MAKING MODERN LIVING POSSIBLE

Design Guide

VLT® AutomationDrive FC 300 90-1200 kW

THE REAL DRIVE

Contents

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1 How to Read this Design Guide

This Design Guide will introduce all aspects of the VLT® AutomationDrive.

Available literature for FC 300

- The *VLT® AutomationDrive Operating Instructions* provide the necessary information for getting the frequency converter up and running.
- The *VLT® AutomationDrive Design Guide* includes all technical information about the frequency converter, customer design and applications.
- The *VLT® AutomationDrive Programming Guide* provides information on how to programme and includes complete parameter descriptions.
- The *VLT® AutomationDrive Profibus Operating Instructions* provides the information required for controlling, monitoring and programming the frequency converter via a Profibus fieldbus.
- The *VLT® AutomationDrive DeviceNet Operating Instructions* provide the information required for controlling, monitoring and programming the frequency converter via a DeviceNet fieldbus.

Danfoss technical literature is also available online at *www.danfoss.com/BusinessAreas/DrivesSolutions/Documentations/Technical+Documentation*.

1.1.1 Symbols

Symbols used in this guide.

NOTE

Indicates something the reader should note.

CAUTION

Indicates a potentially hazardous situation, which could result in minor or moderate injury or equipment damage.

WARNING

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

* indicates a default setting.

1.1.2 Definitions

Frequency converter

Coast

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

I_{MAX}

The maximum output current.

I_N

The rated output current supplied by the frequency converter.

U_{MAX}

The maximum output voltage.

Input

Control command

Start and stop the connected motor by means of LCP and 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 1.1

Motor

f_{JOG}

The motor frequency when the jog function is activated (via digital terminals).

f_M

Motor frequency. Output from the frequency converter. Output frequency is related to the shaft speed on motor depending on number of poles and slip frequency.

f_{MAX}

The maximum output frequency the frequency converter applies on its output. The maximum output frequency is set in limit *4-12 Motor Speed Low Limit [Hz]*, *4-13 Motor Speed High Limit [RPM]* and *4-19 Max Output Frequency*.

f_{MIN}

The minimum motor frequency from frequency converter. Default 0 Hz.

$f_{M,N}$

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).

n_s
Synchronous motor speed

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

$P_{M,N}$
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

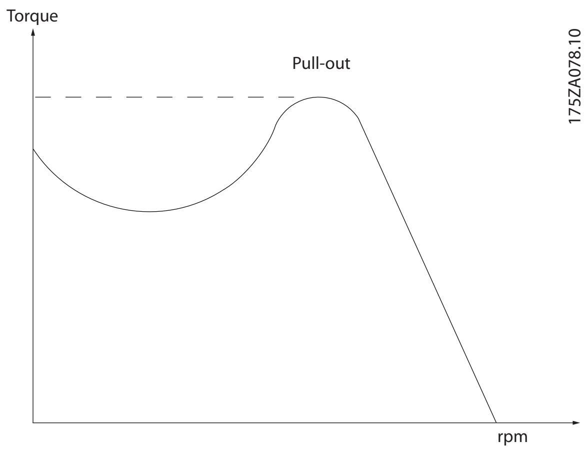


Illustration 1.1

η
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 - see this group.

Stop command
See Control commands.

References

Analogue Reference
An analogue signal applied to input 53 or 54. The signal can be either 0-10 V or -10 to +10 V. Current signal 0-20 mA or 4-20 mA.

Binary Reference
A signal applied to the serial communication port (RS-485 terminal 68–69).

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

Pulse Reference
A pulse reference applied to terminals 29 or 33, selected by parameter *5-13 Terminal 29 Digital Input* or *5-15 Terminal 33 Digital Input* [32]. Scaling in parameter group *5-5* Pulse Input*.

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 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 set in *3-02 Minimum Reference*.

Miscellaneous

Analogue Inputs
The analogue inputs are used for controlling various functions of the frequency converter.
There are two types of analogue inputs:
Current input, 0-20 mA and 4-20 mA
Voltage input, 0-10 V DC
Voltage input, -10 to +10 V DC.

Analogue Outputs
The analogue outputs can supply a signal of 0-20 mA, 4-20 mA.

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

Brake Resistor
The brake resistor is a module capable of absorbing the brake power generated in regenerative braking. This regenerative 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 all applications such as conveyor belts, displacement pumps and cranes.

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.

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

Hiperface®
Hiperface® is a registered trademark by Stegmann.

Initialising
If initialising is carried out (*14-22 Operation Mode*), the frequency converter returns to the default setting.

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

LCP
The Local Control Panel makes up a complete interface for control and programming of the frequency converter. The control panel is detachable and can be installed up to 3 metres from the frequency converter, i.e. in a front panel by means of the installation kit option.

NLCP
Numerical Local Control Panel interface for control and programming of frequency converter. The display is numerical and the panel is used for display process values. The NLCP has no storing and copy function.

lsb
Least significant bit.

msb
Most significant bit.

MCM
Short for Mille Circular Mil, an American measuring unit for cable cross-section. 1 MCM=0.5067 mm^2.

On-line/Off-line Parameters
Changes to on-line parameters are activated immediately after the data value is changed. Changes to off-line parameters are activated with the [OK] command on the LCP.

Process PID
The PID regulator maintains the desired speed, pressure, temperature, etc. 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.

Set-up
Parameter settings are saved in four set-ups. Change between the four parameter set-ups and edit one set-up, while another set-up is active.

SFAVM
Switching pattern called Stator Flux oriented Asynchronous Vector Modulation (*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 Smart Logic Controller. (Parameter group *13-** Smart Logic Control (SLC)*.

STW
Status Word

FC Standard Bus
Includes RS-485 bus with FC protocol or MC protocol. See *8-30 Protocol* in the Programming Guide.

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

THD
Total Harmonic Distortion A state of full harmonic distortion.

Trip
A state entered in fault situations, e.g. if the frequency converter is subject to an over-temperature or when the frequency converter 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. Trip may not be used for personal safety.

Trip Locked
A state entered in fault situations when the frequency converter is protecting itself and requiring physical intervention, e.g. if the frequency converter is subject to a short circuit on the output. A locked trip can only be cancelled by cutting off mains, removing the cause of the fault, and reconnecting the frequency converter. Restart is prevented until the trip state is cancelled by activating

reset or, in some cases, by being programmed to reset automatically. Trip may not be used for personal safety.

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° Asynchronous Vector Modulation (*14-00 Switching Pattern*).

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

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

The power factor for 3-phase control:

$$= \frac{I1 \times \cos\varphi 1}{I_{RMS}} = \frac{I_1}{I_{RMS}} \text{ since } \cos\varphi 1 = 1$$

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

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

In addition, a high power factor indicates that the different harmonic currents are low.
All Danfoss frequency converters have built-in DC coils in the DC link to have a high power factor and to reduce the THD on the main supply.

1.1.3 Enclosure Types

The VLT Series frequency converters are available in a variety of enclosure types in order to best accommodate the needs of the application. Enclosure ratings are provided based on two 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 equipment 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 equipment against fibres, lint, dust and dirt, and 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 that oil tight or dust-tight mechanisms may be mounted through holes in the enclosure when provided with oil-resistant gaskets. 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 1.3 provides a cross-reference between the two standards. *Table 1.2* 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 1.2 IP Number Codes

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 1.3 IP Number Codes

2 Safety and Conformity

2.1 Safety Precautions

WARNING

The voltage of the frequency converter is dangerous whenever connected to mains. Incorrect installation of the motor, frequency converter or fieldbus may cause death, serious personal injury or damage to the equipment. Consequently, the instructions in this manual, as well as national and local rules and safety regulations, must be complied with.

Safety Regulations

1. The mains supply to the frequency converter must be disconnected whenever repair work is to be carried out. Check that the mains supply has been disconnected and that the necessary time has elapsed before removing motor and mains supply plugs.
2. The [OFF] key on the LCP does not disconnect the mains supply and consequently it must not be used as a safety switch.
3. The equipment must be properly earthed, the user must be protected against supply voltage and the motor must be protected against overload in accordance with applicable national and local regulations.
4. The earth leakage current exceeds 3.5 mA.
5. Protection against motor overload is not included in the factory setting. If this function is desired, set *1-90 Motor Thermal Protection* to *[4] data value ETR trip 1* or *[3] data value ETR warning 1*.
6. Do not remove the plugs for the motor and mains supply while the frequency converter is connected to mains. Check that the mains supply has been disconnected and that the necessary time has elapsed before removing motor and mains plugs.
7. Note that the frequency converter has more voltage sources than L1, L2 and L3, when load sharing (linking of DC intermediate circuit) or external 24 V DC are installed. Check that all voltage sources have been disconnected and that the necessary time has elapsed before commencing repair work.

Warning against unintended start

1. The motor can be brought to a stop by means of digital commands, bus commands, references or a local stop, while the frequency converter is connected to mains. If personal safety considerations (e.g. risk of personal injury caused by contact with moving machine parts following an unintentional start) make it necessary to ensure that no unintended start occurs, these stop functions are not sufficient. In such cases the mains supply must be disconnected or the Safe Stop function must be activated.
2. The motor may start while setting the parameters. If this means that personal safety may be compromised (e.g. personal injury caused by contact with moving machine parts), motor starting must be prevented, for instance by use of the Safe Stop function or secure disconnection of the motor connection.
3. A motor that has been stopped with the mains supply connected, may start if faults occur in the electronics of the frequency converter, through temporary overload or if a fault in the power supply grid or motor connection is remedied. If unintended start must be prevented for personal safety reasons (e.g. risk of injury caused by contact with moving machine parts), the normal stop functions of the frequency converter are not sufficient. In such cases the mains supply must be disconnected or the Safe Stop function must be activated.

NOTE

When using the Safe Stop function, always follow the instructions in *3.12 Safe Stop*.

4. Control signals from, or internally within, the frequency converter may in rare cases be activated in error, be delayed or fail to occur entirely. When used in situations where safety is critical, e.g. when controlling the electromagnetic brake function of a hoist application, these control signals must not be relied on exclusively.

WARNING

High Voltage

Touching the electrical parts may be fatal - even after the equipment has been disconnected from mains.
Be sure that other voltage inputs have been disconnected, such as external 24 V DC, load sharing (linkage of DC intermediate circuit), as well as the motor connection for kinetic back up.
Systems where frequency converters are installed must, if necessary, be equipped with additional monitoring and protective devices according to the valid safety regulations. Modifications on the frequency converters by means of the operating software are allowed.

NOTE

Hazardous situations shall be identified by the machine builder/integrator who is responsible for taking necessary preventive means into consideration. Additional monitoring and protective devices may be included, always according to valid national safety regulations, (e.g. laws on mechanical tools, regulations for the prevention of accidents, etc.).

NOTE

Crane, Lifts and Hoists
The controlling of external brakes must always have a redundant system. The frequency converter can under no circumstances be the primary safety circuit. Comply with relevant standards, (e.g. IEC 60204-32 for hoists and cranes; EN81 for lifts.

Protection Mode

Once a hardware limit on motor current or DC link voltage is exceeded, the frequency converter will enter protection mode. Protection mode means a change of the PWM strategy and a low switching frequency to minimize losses. This continues 10 s after the last fault and increases the reliability and the robustness of the frequency converter while re-establishing full control of the motor.
In hoist applications Protection mode is not usable because the frequency converter will usually not be able to leave this mode again and therefore it will extend the time before activating the brake – which is not recommended.
The Protection mode can be disabled by setting *14-26 Trip Delay at Inverter Fault* to zero which means that the frequency converter will trip immediately if one of the hardware limits is exceeded.

NOTE

It is recommended to disable protection mode in hoisting applications (*14-26 Trip Delay at Inverter Fault*=0)

2.2 Caution

WARNING

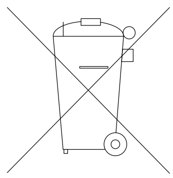
DISCHARGE TIME!

Frequency converters contain DC-link capacitors that can remain charged even when the frequency converter is not powered. To avoid electrical hazards, disconnect AC mains, any permanent magnet type motors, and any 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 *Discharge Time* table. Failure to wait the specified time after power has been removed before doing service or repair could result in death or serious injury.

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

Table 2.1 Capacitor Discharge Times

2.2.1 Disposal Instruction



Equipment containing electrical components should not be disposed of together with domestic waste.
Collect it separately in accordance with local and currently valid legislation.

Table 2.2

2.3 Software Version

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 2.3

2.4 CE Labelling

2.4.1 CE Conformity and Labelling

The 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:
The 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.
The 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 with which standards our products comply. We offer 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 professionals of the trade 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.

2.4.2 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 hobby machine, a kitchen appliance, etc. 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 professionals of the trade. 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 (e.g., an air-conditioning system). The complete 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, the entire system need not be tested.

2.4.3 Danfoss Frequency Converter and CE Labelling

CE labelling is a positive feature when used for its original purpose, i.e. 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 to the EMC directive if the instructions for EMC-correct installation and filtering are followed. On this basis, a declaration of conformity in accordance with the EMC directive is issued.

7.8 EMC-correct Installation offers detailed instructions for installation to ensure EMC-correct installation. Furthermore, Danfoss specifies which our products comply with.

2.4.4 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. It must be noted that 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. The standards and test levels stated for Power Drive systems are complied with, provided that the EMC-correct instructions for installation are followed, see *3.5.4 Immunity Requirements*.

2.5.1 Air Humidity

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

2.5.2 Aggressive Environments

A frequency converter contains a large number of mechanical and electronic components. All are to some extent 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

The safe stop function may only be installed and operated in a control cabinet with degree of protection IP54 or higher (or equivalent environment). This is required to avoid cross faults and short circuits between terminals, connectors, tracks and safety-related circuitry caused by foreign objects.

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 processes 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.
An extra protection in such areas is a coating of the printed circuit boards, which can be ordered as an option.

NOTE

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 on existing installations.

D and E enclosures have a stainless steel back channel option to provide additional protection in aggressive environments. Proper ventilation is still required for the internal components of the drive. Contact Danfoss for additional information.

2.5.3 Vibration and Shock

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

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.

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

2.5.4 D and E-Frames Stainless Steel Backchannel Option

NOTE

D and E-Frames have a stainless steel back channel option to provide additional protection in aggressive environments. Proper ventilation is still required for the internal components of the drive. Contact the factory for additional information.

3 Product Introduction

3.1 Product Overview

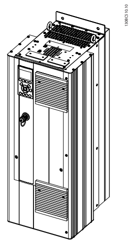
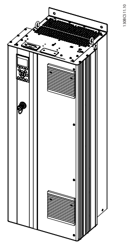
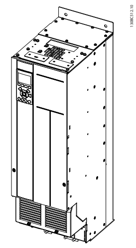
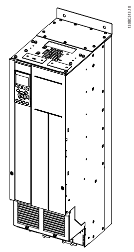
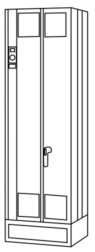
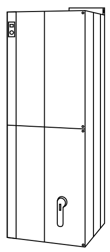
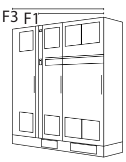
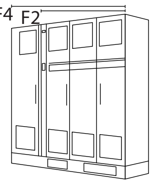
Frame size		D1h	D2h	D3h	D4h
					
Enclosure protection	IP	21/54	21/54	20	20
	NEMA	Type 1/Type 12	Type 1/Type 12	Chassis	Chassis
High overload rated power -160% overload torque		90-132 kW at 400 V (380-500 V) 90-132 kW at 690 V (525-690 V)	160-250 kW at 400 V (380-500 V) 160-315 kW at 690 V (525-690 V)	90-132 kW at 400 V (380-500 V) 90-132 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		**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 (380-500V) 900-1000 kW at 690 V (525-690 V)

Table 3.1 Product Overview, 6-pulse Frequency Converters

NOTE

The F-Frames are available with or without options cabinet. The F1 and F2 consist of an inverter cabinet on the right and rectifier cabinet on the left. The F3 and F4 have an additional options cabinet left of the rectifier cabinet. The F3 is an F1 with an additional options cabinet. The F4 is an F2 with an additional options cabinet.

3

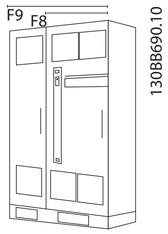
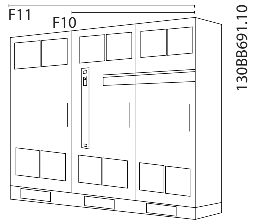
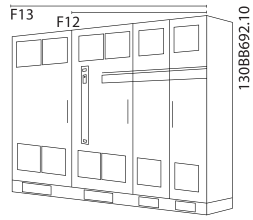
<table>
<tr><th colspan="2">Frame size</th><th>F8</th><th>F9</th><th>F10</th><th>F11</th><th>F12</th><th>F13</th></tr>
<tr><td colspan="2"></td><td colspan="2">
</td><td colspan="2">
</td><td colspan="2">
</td></tr>
<tr><td rowspan="2">Enclosure protection</td><td>IP</td><td>21/54</td><td>21/54</td><td>21/54</td><td>21/54</td><td>21/54</td><td>21/54</td></tr>
<tr><td>NEMA</td><td>Type 1/Type 12</td><td>Type 1/Type 12</td><td>Type 1/Type 12</td><td>Type 1/Type 12</td><td>Type 1/Type 12</td><td>Type 1/Type 12</td></tr>
<tr><td colspan="2">High overload rated power -160% overload torque</td><td>250-400 kW
(380-500 V)
355-560 kW
(525-690 V)</td><td>250-400 kW
(380-500 V)
355-56 kW
(525-690 V)</td><td>450-630 kW
(380-500 V)
630-800 kW
(525-690 V)</td><td>450-630 kW
(380-500 V)
630-800 kW
(525-690 V)</td><td>710-800 kW
(380-500 V)
900-1200 kW
(525-690 V)</td><td>710-800 kW
(380-500V)
900-1200 kW
(525-690 V)</td></tr>
</table>

Table 3.2 Product Overview, 12-pulse Frequency Converters

NOTE

The F-Frames are available with or without options cabinet. The F8, F10 and F12 consist of an inverter cabinet on the right and rectifier cabinet on the left. The F9, F11 and F13 have an additional options cabinet left of the rectifier cabinet. The F9 is an F8 with an additional options cabinet. The F11 is an F10 with an additional options cabinet. The F13 is an F12 with an additional options cabinet.

3.2.1 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 two types of speed control:

- Speed open loop control does not require any feedback from motor (sensorless)
- Speed closed loop PID control requires a speed feedback to an input. A properly optimised speed closed loop control will have higher accuracy than a speed open loop control

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 motor output shaft is controlling the application as tension control. Torque control can be 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 analogue, 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 as the correct motor data are of high importance 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 VVCplus mode. The function is used in mechanical robust applications, but the accuracy is limited. Open loop torque function works basically only in one speed direction. The torque is calculated on the basis of current measurement internal in 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. The handling of references is explained in detail, see *3.3 Reference Handling*.

3.2.2 Control Principle

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

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

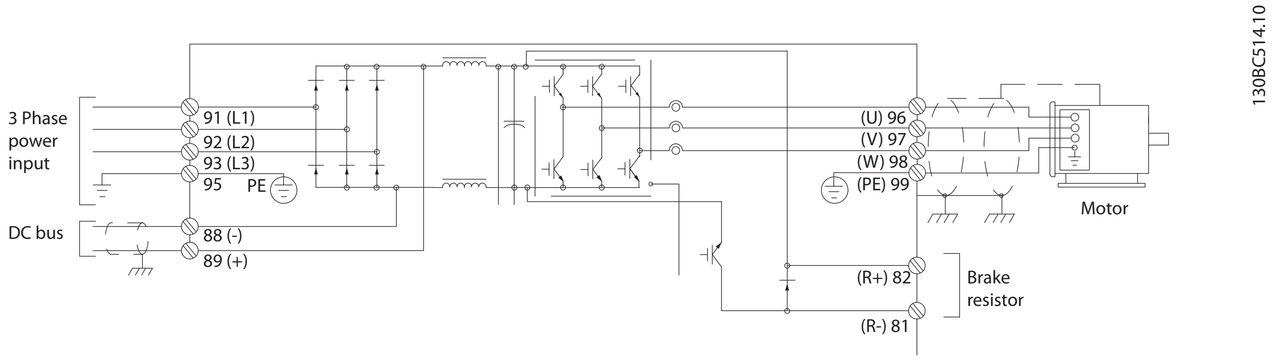


Illustration 3.1 Control Principle for all Frequency Converters

The control terminals provide for wiring feedback, reference, and other input signals to the frequency converter, output of drive status and fault conditions, relays to operate auxiliary equipment, and serial communication interface. 24 V common power is also provided. Control terminals are programmable for various functions by selecting parameter options described in the frequency converter's 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 additional terminals. See *Illustration 3.2* for terminal locations.

NOTE

The example provided does not show optional equipment.

Terminal Nno.	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 analogue and digital outputs.
42	analogue and digital outputs for indicating values such as frequency, reference, current, and torque. The analogue signal is 0/4 to 20 mA at a maximum of 500 Ω. The digital signal is 24 V DC at a minimum of 500 Ω.
50	10 V DC, 15 mA maximum analogue supply voltage for potentiometer or thermistor.
53, 54	Selectable for 0 to 10 V DC voltage input, R=10 kΩ, or analogue 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 Functions

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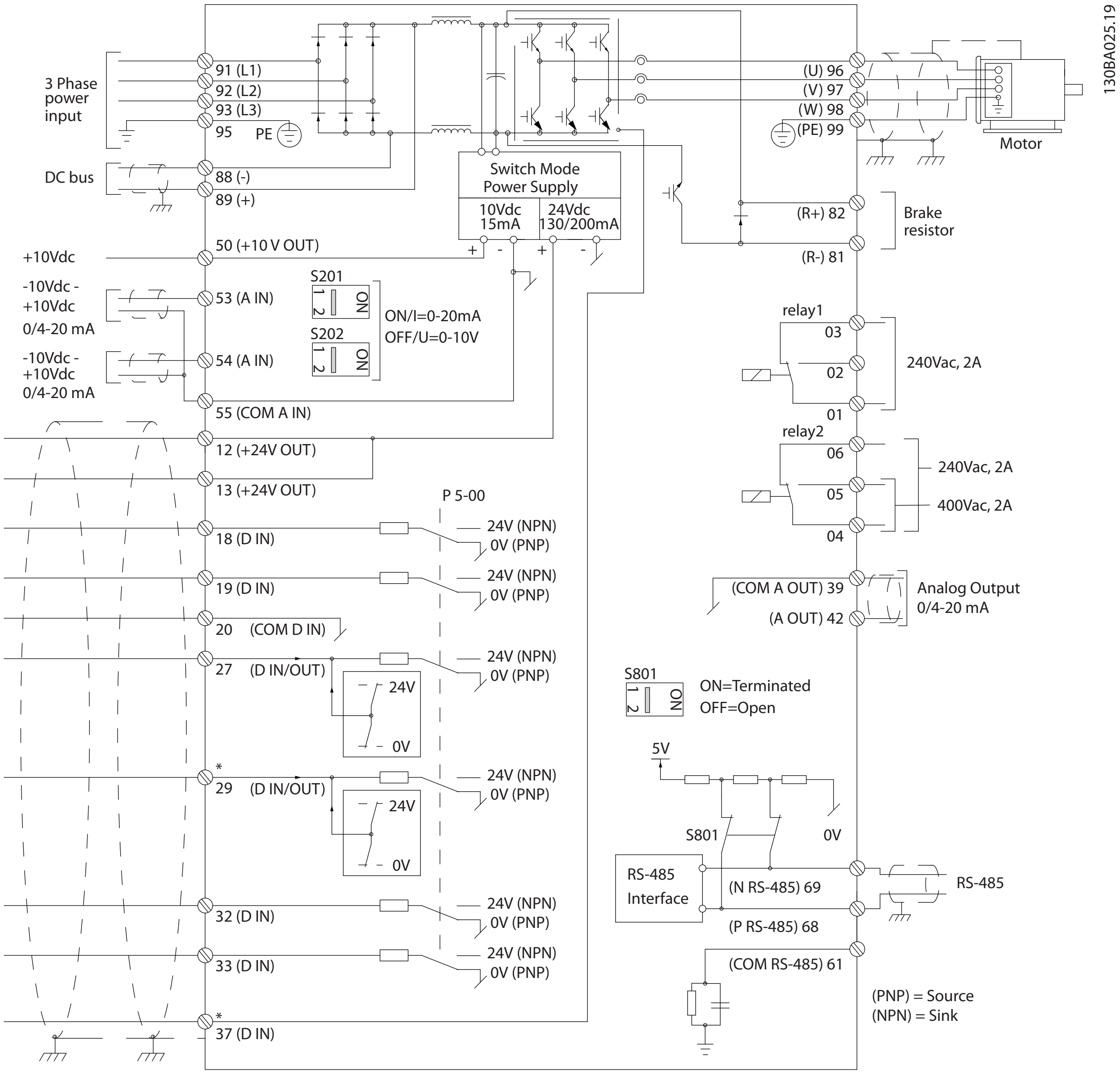

Illustration 3.2 Terminal Locations

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

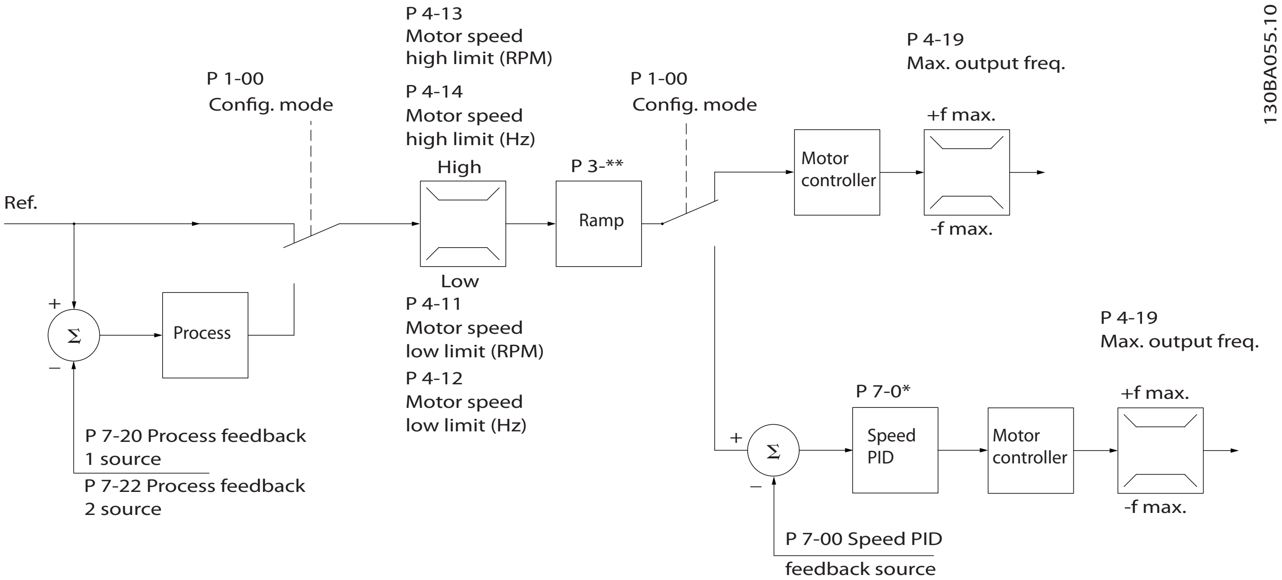

Illustration 3.3 Control Structure in VVC^{plus} Open Loop and Closed Loop Configurations

In *Illustration 3.3*, *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 will be 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.

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

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3.2.4 Control Structure in Flux Sensorless

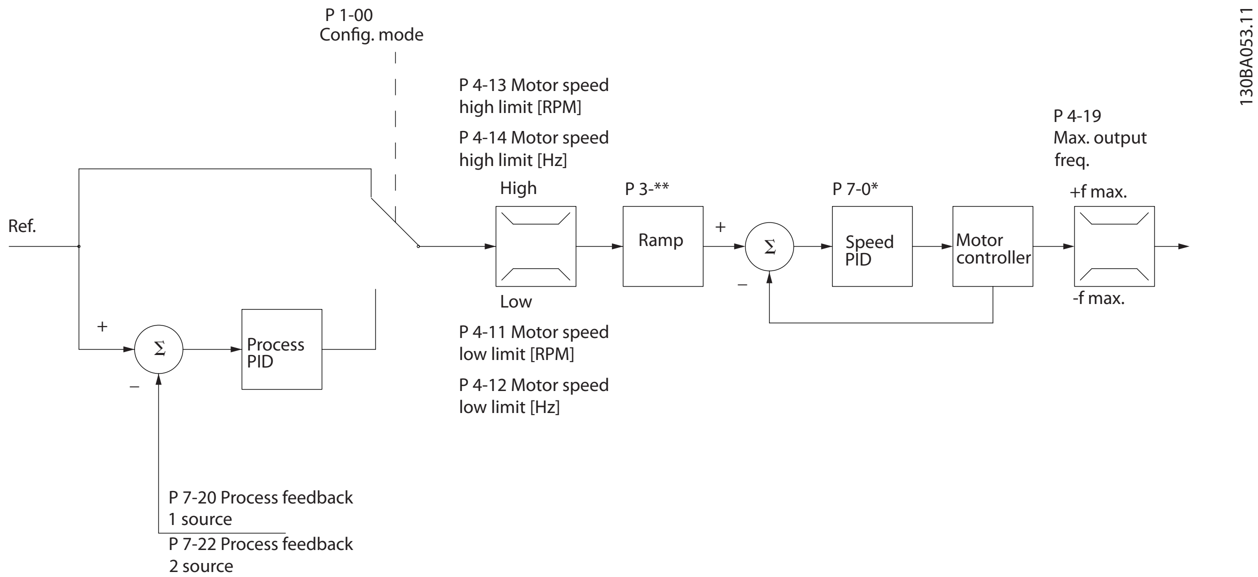

Illustration 3.4 Control Structure in Flux Sensorless Open Loop and Closed Loop Configurations

In *Illustration 3.4*, *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.*).

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

3.2.5 Control Structure in Flux with Motor Feedback

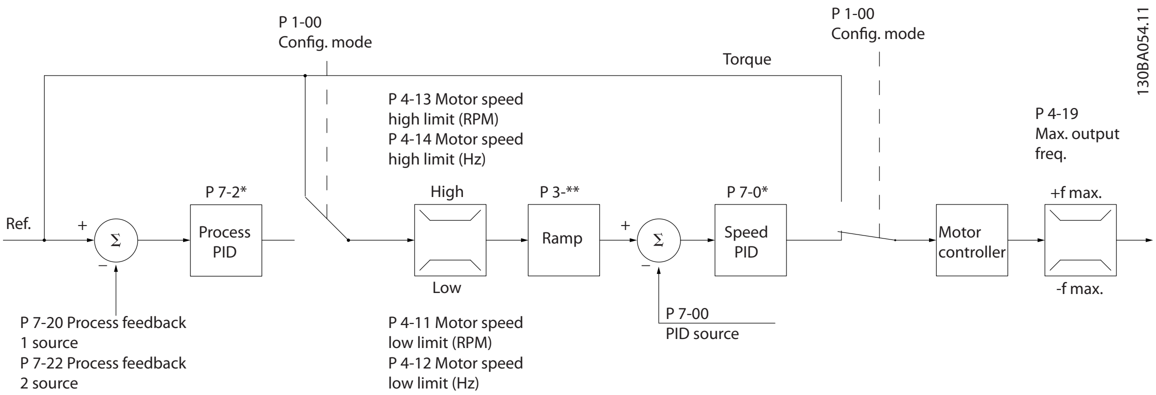

Illustration 3.5 Control Structure in Flux with Motor Feedback Configuration (only available in FC 302)

In *Illustration 3.5*, *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*).

Select *[1] Speed closed loop* in *1-00 Configuration Mode* to use the resulting reference as an input for the Speed PID control. 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 will use 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.

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

3.2.6 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 will try to get below the preset torque limits as quickly as possible without losing control of the motor.

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

The frequency converter can be operated manually via the LCP or remotely via analogue 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 using the [Hand On] and [Off] keys. Alarms can be reset via the [Reset] key. After pressing the [Hand On] key, the frequency converter goes into hand (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*.

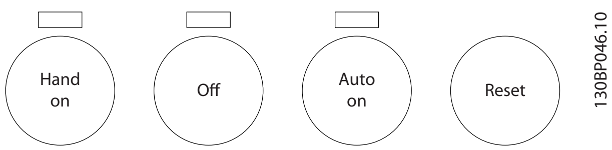

Illustration 3.6

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Active Reference and Configuration Mode

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

In *3-13 Reference Site*, the local reference can be permanently selected by selecting *[2] Local*.
To permanently select the remote reference, select *[1] Remote*. By selecting *[0] Linked to Hand/Auto* (default) the reference site will depend on which mode is active. (Hand Mode or Auto Mode).

