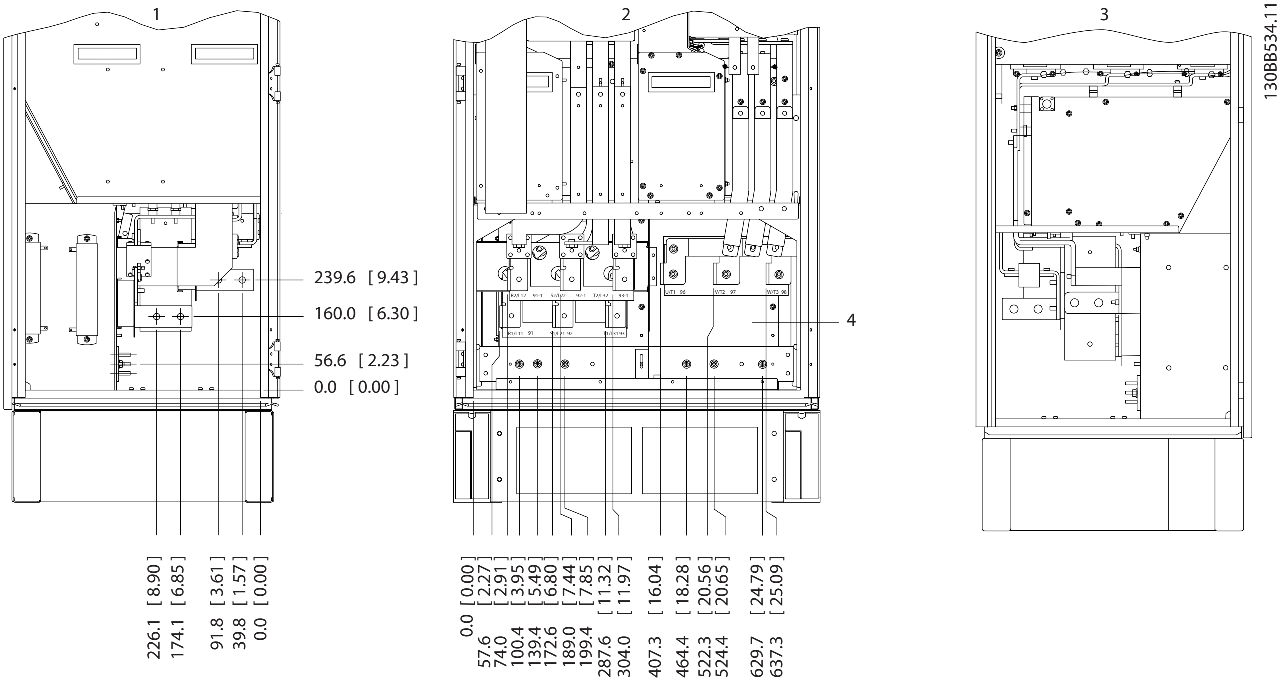


Illustration 6.74 Terminal Locations - Inverter and Rectifier Cabinet - F8 and F9. Gland Plate is 42 mm below .0 Level.

1	Left Side View
2	Front View
3	Right Side View
4	Earth/Ground Bar

Table 6.41 Legend to *Illustration 6.77*

Terminal Locations - Inverter Frame Size F10 and F11

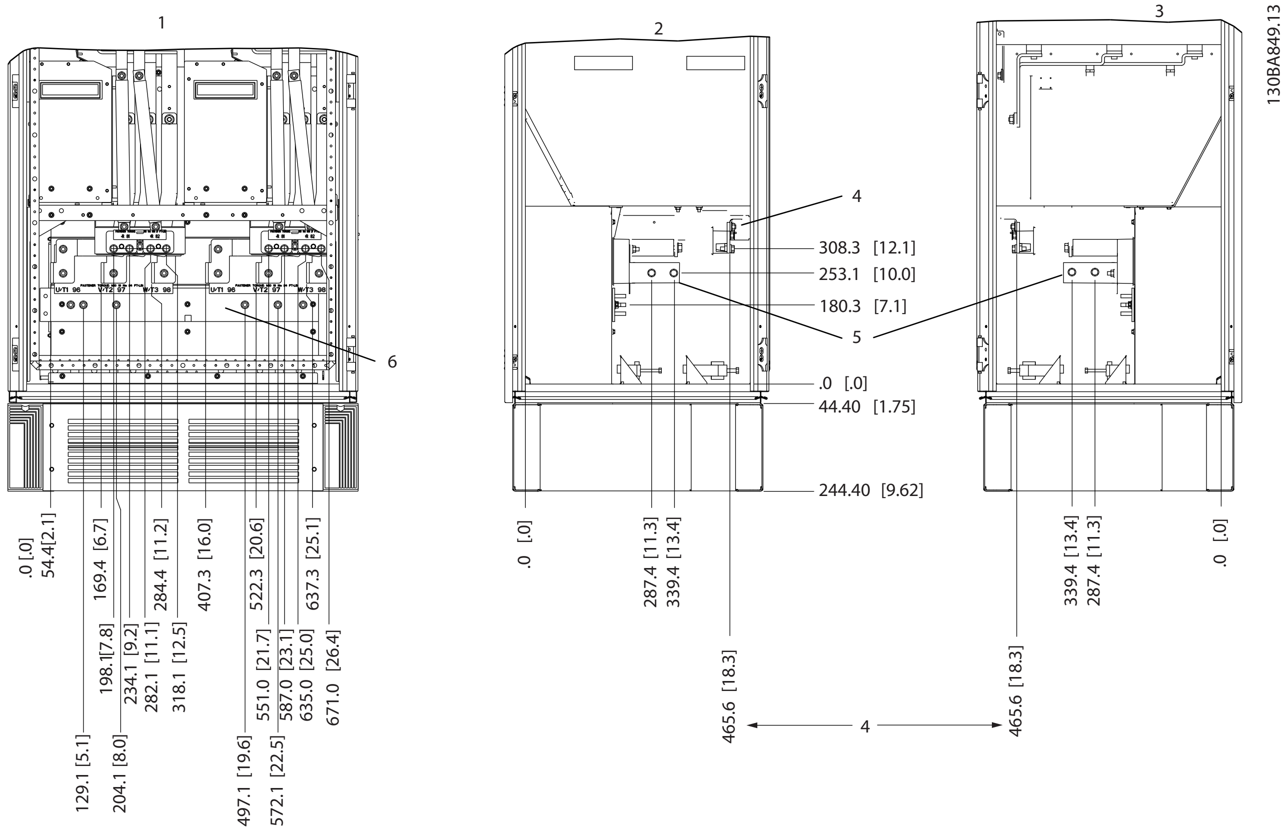


Illustration 6.75 Terminal Locations - Inverter Cabinet. Gland Plate is 42 mm below .0 Level.

1	Front View
2	Left Side View
3	Right Side View
4	Brake Terminals
5	Earth/Ground Bar

Table 6.42 Legend to *Illustration 6.67*

Terminal Locations - Inverter Frame Size F12 and F13

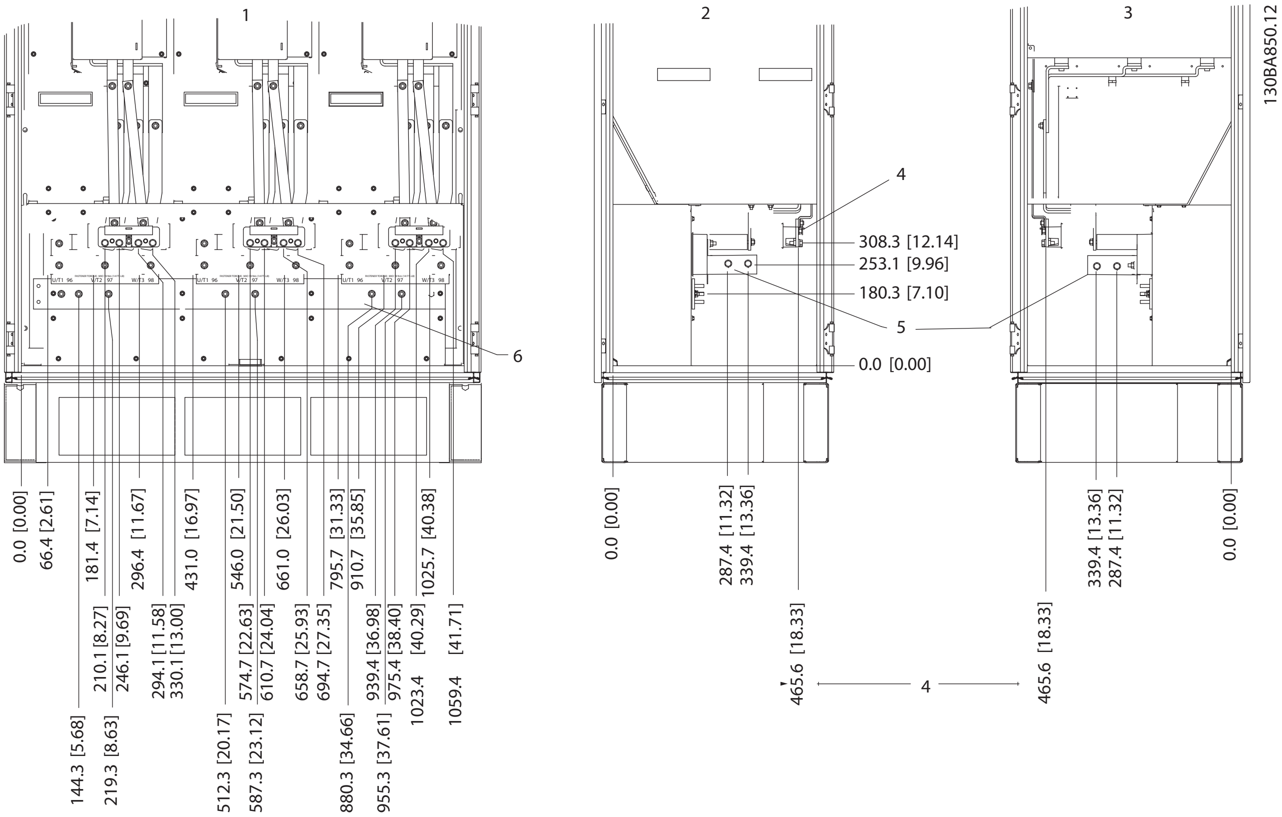


Illustration 6.76 Terminal Locations - Inverter Cabinet. Gland Plate is 42 mm below .0 Level.

1	Front View
2	Left Side View
3	Right Side View
4	Brake Terminals
5	Earth/Ground Bar

Table 6.43 Legend to *Illustration 6.69*

6

Terminal Locations - Rectifier (F10, F11, F12 and F13)

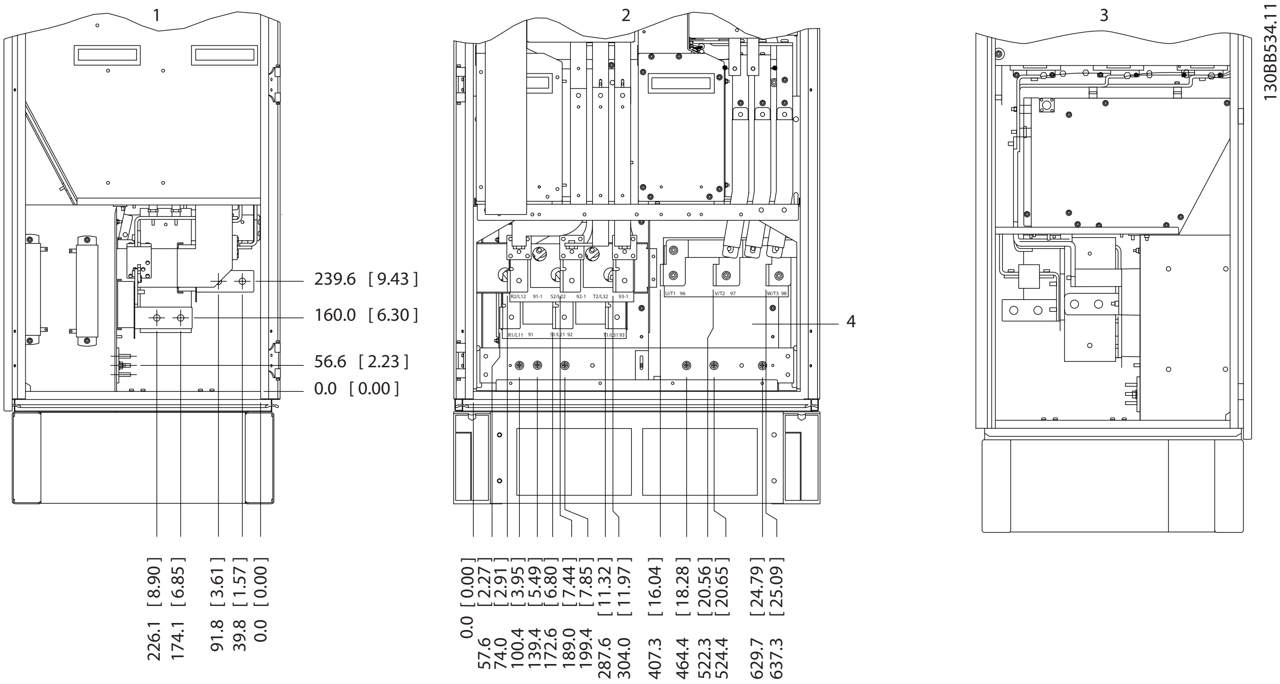


Illustration 6.77 Terminal Locations - Rectifier. Gland Plate is 42 mm below .0 Level.

1	Left Side View
2	Front View
3	Right Side View
4	Earth/Ground Bar

Table 6.44 Legend to *Illustration 6.77*

Terminal Locations - Options Cabinet Frame Size F9

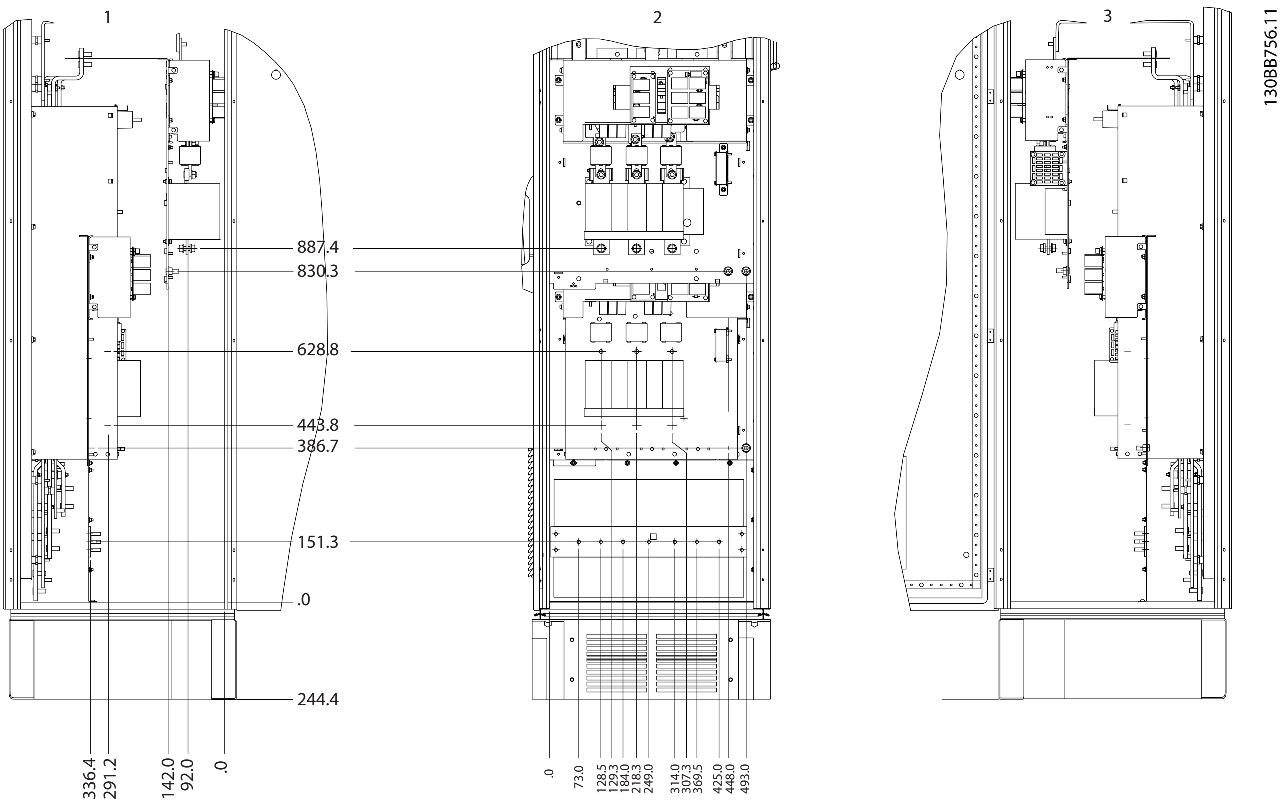


Illustration 6.78 Terminal Locations - Options Cabinet.

1	Left Side View
2	Front View
3	Right Side View

Table 6.45 Legend to *Illustration 6.78*

Terminal Locations - Options Cabinet Frame Size F11/F13

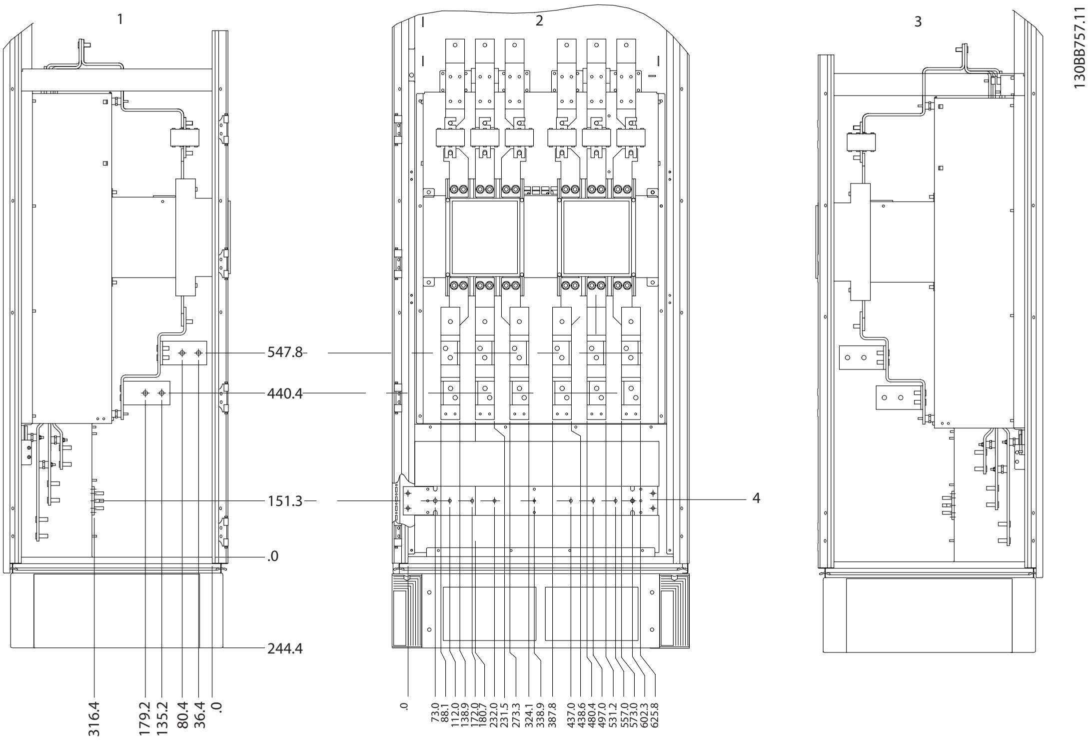


Illustration 6.79 Terminal Locations - Options Cabinet.

1	Left Side View
2	Front View
3	Right Side View
4	Earth/Ground Bar

Table 6.46 Legend to *Illustration 6.79*

6.2.7 Gland/Conduit Entry - IP21 (NEMA 1) and IP54 (NEMA12)

Cables are connected through the gland plate from the bottom. Remove the plate and plan where to place the entry for the glands or conduits. The following illustrations show the cable entry points viewed from the bottom of various frequency converters.

NOTICE

The gland plate must be fitted to the frequency converter to ensure the specified protection degree.

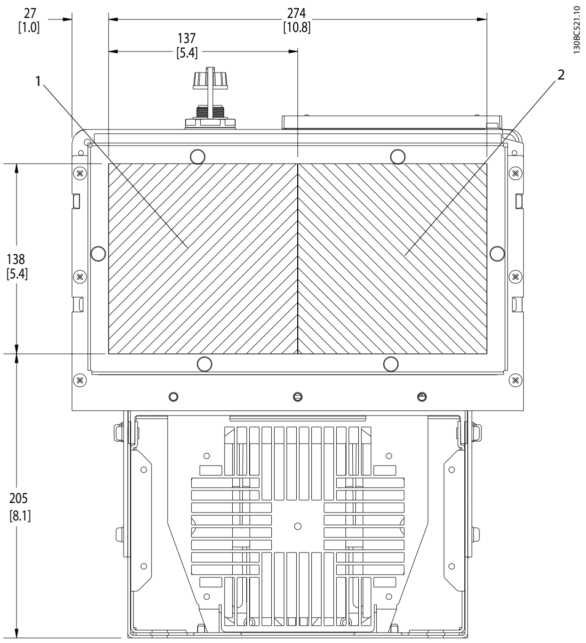


Illustration 6.80 D1h, Bottom View 1) Mains Side 2) Motor Side

1	Mains Side
2	Motor Side

Table 6.47 Legend to *Illustration 6.80*

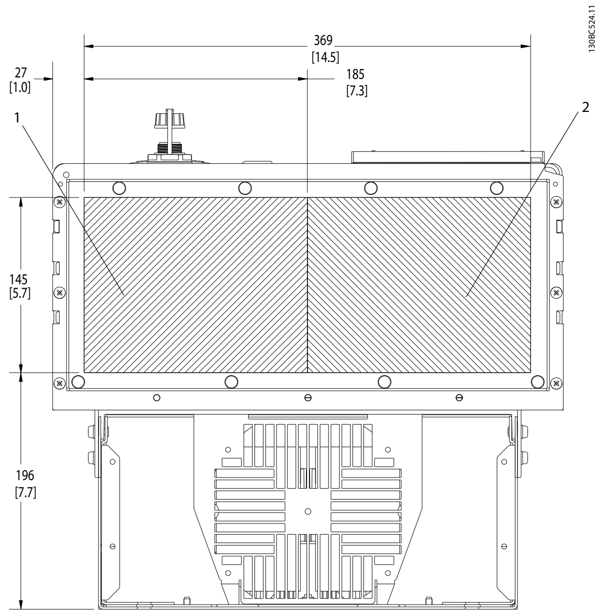


Illustration 6.81 D2h, Bottom View

1	Mains Side
2	Motor Side

Table 6.48 Legend to *Illustration 6.81*

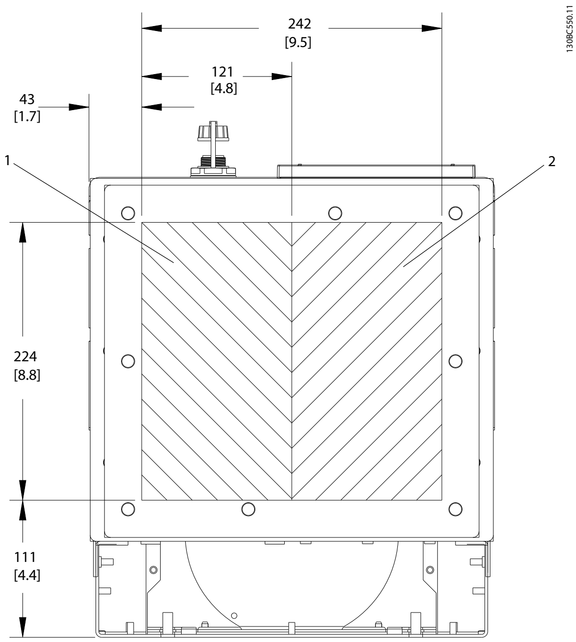


Illustration 6.82 D5h & D6h, Bottom View

1	Mains Side
2	Motor Side

Table 6.49 Legend to *Illustration 6.82*

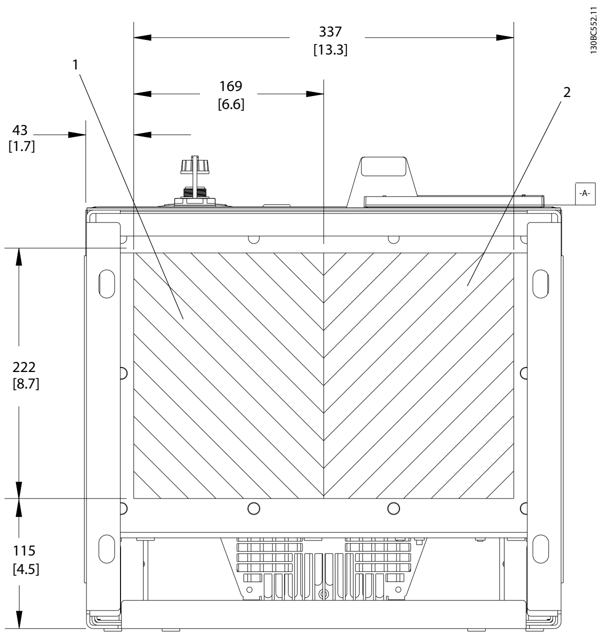


Illustration 6.83 D7h & D8h, Bottom View

1	Mains Side
2	Motor Side

Table 6.50 Legend to *Illustration 6.83*

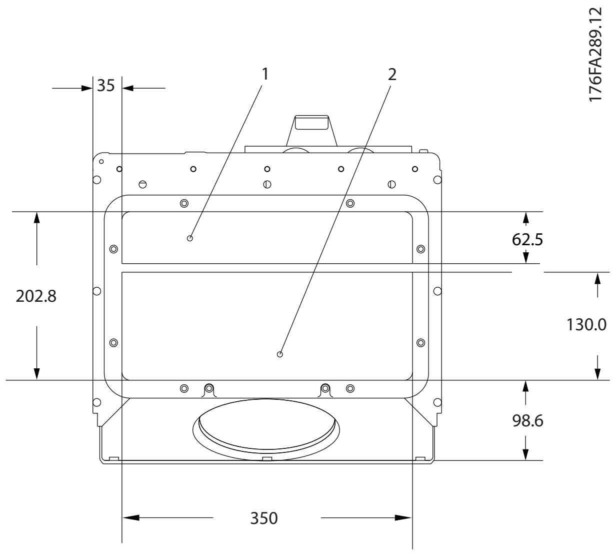


Illustration 6.84 E1, Bottom View

1	Mains Side
2	Motor Side

Table 6.51 Legend to *Illustration 6.84*

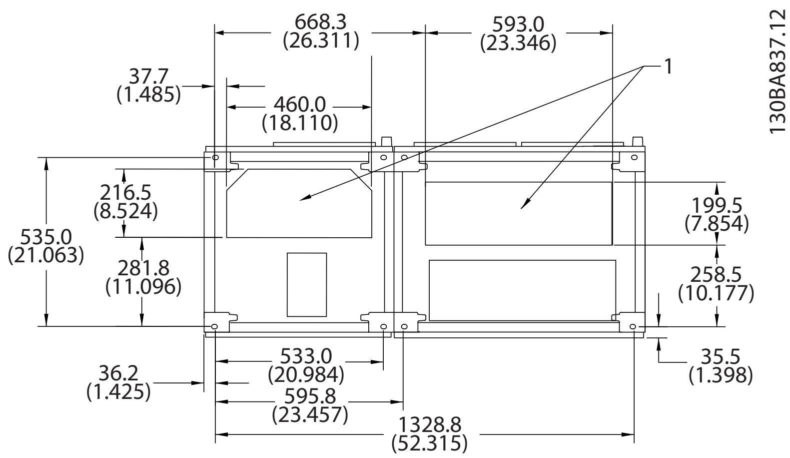


Illustration 6.85 F1, Bottom View

1	Cable conduit entry

Table 6.52 Legend to *Illustration 6.85*

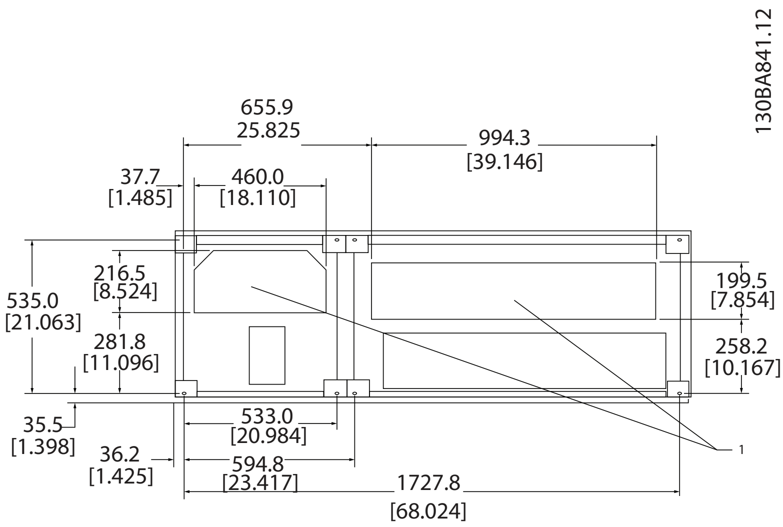


Illustration 6.86 F2, Bottom View

1	Cable conduit entry

Table 6.53 Legend to *Illustration 6.86*

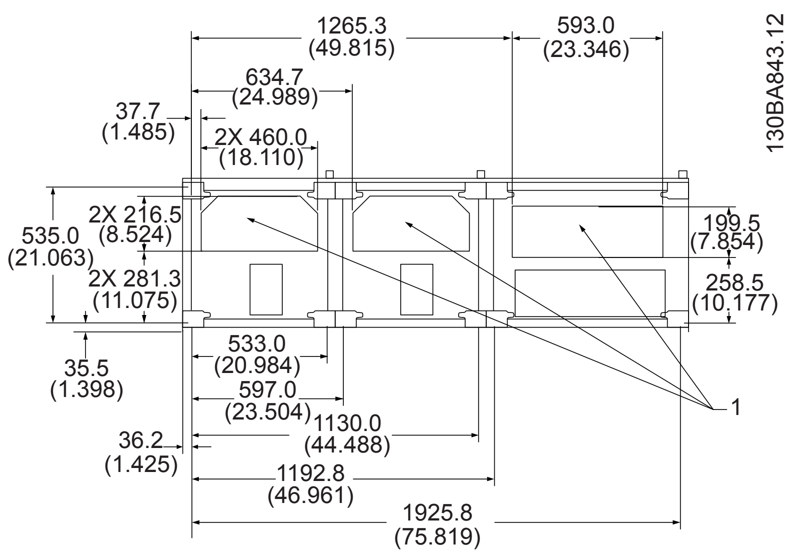


Illustration 6.87 F3, Bottom View

1	Cable conduit entry

Table 6.54 Legend to *Illustration 6.87*

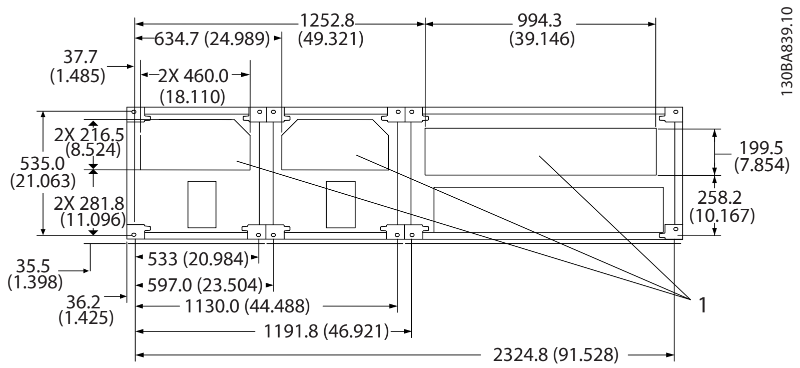


Illustration 6.88 F4, Bottom View

1	Cable conduit entry

Table 6.55 Legend to *Illustration 6.88*

6.2.8 Gland/Conduit Entry, 12-Pulse - IP21 (NEMA 1) and IP54 (NEMA12)

The following illustrations show the cable entry points as viewed from the bottom of the frequency converter.

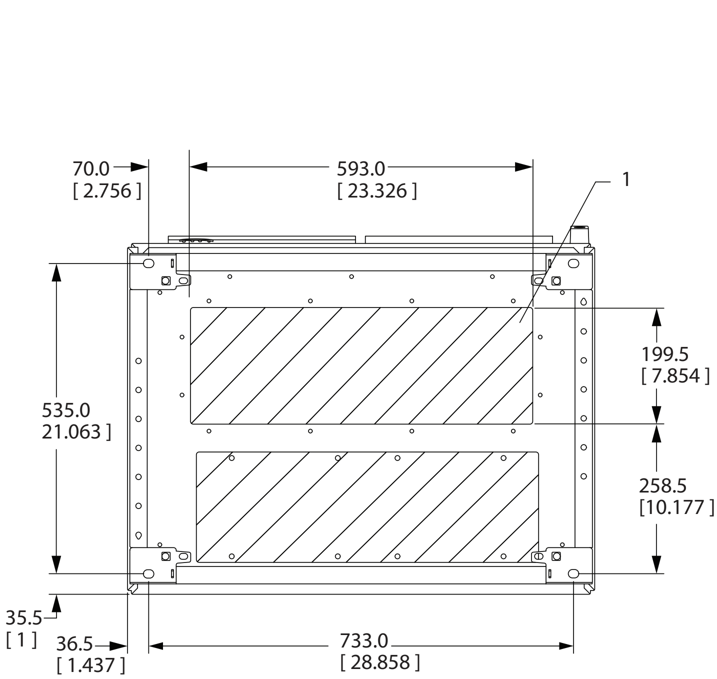


Illustration 6.89 Frame Size F8

1	Place conduits in shaded areas

Table 6.56 Legend to *Illustration 6.89*

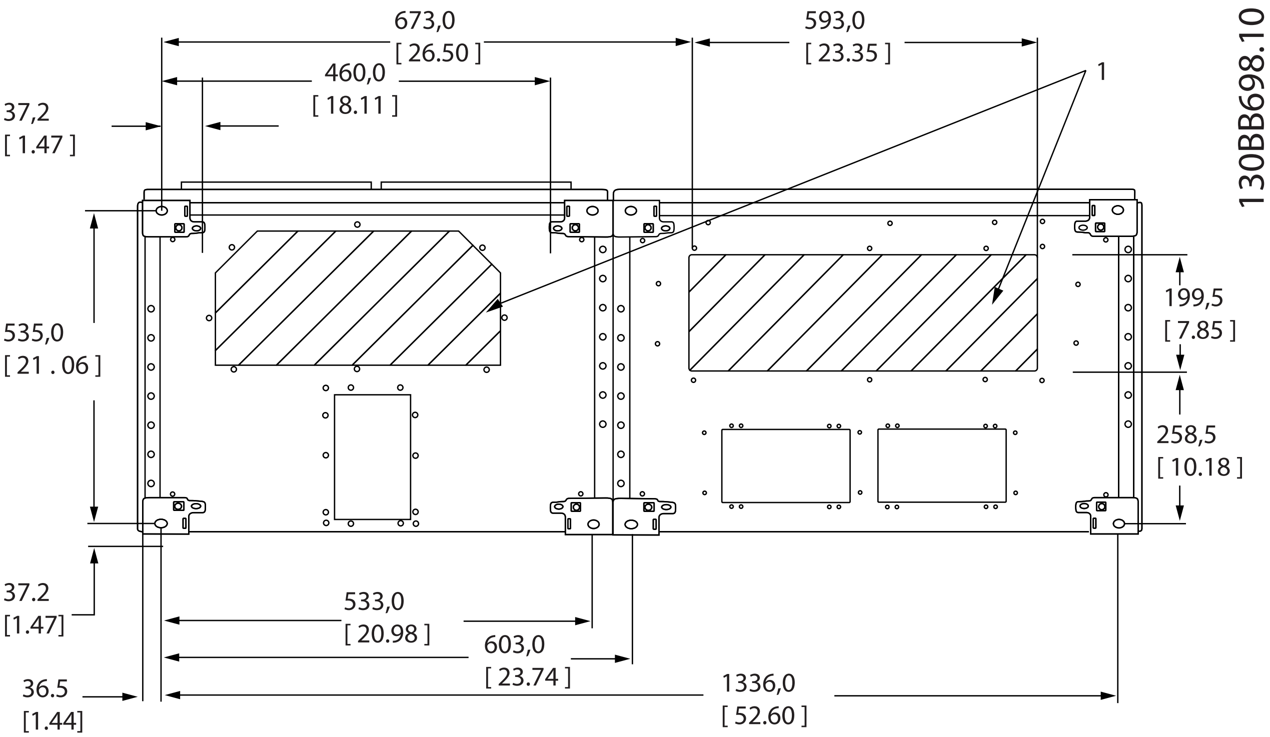


Illustration 6.90 Frame Size F9

1	Place conduits in shaded areas

Table 6.57 Legend to *Illustration 6.90*

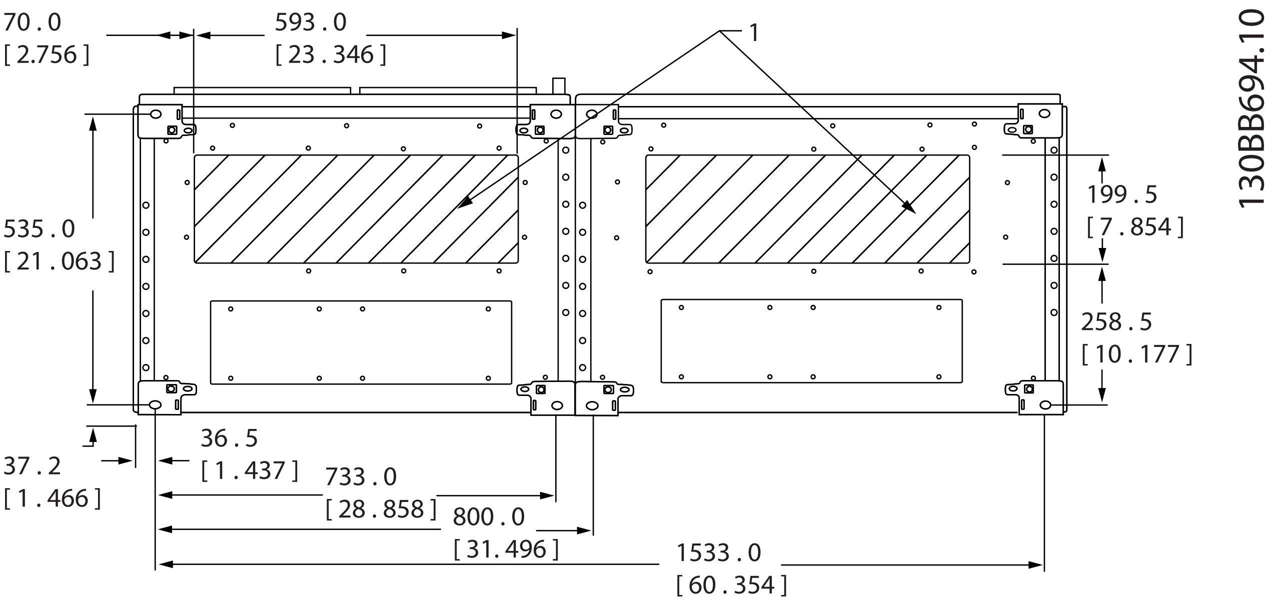


Illustration 6.91 Frame Size F10

1	Place conduits in shaded areas

Table 6.58 Legend to *Illustration 6.91*

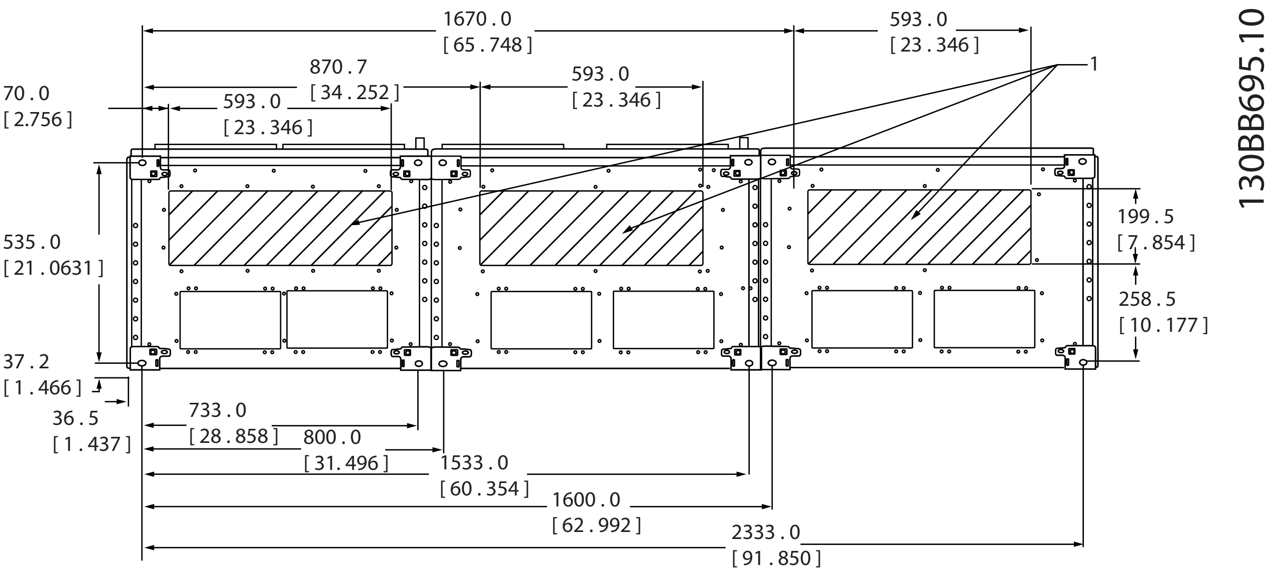


Illustration 6.92 Frame Size F11

1	Place conduits in shaded areas

Table 6.59 Legend to *Illustration 6.92*

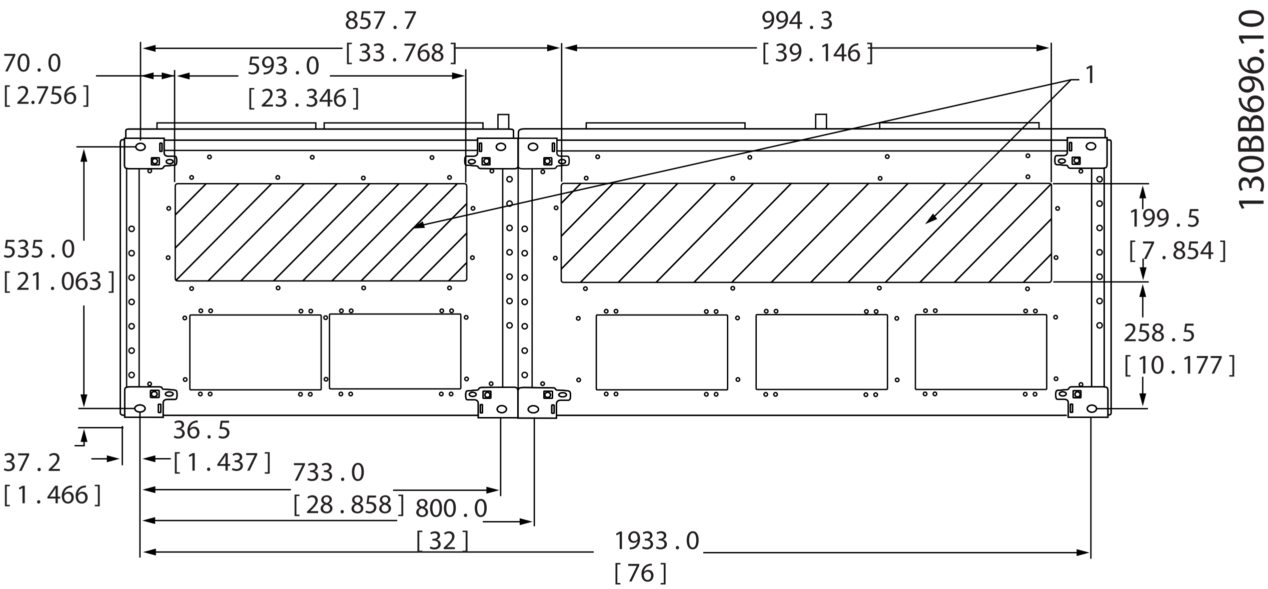


Illustration 6.93 Frame Size F12

1	Place conduits in shaded areas

Table 6.60 Legend to *Illustration 6.93*

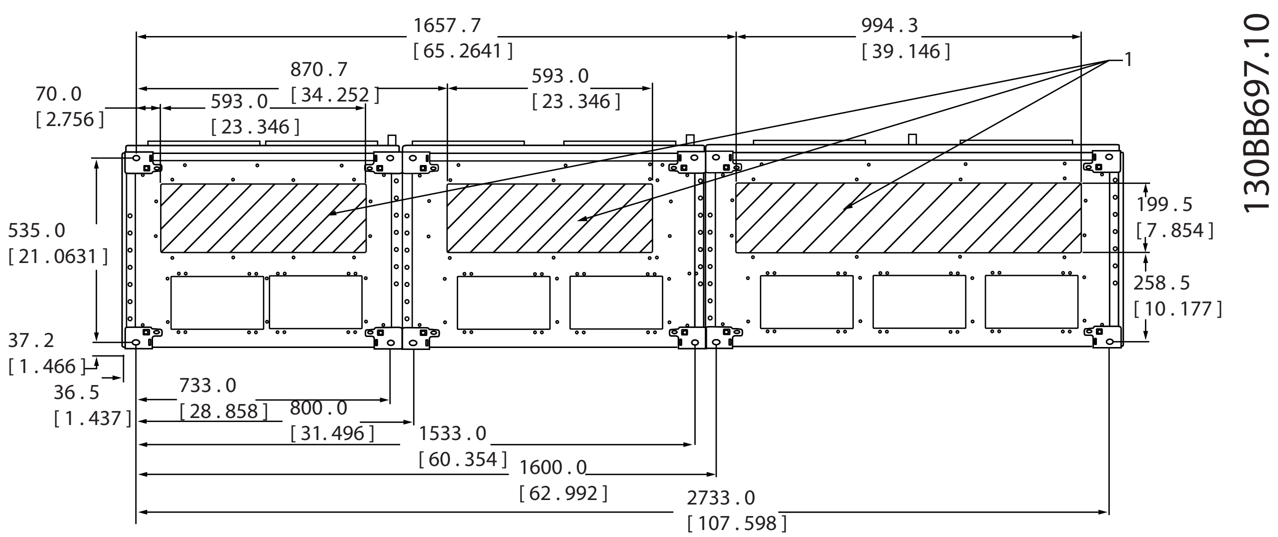


Illustration 6.94 Frame Size F13

1	Place conduits in shaded areas

Table 6.61 Legend to *Illustration 6.94*

6.2.9 Cooling and Airflow

Cooling

Cooling can be achieved through one of the following methods:

- cooling ducts in the bottom and the top of the unit
- back-channel cooling
- combination of the cooling ducts and the back-channel cooling

Duct cooling

A dedicated option has been developed to optimise installation of IP00/chassis frequency converters in Rittal TS8 enclosures utilizing the fan of the frequency converter for forced air cooling of the back channel. The air out the top of the enclosure could be ducted outside a facility so the heat losses from the back channel are not dissipated within the control room, reducing air conditioning requirements of the facility.