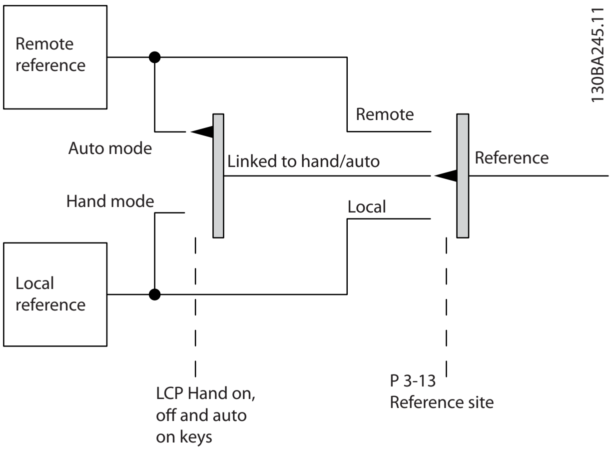

Illustration 3.7

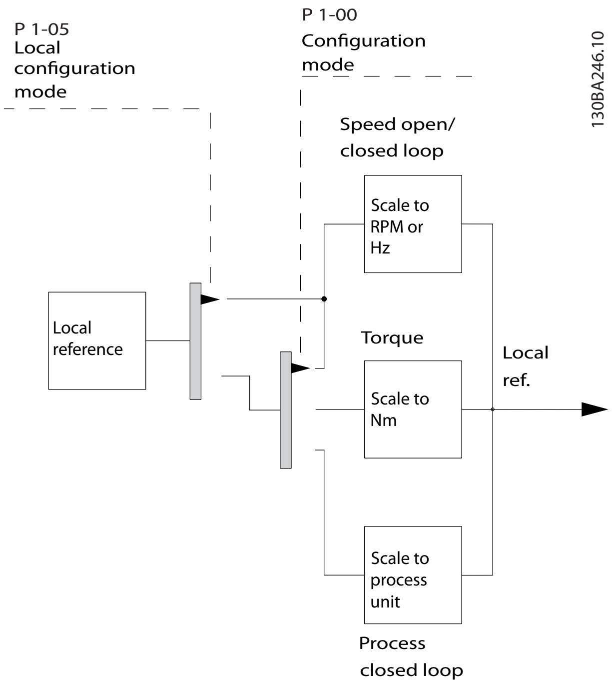

Illustration 3.8

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 (i.e. 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 can not 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 [▲/▼] and [◄/►] keys respectively.

Remote Reference

The reference handling system for calculating the Remote reference is shown in *Illustration 3.9*.

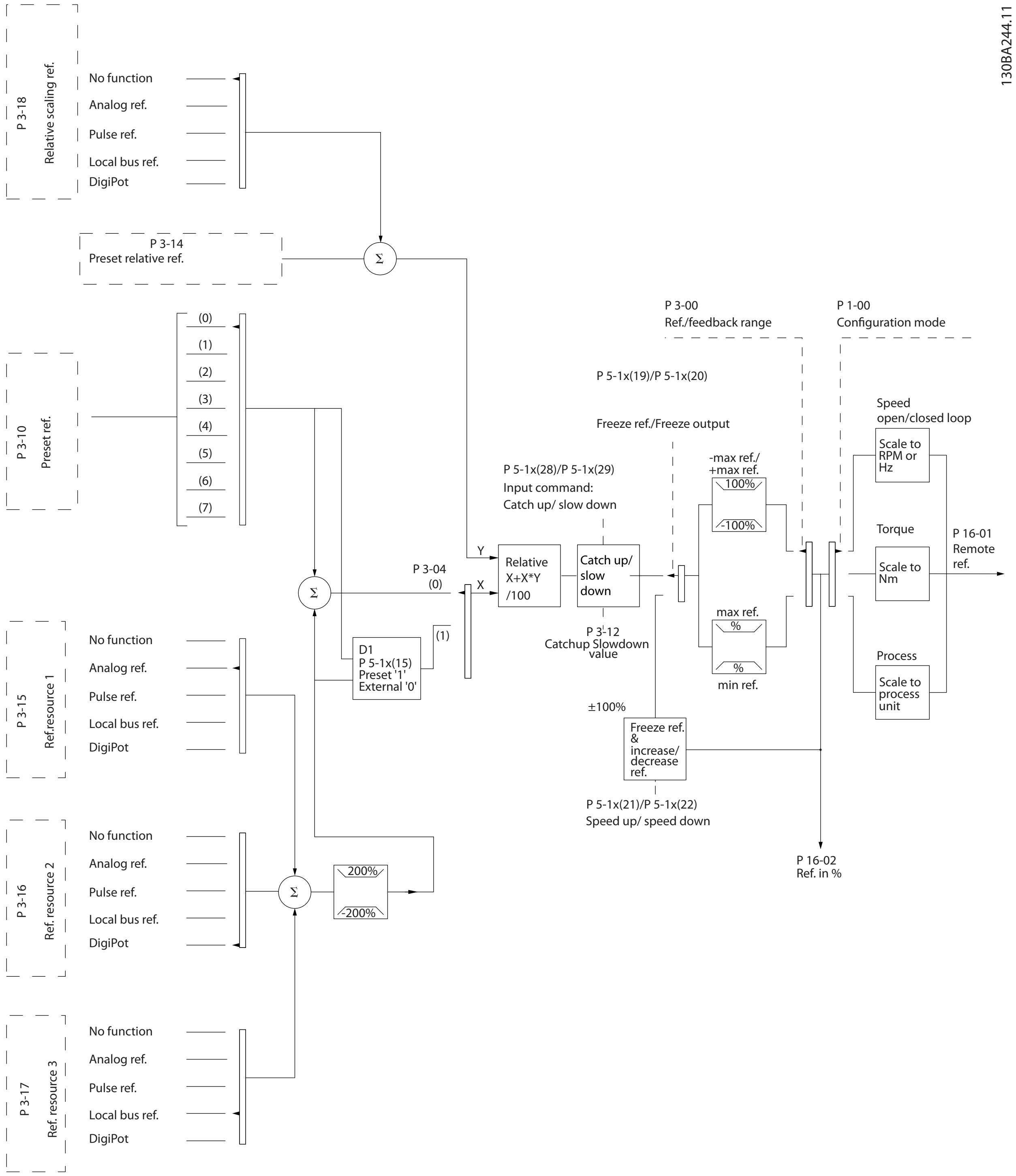

Illustration 3.9 Remote Reference

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

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

The two types of reference inputs are combined in the following formula: Remote reference =X+X*Y/100%. If 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 analogue 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 allowed 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 below.

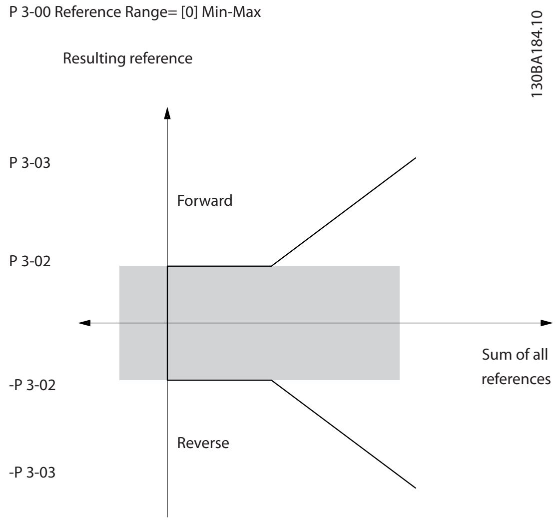

Illustration 3.10

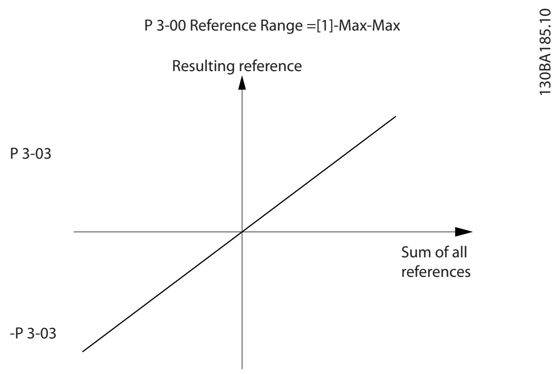

Illustration 3.11

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 3.12*.

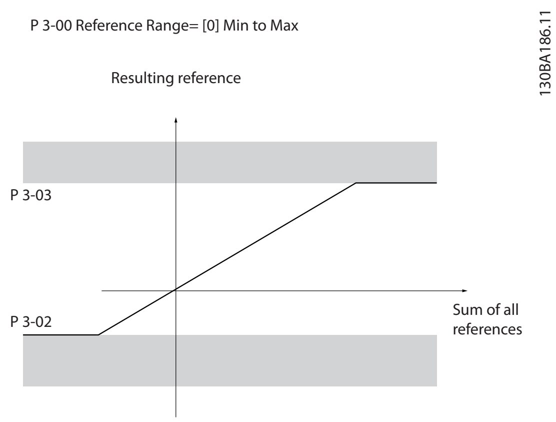

Illustration 3.12 Sum of all References

3.3.2 Scaling of Preset References and Bus References

Preset references are scaled according to the following rules

- When *3-00 Reference Range*: *[0] Min to Max* 0% reference equals 0 [unit] where unit can be any unit e.g. 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 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 analogue and Pulse References and Feedback

References and feedback are scaled from analogue 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 3.13*) are clamped whereas a feedback above or below is not.

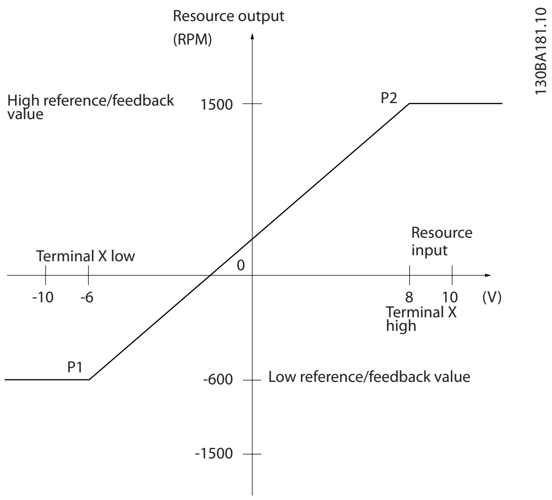

Illustration 3.13 Scaling of Analogue and Pulse References and Feedback

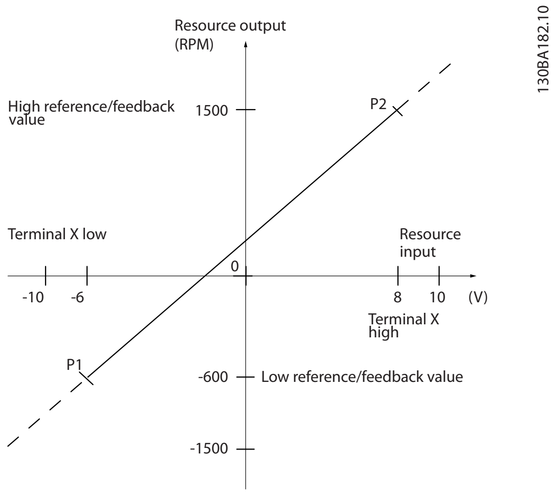

Illustration 3.14

The endpoints P1 and P2 are defined by the following parameters depending on which analogue or pulse input is used.

	Analogue 53 S201=OFF	Analogue 53 S201=ON	Analogue 54 S202=OFF	Analogue 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

3.3.4 Dead Band Around Zero

In some cases the reference (in rare cases also the feedback) should have a Dead Band around zero (i.e. to make sure the machine is stopped when the reference is "near zero").

To make the dead band active and to set the amount of dead band, the following settings must be done

- Either 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 3.15*.
- 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 3.15*.

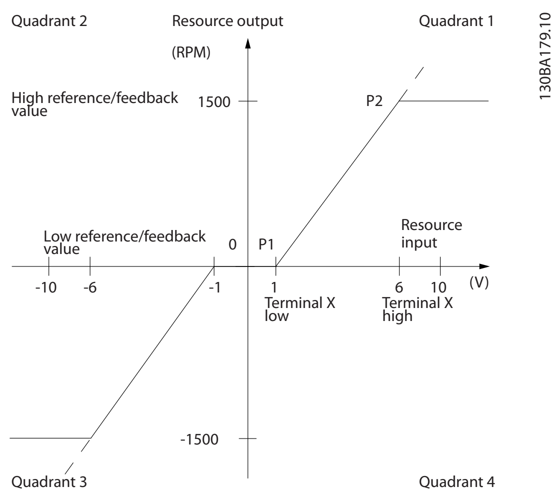

Illustration 3.15

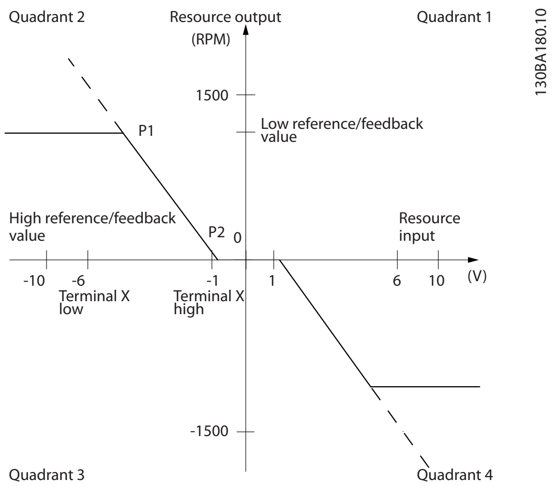

Illustration 3.16

Thus a reference endpoint of P1=(0 V, 0 RPM) will not result in any dead band, but a reference endpoint of P1=(1 V, 0 RPM), e.g., will result in a -1 V to +1 V dead band in this case provided that the end point P2 is placed in either Quadrant 1 or Quadrant 4.

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

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

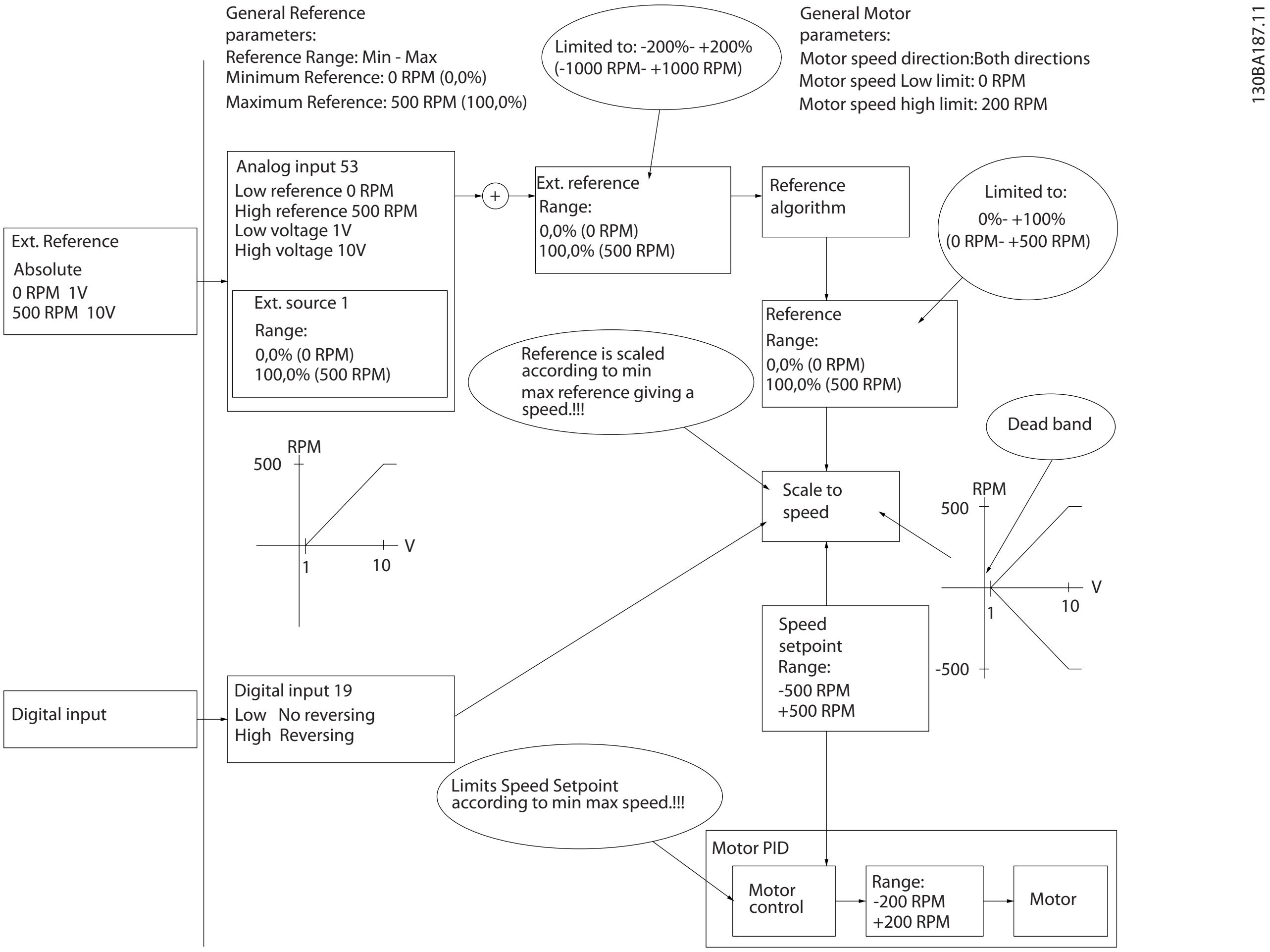


Illustration 3.17

Case 2: Positive reference with dead band, digital input to trigger reverse. Clamping rules.

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 and how the external reference is clamped to -Max to +Max by the reference algorithm.

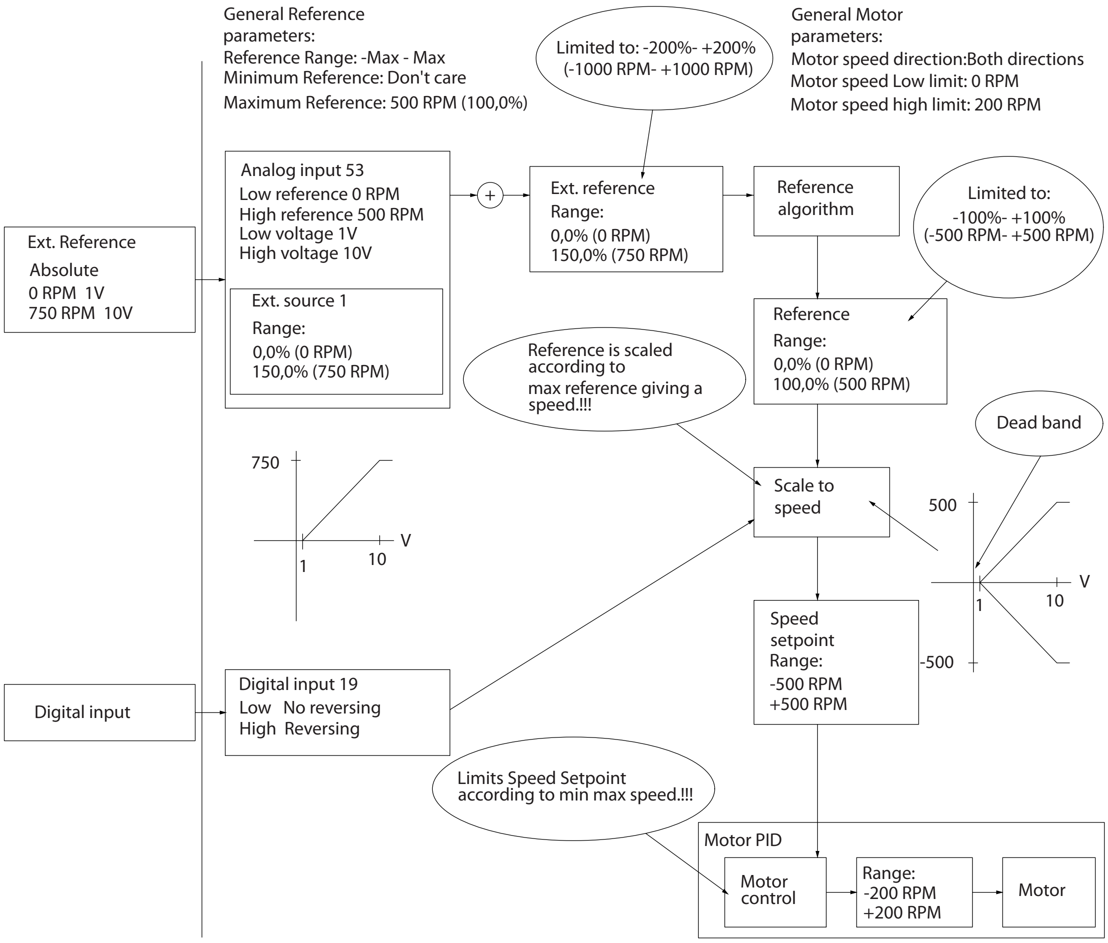


Illustration 3.18

Case 3: Negative to positive reference with dead band, sign determines the direction, -Max to +Max

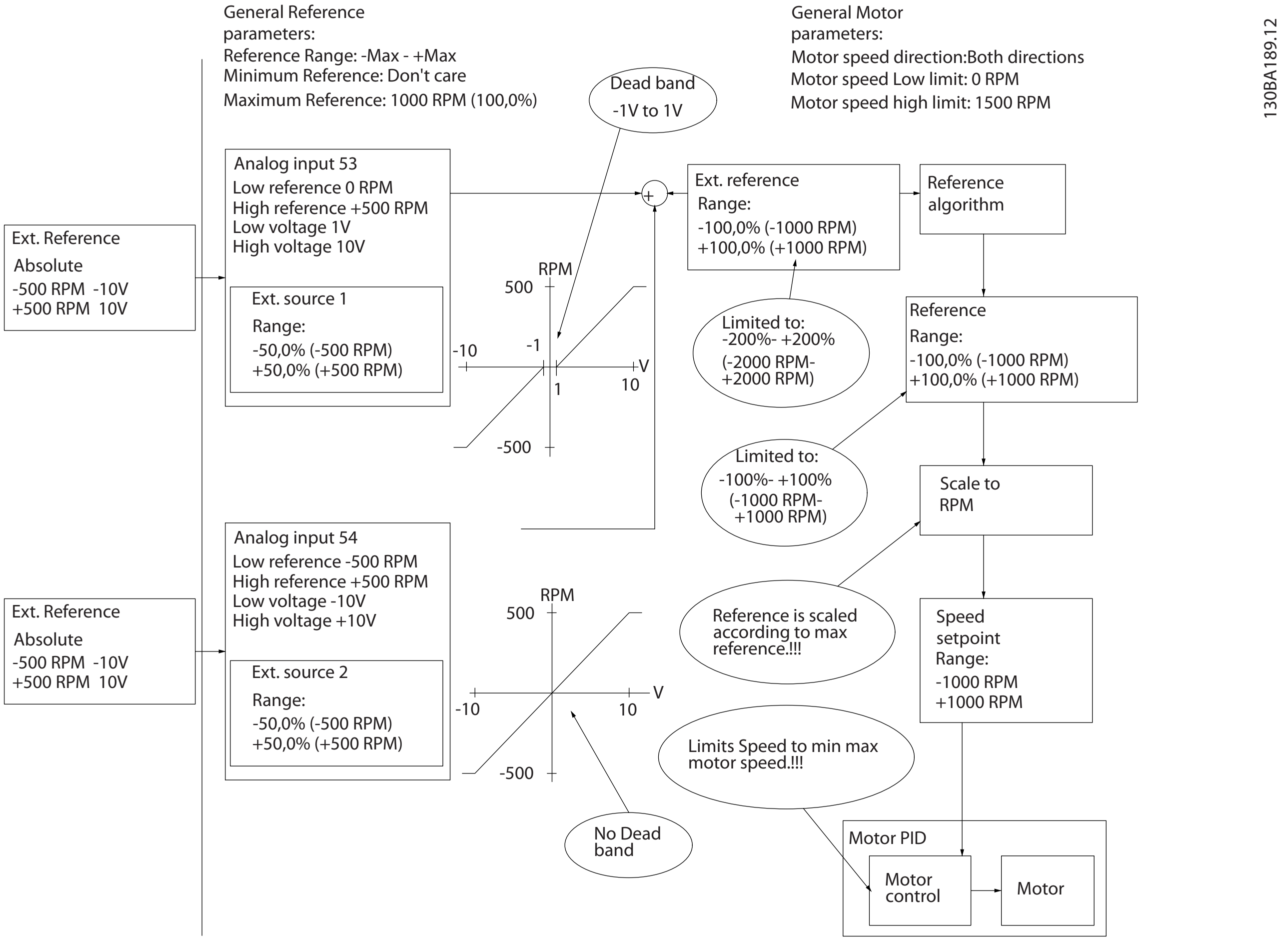


Illustration 3.19

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.

NOTE

The Speed Control PID will work under the default parameter setting, but tuning the parameters is highly recommended to optimize the motor control performance. The two flux motor control principles are particularly dependent on proper tuning to yield their full potential.

Parameter	Description of function
7-00 Speed PID Feedback Source	Select from which input the Speed PID should get its feedback.
30-83 Speed PID Proportional Gain	The higher the value - the quicker the control. However, too high a value may lead to oscillations.
7-03 Speed PID Integral Time	Eliminates steady state speed error. Lower value means quick reaction. However, too low a value may lead to oscillations.
7-04 Speed PID Differentiation Time	Provides a gain proportional to the rate of change of the feedback. A setting of zero disables the differentiator.
7-05 Speed PID Diff. Gain Limit	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.
7-06 Speed PID Lowpass Filter Time	A low-pass filter dampens oscillations on 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 on from encoder (PPR): **Encoder PPR** — **7-06 Speed PID Lowpass Filter Time** 512 — 10 ms 1024 — 5 ms 2048 — 2 ms 4096 — 1 ms

Table 3.7 Relevant Parameters for the Speed Control

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.

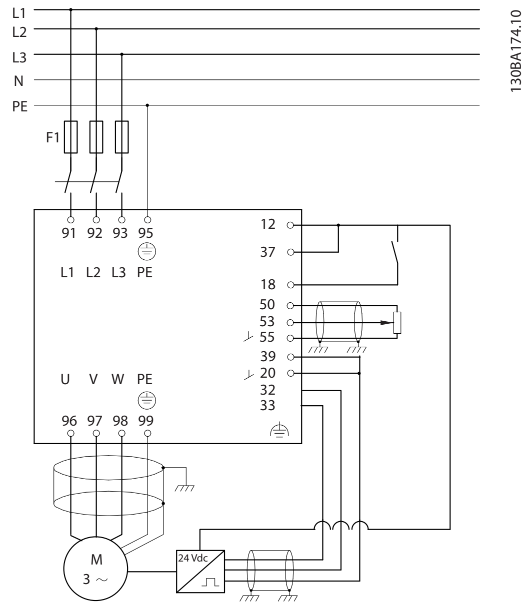


Illustration 3.20

3.4.2 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) Make sure the motor runs properly. Do the following:		
Set the motor parameters using name plate data	1-2* Motor Data	As specified by motor name plate
Perform Automatic Motor Adaptation	1-29 Automatic Motor Adaptation (AMA)	[1] Enable complete AMA
2) Check the motor is running and the encoder is attached properly. Do the following:		
Press the “Hand On” LCP key. 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 analogue Input 53 as a reference Source	3-15 Reference Resource 1	Not necessary (default)
Scale analogue 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 the guidelines below
8) Finished		
Save the parameter setting to the LCP	0-50 LCP Copy	[1] All to LCP

Table 3.8

3.4.3 Tuning PID Speed Control

The following tuning 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, and the selected bandwidth can be calculated using the following formula:

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

NOTE

***1-20 Motor Power [kW]* is the motor power in [kW] (i.e. enter '4' kW instead of '4000' W in the formula).**

A practical value for the Bandwith is 20 rad/s. Check the result of the *30-83 Speed PID Proportional Gain* calculation against the following formula (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 start value for *7-06 Speed PID Lowpass Filter Time* is 5 ms (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 minimize the overshoot, *7-03 Speed PID Integral Time* could be set to approx. 2.5 s (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 experimenting with small increments of this setting.

3.4.4 Process PID Control

The process PID control can be used to control application parameters that can be measured by a sensor (i.e. pressure, temperature, flow) and be affected by the connected motor through a pump, fan or otherwise.

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 *3.2.3 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

NOTE

The process control PID will work under the default parameter setting, but tuning the parameters is highly recommended to optimise the application control performance. The two flux motor control principles are specially dependant on proper speed control PID tuning (prior to tuning the Process Control PID) to yield their full potential.

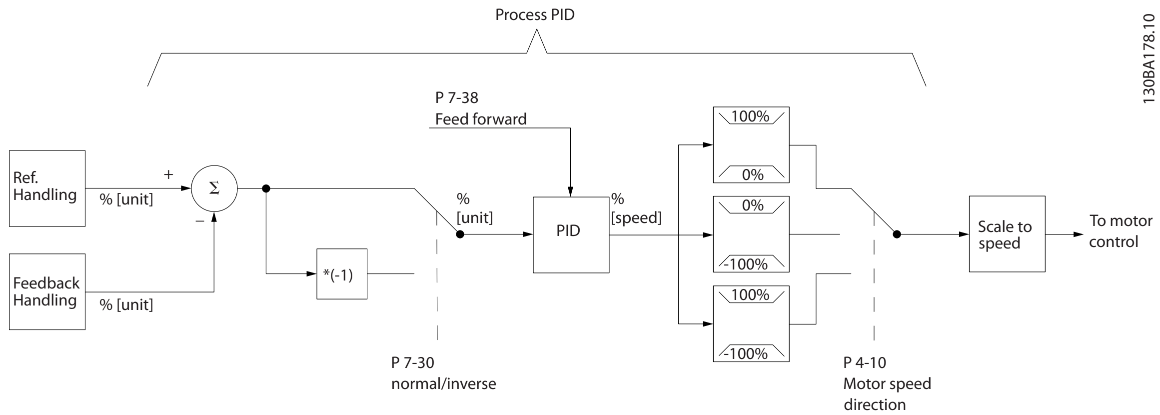


Illustration 3.21 Process PID Control Diagram

3.4.5 Process Control Relevant Parameters

The following parameters are relevant for the process control

Parameter	Description of function
7-20 Process CL Feedback 1 Resource	Select from which source (i.e. analogue or pulse input) the process PID should get its feedback
7-22 Process CL Feedback 2 Resource	Optional: Determine if (and from where) the process PID should get an additional feedback signal. If an additional feedback source is selected, the two feedback signals will be added together before being used in the process PID control.
7-30 Process PID Normal/ Inverse Control	Under *[0] normal operation*, the process control will respond with an increase of the motor speed if the feedback is getting lower than the reference. In the same situation, but under *[1] inverse operation*, the process control will respond with a decreasing motor speed instead.

Parameter	Description of function
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 will be set to a gain that corresponds to the actual frequency. This avoids integrating on an error that cannot in any case be compensated for by means of a speed change. This function can be disabled by selecting *[0] Off*.
7-32 Process PID Start Speed	In some applications, reaching the required speed/set point can take a very long time. In such applications, it might be an advantage 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.
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 change of the feedback. 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 - 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.
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 (analogue term 53), 6-26 Terminal 54 Filter Time Constant (analogue 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 will be 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 will be damped by the filter. The control will only be 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 will deteriorate the dynamic performance of the process PID control.

Table 3.10

3.4.6 Example of Process PID Control

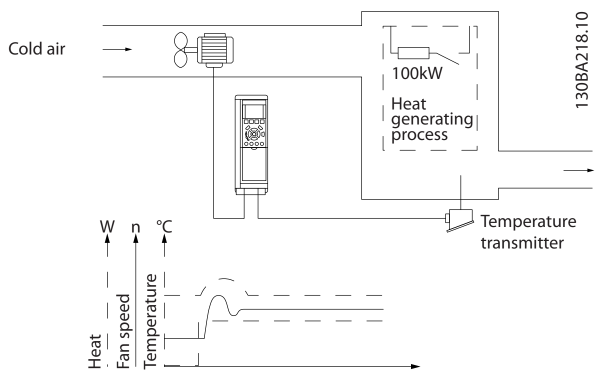


Illustration 3.22 Example of a Process PID Control used in a Ventilation System

In a ventilation system, the temperature is to be adjustable from -5 to 35 °C with a potentiometer of 0–10 V. The set temperature must be kept constant, for which purpose the process control is to be used.

The control is of the inverse type, which means that when the temperature increases, the ventilation speed is increased as well, so as to generate more air. 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.

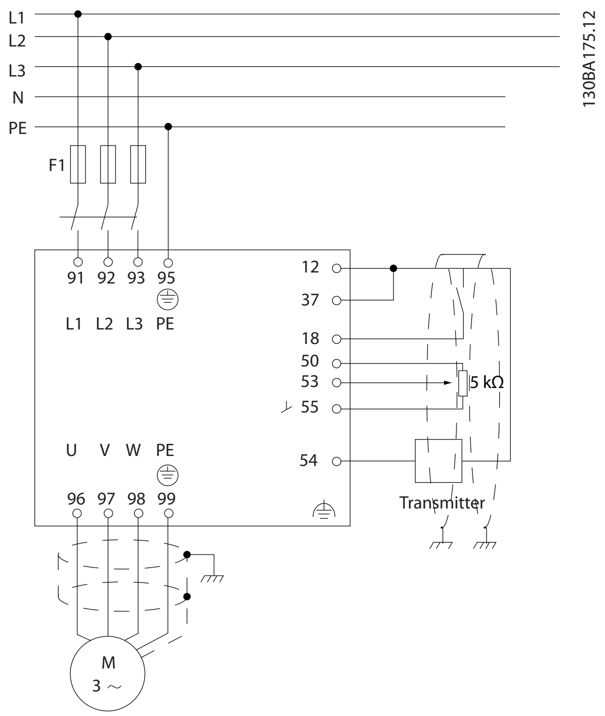


Illustration 3.23 Two-wire Transmitter

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).

3.4.7 Programming Order

Function	Par. no.	Setting
Initialize the frequency converter	14-22	[2] Initialization - make a power cycling - press [Reset]
1) Set motor parameters:		
Set the motor parameters according to name plate data	1-2*	As stated on motor name plate
Perform a full Automation Motor Adaptation	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 analogue input in par. 6-xx		
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% $Ref = \frac{Par. 3-10_{(0)}}{100} \times ((Par. 3-03) - (par. 3-02)) = 24,5°C$ *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 analogue input function (Voltage (V) or milli-Amps (I)) **⚠WARNING** **Switches are sensitive - Make a power cycling keeping default setting of V**		
5) Scale analogue 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] analogue 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

The basic settings have now been made; all that needs to be done is to optimise the proportional gain, the integration time and the differentiation time (*7-33 Process PID Proportional Gain*, *7-34 Process PID Integral Time*, *7-35 Process PID Differentiation Time*). In most processes, this can be done by following the guidelines given below.

1. Start the motor.
2. Set *7-33 Process PID Proportional Gain* to 0.3 and increase it until the feedback signal again 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 again 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 four 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.

NOTE

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

3.4.8 Ziegler Nichols Tuning Method

To tune the PID controls of the frequency converter, several tuning methods can be used. One approach is to use a technique which was developed in the 1950s but which has stood the test of time and is still used today. This method is known as the Ziegler Nichols tuning method.

NOTE

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 (as measured on the feedback), that is, until the system becomes marginally stable. The corresponding gain *(K_u)* is called the ultimate gain. The period of the oscillation *(P_u)* (called the ultimate period) is determined as shown in *Illustration 3.24*.

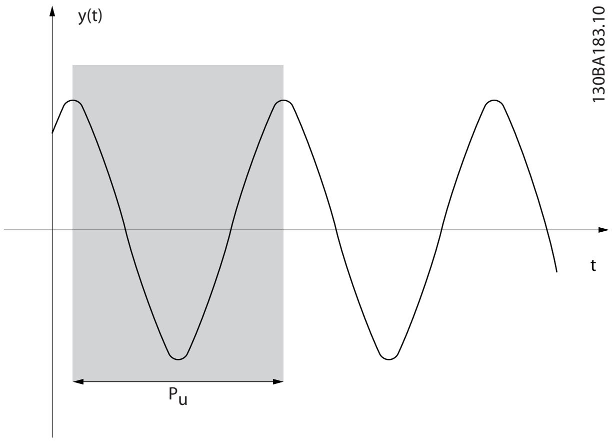


Illustration 3.24 Marginally Stable System

P_u should be measured 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

Experience has shown that the control setting according to Ziegler Nichols rule 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

Step 1: Select only Proportional Control, meaning that the Integral time is selected to the maximum value, while the differentiation time is selected to zero.

Step 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.

Step 3: Measure the period of oscillation to obtain the critical time constant, P_u.

Step 4: Use *Table 3.12* to calculate the necessary PID control parameters.

3.5 General Aspects of EMC

3.5.1 General Aspects of EMC Emissions

Electrical interference is most commonly conducted 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.
As shown in *Illustration 3.25*, capacitive currents in the motor cable coupled with a high dU/dt from the motor voltage generate leakage currents.
The use of a screened motor cable increases the leakage current (see *Illustration 3.25*) because screened cables 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), in principle, there is only a small electromagnetic field (I_4) from the screened motor cable according to *Illustration 3.25*.

The screen reduces the radiated interference but increases the low-frequency interference on the mains. The motor cable screen must be connected to the frequency converter enclosure as well as the motor enclosure. The best way to connect them is by using integrated screen clamps to avoid twisted screen ends (pigtails). These 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, and brake, the screen must be mounted on the enclosure at both ends. In some situations, however, it is necessary to break the screen to avoid current loops.

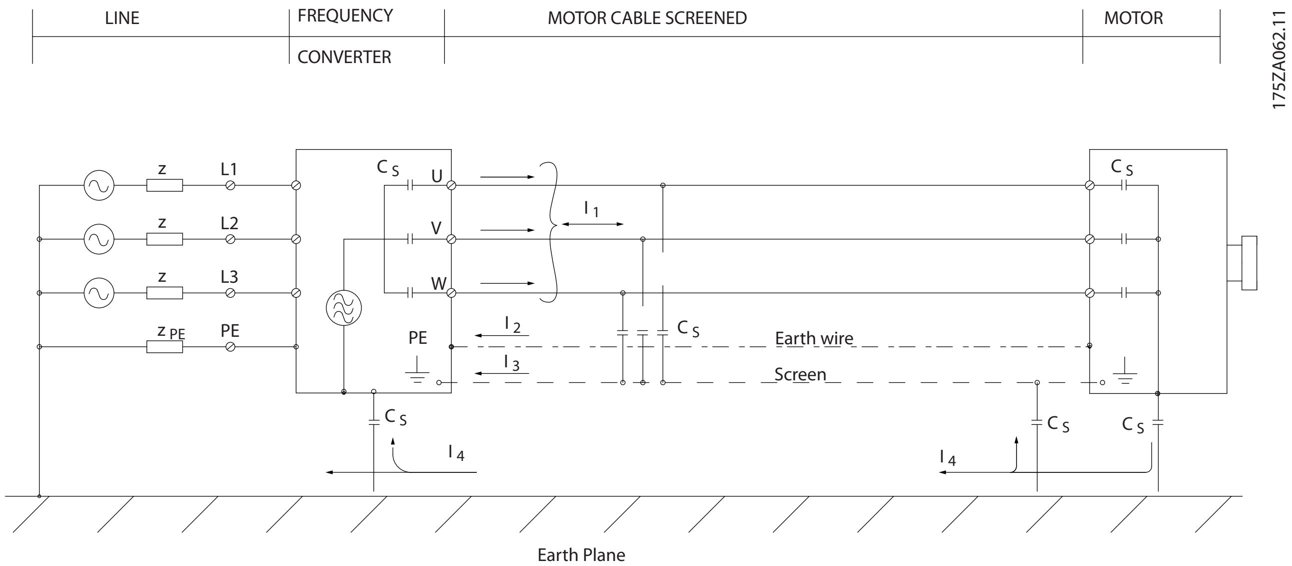


Illustration 3.25

If the screen will be placed on a mounting plate for the frequency converter, the mounting plate must be made of metal, because the screen currents must be conveyed back to the unit. 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.

In order 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) is generated by the control electronics. See *7.8 EMC-correct Installation* for more information on EMC.

3.5.2 EMC Test Results

The following test results have been obtained using a system with 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.

3

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 3.13 EMC Test Results (Emission, Immunity)

WARNING

In a domestic environment, this product may cause radio interference, in which case supplementary mitigation measures may be required. This type of power drive system is not intended to be used on a low-voltage public network which supplies domestic premises. Radio frequency interference is expected if used on such a network.

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. Four categories are defined in the EMC product standard. The definitions of the four categories together with the requirements for mains supply voltage conducted emissions are given in *Table 3.14*.

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

Table 3.14 Emission Requirements

When the generic emission standards are used, the frequency converters are required to comply with *Table 3.15*

Environment	Generic standard	Conducted emission requirement according to the limits given in EN 55011
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 3.15 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 the industrial environment and consequently comply also with the lower requirements for home and office environment with a large safety margin.

To document immunity against electrical interference, the following immunity tests have been made on a system consisting of 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:

- **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, for example.
- **EN 61000-4-6 (IEC 61000-4-6):** RF Common mode: Simulation of the effect from radio-transmission equipment joined by connection cables.

See *Table 3.16*.

3

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 3.16 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 nameplate for the specific unit.
Also make sure that other voltage inputs have been disconnected, such as load sharing (linkage of DC intermediate circuit), as well as the motor connection for kinetic back-up.

PELV offers protection by way of extra low voltage. Protection against electric shock is ensured when the electrical supply is of the PELV type and the installation is made as described in local/national regulations on PELV supplies.

All control terminals and relay terminals 01-03/04-06 comply with PELV (Protective Extra Low Voltage) (Does not apply to grounded Delta leg above 400 V).

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

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 six locations (see *Illustration 3.26*):

In order to maintain PELV all connections made to the control terminals must be PELV, e.g. reinforce/double insulate the thermistor.

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.

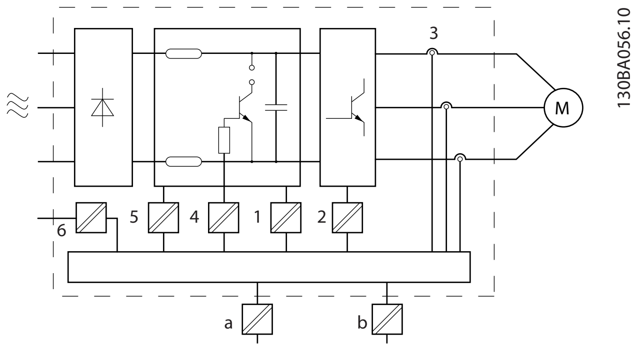


Illustration 3.26 Galvanic Isolation

The functional galvanic isolation (a and b on drawing) 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. This generates a leakage current in the earth connection. A fault current in the frequency converter at the output power terminals could contain a DC component which can charge the filter capacitors and cause a transient earth current.
The earth leakage current is made up of several contributions and depends on various system configurations including RFI filtering, screened motor cables, and frequency converter power.

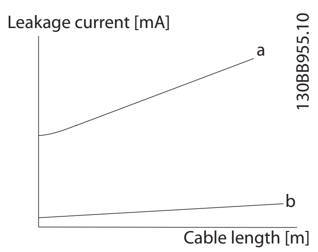


Illustration 3.27 Influence of the Cable Length and Power Size on the Leakage Current. Pa>Pb

The leakage current also depends on the line distortion

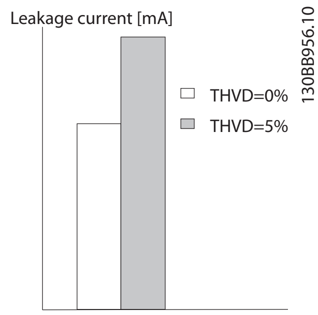


Illustration 3.28 Influence of Line Distortion on Leakage Current

NOTE

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.

EN/IEC61800-5-1 (Power Drive System Product Standard) requires special care if the leakage current exceeds 3.5 mA. Earth grounding must be reinforced in one of the following ways:

- Earth ground wire (terminal 95) of at least 10 mm^2
- Two 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

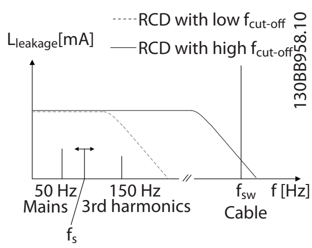


Illustration 3.29 Main Contributions to Leakage Current

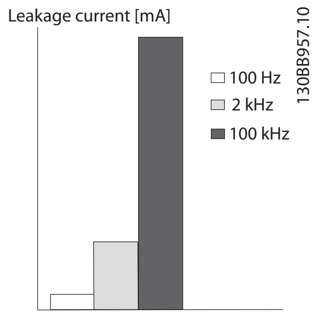


Illustration 3.30 The Influence of the Cut-off Frequency of the RCD on what is responded to/measured

See also *RCD Application Note*.

3.8 Brake Functions

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

3.8.1 Mechanical Holding Brake

A mechanical holding brake mounted directly on the motor shaft normally performs static braking. In some applications, the static holding torque is working as static holding of the motor shaft (usually synchronous permanent motors). A holding brake is either controlled by a PLC or directly by a digital output from the frequency converter (relay or solid state).

NOTE

When the holding brake is included in a safety chain: A frequency converter cannot provide a safe control of a mechanical brake. A redundancy circuitry for the brake control must be included in the total installation.

3.8.2 Dynamic Braking

Dynamic brake established by:

- Resistor brake: A brake IGBT keeps the overvoltage under a certain threshold by directing the brake energy from the motor to the connected brake resistor (*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 that 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 on the basis of the cycle time and braking time also called intermittent duty cycle. The resistor intermittent duty cycle is an indication of the duty cycle at which the resistor is active. *Illustration 3.31* shows a typical braking cycle.

NOTE

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)

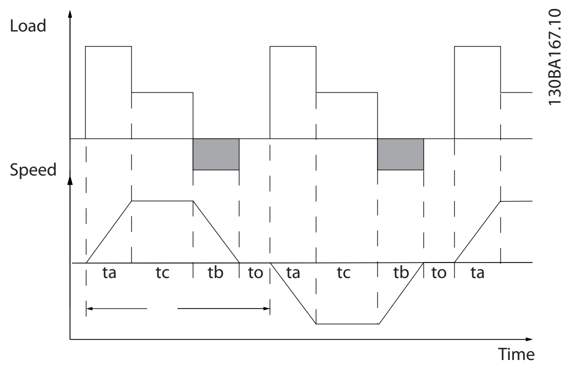


Illustration 3.31

	Cycle time (s)	Braking duty cycle at 100% torque	Braking duty cycle at over torque (150/160%)
380-500 V			
N90K-160K	600	Continuous	10%
N200-N250	600	Continuous	10%
P315-P800	600	40%	10%
525-690 V			
P37K-P400	600	40%	10%
P500-P560	600	40%[1)]	10%[2)]
P630-P1M0	600	40%	10%

Table 3.17 Braking at High Overload Torque Level

[1)] *500 kW at 86% braking torque*

560 kW at 76% braking torque

[2)] *500 kW at 130% braking torque*

560 kW at 115% braking torque

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

NOTE

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 and can be calculated as:

The brake resistance is calculated as shown:

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

where

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

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

The FC 302 brake function is settled in 4 areas of mains.

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 3x525-600 V	943 V	965 V	975 V
FC 302 3x525-690 V	1084 V	1109 V	1130 V

Table 3.18

**) Power size dependent*

NOTE

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

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

η_{motor} is typically at 0.90

η_{VLT} is typically at 0.98

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

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

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

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

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

NOTE

The resistor brake circuit resistance selected should not be higher than that recommended by Danfoss. If a brake resistor with a higher ohmic value is selected, the 160% braking torque may not be achieved because there is a risk that the frequency converter cuts out for safety reasons.

NOTE

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

NOTE

Do not touch the brake resistor as it can get very hot while/after braking. The brake resistor must be placed in a secure environment to avoid fire risk

D-F size frequency converters contain more than one brake chopper. Use one brake resistor per brake chopper for those frame sizes.

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 for protecting the brake resistor against overloading in connection with 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 a limit selected in *2-12 Brake Power Limit (kW)*. In *2-13 Brake Power Monitoring*, select the function to carry out when the power transmitted to the brake resistor exceeds the limit set in *2-12 Brake Power Limit (kW)*.

NOTE

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) (exclusive brake resistor) can be selected as an alternative brake function in *2-17 Over-voltage Control*. This function is active for all units. The function ensures that a trip can be avoided if the DC link voltage increases. This is done by increasing the output frequency to limit the voltage from the DC link. It is a useful function, (e.g. if the ramp-down time is too short since tripping of the frequency converter is avoided. In this situation, the ramp-down time is extended.

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

3.9 Mechanical Brake Control

For hoisting applications, it is necessary to be able to control an electro-magnetic brake. 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, e.g. because of too big a load. 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 stays 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, (*i.e.* over-voltage situation), the mechanical brake immediately cuts in. This is also the case during safe stop.

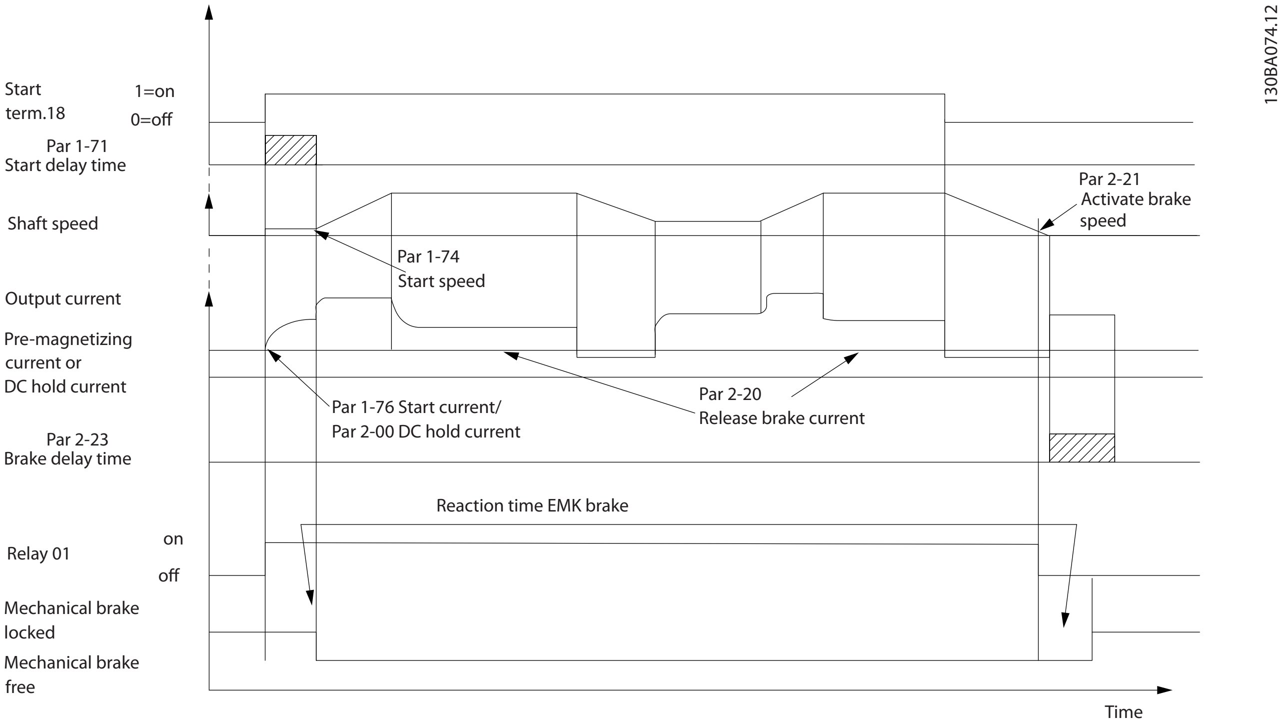


Illustration 3.32

In hoisting/lowering applications, it must be possible to control an electro-mehanical brake.

Step-by-step Description

- To control the mechanical brake, any relay output or digital output (terminal 27 or 29) can be used. If necessary, use a contactor.
- Ensure that the output is switched off as long as the frequency converter is unable to drive the motor, for example due to the load being too heavy or due to the fact that the motor has not been mounted yet.
- Select *[32] Mechanical brake control* in parameter group *5-4* Relays* (or in group *5-3* Digital Outputs*) before connecting the mechanical brake.
- The brake is released when the motor current exceeds the preset value in *2-20 Release Brake Current*.
- 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.

NOTE

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 of a single component such as a contactor, etc.
If the frequency converter is in alarm mode or in an over voltage situation, the mechanical brake cuts in.

NOTE

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 choice [6] in *1-72 Start Function*. The main difference compared to the regular mechanical brake control, where a relay function monitoring the output current is used, is that the hoist mechanical brake function has direct control over the brake relay. This means that instead of setting a current for release of the brake, the torque applied against the closed brake before release is defined. Because the torque is defined directly, the setup is more straightforward for hoisting applications.

By using *2-28 Gain Boost Factor*, a quicker control when releasing the brake can be obtained. The hoist mechanical brake strategy is based on a 3-step sequence, where motor control and brake release are synchronized to obtain the smoothest possible brake release.

3-step sequence

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, set in *2-26 Torque Ref*, is applied in the hoisting direction. This will be used to initialize the speed controller that will finally take over the load. In order 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. In order 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.

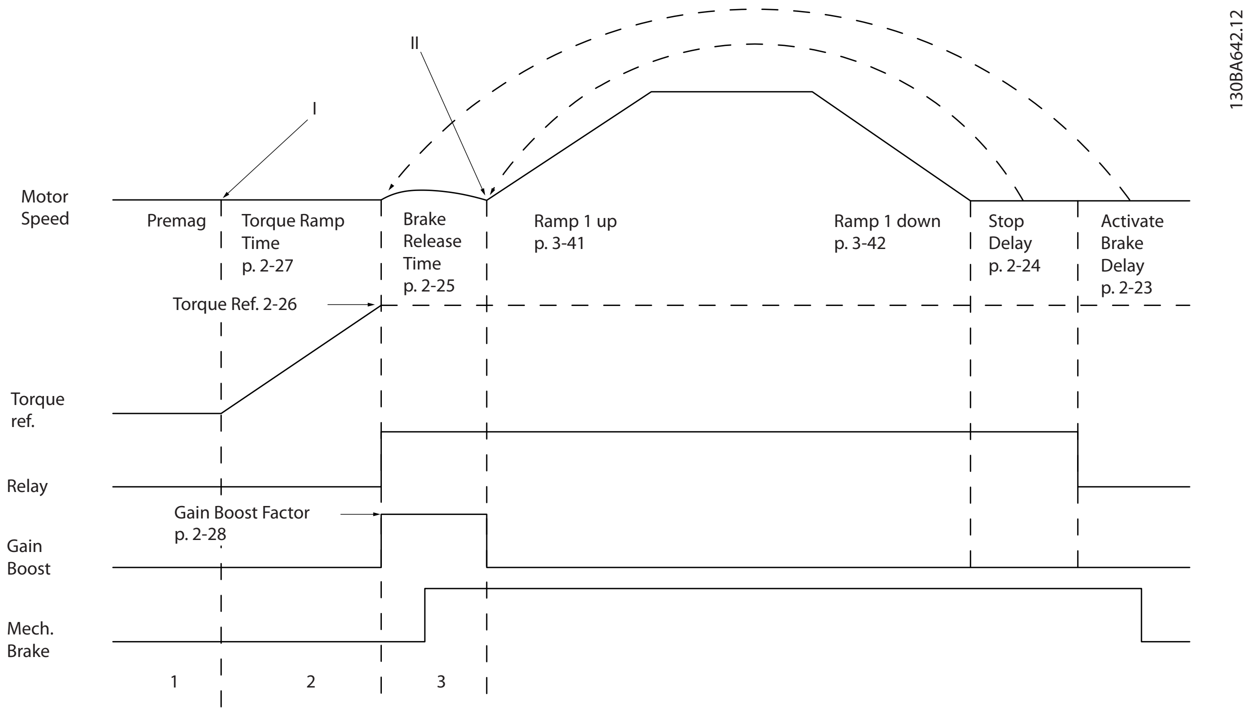


Illustration 3.33 Brake Release Sequence for Hoist Mechanical Brake Control

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 (e.g. reversing).

NOTE

For an example of advanced mechanical brake control for hoisting applications, see *8 Application Examples*

3.9.2 Brake Resistor Cabling

EMC (twisted cables/shielding)
To reduce the electrical noise from the wires between the brake resistor and the frequency converter, the wires must be twisted.

For enhanced EMC performance, a metal screen can be used.

3.10 Smart Logic Controller

Smart Logic Control (SLC) is essentially 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 that the output from a Logic Rule or a Comparator Operand becomes TRUE. That will lead to an associated Action as illustrated:

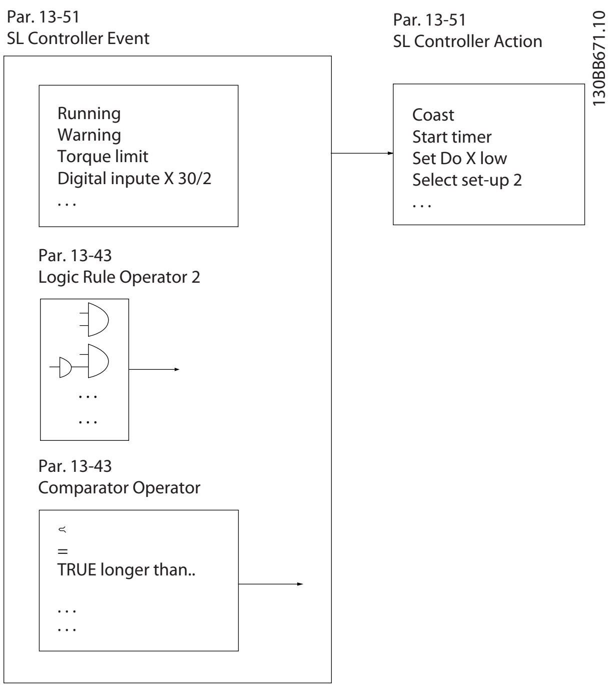


Illustration 3.34

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* will be evaluated and if evaluated TRUE, *[1] action* will be executed and so on. Only one *event* will be 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 *[0] event* (and 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 3.35 shows an example with three event/actions:

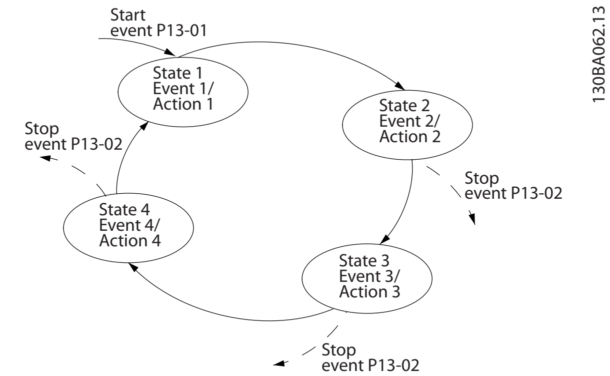


Illustration 3.35

Comparators

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

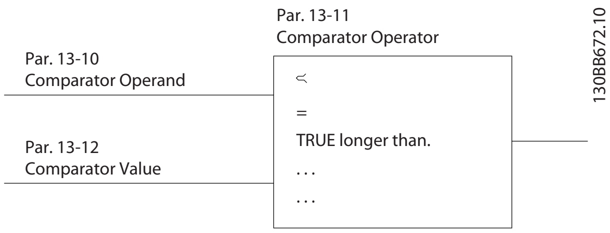


Illustration 3.36

Logic Rules

Combine up to three boolean inputs (TRUE/FALSE inputs) from timers, comparators, digital inputs, status bits and events using the logical operators AND, OR, and NOT.

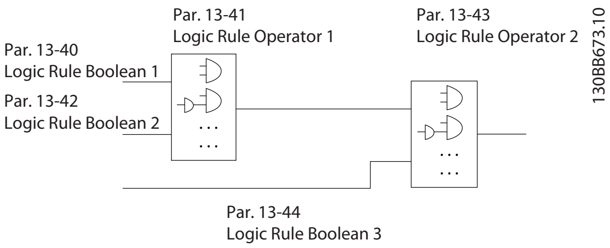
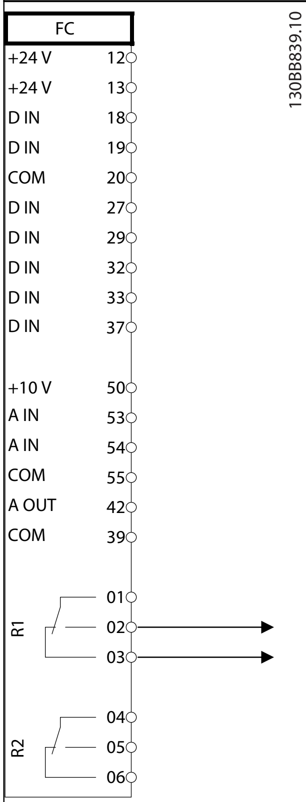


Illustration 3.37

Application Example



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 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 then the drive continues and the warning disappears. But Relay 1 will still be triggered until [Reset] on the LCP.	

Table 3.19 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 three motor phases or in the DC link. A short circuit between two output phases will cause an overcurrent in the inverter. The inverter will be turned 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 the design guidelines.

See certificate in *3.12.6 Approvals & Certificates*.

Switching on the Output

Switching on the output between the motor and the frequency converter is fully permitted. Switching on the output will 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:

1. The load drives the motor (at constant output frequency from the frequency converter), when the load generates energy.
2. During deceleration ("ramp-down"), if 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, the motor and the installation.
3. Incorrect slip compensation setting may cause higher DC link voltage.
4. 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 overspeed (e.g. due to excessive windmilling effects) then it is recommended to equip a brake resistor.

NOTE

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.

NOTE

OVC can not 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, which is typically 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
When the frequency converter is overloaded (the torque limit in *4-16 Torque Limit Motor Mode*/*4-17 Torque Limit Generator Mode* is reached), 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 for being overloaded independent of the speed. Torque limit is controlled in *4-16 Torque Limit Motor Mode* and *4-17 Torque Limit Generator Mode* and 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*

Min 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, e.g. Max Speed Limit: (*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. The characteristic is shown in *Illustration 3.38*.

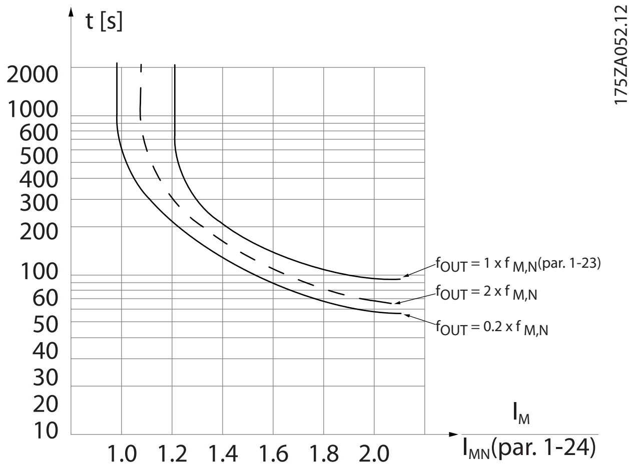


Illustration 3.38 Figure ETR: The X-axis shows the ratio between I_{motor} and I_{motor} nominal. The Y- axis shows the time in seconds before the ETR cut of and trips the drive. The curves show the characteristic nominal speed, at twice the nominal speed and at 0.2 x the nominal speed.
At lower speed the ETR cuts 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.

3.12.1 Safe Stop

The FC 302 in A1 enclosure, can perform the safety function *Safe Torque Off* (STO, as defined by EN IEC 61800-5-2[1]) and *Stop Category 0* (as defined in EN 60204-1[2]).
Danfoss has named this functionality *Safe Stop*. Before integrating and using safe stop in an installation, a thorough risk analysis on the installation must be carried out to determine whether the Safe Stop functionality and safety levels are appropriate and sufficient. It is designed and approved suitable for the requirements of:

- Safety Category 3 in EN 954-1 (and EN ISO 13849-1)
- Performance Level "d" in EN ISO 13849-1:2008
- SIL 2 Capability in IEC 61508 and EN 61800-5-2
- SILCL 2 in EN 62061

[1] Refer to EN IEC 61800-5-2 for details of Safe torque off (STO) function.

[2)] Refer to EN IEC 60204-1 for details of stop category 0 and 1.

Activation and Termination of Safe Stop

The safe stop (STO) function is activated by removing the voltage at terminal 37 of the safe inverter. By connecting the safe inverter to external safety devices providing a safe delay, an installation for a safe stop category 1 can be obtained. The safe stop function of FC 302 can be used for asynchronous, synchronous motors and permanent magnet motors. See examples in *3.12.2 Terminal 37 Safe Stop Function*.

⚠WARNING

After installation of Safe Stop (STO), a commissioning test as specified in *3.12.4 Safe Stop Commissioning Test* must be performed. A successful commissioning test is mandatory after first installation and after each change to the safety installation.

Safe Stop Technical Data

The following values are associated with the different types of safety levels:

Reaction time for T37

- Typical reaction time: 10 ms

Reaction time=delay between de-energizing the STO input and switching off the drive output bridge.

Data for EN ISO 13849-1

- Performance Level "d"
- $MTTF_d$ (Mean Time To Dangerous Failure): 24816 years
- DC (Diagnstic Coverage): 99%
- Category 3
- Lifetime 20 years

Data for EN IEC 62061, EN IEC 61508, EN IEC 61800-5-2

- SIL 2 Capability, SILCL 2
- PFH (Probability of Dangerous failure per Hour)=7e-10FIT=7e-19/h
- SFF (Safe Failure Fraction) >99%
- HFT (Hardware Fault Tolerance)=0 (1oo1 architecture)
- Lifetime 20 years

Data for EN IEC 61508 low demand

- PFDavg for 1 year proof test: 3,07E-14
- PFDavg for 3 year proof test: 9,20E-14
- PFDavg for 5 year proof test: 1,53E-13

SISTEMA Data

Functional safety data is available from Danfoss via a data library for use with the SISTEMA calculation tool from the IFA (Institute for Occupational Safety and Health of the German Social Accident Insurance), and data for manual calculation. The library is permanently completed and extended.