Back cooling

The back channel air can also be ventilated in and out the back of a Rittal TS8 enclosure. Using this method, the back channel could take air from outside the facility and then return the heat losses outside the facility, thus reducing air conditioning requirements.

NOTICE

A door fan is required on the enclosure to remove the heat losses not contained in the back channel of the frequency converter and any additional losses generated from other components installed inside the enclosure. The total required air flow must be calculated so that the appropriate fans can be selected. Some enclosure manufacturers offer software for performing the calculations.

Airflow

The necessary airflow over the heat sink must be secured. The flow rate is shown in *Table 6.62*.

Drive type	Drive size		Frame size	Enclosure protection	Airflow m3/h (cfm)	
	380-480 V (T5)	525-690 V (T7)			Door fan(s)/Top fan	Heatsink fan(s)
6-Pulse	N110 to N160	N75 to N160	D1h, D5h, D6h	IP21/NEMA 1 or IP54/NEMA 12	102 (60)	420 (250)
			D3h	IP20/chassis		
	N200 to N315	N200 to N400	D2h, D7h, D8h	IP21/NEMA 1 or IP54/NEMA 12	204 (120)	840 (500)
			D4h	IP20/chassis		
	-	P450 to P500	E1	IP21/NEMA 1 or IP54/NEMA 12	340 (200)	1105 (650)
			E2	IP00/chassis	255 (150)	
	P355 to P450	P560 to P630	E1	IP21/NEMA 1 or IP54/NEMA 12	340 (200)	1445 (850)
			E2	IP00/chassis	255 (150)	
	P500 to P1M0	P710 to P1M4	F1/F3, F2/F4	IP21/NEMA 1	700 (412)	985 (580)
				IP54/NEMA 12	525 (309)	
12-Pulse	P315 to P1M0	P450 to P1M4	F8/F9, F10/F11, F12/F13	IP21/NEMA 1	700 (412)	985 (580)
				IP54/NEMA 12	525 (309)	

Table 6.62 Heatsink and Front Channel Airflow

** Airflow per fan. F-frames contain multiple fans.*

D-frame cooling fans
All frequency converters in this size range are equipped with cooling fans to provide airflow along the heatsink. Units in IP21 (NEMA 1) and IP54 (NEMA 12) enclosures have a fan mounted in the enclosure door to provide more airflow to the unit. IP20 enclosures have a fan mounted to the top of the unit for more cooling. There is a small 24 V DC mixing fan mounted under the input plate. This fan operates anytime the frequency converter is powered on.

DC voltage from the power card powers the fans. The mixing fan is powered by 24 V DC from the main switch mode power supply. The heatsink fan and the door/top fan are powered by 48 V DC from a dedicated switch mode power supply on the power card. Each fan has tachometer feedback to the control card to confirm that the fan is operating correctly. On/off and speed control of the fans is provided to reduce overall acoustical noise and extend the life of the fans.

The following conditions activate fans on the D-frame:

- Output current greater than 60% of nominal
- IGBT over temperature
- IGBT low temperature
- Control card over temperature
- DC hold active
- DC brake active
- Dynamic brake circuit active
- During pre-magnetization of the motor
- AMA in progress

In addition to these conditions, the fans are always started shortly after mains input power is applied to the frequency converter. Once fans are started, they run for a minimum of one minute.

The following conditions activate fans on the E- and F-frames:

1. AMA
2. DC Hold
3. Pre-Mag
4. DC Brake
5. 60% of nominal current is exceeded
6. Specific heatsink temperature exceeded (power size dependent)
7. Specific power card ambient temperature exceeded (power-size dependent)
8. Specific control card ambient temperature exceeded

External ducts
If more duct work is added externally to the Rittal cabinet the pressure drop in the ducting must be calculated. Use the derating charts to derate the frequency converter according to the pressure drop.

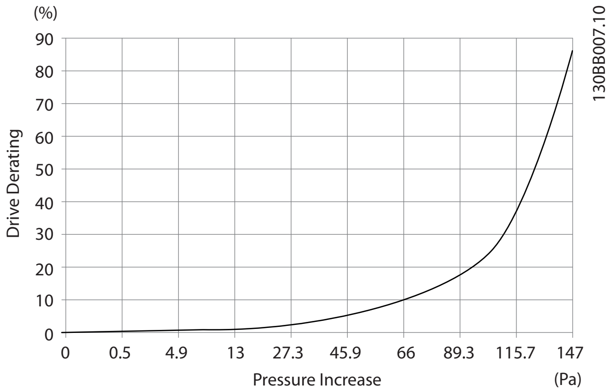


Illustration 6.95 D-frame Derating vs. Pressure Change. Frequency Converter Airflow: 450 cfm (765 m^3/h)

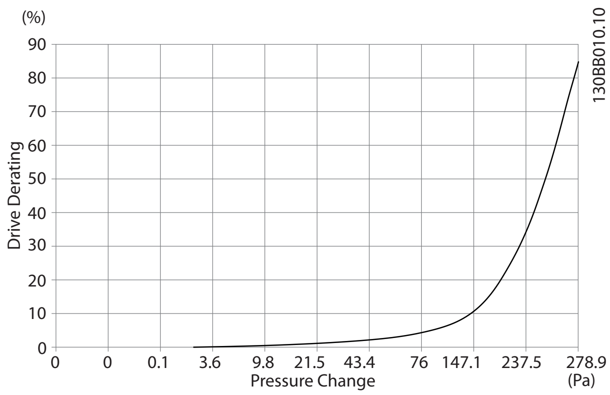


Illustration 6.96 E-frame Derating vs. Pressure Change (Small Fan), P250T5 and P355T7-P400T7. Frequency Converter Airflow: 650 cfm (1,105 m^3/h)

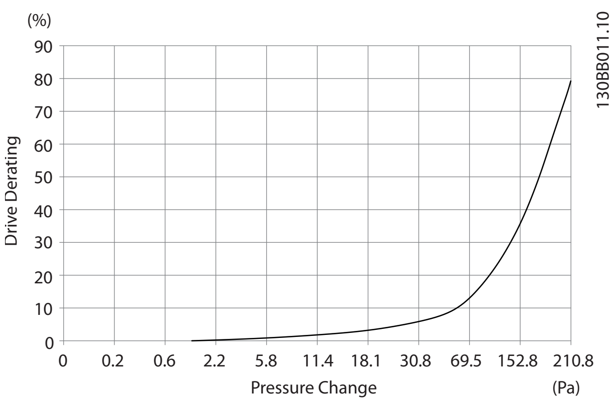


Illustration 6.97 E-frame Derating vs. Pressure Change (Large Fan), P315T5-P400T5 and P500T7-P560T7. Frequency Converter Airflow: 850 cfm (1,445 m^3/h)

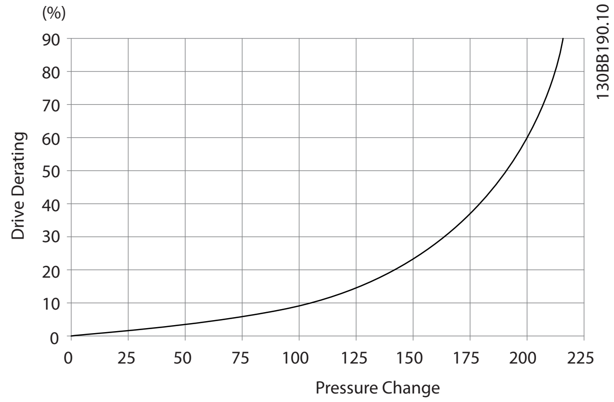


Illustration 6.98 F1, F2, F3, F4 Frame Derating vs. Pressure Change. Frequency Converter Airflow: 580 cfm (985 m^3/h)

6

6.2.10 Wall/Panel Mount Installation

Only the D1h and D2h are recommended to be wall mounted outside an enclosure due to their IP21 (NEMA 1) and IP54 (NEMA 12) rating. While the D3h and D4h units can be wall mounted, it is recommended they be panel mounted inside an enclosure. The E2 unit is designed only to be panel mounted within an enclosure.

To install a wall- or panel-mounted unit, perform the following steps:

1. Make sure there is at least 225 mm (8.9 in) of space between the top of the unit and the ceiling, and at least 225 mm (8.9) space between the unit and the floor to provide for adequate cooling.
2. Make sure there is enough space for cable entry at the bottom of the unit.
3. Mark the mounting holes according to the installation drawings and drill holes where indicated.
4. Mount the bolts at the bottom of the unit and lift the frequency converter up on the bolts.
5. Tilt the frequency converter against the wall and mount the upper bolts.
6. Tighten all 4 bolts to secure the unit against the wall.

6.2.11 Pedestal Installation of D-frames

The D7h and D8h frequency converters are shipped with a pedestal and a wall spacer. Before securing the enclosure to the wall, install the pedestal behind the mounting flange as shown in *Illustration 6.99*.

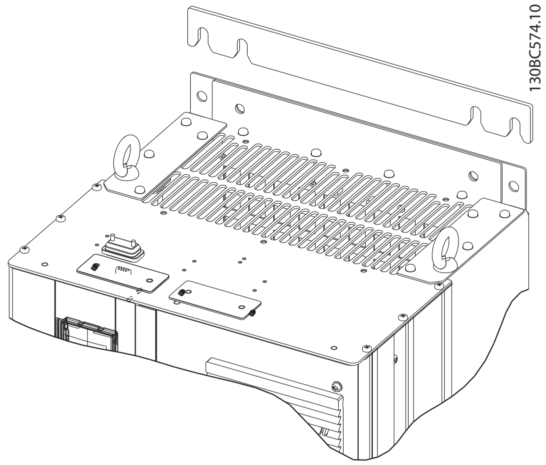


Illustration 6.99 Wall Mounting Spacer

To install a pedestal-mounted D-frame unit, perform the following steps as shown in *Illustration 6.100*:

1. Attach the pedestal to the back channel using 2 M10 nuts.
2. Fasten 2 M5 screws through the back pedestal flange into the pedestal drive mounting bracket.
3. Fasten 4 M5 screws through the front pedestal flange into the front gland plate mounting holes.

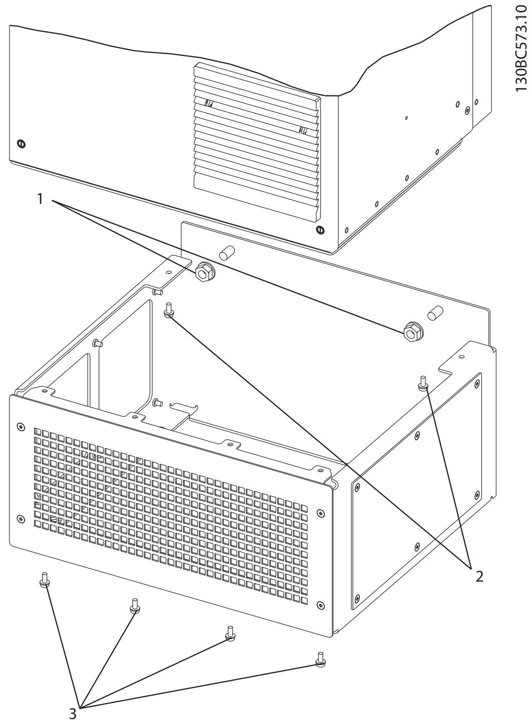


Illustration 6.100 Pedestal Hardware Installation

6.2.12 Pedestal Installation of E-frames

As seen in *Illustration 6.101* the bottom plate of the E1 can be mounted from either inside or outside of the enclosure. If bottom mounted, the glands and cables can be mounted before the frequency converter is placed on the pedestal.

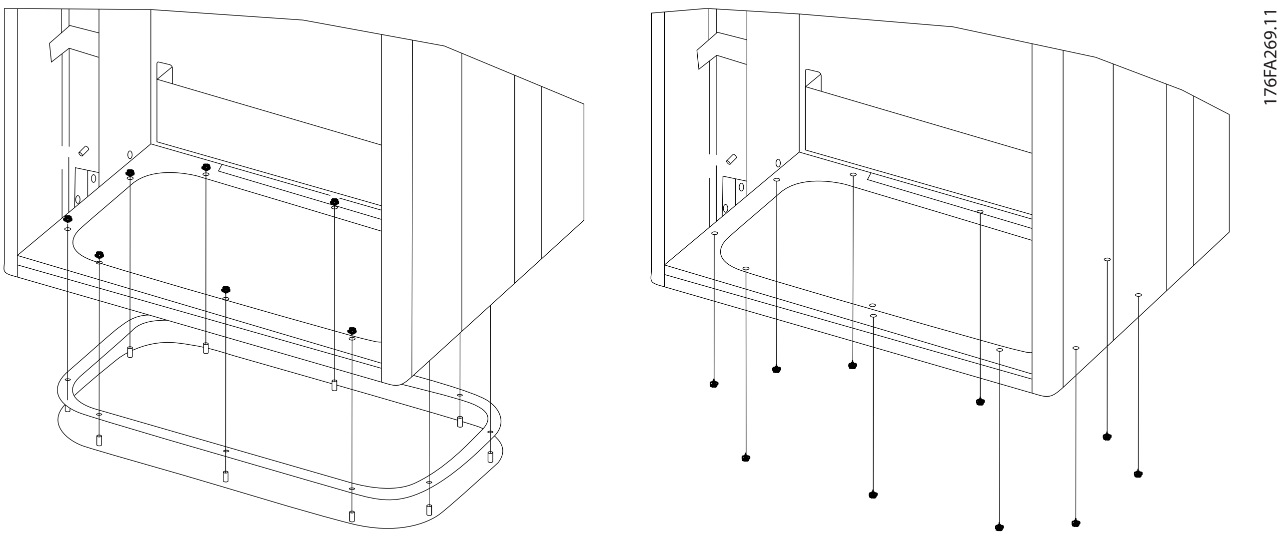


Illustration 6.101 Mounting of Bottom Plate, Frame Size E1.

To assemble a pedestal-mounted E-frame unit, install each M10x30 mm bolt with captive lock washer and flat washer through the base plate and into the threaded hole in the base. Install 4 bolts per cabinet.

6.2.13 Pedestal Installation of F-frames

The F-frame frequency converters are shipped with a pedestal. The F-frame pedestals use 8 bolts instead of 4, as shown in *Illustration 6.102*.

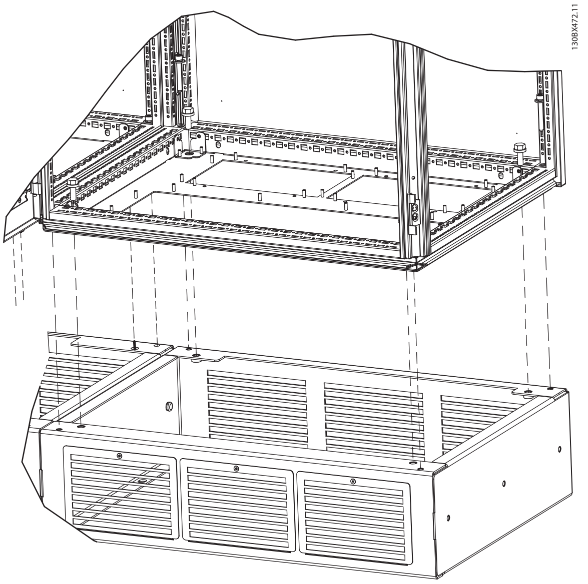


Illustration 6.102 Pedestal Bolt Installation

To install a pedestal-mounted F-frame unit, perform the following steps:

1. If using a kit to direct the airflow from the heat sink to the outside vent on the back of the frequency converter, verify there is a minimum of 100 mm ceiling clearance.
2. Install each M8x60 mm bolt with lock washer and flat washer through the frame into the threaded hole in the base. Install 4 bolts per cabinet. Refer to *Illustration 6.103*
3. Install each M10x30 mm bolt with captive lock washer and flat washer through the base plate and into the threaded hole in the base. Install 4 bolts per cabinet. Refer to *Illustration 6.103*

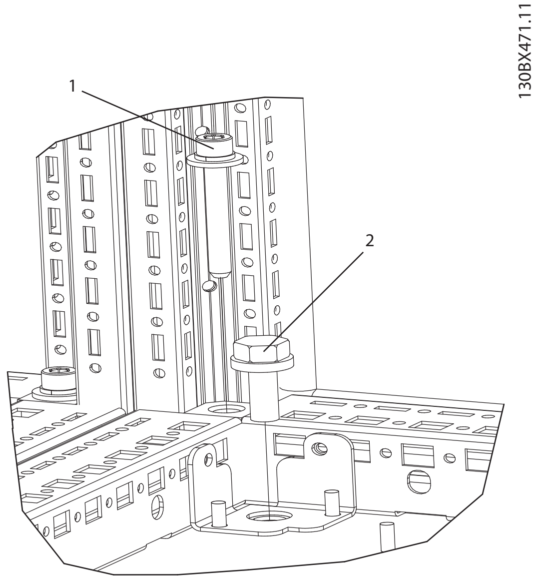


Illustration 6.103 Fastener Location Detail

1	M8x60 mm bolt
2	M10x30 mm bolt

Table 6.63 Legend to *Illustration 6.103*

7 Electrical Installation

7.1 Connections

7.1.1 Torque Settings

When tightening electrical connections, it is important to use a torque wrench to obtain the correct torque. Torque that is too low or too high results in a bad electrical connection.
See the torque settings in *Table 7.1*.

Frame size	Terminal	Size	Torque nominal [Nm (in-lbs)]	Torque range [Nm (in-lbs)]
D1h/D3h/D5h/D6h	Mains Motor Load sharing Regeneration	M10	29.5 (261)	19-40 (168-354)
	Earth (ground) Brake	M8	14.5 (128)	8.5-20.5 (75-181)
D2h/D4h/D7h/D8h	Mains Motor Regeneration Load Sharing Earth (ground)	M10	29.5 (261)	19-40 (168-354)
	Brake	M8		8.5-20.5 (75-181)
E	Mains Motor Load Sharing Earth	M10	19.1 (169)	17.7-20.5 (156-182)
	Regen Brake	M8	9.5 (85)	8.8-10.3 (78.2-90.8 in-lbs.)
F	Mains Motor Load Sharing	M10	19.1 (169)	17.7-20.5 (156-182 in-lbs.)
	Regen: DC-	M8	9.5 (85)	8.8-10.3 (78.2-90.8)
	Regen: DC+	M10	19.1 (169)	17.7-20.5 (156-182)
	F8-F13 Regen	M10	19.1 (169)	17.7-20.5 (156-182.)
	Earth Brake	M8	9.5 (85)	8.8-10.3 (78.2-90.8)

Table 7.1 Terminal Tightening Torques

7.1.2 Power Connections

NOTICE

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

The power cable connections are situated as shown in *Illustration 7.1*. Dimensioning of cable cross section must comply with the current ratings and local legislation. See *4.3 General Specifications* for correct dimensioning of motor cable cross-section and length.

For protection of the frequency converter, use the recommended fuses unless the unit has built-in fuses. Recommended fuses are listed in the Operating Instructions. Ensure that proper fusing complies with local regulations.

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

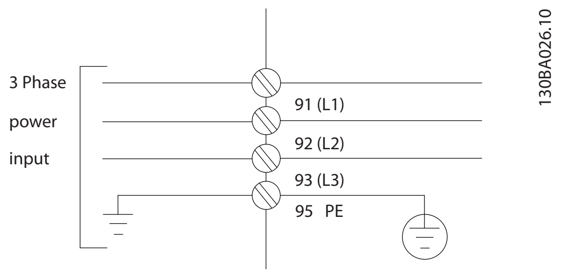


Illustration 7.1 Power Cable Connections

NOTICE

The motor cable must be screened/armoured. If an unscreened/unarmoured cable is used, some EMC requirements are not complied with. Use a screened/ armoured motor cable to comply with EMC emission specifications. For more information, see *7.8 EMC-Correct Installation*.

Screening of cables

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

Connect the motor cable screen to both the de-coupling plate of the frequency converter and the metal housing of the motor.

Make the screen connections with the largest possible surface area (cable clamp) by using the installation devices within the frequency converter.

Cable-length and cross-section

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

Switching frequency

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

Term. no.	96	97	98	99	
	U	V	W	PE[1)]	Motor voltage 0-100% of mains voltage. 3 wires out of motor
	U1	V1	W1	PE[1)]	Delta-connected
	W2	U2	V2		6 wires out of motor
	U1	V1	W1	PE[1)]	Star-connected U2, V2, W2 U2, V2, and W2 to be interconnected separately.

Table 7.2 Motor Cable Connection

[1)]*Protected Earth Connection*

NOTICE

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

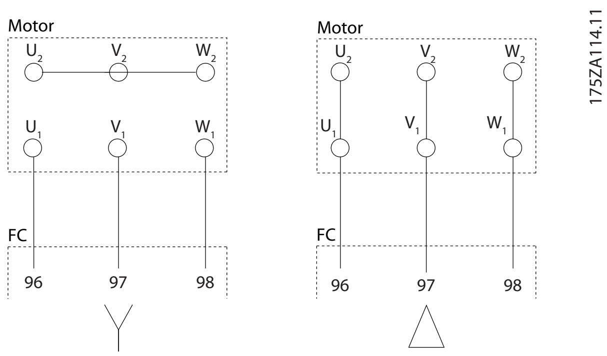


Illustration 7.2 Motor Cable Connection

7

D-frame Interior Components

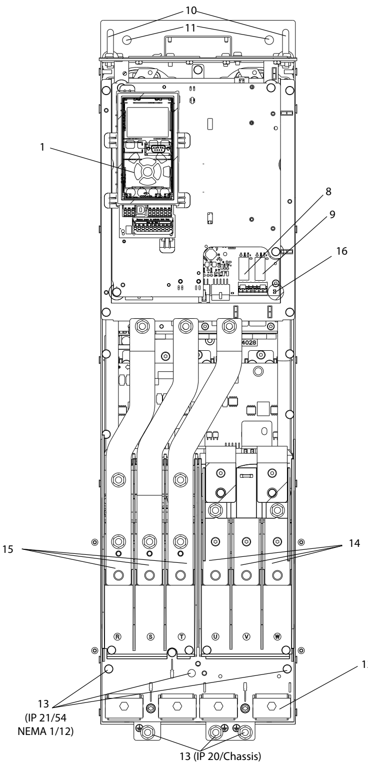


Illustration 7.3 D-frame Interior Components

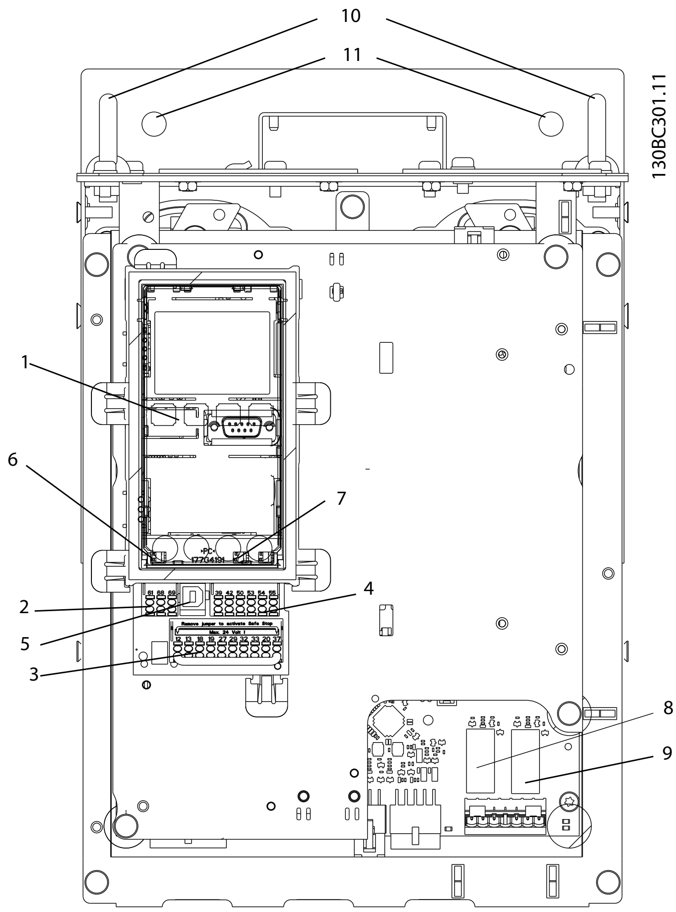


Illustration 7.4 Close-up View: LCP and Control Functions

1	LCP (Local Control Panel)	9	Relay 2 (04, 05, 06)
2	RS-485 serial bus connector	10	Lifting ring
3	Digital I/O and 24 V power supply	11	Mounting slot
4	Analog I/O connector	12	Cable clamp (PE)
5	USB connector	13	Earth (ground)
6	Serial bus terminal switch	14	Motor output terminals 96 (U), 97 (V), 98 (W)
7	Analog switches (A53), (A54)	15	Mains input terminals 91 (L1), 92 (L2), 93 (L3)
8	Relay 1 (01, 02, 03)		

Table 7.3 Legend to *Illustration 7.3* and *Illustration 7.4*

Terminal Locations - D1h/D2h

Take the following position of the terminals into consideration when designing the cable access.

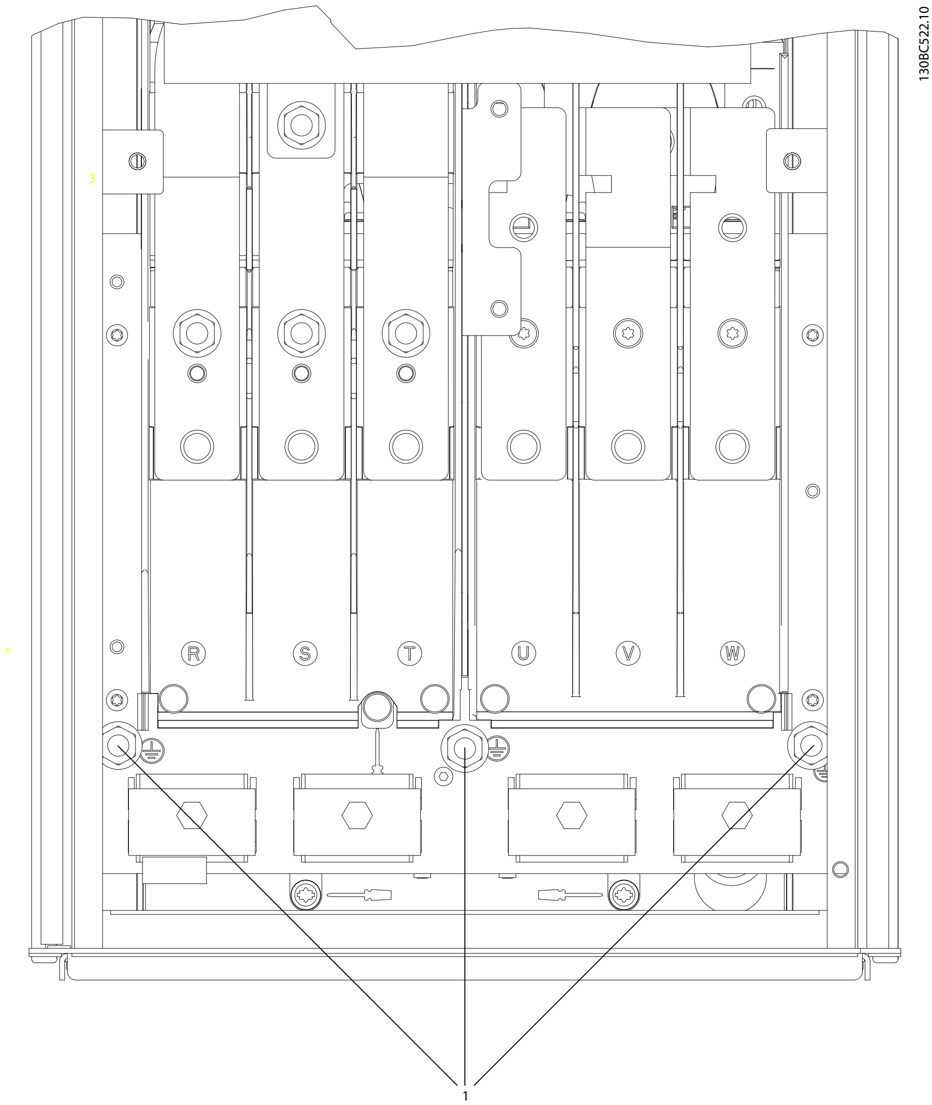


Illustration 7.5 Position of Earth Terminals IP21 (NEMA Type 1) and IP54 (NEMA Type 12), D1h/D2h

Terminal Locations - D3h/D4h

Take the following position of the terminals into consideration when designing the cable access.

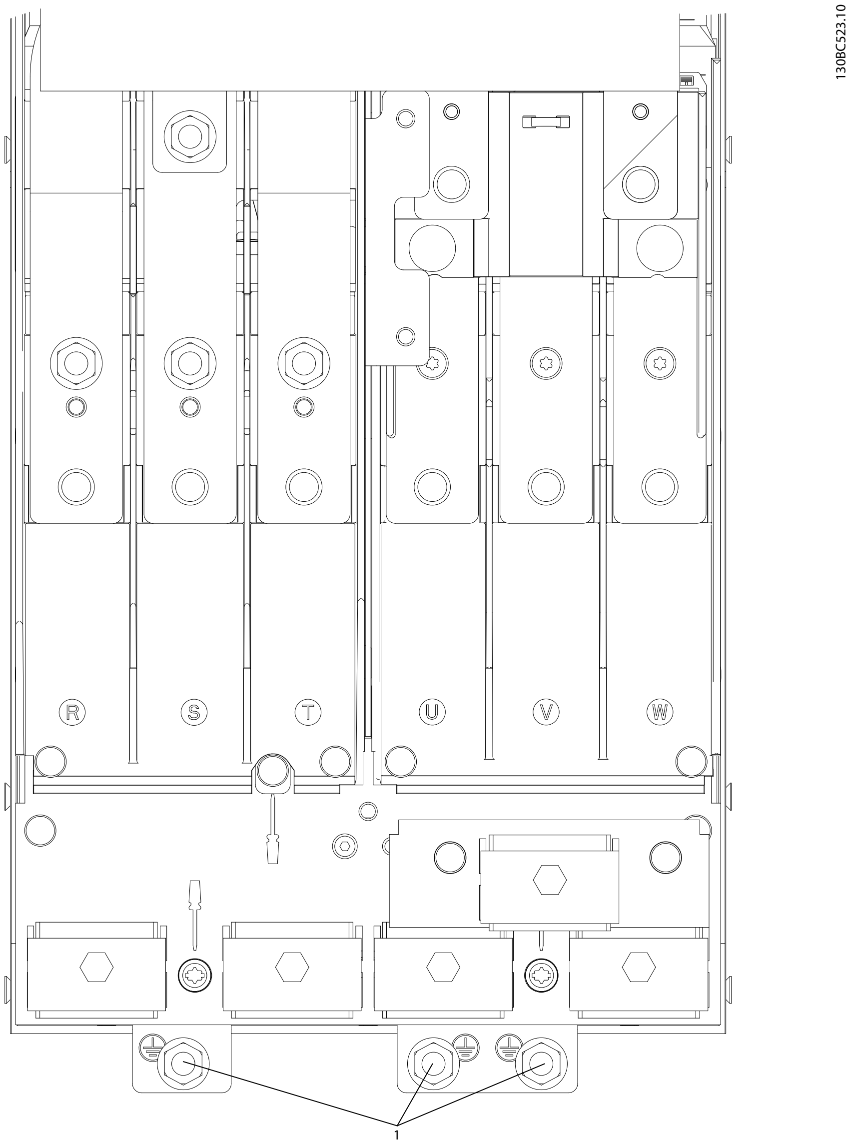


Illustration 7.6 Position of Earth Terminals IP20 (Chassis), D3h/D4h

1	Earth Terminals

Table 7.4 Legend to *Illustration 7.5* and *Illustration 7.6*

Terminal Locations - D5h

Take the following position of the terminals into consideration when designing the cable access.

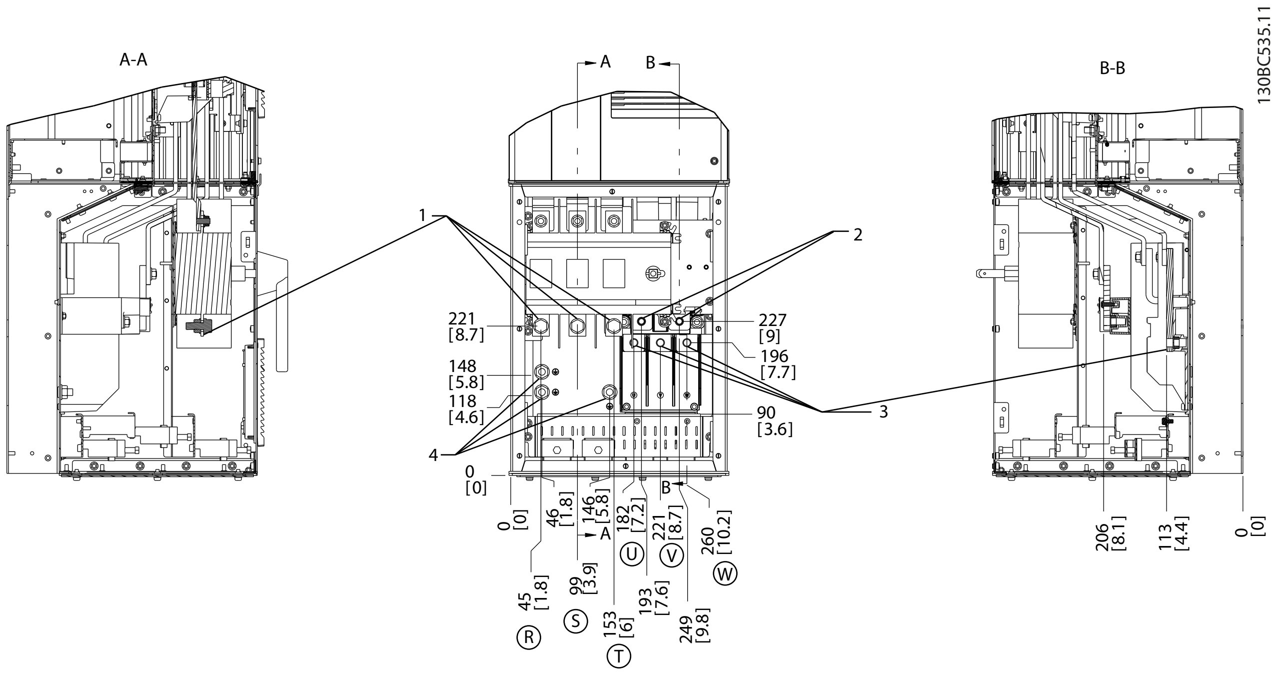


Illustration 7.7 Terminal Locations, D5h with Disconnect Option

1	Mains Terminals	3	Motor Terminals
2	Brake Terminals	4	Earth/Ground Terminals

Table 7.5 Legend to *Illustration 7.7*

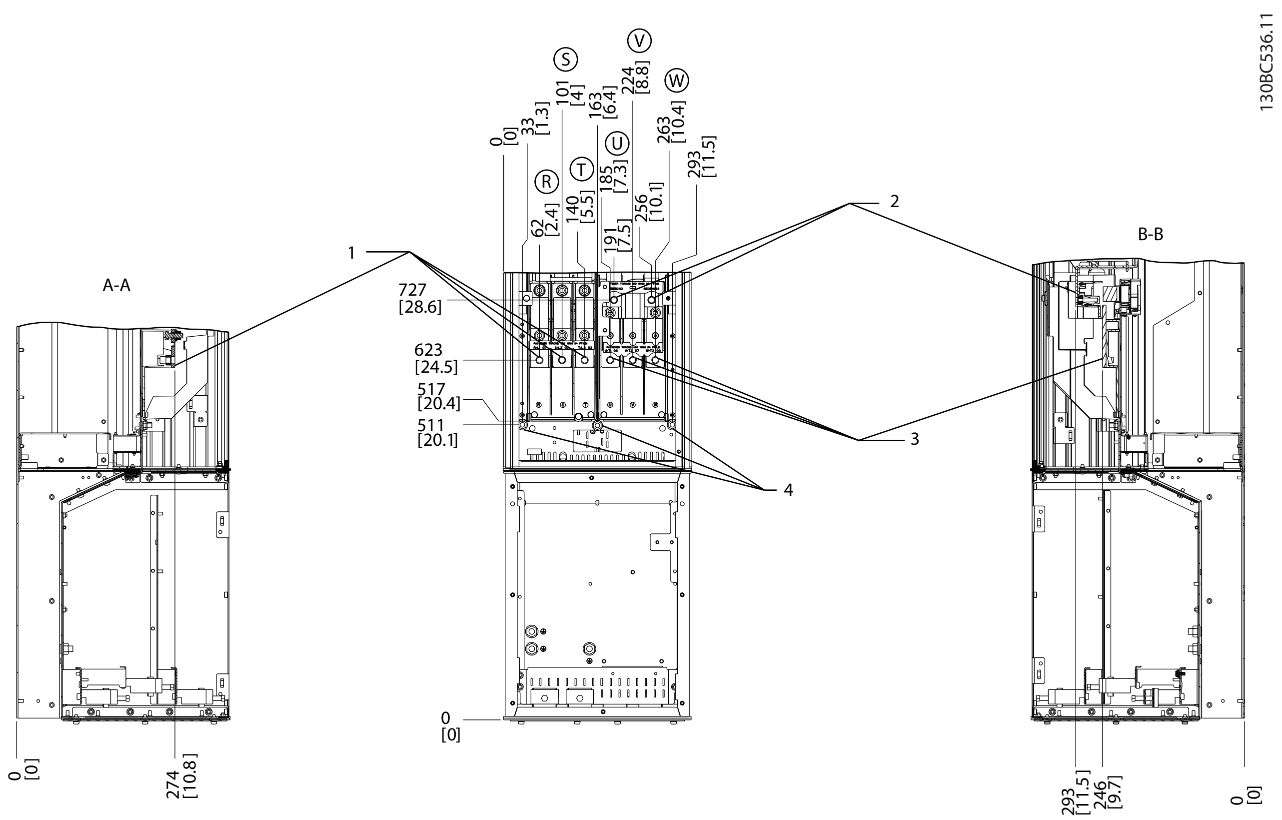


Illustration 7.8 Terminal Locations, D5h with Brake Option

1	Mains Terminals	3	Motor Terminals
2	Brake Terminals	4	Earth/Ground Terminals

Table 7.6 Legend to *Illustration 7.8*

Terminal Locations - D6h

Take the following position of the terminals into consideration when designing the cable access.