Abbrev.	Ref.	Description
Cat.	EN 954-1	Category, level "B, 1-4"
FIT		Failure In Time: 1E-9 hours
HFT	IEC 61508	Hardware Fault Tolerance: HFT=n means, that n+1 faults could cause a loss of the safety function
MTTFd	EN ISO 13849-1	Mean Time To Failure - dangerous. Unit: years
PFH	IEC 61508	Probability of Dangerous Failures per Hour. This value shall be considered if the safety device is operated in high demand (more often than once per year) or continuous mode of operation, where the frequency of demands for operation made on a safety-related system is greater than one per year
PL	EN ISO 13849-1	Discrete level used to specify the ability of safety related parts of control systems to perform a safety function under foreseeable conditions. Levels a-e
SFF	IEC 61508	Safe Failure Fraction [%] ; Percentage part of safe failures and dangerous detected failures of a safety function or a subsystem related to all failures.
SIL	IEC 61508	Safety Integrity Level
STO	EN 61800-5-2	Safe Torque Off
SS1	EN 61800-5-2	Safe Stop 1

Table 3.20 Abbreviations related to Functional Safety

The PFDavg value (Probability of Failure on Demand) failure probability in the event of a request of the safety function.

3.12.2 Terminal 37 Safe Stop Function

The FC 302 is available with safe stop functionality via control terminal 37. Safe stop disables the control voltage of the power semiconductors of the frequency converter output stage, which in turn prevents generating the voltage required to rotate the motor. When the safe stop (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 stop function can be used for stopping the frequency converter in emergency stop situations. In the normal operating mode when safe stop 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.

Liability Conditions
It is the responsibility of the user to ensure personnel installing and operating the safe stop function:

- Read and understand the safety regulations concerning health and safety/accident prevention
- Understand the generic and safety guidelines given in this description and the extended description in the *VLT® AutomationDrive Design Guide*
- Have a good knowledge of the generic and safety standards for the specific application

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

Standards
Use of safe stop on terminal 37 requires that the user satisfy all provisions for safety including relevant laws, regulations and guidelines. The optional safe stop function complies with the following standards.

- EN 954-1: 1996 Category 3
- IEC 60204-1: 2005 Category 0–uncontrolled stop
- IEC 61508: 1998 SIL2
- IEC 61800-5-2: 2007–safe torque off (STO) function
- IEC 62061: 2005 SIL CL2
- ISO 13849-1: 2006 Category 3 PL d
- ISO 14118: 2000 (EN 1037)–prevention of unexpected start up

Protective Measures

- Safety engineering systems may only be installed and commissioned by qualified and skilled personnel
- The unit must be installed in an IP54 cabinet or in an equivalent environment. In special applications, a higher IP degree may be necessary
- The cable between terminal 37 and the external safety device must be short circuit protected according to ISO 13849-2 table D.4
- If any external forces influence the motor axis (e.g. suspended loads), additional measures (e.g. a safety holding brake) are required in order to eliminate hazards

Safe Stop Installation and Set-Up

⚠WARNING

SAFE STOP FUNCTION!

The safe stop function does NOT isolate mains voltage to the frequency converter or auxiliary circuits. Perform work on electrical parts of the frequency converter or the motor only after isolating the mains voltage supply and waiting the length of time specified in *2 Safety and Conformity*. Failure to isolate the mains voltage supply from the unit and waiting the time specified could result in death or serious injury.

- It is not recommended to stop the frequency converter by using the safe torque off function. If a running frequency converter is stopped by using the function, the unit will trip and stop by coasting. If this is not acceptable, the frequency converter and machinery must be stopped using the appropriate stopping mode before using this function. Depending on the application, a mechanical brake may be required.
- Concerning synchronous and permanent magnet motor frequency converters in case of a multiple IGBT power semiconductor failure: In spite of the activation of the safe torque off function, the frequency converter system can produce an alignment torque which maximally rotates the motor shaft by 180/p degrees. p denotes the pole pair number.
- This function is suitable for performing mechanical work on the frequency converter system or affected area of a machine only. It does not provide electrical safety. This function should not be used as a control for starting and/or stopping the frequency converter.

The following requirements have to be met to perform a safe installation of the frequency converter:

1. Remove the jumper wire between control terminals 37 and 12 or 13. Cutting or breaking the jumper is not sufficient to avoid short-circuiting. (See jumper on *Illustration 3.39*.)
2. Connect an external safety monitoring relay via a NO safety function (the instruction for the safety device must be followed) to terminal 37 (safe stop) and either terminal 12 or 13 (24 V DC). The safety monitoring relay must comply with Category 3 (EN 954-1)/PL “d” (ISO 13849-1) or SIL 2 (EN 62061).

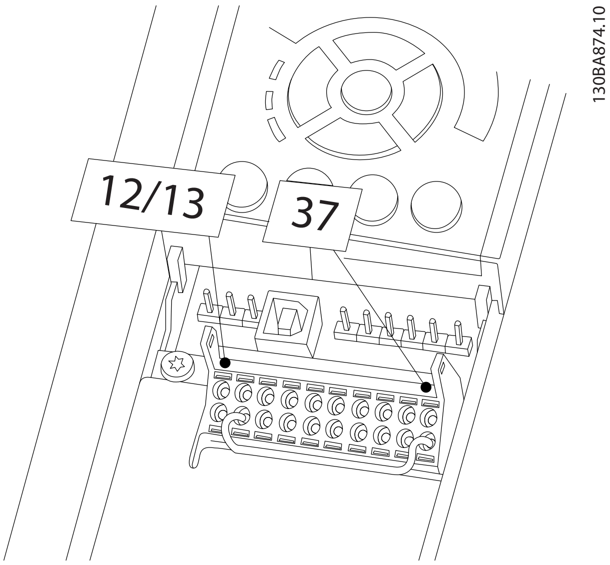


Illustration 3.39 Jumper between Terminal 12/13 (24 V) and 37

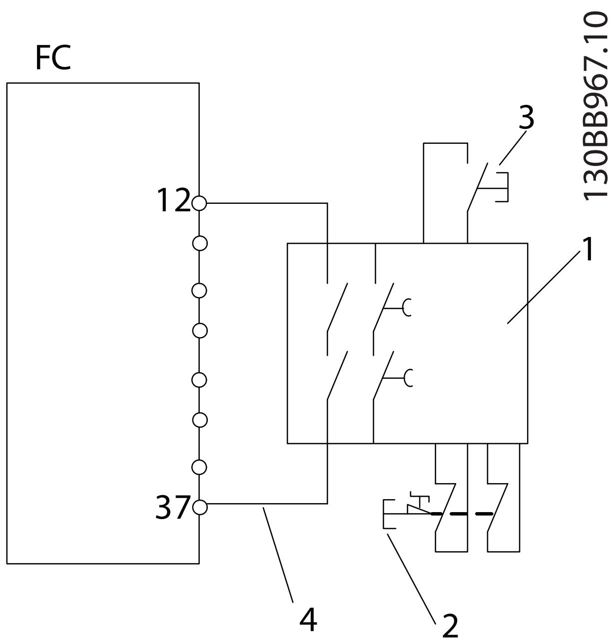


Illustration 3.40 Installation to Achieve a Stopping Category 0 (EN 60204-1) with Safety Cat. 3 (EN 954-1) / PL "d" (ISO 13849-1) or SIL 2 (EN 62061).

1	Safety relay (cat. 3, PL d or SIL2
2	Emergency stop button
3	Reset button
4	Short-circuit protected cable (if not inside installation IP54 cabinet)

Table 3.21 Legend to *Illustration 3.40*

Safe Stop Commissioning Test

After installation and before first operation, perform a commissioning test of the installation making use of safe stop. Moreover, perform the test after each modification of the installation.

Example with STO

A safety relay evaluates the E-Stop button signals and triggers an STO function on the frequency converter in the event of an activation of the E-Stop button (See *Illustration 3.41*). This safety function corresponds to a category 0 stop (uncontrolled stop) in accordance with IEC 60204-1. If the function is triggered during operation, the motor will run down in an uncontrolled manner. The power to the motor is safely removed, so that no further movement is possible. It is not necessary to monitor the motor at a standstill. If an external force effect is to be anticipated, additional measures should be provided to safely prevent any potential movement (e.g. mechanical brakes).

NOTE

For all applications with safe stop it is important that short circuit in the wiring to T37 can be excluded. This can be done as described in EN ISO 13849-2 D4 by the use of protected wiring, (shielded or segregated).

Example with SS1

SS1 correspond to a controlled stop, stop category 1 according to IEC 60204-1 (see *Illustration 3.42*). When activating the safety function a normal controlled stop will be performed. This can be activated through terminal 27. After the safe delay time has expired on the external safety module, the STO will be triggered and terminal 37 will be set low. Ramp down will be performed as configured in the drive. If the frequency converter is not stopped after the safe delay time, the activation of STO will coast it.

NOTE

When using the SS1 function, the brake ramp of the drive is not monitored with respect to safety.

Example with Category 4/PL e application

Where the safety control system design requires two channels for the STO function to achieve Category 4/PL e, one channel can be implemented by safe stop T37 (STO) and the other by a contactor, which may be connected in either the drive input or output power circuits and controlled by the safety relay (see *Illustration 3.43*). The contactor must be monitored through an auxiliary guided contact, and connected to the reset input of the Safety Relay.

Paralleling of Safe Stop input the one Safety Relay

Safe Stop inputs T37 (STO) may be connected directly together if it is required to control multiple frequency converters from the same control line via one safety relay (see *Illustration 3.44*). Connecting inputs together increases the probability of a fault in the unsafe direction, since a fault in one frequency converter might result in all units becoming enabled. The probability of a fault for T37 is so low, that the resulting probability still meets the requirements for SIL2.

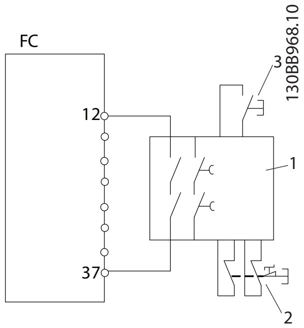


Illustration 3.41 STO Example

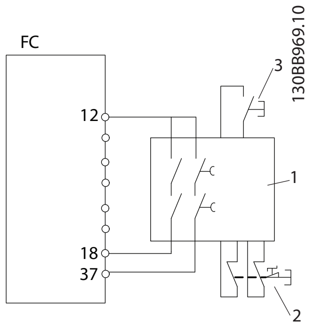


Illustration 3.42 SS1 Example

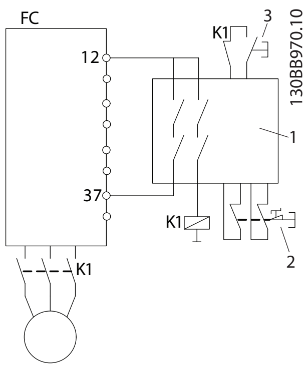


Illustration 3.43 STO Category 4 Example

1	Safety relay
2	Emergency stop button
3	Reset button

Table 3.22 Legend to *Illustration 3.41* to *Illustration 3.43*

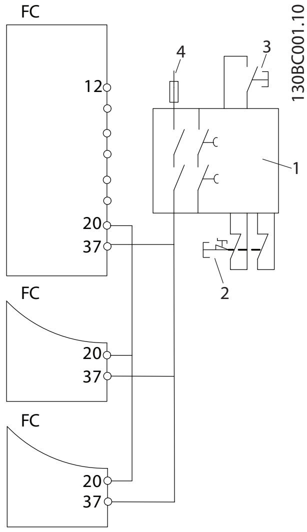


Illustration 3.44 Paralleling of Multiple Drives Example

1	Safety relay
2	Emergency stop button
3	Reset button
4	24 V DC

Table 3.23 Legend to *Illustration 3.44*

WARNING

Safe Stop activation (i.e. removal of 24 V DC voltage supply to terminal 37) does not provide electrical safety. The safe stop function itself is therefore not sufficient to implement the Emergency-Off function as defined by EN 60204-1. Emergency-Off requires measures of electrical isolation, (e.g. by switching off mains via an additional contactor.)

1. Activate the Safe Stop function by removing the 24 V DC voltage supply to the terminal 37.
2. After activation of safe stop (i.e. after the response time), the frequency converter coasts (stops creating a rotational field in the motor). The response time is typically shorter than 10ms for the complete performance range of FC 302.

The frequency converter is guaranteed not to restart creation of a rotational field by an internal fault (in accordance with Cat. 3 of EN 954-1, PL d acc. EN ISO 13849-1 and SIL 2 acc. EN 62061). After activation of safe stop, the FC 302 display will show the text safe stop activated. The associated help text says "Safe Stop has been activated," this means that safe stop has been activated and normal operation has not been resumed yet after safe stop activation.

NOTE

The requirements of Cat. 3 (EN 954-1)/PL “d” (ISO 13849-1) are only fulfilled while 24 V DC supply to terminal 37 is kept removed or low by a safety device which itself fulfills Cat. 3 (EN 954-1)/PL “d” (ISO 13849-1). If external forces act on the motor in case of vertical axis (suspended loads) and an unwanted movement, (e.g. caused by gravity) could cause a hazard, the motor must not be operated without additional measures for fall protection (e.g. mechanical brakes).

In order to resume operation after activation of safe stop:

1. Reapply 24 V DC voltage to terminal 37 (the text Safe Stop activated is still displayed).
2. Create a reset signal via bus, digital I/O, or the [Reset] key on the inverter.

By default, the safe stop function is set to an unintended restart prevention behaviour. This means, in order to terminate safe stop and resume normal operation, the 24 V DC must be reapplied to Terminal 37 and a reset signal given, as described above.

The safe stop function can be set to an automatic restart behaviour by setting the value of *5-19 Terminal 37 Safe Stop* from default value [1] to value [3]. If an MCB 112 Option is connected to the drive, automatic restart behaviour is set by values [7] and [8].
Automatic Restart means that safe stop is terminated, and normal operation is resumed. As soon as the 24 V DC is applied to Terminal 37, no reset signal is required.

⚠WARNING

Automatic restart behaviour is only allowed in one of two situations:

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

3.12.3 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 the safety-related sensor (such as emergency stop button, safety-guard switch, etc.) that activates Safe Stop. This means that the output to Safe Stop 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 one of the two 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 connection from the output of the safety device with safe AND logic to Safe Stop terminal 37 must be short-circuit protected. See *Illustration 3.45*.

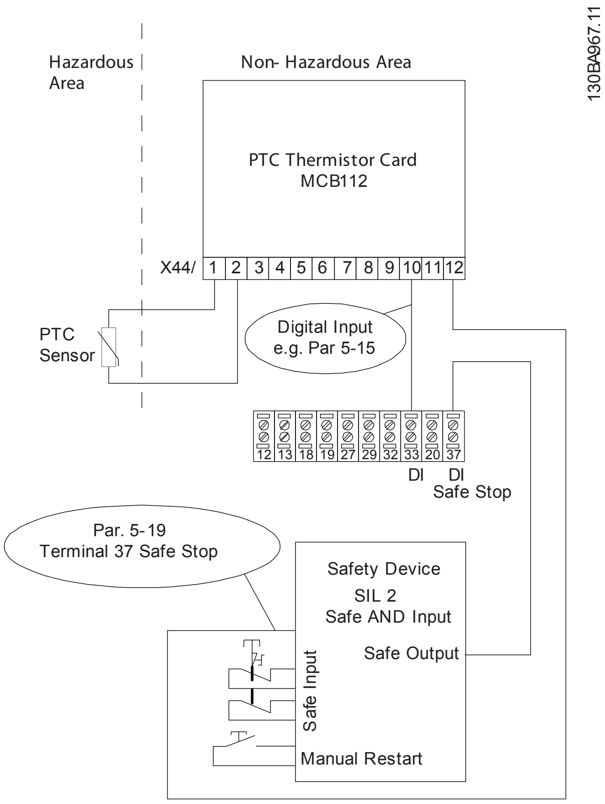


Illustration 3.45 Illustration of the essential aspects for installing a combination of a Safe Stop application and a MCB 112 application. The diagram shows a Restart input for the external Safety Device. This means that in this installation *5-19 Terminal 37 Safe Stop* might be set to value [7] or [8]. Refer to MCB 112 operating instructions for further details.

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 Stop). Selection [1]* and [3] 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] should be chosen 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] are not to be selected when an external safety device is used. Those selections are for when only MCB 112 uses the safe stop. If selections [4] or [5] are chosen by mistake and the external safety device triggers safe stop, the frequency converter

will react with an alarm "Dangerous Failure [A72]" and coast the frequency converter safely, without automatic restart.
Selections [6]–[9] must be chosen for the combination of external safety device and MCB 112.

NOTE

Note that selections [7] and [8] open up for Automatic restart when the external safety device is de-activated again.

This is only allowed in the following cases:

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

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

3.12.4 Safe Stop Commissioning Test

After installation and before first operation, perform a commissioning test of an installation or application making use of FC 300 Safe Stop.
Perform the test after each modification of the installation or application, of which the FC 300 safe stop is part.

NOTE

A passed commissioning test is mandatory after first installation and after each change to the safety installation.

The commissioning test (select one of cases 1 or 2 as applicable):

Case 1: restart prevention for safe stop is required (i.e. safe stop only where *5-19 Terminal 37 Safe Stop* is set to default value [1], or combined Safe Stop and MCB 112 where *5-19 Terminal 37 Safe Stop* is set to [6] or [9]):

1.1 Remove the 24 V DC voltage supply to terminal 37 by the interrupt device while the motor is driven by the FC 302 (i.e. mains supply is not interrupted). The test step is passed if the motor reacts with a coast and the mechanical brake (if connected) is activated, and if an LCP is mounted, the alarm "Safe Stop [A68]" is displayed.

1.2 Send reset signal (via bus, digital I/O, or [Reset] key). The test step is passed if the motor remains in the safe stop state, and the mechanical brake (if connected) remains activated.

1.3 Reapply 24 V DC to terminal 37. The test step is passed if the motor remains in the coasted state, and the mechanical brake (if connected) remains activated.

1.4 Send reset signal (via bus, digital I/O, or [Reset] key). The test step is passed if the motor becomes operational again.

The commissioning test is passed if all four test steps 1.1, 1.2, 1.3 and 1.4 are passed.

Case 2: Automatic restart of safe stop is wanted and allowed (*i.e.* safe stop only where *5-19 Terminal 37 Safe Stop* is set to [3], or combined safe stop and MCB 112 where *5-19 Terminal 37 Safe Stop* is set to [7] or [8]):

2.1 Remove the 24 V DC voltage supply to terminal 37 by the interrupt device while the motor is driven by the FC 302 (*i.e.* mains supply is not interrupted). The test step is passed if the motor reacts with a coast and the mechanical brake (if connected) is activated, and if an LCP is mounted, the warning "Safe Stop [W68]" is displayed.

2.2 Reapply 24 V DC to terminal 37.

The test step is passed if the motor becomes operational again. The commissioning test is passed if both test steps 2.1 and 2.2 are passed.

NOTE

See warning on the restart behaviour in *3.12.2 Terminal 37 Safe Stop Function*

3.12.5 Safe Stop Operation (FC 302 only)

NOTE

The safe stop function of FC 302 can be used for asynchronous, synchronous and permanent magnet motors. It may happen that two 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.

3.12.6 Approvals & Certificates

The latest certificates and approvals are available on the Internet, see *http://www.danfoss.com/BusinessAreas/DrivesSolutions/Documentations/DDapprovalscertificate.htm*

4

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
Max. 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 [mm^2 (AWG[2]))][5]	2x95 (2x3/0)						2x185 (2x350 mcm)					
Max. external mains fuses [A[1]]	315		350		400		550		630		800	
Estimated power loss at 400 V [W][4]	2031	2559	2289	2954	2923	3770	3093	4116	4039	5137	5005	6674
Estimated power loss at 460 V [W]	1828	2261	2051	2724	2089	3628	2872	3569	3575	4566	4458	5714
Weight, enclosure IP21, IP54 kg (lbs.)	62 (135)						125 (275)					
Weight, enclosure IP20 kg (lbs.)	62 (135)						125 (275)					
Efficiency[4]	0.98											
Output frequency	0-590 Hz											
Heatsink overtemp trip	110 °C											
Control card ambient trip	75 °C											
*High overload=150% current for 60 s, Normal overload=110% current for 60 s												

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

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
Max. 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[2])]	4x240 (4x500 mcm)		4x240 (4x500 mcm)		4x240 (4x500 mcm)	
Max. cable size, brake [mm^2 (AWG[2])]	2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)	
Max. external mains fuses [A][1]	900		900		900	
Estimated power loss at 400 V [W][4]	6794	7532	7498	8677	7976	9473
Estimated power loss at 460 V [W]	6118	6724	6672	7819	7814	8527
Weight, enclosure IP21, IP54 [kg]	270		272		313	
Weight, enclosure IP00 [kg]	234		236		277	
Efficiency[4]	0.98					
Output frequency	0-590 Hz					
Heatsink overtemp. trip	110 °C					
Power card ambient trip	75 °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

4

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
Max. 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$^{2)}$)]	8x150 (8x300 mcm)								12x150 (12x300 mcm)			
Max. cable size,mains F1/F2 [mm^2 (AWG$^{2)}$)]	8x240 (8x500 mcm)											
Max. cable size,mains F3/F4 [mm^2 (AWG$^{2)}$)]	8x456 (8x900 mcm)											
Max. cable size, loadsharing [mm^2 (AWG$^{2)}$)]	4x120 (4x250 mcm)											
Max. cable size, brake [mm^2 (AWG$^{2)}$)	4x185 (4x350 mcm)								6x185 (6x350 mcm)			
Max. external mains fuses [A]$^{1)}$	1600				2000				2500			
Estimated power loss at 400 V [W]$^{4)}$	9031	10162	10146	11822	10649	12512	12490	14674	14244	17293	15466	19278
Estimated power loss at 460 V [W]	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	95 °C											
Power card ambient trip	75 °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

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
Max. 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[2])]	4x90 (3/0)		4x90 (3/0)		4x240 (500 mcm)		4x240 (500 mcm)	
Max. cable size, motor [mm^2 (AWG[2])]	4x240 (4x500 mcm)		4x240 (4x500 mcm)		4x240 (4x500 mcm)		4x240 (4x500 mcm)	
Max. cable size, brake [mm^2 (AWG[2])]	2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)	
Max. external mains fuses [A][1]	700							
Estimated power loss at 400 V [W][4]	5164	6790	6960	7701	7691	8879	8178	9670
Estimated power loss at 460 V [W]	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	95 °C							
Power card ambient trip	75 °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

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
Max. 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[2]))]	8x150 (8x300 mcm)								12x150 (12x300 mcm)			
Max. cable size, mains [mm^2 (AWG[2]))]	6x120 (6x250 mcm)											
Max. cable size, brake [mm^2 (AWG[2]))]	4x185 (4x350 mcm)								6x185 (6x350 mcm)			
Max. external mains fuses [A][1)]	900						1500					
Estimated power loss at 400 V [W][4)]	9492	10647	10631	12338	11263	13201	13172	15436	14967	18084	16392	20358
Estimated power loss at 460 V [W]	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	75 °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

For fuse ratings, see 7.2.1 Fuses

[1)] High overload=160% torque during 60 s, Normal overload=110% torque during 60 s.

[2)] American Wire Gauge.

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

[4)] The typical power loss is at nominal load conditions and expected to be within ±15% (tolerence relates to variety in voltage and cable conditions).
Values are based on a typical motor efficiency (eff2/eff3 border line). Motors with lower efficiency will also add to the power loss in the frequency converter and opposite.

If the switching frequency is increased compared to the default setting, the power losses may rise significantly.
LCP and typical control card power consumptions are included. Further options and customer load may add up to 30 W to the losses. (Though typical only 4 W extra for a fully loaded control card, or options for slot A or slot B, each).
Although measurements are made with state of the art equipment, some measurement inaccuracy must be allowed for (±5%).

5) The three values for the max. cable cross section are for single core, flexible wire and flexible wire with sleeve, respectively.

6) Field wiring terminals on FC302 N110, N132, and N250 models are not intended to receive conductors one size larger.

4.2 Electrical Data - 525-690 V

4.2.1 Electrical Data - 525-690 V AC

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
Max. 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)]	4x240 (4x500 mcm)	
Max. cable size, brake [mm^2 (AWG)]	2x185 (2x350 mcm)	
Max. external mains fuses [A][1)]	700	
Estimated power loss at 600 V [W][4)]	4424	5323
Estimated power loss at 690 V [W][4)]	4589	5529
Weight, enclosure IP21, IP54 [kg]	263	
Weight, enclosure IP00 [kg]	221	
Efficiency[4)]	0.98	
Output frequency	0-500 Hz	
Heatsink overtemp. trip	110 °C	
Power card ambient trip	75 °C	
* High overload=160% torque during 60 s, Normal overload=110% torque during 60 s.		

Table 4.6 Technical Specifications, E-Frame, 525-690 V Mains Supply 3x525-690 V AC

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
Max. 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)]	4x240 (4x500 mcm)		4x240 (4x500 mcm)		4x240 (4x500 mcm)	
Max. cable size, brake [mm^2 (AWG)]	2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)	
Max. external mains fuses [A][1)]	700		900		900	
Estimated power loss at 600 V [W][4)]	4795	6010	6493	7395	7383	8209
Estimated power loss at 690 V [W][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	75 °C					
* High overload=160% torque during 60 s, Normal overload=110% torque during 60 s.						

Table 4.7 Technical Specifications, E-Frame 525-690 V Mains Supply 3x525-690 V AC

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
Max. 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[2])]	8x150 (8x300 mcm)					
Max. cable size,mains F1 [mm^2 (AWG[2])]	8x240 (8x500 mcm)					
Max. cable size,mains F3 [mm^2 (AWG[2])]	8x456 (8x900 mcm)					
Max. cable size, loadsharing [mm^2 (AWG[2])]	4x120 (4x250 mcm)					
Max. cable size, brake [mm^2 (AWG[2])]	4x185 (4x350 mcm)					
Max. external mains fuses [A][1]	1600					
Estimated power loss at 600 V [W][4]	8075	9500	9165	10872	10860	12316
Estimated power loss at 690 V [W][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	75 °C					
* High overload=160% torque during 60 s, Normal overload=110% torque during 60 s.						

Table 4.8 Technical Specifications, F1/F3 Frames, 525-690 V Mains Supply 3x525-690 V AC

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
Max. 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[2])]	12x150 (12x300 mcm)					
Max. cable size, mains F2 [mm^2 (AWG[2])]	8x240 (8x500 mcm)					
Max. cable size, mains F4 [mm^2 (AWG[2])]	8x456 (8x900 mcm)					
Max. cable size, loadsharing [mm^2 (AWG[2])]	4x120 (4x250 mcm)					
Max. cable size, brake [mm^2 (AWG[2])]	6x185 (6x350 mcm)					
Max. external mains fuses [A][1]	1600		2000		2500	
Estimated power loss at 600 V [W][4]	12062	13731	13269	16190	16089	18536
Estimated power loss at 690 V [W][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	105 °C		105 °C		95 °C	
Power card ambient trip	75 °C					
* High overload=160% torque during 60 s, Normal overload=110% torque during 60 s.						

Table 4.9 Technical Specifications, F2/F4 Frames, 525-690 V Mains Supply 3x525-690 V AC

[1] For type of fuse see 7.2.1 Fuses

[2] American Wire Gauge.

[3] Measured using 5 m screened motor cables at rated load and rated frequency.

[4] The typical power loss is at nominal full load conditions and expected to be within ±15% (tolerence relates to variety in voltage and cable conditions).
Values are based on a typical motor efficiency (eff2/eff3 border line). Motors with lower efficiency will also add to the power loss in the frequency converter and opposite.
If the switching frequency is increased compared to the default setting, the power losses may rise significantly.
LCP and typical control card power consumptions are included. Further options and customer load may add up to 30 W to the losses. (Though typical only 4 W extra for a fully loaded control card, or options for slot A or slot B, each).
Although measurements are made with state of the art equipment, some measurement inaccuracy must be allowed for (±5%).

4

4.2.2 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
Max. 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)]	4x85 (3/0)							
Max. cable size, motor [mm^2 (AWG)]	4x250 (500 mcm)							
Max. cable size, brake [mm^2 (AWG)]	2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)		2x185 (2x350 mcm)	
Max. external mains fuses [A][1)]	630							
Estimated power loss at 600 V [W][4)]	4424	5323	4795	6010	6493	7395	7383	8209
Estimated power loss at 690 V [W][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	85 °C							
Power card ambient trip	75 °C							
* High overload=160% torque during 60 s, Normal overload=110% torque during 60 s.								

Table 4.10 Technical Speficiations F8/F9 Frames, 525-690 V Mains Supply 6x525-690 V AC, 12-Pulse

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
Max. 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[2])]	8x150 (8x300 mcm)					
Max. cable size, mains [mm^2 (AWG[2])]	6x120 (6x250 mcm)					
Max. cable size, brake [mm^2 (AWG[2])]	4x185 (4x350 mcm)					
Max. external mains fuses [A][1]	900					
Estimated power loss at 600 V [W][4]	8075	9500	9165	10872	10860	12316
Estimated power loss at 690 V [W][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					
Heatsink overtemp. trip	85 °C					
Power card ambient trip	75 °C					
* High overload=160% torque during 60 s, Normal overload=110% torque during 60 s						

Table 4.11 Technical Specifications, F10/F11 Frames, 525-690 V Mains Supply 6x525-690 V AC, 12-Pulse

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
Max. 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 [mm² (AWG[2])]	12x150 (12x300 mcm)					
Max. cable size, mains F12 [mm² (AWG[2])]	8x240 (8x500 mcm)					
Max. cable size, mains F13 [mm² (AWG[2])]	8x400 (8x900 mcm)					
Max. cable size, brake [mm² (AWG[2])]	6x185 (6x350 mcm)					
Max. external mains fuses [A][1]	1600		2000		2500	
Estimated power loss at 600 V [W][4]	12062	13731	13269	16190	16089	18536
Estimated power loss at 690 V [W][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					
Heatsink overtemp. trip	85 °C					
Power card ambient trip	75 °C					
* High overload=160% torque during 60 s, Normal overload=110% torque during 60 s.						

Table 4.12 Technical Specifications, F12/F13 Frames, 525-690 V Mains Supply 6x525-690 V AC, 12-Pulse

[1] For type of fuse see 7.2.1 Fuses

[2] American Wire Gauge.

[3] Measured using 5 m screened motor cables at rated load and rated frequency.

[4] The typical power loss is at nominal load conditions and expected to be within ±5% (tolerence relates to variety in voltage and cable conditions).
Values are based on a typical motor efficiency (eff2/eff3 border line). Motors with lower efficiency will also add to the power loss in the frequency converter and opposite.
If the switching frequency is increased compared to the default setting, the power losses may rise significantly.

LCP and typical control card power consumptions are included. Further options and customer load may add up to 30 W to the losses. (Though typical only 4W extra for a fully loaded control card, or options for slot A or slot B, each).
Although measurements are made with state of the art equipment, some measurement inaccuracy must be allowed for (±5%).

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	50/60Hz ±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)]
Overload torque (Variable torque)	maximum 110% for 60 s

Pulse	Pause
160%/1 min	91.8%/10 min
150%/1 min	93.5%/10 min
110%/1 min	98.9%/10 min

Table 4.13 Overload Capability

Pulse	Pause
160%/1 min	0%/94 s
150%/1 min	0%/75 s
110%/1 min	0%/60 s

Table 4.14 Overload Capability

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 mm^2/16 AWG

Maximum cross section to control terminals, flexible wire with cable end sleeves	1 mm^2/18 AWG
Maximum cross section to control terminals, flexible wire with cable end sleeves with collar	0.5 mm^2/20 AWG
Minimum cross section to control terminals	0.25 mm^2/24 AWG

[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 predefined 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 (Guideline - 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 stop 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 stop input Terminal 37.

[3)] See 3.12 Safe Stop for further information about terminal 37 and Safe Stop.

[4)] When using a contactor with a DC coil inside in combination with Safe Stop, 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.

Analogue inputs

Number of analogue 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 analogue inputs	10 bit (+sign)
Accuracy of analogue inputs	Max. error 0.5% of full scale
Bandwidth	100 Hz

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

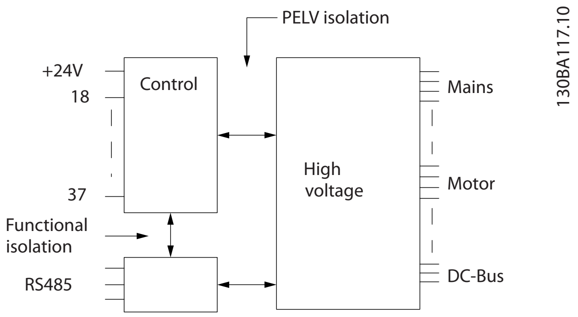


Illustration 4.1 PELV Isolation

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

Analogue output	
Number of programmable analogue outputs	1
Terminal number	42
Current range at analogue output	0/4-20 mA
Max. load GND - analogue output	500Ω
Accuracy on analogue output	Max. error: 0.5% of full scale
Resolution on analogue output	12 bit

The analogue 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 analogue 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)	
Ambient temperature, frame size D, E and F	Max. 45 °C

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

4.4 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 $f_{M,N}$, even if the motor supplies 100% of the rated shaft torque or only 75%, i.e. in case of part 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*.

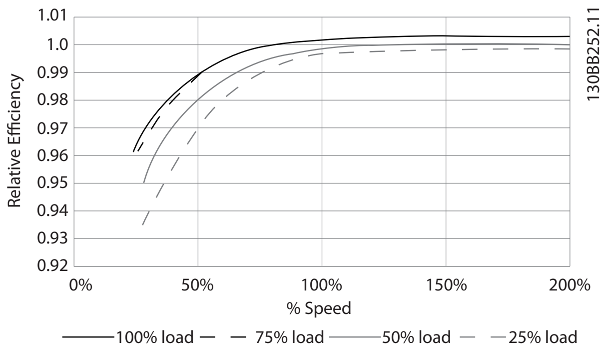


Illustration 4.2 Typical Efficiency Curves

Example: Assume a 160 kW, 380-480 V AC frequency converter at 25% load at 50% speed. The graph is showing 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 the 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.

The typical 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*

4.6 dU/dt Conditions

NOTE

To avoid premature ageing of motors (without phase insulation paper or other insulation reinforcement) not designed for frequency converter operation, 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. If the peak voltage is too high, especially motors without phase coil insulation are affected. 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 FC 300 complies with the demands of IEC 60034-25 regarding motors designed to be controlled by frequency converters. The FC 300 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.

Cable length [m]	Mains voltage [V]	Rise time [μs]	Peak voltage [V]	dU/dt [V/μs]
30	400	0.26	1180	2109`

Table 4.16 dU/dt, D-Frame, 380-500 V, 90-250 kW/380-500 V

Cable length [m]	Mains voltage [V]	Rise time [μs]	Peak voltage [V]	dU/dt [V/μs]
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, 315-800 kW/380-500 V

[1)] *With Danfoss dU/dt filter*

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

Table 4.18 dUu/dt E- and F-Frames 525-690 V, 355-1200 kW/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 the 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.

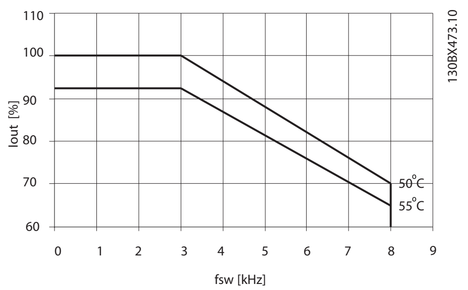
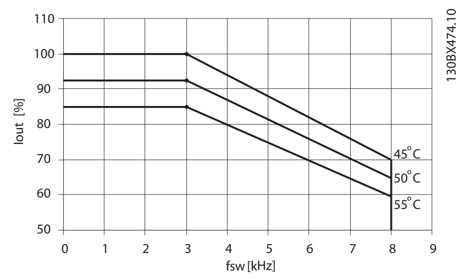
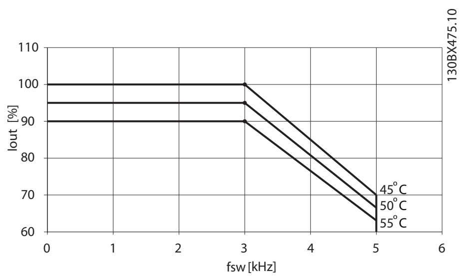
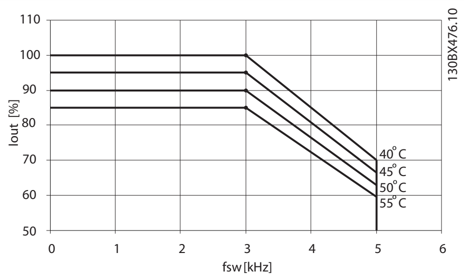
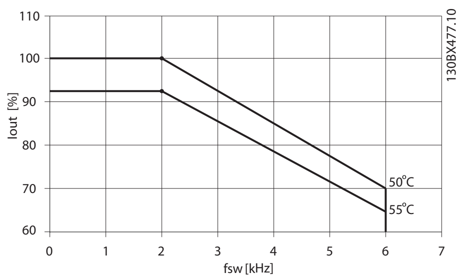
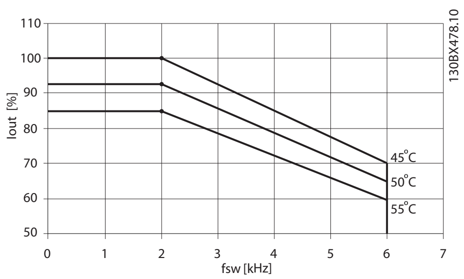
4.7.1 Manual Derating

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 4.19* and *Table 4.20*.

<table>
<tr><th>Frame model</th><th>Switching pattern</th><th>High overload HO, 150%</th><th>Normal overload NO, 110%</th></tr>
<tr><td rowspan="2">D-Frame
P90 to P200
380-500V</td><td>60 AVM</td><td>
</td><td>
</td></tr>
<tr><td>SFAVM</td><td>
</td><td>
</td></tr>
<tr><td rowspan="2">E & F-Frame
P250 to P1M0
380-500V</td><td>60 AVM</td><td>
</td><td>
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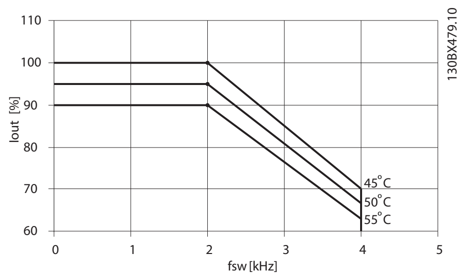
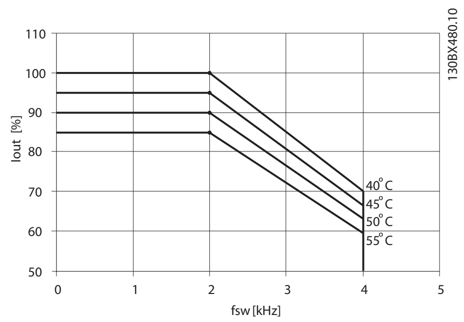
<tr><td>SFAVM</td><td>
</td><td>
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Table 4.19 Derating Tables for Drives Rated 380-500 V (T5)

<table>
<tr><th>Frame model</th><th>Switching pattern</th><th>High overload HO, 150%</th><th>Normal overload NO, 110%</th></tr>
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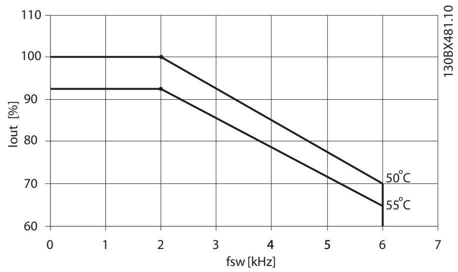
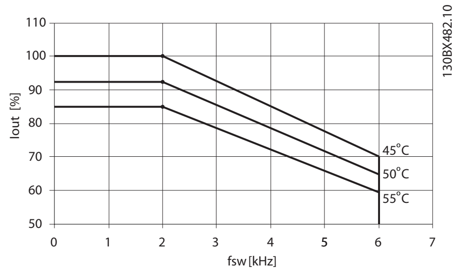
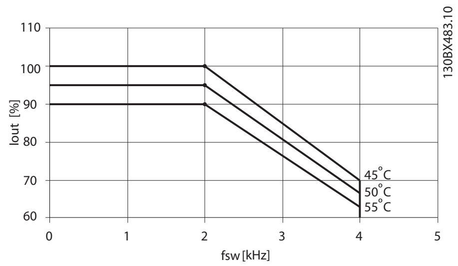
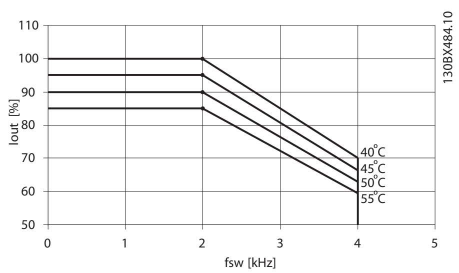
525-690V</td><td>60 AVM</td><td></td><td></td></tr>
<tr><td>SFAVM</td><td></td><td></td></tr>
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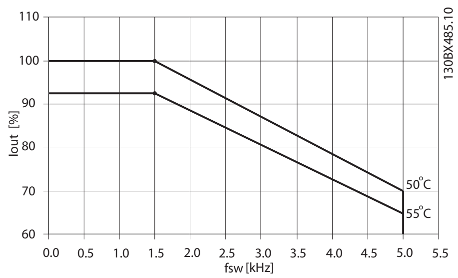
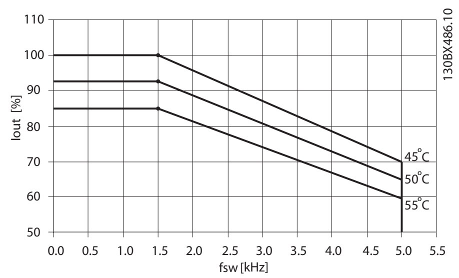
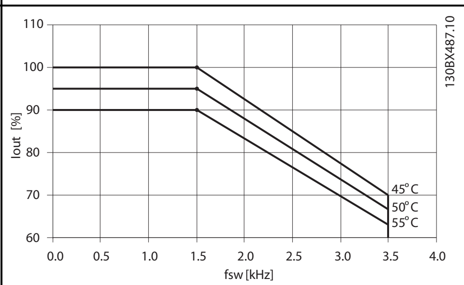
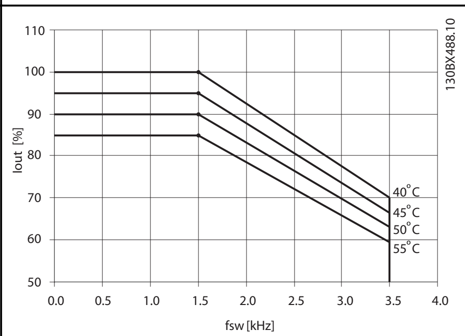
P315
525-690V</td><td>60 AVM</td><td></td><td></td></tr>
<tr><td>SFAVM</td><td></td><td></td></tr>
</table>

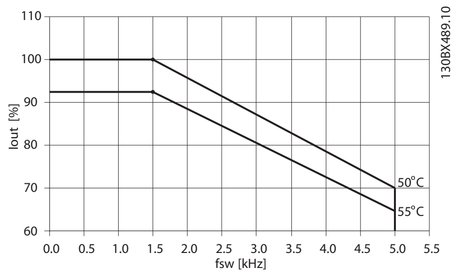
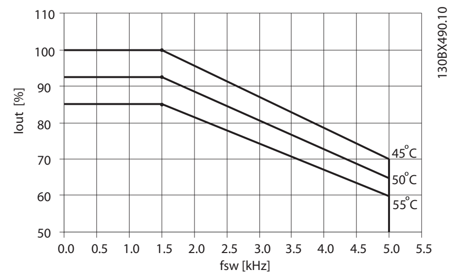
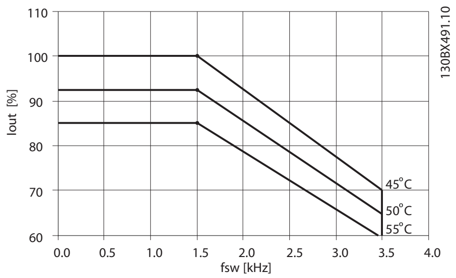
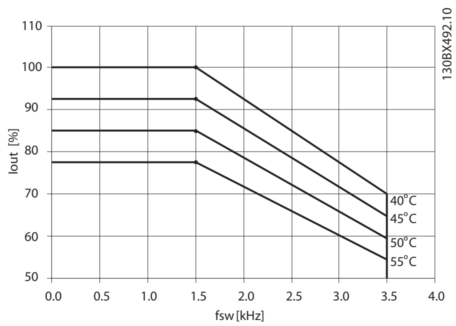
<table>
<tr><th>Frame model</th><th>Switching pattern</th><th>High overload HO, 150%</th><th>Normal overload NO, 110%</th></tr>
<tr><td rowspan="2">E & F-Frame
P250 to P1M0
525-690V</td><td>60 AVM</td><td>
</td><td>
</td></tr>
<tr><td>SFAVM</td><td>
</td><td>
</td></tr>
</table>

Table 4.20 Derating Tables for Drives Rated 525-690 V (T7)

Automation Drives will automatically derate the switching frequency, switching type, or output current under certain load or ambient conditions. For detailed information see *Application Note*.

4.7.3 Automatic Derating

The drive constantly checks for critical levels:

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

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 converter can also force the PWM pattern to SFAVM.

NOTE

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

5 How to Order

5.1.1 Ordering from Type Code

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

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

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.

5.1.2 Drive Configurator

It is possible to design an FC 300 frequency converter according to the application requirements by using the ordering number system.

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, i.e.:

FC-302PK75T5E20H1BGCXXXSXXXXA0BXCXXXXD0

The meaning of the characters in the string 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.

From the drive configurator, it is possible to configure the right drive for the right application and generate the type code string. The drive configurator will automatically generate an eight-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 will automatically be delivered 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) E21: IP21 (NEMA 1) E54: IP54 (NEMA 12) E2M: IP21 (NEMA 1) with mains shield E5M: IP54 (NEMA 12) with mains shield C20: IP20 (chassis) + stainless steel back channel 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)] N2: LHD with RFI filter, class A2 N4: LHD with RFI filter, class A1
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
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
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 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 disconnected 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

5

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
Description	Pos	Possible choice
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 Codemodel Number Frame Size F

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 Type Codemodel Number, Options (all Frame Sizes)

5.2.1 Ordering Numbers: Options and Accessories

Type	Description	Ordering no.	
Miscellaneous hardware			
Profibus top entry	Top entry for D and E-Frame, enclosure type IP 00 and IP21	176F1742	
Profibus D-Sub 9	D-Sub connector kit for IP20, frame sizes A1, A2 and A3	130B1112	
Profibus screen plate	Profibus screen plate kit for IP20, frame sizes A1, A2 and A3	130B0524	
DC link connector	Terminal block for DC link connection on frame size A2/A3	130B1064	
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 VLT3000 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

Table 5.7 Options and Accessories

Type	Description	Ordering no.	
Option for Slot D			
MCB 107	24 V DC back-up	130B1108	130B1208
External Options			
Ethernet IP	Ethernet master	175N2584	
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

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

5.2.2 Ordering Numbers: Brake Resistors

The requirements for brake resistors vary in different applications. Always consult the 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 two 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					10% stopping typical horizontal loads				40% stopping typical vertical loads			
					Max 30 s braking per 300 s period				Max 30 s braking per 75 s period			
Drive data					Resistor data				Resistor data			
Automation FC 302 [T5]	Pm (HO) [kW]	Number of brake choppersm1)	Rmin	Rbr, nom	Rrec	Max brake torque [%]	Pbr avg [kW]	Order number	Rrec	Max brake torque [%]	Pbr avg [kW]	Order number
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	See the *Brake Resistor Design Guide*							
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

525-690 V AC					10% stopping typical horizontal Loads				40% stopping typical vertical loads			
					Max 30 s braking per 300 s period				Max 30 s braking per 75 s period			
Drive data					Resister data				Resister data			
Automation FC302 [T7]	Pm (HO) [kW]	Number of brake choppers (1)	Rmin	Rbr, nom	Rrec	Max brake torque [%]	Pbr avg [kW]	Order number	Rrec	Max brake torque [%]	Pbr avg [kW]	Order number
P355	355	1	2.3	2.4	See the *Brake Resistor Design Guide*							
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 Ordering Numbers: Advanced Harmonic Filters

Harmonic filters are used to reduce mains harmonics.

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

Code number AHF005 IP00 IP20	Code number AHF010 IP00 IP20	Filter current rating	Typical motor	VLT power 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	P110	204	1080	742	<75	X6	X6
130B1447 130B1258	130B1369 130B1215	251	132	P132	251	1195	864	<75	X7	X7
130B1448 130B1259	130B1370 130B1216	304	160	P160	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	P200	381	1510	1175	<77	X8	X7
130B1469 130B1261	130B1391 130B1228	480	250	P250	472	1852	1542	<77	X8	X8

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 power and current ratings		Losses		Acoustic noise	Frame size	
						AHF005	AHF010			
		A	kW	kW	A	W	W	dBA	AHF005	AHF010
2x130B1448 2x130B1259	2x130B1370 2x130B1216	608	315	N315	590	2576	1810	<80		
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

Code number AHF005 IP00 IP20	Code number AHF010 IP00 IP20	Filter current rating	Typical motor	VLT power and current ratings		Losses		Acoustic noise	Frame size	
						AHF005	AHF010			
		A	kW	kW	A	W	W	dBA	AHF005	AHF010
130B3130 130B2868	130B3089 130B2499	171	90	N90K	171	962	692	<75	X6	X6
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	X7	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	X8
130B3135 130B2873	130B3094 130B2856	480	250	N250	472	1850	1542	<77	X8	X8
2x130B3133 2x130B2871	2x130B3092 2x130B2819	608	315	P315	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 power and current ratings		Losses		Acousti c noise	Frame size	
						AHF00 5	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

5

Code number AHF005 IP00 IP20	Code number AHF010 IP00 IP20	Filter current rating	Typical motor	VLT power and current ratings		Losses		Acoustic noise	Frame size	
						AHF005	AHF010			
		A	HP	HP	A	W	W	dBA	AHF005	AHF010
130B1798 130B1763	130B1781 130B1495	154	125	N90K	154	962	692	<75	X6	X6
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	X7	X7
130B2257 130B1768	130B1785 130B1499	355	300	N200	348	1406	952	<75	X8	X8
130B3168 130B3167	130B3166 130B3165	380				1510	1175	<77	X8	X7
130B2259 130B1769	130B1786 130B1751	436	350	N250	436	1852	1542	<77	X8	X7
130B1900+ 130B2200 130B1765+ 130B1766	130B1783+ 130B1784 130B1497+ 130B1498	522	450	P315	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 power and 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	Typical motor	VLT power and current ratings		Losses		Acoustic noise	Frame size	
		50 Hz				AHF005	AHF010			
		A	HP	kW	A	W	W	dBa	AHF005	AHF010
130B5268 130B5253	130B5236 130B5219	77	60	N55K	74	841	488	<72	X6	X6
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	P315/ P355	339/366	2812	1542	<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	Typical motor	VLT Power and Current Ratings		Losses		Acoustic noise	Frame size	
		50 Hz				AHF005	AHF010			
		A	HP	kW	A	W	W	dBa	AHF005	AHF010
2x130B5273 2x130B5258	130B5245 130B5228	395	400	P400	395	2812	1852	<75		X8
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 power 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
130B5023	130B5324	58	37	N45K	59	55	P55K	57	747	428	<70	X5	X5
130B5168	130B5286												
130B5024	130B5325	77	45	N55K	71	75	P75K	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	P90K	104	1080	743	<72	X6	X6
130B5172	130B5289												
130B5028	130B5328	128	90	N110	130	110	P110	126	1194	864	<72	X6	X6
130B5195	130B5290												
130B5029	130B5329	155	110	N132	158	132	P132	150	1288	905	<72	X7	X7
130B5196	130B5291												
130B5042	130B5330	197	132	N160	198	160	P160	186	1406	952	<72	X7	X7
130B5197	130B5292												
130B5066	130B5331	240	160	N200	245	200	P200	234	1510	1175	<75	X8	X8
130B5198	130B5293												
130B5076	130B5332	296	200	N250	299	250	P250	280	1852	1288	<75	X8	X8
130B5199	130B5294												
2x130B5042	130B5333	366	250	N315	355	315/355	P315/ P355	333/368	2812	1542			
2x130B5197	130B5295												
2x130B5042	130B5334	395	315	P355	381	400			2812	1852			
2x130B5197	130B5296												

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 power 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
130B5042 +130B5066	130B5330 +130B5331	437	355	P400	413	500	P400	395	2916	2127			
130B5197 +130B5198	130B5292 +130B5293												
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

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5.2.4 Ordering Numbers: 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	130B3182	130B3183
110	212	150	190	132	190	D1h/D3h	130B3184	130B3185
132	260	200	240	160	240	D1h/D3h, D2h/D4h, D11		
160	315	250	302	200	302	D2h/D4h, D11	130B3186	130B3187
200	395	300	361	250	361	D2h/D4h, D11		
250	480	350	443	315	443	D2h/D4h, D11, E1/E2, E7, F8/F9	130B3188	130B3189
315	600	450	540	355	540	E1/E2, E7, F8/F9	130B3191	130B3192
355	658	500	590	400	590	E1/E2, E7, F8/F9		
400	745	600	678	500	678	E1/E2, E7, F8/F9	130B3193	130B3194
450	800	600	730	530	730	E1/E2, E7, F8/F9		
450	800	600	730	530	730	F1/F3, F10/F11, F17	2X130B3186	2X130B3187
500	880	650	780	560	780	F1/F3, F10/F11, F17	2X130B3188	2X130B3189
560	990	750	890	630	890	F1/F3, F10/F11, F17		
630	1120	900	1050	710	1050	F1/F3, F10/F11, F17	2X130B3191	2X130B3192
710	1260	1000	1160	800	1160	F1/F3, F10/F11, F17		
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

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
75	113	100	108	90	108	D1h/D3h	130B4118	130B4119
90	137	125	131	110	131	D1h/D3h	130B4121	130B4124
110	162	150	155	132	155	D1h/D3h		
132	201	200	192	160	192	D1h/D3h, D2h/D4h	130B4125	130B4126
160	253	250	242	200	242	D2h/D4h		
200	303	300	290	250	290	D2h/D4h	130B4129	130B4151
250	360			315	344	F8/F9		
		350	344	355	380	D2h/D4h, F8/F9	130B4152	130B4153
315	429	400	400	400	410	D2h/D4h, E1/E2, 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

NOTE

When using Sine-wave filters, the switching frequency should comply with filter specifications in *14-01 Switching Frequency*.

NOTE

See also *Output Filter Design Guide*

5.2.5 Ordering Numbers: dU/dt Filters

Typical application ratings												Frame Size	Filter ordering number	
380-500 V [T5]						525-690 V [T7]								
400 V, 50 Hz		460 V, 60 Hz		500 V, 50 Hz		525 V, 50 Hz		575 V, 60 Hz		690 V, 50 Hz				
kW	A	HP	A	kW	A	kW	A	HP	A	kW	A		IP00	IP23
90	177	125	160	110	160	90	137	125	131			D1h/D3h	130B2847	130B2848
110	212	150	190	132	190	110	162	150	155	110	131	D1h/D3h		
132	260	200	240	160	240	132	201	200	192	132	155	D1h/D3h, D2h/D4h, D11		
160	315	250	302	200	302	160	253	250	242	160	192	D2h/D4h, D11		
200	395	300	361	250	361	200	303	300	290	200	242	D2h/D4h, D11	130B2849	130B3850
250	480	350	443	315	443	250	360	350	344	250	290	D2h/D4h, D11 E1/E2, E7, F8/F9		
315	600	450	540	355	540	315	429	400	410	315	344	E1/E2, E7, F8/F9	130B2851	130B2852
355	658	500	590	400	590	355	470	450	450	355	380	E1/E2, E7, F8/F9		
										400	410	E1/E2, F8/F9		
										450	450	E1/E2, F8/F9	130B2853	130B2854
400	745	600	678	500	678	400	523	500	500	500	500	E1/E2, E7, F8/F9		
450	800	600	730	530	730	450	596	600	570	560	570	E1/E2, E7, F8/F9		
						500	630	650	630	630	630	E1/E2, F8/F9		
450	800	600	730	530	730							F1/F3, F10/F11, F17	2x130B28492	2x130B28502
500	880	650	780	560	780	500	659	650	630			F1/F3, F10/F11, F17		
										630[2]	630[2]	F1/F3, F10/F11	2x130B2851	2x130B2852
560	990	750	890	630	890	560	763	750	730	710	730	F1/F3, F10/F11, F17		
630	1120	900	1050	710	1050	670	889	950	850	800	850	F1/F3, F10/F11, F17		
710	1260	1000	1160	800	1160	750	988	1050	945			F1/F3, F10/F11, F17	2x130B2851	2x130B2852
										900	945	F1/F3, F10/F11	2x130B2853	2x130B2854
710	1260	1000	1160	800	1160	750	988	1050	945			F2/F4, F12/F13	3x130B2849	3x130B2850
										900	945	F2/F4, F12/F13	3x130B2851	3x130B2852
800	1460	1200	1380	1000	1380	850	1108	1150	1060	1000	1060	F2/F4, F12/F13		
1000	1720	1350	1530	1100	1530	1000	1317	1350	1260	1200	1260	F2/F4, F12/F13		
						1100	1479	1550	1415	1400	1415	F2/F4, F12/F13	3x130B2853	3x130B2854

Table 5.23 dU/dt Filter Ordering Numbers

NOTE

See also *Output Filter Design Guide*

6 Mechanical Installation

6.1.1 Pre-installation

NOTE

Before performing the installation 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 (see details on the following pages, and the respective design guides):

- 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.

6.1.2 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.

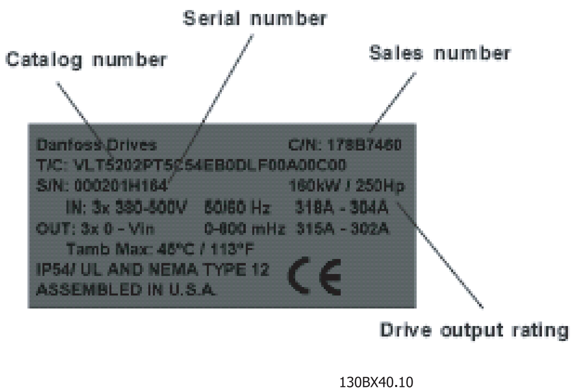


Illustration 6.1 Nameplate Label

6.1.3 Transportation and Unpacking

Before unpacking the frequency converter it is recommended to position it as close as possible to the final installation site.

Remove the box and leave the frequency converter on the pallet as long as possible.

6.1.4 Lifting

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

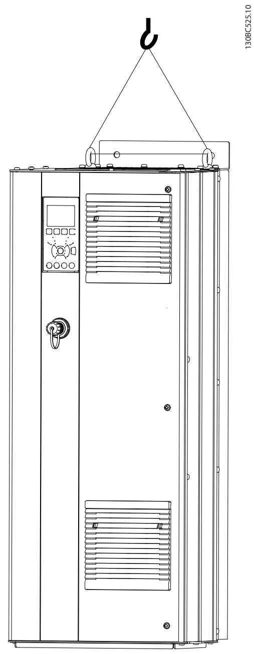


Illustration 6.2 Recommended Lifting Method, D-Frame Size

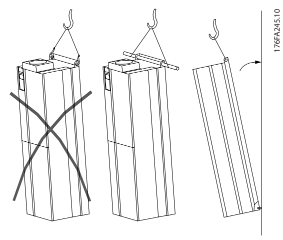


Illustration 6.3 Recommended Lifting Method, E-Frame Size

⚠WARNING

The lifting bar must be able to handle the weight of the frequency converter. See *6.1.5 Mechanical Dimensions* for the weight of the different frame sizes. 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.

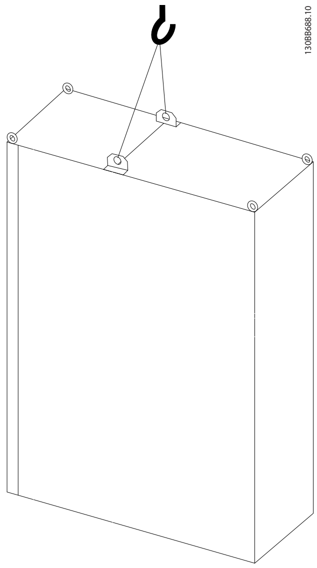


Illustration 6.4 Recommended Lifting Method, Frame Sizes F1, F2, F9 and F10

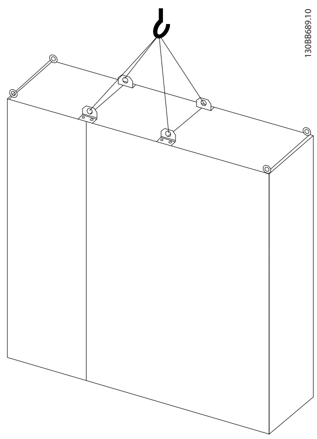


Illustration 6.5 Recommended Lifting Method, Frame Sizes F3, F4, F11, F12 and F13

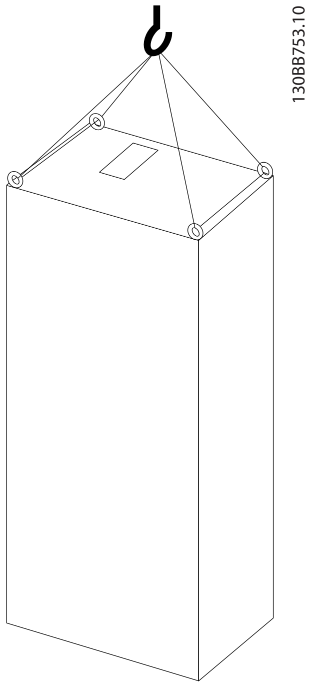


Illustration 6.6 Recommended Lifting Method, Frame Sizes F8

NOTE

The plinth is provided in the same packaging as the frequency converter but is not attached to frame sizes F1-F4 during shipment. The plinth is required to allow airflow to the frequency converter to provide proper cooling. Position F-Frames on top of the plinth in the final installation location. The angle from the top of the frequency converter to the lifting cable should be 60° or greater.
In addition to the drawings above, a spreader bar is an acceptable way to lift the F-Frame.