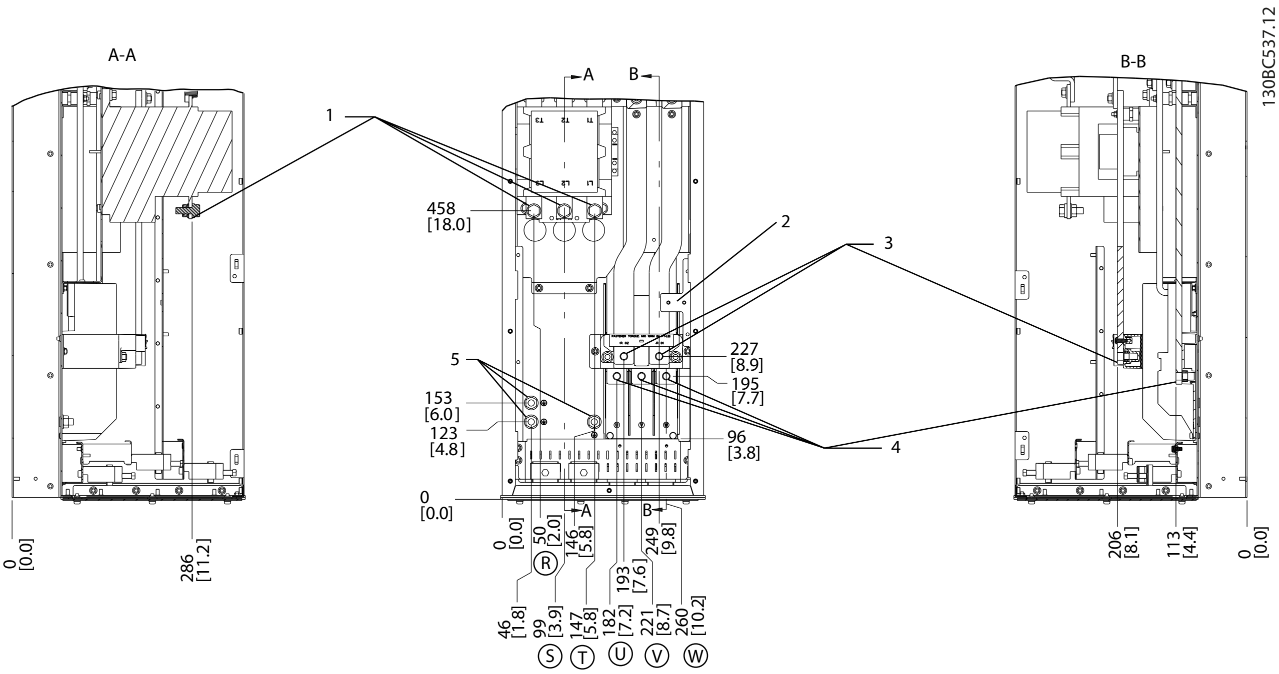


Illustration 7.9 Terminal Locations, D6h with Contactor Option

1	Mains Terminals	4	Motor Terminals
2	TB6 Terminal block for contactor	5	Earth/Ground Terminals
3	Brake Terminals		

Table 7.7 Legend to *Illustration 7.9*

7

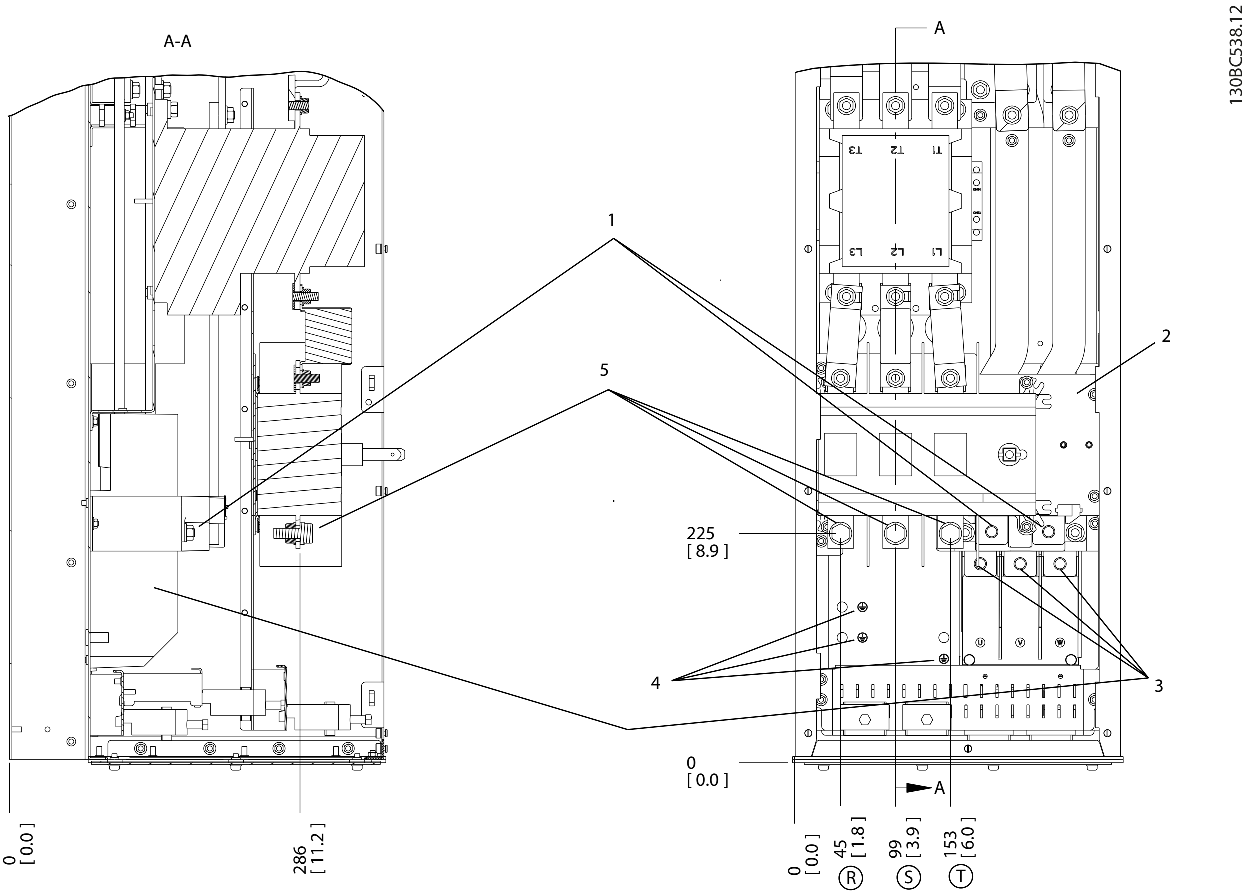


Illustration 7.10 Terminal Locations, D6h with Contactor and Disconnect Options

1	Brake Terminals	4	Earth/Ground Terminals
2	TB6 Terminal block for contactor	5	Mains Terminals
3	Motor Terminals		

Table 7.8 Legend to *Illustration 7.10*

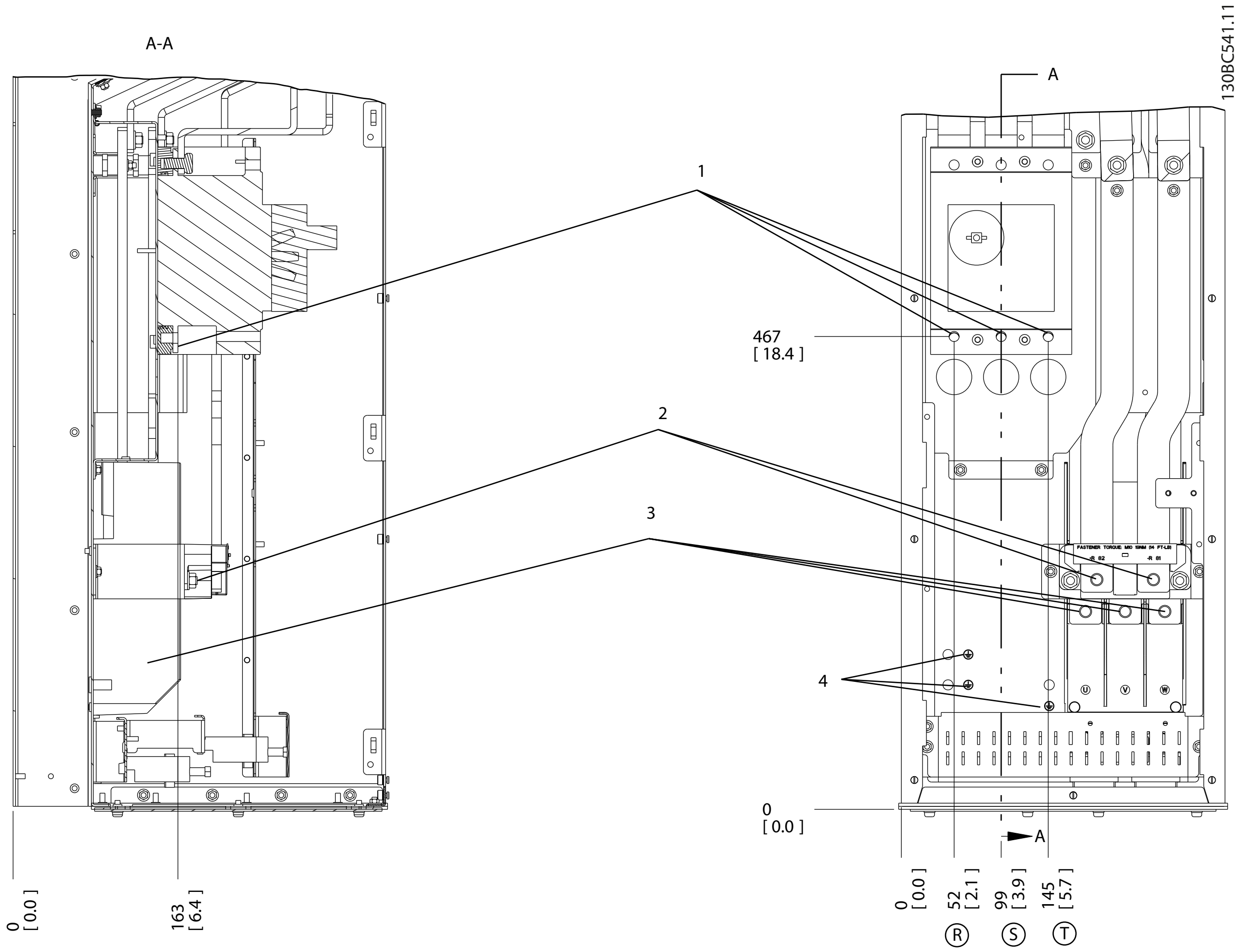


Illustration 7.11 Terminal Locations, D6h with Circuit Breaker Option

1	Mains Terminals	3	Motor Terminals
2	Brake Terminals	4	Earth/Ground Terminals

Table 7.9 Legend to *Illustration 7.11*

Terminal Locations - D7h

Take the following position of the terminals into consideration when designing the cable access.

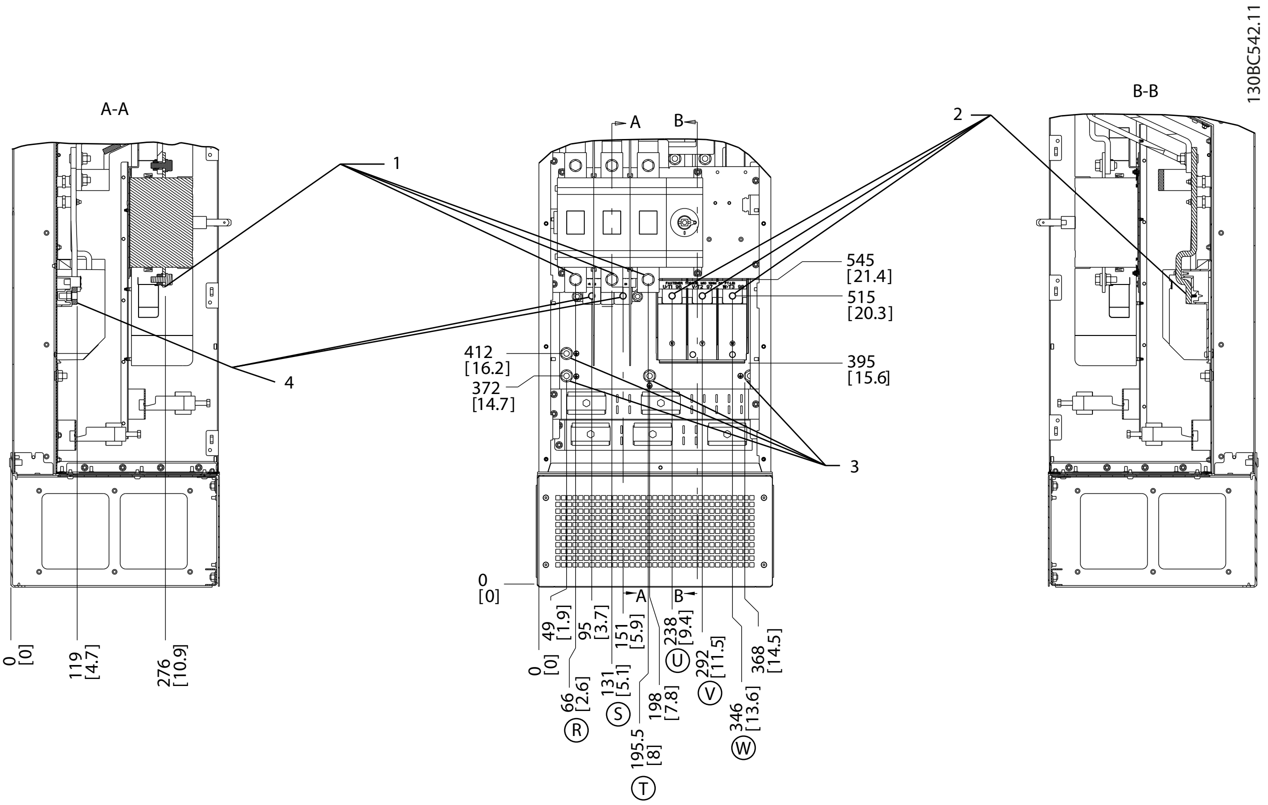


Illustration 7.12 Terminal Locations, D7h with Disconnect Option

1	Mains Terminals	3	Earth/Ground Terminals
2	Motor Terminals	4	Brake Terminals

Table 7.10 Legend to *Illustration 7.12*

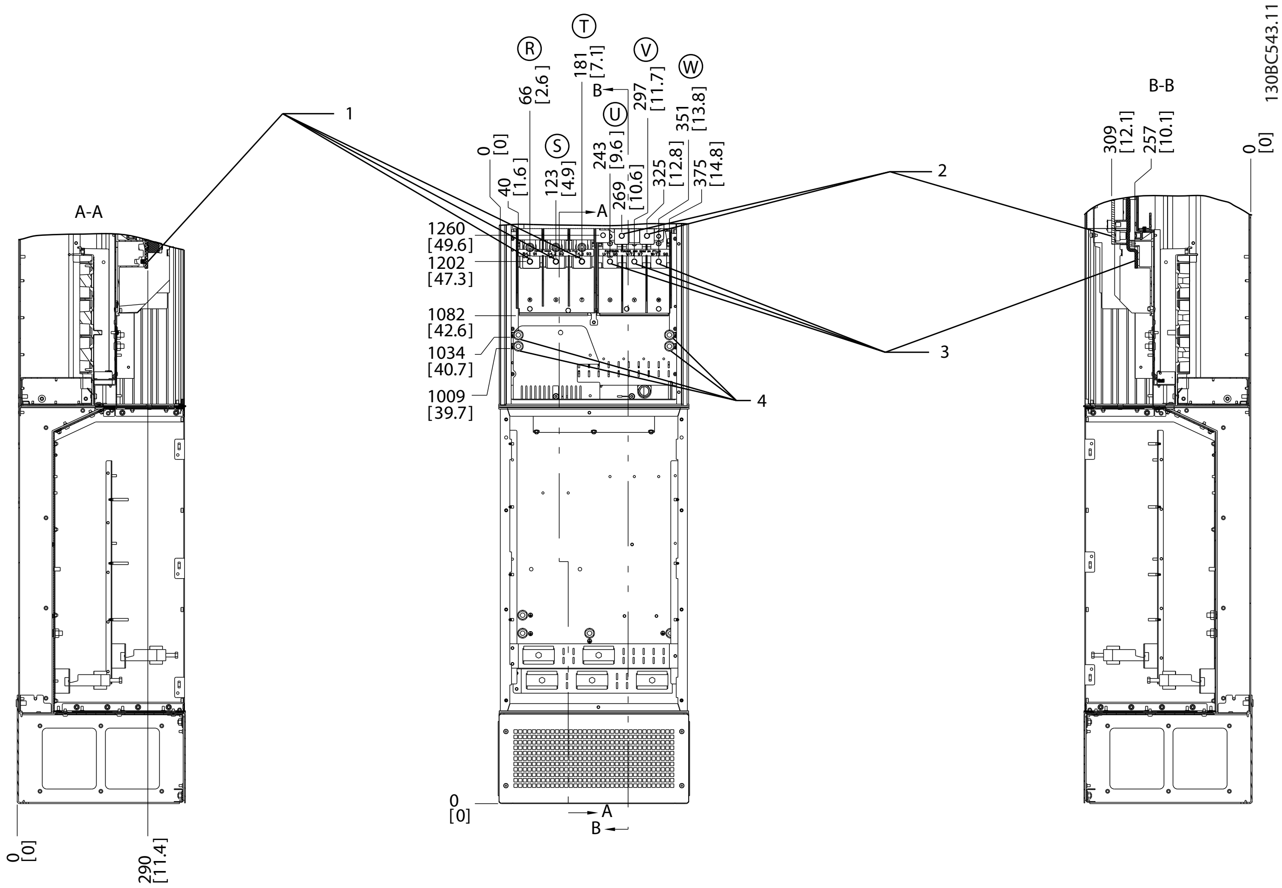


Illustration 7.13 Terminal Locations, D7h with Brake Option

1	Mains Terminals	3	Motor Terminals
2	Brake Terminals	4	Earth/Ground Terminals

Table 7.11 Legend to *Illustration 7.13*

Terminal Locations - D8h

Take the following position of the terminals into consideration when designing the cable access.

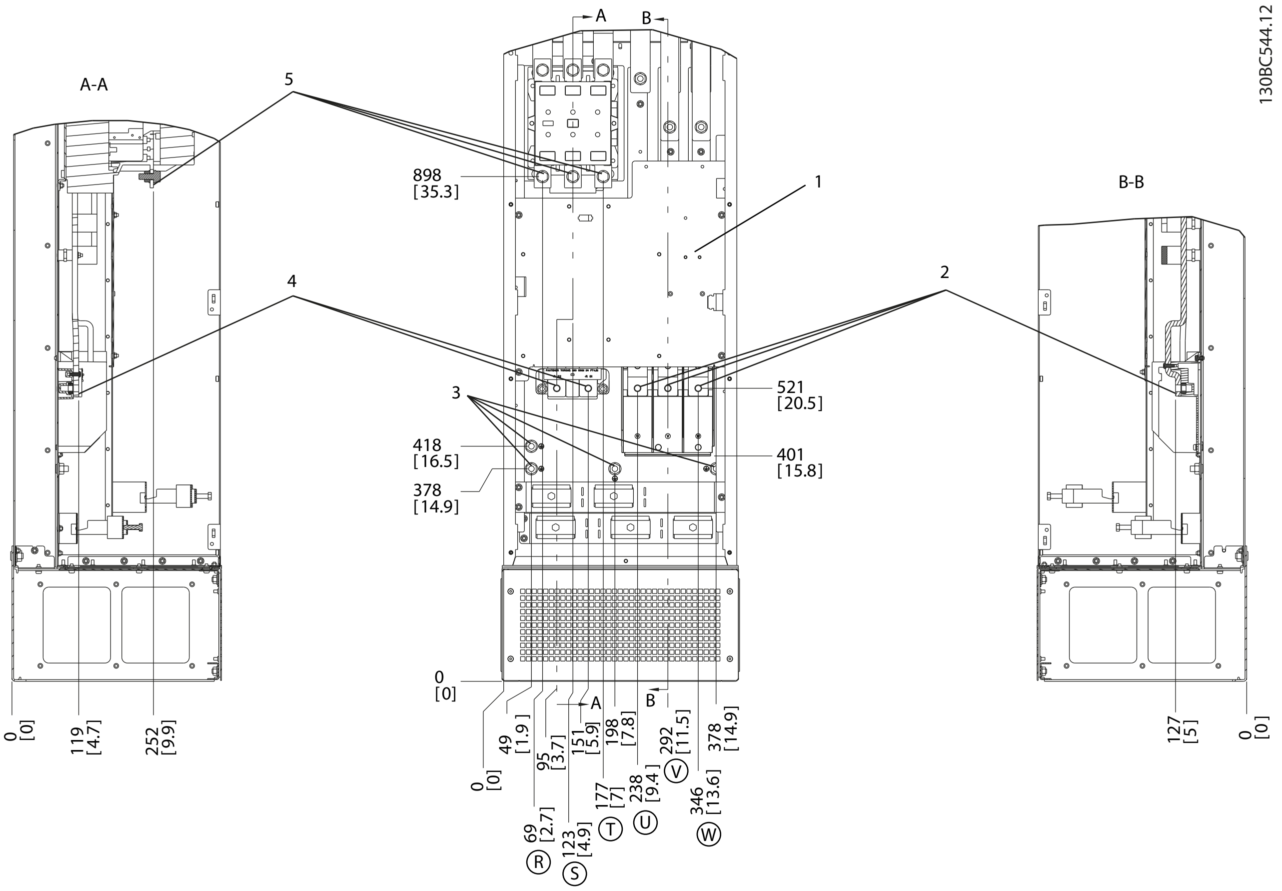


Illustration 7.14 Terminal Locations, D8h with Contactor Option

1	TB6 Terminal block for contactor	4	Brake Terminals
2	Motor Terminals	5	Mains Terminals
3	Earth/Ground Terminals		

Table 7.12 Legend to *Illustration 7.14*

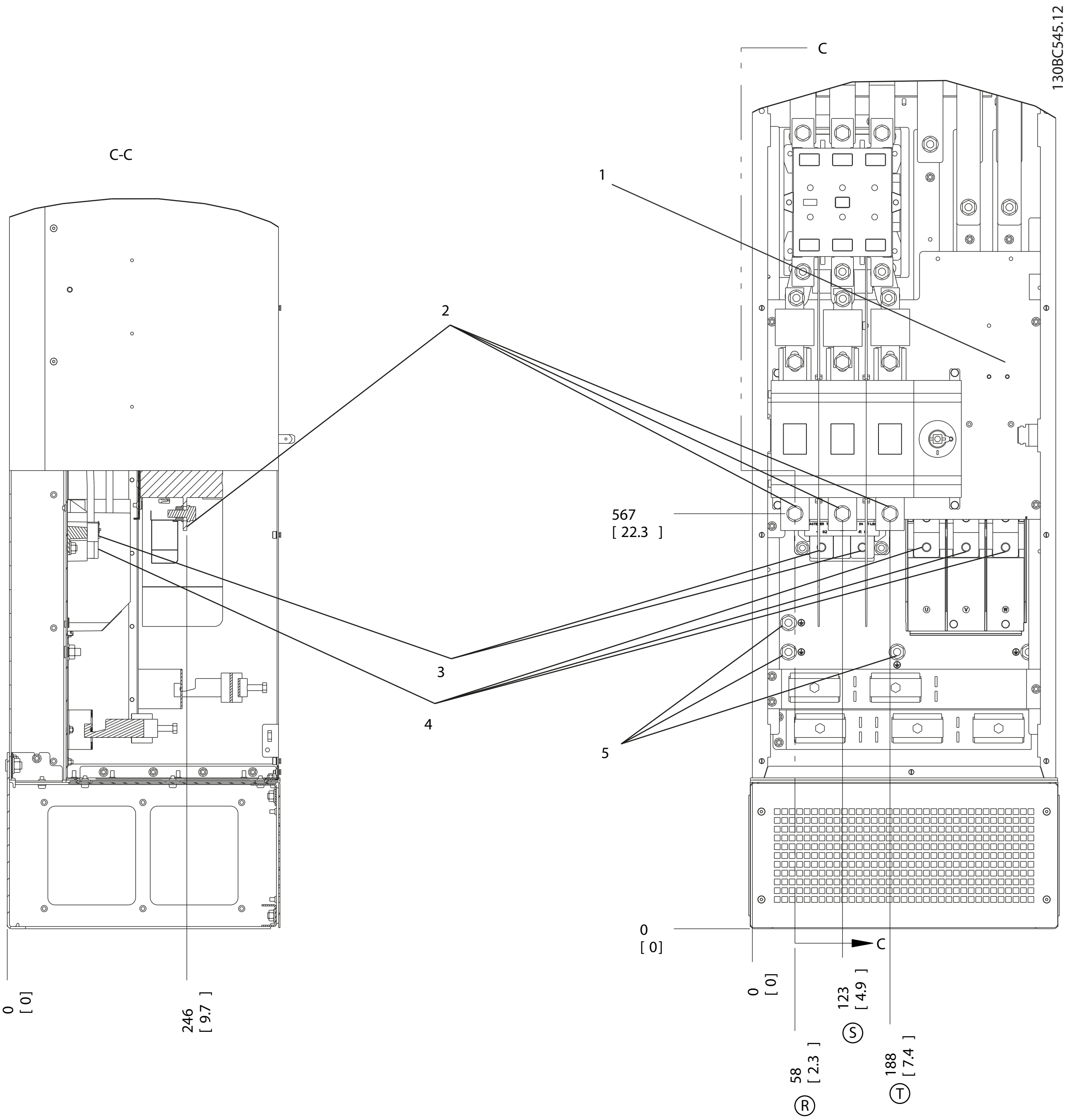


Illustration 7.15 Terminal Locations, D8h with Contactor and Disconnect Options

1	TB6 Terminal block for contactor	4	Motor Terminals
2	Mains Terminals	5	Earth/Ground Terminals
3	Brake Terminals		

Table 7.13 Legend to *Illustration 7.15*

7

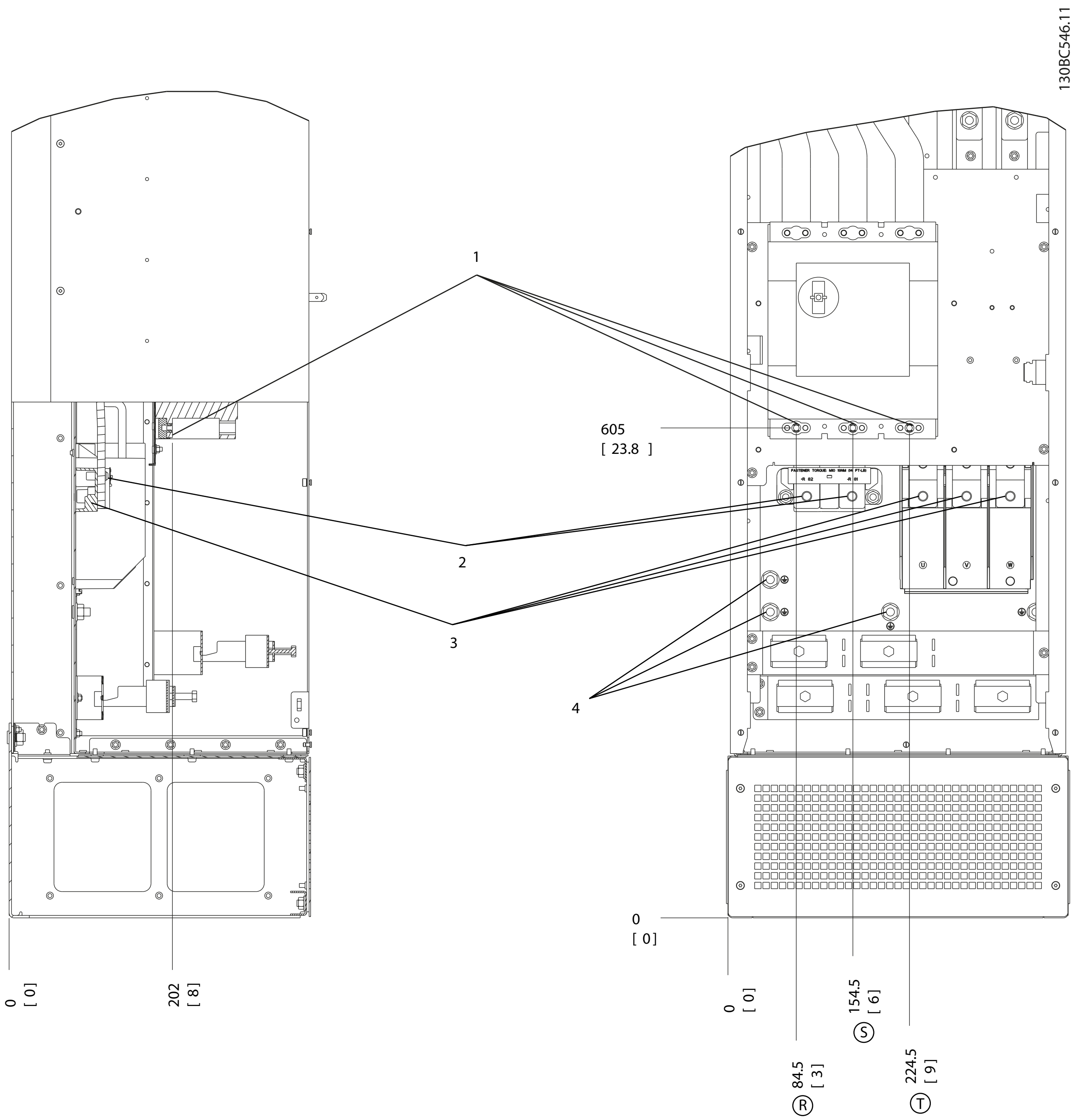


Illustration 7.16 Terminal Locations, D8h with Circuit Breaker Option

1	Mains Terminals	3	Motor Terminals
2	Brake Terminals	4	Earth/Ground Terminals

Table 7.14 Legend to *Illustration 7.16*

Terminal Locations - E1

Take the following position of the terminals into consideration when designing the cable access.

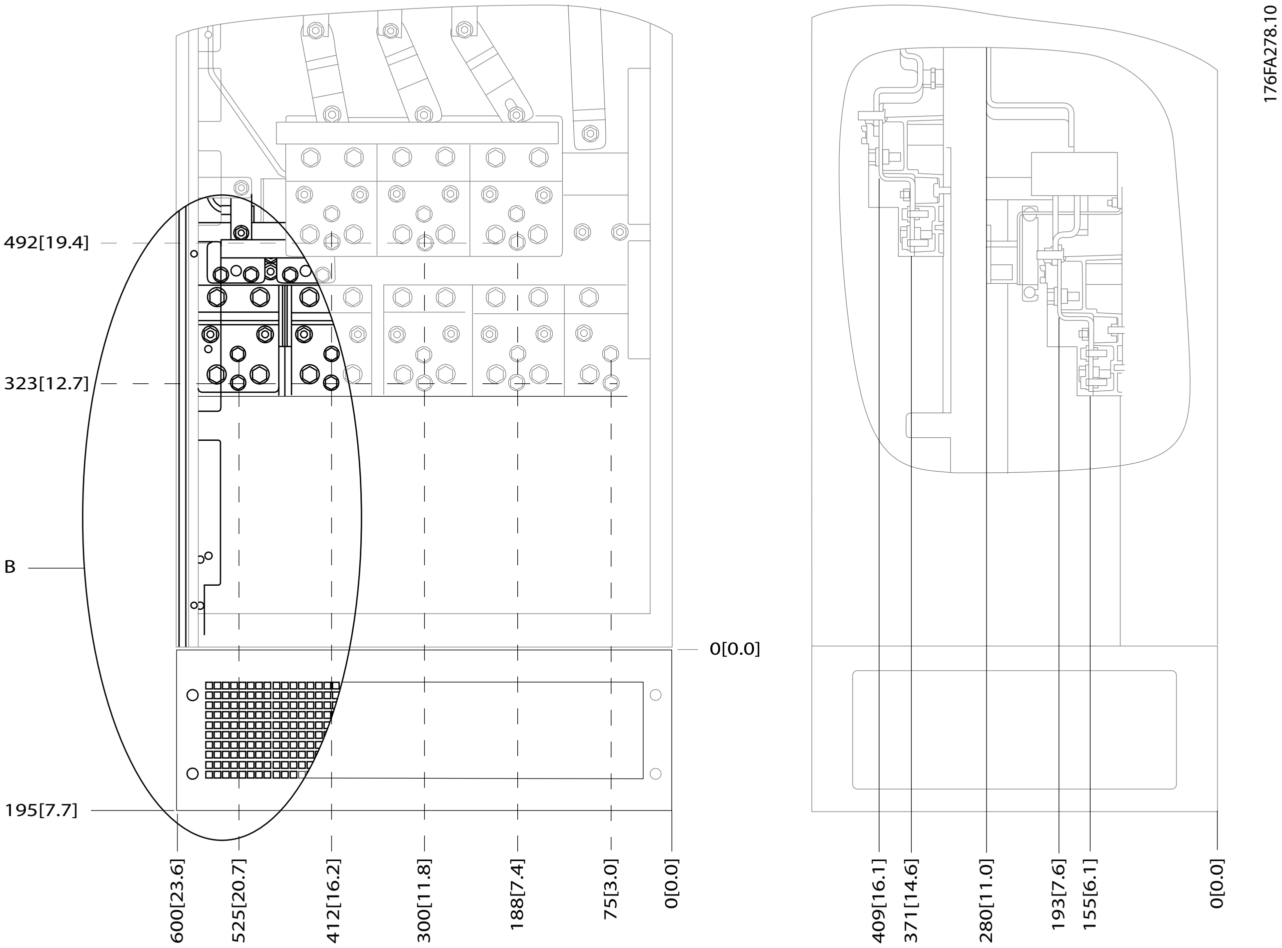


Illustration 7.17 IP21 (NEMA Type 1) and IP54 (NEMA Type 12) Enclosure Power Connection Positions

B	Front View of Unit

Table 7.15 Legend to *Illustration 7.17*

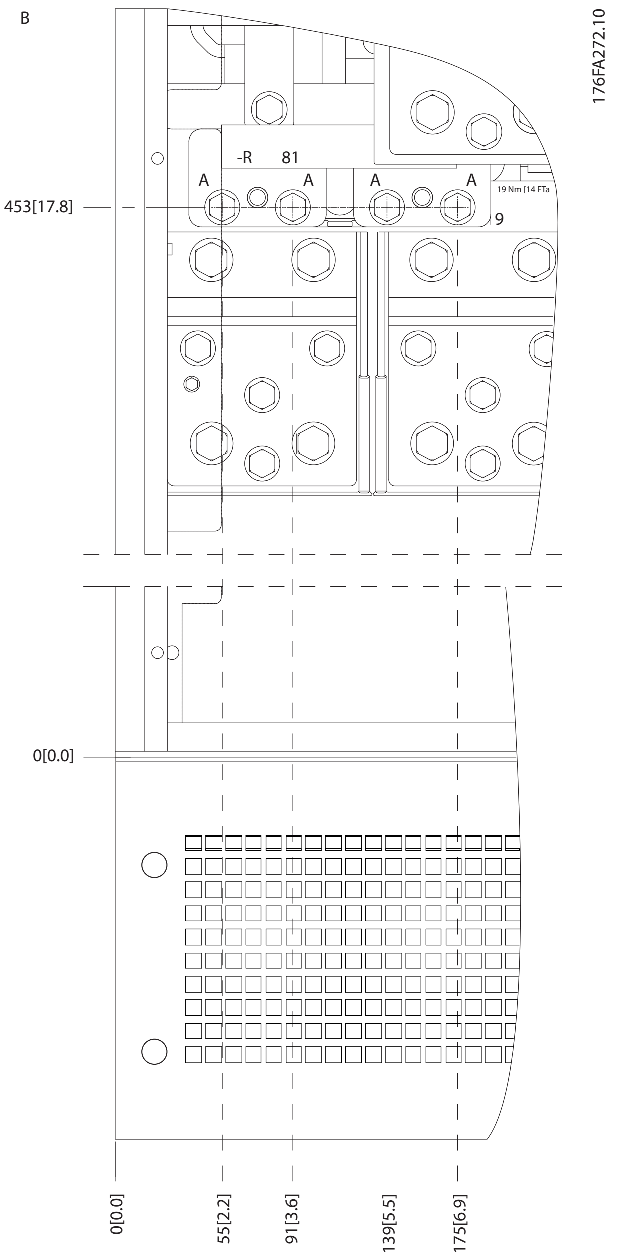


Illustration 7.18 IP21 (NEMA Type 1) and IP54 (NEMA Type 12) Enclosure Power Connection Positions (Detail B)

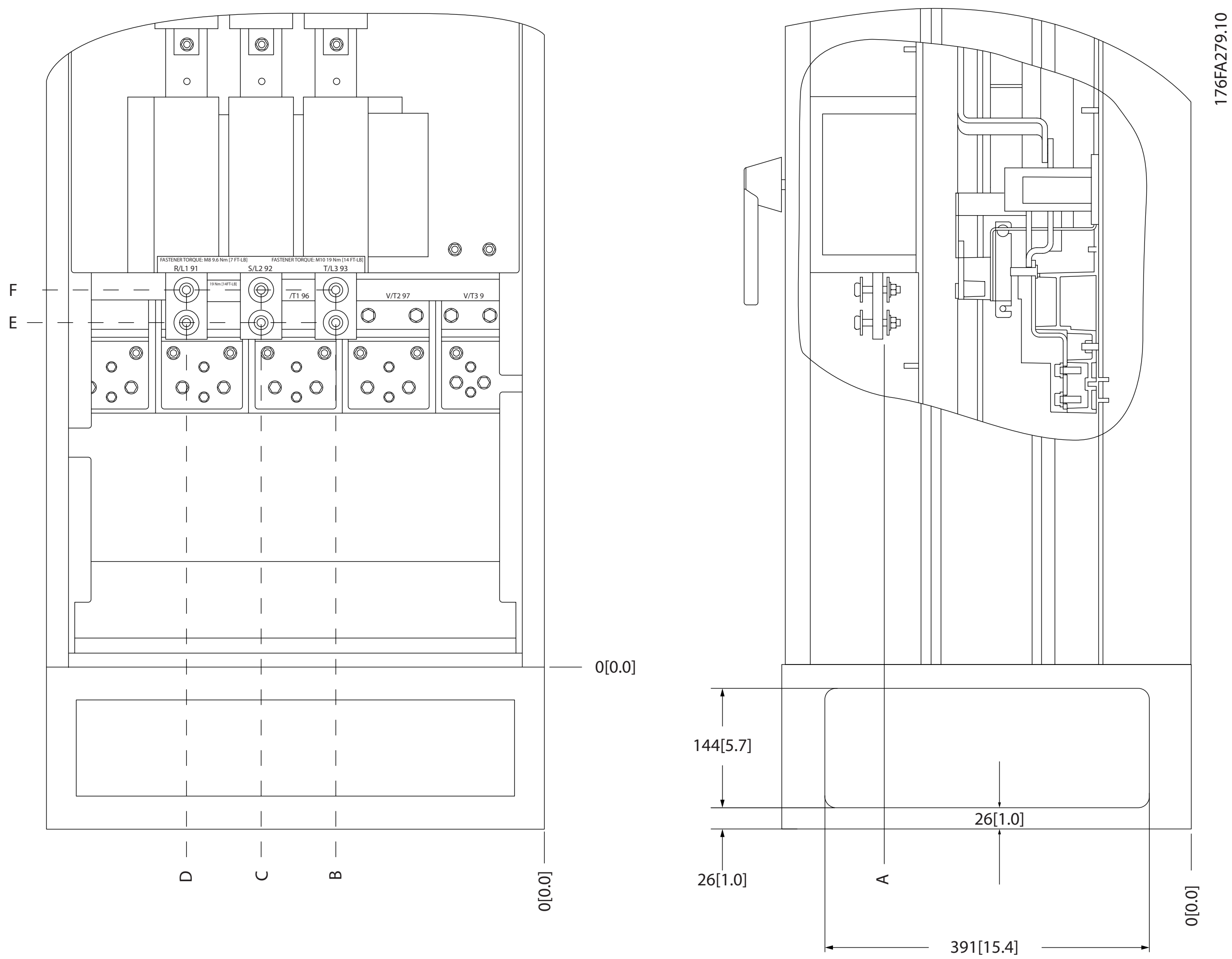


Illustration 7.19 IP21 (NEMA Type 1) and IP54 (NEMA Type 12) Enclosure Power Connection Position of Disconnect Switch

Frame size	Unit type	Dimension for disconnect terminal					
E1	IP54/IP21 UL and NEMA1/NEMA12						
	250/315 kW (400 V) and 355/450-500/630 KW (690 V)	381 (15.0)	253 (9.9)	253 (9.9)	431 (17.0)	562 (22.1)	N/A
	315/355-400/450 kW (400 V)	371 (14.6)	371 (14.6)	341 (13.4)	431 (17.0)	431 (17.0)	455 (17.9)

Table 7.16 Legend to *Illustration 7.19*

Terminal Locations - Frame Size E2

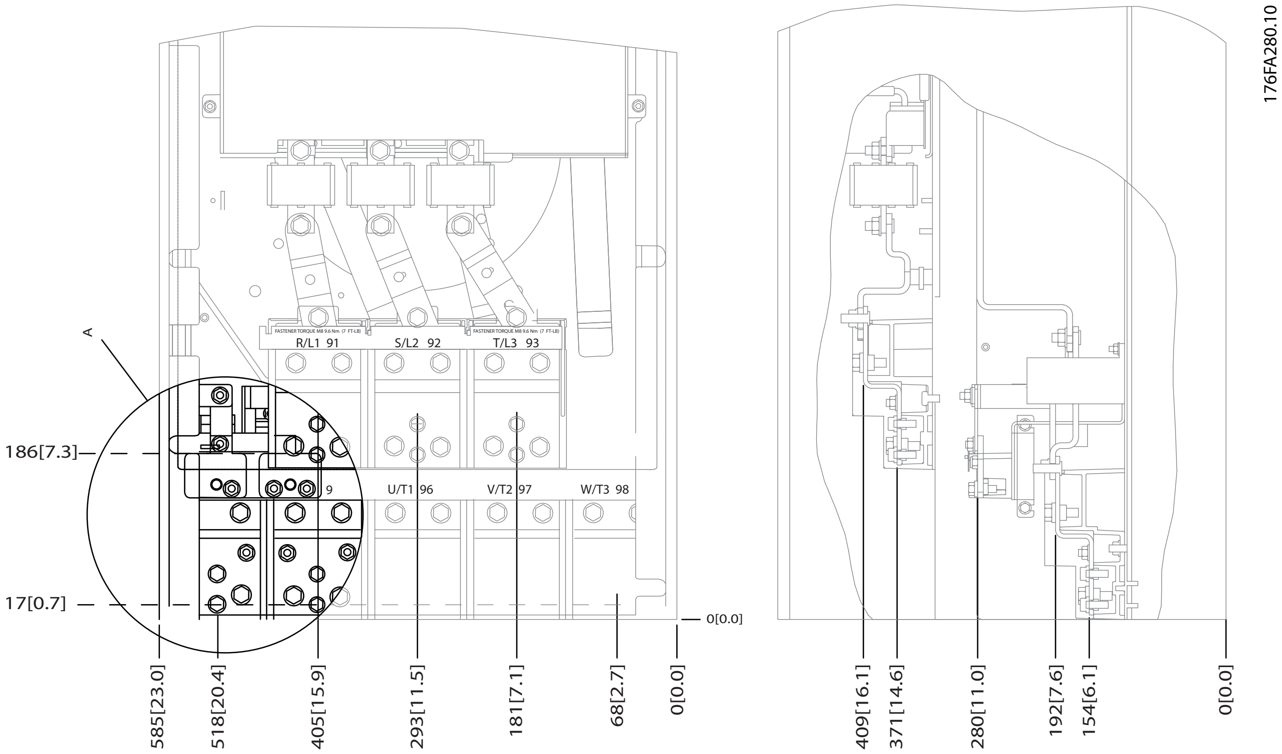


Illustration 7.20 IP00 Enclosure Power Connection Positions

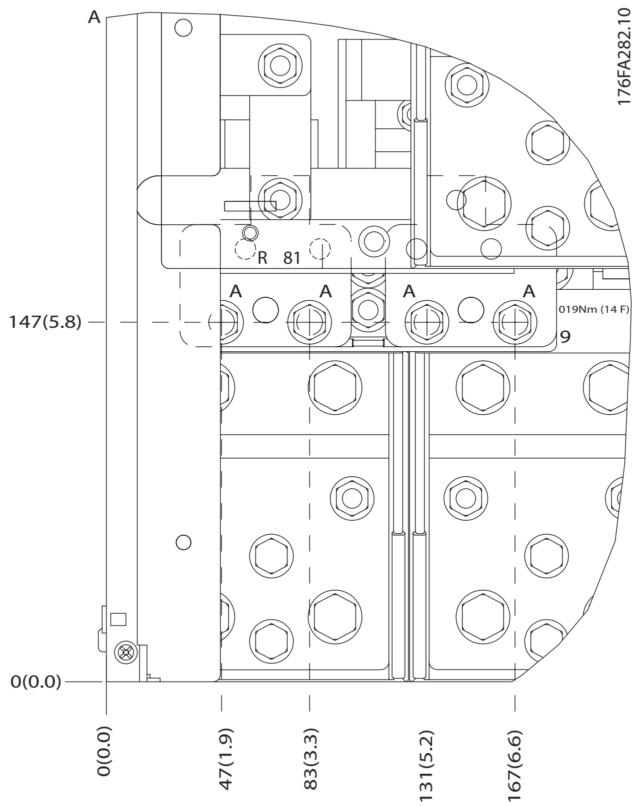


Illustration 7.21 IP00 Enclosure Power Connection Positions

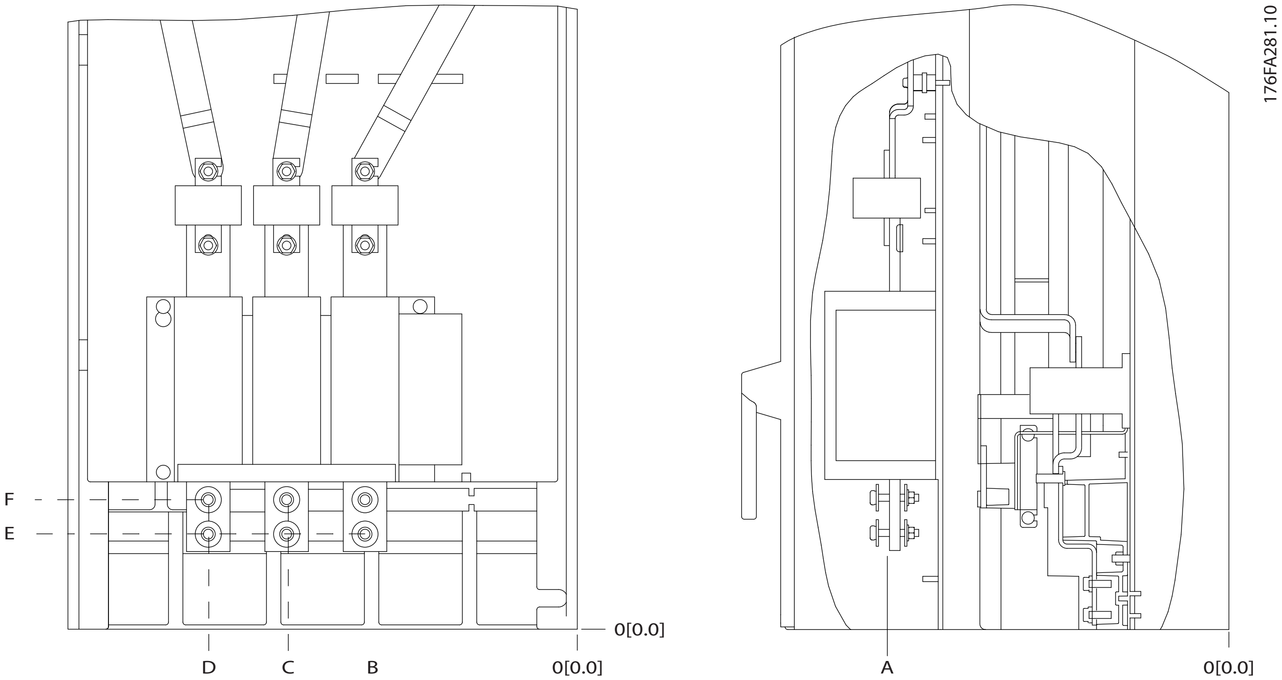


Illustration 7.22 IP00 Enclosure Power Connections, Position of Disconnect Switch

NOTICE

The power cables are heavy and difficult to bend. Consider the optimum position of the frequency converter to ensure easy cable installation. Each terminal allows use of up to 4 cables with cable lugs or use of standard box lugs. Earth is connected to a relevant termination point in the frequency converter.

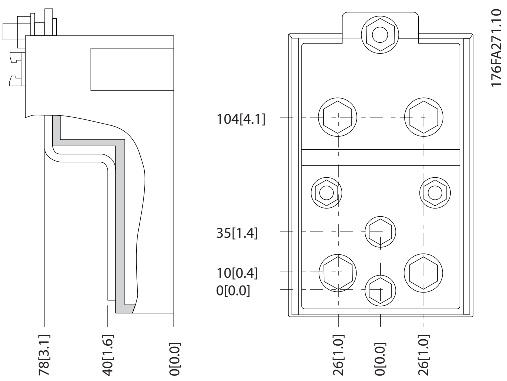


Illustration 7.23 Terminal in Detail

NOTICE

Power connections can be made to positions A or B.

Frame size	Unit type	Dimension for disconnect terminal					
		A	B	C	D	E	F
E2	250/315 kW (400 V) and 355/450-500/630 KW (690 V)	381 (15.0)	245 (9.6)	334 (13.1)	423 (16.7)	256 (10.1)	N/A
	315/355-400/450 kW (400 V)	383 (15.1)	244 (9.6)	334 (13.1)	424 (16.7)	109 (4.3)	149 (5.8)

Table 7.17 Power Connections, E2

NOTICE

The F-Frames have 4 different sizes - F1, F2, F3 and F4. The F1 and F2 consist of an inverter cabinet on the right and rectifier cabinet on the left. The F3 and F4 are F1 and F2 units, respectively, with an additional options cabinet to the left of the rectifier.

Terminal Locations - Frame Sizes F1 and F3

Take the following position of the terminals into consideration when designing the cable access.

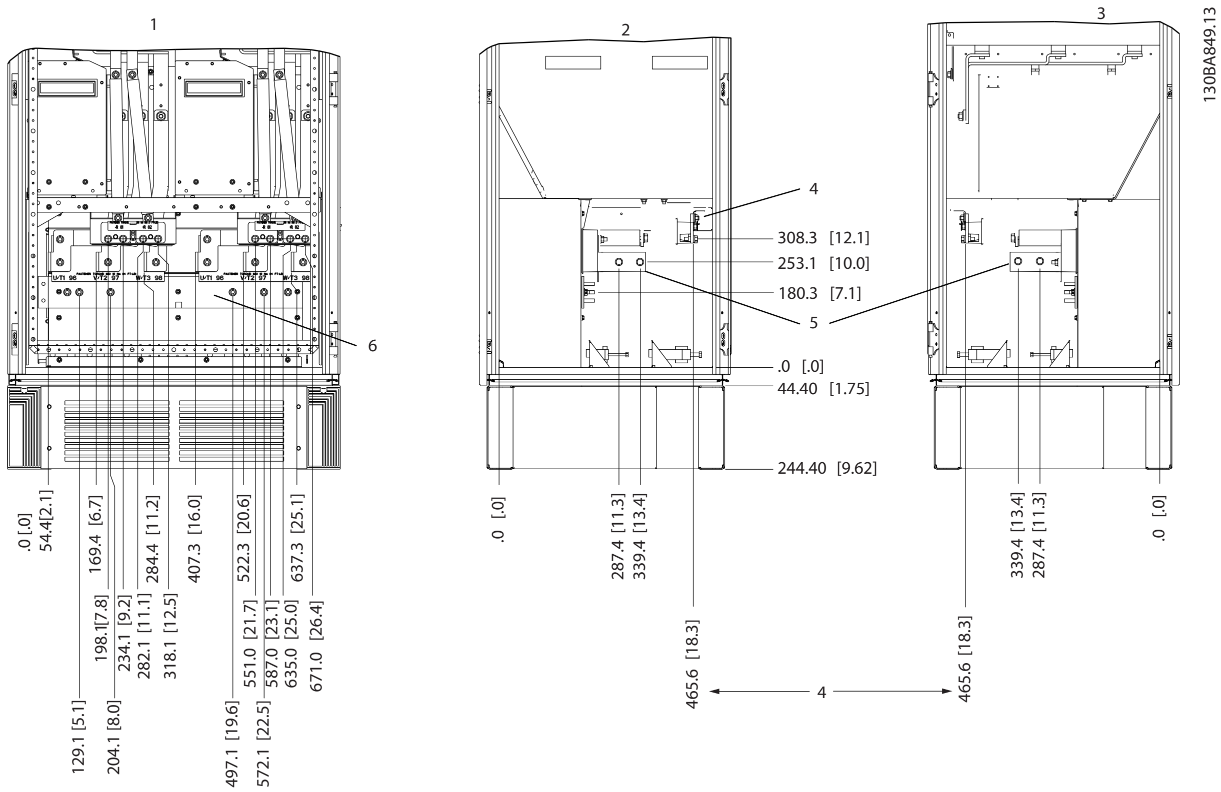


Illustration 7.24 Terminal Locations - Inverter Cabinet - F1 and F3. Gland Plate is 42 mm below .0 Level.

1	Front Side	4	Earth ground bar
2	Left Side	5	Motor Terminals
3	Right Side	6	Brake Terminals

Table 7.18 Legend to *Illustration 7.24*

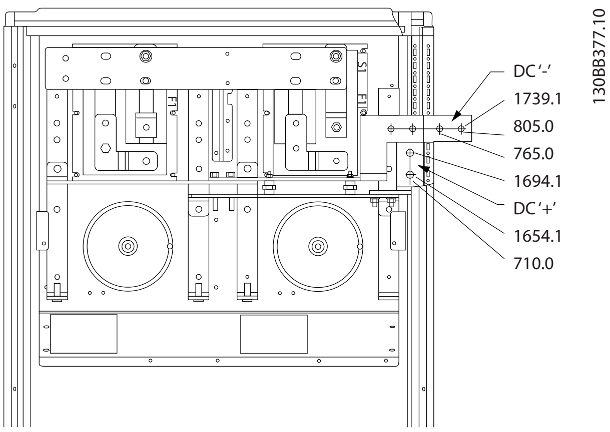


Illustration 7.25 Regeneration Terminal Locations - F1 and F3

Terminal Locations - Frame Size F2 and F4

Take the following position of the terminals into consideration when designing the cable access.

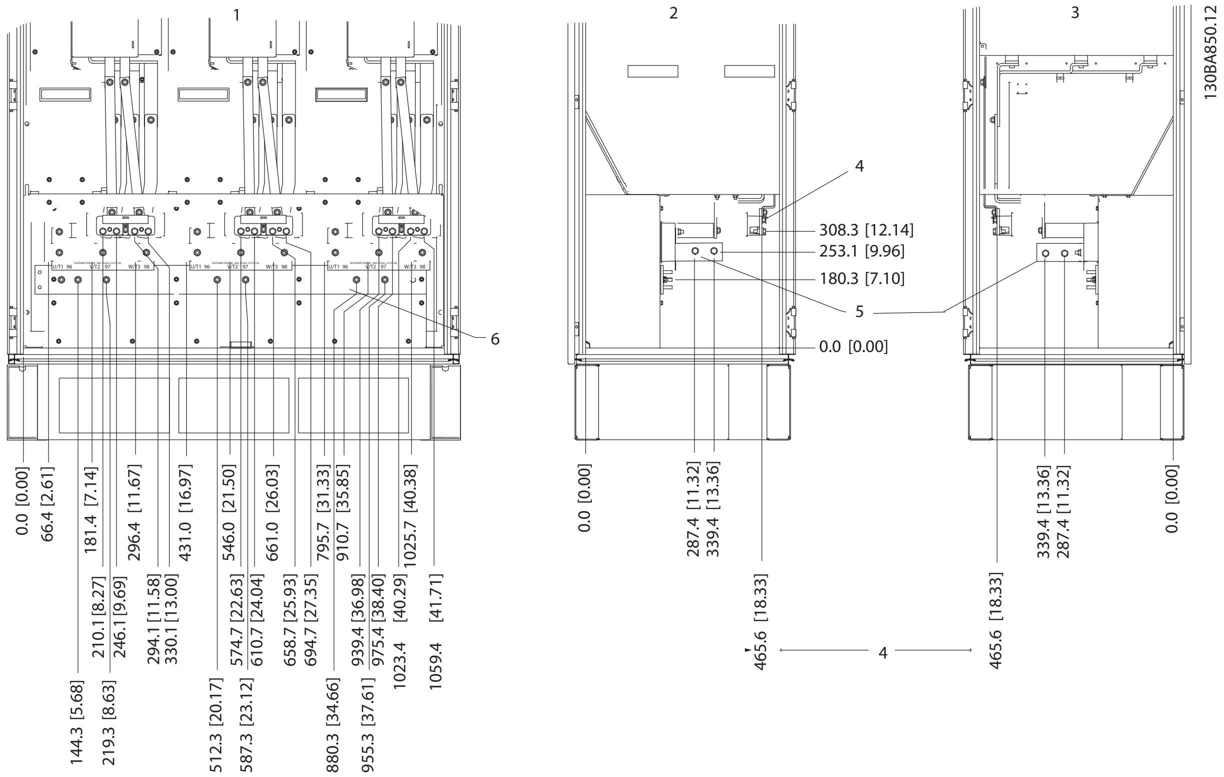


Illustration 7.26 Terminal Locations - Inverter Cabinet - F2 and F4. Gland Plate is 42 mm below .0 Level.

1	Front Side	3	Right Side
2	Left Side	4	Earth ground bar

Table 7.19 Legend to *Illustration 7.26*

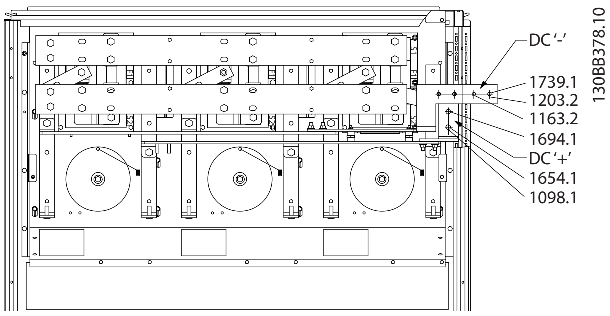
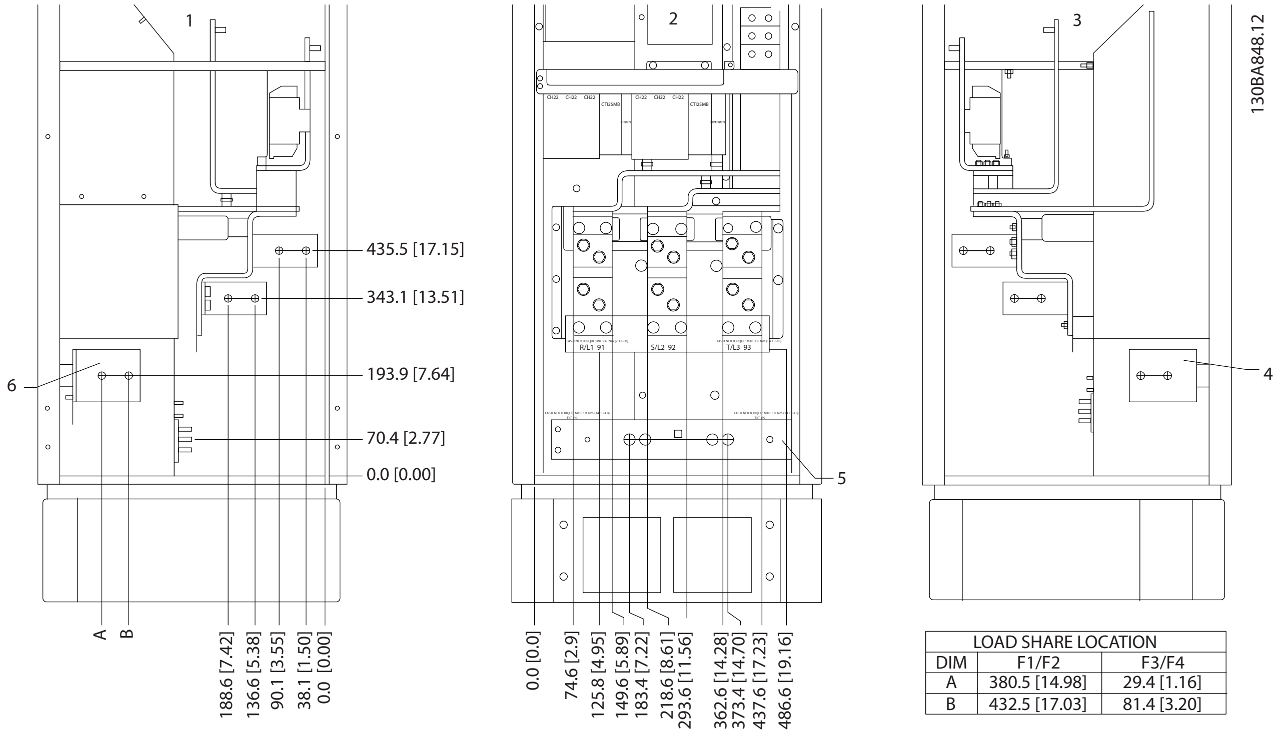


Illustration 7.27 Regeneration Terminal Locations - F2 and F4

Terminal Locations - Rectifier (F1, F2, F3 and F4)

Take the following position of the terminals into consideration when designing the cable access.



LOAD SHARE LOCATION		
DIM	F1/F2	F3/F4
A	380.5 [14.98]	29.4 [1.16]
B	432.5 [17.03]	81.4 [3.20]

Illustration 7.28 Terminal Locations - Rectifier. Gland Plate is 42 mm below .0 Level.

1	Left Side	4	Loadshare Terminal (-)
2	Front Side	5	Earth ground bar
3	Right Side	6	Loadshare Terminal (+)

Table 7.20 Legend to *Illustration 7.28*

Terminal Locations - Options Cabinet (F3 and F4)

Take the following position of the terminals into consideration when designing the cable access.

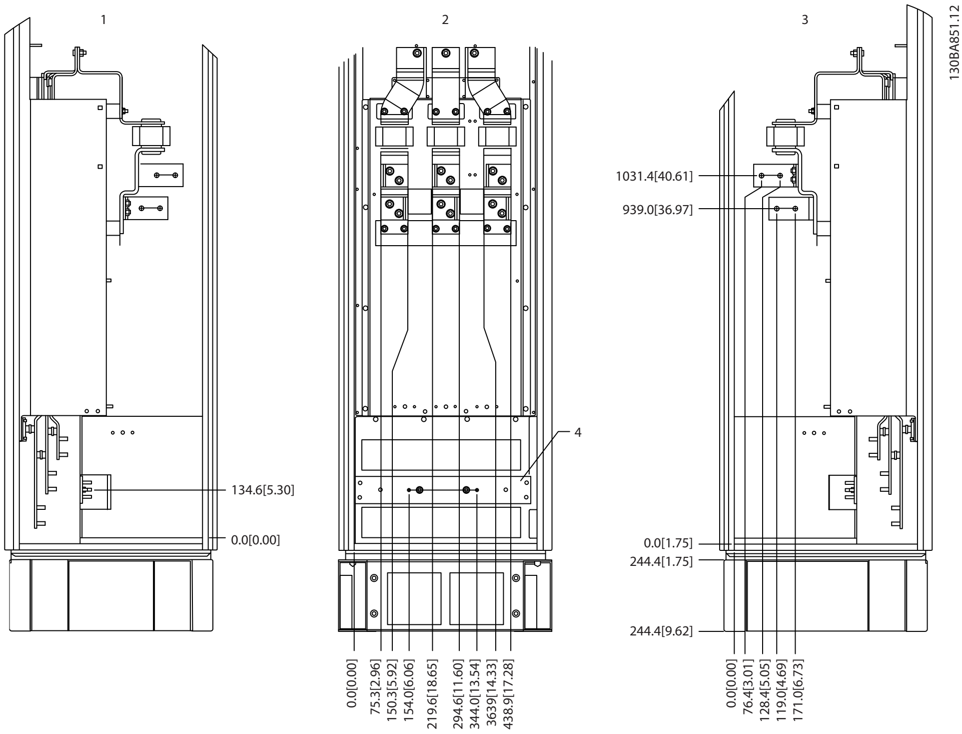


Illustration 7.29 Terminal Locations - Options Cabinet. Gland Plate is 42 mm below .0 Level.

1	Left Side	3	Right Side
2	Front Side	4	Earth ground bar

Table 7.21 Legend to *Illustration 7.29*

Terminal Locations - Options Cabinet with Circuit Breaker/Molded Case Switch (F3 and F4)

Take the following position of the terminals into consideration when designing the cable access.

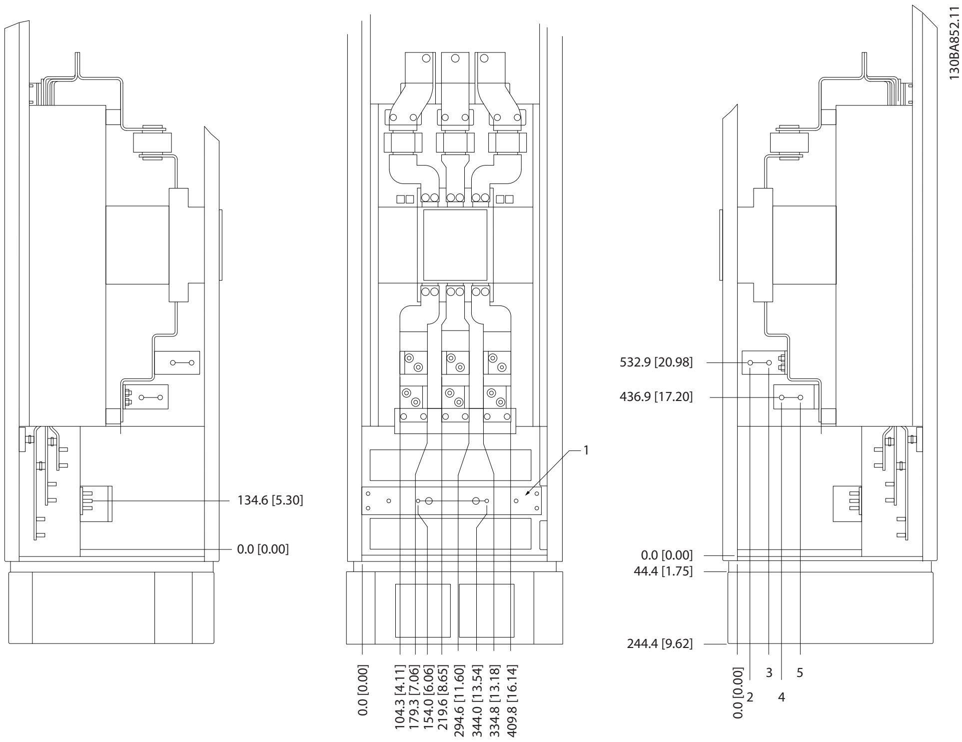


Illustration 7.30 Terminal Locations - Options Cabinet with Circuit Breaker/Molded Case Switch. Gland Plate is 42 mm below .0 Level.

1	Left Side	3	Right Side
2	Front Side	4	Earth ground bar

Table 7.22 Legend to *Illustration 7.30*

Power size	2	3	4	5
450 kW (480 V), 630-710 kW (690 V)	34.9	86.9	122.2	174.2
500-800 kW (480 V), 800-1000 kW (690 V)	46.3	98.3	119.0	171.0

Table 7.23 Dimension for Terminal

7.1.3 Power Connections 12-Pulse Frequency Converters

NOTICE

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

The power cable connections are situated as shown in *Illustration 7.31*. Dimensioning of cable cross section must be done in accordance with the current ratings and local legislation. See *7.8 EMC-Correct Installation* for correct dimensioning of motor cable cross-section and length.

For protection of the frequency converter, use the recommended fuses unless the unit is fitted with built-in fuses. Recommended fuses can be seen in *7.2.1 Fuses*. Always ensure that fusing complies with local regulations.

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

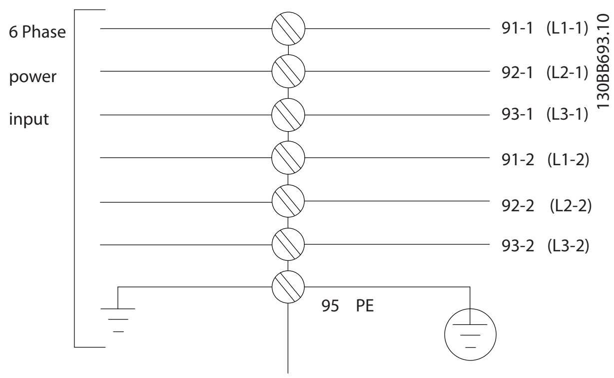


Illustration 7.31 Mains Connection

NOTICE

For more information, see *7.8 EMC-Correct Installation*.

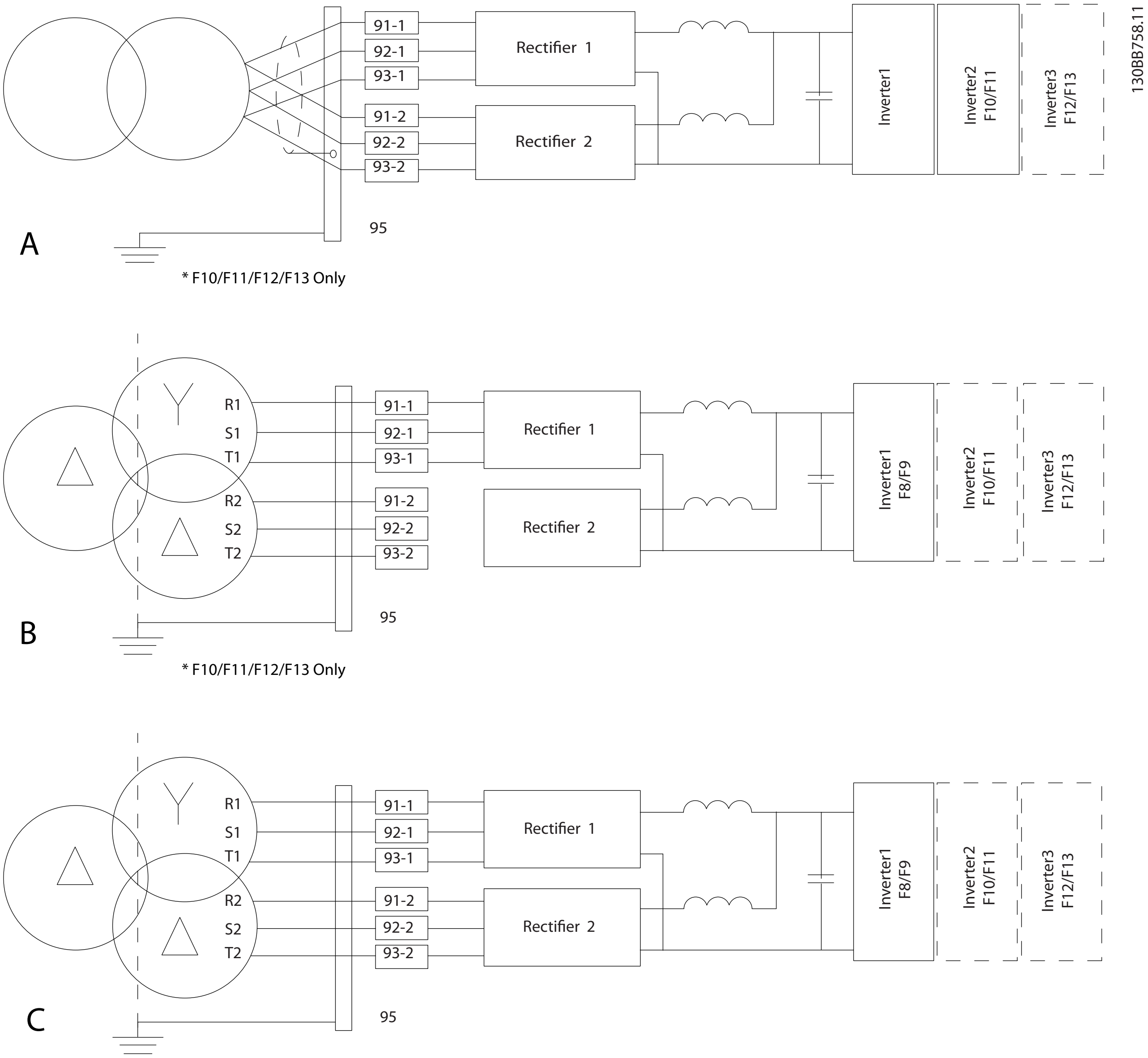


Illustration 7.32 Mains Connection Options for 12-Pulse Frequency Converters

A	6-Pulse Connection[1), 2), 3)]
B	Modified 6-Pulse Connection[2), 3), 4)]
C	12-Pulse Connection[3), 5)]

Table 7.24 Legend to ***Illustration 7.32***

Notes:

[1)] Parallel connection shown. A single 3-phase cable may be used with sufficient carrying capability. Install shorting bus bars.

[2)] 6-pulse connection eliminates the harmonics reduction benefits of the 12-pulse rectifier.

[3)] Suitable for IT and TN mains connection.

[4)] If one of the 6-pulse modular rectifiers becomes inoperable, it is possible to operate the frequency converter at reduced load with a single 6-pulse rectifier. Contact Danfoss for reconnection details.

[5)] No paralleling of mains cabling is shown here. A 12-pulse frequency converter used as a 6-pulse should have mains cables of equal numbers and lengths.

NOTICE

Use mains cables of equal length (±10%) and the same wire size for all 3 phases on both rectifier sections.

Screening of Cables
Avoid installation with twisted screen ends (pigtails). They spoil the screening effect at higher frequencies. If it is necessary to break the screen to install a motor isolator or motor contactor, the screen must be continued at the lowest possible HF impedance.

Connect the motor cable screen to both the de-coupling plate of the frequency converter and the metal housing of the motor.

Make the screen connections with the largest possible surface area (cable clamp) using the supplied installation devices within the frequency converter.

Cable-Length and Cross-Section
Keep the motor cable as short as possible to reduce the noise level and leakage currents.

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

Term. no.	96	97	98	99	
	U	V	W	PE[1]	Motor voltage 0–100% of mains voltage. 3 wires out of motor
	U1	V1	W1	PE[1]	Delta-connected
	W2	U2	V2		6 wires out of motor
	U1	V1	W1	PE[1]	Star-connected U2, V2, W2 U2, V2, and W2 to be interconnected separately.

Table 7.25 Terminals

[1] *Protective Earth Connection*

NOTICE

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

7.1.4 12-Pulse Transformer Selection Guidelines

Transformers used in conjunction with 12-Pulse frequency converters must conform to the following specifications. Loading is based on 12-pulse K-4 rated transformer with 0.5% voltage and impedance balance between secondary windings. Leads from the transformer to the input terminals on the frequency converter are required to be equal length within 10%.

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 screen recommended

7.1.5 Shielding against Electrical Noise

F-frame Size Units Only
Before mounting the mains power cable, mount the EMC metal cover to ensure best EMC performance.

NOTICE

The EMC metal cover is only included in units with an RFI filter.

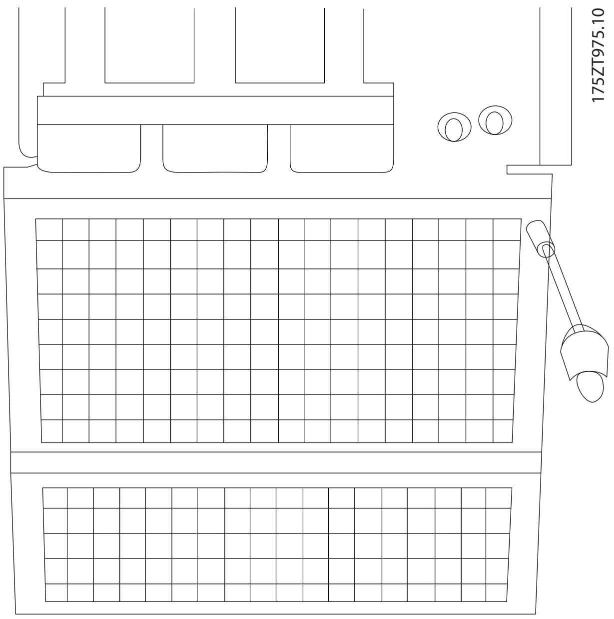


Illustration 7.33 Mounting of EMC Shield

7.1.6 External Fan Power Supply

Frame Sizes E and F
In case the frequency converter is supplied by DC or if the fan must run independently of the mains supply, an external power supply can be connected via the power card.

The connector located on the power card provides the connection of line voltage for the cooling fans. The fans are connected at the factory to connect to a common AC line. Use jumpers between terminals 100-102 and 101-103. If external supply is needed, the jumpers are removed and the supply is connected to terminals 100 and 101. Use a 5 A fuse for protection. In UL applications, use a LittelFuse KLK-5 or equivalent.

Terminal no.	Function
100, 101	Auxiliary supply S, T
102, 103	Internal supply S, T

Table 7.26 External Power Supply

7.2 Fuses and Circuit Breakers

7.2.1 Fuses

It is recommended to use fuses and/or circuit breakers on the supply side as protection in case of a component breakdown inside the frequency converter.

NOTICE

This is mandatory to ensure compliance with IEC 60364 for CE or NEC 2009 for UL.

WARNING

Personnel and property must be protected against the consequence of internal component breakdown in the frequency converter.

Branch Circuit Protection

In order to protect the installation against electrical and fire hazard, all branch circuits in an installation, such as those found in switch gear and machines, must be protected against short-circuit and over-current according to national/international regulations.

NOTICE

These recommendations do not cover branch circuit protection for UL.

Short-Circuit Protection

Danfoss recommends using the fuses/circuit breakers mentioned in *7.2.4 Power/Semiconductor Fuse Size* to protect service personnel and property in case of component break-down in the frequency converter.

7.2.2 D-frame Short Circuit Current Rating (SCCR)

If the frequency converter is not supplied with a mains disconnect, contactor, or circuit breaker, the Short Circuit Current Rating (SCCR) of the frequency converters is 100,000 A at all voltages (380–690 V).

If the frequency converter is supplied with a mains disconnect, the SCCR of the frequency converter is 100,000 amps at all voltages (380–690 V).

If the frequency converter is supplied with a circuit breaker, the SCCR depends on the voltage. See *Table 7.27*.

	415 V	480 V	600 V	690 V
D6h frame	120,000 A	100,000 A	65,000 A	70,000 A
D8h frame	100,000 A	100,000 A	42,000 A	30,000 A

Table 7.27 Frequency Converter Supplied with a Circuit Breaker

If the frequency converter is supplied with a contactor-only option and is externally fused according to *Table 7.28*, the SCCR of the frequency converter is as follows:

	415 V IEC[1)]	480 V UL[2)]	600 V UL[2)]	690 V IEC[1)]
D6h frame	100,000 A	100,000 A	100,000 A	100,000 A
D8h frame (not including the N250T5)	100,000 A	100,000 A	100,000 A	100,000 A
D8h frame (N250T5 only)	100,000 A	Consult factory	Not applicable	

Table 7.28 Frequency Converter Supplied with a Contactor

1) With a Bussmann type LPJ-SP or Gould Shawmut type AJT fuse. 450 A max fuse size for D6h and 900 A max fuse size for D8h.

2) Must use Class J or L branch fuses for UL approval. 450 A max fuse size for D6h and 600 A max fuse size for D8h.

7.2.3 Recommendations

WARNING

In case of malfunction, failure to follow these recommendations may result in personnel risk and damage to the frequency converter and other equipment.

Danfoss recommends the fuses from the following tables. Selecting the proper fuses and circuit breakers minimises damage due to an over-current condition within the frequency converter. If fuses/circuit breakers are chosen according to recommendations, possible damages are limited mainly to inside the unit.

For further information, see *Application Note for FC 100, FC 200 and FC 300 Fuses and Circuit Breakers*.

7

7.2.4 Power/Semiconductor Fuse Size

Fuses or Circuit Breakers are mandatory to comply with IEC 60364.

Enclosure size	FC 300 Model [kW]	Recommended fuse size	Recommended maximum fuse
D	N90K	aR-315	aR-315
	N110	aR-350	aR-350
	N132	aR-400	aR-400
	N160	aR-500	aR-500
	N200	aR-630	aR-630
	N250	aR-800	aR-800
E	P315	aR-900	aR-900
	P355	aR-900	aR-900
	P400	aR-900	aR-900
F	P450	aR-1600	aR-1600
	P500	aR-2000	aR-2000
	P560	aR-2500	aR-2500
	P630	aR-2500	aR-2500
	P710	aR-2500	aR-2500
	P800	aR-2500	aR-2500

Table 7.29 Recommended Fuses for CE Compliance, 380-500 V

Enclosure size	FC 300 Model [kW]	Recommended fuse size	Recommended maximum fuse
D	N55	aR-160	aR-160
	N75	aR-315	aR-315
	N90	aR-315	aR-315
	N110	aR-315	aR-315
	N132	aR-315	aR-315
	N160	aR-550	aR-550
	N200	aR-550	aR-550
	N250	aR-550	aR-550
	N315	aR-550	aR-550
E	P355	aR-700	aR-700
	P400	aR-900	aR-900
	P500		
	P560		
F	P630	aR-1600	aR-1600
	P710	aR-2000	aR-2000
	P800	aR-2500	aR-2500
	P900		
	P1M0		

Table 7.30 Recommended Fuses for CE Compliance, 525-690 V

7.2.5 Power/Semiconductor Fuse Options

Power size	Fuse Options							
	Bussman PN	Littelfuse PN	Littelfuse PN	Bussmann PN	Siba PN	Ferraz-Shawmut PN	Ferraz-Shawmut PN (Europe)	Ferraz-Shawmut PN (North America)
N90K	170M2619	LA50QS300-4	L50S-300	FWH-300A	20 189 20.315	A50QS300-4	6,9URD31D08A0315	A070URD31KI0315
N110	170M2620	LA50QS350-4	L50S-350	FWH-350A	20 189 20.350	A50QS350-4	6,9URD31D08A0350	A070URD31KI0350
N132	170M2621	LA50QS400-4	L50S-400	FWH-400A	20 189 20.400	A50QS400-4	6,9URD31D08A0400	A070URD31KI0400
N160	170M4015	LA50QS500-4	L50S-500	FWH-500A	20 610 31.550	A50QS500-4	6,9URD31D08A0550	A070URD31KI0550
N200	170M4016	LA50QS600-4	L50S-600	FWH-600A	20 610 31.630	A50QS600-4	6,9URD31D08A0630	A070URD31KI0630
N250	170M4017	LA50QS800-4	L50S-800	FWH-800A	20 610 31.800	A50QS800-4	6,9URD32D08A0800	A070URD31KI0800

Table 7.31 380-480/500 V, Frame Size D, Line Fuse Options

NOTICE

For UL compliance, the Bussmann 170M series fuses must be used for units supplied without a contactor-only option. For units supplied with a contactor-only option, see *Table 7.28* for SCCR ratings and UL fuse criteria.

FC 302 [kW]	Recommended drive external fuse Bussmann PN	Rating	Drive internal option Bussmann PN	Alternate external Siba PN	Alternate external Ferraz-Shawmut PN
250	170M4017	700 A, 700 V	170M4017	20 610 32.700	6.9URD31D08A0700
315	170M6013	900 A, 700 V	170M6013	22 610 32.900	6.9URD33D08A0900
355	170M6013	900 A, 700 V	170M6013	22 610 32.900	6.9URD33D08A0900
400	170M6013	900 A, 700 V	170M6013	22 610 32.900	6.9URD33D08A0900

Table 7.32 380-480/500 V, Frame Size E, Line Fuse Options for UL Compliance

FC 302 [kW]	Recommended drive external fuse Bussmann PN	Rating	Drive internal option Bussmann PN	Alternate Siba PN
450	170M7081	1600 A, 700 V	170M7082	20 695 32.1600
500	170M7081	1600 A, 700 V	170M7082	20 695 32.1600
560	170M7082	2000 A, 700 V	170M7082	20 695 32.2000
630	170M7082	2000 A, 700 V	170M7082	20 695 32.2000
710	170M7083	2500 A, 700 V	170M7083	20 695 32.2500
800	170M7083	2500 A, 700 V	170M7083	20 695 32.2500

Table 7.33 380-480/500 V, Frame Size F, Line Fuse Options for UL Compliance

FC 302 [kW]	Drive internal Bussmann PN	Rating	Alternate Siba PN
450	170M8611	1100 A, 1000 V	20 781 32.1000
500	170M8611	1100 A, 1000 V	20 781 32.1000
560	170M6467	1400 A, 700 V	20 681 32.1400
630	170M6467	1400 A, 700 V	20 681 32.1400
710	170M8611	1100 A, 1000 V	20 781 32.1000
800	170M6467	1400 A, 700 V	20 681 32.1400

Table 7.34 380-480/500 V, Frame Size F, Inverter Module DC Link Fuses

VLT© Model	Bussmann PN	Siba PN	Ferraz-Shawmut European PN	Ferraz-Shawmut North American PN
N55k T7	170M2616	20 610 31.160	6,9URD30D08A0160	A070URD30KI0160
N75k T7	170M2619	20 610 31.315	6,9URD31D08A0315	A070URD31KI0315
N90k T7	170M2619	20 610 31.315	6,9URD31D08A0315	A070URD31KI0315
N110 T7	170M2619	20 610 31.315	6,9URD31D08A0315	A070URD31KI0315
N132 T7	170M2619	20 610 31.315	6,9URD31D08A0315	A070URD31KI0315
N160 T7	170M4015	20 620 31.550	6,9URD32D08A0550	A070URD32KI0550
N200 T7	170M4015	20 620 31.550	6,9URD32D08A0550	A070URD32KI0550
N250 T7	170M4015	20 620 31.550	6,9URD32D08A0550	A070URD32KI0550
N315 T7	170M4015	20 620 31.550	6,9URD32D08A0550	A070URD32KI0550

Table 7.35 Fuse Options for 525-690 V, Frame Size D

NOTICE

For UL compliance, the Bussmann 170M series fuses must be used for units supplied without a contactor-only option. For units supplied with a contactor-only option, see *Table 7.28* for SCCR ratings and UL fuse criteria.

7

FC 302 [kW]	Recommended drive external fuse Bussmann PN	Rating	Drive internal option Bussmann PN	Alternate external Siba PN	Alternate external Ferraz-Shawmut PN
355	170M4017	700 A, 700 V	170M4017	20 610 32.700	6.9URD31D08A0700
400	170M4017	700 A, 700 V	170M4017	20 610 32.700	6.9URD31D08A0700
500	170M6013	900 A, 700 V	170M6013	22 610 32.900	6.9URD33D08A0900
560	170M6013	900 A, 700 V	170M6013	22 610 32.900	6.9URD33D08A0900

Table 7.36 525-690 V, Frame Size E, Line Fuse Options for UL Compliance

FC 302 [kW]	Recommended drive external fuse Bussmann PN	Rating	Drive internal option Bussmann PN	Alternate Siba PN
630	170M7081	1600 A, 700 V	170M7082	20 695 32.1600
710	170M7081	1600 A, 700 V	170M7082	20 695 32.1600
800	170M7081	1600 A, 700 V	170M7082	20 695 32.1600
900	170M7081	1600 A, 700 V	170M7082	20 695 32.1600
1000	170M7082	2000 A, 700 V	170M7082	20 695 32.2000
1200	170M7083	2500 A, 700 V	170M7083	20 695 32.2500

Table 7.37 525-690 V, Frame Size F, Line Fuse Options for UL Compliance

FC 302 [kW]	Drive internal Bussmann PN	Rating	Alternate Siba PN
630	170M8611	1100 A, 1000 V	20 781 32.1000
710	170M8611	1100 A, 1000 V	20 781 32.1000
800	170M8611	1100 A, 1000 V	20 781 32.1000
900	170M8611	1100 A, 1000 V	20 781 32.1000
1000	170M8611	1100 A, 1000 V	20 781 32.1000
1200	170M8611	1100 A, 1000 V	20 781 32.1000

Table 7.38 525-690 V, Frame Size F, Inverter Module DC Link Fuses

1) 170M fuses from Bussmann shown use the -/80 visual indicator, -TN/80 Type T, -/110 or TN/110 Type T indicator fuses of the same size and amperage may be substituted for external use

2) Any minimum 500 V UL listed fuse with associated current rating may be used to meet UL requirements.

7.2.6 Supplementary Fuses

Supplementary Fuses

Frame size	Bussmann PN	Rating
D	LPJ-21/2SP	2.5 A, 600 V

Table 7.39 D-frame Anti-Condensation Heater Fuse Recommendation

NOTICE

If a D-frame frequency converter comes with an anti-condensation heater, the heater must be powered, controlled, and protected by the installing contractor.