6

6.1.5 Mechanical Dimensions

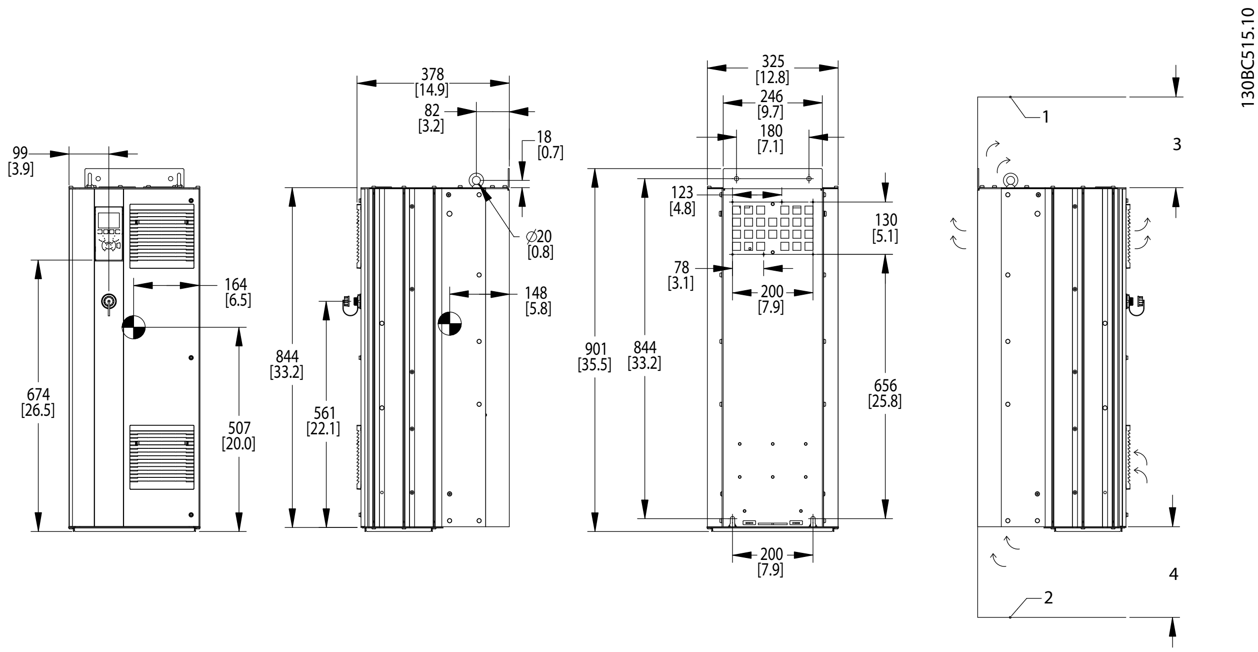


Illustration 6.7 Mechanical Dimensions, D1h

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

Table 6.1 Legend to *Illustration 6.7*

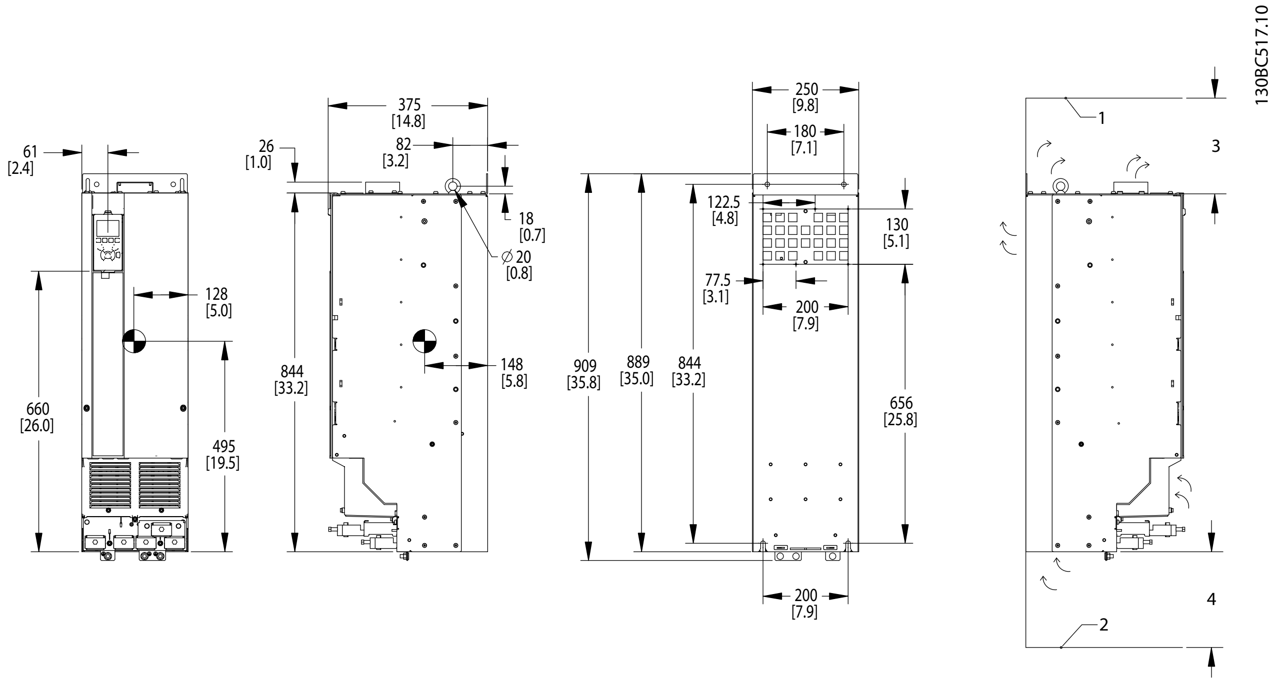


Illustration 6.8 Mechanical Dimensions, D3h

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

Table 6.2 Legend to *Illustration 6.8*

6

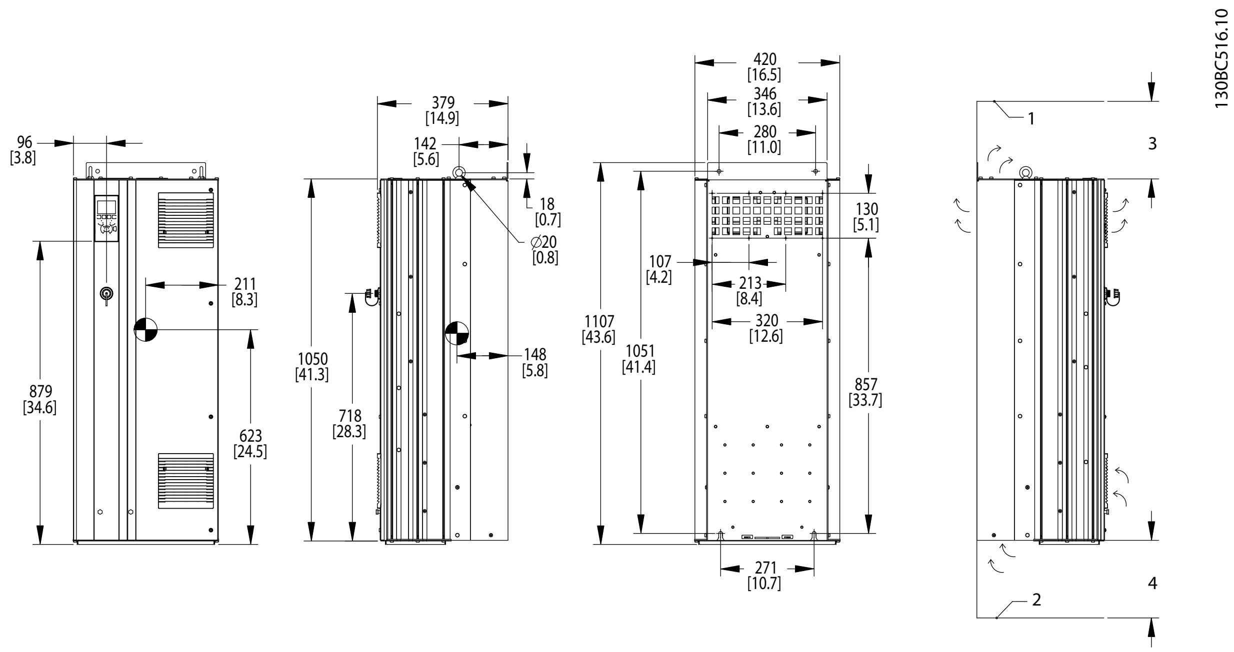


Illustration 6.9 Mechanical Dimensions, D2h

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

Table 6.3 Legend to *Illustration 6.9*

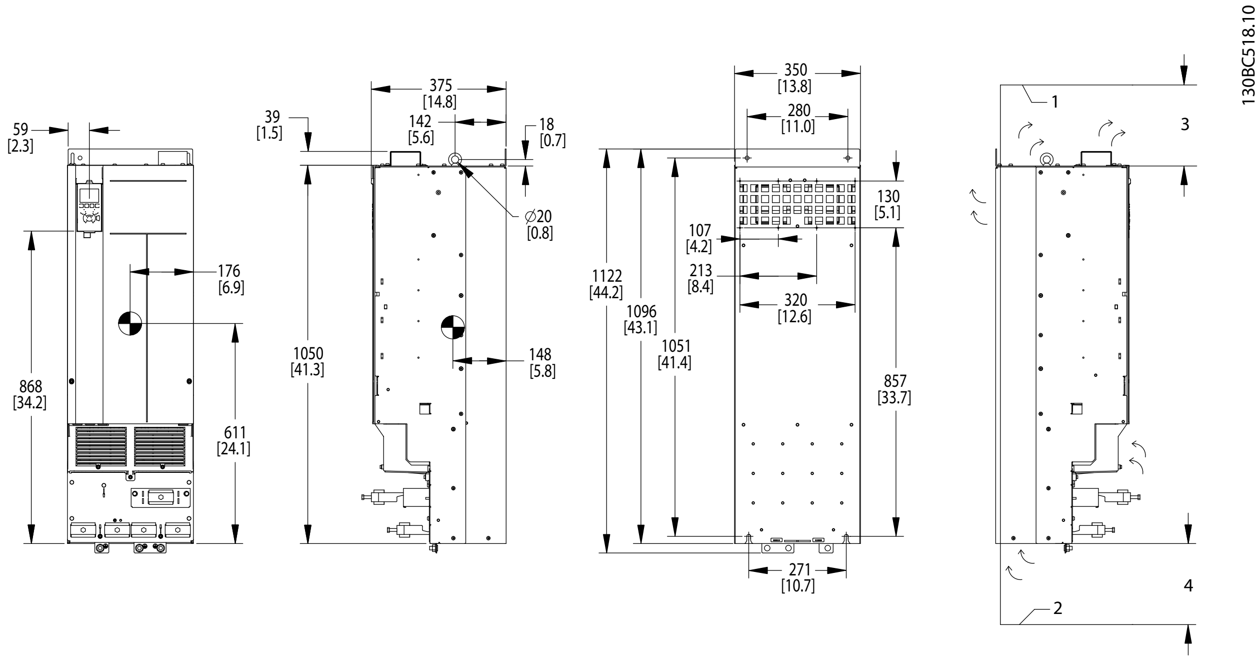


Illustration 6.10 Mechanical Dimensions, D4h

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

Table 6.4 Legend to *Illustration 6.10*

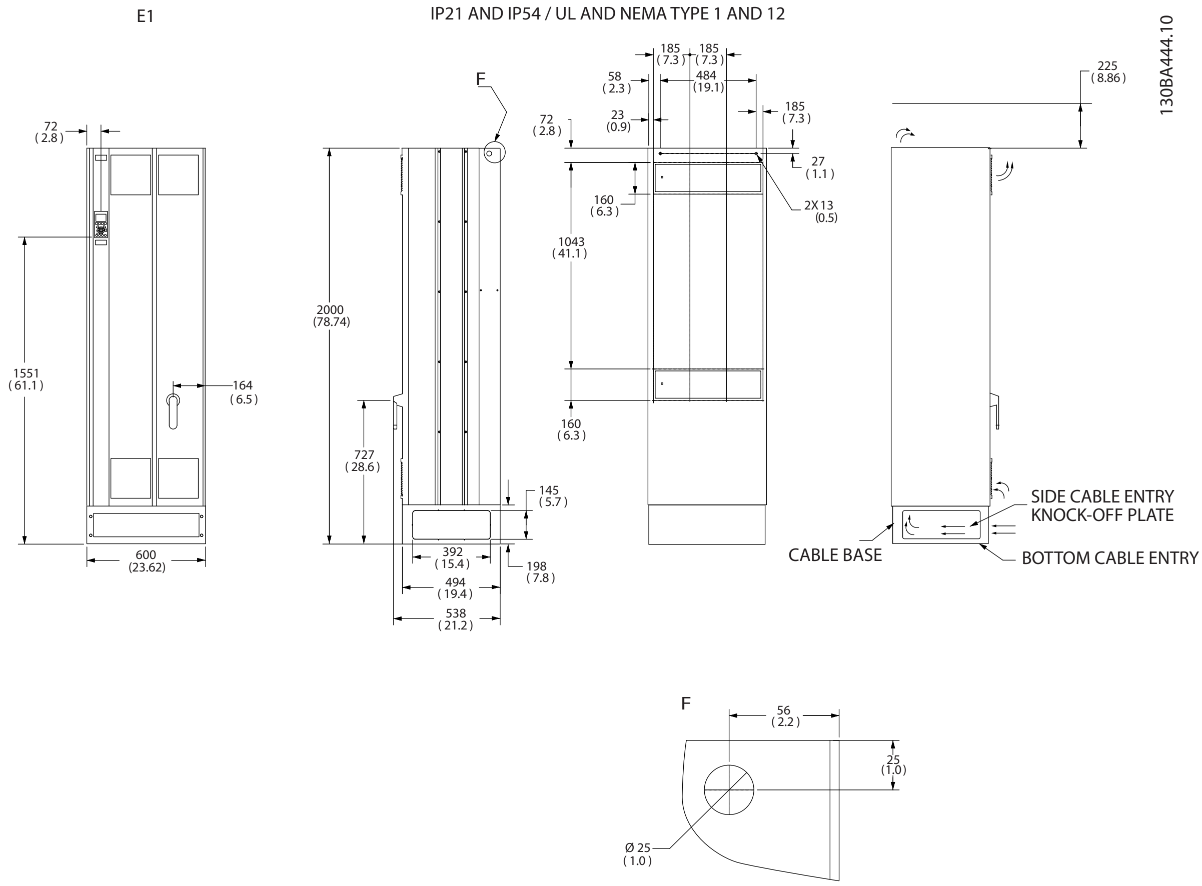


Illustration 6.11 Mechanical Dimensions, E1

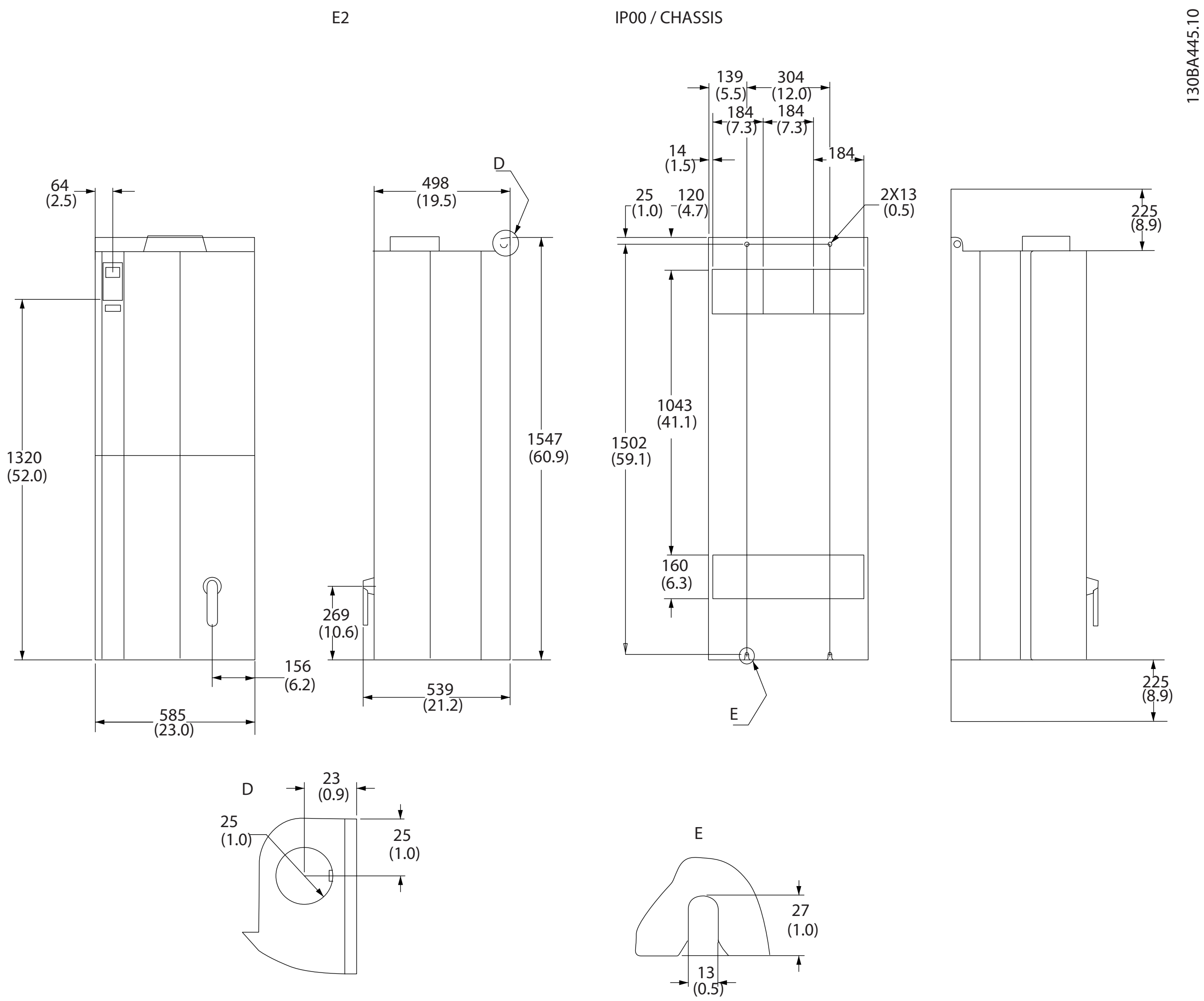


Illustration 6.12 Mechanical Dimensions, E2

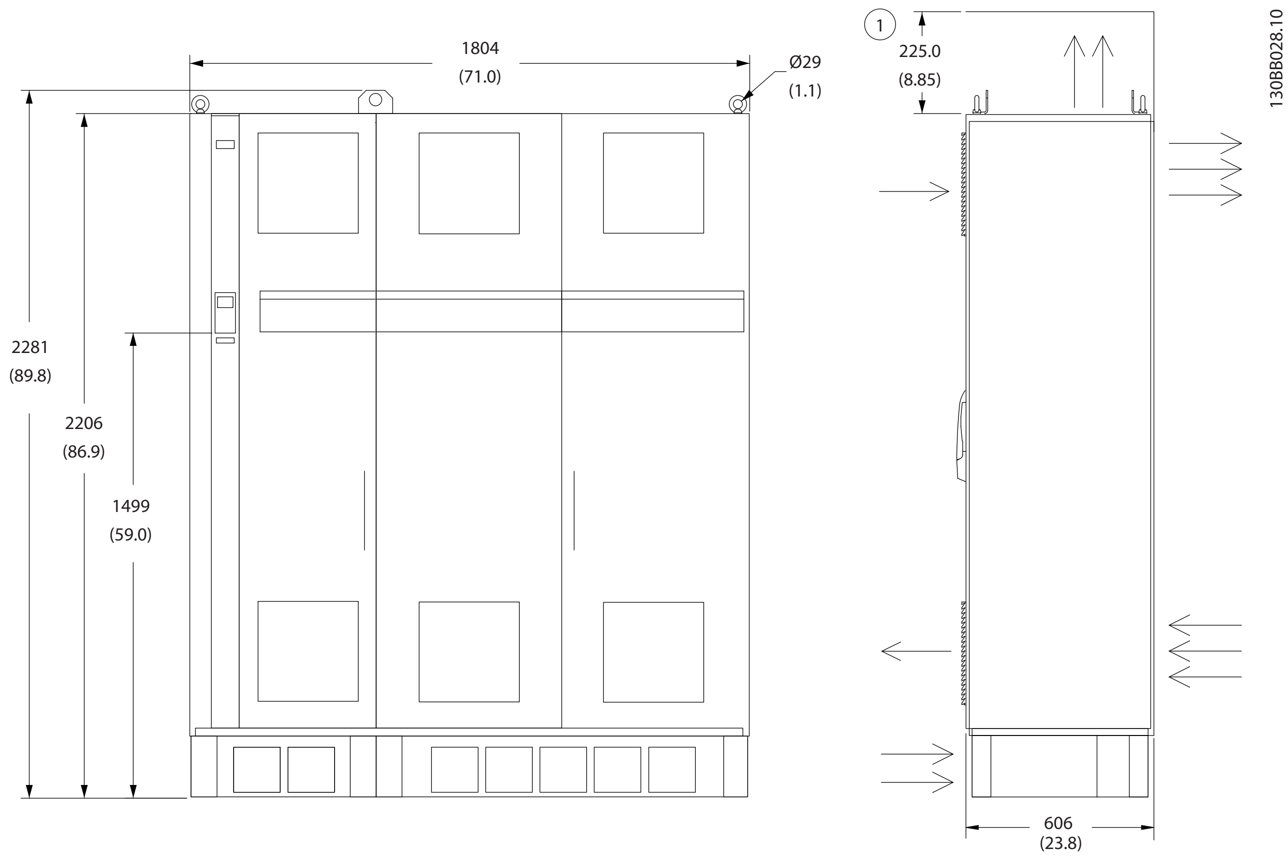


Illustration 6.13 Mechanical Dimensions, F2

1) Minimum clearance from ceiling

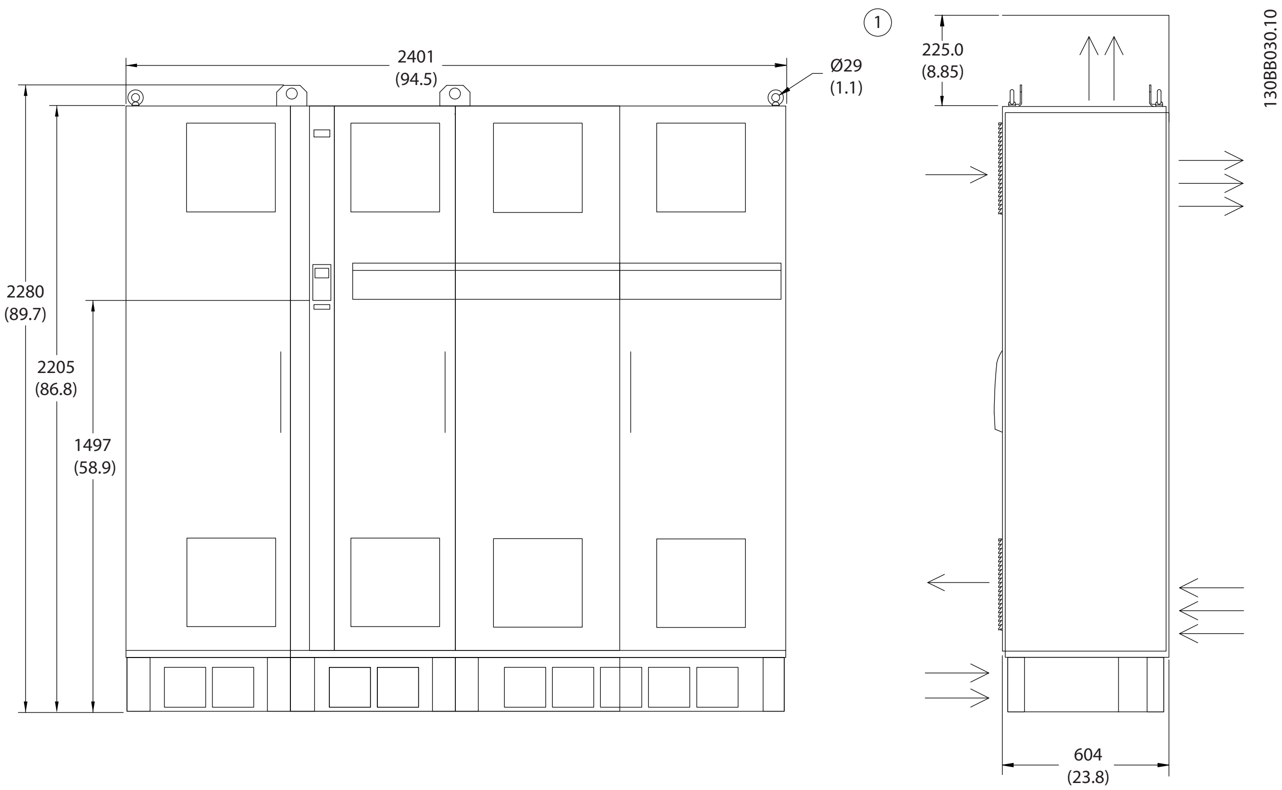


Illustration 6.14 Mechanical Dimensions, F4

1) Minimum clearance from ceiling

6

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 6.5 Mechanical Dimensions, Frame Size D

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 6.6 Mechanical Dimensions, Frame Sizes E and F