Frame size	Bussmann PN	Rating
E and F	KTK-4	4 A, 600 V

Table 7.40 SMPS Fuse

7

Size/Type	Bussmann PN	LittelFuse	Rating
P355-P400, 525-690 V	KTK-4		4 A, 600 V
P315-P800, 380-500 V		KLK-15	15 A, 600 V
P500-P1M2, 525-690 V		KLK-15	15 A, 600 V

Table 7.41 Fan Fuses

	Size/Type	Bussmann PN	Rating	Alternative fuses
2.5-4.0 A Fuse	P450-P800, 380-500 V	LPJ-6 SP or SPI	6 A, 600 V	Any listed Class J Dual Element, Time Delay, 6 A
	P630-P1M2, 525-690 V	LPJ-10 SP or SPI	10 A, 600 V	Any listed Class J Dual Element, Time Delay, 10 A
4.0-6.3 A Fuse	P450-P800, 380-500 V	LPJ-10 SP or SPI	10 A, 600 V	Any listed Class J Dual Element, Time Delay, 10 A
	P630-P1M2, 525-690 V	LPJ-15 SP or SPI	15 A, 600 V	Any listed Class J Dual Element, Time Delay, 15 A
6.3-10 A Fuse	P450-P800600HP-1200HP, 380-500 V	LPJ-15 SP or SPI	15 A, 600 V	Any listed Class J Dual Element, Time Delay, 15 A
	P630-P1M2, 525-690 V	LPJ-20 SP or SPI	20 A, 600 V	Any listed Class J Dual Element, Time Delay, 20 A
10-16 A Fuse	P450-P800, 380-500 V	LPJ-25 SP or SPI	25 A, 600 V	Any listed Class J Dual Element, Time Delay, 25 A
	P630-P1M2, 525-690 V	LPJ-20 SP or SPI	20 A, 600 V	Any listed Class J Dual Element, Time Delay, 20 A

Table 7.42 Manual Motor Controller Fuses

Frame Size	Bussmann PN	Rating	Alternative fses
F	LPJ-30 SP or SPI	30 A, 600 V	Any listed Class J Dual Element, Time Delay, 30 A

Table 7.43 30 A Fuse Protected Terminal Fuse

Frame size	Bussmann PN	Rating	Alternative fuses
F	LPJ-6 SP or SPI	6 A, 600 V	Any listed Class J Dual Element, Time Delay, 6 A

Table 7.44 Control Transformer Fuse

Frame Size	Bussmann PN	Rating
F	GMC-800 MA	800 mA, 250 V

Table 7.45 NAMUR Fuse

Frame size	Bussmann PN	Rating	Alternative fuses
F	LP-CC-6	6 A, 600 V	Any listed Class CC, 6 A

Table 7.46 Safety Relay Coil Fuse with PILZ Relay

7.2.7 High Power Fuses 12-Pulse

The fuses below are suitable for use on a circuit capable of delivering 100,000 A_{rms} (symmetrical), 240 V, or 480 V, or 500 V, or 600 V depending on the frequency converter voltage rating. With the proper fusing, the frequency converter short circuit current rating (SCCR) is 100,000 A_{rms}.

Power size	Frame	Rating		Bussmann	Spare Bussmann	Estimated fuse power loss [W]	
FC 302	Size	Voltage (UL)	Amperes	P/N	P/N	400 V	460 V
P250T5	F8/F9	700	700	170M4017	176F8591	25	19
P315T5	F8/F9	700	700	170M4017	176F8591	30	22
P355T5	F8/F9	700	700	170M4017	176F8591	38	29
P400T5	F8/F9	700	700	170M4017	176F8591	3500	2800
P450T5	F10/F11	700	900	170M6013	176F8592	3940	4925
P500T5	F10/F11	700	900	170M6013	176F8592	2625	2100
P560T5	F10/F11	700	900	170M6013	176F8592	3940	4925
P630T5	F10/F11	700	1500	170M6018	176F8592	45	34
P710T5	F12/F13	700	1500	170M6018	176F9181	60	45
P800T5	F12/F13	700	1500	170M6018	176F9181	83	63

Table 7.47 Line Fuses, 380-500 V

Power size	Frame	Rating		Bussmann	Spare Bussmann	Estimated fuse power loss [W]	
FC 302	Size	Voltage (UL)	Amperes	P/N	P/N	600 V	690 V
P355T7	F8/F9	700	630	170M4016	176F8335	13	10
P400T7	F8/F9	700	630	170M4016	176F8335	17	13
P500T7	F8/F9	700	630	170M4016	176F8335	22	16
P560T7	F8/F9	700	630	170M4016	176F8335	24	18
P630T7	F10/F11	700	900	170M6013	176F8592	26	20
P710T7	F10/F11	700	900	170M6013	176F8592	35	27
P800T7	F10/F11	700	900	170M6013	176F8592	44	33
P900T7	F12/F13	700	1500	170M6018	176F9181	26	20
P1M0T7	F12/F13	700	1500	170M6018	176F9181	37	28
P1M2T7	F12/F13	700	1500	170M6018	176F9181	47	36

Table 7.48 Line Fuses, 525-690 V

Size/Type	Bussmann PN*	Rating	Siba
P450	170M8611	1100 A, 1000 V	20 781 32.1000
P500	170M8611	1100 A, 1000 V	20 781 32.1000
P560	170M6467	1400 A, 700 V	20 681 32.1400
P630	170M6467	1400 A, 700 V	20 681 32.1400
P710	170M8611	1100 A, 1000 V	20 781 32.1000
P800	170M6467	1400 A, 700 V	20 681 32.1400

Table 7.49 Inverter Module DC Link Fuses, 380-500 V

Size/Type	Bussmann PN*	Rating	Siba
P630	170M8611	1100 A, 1000 V	20 781 32. 1000
P710	170M8611	1100 A, 1000 V	20 781 32. 1000
P800	170M8611	1100 A, 1000 V	20 781 32. 1000
P900	170M8611	1100 A, 1000 V	20 781 32. 1000
P1M0	170M8611	1100 A, 1000 V	20 781 32. 1000
P1M2	170M8611	1100 A, 1000 V	20 781 32.1000

Table 7.50 Inverter Module DC Link Fuses, 525-690 V

**170M fuses from Bussmann shown use the -/80 visual indicator, -TN/80 Type T, -/110 or TN/110 Type T indicator fuses of the same size and amperage may be substituted for external use.*

7.2.8 Supplementary Fuses - High Power

Supplementary Fuses

	Size/Type	Bussmann PN*	Rating	Alternative fuses
2.5-4.0 A Fuse	P450-P800, 380-500 V	LPJ-6 SP or SPI	6 A, 600 V	Any listed Class J Dual Element, Time Delay, 6A
	P630-P1M2, 525-690 V	LPJ-10 SP or SPI	10 A, 600 V	Any listed Class J Dual Element, Time Delay, 10 A
4.0-6.3 A Fuse	P450-P800, 380-500 V	LPJ-10 SP or SPI	10 A, 600 V	Any listed Class J Dual Element, Time Delay, 10 A
	P630-P1M2, 525-690 V	LPJ-15 SP or SPI	15 A, 600 V	Any listed Class J Dual Element, Time Delay, 15 A
6.3-10 A Fuse	P450-P800, 380-500 V	LPJ-15 SP or SPI	15 A, 600 V	Any listed Class J Dual Element, Time Delay, 15 A
	P630-P1M2, 525-690 V	LPJ-20 SP or SPI	20 A, 600 V	Any listed Class J Dual Element, Time Delay, 20A
10-16 A Fuse	P450-P800, 380-500 V	LPJ-25 SP or SPI	25 A, 600 V	Any listed Class J Dual Element, Time Delay, 25 A
	P630-P1M2, 525-690 V	LPJ-20 SP or SPI	20 A, 600 V	Any listed Class J Dual Element, Time Delay, 20 A

Table 7.51 Manual Motor Controller Fuses

Frame size	Bussmann PN	Rating
F8-F13	KTK-4	4 A, 600 V

Table 7.52 SMPS Fuse

Size/Type	Bussmann PN	LittelFuse	Rating
P315-P800, 380-500 V		KLK-15	15 A, 600 V
P500-P1M2, 525-690 V		KLK-15	15 A, 600 V

Table 7.53 Fan Fuses

Frame size	Bussmann PN	Rating	Alternative fuses
F8-F13	LPJ-30 SP or SPI	30 A, 600 V	Any listed Class J Dual Element, Time Delay, 30 A

Table 7.54 30 A Fuse Protected Terminal Fuse

Frame size	Bussmann PN	Rating	Alternative fuses
F8-F13	LPJ-6 SP or SPI	6 A, 600 V	Any listed Class J Dual Element, Time Delay, 6 A

Table 7.55 Control Transformer Fuse

Frame size	Bussmann PN	Rating
F8-F13	GMC-800 MA	800 mA, 250 V

Table 7.56 NAMUR Fuse

Frame size	Bussmann PN	Rating	Alternative fuses
F8-F13	LP-CC-6	6 A, 600 V	Any listed Class CC, 6 A

Table 7.57 Safety Relay Coil Fuse with Pilz Relay

Frame size	Power & Voltage	Type	Default breaker settings	
			Trip level [A]	Time [s]
F3	P450 380-500 V & P630-P710 525-690 V	Merlin Gerin NPJF36120U31AABSCYP	1200	0.5
F3	P500-P630 380-500 V & P800 525-690 V	Merlin Gerin NRJF36200U31AABSCYP	2000	0.5
F4	P710 380-500 V & P900-P1M2 525-690 V	Merlin Gerin NRJF36200U31AABSCYP	2000	0.5
F4	P800 380-500 V	Merlin Gerin NRJF36250U31AABSCYP	2500	0.5

Table 7.58 F-frame Circuit Breakers

7.3 Disconnectors and Contactors

7.3.1 Mains Disconnects - Frame Sizes E and F

Frame size	Power	Type
380-500 V		
D5h/D6h	N55K-N132	ABB OT400U03
D7h/D8h	N160-N315	ABB OT600U03
E1/E2	P250	ABB OETL-NF600A
E1/E2	P315-P400	ABB OETL-NF800A
F3	P450	Merlin Gerin NPJF36000S12AAYP
F3	P500-P630	Merlin Gerin NRKF36000S20AAYP
F4	P710-P800	Merlin Gerin NRKF36000S20AAYP
525-690 V		
D5h/D6h	N90K-N132	ABB OT400U03
D7h/D8h	N160-N250	ABB OT600U03
E1/E2	P355-P560	ABB OETL-NF600A
F3	P630-P710	Merlin Gerin NPJF36000S12AAYP
F3	P800	Merlin Gerin NRKF36000S20AAYP
F4	P900-P1M2	Merlin Gerin NRKF36000S20AAYP

Table 7.59 Mains Disconnects, 6-Pulse Frequency Converters

7.3.2 Mains Disconnects, 12-Pulse

Frame size	Power	Type
380-500 V		
F9	P250	ABB OETL-NF600A
F9	P315	ABB OETL-NF600A
F9	P355	ABB OETL-NF600A
F9	P400	ABB OETL-NF600A
F11	P450	ABB OETL-NF800A
F11	P500	ABB OETL-NF800A
F11	P560	ABB OETL-NF800A
F11	P630	ABB OT800U21
F13	P710	Merlin Gerin NPJF36000S12AAYP
F13	P800	Merlin Gerin NPJF36000S12AAYP
525-690 V		
F9	P355	ABB OT400U12-121
F9	P400	ABB OT400U12-121
F9	P500	ABB OT400U12-121
F9	P560	ABB OT400U12-121
F11	P630	ABB OETL-NF600A
F11	P710	ABB OETL-NF600A
F11	P800	ABB OT800U21
F13	P900	ABB OT800U21
F13	P1M0	Merlin Gerin NPJF36000S12AAYP
F13	P1M2	Merlin Gerin NPJF36000S12AAYP

Table 7.60 Mains Disconnects, 12-Pulse Frequency Converters

7.3.3 Mains Contactors

NOTICE

Customer-supplied 230 V supply is required for mains contactors.

Frame size	Power & Voltage	Contactor
D6h	N90K-N132 380-500 V	GE CK95CE311N
	N110-N160 380-480 V	GE CK95BE311N
	N55-N132 525-690 V	GE CK95CE311N
	N75-N160 525-690 V	GE CK95BE311N
D8h	N160-N250 380-500 V	GE CK11CE311N
	N200-N315 380-480 V	
	N160-N315 525-690 V	
	N200-N400 525-690 V	

Table 7.61 D-frame Contactors

Frame size	Power & Voltage	Contactor
F3	P450-P500 380-500 V & P630-P800 525-690 V	Eaton XTCE650N22A
F3	P560 380-500 V	Eaton XTCE820N22A
F3	P630 380-500 V	Eaton XTCEC14P22B
F4	P900 525-690 V	Eaton XTCE820N22A
F4	P710-P800 380-500 V & P1M2 525-690 V	Eaton XTCEC14P22B

Table 7.62 F-frame Contactors

7.4 Additional Motor Information

7.4.1 Motor Cable

All types of 3-phase asynchronous standard motors can be used with a frequency converter unit. The motor must be connected to the following terminals:

- U/T1/96
- V/T2/97
- W/T3/98
- earth to terminal 99

Factory setting is for clockwise rotation with the frequency converter output connected as follows:

Terminal no.	Function
96	Mains U/T1
97	V/T2
98	W/T3
99	Earth

Table 7.63 Motor Cable Terminals

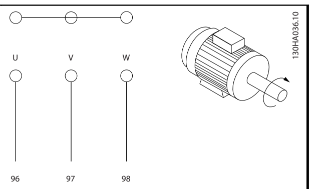
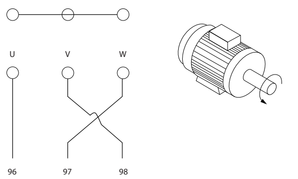
• Terminal U/T1/96 connected to U-phase • Terminal V/T2/97 connected to V-phase • Terminal W/T3/98 connected to W-phase	
	

Table 7.64 Changing Motor Rotation

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

Motor rotation check can be performed using *1-28 Motor Rotation Check* and following the steps shown in *Table 7.64*.

F-frame requirements
F1/F3 frame
Each inverter module must have the same number of motor phase cables and they must be in quantities of 2 (for example, 2, 4, 6, or 8). 1 cable is not allowed. The cables are required to be equal length or within 10% between the inverter module terminals and the first common point of a phase. The recommended common point is the motor terminals. For example, if inverter module A used a 100 m cable, then subsequent inverter modules could use a cable between 90-110 m in length.

F2/F4 frame
Each inverter module must have the same number of motor phase cables and they must be in quantities of 3 (for example, 3, 6, 9, or 12). 1 or 2 cables are not allowed. The cables are required to be equal length or within 10% between the inverter module terminals and the first common point of a phase. The recommended common point is the motor terminals. For example, if inverter module A used a 100 m cable, then subsequent inverter modules could use a cable between 90-110 m in length.

Output junction box requirements
The length (minimum 2.5 m) and quantity of cables must be equal from each inverter module to the common terminal in the junction box.

NOTICE

If a retrofit application requires an unequal number of wires per phase, consult the factory for requirements and documentation, or use the top/bottom entry side cabinet option.

The electronic thermal relay in the frequency converter has received UL-approval for single motor protection, when *1-90 Motor Thermal Protection*is set for *ETR Trip* and *1-24 Motor Current* is set to the rated motor current (see the motor name plate).
For thermal motor protection it is also possible to use the MCB 112 PTC Thermistor Card option. This card provides ATEX certificate to protect motors in explosion hazardous areas, Zone 1/21 and Zone 2/22. When *1-90 Motor Thermal Protection* is 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.

7.4.2 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).
- VCC^{plus} mode may be used in some applications.
- Total current consumption of motors must not exceed the rated output current I_{INV} for the frequency converter.
- Problems may arise at start and at low RPM if motor sizes are widely different because the small motors' relatively high ohmic resistance in the stator 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, *1-02 Flux Motor Feedback Source* cannot be used, and *1-01 Motor Control Principle* must be set to *Special motor characteristics (U/f)*.

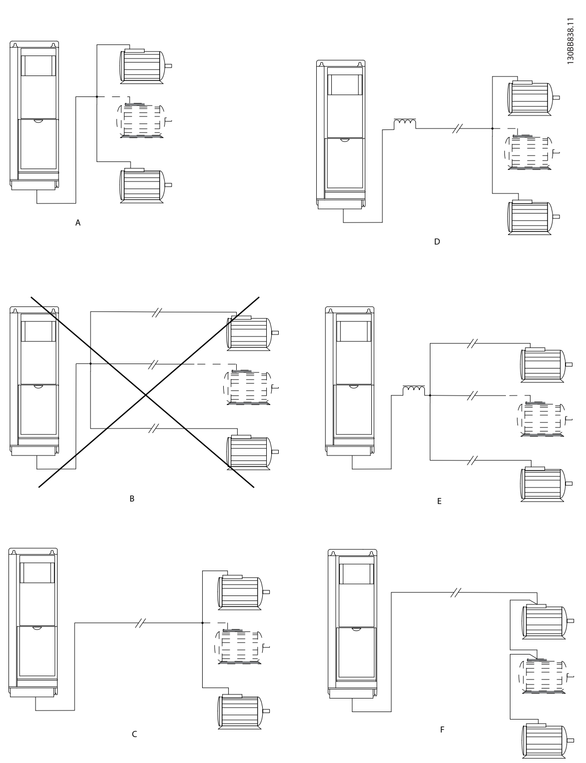


Illustration 7.34 Different Parallel Connections of Motors

A	Installations with cables connected in a common joint as shown in A and B are only recommended for short cable lengths.
B	Be aware of the maximum motor cable length specified in *4.3 General Specifications*.
C	The total motor cable length specified in *4.3 General Specifications* is valid as long as the parallel cables are kept short less than 10 m each. (Example 1)
D	Consider voltage drop across the motor cables. (Example 1)
E	Consider voltage drop across the motor cables. (Example 2)
F	The total motor cable length specified in *4.3 General Specifications* is valid as long as the parallel cables are kept less than 10 m each. (Example 2).

Table 7.65 Legend to *Illustration 7.34*

7.4.3 Motor Insulation

For motor cable lengths that are less than or equal to the maximum cable length listed in *4.3 General Specifications*, use the motor insulation ratings shown in *Table 7.66*. If a motor has lower insulation rating, Danfoss recommends using a dU/dt or sine wave filter.

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

Table 7.66 Motor Insulation Ratings

7.4.4 Motor Bearing Currents

All motors installed with FC 302 90 kW or higher power frequency converters should have NDE (Non-Drive End) insulated bearings installed to eliminate circulating bearing currents. 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.

Here are some standard mitigation strategies:

- Use an insulated bearing.
- Follow proper installation procedures.
  - Ensure 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 screened cable that has a 360° connection in the motor and the frequency converter.
  - Ensure the impedance from the frequency converter to building ground is lower that the grounding impedance of the machine. This can be difficult for pumps.
  - Make a direct earth connection between the motor and load motor.
- Lower the IGBT switching frequency.
- Modify the inverter waveform, 60° AVM vs. SFAVM.
- Install a shaft grounding system or use an isolating coupling.
- Apply conductive lubrication.
- Use minimum speed settings if possible.
- Try to ensure that the line voltage is balanced to ground. This can be difficult for IT, TT, TN-CS, or Grounded leg systems.
- Use a dU/dt or sine-wave filter.

7.5 Control Cables and Terminals

7.5.1 Access to Control Terminals

All terminals to the control cables are located underneath the terminal cover on the front of the frequency converter. Remove the terminal cover with a screw driver.

7.5.2 Control Cable Routing

Tie down and route all control wires as shown in *Illustration 7.35* and *Illustration 7.36*. Remember to connect the shields in a proper way to ensure optimum electrical immunity.

Fieldbus Connection
Connections are made to the relevant options on the control card. For more detail, see the relevant fieldbus instruction. The cable must be tied down and routed along with other control wires inside the unit. See *Illustration 7.35* through *Illustration 7.39*.

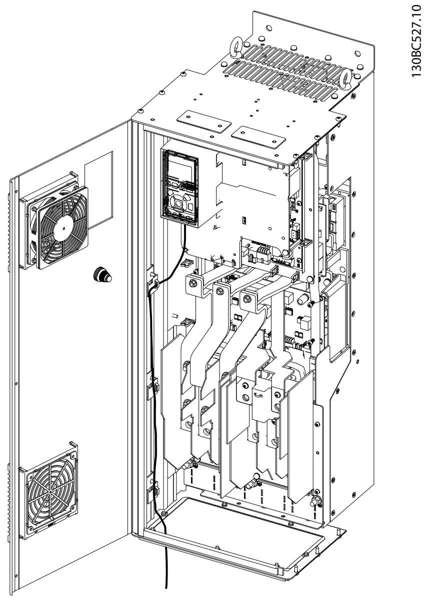


Illustration 7.35 Control Card Wiring Path for the D3h. Control Card Wiring for the D1h, D2h, D4h, E1 and E2 Use the Same Path

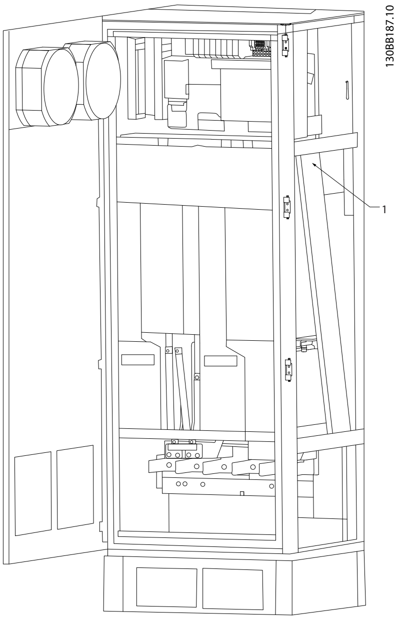


Illustration 7.36 Control Card Wiring Path for the F1/F3. Control Card Wiring for the F2/F4 Use the Same Path

In the D- and E-Frame frequency converters, it is possible to connect the fieldbus from the top of the unit, as shown in the following illustrations. On the IP21/54 (NEMA-1/ NEMA-12) unit, a cover plate must be removed.
The kit number for the fieldbus top connection is 176F1742.

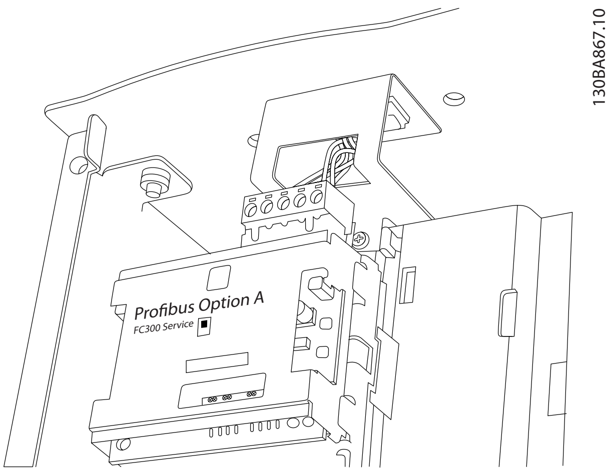


Illustration 7.37 Top Connection for Fieldbus

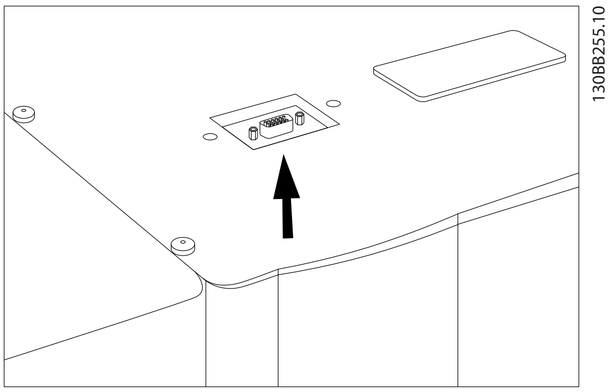


Illustration 7.38 Profibus Top Entry Kit, Installed

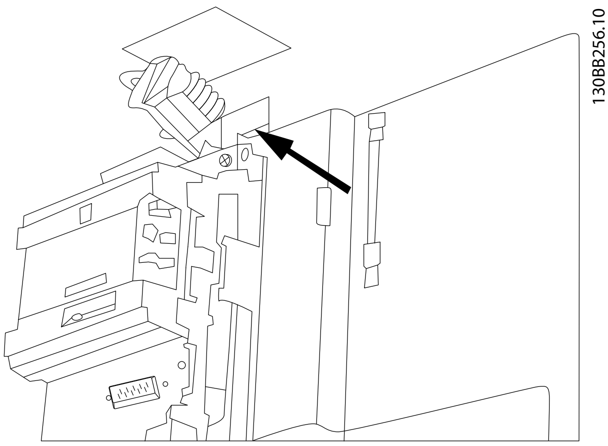


Illustration 7.39 Shield Termination/Strain Relief for Fieldbus Conductors

Installation of 24 V External DC Supply
Torque: 0.5-0.6 Nm (5 in-lbs)
Screw size: M3

24 V DC external supply can be used as a low-voltage supply to the control card and any installed option cards. This enables full operation of the LCP (including parameter setting) without connection to mains. Note that a warning of low voltage displays when 24 V DC has been connected; however, there is no tripping.

No.	Function
35 (-), 36 (+)	24 V external DC supply

Table 7.67 Terminal Numbers for External 24 V Supply

⚠WARNING

Use 24 V DC supply of type PELV to ensure correct galvanic isolation (type PELV) on the control terminals of the frequency converter.

7.5.3 Control Terminals

Drawing Reference Numbers:

1. 10-pole plug digital I/O
2. 3-pole plug RS-485 Bus
3. 6-pole analog I/O
4. USB Connection

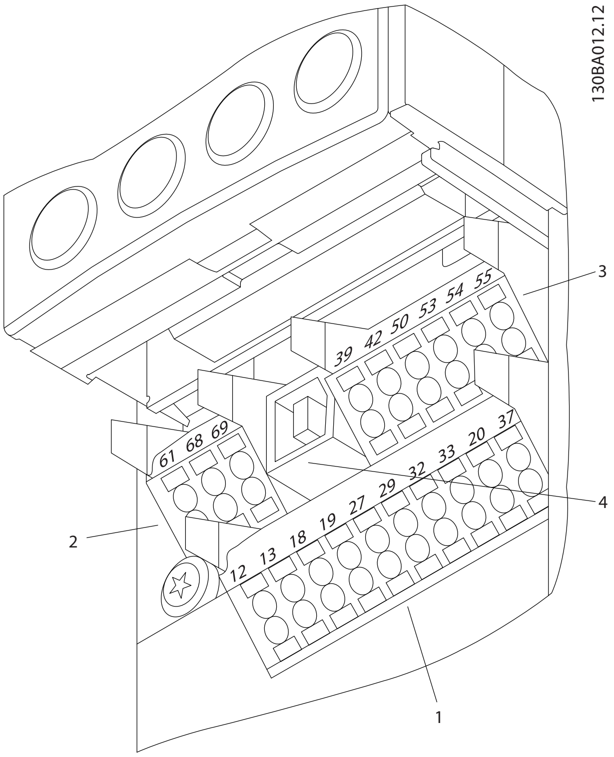


Illustration 7.40 Control Terminals (All Frame Sizes)

7.5.4 Switches S201 (A53), S202 (A54), and S801

Switches S201 (A53) and S202 (A54) are used to select a current (0-20 mA) or a voltage (-10 to 10 V) configuration of the analog input terminals 53 and 54, respectively.

Switch S801 (BUS TER.) can be used to enable termination on the RS-485 port (terminals 68 and 69). See *Illustration 7.43*.

Default Setting:

S201 (A53)=OFF (voltage input)

S202 (A54)=OFF (voltage input)

S801 (Bus termination)=OFF

NOTICE

Change the switch position at power off only.

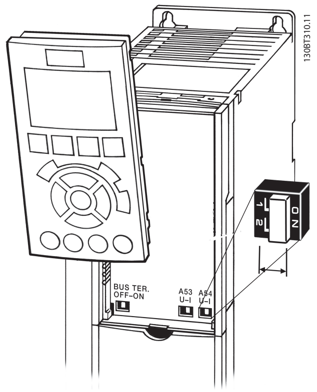


Illustration 7.41 Location of Switches S801, S201, and S202 (Left to Right)

7.5.5 Installing Control Terminals

Control Terminals

To mount the cable to the terminal, perform the following steps:

1. Strip insulation of 9-10 mm.
2. Insert a screwdriver (Max. 0.4x2.5 mm) in the square hole.
3. Insert the cable in the adjacent circular hole.
4. Remove the screw driver. The cable is now mounted to the terminal.

To remove the cable from the terminal, perform the following steps:

1. Insert a screwdriver (Max. 0.4x2.5 mm) in the square hole.
2. Pull out the cable.

7.5.6 Basic Wiring Example

1. Mount the terminals from the accessory bag to the front of the frequency converter.
2. Connect terminals 18, 27, and 37 to +24 V (terminal 12/13)

Default Settings:
18=Start, *5-10 Terminal 18 Digital Input* [9]
27=Stop inverse, *5-12 Terminal 27 Digital Input* [6]
37=Safe torque off inverse

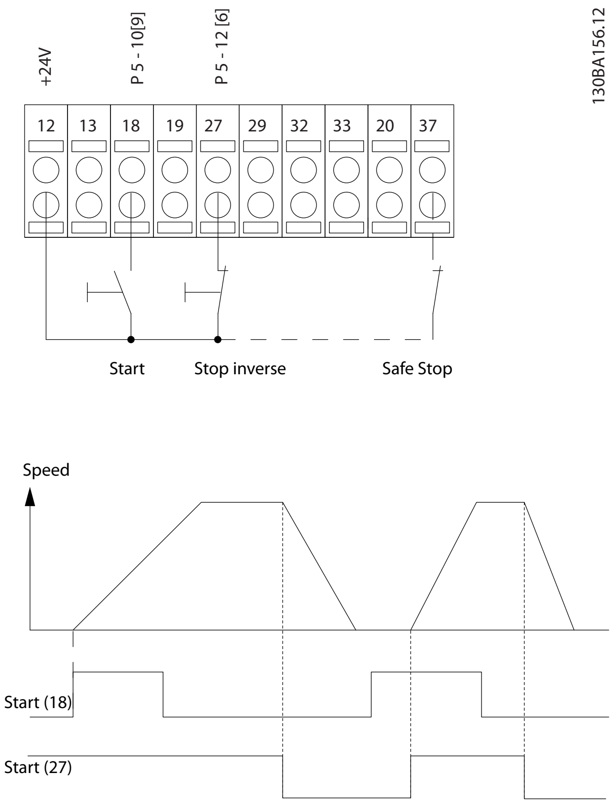


Illustration 7.42 Basic Wiring

7.5.7 Installing Control Cables

Electrical Installation

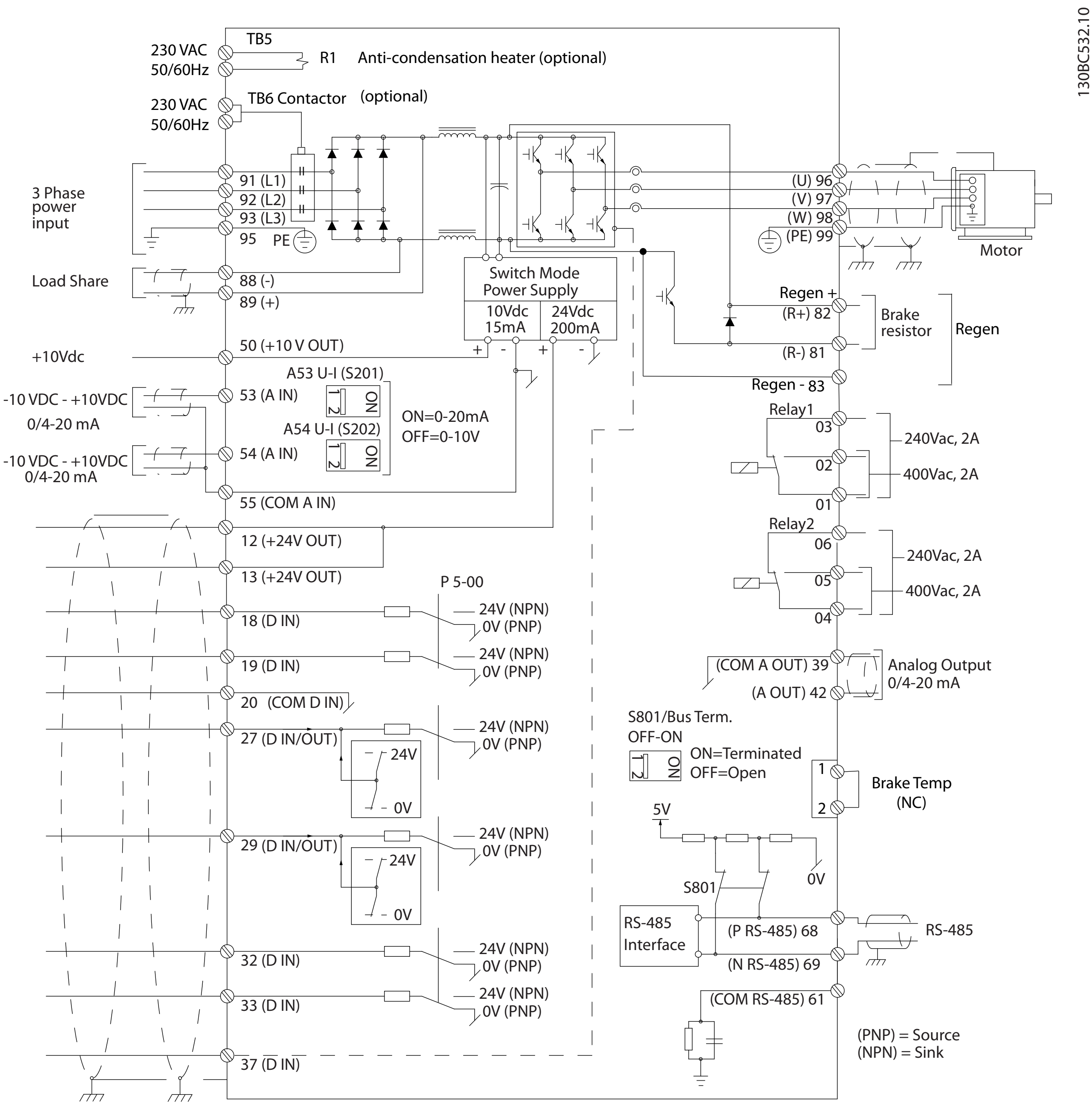


Illustration 7.43 Interconnect Diagram, D-Frame Frequency Converters (A=analog, D=digital)

Terminal 37 is used for Safe Torque Off. For Instructions on Safe Torque Off Installation, Refer to *3.12 Safe Torque Off*.

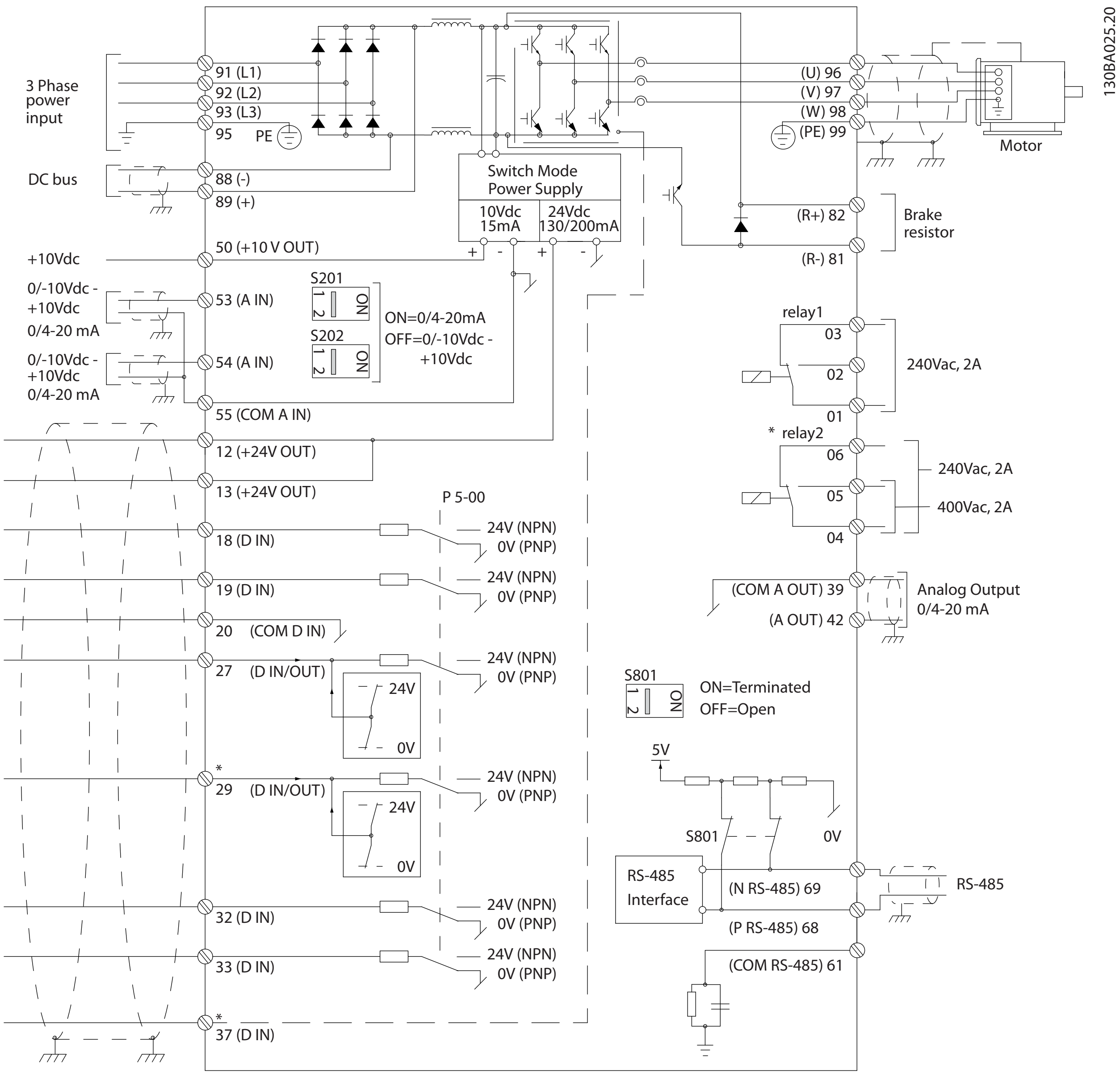


Illustration 7.44 Interconnect Diagram, E- and F-Frame Frequency Converters

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

7

Input Polarity of Control Terminals

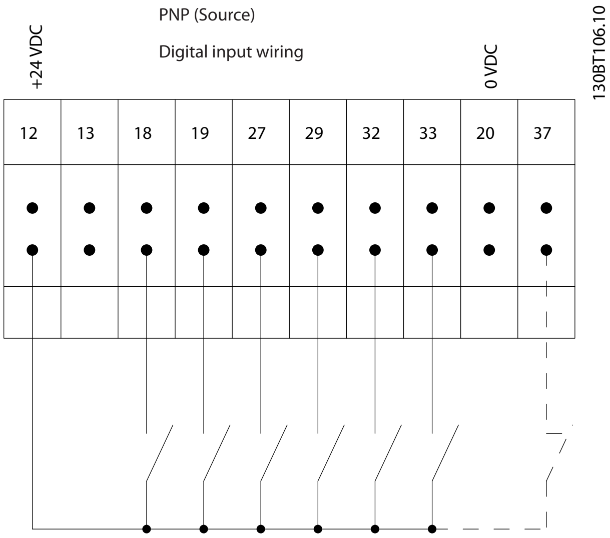


Illustration 7.45 Input Polarity of Control Terminals (PNP Source)

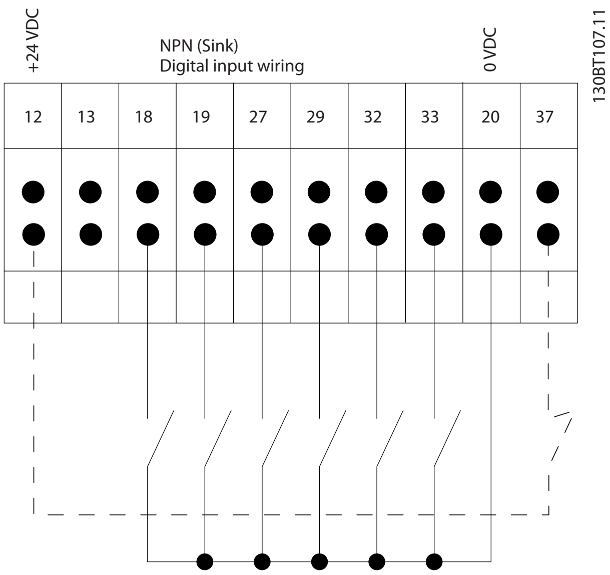


Illustration 7.46 Input Polarity of Control Terminals (NPN Sink)

NOTICE

Use screened/armoured cables to comply with EMC emission specifications. For more information, see *7.8 EMC-Correct Installation*.

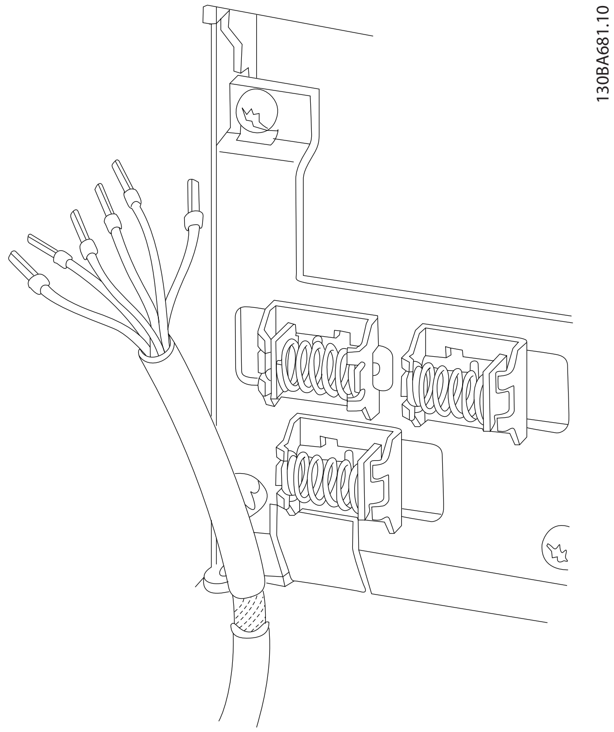


Illustration 7.47 Shield Termination and Strain Relief of Control Cable

7.5.8 12-Pulse Control Cables

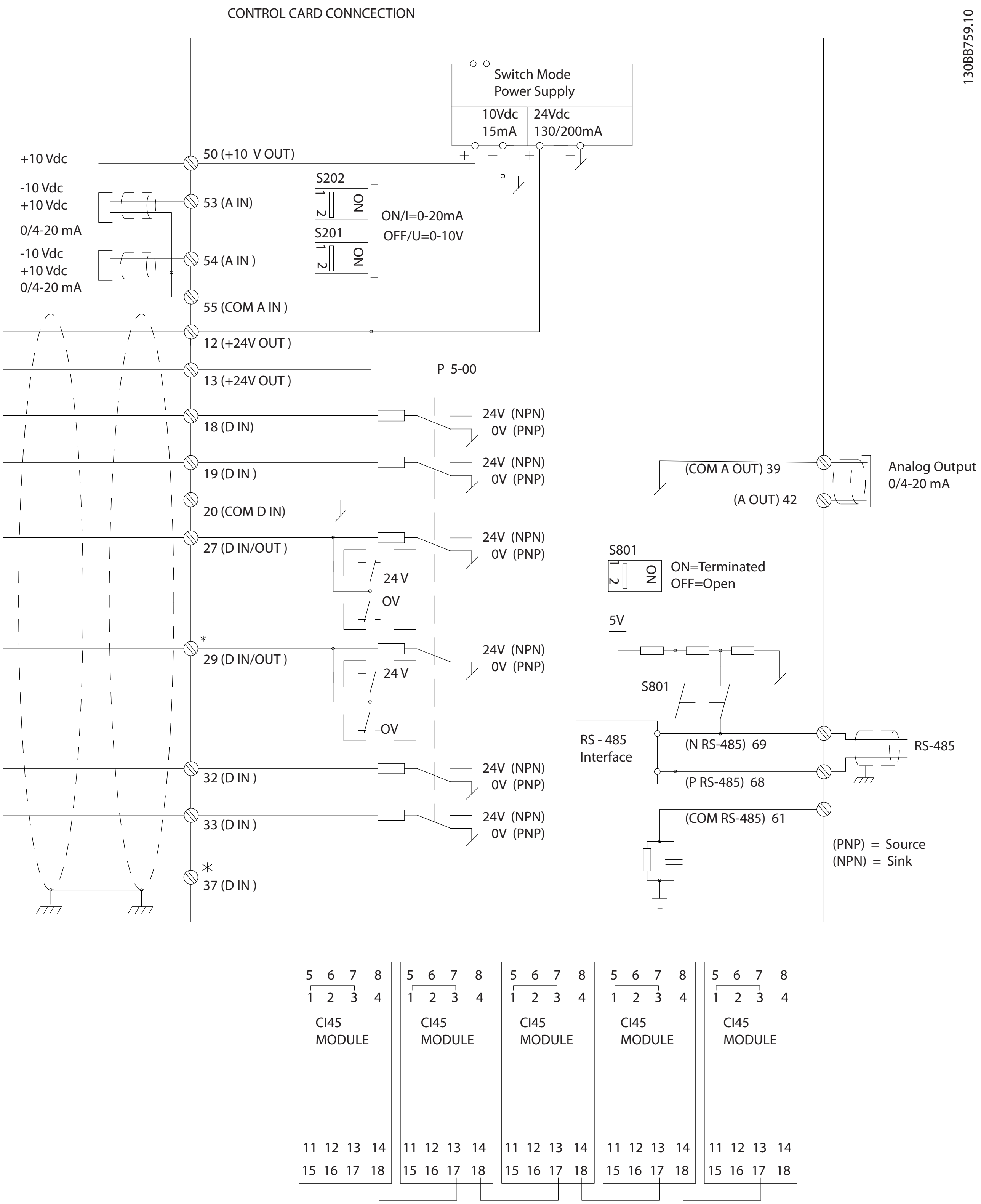


Illustration 7.48 Control Cable Diagram

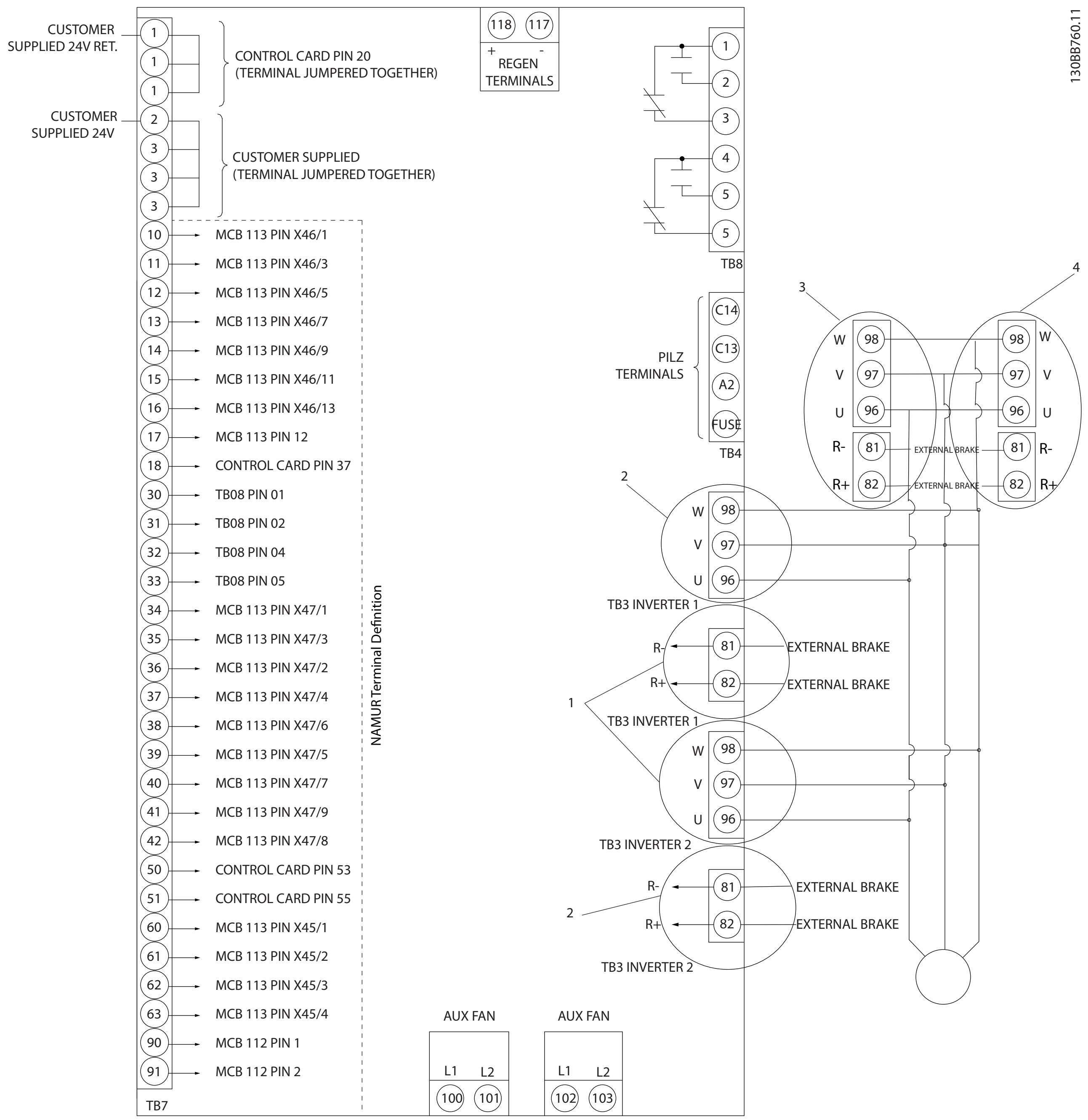


Illustration 7.49 Electrical Terminals without Options

Terminal 37 is the input to be used for Safe Torque Off. For instructions on Safe Torque Off installation, refer to *3.12 Safe Torque Off*.

1) F8/F9 = (1) set of terminals.

2) F10/F11 = (2) sets of terminals.

3) F12/F13 = (3) sets of terminals.

Input Polarity of Control Terminals

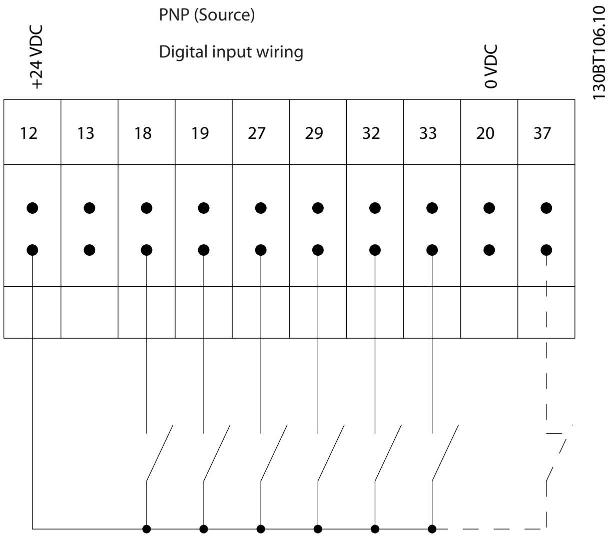


Illustration 7.50 Input Polarity of Control Terminals

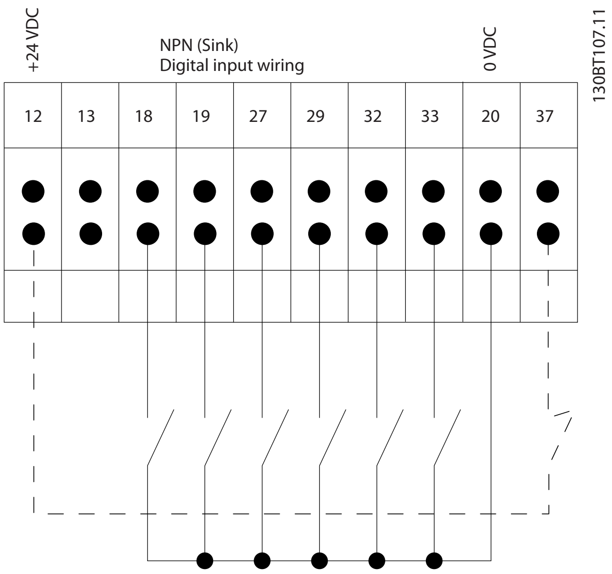


Illustration 7.51 Input Polarity of Control Terminals

7.5.9 Relay Output D Frame

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 *5-40 Function Relay*, *5-41 On Delay, Relay*, and *5-42 Off Delay, Relay*.

Use option module MCB 105 for additional relay outputs.

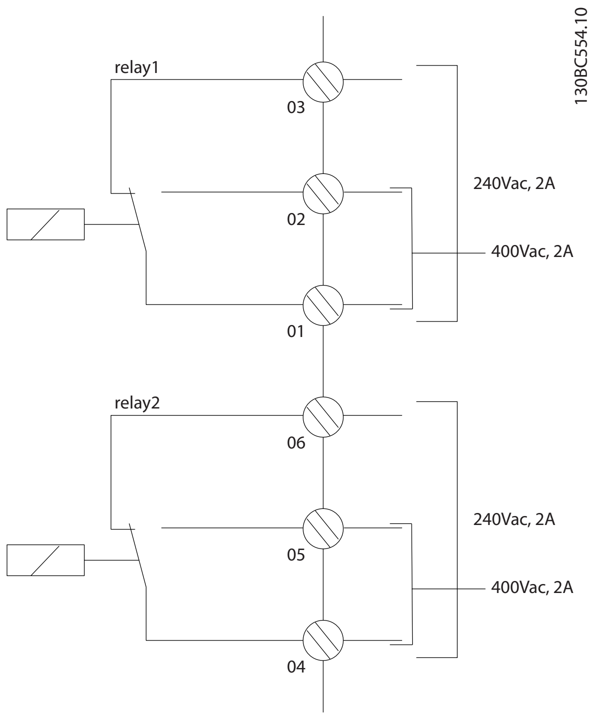


Illustration 7.52 D-Frame Additional Relay Outputs

7.5.10 Relay Output E & F-Frame

Relay 1

- Terminal 01: common
- Terminal 02: normally open 240 V AC
- Terminal 03: normally closed 240 V AC

Relay 2

- Terminal 04: common
- Terminal 05: normally open 400 V AC
- Terminal 06: normally closed 240 V AC

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

Use option module MCB 105 for additional relay outputs.

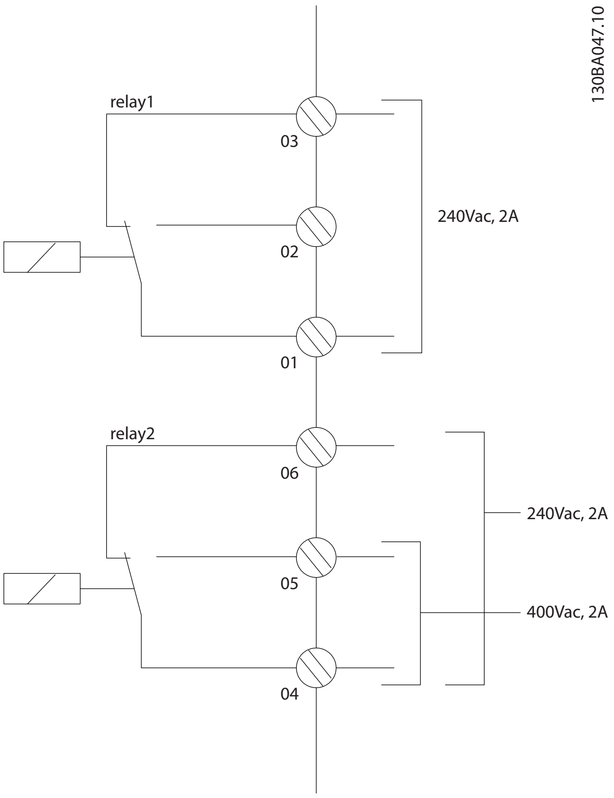


Illustration 7.53 E- and F-Frame Additional Relay Outputs

7.5.11 Brake Resistor Temperature Switch

Frame Size D-E-F
Torque: 0.5-0.6 Nm (5 in-lbs)
Screw size: M3

This input monitors the temperature of an externally connected brake resistor. If the input between 104 and 106 is established, the frequency converter trips on warning/ alarm 27, “Brake IGBT”. If the connection is closed between 104 and 105, the frequency converter trips on warning/ alarm 27, “Brake IGBT.”
Install a KLIXON switch that is “normally closed”. If this function is not used, short circuit 106 and 104 together.
Normally closed: 104-106 (factory installed jumper)
Normally open: 104-105

Terminal no.	Function
106, 104, 105	Brake resistor temperature switch.

Table 7.68 Brake Resistor Temperature Switch Terminals

NOTICE

If the temperature of the brake resistor gets too high and the thermal switch trips, the frequency converter stops braking and the motor coasts.

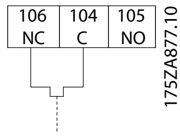


Illustration 7.54 Brake Resistor Temperature Switch Interconnect

7.6 Additional Connections

7.6.1 DC Bus Connection

The DC bus terminal is used for DC back-up, with the intermediate circuit being supplied from an external source.

Terminal no.	Function
88, 89	DC Bus

Table 7.69 DC Bus Terminals

Contact Danfoss if further information is required.

7.6.2 Load Sharing

Load Sharing calls for extra equipment and safety considerations. For further information, *Load Sharing Application Note*.

CAUTION

Note that voltages up to 1099 V DC may occur on the terminals.

Terminal no.	Function
88, 89	Loadsharing

Table 7.70 Load Sharing Terminals

The connection cable must be screened and the maximum length from the frequency converter to the DC bar is limited to 25 m (82 ft).
Load sharing links together the DC intermediate circuits of several frequency converters.

WARNING

Note that mains disconnect may not isolate the frequency converter due to DC link connection.

7.6.3 Installation of Brake Cable

The connection cable to the brake resistor must be screened and the maximum length from the frequency converter to the DC bar is limited to 25 metres (82 ft).

1. Use cable clamps to connect the screen to the conductive back plate on the frequency converter and to the metal cabinet of the brake resistor.
2. Size the brake cable cross-section to match the brake torque.

No.	Function
81, 82	Brake resistor terminals

Table 7.71 Brake Resistor Terminals

See the *Brake Resistor Design Guide* for more details.

NOTICE

If a short circuit in the brake IGBT occurs, prevent power dissipation in the brake resistor by using a mains switch or contactor to disconnect the mains for the frequency converter. Only the frequency converter should control the contactor.

CAUTION

Note that voltages up to 1099 V DC may occur on the terminals.

F-Frame Requirements
Connect the brake resistor(s) to the brake terminals in each inverter module.

7.6.4 How to Connect a PC to the Frequency Converter

To control the frequency converter from a PC, install the MCT 10 Set-up Software. The PC is connected via a standard (host/device) USB cable, or via the RS-485 interface as shown in the section *Bus Connection* in the Programming Guide.

USB is a serial bus utilises 4 shielded wires with ground pin 4 connected to the shield in the PC USB port. All standard PCs are manufactured without galvanic isolation in the USB port.
Follow the earth/ground recommendations described in *Connection to Mains and Earthing*, *VLT® AutomationDrive Operating Instructions* to prevent damage to the USB host controller through the shield of the USB cable.
When connecting the PC to the frequency converter through a USB cable, Danfoss recommends using a USB isolator with galvanic isolation to protect the PC USB host controller from earth/ground potential differences. It is also recommended not to use a PC power cable with a ground plug when the PC is connected to the frequency converter through a USB cable. This reduces the earth/ground potential difference, but does not eliminate all potential differences due to the ground and shield connected in the PC USB port.

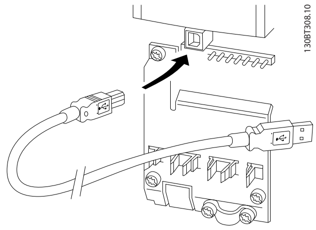


Illustration 7.55 USB Connection

7.6.5 PC Software

To store data in PC via MCT 10 Set-Up Software, use the following steps:

1. Connect a PC to the unit via USB com port.
2. Open MCT 10 Set-up Software.
3. Select the USB port in the “network” section.
4. Select “Copy”.
5. Select the “project” section.
6. Select “Paste”.
7. Select “Save as”.

All parameters are now stored.

To transfer data from PC to frequency converter via MCT 10 Set-Up Software, use the following steps:

1. Connect a PC to the unit via USB com port.
2. Open MCT 10 Set-up software.
3. Select “Open”– stored files will be shown.
4. Open the appropriate file.
5. Select “Write to drive”.

All parameters are now transferred to the frequency converter.

A separate manual for *MCT 10 Set-up Software* is available.

7.7 Safety

7.7.1 High Voltage Test

Carry out a high voltage test by short-circuiting terminals U, V, W, L_1, L_2, and L_3. Energize maximum 2.15 kV DC for 380-500 V frequency converters and 2.525 kV DC for 525–690 V frequency converters for one second between this short-circuit and the chassis.

7

WARNING

When running high voltage tests of the entire installation, interrupt the mains and motor connection if the leakage currents are too high.

7.7.2 Earthing

The following basic issues need to be considered when installing a frequency converter to obtain electromagnetic compatibility (EMC).

- Safety earthing:
  The frequency converter has a high leakage current and must be earthed appropriately for safety reasons. Comply with all local safety regulations.
- High-frequency earthing:
  Keep the earth wire connections as short as possible.

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

7.7.3 Safety Earth Connection

The frequency converter has a high leakage current and must be earthed appropriately for safety reasons according to EN 50178.

WARNING

The earth leakage current from the frequency converter exceeds 3.5 mA. To ensure a good mechanical connection from the earth cable to the earth connection (terminal 95), the earth grounding must be reinforced in one of the following ways:

- **earth ground wire of at least 10 mm^2**
- **2 separate earth ground wires both complying with the dimensioning rules**

7.8 EMC-Correct Installation

7.8.1 Electrical Installation - EMC Precautions

The following is a guideline to good engineering practice when installing frequency converters. Follow these guidelines in compliance with EN 61800-3 *First environment*. If the installation is in EN 61800-3 *Second environment,* industrial networks, or in an installation with its own transformer, deviation from these guidelines is allowed but not recommended. See also *2.3.3 Danfoss Frequency Converter and CE Labelling*, *3.5 General Aspects of EMC*, *3.5.2 EMC Test Results*, and *7.8.3 Earthing of Screened Control Cables*.

Good Engineering Practice to Ensure EMC-Correct Electrical Installation:

- Use only braided screened/armoured motor cables and braided screened control cables. The screen provides a minimum coverage of 80%. The screen 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 screened 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 screen conduit to earth at both ends for motor cables as well as for control cables. In some cases, it is not possible to connect the screen in both ends. If so, connect the screen at the frequency converter. See also *7.7.2 Earthing*.
- Avoid terminating the screen with twisted ends (pigtails). It increases the high frequency impedance of the screen, which reduces its effectiveness at high frequencies. Use low impedance cable clamps or EMC cable glands instead.
- Avoid using unscreened motor or control cables inside cabinets housing the frequency converter, whenever possible.

Leave the screen as close to the connectors as possible.

Illustration 7.56 shows an example of an EMC-correct electrical installation of an IP 20 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 unscreened cables and control wires are used, some emission requirements are not complied with, although the immunity requirements are fulfilled. See *3.5.2 EMC Test Results*.

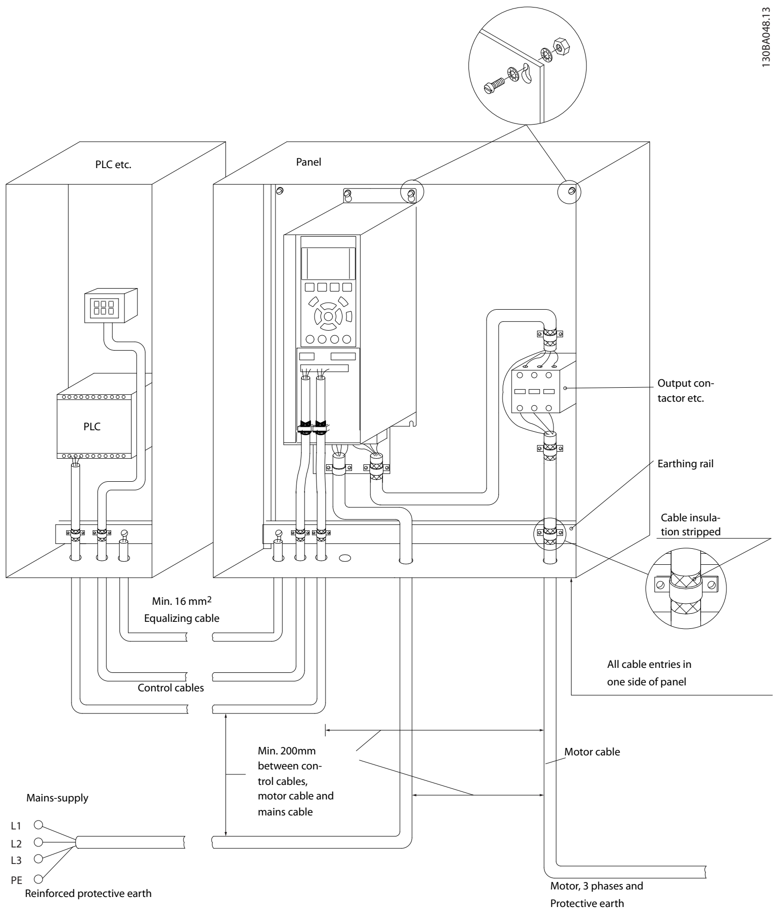


Illustration 7.56 EMC-Correct Electrical Installation of a Frequency Converter in Cabinet

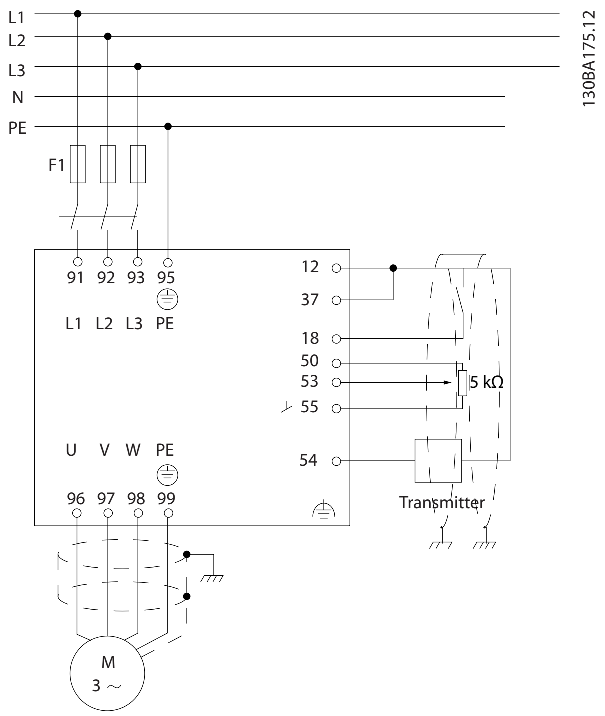


Illustration 7.57 Electrical Connection Diagram (6-Pulse Example Shown)

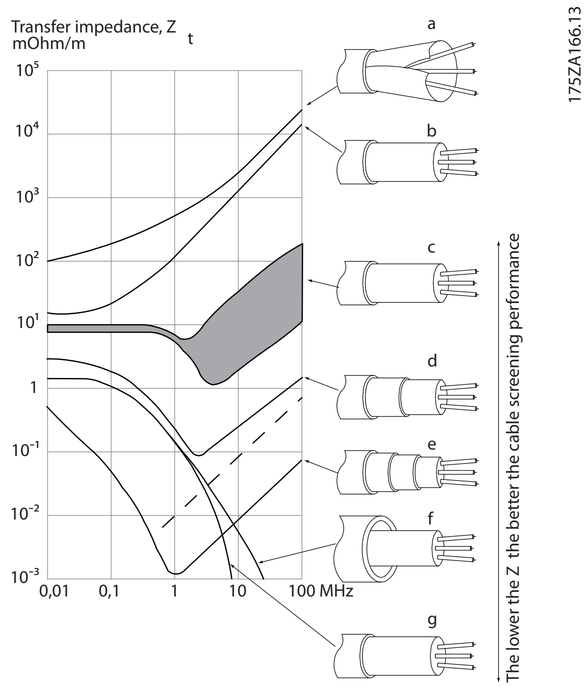


Illustration 7.58 Transfer Impedance Z_T

7.8.2 Use of EMC-Correct Cables

Danfoss recommends braided screened/armoured cables to optimise EMC immunity of the control cables and the EMC emission from the motor cables.

The cable's ability to reduce the incoming and outgoing radiation of electric noise depends on the transfer impedance (Z_T). The cable's screen is normally designed to reduce the transfer of electric noise; however, a screen with a lower transfer impedance (Z_T) value is the most effective.

Cable manufacturers rarely state transfer impedance (Z_T), but it is often possible to estimate transfer impedance (Z_T) by assessing the physical design of the cable. See *Illustration 7.58*.

7.8.3 Earthing of Screened Control Cables

Correct Screening

The preferred method is to secure control and serial communication cables with screening clamps at both ends to ensure best possible high frequency cable contact.

If the earth potential between the frequency converter and the PLC is different, electric noise may occur. Solve this problem by fitting an equalizing cable next to the control cable. Minimum cable cross section is 16 mm^2.

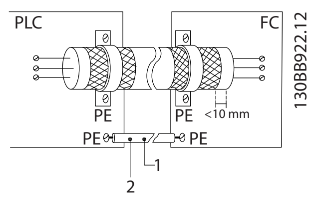


Illustration 7.59 Equalizing Cable next to a Control Cable

1	Min. 16 mm^2
2	Equalizing cable

Table 7.72 Legend to *Illustration 7.59*

50/60 Hz Ground Loops
With very long control cables, ground loops may occur. Eliminate ground loops by connecting one end of the screen-to-ground with a 100nF capacitor (keeping leads short).

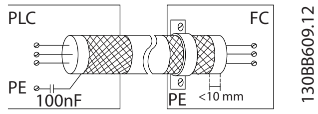


Illustration 7.60 Eliminating Ground Loops by Connecting Earth/Ground to 100nF Capacitor

Avoid EMC Noise on Serial Communication
This terminal is connected to earth via an internal RC link. Use twisted-pair cables to reduce interference between conductors. The recommended method is shown in *Illustration 7.62*.

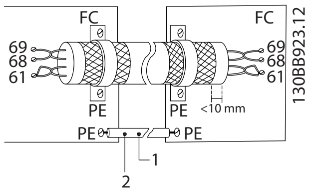


Illustration 7.61 Using Twisted Pair Cables to Reduce Interference

1	Min. 16 mm²
2	Equalizing cable

Table 7.73 Legend to *Illustration 7.61*

Alternatively, the connection to terminal 61 can be omitted:

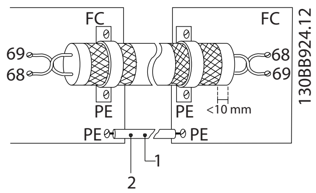


Illustration 7.62 Reducing Interference by Omitting Terminal 61

1	Min. 16 mm²
2	Equalizing cable

Table 7.74 Legend to *Illustration 7.62*

7.8.4 RFI Switch

Mains Supply Isolated from Earth
If the frequency converter is supplied from an isolated mains source (IT mains, floating delta, or grounded delta) or TT/TN-S mains with grounded leg, the RFI switch is recommended to be turned off (OFF)1) via *14-50 RFI Filter* on the frequency converter and *14-50 RFI Filter* on the filter. For more detail, see IEC 364-3. In OFF, the filter capacitors between the chassis and the intermediate circuit are cut off to avoid damage to the intermediate circuit and to reduce the earth capacity currents (according to IEC 61800-3).
If optimum EMC performance is needed or parallel motors are connected or the motor cable length is above 25 m, Danfoss recommends setting the *14-50 RFI Filter* to [ON].
Refer also to the *Application Note, VLT on IT Mains, MN50P*.
It is important to use isolation monitors that are capable for use together with power electronics (IEC 61557-8).

7.9 Mains Supply Interference/Harmonics

A frequency converter takes up a non-sinusoidal current from mains, which increases the input current I_{RMS}. A non-sinusoidal current is transformed by means of a Fourier analysis and split into sine-wave currents with different frequencies. See *Table 7.75*.

Harmonic currents	I_1	I_5	I_7
Hz	50 Hz	250 Hz	350 Hz

Table 7.75 Non-Sinusoidal Current Split into Sine-Wave Currents with Different Frequencies

The harmonics do not affect the power consumption directly, but increase the heat losses in the transformer and cables. Therefore, in plants with a high percentage of rectifier load, it is necessary to maintain harmonic currents at a low level to avoid overload of the transformer and high temperature in the cables.

NOTICE

Some of the harmonic currents might disturb communication equipment connected to the same transformer or cause resonance in connection with power-factor correction batteries.

Harmonic current	Input current
I_{RMS}	1.0
I_1	0.9
I_5	0.4
I_7	0.2
I_{11-49}	<0.1

Table 7.76 Harmonic Currents Compared to the RMS Input Current

To ensure low harmonic currents, the frequency converter is equipped with intermediate circuit coils as standard. DC-coils reduce the total harmonic distortion (THD) to 40%.

7.9.1 The Effect of Harmonics in a Power Distribution System

In *Illustration 7.63*, 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 a number of loads. The point of common coupling where all loads are connected together is PCC2. Each load is connected through cables that have an impedance Z_1, Z_2, Z_3.

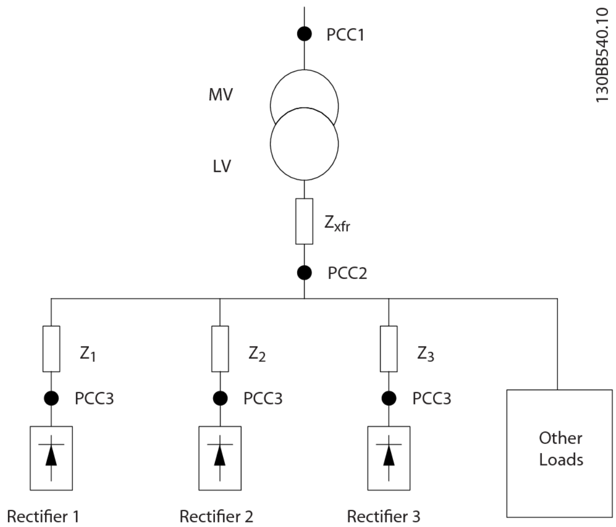


Illustration 7.63 Small Distribution System

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

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

$$R_{sce} = \frac{S_{ce}}{S_{equ}}$$

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

The negative effect of harmonics is two-fold

- Harmonic currents contribute to system losses in cabling and the, transformer
- Harmonic voltage distortion causes disturbance to other loads and increases losses in other loads

7.9.2 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 one of the motors is connected directly on-line and the other is supplied through a frequency converter, a 250 kVA transformer with 2 110 kW motors connected is sufficient. However, the transformer will be undersized if both motors are frequency converter supplied. Using additional means of harmonic reduction within the installation or choosing 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
- IEEE 519
- G5/4

See *Harmonic Filter AHF 005/010 for VLT 5000* for specific details on each standard.

7.9.3 Harmonic Mitigation

Where additional harmonic suppression is required, Danfoss offers the following mitigation equipment:

- VLT 12-pulse drives
- VLT AHF filters
- VLT Low Harmonic Drives
- VLT Active Filters

Choosing the right solution depends on several factors:

- The grid (background distortion, mains unbalance, resonance, and type of supply (transformer/generator)
- Application (load profile, number of loads, and load size)
- Local/national requirements/regulations (IEEE519, IEC, G5/4, etc.)
- Total cost of ownership (initial cost, efficiency, and maintenance)

7.9.4 Harmonic Calculation

Use the free Danfoss MCT 31 calculation software to determine the degree of voltage pollution on the grid and needed precaution. The *VLT® Harmonic Calculation MCT 31* is available at *www.danfoss.com*.

7.10 Residual Current Device

Use RCD relays, multiple protective earthing, or earthing as extra protection, provided they comply with local safety regulations.
If an earth fault appears, a DC current may develop in the faulty current. If RCD relays are used, local regulations must be observed. Relays must be suitable for protection of 3-phase equipment with a bridge rectifier and for a brief discharge on power-up. See *3.7 Earth Leakage Current* for more details.

7.11 Final Setup and Test

To test the set-up and ensure that the frequency converter is running, follow these steps:

Step 1. Locate the motor name plate.
The motor is either star- (Y) or delta- connected (Δ). This information is located on the motor name plate data.

Step 2. Enter the name plate data into the parameter list.
To access the list, first press [Quick Menu] then select "Q2 Quick Setup".

1. 1-20 Motor Power [kW]
   1-21 Motor Power [HP]
2. 1-22 Motor Voltage
3. 1-23 Motor Frequency
4. 1-24 Motor Current
5. 1-25 Motor Nominal Speed

Step 3. Activate the Automatic Motor Adaptation (AMA). To stop the AMA during operation, press [Off].
Performing an AMA will ensure optimum performance. The AMA measures the values from the motor model equivalent diagram.

1. Connect terminal 37 to terminal 12 (if terminal 37 is available).
2. Connect terminal 27 to terminal 12 or set *5-12 Terminal 27 Digital Input* to *[0] No operation*.
3. Activate the AMA *1-29 Automatic Motor Adaptation (AMA)*.
4. Choose between complete or reduced AMA Auto Tune. If a Sine-wave filter is mounted, run only the reduced AMA, or remove the Sine-wave filter during the AMA procedure.
5. Press [OK].
   The display shows "Press [Hand on] to start."
6. Press [Hand On].
   A progress bar indicates if the AMA is in progress.

Successful AMA

1. The display shows "Press [Ok] to finish AMA."
2. Press [Ok] to exit the AMA state.

Unsuccessful AMA

1. The frequency converter enters into alarm mode. A description of the alarm can be found in Operating Instructions.
2. "Report Value" in the [Alarm Log] shows the last measuring sequence carried out by the AMA, before the frequency converter entered alarm mode. This number, along with the description of the alarm, will assist in troubleshooting. If contacting Danfoss for service, mention number and alarm description.

NOTICE

Unsuccessful AMA is often caused by:

- **incorrectly registered motor name plate data**
- **difference between the motor power size and the frequency converter power size**

Step 4. Set speed limit and ramp times.

- 3-02 Minimum Reference
- 3-03 Maximum Reference
- 4-11 Motor Speed Low Limit [RPM] or *4-12 Motor Speed Low Limit [Hz]*
- *4-13 Motor Speed High Limit [RPM]* or *4-14 Motor Speed High Limit [Hz]*
- 3-41 Ramp 1 Ramp Up Time
- 3-42 Ramp 1 Ramp Down Time

8 Application Examples

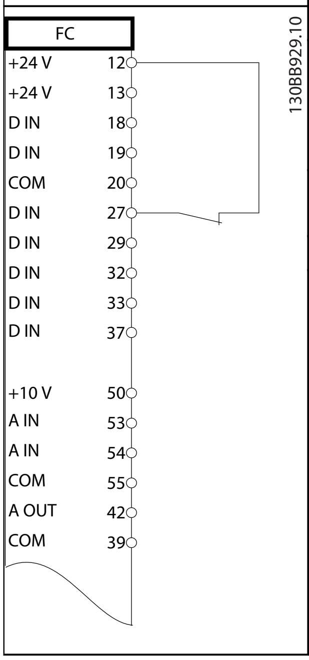
8.1 Automatic Motor Adaptation (AMA)

NOTICE

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

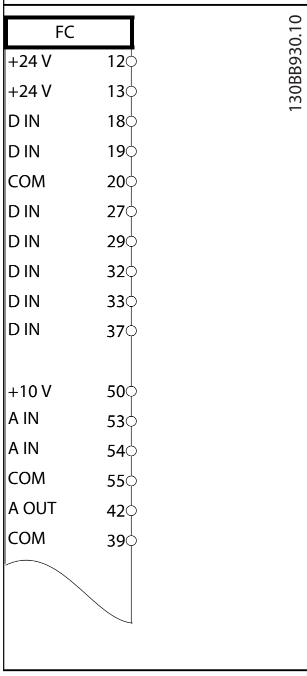
The examples in this section are intended as a quick reference for common applications. The following notes apply to all examples in this chapter.

- Parameter settings are the regional default values unless otherwise indicated (selected in *0-03 Regional Settings*)
- Parameters associated with the terminals and their settings are shown next to the drawings
- Where switch settings for analog terminals A53 or A54 are required, these are also shown



Parameters	
Function	**Setting**
1-29 Automatic Motor Adaptation (AMA)	[1] Enable complete AMA
5-12 Terminal 27 Digital Input	[2]* Coast inverse
*=Default Value	
Notes/Comments: Parameter group *1-2* Motor Data* must be set according to motor	

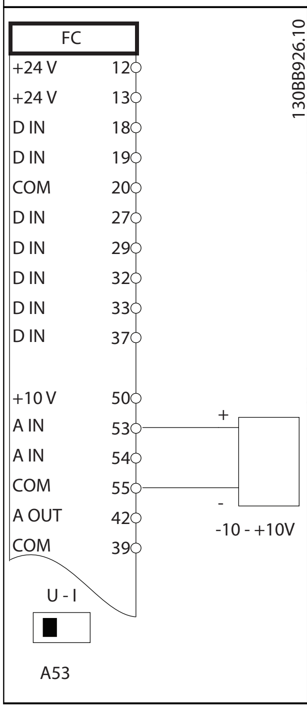
Table 8.1 AMA with T27 Connected



Parameters	
Function	**Setting**
1-29 Automatic Motor Adaptation (AMA)	[1] Enable complete AMA
5-12 Terminal 27 Digital Input	[0] No operation
*=Default Value	
Notes/Comments: Parameter group *1-2* Motor Data* must be set according to motor	

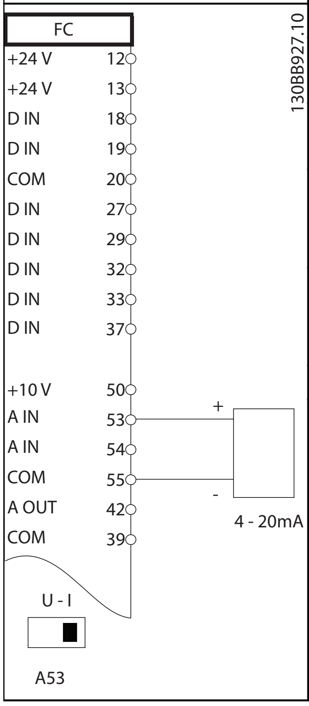
Table 8.2 AMA without T27 Connected

8.2 Analog Speed Reference



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

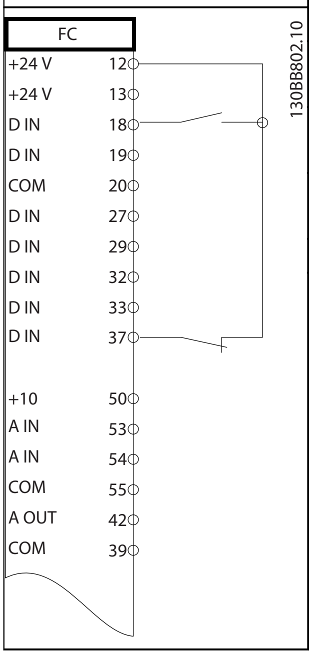
Table 8.3 Analog Speed Reference (Voltage)



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

Table 8.4 Analog Speed Reference (Current)

8.3 Start/Stop



Parameters	
Function	**Setting**
5-10 Terminal 18 Digital Input	[8] Start*
5-12 Terminal 27 Digital Input	[0] No operation
5-19 Terminal 37 Safe Stop	[1] Safe Stop Alarm
*=Default Value	
Notes/Comments: If *5-12 Terminal 27 Digital Input* is set to *[0] No operation*, a jumper wire to terminal 27 is not needed.	

Table 8.5 Start/Stop Command with Safe Stop

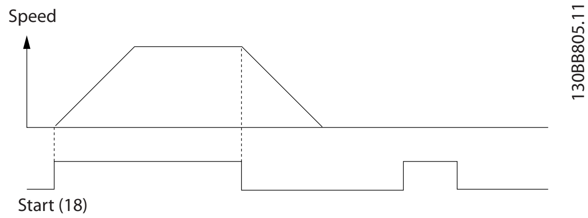
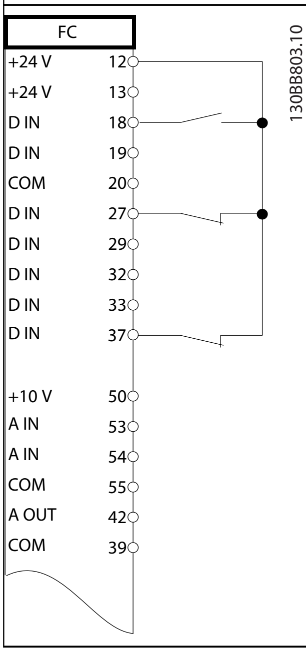


Illustration 8.1 Start/Stop with Safe Stop



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

Table 8.6 Pulse Start/Stop

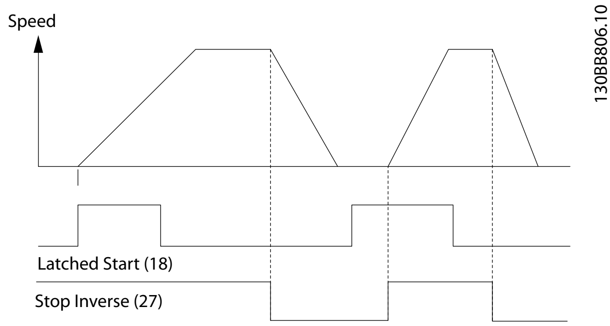
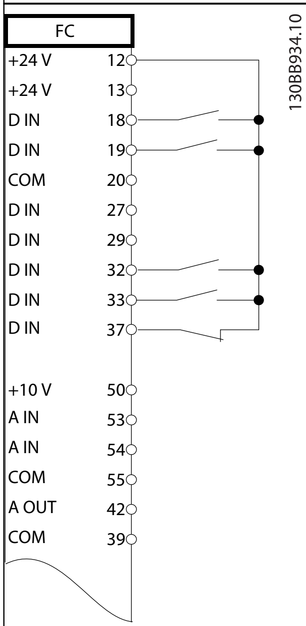


Illustration 8.2 Latched Start/Stop Inverse

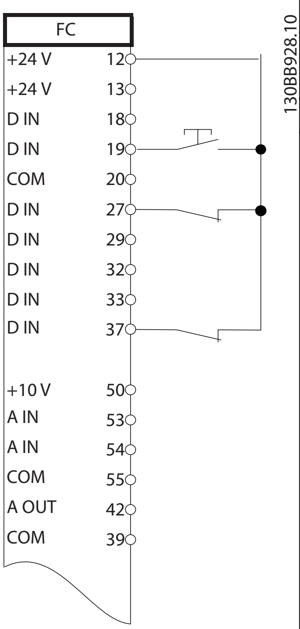
8



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

Table 8.7 Start/Stop with Reversing and 4 Preset Speeds

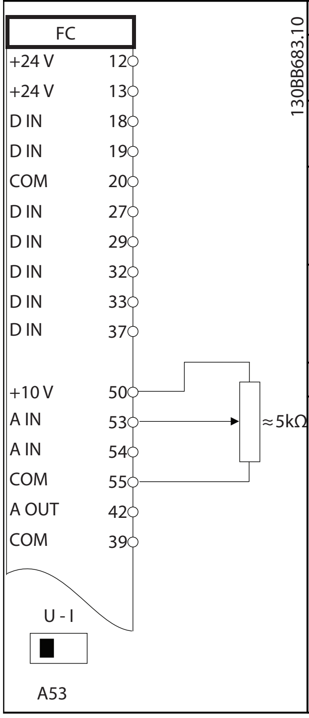
8.4 External Alarm Reset



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

Table 8.8 External Alarm Reset

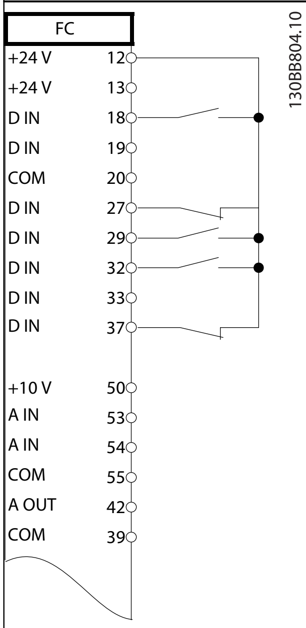
8.5 Speed Reference with Manual Potentiometer



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

Table 8.9 Speed Reference (Using a Manual Potentiometer)

8.6 Speed Up/Down



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

Table 8.10 Speed Up/Down

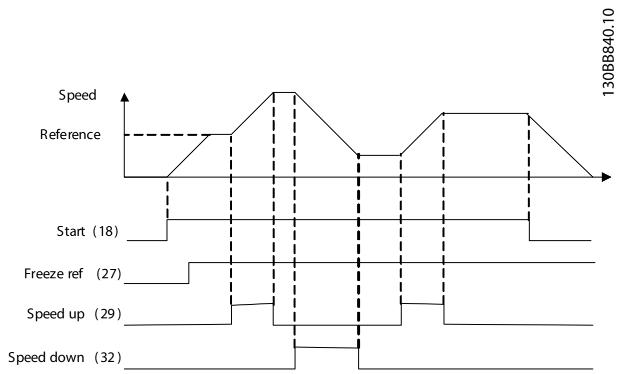
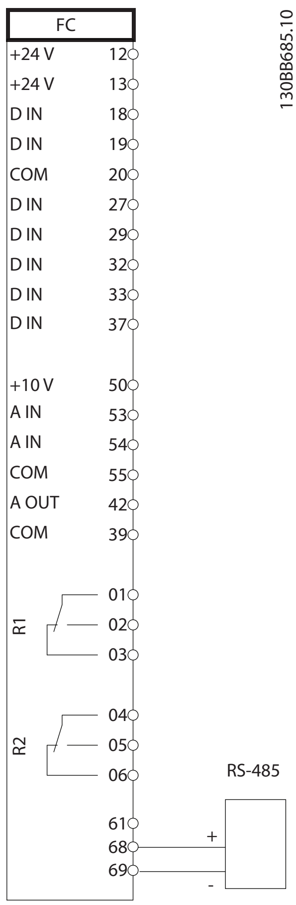


Illustration 8.3 Speed Up/Down

8.7 RS-485 Network Connection



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

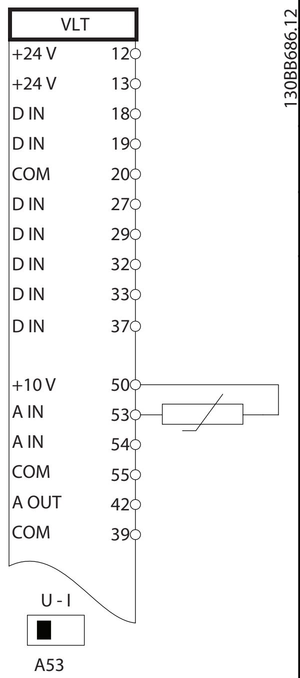
Table 8.11 RS-485 Network Connection

8

8.8 Motor Thermistor

CAUTION

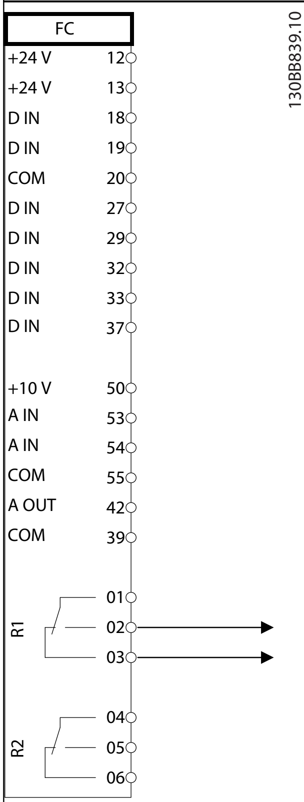
Thermistors must use reinforced or double insulation to meet PELV insulation requirements.