6.1.6 Mechanical Dimensions, 12-Pulse Units

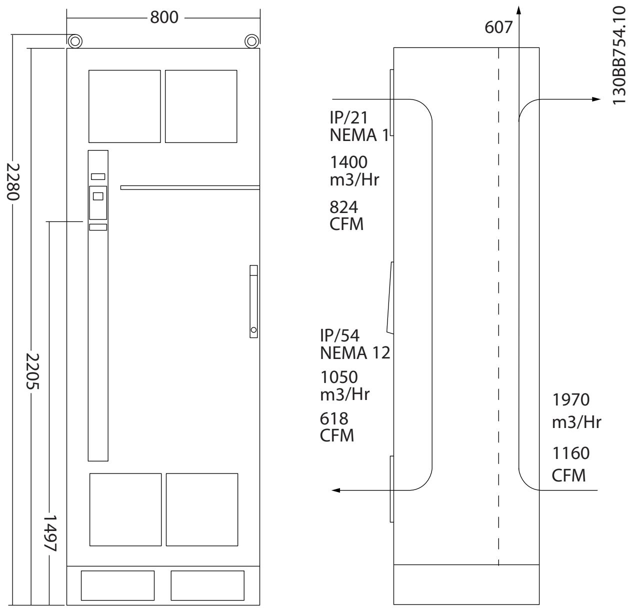


Illustration 6.15 Mechanical Dimensions, F8

All dimensions in millimeters

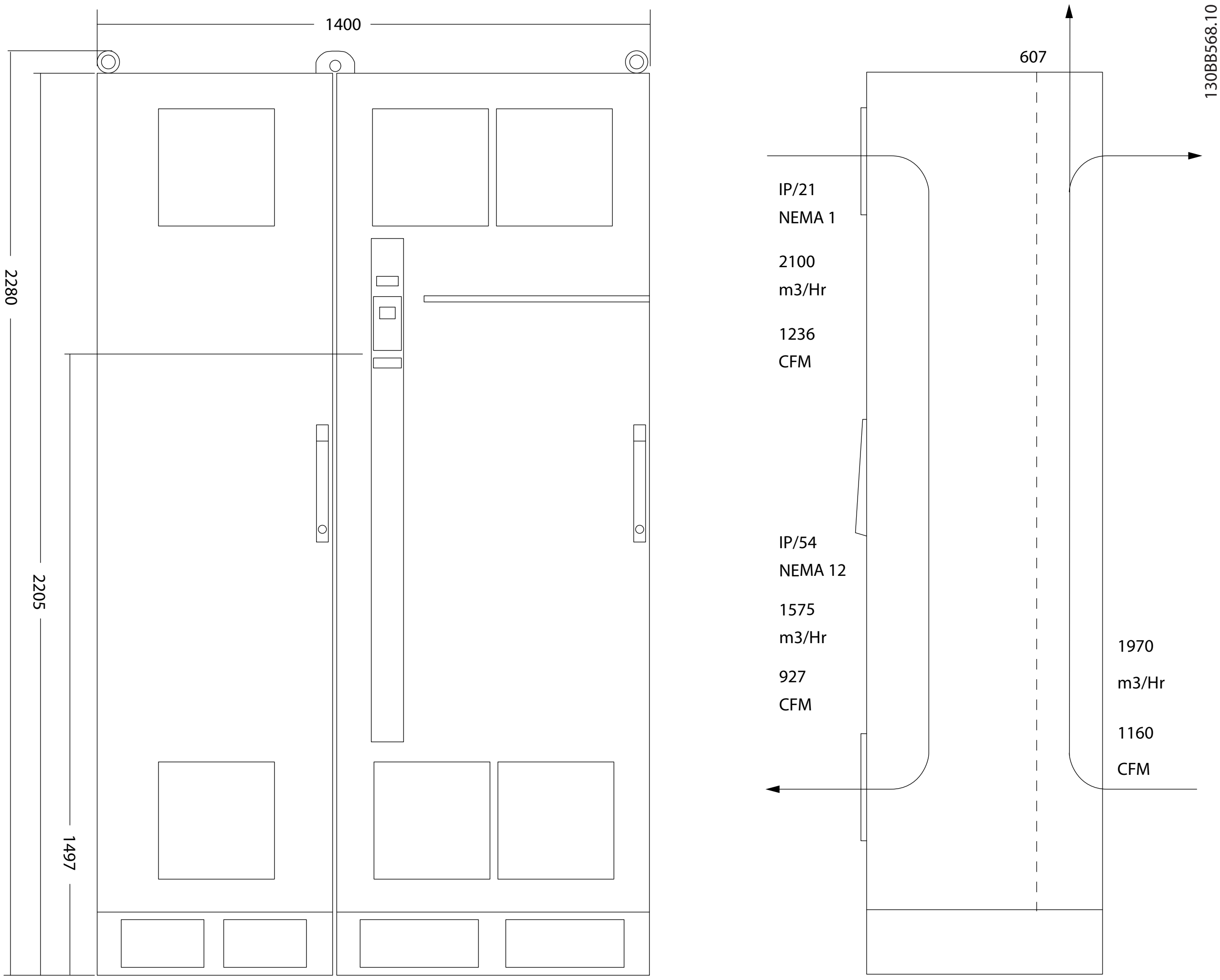


Illustration 6.16 Mechanical Dimensions, F9

All dimensions in millimeters

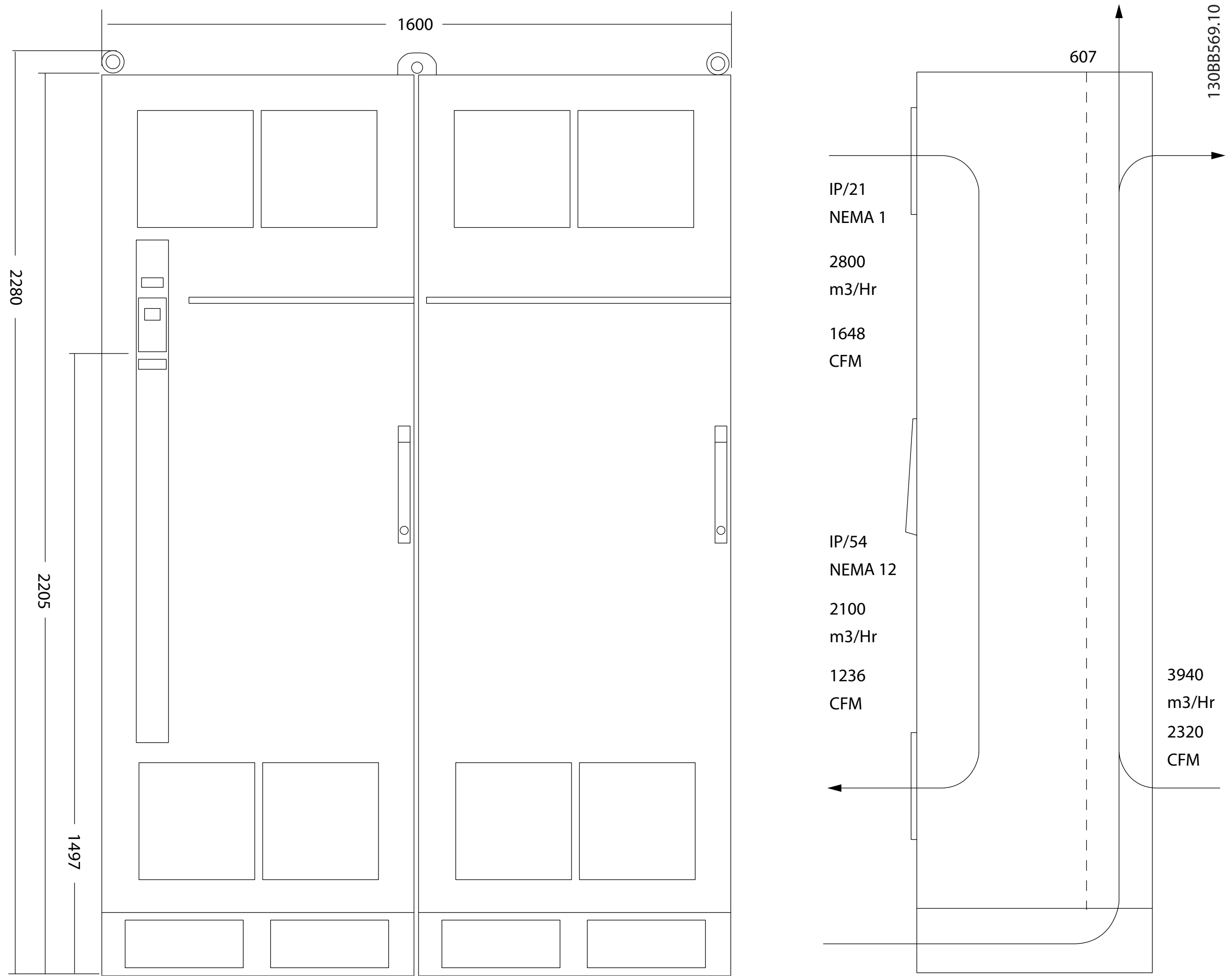


Illustration 6.17 Mechanical Dimensions, F10

All dimensions in millimeters

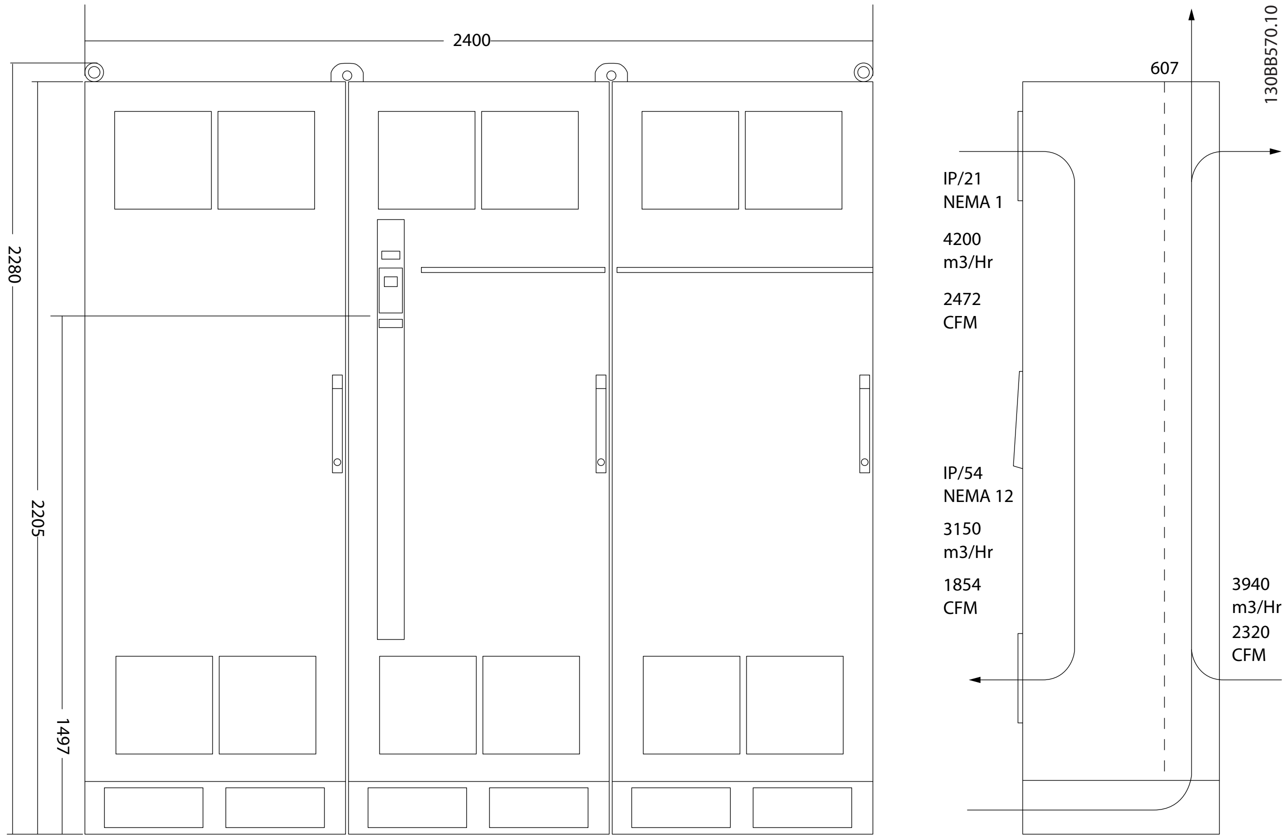


Illustration 6.18 Mechanical Dimensions, F11

All dimensions in millimeters

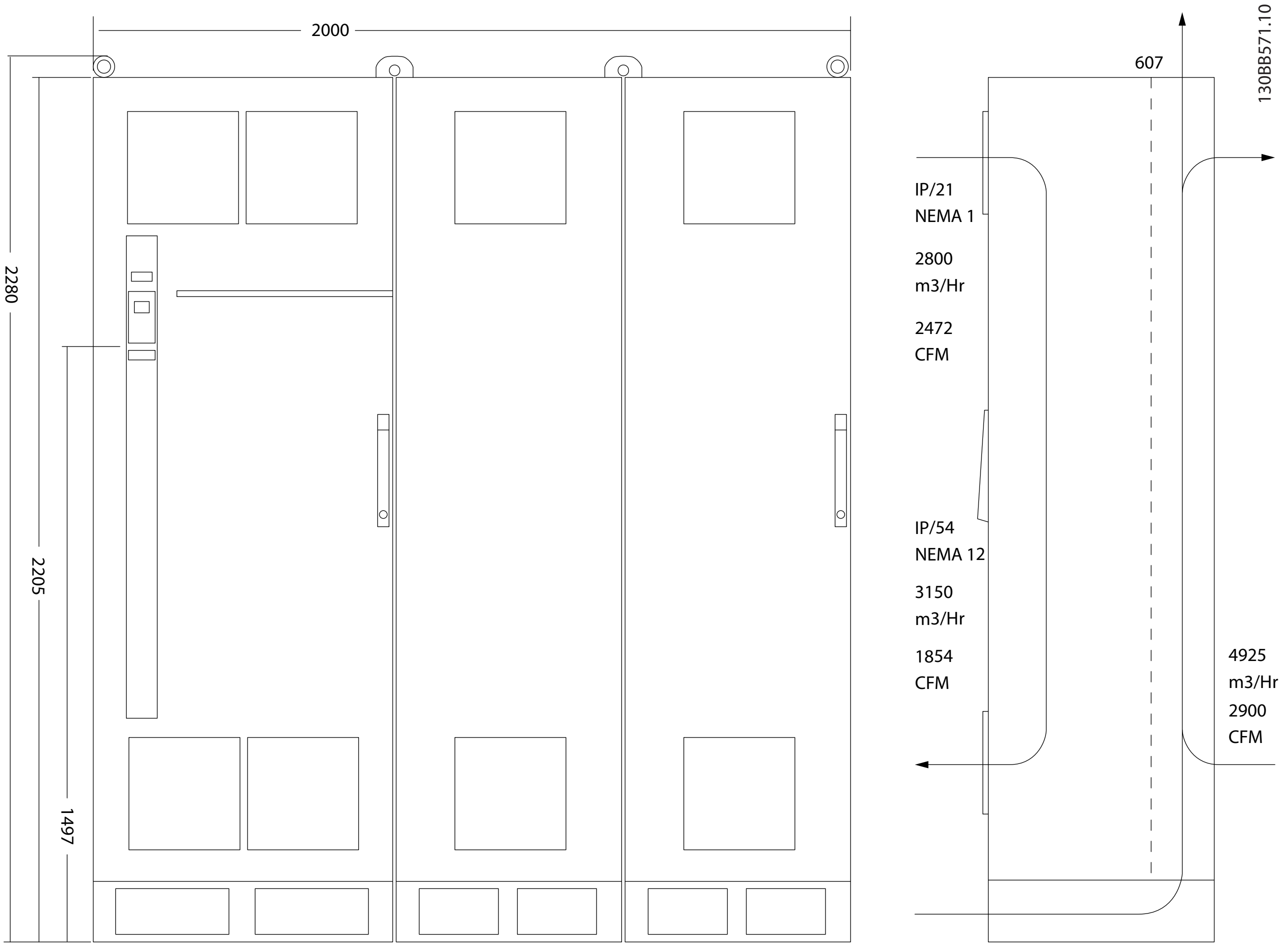


Illustration 6.19 Mechanical Dimensions, F12

All dimensions in millimeters

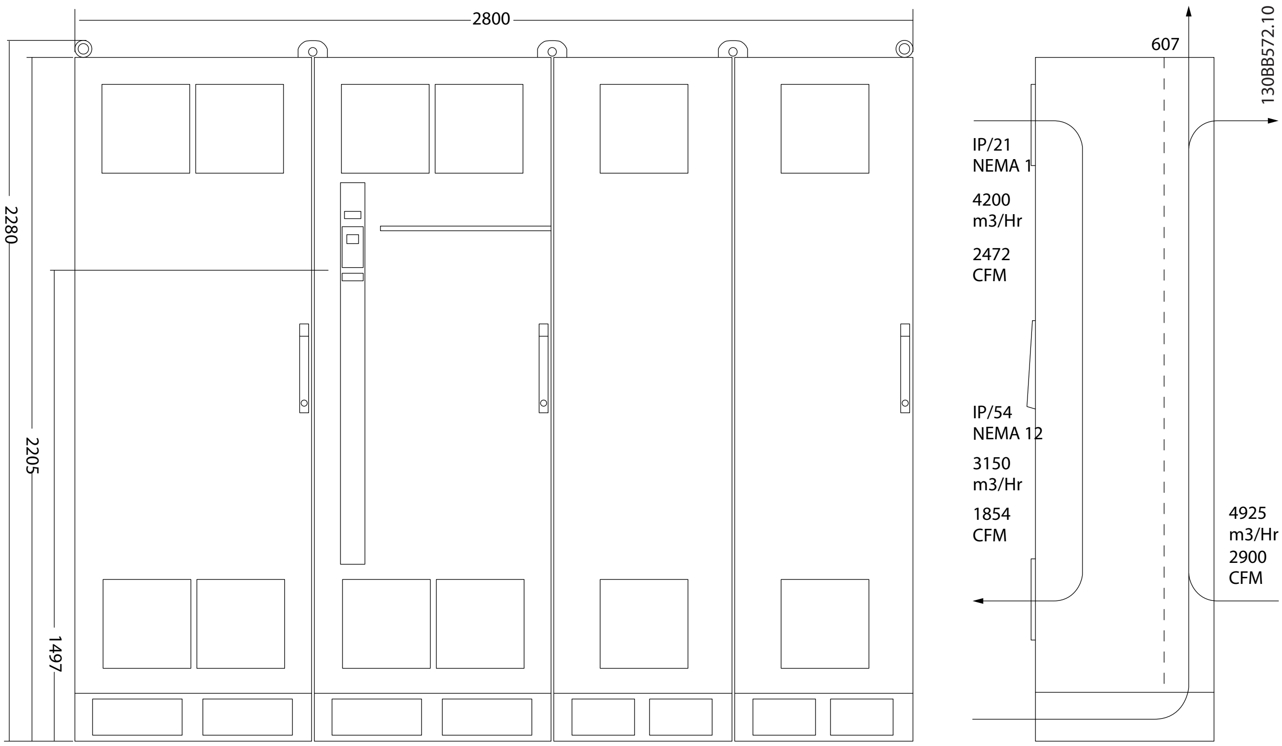


Illustration 6.20 Mechanical Dimensions, F13

All dimensions in millimeters

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	2324	2324	2324	2324	2324
	Width	970	1568	1760	2559	2160	2960
	Depth	1130	1130	1130	1130	1130	1130
Drive dimensions [mm]	Height	2204	2204	2204	2204	2204	2204
	Width	800	1400	1600	2200	2000	2600
	Depth	606	606	606	606	606	606
Max weight [kg]		447	669	893	1116	1037	1259

Table 6.7 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 result and to avoid additional work during installation. The mechanical drawings in *6.1.5 Mechanical Dimensions* provide more information about the space demands.

6.2.1 Tools Needed

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

- Drill with 10 mm or 12 mm drill
- Tape measure
- Wrench with relevant metric sockets (7-17 mm)
- Extensions to wrench
- 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, i.e. by using cable clamps.

NOTE

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.

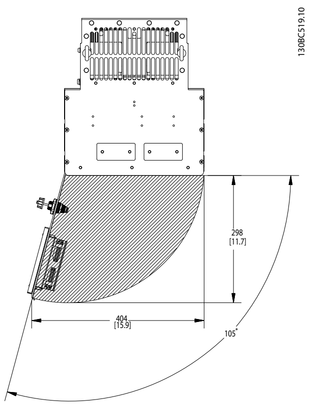


Illustration 6.21 Front Clearance of IP21/IP54 Enclosure Type, Frame Size D1h.

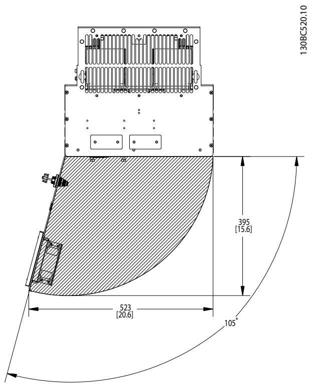


Illustration 6.22 Front Clearance of IP21/IP54 Enclosure Type, Frame Size D2h.

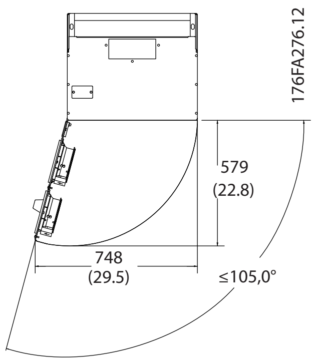


Illustration 6.23 Front Clearance of IP21/IP54 Enclosure Type, Frame Size E1.

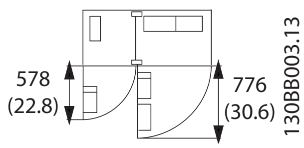


Illustration 6.24 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F1

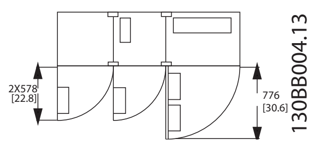


Illustration 6.25 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F3

6

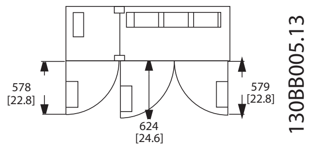


Illustration 6.26 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F2

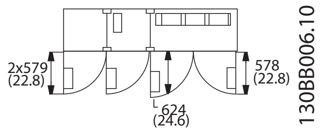


Illustration 6.27 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F4

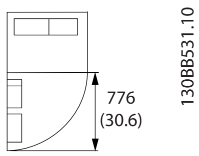


Illustration 6.28 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F8

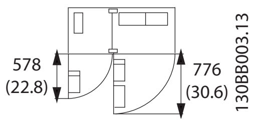


Illustration 6.29 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F9

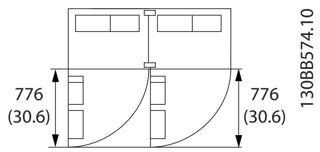


Illustration 6.30 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F10

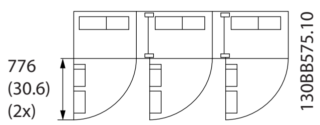


Illustration 6.31 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F11

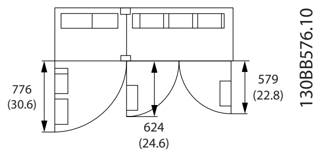


Illustration 6.32 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F12

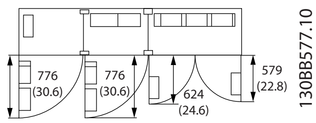


Illustration 6.33 Front Clearance of IP21/IP54 Enclosure Type, Frame Size F13

6.2.3 Terminal Locations - Frame Size D

Take the following position of the terminals into consideration when designing for cables access. Dimensions are shown in mm [in].

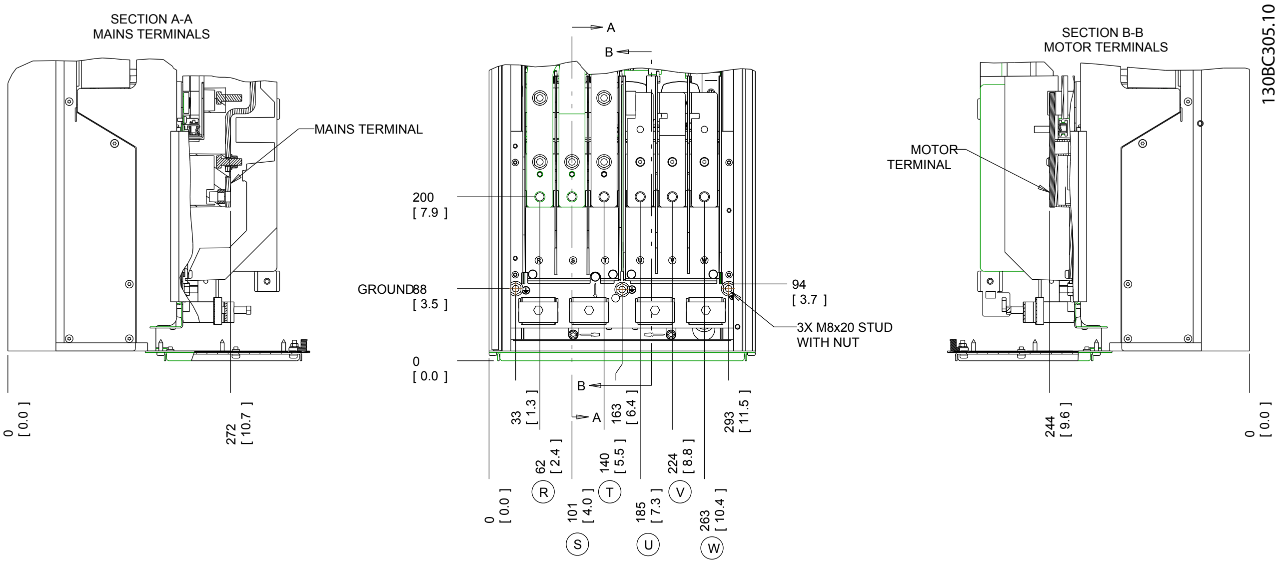


Illustration 6.34 Position of Power Connections, Frame Size D1h

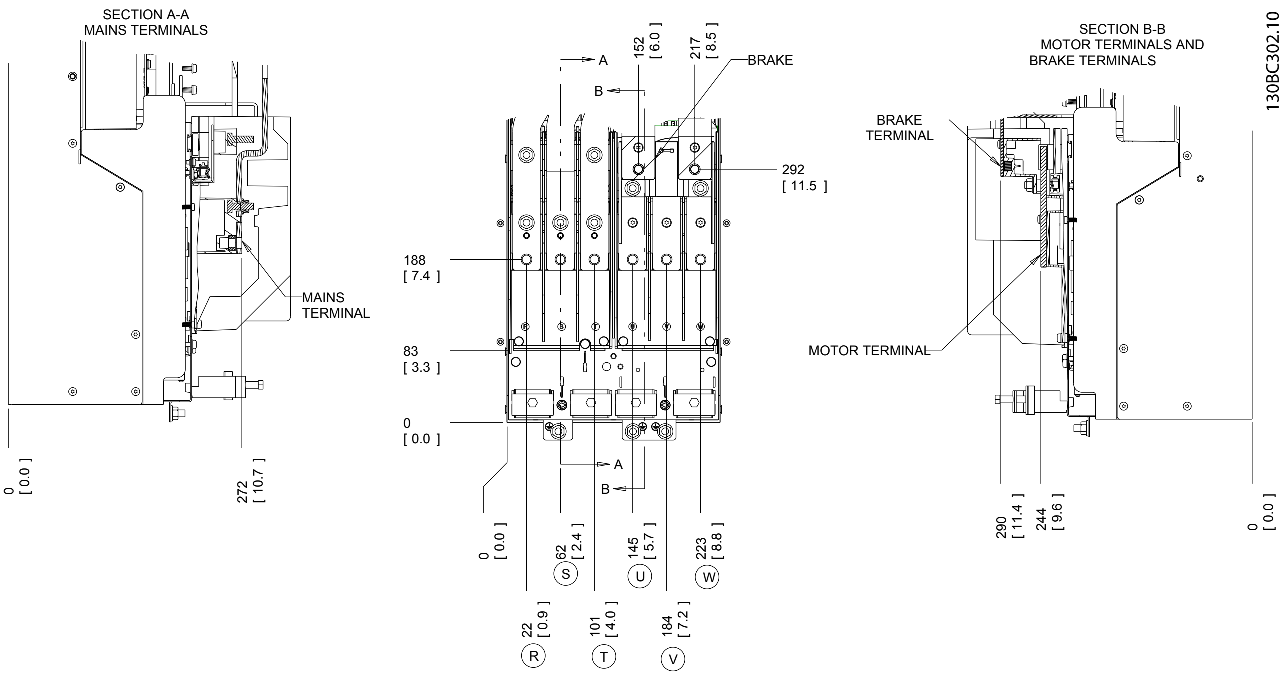


Illustration 6.35 Position of Power Connections, Frame Size D3h

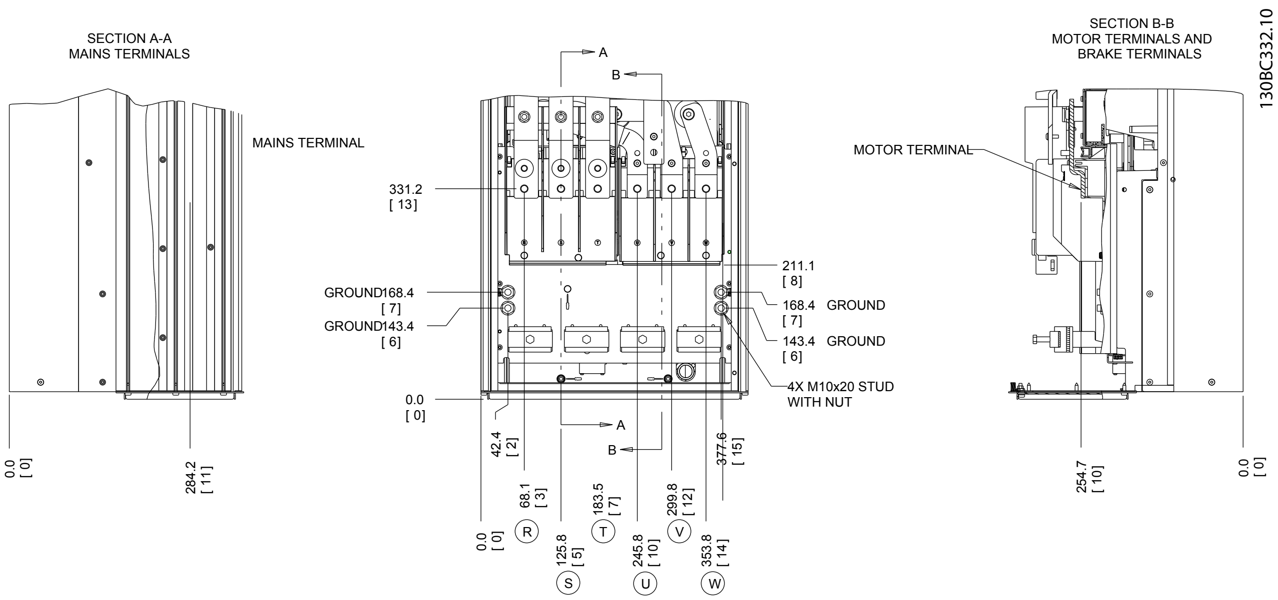


Illustration 6.36 Position of Power Connections, Frame Size D2h

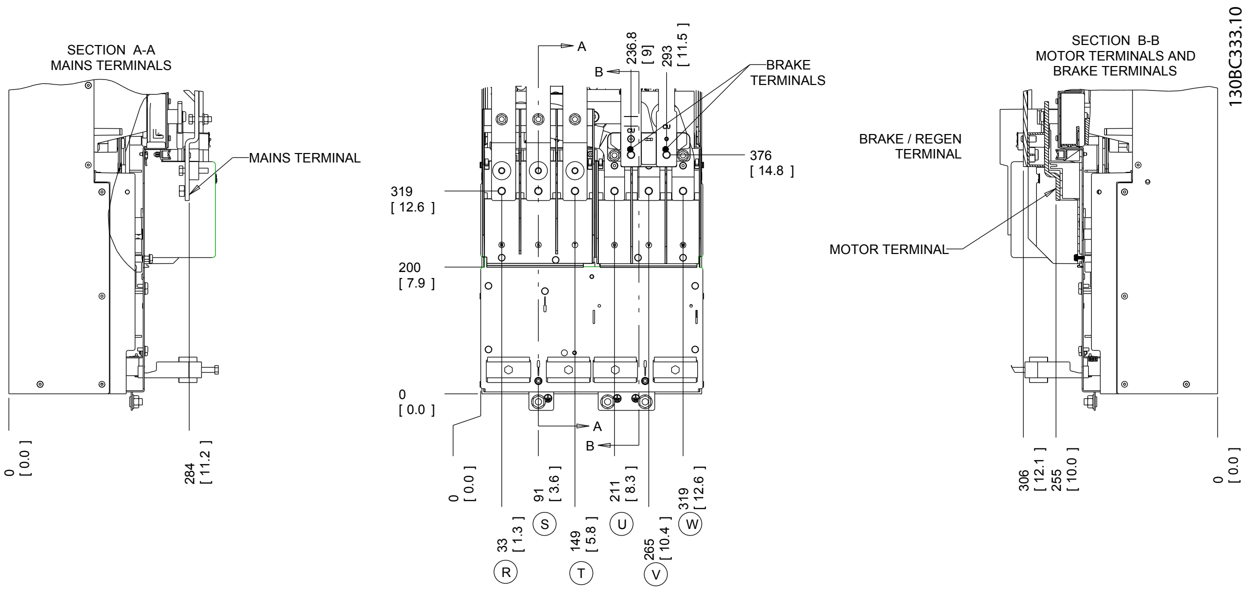


Illustration 6.37 Position of Power Connections, Frame Size D4h

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

6.2.4 Terminal Locations - Frame Size E

Terminal Locations - E1

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

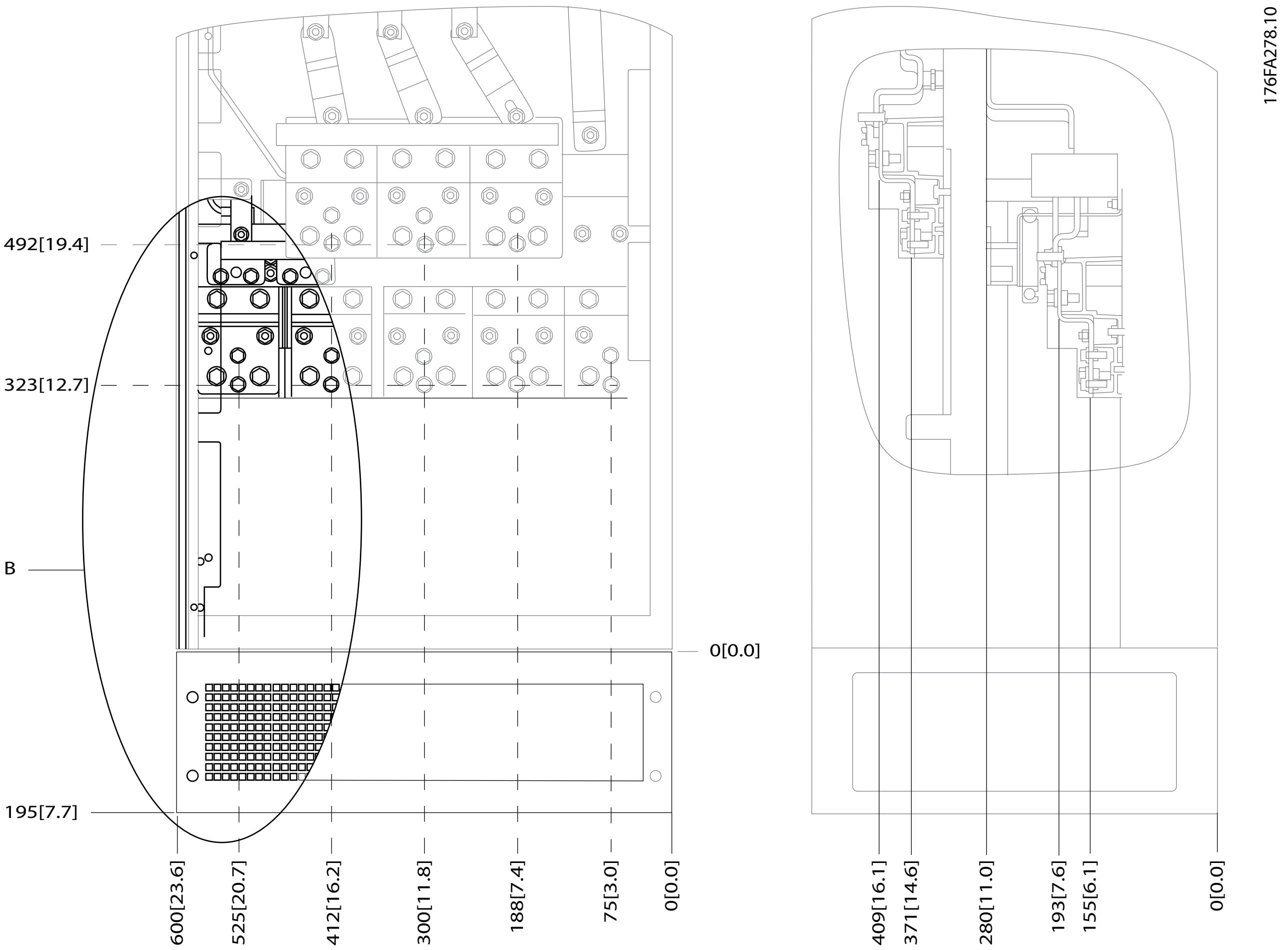


Illustration 6.38 IP21 (NEMA Type 1) and IP54 (NEMA Type 12) Enclosure Power Connection Positions

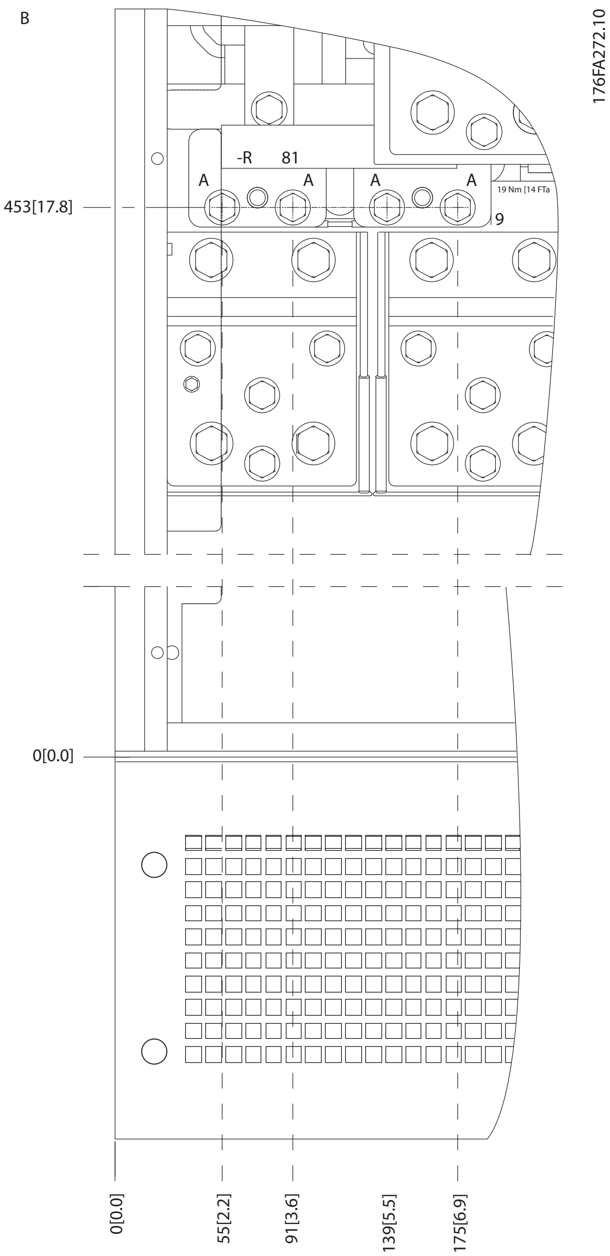


Illustration 6.39 IP21 (NEMA type 1) and IP54 (NEMA type 12) Enclosure Power Connection Positions (detail B)

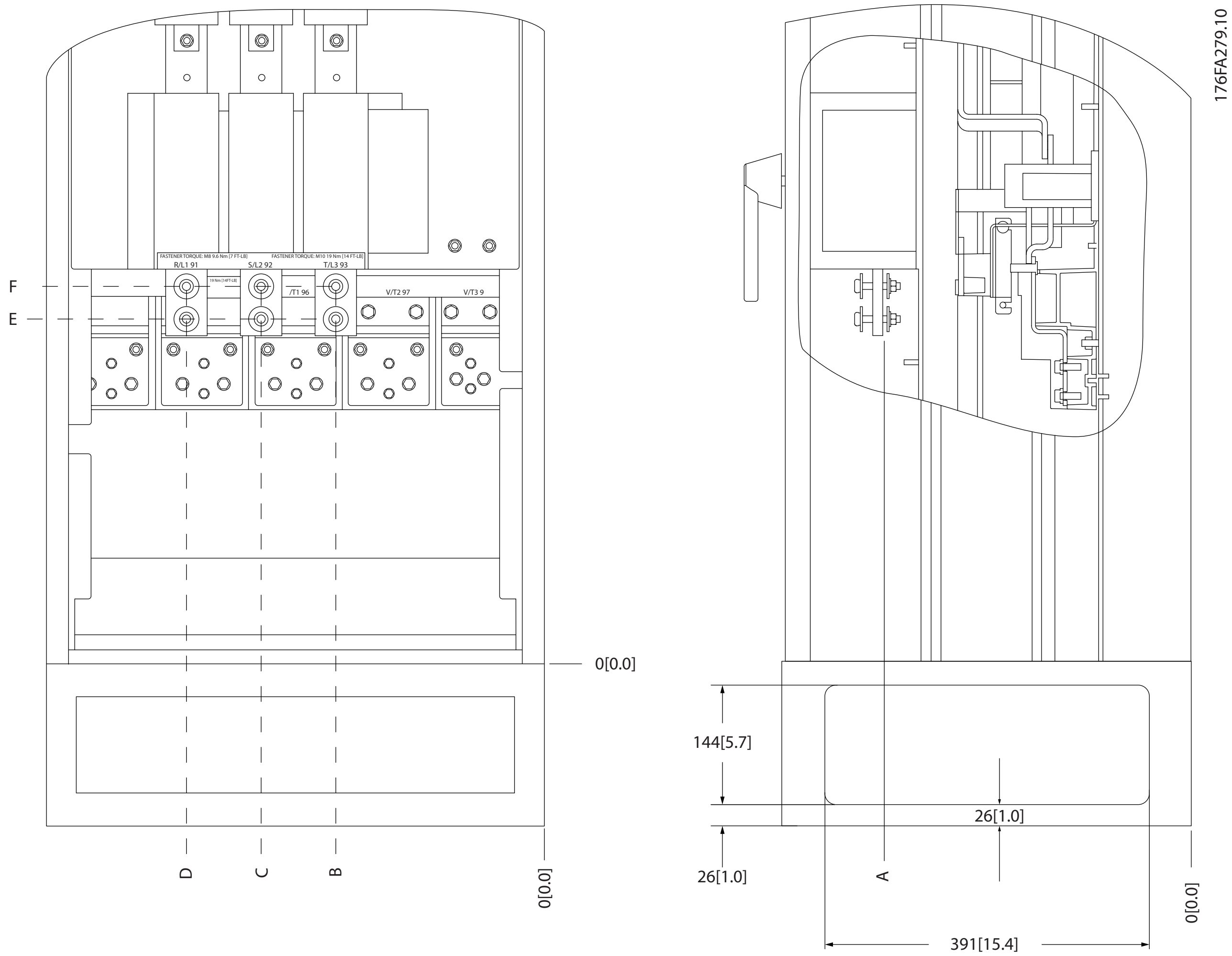


Illustration 6.40 IP21 (NEMA type 1) and IP54 (NEMA type 12) Enclosure Power Connection Position of Disconnect Switch