Parameters	
Function	**Setting**
1-90 Motor Thermal Protection	[2] Thermistor trip
1-93 Thermistor Source	[1] analog input 53
*=Default Value	
Notes/Comments: If only a warning is desired, *1-90 Motor Thermal Protection* should be set to *[1] Thermistor warning*.	

Table 8.12 Motor Thermistor

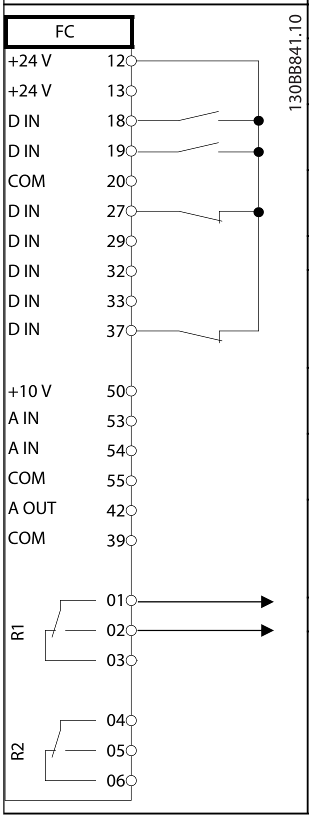
8.9 Relay Setup with Smart Logic Control



Parameters	
Function	**Setting**
4-30 Motor Feedback Loss Function	[1] Warning
4-31 Motor Feedback Speed Error	100 RPM
4-32 Motor Feedback Loss Timeout	5 s
7-00 Speed PID Feedback Source	[2] MCB 102
17-11 Resolution (PPR)	1024*
13-00 SL Controller Mode	[1] On
13-01 Start Event	[19] Warning
13-02 Stop Event	[44] Reset key
13-10 Comparator Operand	[21] Warning no.
13-11 Comparator Operator	[1]*
13-12 Comparator Value	90
13-51 SL Controller Event	[22] Comparator 0
13-52 SL Controller Action	[32] Set digital out A low
5-40 Function Relay	[80] SL digital output A
*=Default Value	
Notes/Comments: If the limit in the feedback monitor is exceeded, Warning 90 is issued. The SLC monitors Warning 90 and in the case that Warning 90 becomes TRUE then Relay 1 is triggered. External equipment may require service. If the feedback error goes below the limit again within 5 s, then the frequency converter continues and the warning disappears. Press [Reset] on the LCP to reset Relay 1.	

Table 8.13 Using SLC to Set a Relay

8.10 Mechanical Brake Control



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

Table 8.14 Mechanical Brake Control

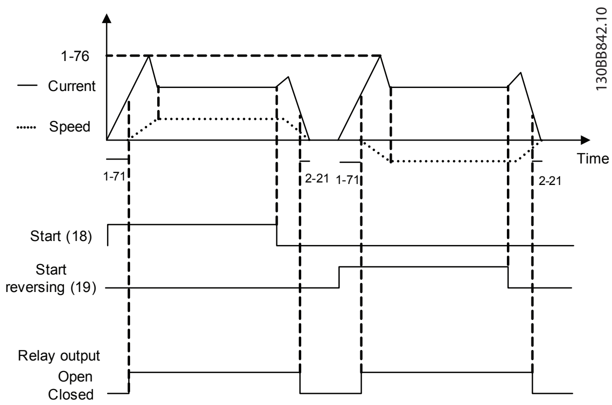


Illustration 8.4 Mechanical Brake Control

8.11 Encoder Connection

Before setting up the encoder, the basic settings for a closed loop speed control system is shown.
See also *9.3 Encoder Option MCB 102*.

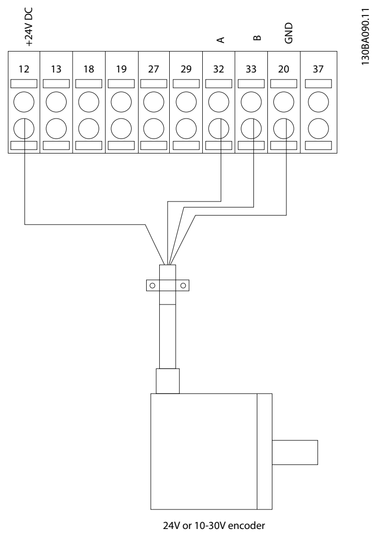


Illustration 8.5 Encoder Connection to the Frequency Converter

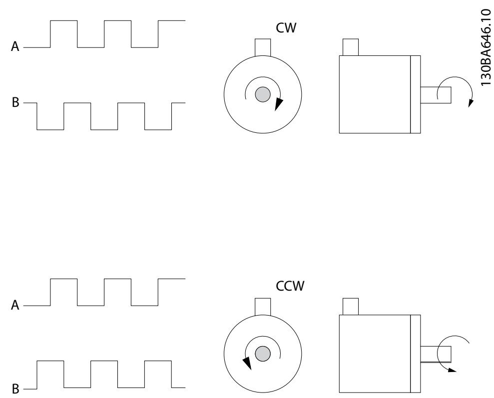


Illustration 8.6 24 V Incremental Encoder. Maximum Cable Length 5 m

8.12 Encoder Direction

The direction of the encoder is determined by which order the pulses are entering the frequency converter.
Clockwise (CW) direction means channel A is 90 electrical degrees before channel B.
Counter Clockwise (CCW) direction means channel B is 90 electrical degrees before A.
The direction can be determined by looking into the shaft end.

8.13 Closed Loop Drive System

A closed loop drive system usually consists of the following:

- Motor
- Add
  (Gearbox)
  (Mechanical Brake)
- FC 302
- Encoder as feed-back system
- Brake resistor for dynamic braking
- Transmission
- Load

Applications demanding mechanical brake control typically needs a brake resistor.

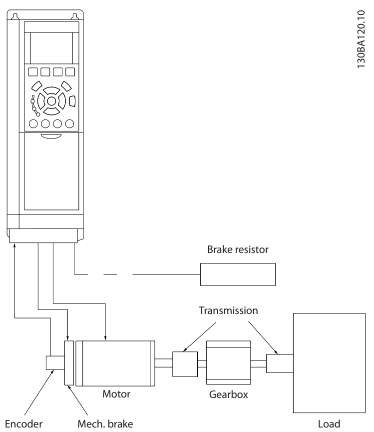


Illustration 8.7 Basic Set-Up for FC 302 Closed Loop Speed Control

8.14 Stop and Torque Limit

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.
The example given below illustrates the programming of these frequency converter connections. The external brake can be connected to relay 1 or 2 (See *3.9 Mechanical Brake Control*). Program terminal 27 to [2] Coast, inverse or [3] Coast and Reset, inverse, and program terminal 29 to [1] Terminal mode 29 Output and [27] Torque limit & stop.

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, terminal 29 Output (programmed to [27] Torque limit and stop) is activated. The signal to terminal 27 changes from 'logic 1' to 'logic 0', and the motor starts to coast, thereby 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
  5-10 Terminal 18 Digital Input Start [8]
- Quickstop via terminal 27
  5-12 Terminal 27 Digital Input Coasting Stop, Inverse [2]
- Terminal 29 Output
  5-02 Terminal 29 Mode Terminal 29 Mode Output [1]
  5-31 Terminal 29 Digital Output Torque Limit & Stop [27]
- Relay output [0] (Relay 1)
  5-40 Function Relay Mechanical Brake Control [32]

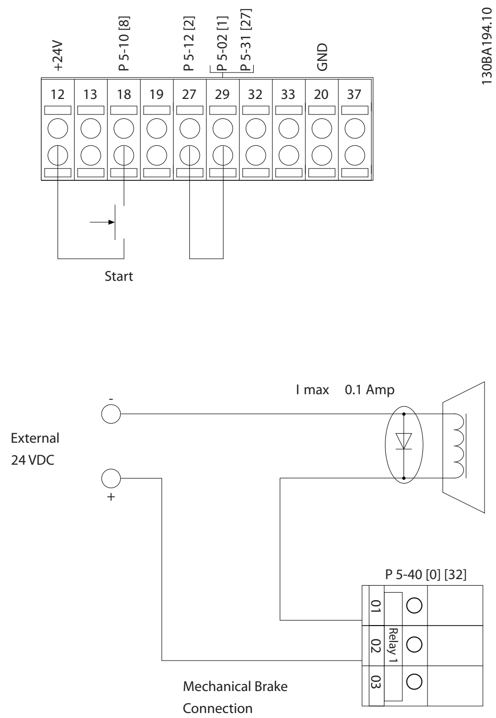


Illustration 8.8 Stop and Torque Limit Terminal Connections

9 Options and Accessories

9.1 Options and Accessories

Danfoss offers a wide range of options and accessories for the VLT® AutomationDrive.

9.1.1 Slot A

Slot A position is dedicated to Fieldbus options. For further information, see the instructions that accompany the optional equipment.

9.1.2 Slot B

The power to the frequency converter must be disconnected. For discharge time, see the instructions supplied with the option.

First, ensure that the parameter data has been saved before option modules are inserted/removed from the frequency converter. To save parameter data, use MCT 10 or similar software. Then perform the following steps:

1. Remove the LCP, the terminal cover, and the LCP frame from the frequency converter
2. Fit the MCB 10x option card into slot B
3. Connect the control cables and relieve the cable using the enclosed cable strips
4. Remove the knock out in the extended LCP frame so that the option fits under the extended LCP frame
5. Fit the extended LCP frame and terminal cover
6. Fit the LCP or blind cover in the extended LCP frame
7. Connect power to the frequency converter
8. Set up the input/output functions in the corresponding parameters, as mentioned in *4.3 General Specifications*

9.1.3 Slot C

The power to the frequency converter must be disconnected. For discharge time, see the instructions supplied with the option.

Ensure that the parameter data has been saved before option modules are inserted/removed from the frequency converter. To save parameter data, use MCT 10 or similar software.

When installing a C option, a mounting kit is required. For a list of mounting kit ordering numbers, refer to *5 How to Order*. The installation is illustrated using MCB 112 as an example. For more information on installation of MCO 305, see the separate operating instructions that accompany the optional equipment.

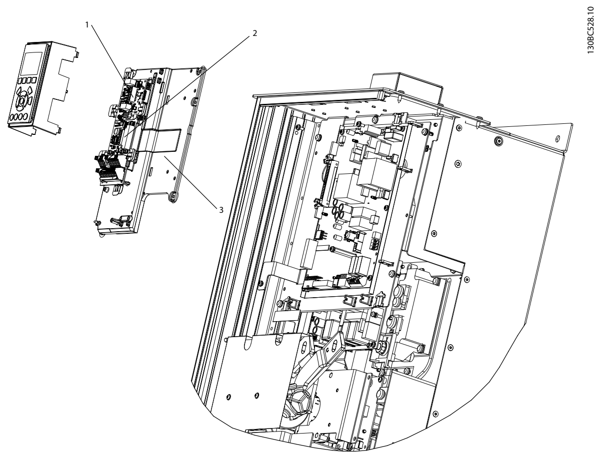


Illustration 9.1 Locations of Option Mounting Slots

1	Slot A
2	Slot B
3	Slot C

Table 9.1 Legend to *Illustration 9.1*

9.2 General Purpose Input Output Module MCB 101

MCB 101 is used for extension of digital and analog inputs and outputs of FC 302. MCB 101 must be fitted into slot B in the VLT® AutomationDrive.

Contents:

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

9

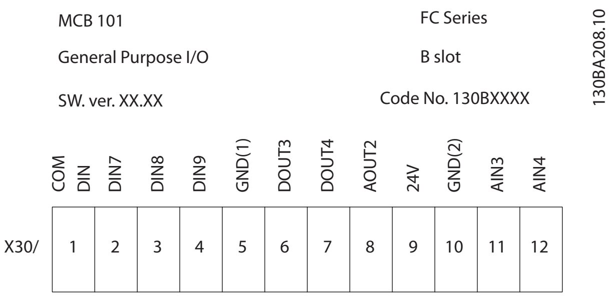


Illustration 9.2 MCB 101 Options Module

9.2.1 Galvanic Isolation in the 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 those on the control card of the frequency converter.

If the digital inputs 7, 8, or 9 are to be switched by use of the internal 24 V power supply (terminal 9), the connection between terminal 1 and 5, which is illustrated in *Illustration 9.3* has to be established.

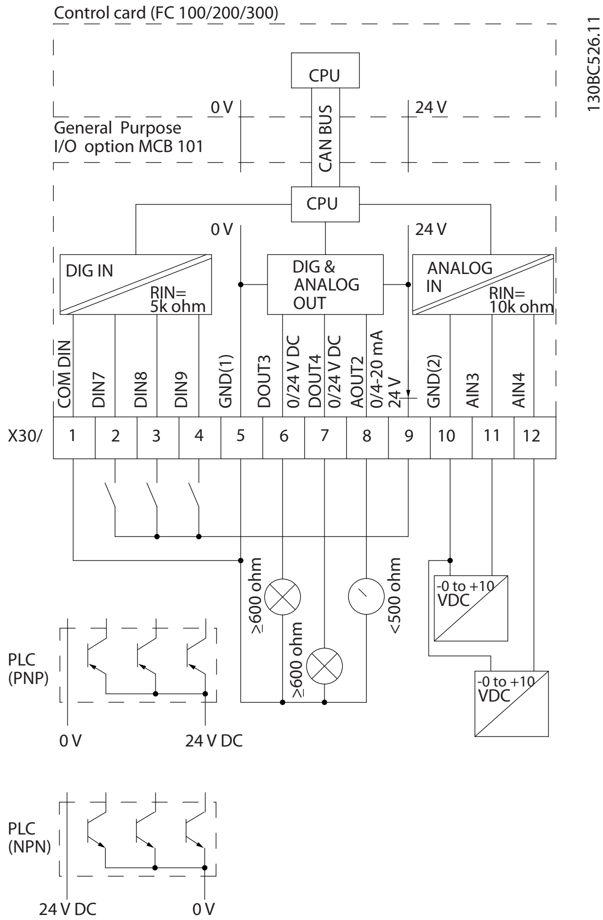


Illustration 9.3 Principle Diagram

9.2.2 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 continous
Pulse frequency range	0-110 kHz
Duty cycle, min. pulse width	4.5 ms
Input impedance	>2 kΩ

9.2.3 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
Max. voltage	20 V
Resolution for analog inputs	10 bit (+ sign)
Accuracy of analog inputs	Max. error 0.5% of full scale
Bandwidth	FC 302: 100 Hz

9.2.4 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
Max. output current	40 mA
Max. load	≥600 Ω
Max. capacitive load	<10 nF
Minimum output frequency	0 Hz
Maximum output frequency	≤32 kHz
Accuracy of frequency output	Max. error: 0.1 % of full scale

9.2.5 Analog Output - Terminal X30/8

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

9.3 Encoder Option MCB 102

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

The Encoder Option MCB 102 is used for

- VVC^{plus} 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 (Heidenhain) Supports version 2.1
- SSI encoder: Absolute

NOTICE

The LEDs are only visible when removing the LCP. Reaction in case of an encoder error can be selected in *17-61 Feedback Signal Monitoring*: None, Warning or Trip.

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

- Encoder Option MCB 102
- Enlarged LCP fixture and enlarged terminal cover

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

Connector designation X31	Incremental encoder (refer to *Illustration 9.4*)	SinCos encoder Hiperface® (refer to *Illustration 9.5*)	EnDat encoder	SSI encoder	Description
1	NC			24 V*	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 V*	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 RS-485	Clock out	Clock out	Z input OR +Data RS-485
10	Z inv input	-Data RS-485	Clock out inv.	Clock out inv.	Z input OR -Data RS-485
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 9.2 Encoder Option MCB 102 Terminal Descriptions for Supported Encoder Types

** Supply for encoder: see data on encoder*

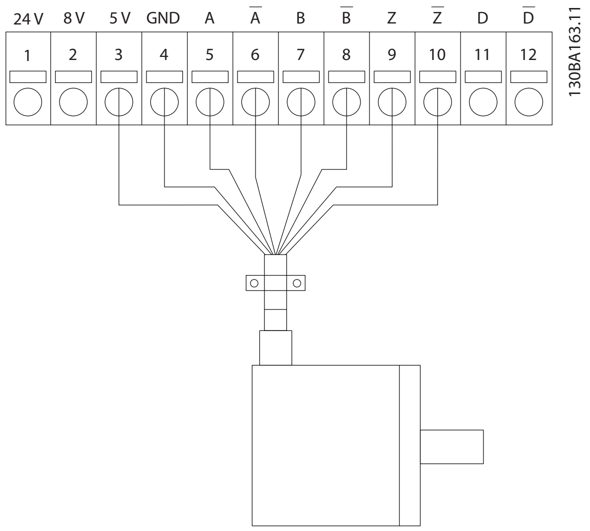


Illustration 9.4 Incremental Encoder

Max. cable length 150 m.

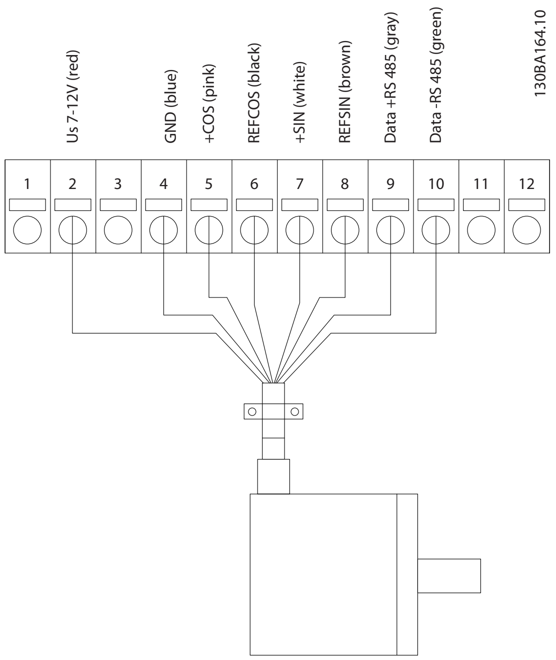


Illustration 9.5 SinCos Encoder Hiperface

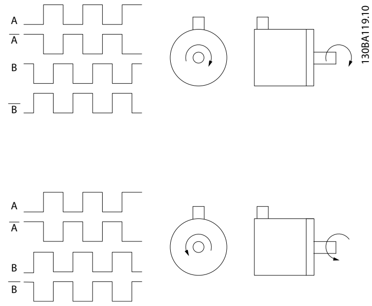


Illustration 9.6 Rotation Direction

9.4 Resolver Option MCB 103

MCB 103 Resolver option is used for interfacing resolver motor feedback to VLT® AutomationDrive. Resolvers are used as motor feedback devices for permanent magnet brushless synchronous motors.
When the Resolver option is ordered separately, the kit includes:

- Resolver option MCB 103
- Enlarged LCP fixture and enlarged terminal cover

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

MCB 103 Resolver Option supports a various number of rotor resolver types.

Resolver Poles	*17-50 Poles*: 2 *2
Resolver Input Voltage	*17-51 Input Voltage*: 2.0–8.0 Vrms *7.0 Vrms
Resolver Input Frequency	*17-52 Input Frequency*: 2–15 kHz *10.0 kHz
Transformation ratio	*17-53 Transformation Ratio*: 0.1–1.1 *0.5
Secondary input voltage	Max 4 Vrms
Secondary load	App. 10 kΩ

Table 9.3 Resolver Specifications

9

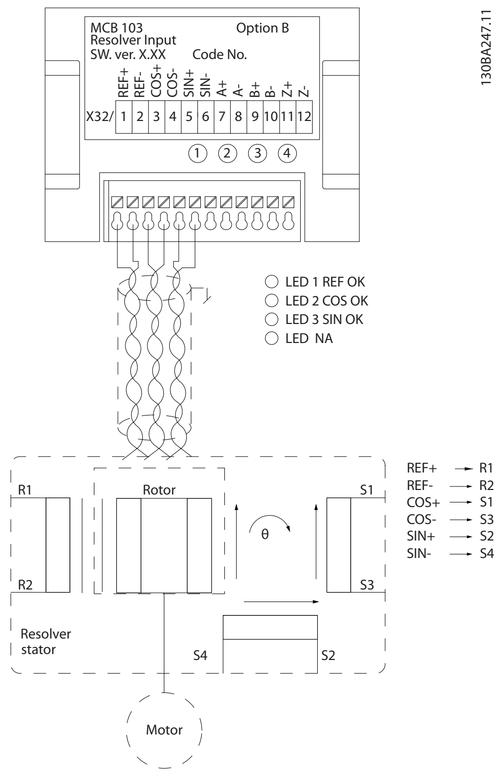


Illustration 9.7 Resolver Option MCB 103 used with a Permanent Magnet Motor

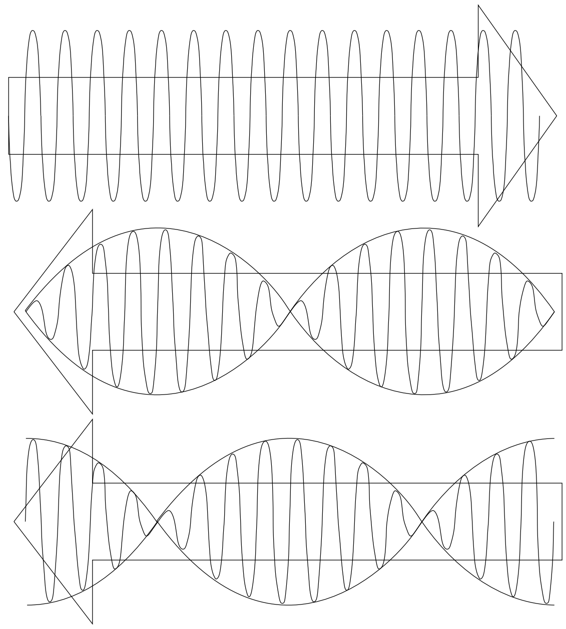


Illustration 9.8 Permanent Magnet (PM) Motor with Resolver as Speed Feedback

NOTICE

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

LED Indicators

The LEDs are active when *17-61 Feedback Signal Monitoring* is set to *Warning* or *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

Set-Up example

In *Illustration 9.7* a permanent magnet (PM) Motor is used with resolver as speed feedback. A PM motor must usually operate in flux mode.

Wiring

The max cable length is 150 m when a twisted pair type of cable is used.

NOTICE

Always use screened motor cables and brake chopper cables. Resolver cables must be screened and separated from the motor cables. The screen of the resolver cable must be correctly connected to the de-coupling plate and connected to chassis (earth) on the motor side.

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

Table 9.4 Parameters to be Adjusted

9.5 Relay Option MCB 105

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

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

[1)] IEC 947 part 4 and 5

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

- Relay Module MCB 105
- Enlarged LCP fixture and enlarged terminal cover
- Label for covering access to switches S201 (A53), S202 (A54) and S801
- Cable strips for fastening cables to relay module

The relay option does not support FC 302 frequency converters manufactured before week 50/2004.
Min. software version: 2.03 (*15-43 Software Version*).

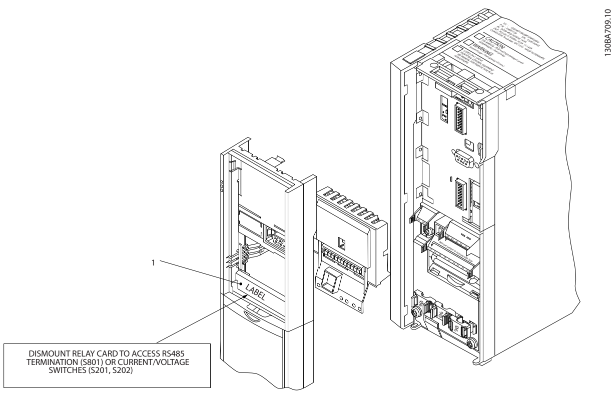


Illustration 9.9 A2, A3, and B3

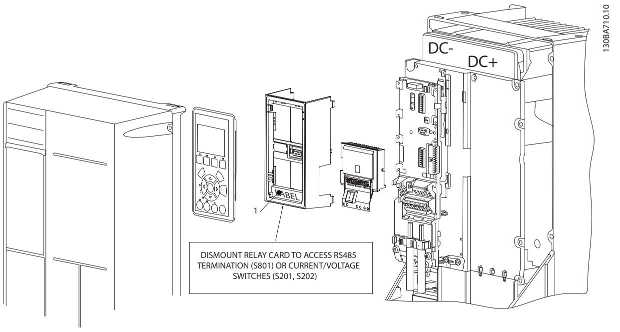


Illustration 9.10 A5, B1-B4, and C1-C4

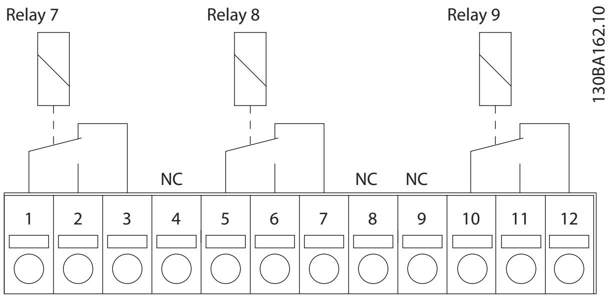


Illustration 9.11 Disconnect Relay Terminals

[1] **IMPORTANT !** The label MUST be placed on the LCP frame as shown in *Illustration 9.10* to meet UL approval.

⚠WARNING

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

To add the MCB 105 option, perform the following steps:

- The power to the frequency converter must be disconnected. For discharge times, see the instructions supplied with this option
- The power to the live part connections on relay terminals must be disconnected. See *Illustration 9.11*
- Remove the LCP, the terminal cover, and the LCP fixture from the frequency converter
- Fit the MCB 105 option in slot B
- Connect the control cables and fasten the cables with the enclosed cable strips
- Make sure the length of the stripped wire is correct. See *Illustration 9.12*
- Do not mix the live parts (high voltage) with the control signals (PELV). See *Illustration 9.13*
- Fit the enlarged LCP fixture and enlarged terminal cover
- Replace the LCP
- Connect power to the frequency converter
- Select the relay functions in *5-40 Function Relay* [6-8], *5-41 On Delay, Relay* [6-8] and *5-42 Off Delay, Relay* [6-8].

NOTICE

Array [6] is relay 7, array [7] is relay 8, and array [8] is relay 9.

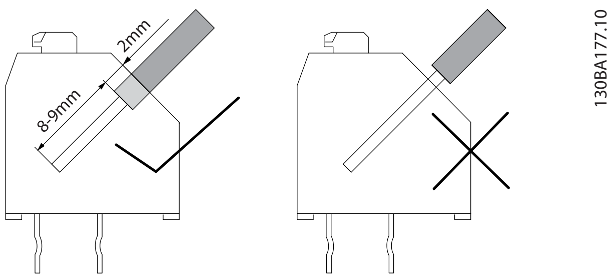


Illustration 9.12 Proper Length of Stripped Wire

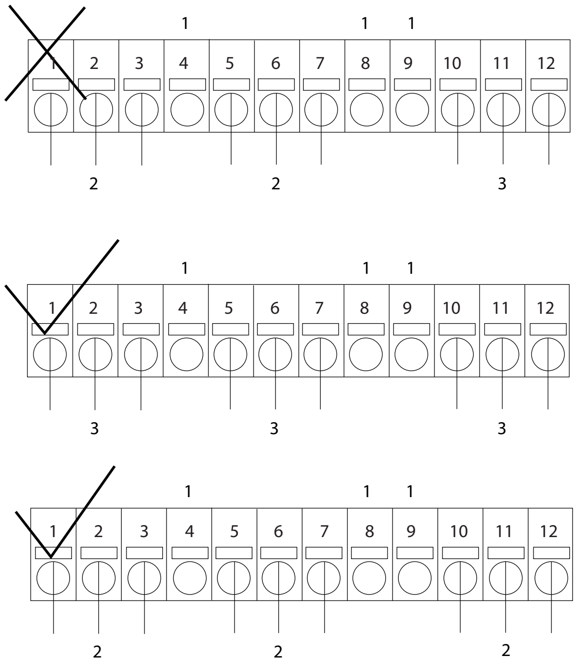


Illustration 9.13 Correct Method to Install Live Parts and Control Signals

9.6 24 V Back-Up Option MCB 107

An external 24 V DC 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.

External 24 V DC Supply Specification	
Input voltage range	24 V DC ±15% (max. 37 V in 10 s)
Max. input current	2.2 A
Average input current for FC 302	0.9 A
Max cable length	75 m
Input capacitance load	10 uF
Power-up delay	0.6 s

The inputs are protected.

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

To install the 24 V Back-Up Option MCB 107, follow these steps:

1. Remove the LCP or blind cover
2. Remove the terminal cover
3. Remove the cable decoupling plate and the plastic cover underneath
4. Insert the 24 V DC backup external supply option in the option slot
5. Mount the cable decoupling plate
6. Attach the terminal cover and the LCP or blind cover

When MCB 107, 24 V back-up option is supplying 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.

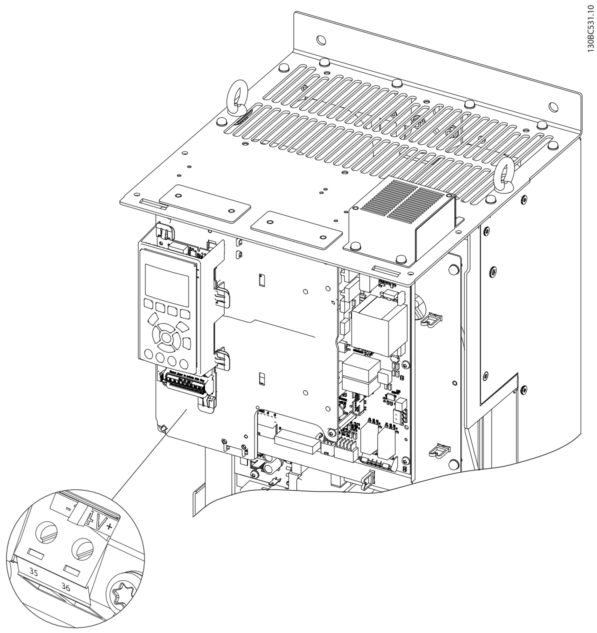


Illustration 9.14 24 V Back-up Power Supply Connection

9.7 PTC Thermistor Card MCB 112

The 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 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 .

X44/1 and X44/2 are the thermistor inputs. X44/12 enables Safe Torque Off of the FC 302 (T-37) if the thermistor values make it necessary, and X44/10 informs the FC 302 that a request for Safe Torque Off has come from the MCB 112 to ensure suitable alarm handling. One of the digital inputs of the FC 302 (or a DI of a mounted option) must be set to PTC Card 1 [80] in order to use the information from X44/10. *5-19 Terminal 37 Safe Stop* must be configured to the desired Safe Torque Off functionality. Default is Safe Torque Off alarm.

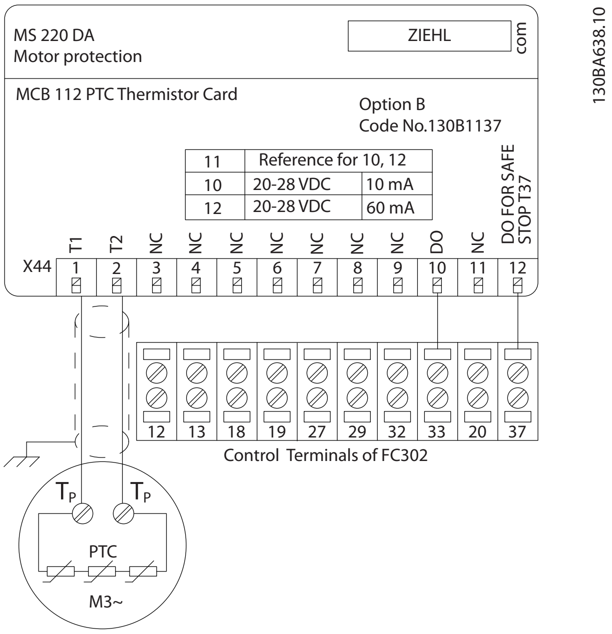


Illustration 9.15 Installation of MCB 112

ATEX Certification with FC 302

The MCB 112 has been certified for ATEX, which means that the FC 302 together with the MCB 112 can now be used with motors in potentially explosive atmospheres. See the *MCB 112 VLT® PTC Themistor Card* for more information.

Illustration 9.16 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
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
Reliable galvanic isolation until Vi	500 V
Perm. ambient temperature	-20 °C ... +60 °C
	EN 60068-2-1 Dry heat
Moisture	5 --- 95%, no condensation permissible
EMC resistance	EN61000-6-2
EMC emissions	EN61000-6-4
Vibration resistance	10 ... 1000 Hz 1.14 g
Shock resistance	50 g

Safety System Values	
EN 61508 for Tu=75 °C 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

9.8 MCB 113 Extended Relay Card

The 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® AutomationDrive and is detected automatically after mounting. For information on mounting and installing the option, see *9.1.3 Slot C*.

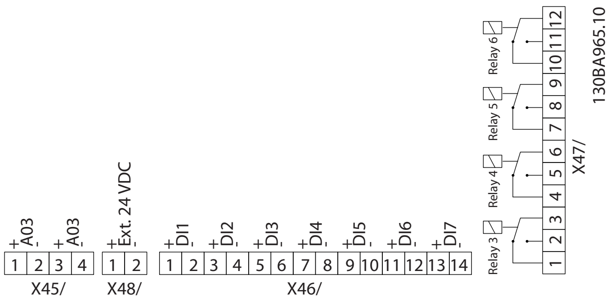


Illustration 9.17 Electrical Connections of MCB 113

MCB 113 can be connected to an external 24 V on X58/ in order to ensure galvanic isolation between the VLT® AutomationDrive and the option card. 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 one 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	8A
Load at 250 V AC/30 V DC with cos=0.4	3.5 A
Over voltage category (contact-earth)	III
Over voltage category (contact-contact)	II
Combination of 250 V and 24 V signals	Possible with one unused relay in between
Maximum thru-put delay	10 ms
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%

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

9.9 Brake Resistors

In applications where the motor is used as a brake, energy is generated in the motor and sent back into the frequency converter. If the energy cannot be transported back to the motor, it increases the voltage in the converter DC line. In applications with frequent braking and/or high inertia loads, this voltage increase may lead to an over voltage trip in the converter and possibly a shut down. 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 the dimensioning of brake resistors, see *3.8.3 Selection of Brake Resistor* .Code numbers can be found in *5 How to Order*.

9.10 LCP Panel Mounting Kit

The LCP can be moved to the front of a cabinet by using the remote built-in kit. The fastening screws must be tightened with a torque of max. 1 Nm.

Enclosure	IP66 front
Max. cable length between and unit	3 m
Communication std	RS-485

Table 9.5 Technical Data for Mounting an LCP to the IP66 Enclosure

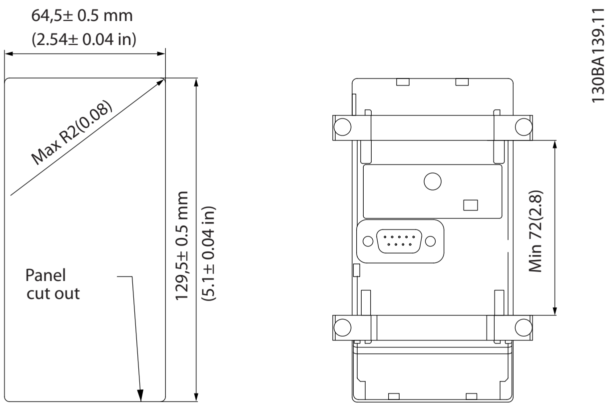


Illustration 9.18 Dimensions

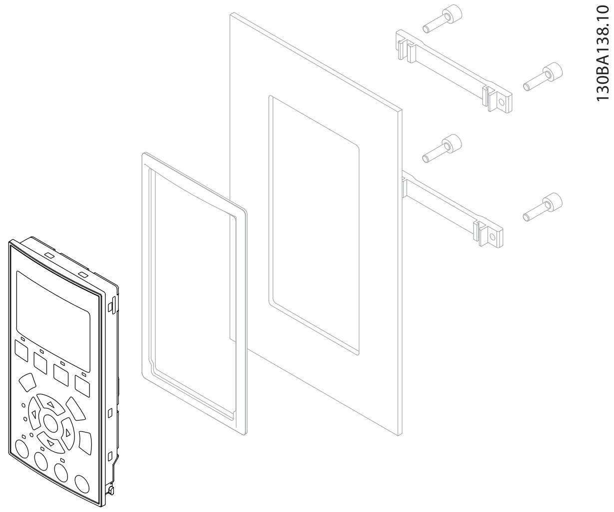


Illustration 9.19 Ordering No. 130B1113, LCP Kit with Graphical LCP, Fasteners, 3 m Cable and Gasket

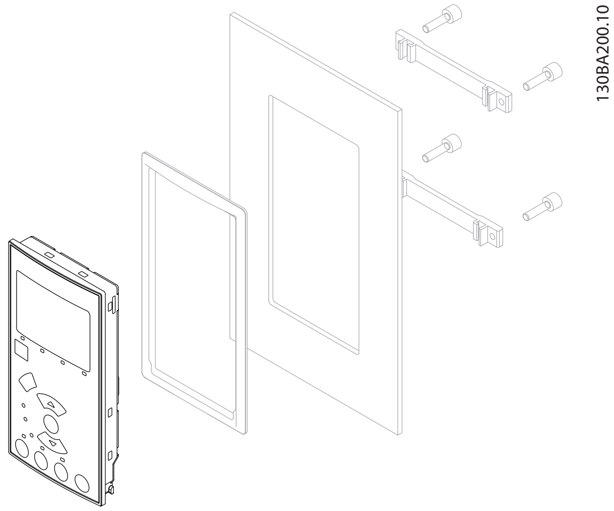


Illustration 9.20 Ordering No. 130B1114, LCP Kit with Numerical LCP, Fasteners and Gasket

Also available is an LCP Kit without LCP. For IP66 units, the ordering number is 130B1117. Use ordering number 130B1129 for IP55 units.

9.11 Sine-wave Filters

When a motor is controlled by a frequency converter, resonance noise is heard from the motor. This noise, which results from the motor design, arises 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 FC 300, 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. This 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.

9.12 High Power Options

Ordering numbers for high power options can be found in *5 How to Order*.

9.12.1 Frame Size D Options

9.12.1.1 Load Share Terminals

Load share terminals enable the connection of the DC circuits of several frequency converters. Load share terminals are available in IP20 frequency converters and extend out the top of the unit. A terminal cover, supplied with the frequency converter, must be installed to maintain the IP20 rating of the enclosure. *Illustration 9.21* shows both the covered and uncovered terminals.

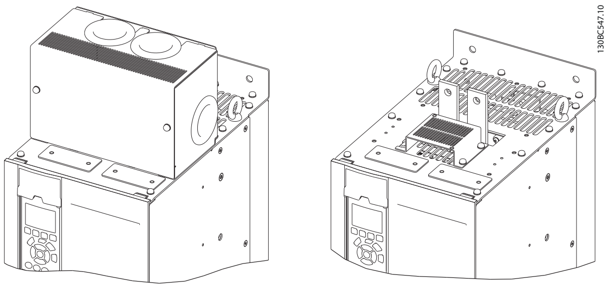


Illustration 9.21 Load Share or Regeneration Terminal with Cover (Left) and without Cover (Right)

9.12.1.2 Regeneration Terminals

Regen (regeneration) terminals can be supplied for applications that have a regenerative load. A regenerative unit, supplied by a third party, connects to the regen terminals so that power can be sent back onto the mains, resulting in energy savings. Regen terminals are available in IP20 frequency converters and extend out the top of the unit. A terminal cover, supplied with the frequency converter, must be installed to maintain the IP20 rating of the enclosure. *Illustration 9.21* shows both the covered and uncovered terminals.

9.12.1.3 Anti-Condensation Heater

An anti-condensation heater can be installed inside the frequency converter to prevent condensation from forming inside the enclosure when the unit is turned off. The heater is controlled by customer-supplied 230 V AC. For best results, operate the heater only when the unit is not running.

A 2.5 amp time-delay fuse, such as the Bussmann LPJ-21/2SP, is recommended to protect the heater.

9.12.1.4 Brake Chopper

A brake chopper can be supplied for applications that have a regenerative load. The brake chopper connects to a brake resistor, which consumes the braking energy and prevents an overvoltage fault on the DC bus. The brake chopper is automatically activated when the DC bus voltage exceeds a specified level, depending on the nominal voltage of the frequency converter.

9.12.1.5 Mains Shield

The mains shield is a Lexan cover installed inside the enclosure to provide protection according to VBG-4 accident-prevention requirements.

9.12.1.6 Ruggedized Printed Circuit Boards

Ruggedized boards are available for marine and other applications that experience higher than average vibration.

NOTICE

Ruggedized boards are required to meet marine approval requirements.

9.12.1.7 Heat Sink Access Panel

An optional heat sink access panel is available to facilitate cleaning of the heat sink. Debris buildup is typical in environments prone to airborne contaminants, such as the textile industry.

9.12.1.8 Mains Disconnect

A mains disconnect can be supplied when a local method of disconnecting the frequency converter from the mains is desired. The location of the disconnect is based on the size of the options cabinet and whether other options are present.

9.12.1.9 Contactor

A contactor can be supplied when a remote method of disconnecting the frequency converter from the mains is desired. A customer-supplied 230 V AC 50/60 Hz signal is used to power the contactor.

NOTICE

When UL listing is required and the frequency converter is supplied with a contactor, the customer must provide external fusing to maintain both the unit's UL rating and the short circuit current rating of 100,000 A. See *7.2 Fuses and Circuit Breakers* for fuse recommendations.

9.12.1.10 Circuit Breaker

A circuit breaker can be supplied when over-current protection via a circuit breaker is desired.

9.12.2 Frame Size F Options

Space Heaters and Thermostat
Mounted on the cabinet interior of frame size F frequency converters, space heaters controlled via an automatic thermostat help control humidity inside the enclosure, prolonging component life in damp environments. The thermostat default settings turn on the heaters at 10 °C (50 °F) and turn them off at 15.6 °C (60 °F).

Cabinet light with power outlet
A light mounted on the cabinet interior of frame size F frequency converters increases visibility during servicing and maintenance. The housing includes a power outlet for temporarily powering tools or other devices. The power outlet is available in two voltages:

- 230 V, 50 Hz, 2.5A, CE/ENEC
- 120 V, 60 Hz, 5A, UL/cUL

Transformer tap setup
Transformer T1 requires that taps be set to the proper input voltage if any of the following options are installed:

- Space heaters and thermostat
- Cabinet light with power outlet

A 380-480/500 V frequency converter is initially set to the 525 V tap and a 525–690 V frequency converter is set to the 690 V tap to ensure no over-voltage of secondary equipment occurs if the tap is not changed before power is applied. See *Table 9.6* to set the proper tap on TB3 located in the rectifier cabinet. For location in the frequency converter, see *7.1.2 Power Connections*.

Input voltage range [V]	Tap to select [V]
380-440	400
441-490	460
491-550	525
551-625	575
626-660	660
661-690	690

Table 9.6 Transformer tap

NAMUR terminals
NAMUR is an international association of automation technology users in the process industries, primarily chemical and pharmaceutical industries in Germany. Selection of this option provides terminals organised and labelled to the specifications of the NAMUR standard for drive input and output terminals, which requires an MCB 112PTC thermistor card and anMCB 113 extended relay card.

Residual current device (RCD)
Uses the core balance method to monitor ground fault currents in grounded and high-resistance grounded systems (TN and TT systems in IEC terminology). There is a pre-warning (50% of main alarm set-point) and a main alarm set-point. Each set-point is associated with an SPDT alarm relay for external use. The RCD requires an external "window-type" current transformer, which is supplied and installed by the customer. Features include:

- Integrated into the Safe Torque Off circuit of the frequency converter
- IEC 60755 Type B device monitors AC, pulsed DC, and pure DC ground fault currents
- LED bar graph indicator of the ground fault current level from 10–100% of the set-point
- Fault memory
- [Test/Reset] key

Insulation resistance monitor (IRM)
Monitors the insulation resistance in ungrounded systems (IT systems in IEC terminology) between the system phase conductors and ground. There is an ohmic pre-warning and a main alarm set-point for the insulation level. Each set-point is associated with an SPDT alarm relay for external use.

NOTICE

Only one insulation resistance monitor can be connected to each ungrounded (IT) system.

Features include:

- Integrated into the Safe Torque Off circuit of the frequency converter
- LCD display of the ohmic value of the insulation resistance
- Fault Memory
- [Info], [Test] and [Reset] keys

IEC emergency stop with Pilz safety relay
Includes a redundant four-wire emergency-stop push button mounted on the front of the enclosure. A Pilz relay monitors it with the Safe Torque Off circuit and the mains contactor located in the options cabinet.

9

Safe Stop with Pilz Relay
Provides a solution for the "Emergency Stop" option without the contactor in F-Frame frequency converters.

Manual motor starters
Provides 3-phase power for electric blowers that are often required for larger motors. Power for the starters is provided from the load side of any supplied contactor, circuit breaker, or disconnect switch. Power is fused before each motor starter, and is off when the incoming power to the frequency converter is off. If a 30 A fuse-protected circuit is ordered, only one starter is allowed, otherwise 2 starters may be selected. The starter is integrated into the Safe Torque Off circuit.
Unit features include:

- Operation switch (on/off)
- Short-circuit and overload protection with test function
- Manual reset function

30 A, fuse-protected terminals

- 3-phase power matching incoming mains voltage for powering auxiliary customer equipment
- Not available if 2 manual motor starters are selected
- Terminals are off when the incoming power to the frequency converter is off
- Power for the fused protected terminals is provided from the load side of any supplied contactor, circuit breaker, or disconnect switch.

24 V DC power supply

- 5 A, 120 W, 24 V DC
- Protected against output over-current, overload, short circuits, and over-temperature
- For powering customer-supplied accessory devices such as sensors, PLC I/O, contactors, temperature probes, indicator lights, and/or other electronic hardware
- Diagnostics include a dry DC-ok contact, a green DC-ok LED, and a red overload LED

External temperature monitoring
Monitors temperatures of external system components such as the motor windings and/or bearings. This option includes 5 universal input modules. The modules are integrated into the Safe Torque Off circuit and can be monitored via a fieldbus network. This requires the purchase of the Safe Torque Off option and separate module/bus couplers.

Universal Inputs (5)
Signal types:

- RTD inputs (including PT100), 3-wire or 4-wire
- Thermocouple
- Analog current or analog voltage

Additional features:

- One universal output, configurable for analog voltage or analog current
- Two output relays (N.O.)
- Dual-line LC display and LED diagnostics
- Sensor lead wire break, short-circuit, and incorrect polarity detection
- Interface setup software

9

10 RS-485 Installation and Set-up

10.1 Overview

RS-485 is a 2-wire bus interface compatible with multi-drop network topology. Nodes can be connected as a bus, or via drop cables from a common trunk line. A total of 32 nodes can be connected to one network segment. Repeaters divide network segments. Note each repeater function as a node within the segment in which it is installed. Each node connected within a given network must have a unique node address, across all segments. Terminate each segment at both ends, using either the termination switch (S801) of the frequency converters or a biased termination resistor network. Always use screened twisted pair (STP) cable for bus cabling, and always follow good common installation practice.
Low-impedance earth connection of the screen at every node is important, including at high frequencies. Thus, connect a large surface of the screen to earth, e.g. with a cable clamp or a conductive cable gland. If necessary, apply potential-equalizing cables to maintain the same earth potential throughout the network. Particularly in installations with long cables.
To prevent impedance mismatch, always use the same type of cable throughout the entire network. When connecting a motor to the frequency converter, always use screened motor cable.

Cable	Screened twisted pair (STP)
Impedance	120 Ω
Cable length	Max. 1,200 m (including drop lines)
Max. 500 m station-to-station	

Table 10.1 Motor Cable

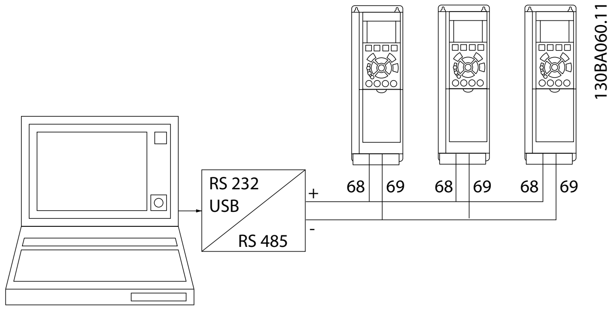


Illustration 10.1 Parallel Connections

To avoid potential equalising currents in the screen, earth the cable screen via terminal 61, which is connected to the frame via an RC-link.

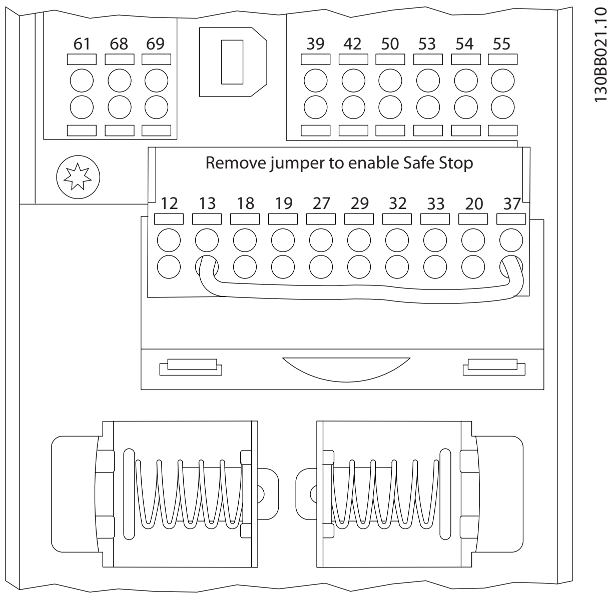


Illustration 10.2 Control Card Terminals

10.2 Network Connection

One or more frequency converters can be connected to a control (or master) using the RS-485 standardised interface. Terminal 68 is connected to the P signal (TX+, RX+), while terminal 69 is connected to the N signal (TX-, RX-). See illustrations in *7.7.2 Earthing*

If more than one frequency converter is connected to a master, use parallel connections.

10.3 Bus Termination

The RS-485 bus must be terminated by using a resistor network at both ends. For this purpose, set switch S801 on the control card to "ON".
For more information, see *7.5.4 Switches S201 (A53), S202 (A54), and S801*.

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

10.4 RS-485 Installation and Set-up

10.4.1 EMC Precautions

To achieve interference-free operation of the RS-485 network, the following EMC precautions are recommended.

Relevant national and local regulations, regarding protective earth connection, for example, must be observed. The RS-485 communication cable must be kept away from motor and brake resistor cables to avoid coupling of high-frequency noise from one cable to another. Normally a distance of 200 mm (8 in) is sufficient. However, in situations where cables run in parallel over long distances, keeping the greatest possible distance between cables is recommended. When crossing is unavoidable, the RS-485 cable must cross motor and brake resistor cables at an angle of 90°.

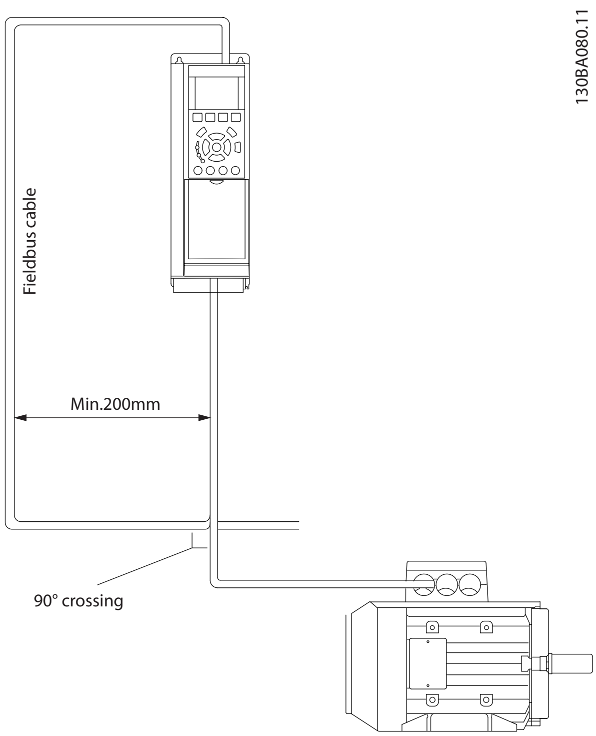


Illustration 10.3 EMC Precautions

10.5 FC Protocol Overview

The FC protocol, also referred to as FC bus or Standard bus, is the Danfoss standard fieldbus. It defines an access technique according to the master/follower principle for communications via a serial bus.
One master and a maximum of 126 followers can be connected to the bus. The master selects the individual followers via an address character in the telegram. A follower itself can never transmit without first being requested to do so, and direct message transfer between the individual followers is not possible. Communications occur in the half-duplex mode.
The master function cannot be transferred to another node (single-master system).

The physical layer is RS-485, thus utilising the RS-485 port built into the frequency converter. The FC protocol supports different telegram formats:

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

10.6 Network Configuration

10.6.1 Frequency Converter Set-Up

Set the following parameters to enable the FC protocol for the frequency converter.

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

Table 10.2 FC Protocol Parameters

10.7 FC Protocol Message Framing Structure

10.7.1 Content of a Character (Byte)

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

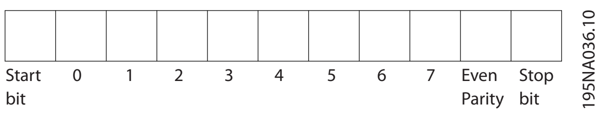


Illustration 10.4 Character (Byte)

10.7.2 Telegram Structure

Each telegram has the following structure:

1. Start character (STX)=02 Hex
2. A byte denoting the telegram length (LGE)
3. A byte denoting the frequency converter address (ADR)

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

A data control byte (BCC) completes the telegram.

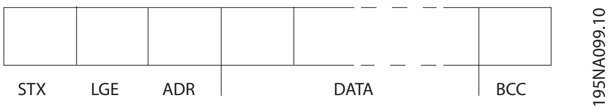


Illustration 10.5 Telegram Structure

10.7.3 Telegram Length (LGE)

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

- The length of telegrams with 4 data bytes is LGE=4+1+1=6 bytes
- The length of telegrams with 12 data bytes is LGE=12+1+1=14 bytes
- The length of telegrams containing texts is 10[1)]+n bytes

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

10.7.4 Frequency Converter Address (ADR)

Two different address formats are used.
The address range of the frequency converter is either 1–31 or 1–126.

1. Address format 1–31:

Bit 7=0 (address format 1–31 active)

Bit 6 is not used

Bit 5=1: Broadcast, address bits (0–4) are not used

Bit 5=0: No Broadcast

Bit 0–4=frequency converter address 1–31

2. Address format 1–126:

Bit 7=1 (address format 1–126 active)

Bit 0–6=frequency converter address 1–126

Bit 0–6=0 Broadcast

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

10.7.5 Data Control Byte (BCC)

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

10.7.6 The Data Field

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

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

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

Illustration 10.6 PCD

Parameter block

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

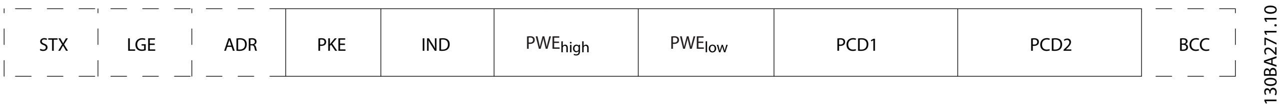


Illustration 10.7 Parameter block

Text block

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

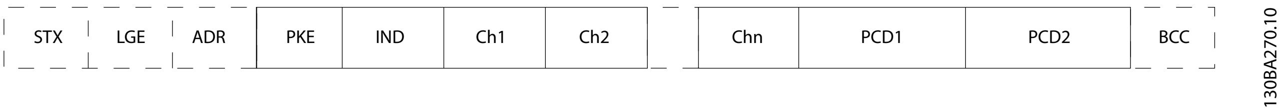


Illustration 10.8 Text Block

10.7.7 The PKE Field

The PKE field contains 2 sub fields:

- Parameter command and response AK
- Parameter number PNU

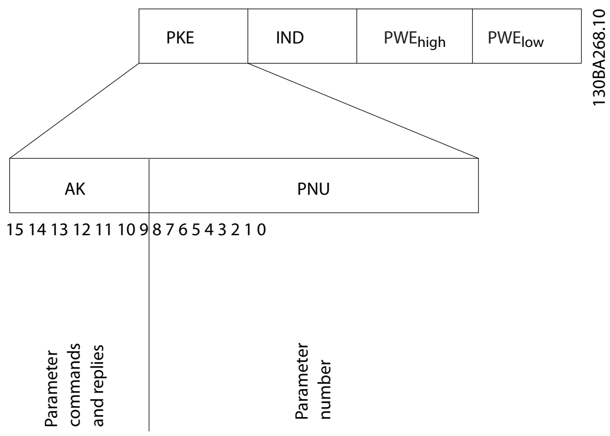


Illustration 10.9 PKE Field

Bits no. 12–15 transfer parameter commands from master to follower and return processed follower responses to the master.

Bit no.				Parameter command
15	**14**	**13**	**12**	
0	0	0	0	No command
0	0	0	1	Read parameter value
0	0	1	0	Write parameter value in RAM (word)
0	0	1	1	Write parameter value in RAM (double word)
1	1	0	1	Write parameter value in RAM and EEprom (double word)
1	1	1	0	Write parameter value in RAM and EEprom (word)
1	1	1	1	Read/write text

Table 10.3 Parameter Commands Master⇒Follower

Bit no.				Response
15	**14**	**13**	**12**	
0	0	0	0	No response
0	0	0	1	Parameter value transferred (word)
0	0	1	0	Parameter value transferred (double word)
0	1	1	1	Command cannot be performed
1	1	1	1	text transferred

Table 10.4 Response Follower⇒Master

If the command cannot be performed, the follower sends this response:
0111 Command cannot be performed
- and issues the following fault report in the parameter value (PWE):

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

Table 10.5 Fault Report

10.7.8 Parameter Number (PNU)

Bits no. 0–11 transfer parameter numbers. The function of the relevant parameter is defined in the parameter description in the *Programming Guide*.

10.7.9 Index (IND)

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

Only the low byte is used as an index.

10.7.10 Parameter Value (PWE)

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

When a follower responds to a parameter request (read command), the present parameter value in the PWE block is transferred and returned to the master. If a parameter contains not a numerical value but several data options, for example, *0-01 Language [0] English*, and *[4] Danish*, select the data value by entering the value in the PWE block. Serial communication is only capable of reading parameters containing data type 9 (text string).

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

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

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

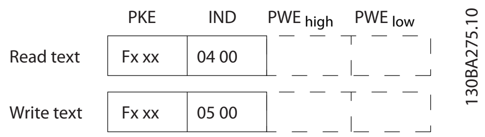


Illustration 10.10 PWE

10.7.11 Data Types Supported

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

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

Table 10.6 Data Types Supported

10.7.12 Conversion

The various attributes of each parameter are displayed in the section factory settings. Parameter values are transferred as whole numbers only. Conversion factors are therefore used to transfer decimals.

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

Examples:
0 s⇒conversion index 0
0.00 s⇒conversion index -2
0 ms⇒conversion index -3
0.00 ms⇒conversion index -5

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

Table 10.7 Conversion Table

10.7.13 Process Words (PCD)

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

PCD 1	PCD 2
Control Telegram (master⇒follower Control word)	Reference-value
Control Telegram (follower⇒master) Status word	Present output frequency

Table 10.8 PCD Sequence

10.8 Examples

10.8.1 Writing a Parameter Value

Change *4-14 Motor Speed High Limit [Hz]* to 100 Hz.
Write the data in EEPROM.

PKE=E19E Hex - Write single word in *4-14 Motor Speed High Limit [Hz]*
IND=0000 Hex
PWE_{high}=0000 Hex
PWE_{low}=03E8 Hex - Data value 1,000, corresponding to 100 Hz, see *10.7.12 Conversion*.

E19E H	0000 H	0000 H	03E8 H
PKE	IND	PWE_{high}	PWE_{low}

130BA092.10

Illustration 10.11 Telegram

NOTICE

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

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

130BA093.10

Illustration 10.12 Response from Master to Follower

10.8.2 Reading a Parameter Value

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

PKE=1,155 Hex - Read parameter value in *3-41 Ramp 1 Ramp Up Time*
IND=0000 Hex
PWE_{high}=0000 Hex
PWE_{low}=0000 Hex

1155 H	0000 H	0000 H	0000 H
PKE	IND	PWE_{high}	PWE_{low}

130BA094.10

Illustration 10.13 Parameter Value

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

1155 H	0000 H	0000 H	03E8 H
PKE	IND	PWE_{high}	PWE_{low}

130BA267.10

Illustration 10.14 Response from Follower to Master

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

10.9 Modbus RTU Overview

10.9.1 Assumptions

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

10.9.2 Prerequisite Knowledge

The Modbus RTU (Remote Terminal Unit) is designed to communicate with any controller that supports the interfaces defined in this document. It is assumed that the reader has full knowledge of the capabilities and limitations of the controller.

10.9.3 Modbus RTU Overview

Regardless of the type of physical communication networks, the Modbus RTU Overview describes the process a controller uses to request access to another device. This process includes how the Modbus RTU responds to requests from another device, and how errors are detected and reported. It also establishes a common format for the layout and contents of message fields.
During communications over a Modbus RTU network, the protocol determines:

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

If a reply is required, the controller constructs the reply message and sends it.
Controllers communicate using a master-follower technique in which only one device (the master) can initiate transactions (called queries). The other devices (slaves) respond by supplying the requested data to the master, or by responding to the the query.
The master can address individual slaves, or can initiate a broadcast message to all slaves. Slaves return a message, called a response, to queries that are addressed to them individually. No responses are returned to broadcast queries from the master. The Modbus RTU protocol establishes the format for the master query by placing into it the device (or broadcast) address, a function code defining the requested action, any data to send, and an error-checking field. The follower response message is also constructed using Modbus protocol. It contains fields confirming the action taken, any data to return, and an error-checking field. If an error occurs in receipt of the message, or if the follower is unable to perform the requested action, the follower constructs an error message, and send it in response, or a time-out occurs.

10.9.4 Frequency Converter with Modbus RTU

The frequency converter communicates in Modbus RTU format over the built-in RS-485 interface. Modbus RTU provides access to the control word and bus reference of the frequency converter.

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

- Start
- Stop of the frequency converter in various ways:
  Coast stop
  Quick stop
  DC Brake stop
  Normal (ramp) stop
- Reset after a fault trip
- Run at various preset speeds
- Run in reverse
- Change the active set-up
- Control the built-in relay of the frequency converter

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

10.10 Network Configuration

10.10.1 Frequency Converter with Modbus RTU

To enable Modbus RTU on the frequency converter, set the following parameters:

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

10

10.11 Modbus RTU Message Framing Structure

10.11.1 Frequency Converter with Modbus RTU

The controllers are set up to communicate on the Modbus network using RTU (Remote Terminal Unit) mode, with each byte in a message containing 2 4-bit hexadecimal characters. The format for each byte is shown in *Table 10.10*.

Start bit	Data byte								Stop/ Parity	Stop

Table 10.9 Example Format

Coding System	8-bit binary, hexadecimal 0–9, A-F. two hexadecimal characters contained in each 8-bit field of the message
Bits Per Byte	1 start bit 8 data bits, least significant bit sent first 1 bit for even/odd parity; no bit for no parity 1 stop bit if parity is used; 2 bits if no parity
Error Check Field	Cyclical Redundancy Check (CRC)

Table 10.10 Bit Detail

10.11.2 Modbus RTU Message Structure

The transmitting device places a Modbus RTU message into a frame with a known beginning and ending point. Receiving devices are able to begin at the start of the message, read the address portion, determine which device is addressed (or all devices, if the message is broadcast), and to recognise when the message is completed. Partial messages are detected and errors set as a result. Characters for transmission must be in hexadecimal 00 to FF format in each field. The frequency converter continuously monitors the network bus, also during 'silent' intervals. When the first field (the address field) is received, each frequency converter or device decodes it to determine which device is being addressed. Modbus RTU messages addressed to zero are broadcast messages. No response is permitted for broadcast messages. A typical message frame is shown in *Table 10.12*.

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

Table 10.11 Typical Modbus RTU Message Structure

10.11.3 Start/Stop Field

Messages start with a silent period of at least 3.5 character intervals, implemented as a multiple of character intervals at the selected network baud rate (shown as Start T1-T2-T3-T4). The first transmitted field is the device address. Following the last transmitted character, a similar period of at least 3.5 character intervals marks the end of the message. A new message can begin after this period. The entire message frame must be transmitted as a continuous stream. If a silent period of more than 1.5 character intervals occurs before completion of the frame, the receiving device flushes the incomplete message and assumes that the next byte is the address field of a new message. Similarly, if a new message begins before 3.5 character intervals after a previous message, the receiving device considers it a continuation of the previous message, causing a time-out (no response from the follower), since the value in the final CRC field is not valid for the combined messages.

10.11.4 Address Field

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

10.11.5 Function Field

The function field of a message frame contains 8 bits. Valid codes are in the range of 1-FF. Function fields are used to send messages between master and follower. When a message is sent from a master to a follower device, the function code field tells the follower what action to perform. When the follower responds to the master, it uses the function code field to indicate either a normal (error-free) response, or that an error has occurred (called an exception response). For a normal response, the follower simply echoes the original function code. For an exception response, the follower returns a code that is equivalent to the original function code with its most significant bit set to logic 1. In addition, the follower places a unique code into the data field of the response message. This code tells the master what error occurred, or the reason for the exception. See *10.11.10 Function Codes Supported by Modbus RTU*.

10.11.6 Data Field

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

10.11.7 CRC Check Field

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

10.11.8 Coil Register Addressing

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

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

10

Coil number	Description	Signal direction
1–16	Frequency converter control word (see *Table 10.14*)	Master to follower
17–32	Frequency converter speed or set-point reference Range 0x0–0xFFFF (-200% ... ~200%)	Master to follower
33–48	Frequency converter status word (see *Table 10.14*)	Follower to master
49–64	Open loop mode: Frequency converter output frequency Closed loop mode: Frequency converter feedback signal	Follower to master
65	Parameter write control (master to follower)	Master to follower
	0 = Parameter changes are written to the RAM of the frequency converter	
	1 =Parameter changes are written to the RAM and EEPROM of the frequency converter.	
66-65536	Reserved	

Table 10.12 Coils and Holding Registers

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

Table 10.13 Frequency Converter Control Word (FC Profile)

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

Table 10.14 Frequency Converter Status Word (FC Profile)

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

Table 10.15 Holding Registers

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

10.11.9 How to Control the Frequency Converter

This section describes codes that are used in the function and data fields of a Modbus RTU message.

10.11.10 Function Codes Supported by Modbus RTU

Modbus RTU supports use of the function codes in *Table 10.17* in the function field of a message.

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

Table 10.16 Function Codes

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

Table 10.17 Function Codes

10.11.11 Modbus Exception Codes

For a full explanation of the structure of an exception code response, refer to *10.11.2 Modbus RTU Message Structure*.

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

Table 10.18 Modbus Exception Codes

10.12 How to Access Parameters

10.12.1 Parameter Handling

The PNU (Parameter Number) is translated from the register address contained in the Modbus read or write message. The parameter number is translated to Modbus as (10xparameter number) DECIMAL.

10.12.2 Storage of Data

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

10

10.12.3 IND

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

10.12.4 Text Blocks

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

10.12.5 Conversion Factor

Since a parameter value can only be transferred as a whole number, a conversion factor must be used to transfer decimals. See *10.8 Examples*.

10.12.6 Parameter Values

Standard data types
Standard data types are int16, int32, uint8, uint16, and uint32. They are stored as 4x registers (40001–4FFFF). The parameters are read using function 03 HEX "Read Holding Registers." Parameters are written using the function 6 HEX "Preset Single Register" for 1 register (16-bits), and the function 10 HEX "Preset Multiple Registers" for 2 registers (32-bits). Readable sizes range from 1 register (16 bits) up to 10 registers (20 characters).

Non-standard data types
Non-standard data types are text strings and are stored as 4x registers (40001–4FFFF). The parameters are read using function 03 HEX "Read Holding Registers" and written using function 10 HEX "Preset Multiple Registers." Readable sizes range from 1 register (2 characters) up to 10 registers (20 characters).

10.13 FC Control Profile

10.13.1 Control Word According to FC Profile

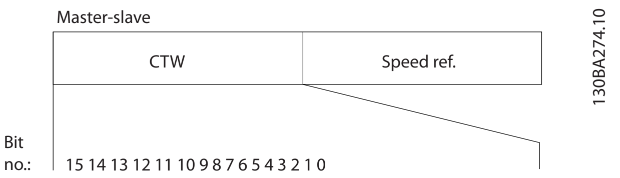


Illustration 10.15 CW Master to Follower

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

Explanation of the control bits

Bits 00/01
Bits 00 and 01 are used to select between the 4 reference values, which are pre-programmed in *3-10 Preset Reference* according to *Table 10.21*.

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

Table 10.19 Control Bits

NOTICE

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

Bit 02, DC brake
Bit 02=’0’ leads to DC braking and stop. Set braking current and duration in *2-01 DC Brake Current* and *2-02 DC Braking Time*.
Bit 02=’1’ leads to ramping.

Bit 03, Coasting
Bit 03=’0’: The frequency converter immediately "lets go" of the motor (the output transistors are "shut off") and it coasts to a standstill.
Bit 03=’1’: The frequency converter starts the motor if the other starting conditions are met.

Make a selection in *8-50 Coasting Select* to define how Bit 03 gates with the corresponding function on a digital input.

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

Bit 05, Hold output frequency
Bit 05=’0’: The present output frequency (in Hz) freezes. Change the frozen output frequency only with the digital inputs (*5-10 Terminal 18 Digital Input* to *5-15 Terminal 33 Digital Input*) programmed to *Speed up* and *Slow down*.

NOTICE

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

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

Bit 06, Ramp stop/start
Bit 06=’0’: Causes a stop and makes the motor speed ramp down to stop via the selected ramp down parameter.
Bit 06=’1’: Permits the frequency converter to start the motor, if the other starting conditions are met.

Make a selection in *8-53 Start Select* to define how Bit 06 Ramp stop/start gates with the corresponding function on a digital input.

Bit 07, Reset:
Bit 07=’0’: No reset.
Bit 07=’1’: Resets a trip. Reset is activated on the leading edge of the signal, that is, when changing from logic ’0’ to logic ’1’.

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

Bit 09, Selection of ramp 1/2
Bit 09="0": Ramp 1 is active (*3-41 Ramp 1 Ramp Up Time* to *3-42 Ramp 1 Ramp Down Time*).
Bit 09="1": Ramp 2 (*3-51 Ramp 2 Ramp Up Time* to *3-52 Ramp 2 Ramp Down Time*) is active.

Bit 10, Data not valid/Data valid
Tell the frequency converter whether to use or ignore the control word. Bit 10=’0’: The control word is ignored.
Bit 10=’1’: The control word is used. This function is relevant because the telegram always contains the control word, regardless of the telegram type. Thus, it is possible to turn off the control word if not in use when updating or reading parameters.

Bit 11, Relay 01
Bit 11="0": Relay not activated.
Bit 11="1": Relay 01 activated if *Control word bit 11* is chosen in *5-40 Function Relay*.

Bit 12, Relay 04
Bit 12="0": Relay 04 is not activated.
Bit 12="1": Relay 04 is activated if *Control word bit 12* is chosen in *5-40 Function Relay*.

Bit 13/14, Selection of set-up
Use bits 13 and 14 to select from the 4 menu set-ups according to *Table 10.22*.

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

Table 10.20 Selection of Set-Up

The function is only possible when **Multi Set-Ups** is selected in *0-10 Active Set-up*.

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

Bit 15 Reverse
Bit 15=’0’: No reversing.
Bit 15=’1’: Reversing. In the default setting, reversing is set to digital in *8-54 Reversing Select*. Bit 15 causes reversing only when Ser. communication, Logic, or Logic and is selected.

10.13.2 Status Word According to FC Profile

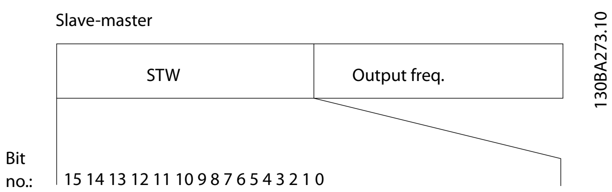


Illustration 10.16 STW Follower to Master

Bit	Bit=0	Bit=1
00	Control not ready	Control ready
01	Drive not ready	Drive ready
02	Coasting	Enable
03	No error	Trip
04	No error	Error (no trip)
05	Reserved	-
06	No error	Triplock
07	No warning	Warning
08	Speed≠reference	Speed=reference
09	Local operation	Bus control
10	Out of frequency limit	Frequency limit OK
11	No operation	In operation
12	Drive OK	Stopped, auto start
13	Voltage OK	Voltage exceeded
14	Torque OK	Torque exceeded
15	Timer OK	Timer exceeded

Explanation of the status bits

Bit 00, Control not ready/ready
Bit 00='0': The frequency converter trips.
Bit 00='1': The frequency converter controls are ready but the power component does not necessarily receive any power supply (in case of external 24 V supply to controls).

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

Bit 02, Coasting stop
Bit 02='0': The frequency converter releases the motor.
Bit 02='1': The frequency converter starts the motor with a start command.

Bit 03, No error/trip
Bit 03='0': The frequency converter is not in fault mode.
Bit 03='1': The frequency converter trips. To re-establish operation, enter [Reset].

Bit 04, No error/error (no trip)
Bit 04='0': The frequency converter is not in fault mode.
Bit 04="1": The frequency converter shows an error but does not trip.

Bit 05, Not used
Bit 05 is not used in the status word.

Bit 06, No error/triplock
Bit 06='0': The frequency converter is not in fault mode.
Bit 06="1": The frequency converter is tripped and locked.

Bit 07, No warning/warning
Bit 07='0': There are no warnings.
Bit 07='1': A warning has occurred.

Bit 08, Speed≠ reference/speed=reference
Bit 08='0': The motor is running but the present speed is different from the preset speed reference. It could be the case when the speed ramps up/down during start/stop.
Bit 08='1': The motor speed matches the preset speed reference.

Bit 09, Local operation/bus control
Bit 09='0': [Stop/Reset] is activated on the control unit or *Local control* in *3-13 Reference Site* is selected. The frequency converter cannot be controlled via serial communication.
Bit 09='1' It is possible to control the frequency converter via the fieldbus/serial communication.

Bit 10, Out of frequency limit
Bit 10='0': The output frequency has reached the value in *4-11 Motor Speed Low Limit [RPM]* or *4-13 Motor Speed High Limit [RPM]*.
Bit 10="1": The output frequency is within the defined limits.

Bit 11, No operation/in operation
Bit 11='0': The motor is not running.
Bit 11='1': The frequency converter has a start signal or the output frequency is greater than 0 Hz.

Bit 12, Drive OK/stopped, autostart
Bit 12='0': There is no temporary over temperature on the inverter.
Bit 12='1': The inverter stops because of over temperature but the unit does not trip and resumes operation once the over temperature stops.

Bit 13, Voltage OK/limit exceeded
Bit 13='0': There are no voltage warnings.
Bit 13='1': The DC voltage in the intermediate circuit is too low or too high.

Bit 14, Torque OK/limit exceeded
Bit 14='0': The motor current is lower than the torque limit selected in *4-18 Current Limit*.
Bit 14='1': The torque limit in *4-18 Current Limit* is exceeded.

Bit 15, Timer OK/limit exceeded
Bit 15='0': The timers for motor thermal protection and thermal protection are not exceeded 100%.
Bit 15='1': One of the timers exceeds 100%.

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

10.13.3 Bus Speed Reference Value

Speed reference value is transmitted to the frequency converter in a relative value in %. The value is transmitted in the form of a 16-bit word; in integers (0–32767) the value 16384 (4000 Hex) corresponds to 100%. Negative figures are formatted with 2's complement. The Actual Output frequency (MAV) is scaled in the same way as the bus reference.

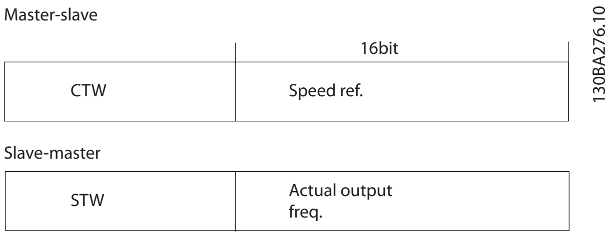


Illustration 10.17 Bus Speed Reference Value

The reference and MAV are scaled as showed in *Illustration 10.18*.

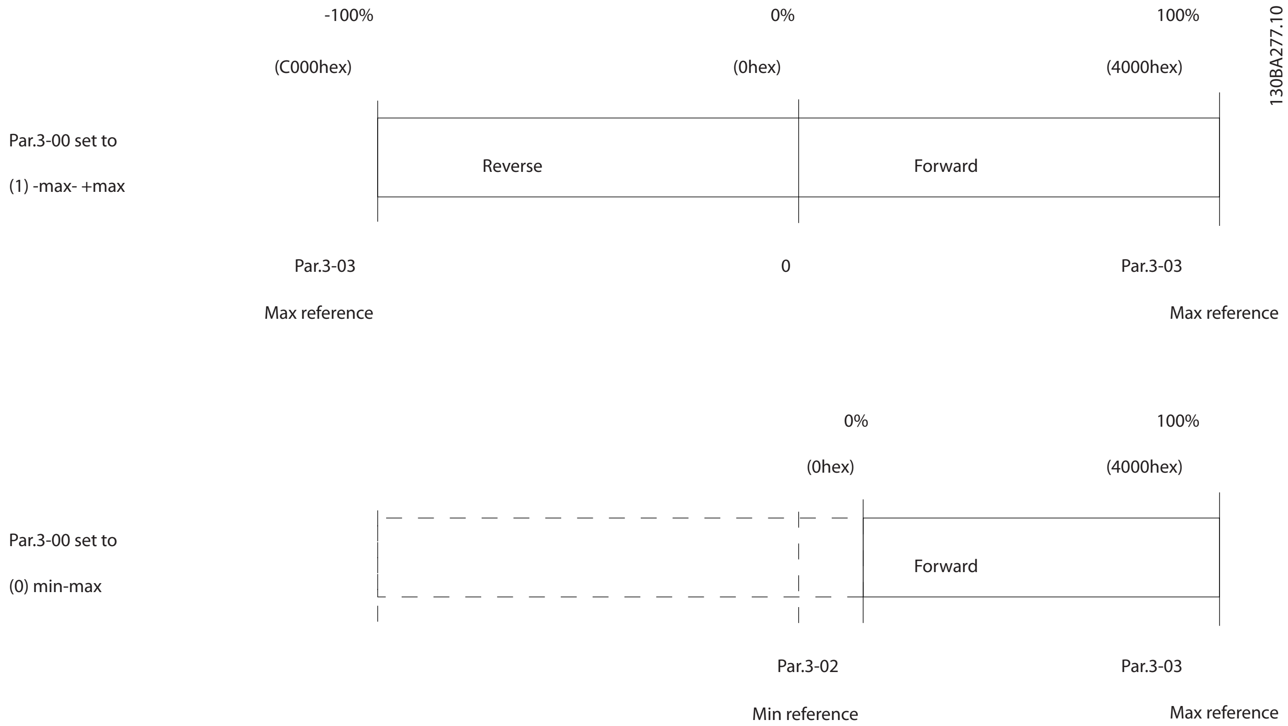


Illustration 10.18 Reference and MAV

10.13.4 Control Word According to PROFIdrive Profile (CTW)

The control word is used to send commands from a master (e.g. a PC) to a follower.

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

Table 10.21 Bit Values for Control Word, PROFIdrive Profile

Explanation of the control bits

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

Bit 01, OFF 2/ON 2
Coasting stop
When bit 01="0", a coasting stop and activation of the output relay 1 or 2 occurs if the output frequency is 0 Hz and if [Relay 123] has been selected in *5-40 Function Relay*.
When bit 01="1", the frequency converter is in State 1: “Switching on inhibited”. Refer to *Table 10.25*, at the end of this section.

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

Bit 03, Coasting/No coasting
Coasting stop Bit 03="0" leads to a stop.
When bit 03="1", the frequency converter can start if the other start conditions are satisfied.

NOTICE

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

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

NOTICE

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

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

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

NOTICE

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

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

Bit 08, Jog 1 OFF/ON
Activates the pre-programmed speed in *8-90 Bus Jog 1 Speed*. JOG 1 is only possible if bit 04="0" and bit 00-03="1".

Bit 09, Jog 2 OFF/ON
Activates the pre-programmed speed in *8-91 Bus Jog 2 Speed*. JOG 2 is only possible if bit 04="0" and bit 00-03="1".

Bit 10, Data invalid/valid
Tells the frequency converter whether the control word is to be used or ignored.

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

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

Bit 12, No function/Catch up
Increases the speed reference value by the amount given in *3-12 Catch up/slow Down Value*.
When bit 12="0", no modification of the reference value occurs.
When bit 12="1", the reference value is increased.
If both slowing down and accelerating are activated (bit 11 and 12="1"), slowing down has priority, i.e. the speed reference value will be reduced.

Bits 13/14, Set-up selection
Selects between the 4 parameter set-ups according to *Table 10.25*:

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

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

Table 10.22 Bits 13/14 Set-Up Options

Bit 15, No function/Reverse
Bit 15="0" causes no reversing.
Bit 15="1" causes reversing.
Note: In the factory setting reversing is set to *digital* in *8-54 Reversing Select*.

NOTICE

Bit 15 causes reversing only when *Ser. communication, Logic or* or *Logic and* is selected.

10.13.5 Status Word According to PROFIdrive Profile (STW)

The status word notifies a master (e.g. a PC) about the status of a follower.

Bit	Bit=0	Bit=1
00	Control not ready	Control ready
01	Drive not ready	Drive ready
02	Coasting	Enable
03	No error	Trip
04	OFF 2	ON 2
05	OFF 3	ON 3
06	Start possible	Start not possible
07	No warning	Warning
08	Speed≠reference	Speed=reference
09	Local operation	Bus control
10	Out of frequency limit	Frequency limit ok
11	No operation	In operation
12	Drive OK	Stopped, autostart
13	Voltage OK	Voltage exceeded
14	Torque OK	Torque exceeded
15	Timer OK	Timer exceeded

Table 10.23 Bit Values for Status Word, PROFIdrive Profile

Explanation of the status bits

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

Bit 01, VLT not ready/ready
Same significance as bit 00, however, there is a supply of the power unit. The frequency converter is ready when it receives the necessary start signals.

Bit 02, Coasting/Enable
When bit 02="0", bit 00, 01 or 02 of the Control word is "0" (OFF 1, OFF 2 or OFF 3 or coasting) - or the frequency converter is switched off (trip).
When bit 02="1", bit 00, 01 or 02 of the Control word is "1"; the frequency converter has not tripped.

Bit 03, No error/Trip
When bit 03="0", no error condition of the frequency converter exists.
When bit 03="1", the frequency converter has tripped and requires a reset signal before it can start.

Bit 04, ON 2/OFF 2
When bit 01 of the Control word is "0", then bit 04="0".
When bit 01 of the Control word is "1", then bit 04="1".

Bit 05, ON 3/OFF 3
When bit 02 of the Control word is "0", then bit 05="0".
When bit 02 of the Control word is "1", then bit 05="1".

Bit 06, Start possible/Start not possible
If PROFIdrive has been selected in *8-10 Control Word Profile*, bit 06 is "1" after a switch-off acknowledgement, after activation of OFF2 or OFF3, and after switching on the mains voltage. Start not possible is reset with bit 00 of the Control word being set to "0" and bit 01, 02 and 10 being set to "1".

Bit 07, No warning/Warning
Bit 07="0" means that there are no warnings.
Bit 07="1" means that a warning has occurred.

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

Bit 09, Local operation/Bus control
Bit 09="0" indicates that the frequency converter has been stopped with the [Stop] key on the LCP, or that [2] *Linked to Hand/Auto* or [0] *Local* has been selected in *3-13 Reference Site*.
When bit 09="1", the frequency converter can be controlled through the serial interface.

Bit 10, Out of frequency limit/Frequency limit OK
When bit 10="0", the output frequency is outside the limits set in *4-52 Warning Speed Low* and *4-53 Warning Speed High*.
When bit 10="1", the output frequency is within the indicated limits.

Bit 11, No operation/Operation
When bit 11="0", the motor does not turn.
When bit 11="1", the frequency converter has a start signal, or the output frequency is higher than 0 Hz.

Bit 12, Drive OK/Stopped, autostart
When bit 12="0", there is no temporary overloading of the inverter.
When bit 12="1", the inverter has stopped due to overloading. However, the frequency converter has not switched off (trip) and will start again after the overloading has ended.

Bit 13, Voltage OK/Voltage exceeded
Bit 13, Voltage OK/Voltage exceeded
When bit 13="0", the voltage limits of the frequency converter are not exceeded.
When bit 13="1", the direct voltage in the intermediate circuit of the frequency converter is too low or too high.

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

Bit 15, Timer OK/Timer exceeded
When bit 15="0", the timers for the thermal motor protection and thermal frequency converter protection have not exceeded 100%.
When bit 15="1", one of the timers has exceeded 100%.

Index

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130R0280 MG34S202 *MG34S202* Rev. 2013-08-19