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 6.8 Legend to *Illustration 6.40*

Terminal locations - Frame size E2

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

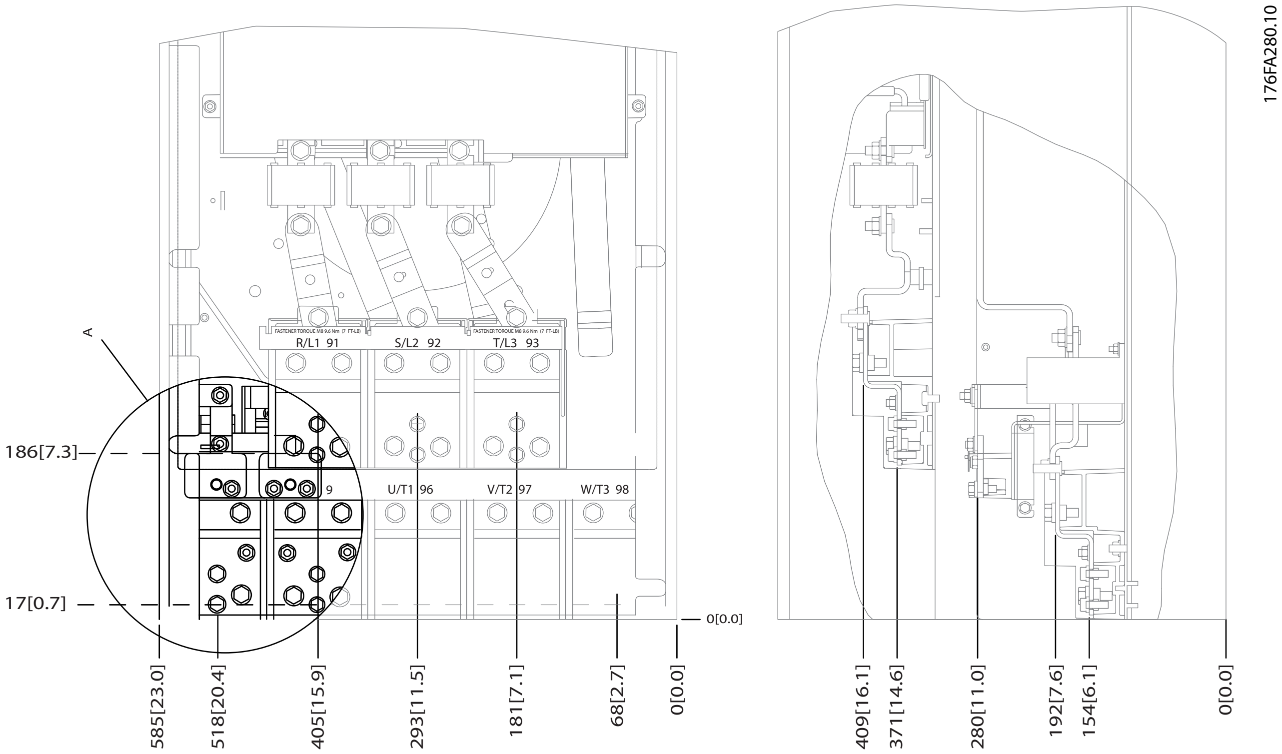


Illustration 6.41 IP00 Enclosure Power Connection Positions

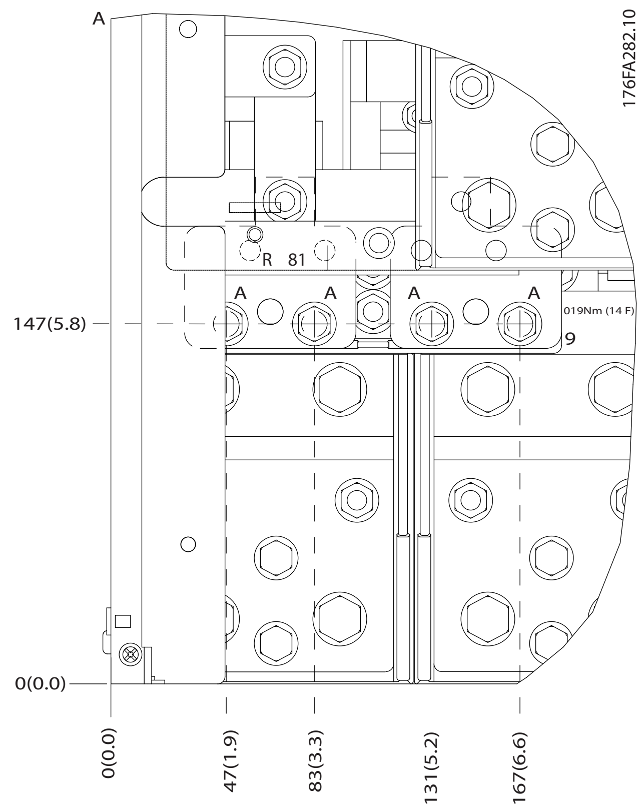


Illustration 6.42 IP00 Enclosure Power Connection Positions

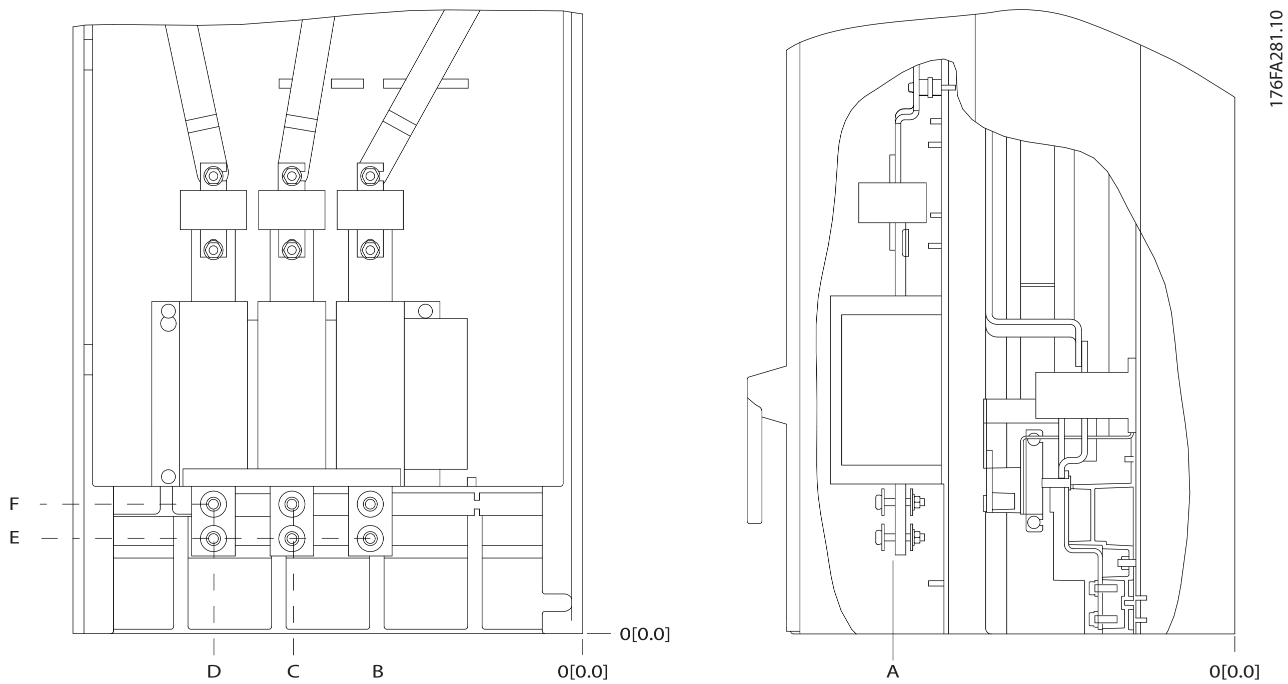


Illustration 6.43 IP00 Enclosure Power Connections, Position of Disconnect Switch

NOTE

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

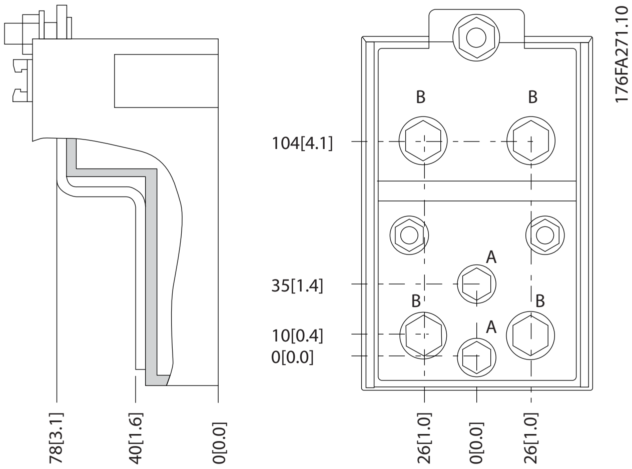


Illustration 6.44 Terminal in Detail

NOTE

Power connections can be made to positions A or B

Frame size	Unit type	Dimension for disconnect terminal					
	IP00/CHASSIS	A	B	C	D	E	F
E2	250/315kW (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 6.9

6.2.5 Terminal Locations - Frame Size F

NOTE

The F-Frames have four 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 have an additional options cabinet to the left of the rectifier cabinet. The F3 is an F1 with an additional options cabinet. The F4 is an F2 with an additional options cabinet.

Terminal locations - Frame size F1 and F3

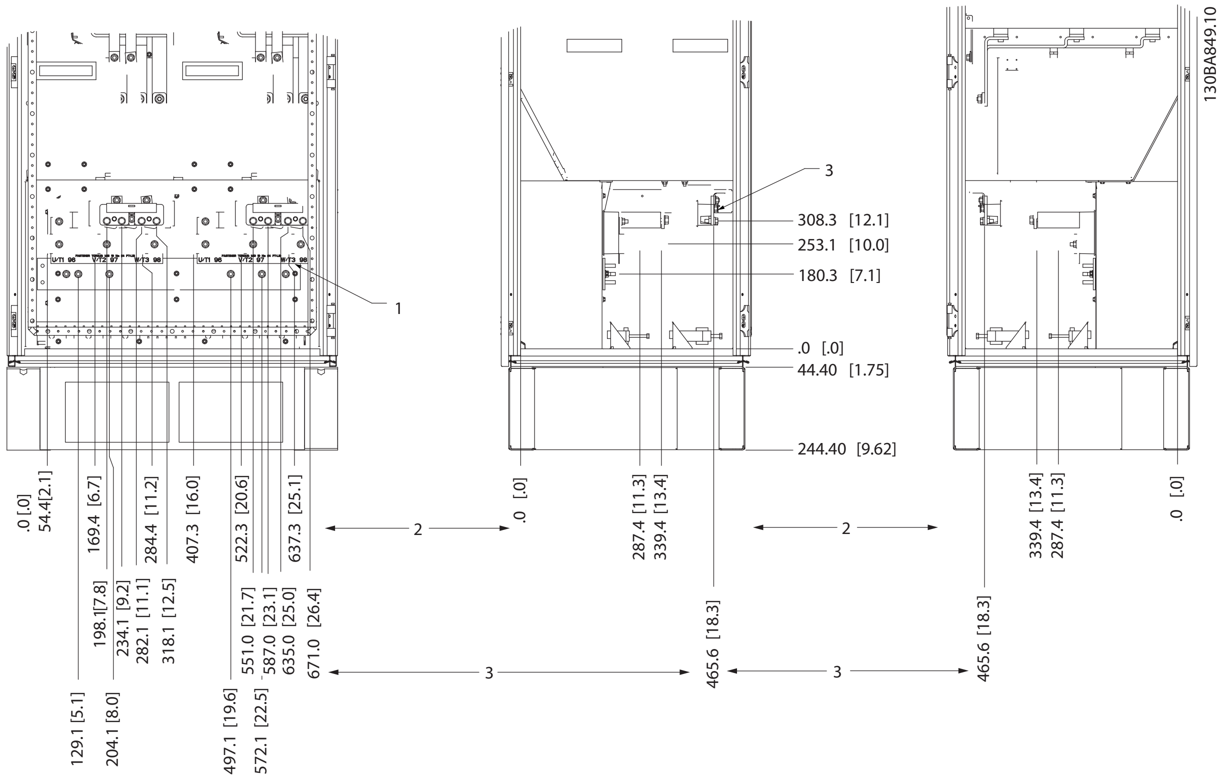


Illustration 6.45 Terminal Locations - Inverter Cabinet - F1 and F3 (Front, Left and Right Side View). The Gland Plate is 42 mm below .0 level.

1) Earth ground bar

2) Motor terminals

3) Brake terminals

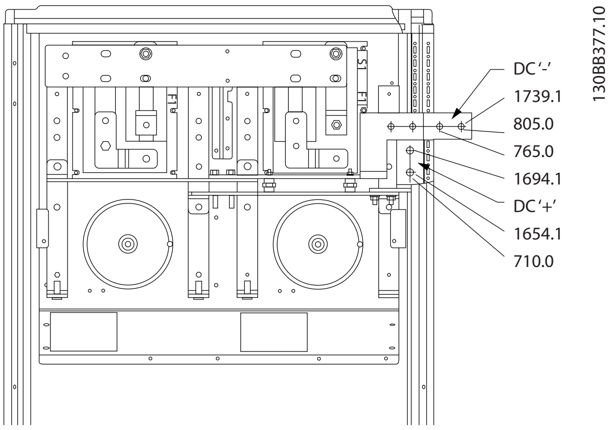


Illustration 6.46 Terminal Locations - Regeneration Terminals - F1 and F3

Terminal locations - Frame size F2 and F4

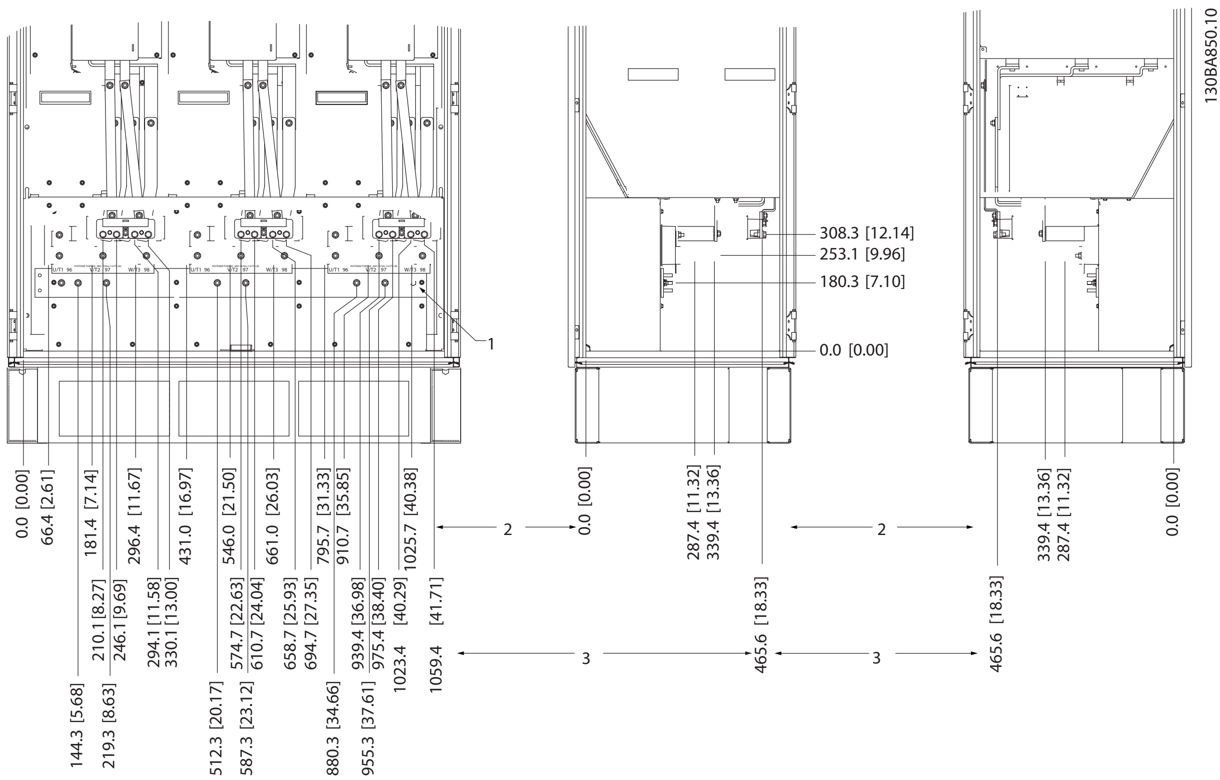


Illustration 6.47 Terminal Locations - Inverter Cabinet - F2 and F4 (Front, Left and Right Side View). The Gland Plate is 42 mm below .0 level.

1) Earth ground bar

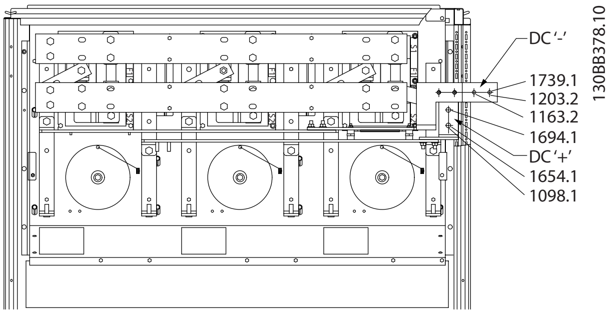
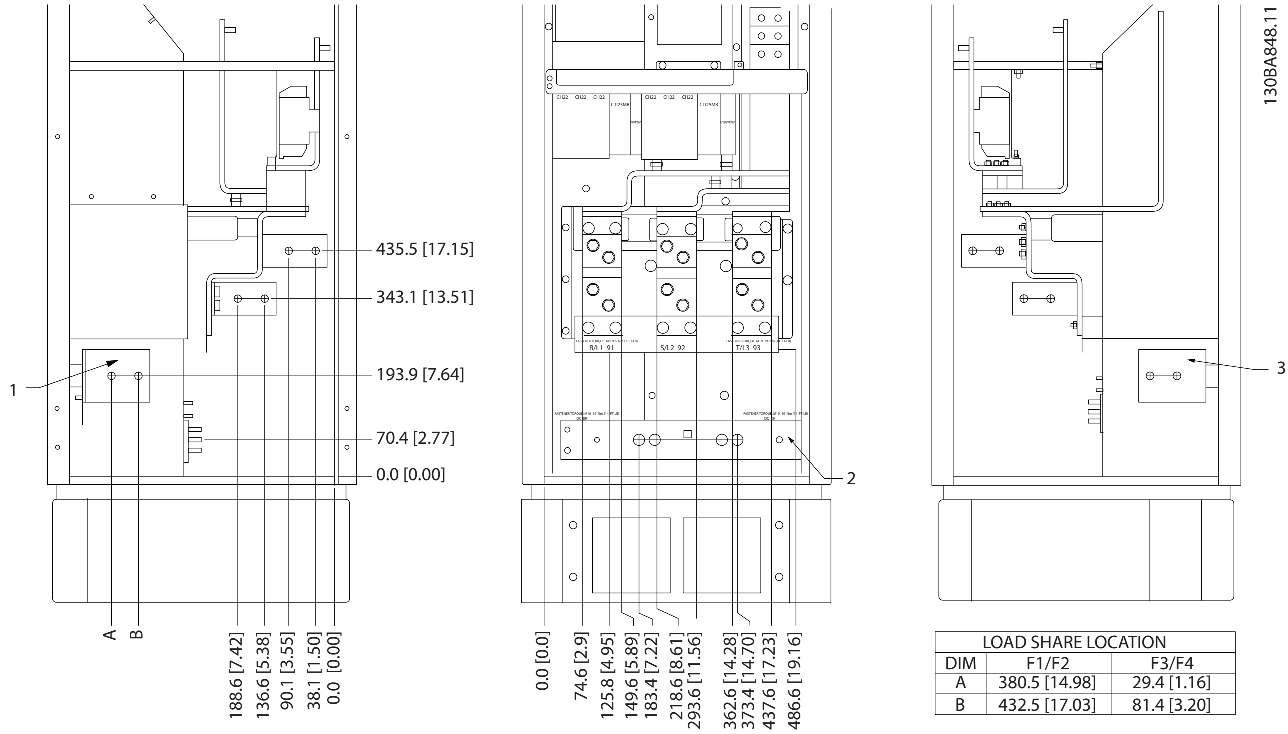


Illustration 6.48 Terminal Locations - Regeneration Terminals - F2 and F4

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 6.49 Terminal Locations - Rectifier (Left, Front and Right Side View). The Gland Plate is 42 mm below .0 level.

1) Loadshare Terminal (-)

2) Earth ground bar

3) Loadshare Terminal (+)

Terminal locations - Options Cabinet (F3 and F4)

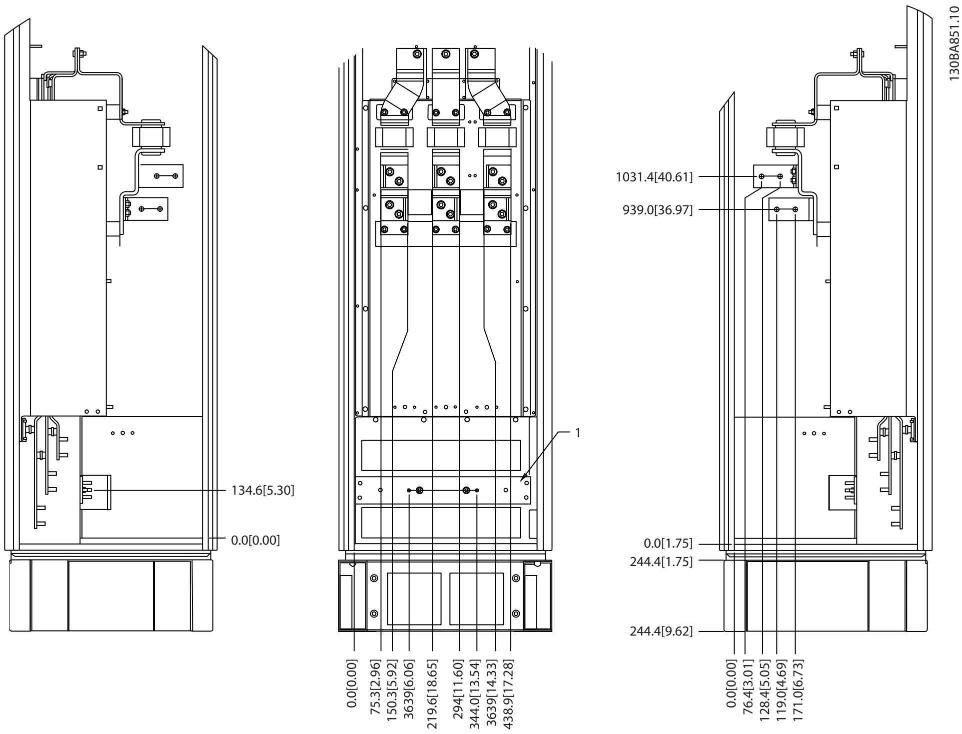


Illustration 6.50 Terminal Locations - Options Cabinet (Left, Front and Right Side View). The Gland Plate is 42 mm below .0 level.
1) Earth ground bar

Terminal locations - Options Cabinet with circuit breaker/molded case switch (F3 and F4)

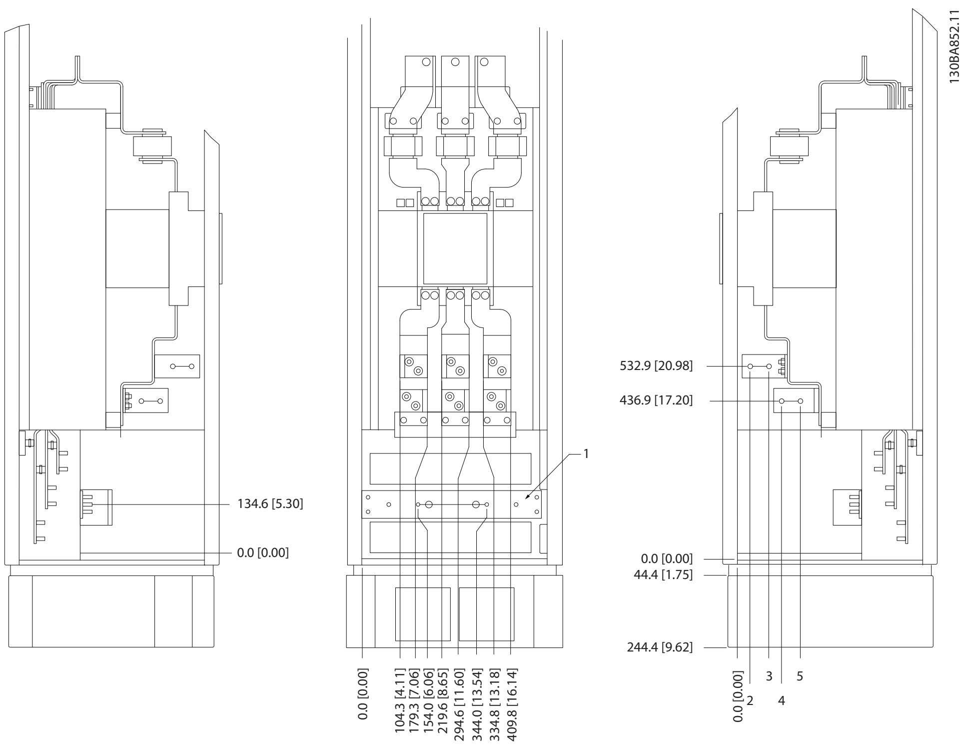


Illustration 6.51 Terminal Locations - Options Cabinet with Circuit Breaker/Molded Case Switch (Left, Front and Right Side View). The Gland Plate is 42 mm below .0 level.
1) Earth ground bar

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 6.10 Dimension for Terminal

6.2.6 Terminal Locations, F8-F13 - 12-Pulse

The 12-pulse F-Frame enclosures have six different sizes, F8, F9, F10, F11, F12 and F13 The F8, F10 and F12 consisting of an inverter cabinet on the right and rectifier cabinet on the left. The F9, F11 and F13 have an additional options cabinet to the left of the rectifier cabinet. The F9 is an F8 with an additional options cabinet. The F11 is an F10 with an additional options cabinet. The F13 is an F12 with an additional options cabinet.

Terminal locations - Inverter and Rectifier Frame size F8 and F9

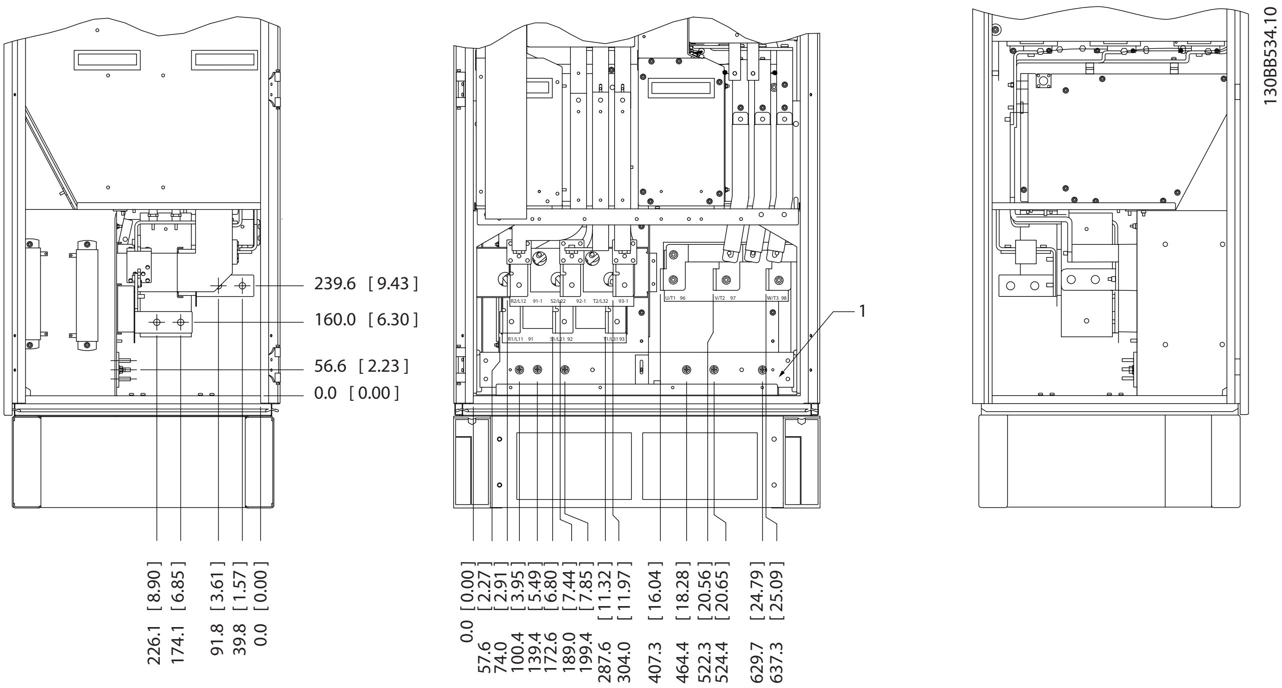


Illustration 6.52 Terminal Locations - Inverter and Rectifier Cabinet - F8 and F9 (Front, Left and Right Side View). The Gland Plate is 42 mm below .0 level.

1) Earth ground bar

Terminal locations - Inverter Frame size F10 and F11

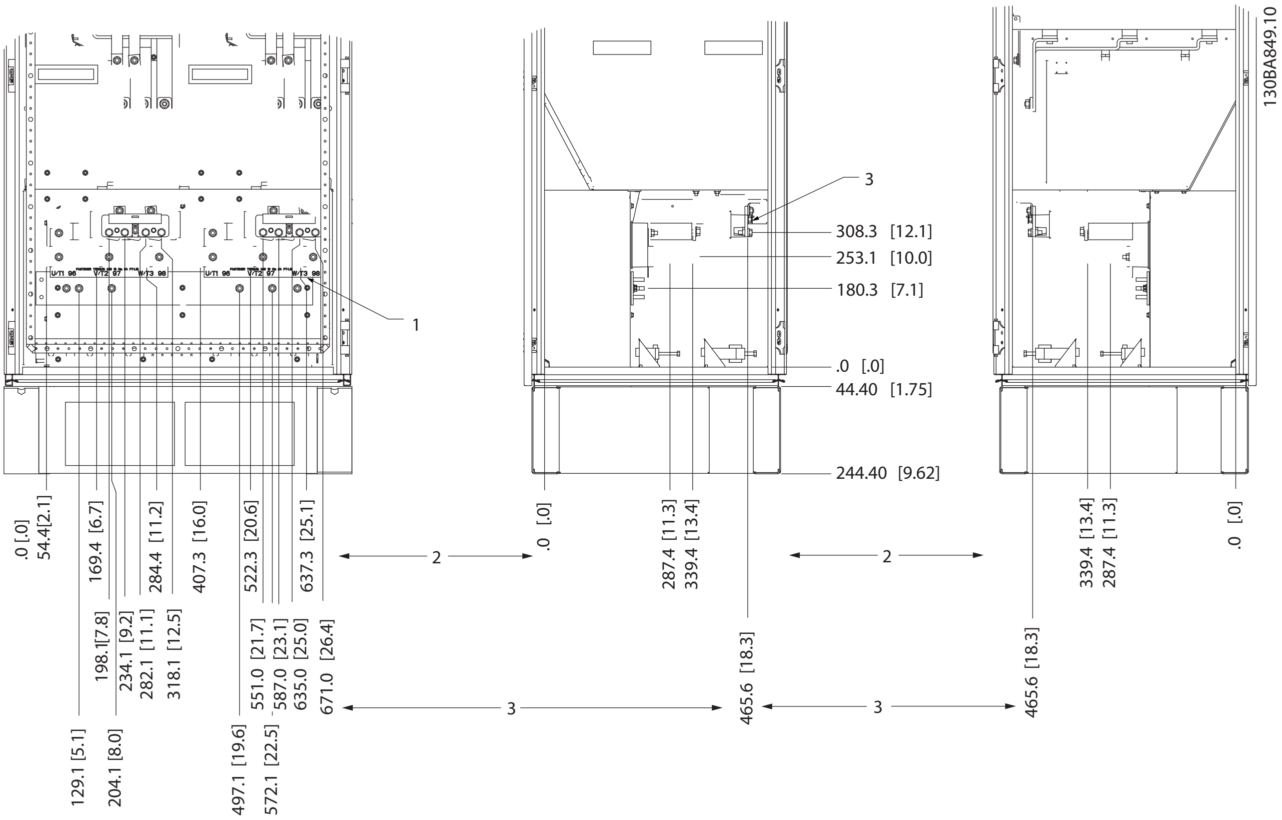


Illustration 6.53 Terminal Locations - Inverter Cabinet (Front, Left and Right Side View). The Gland Plate is 42 mm below .0 level.

1) Earth ground bar

2) Motor terminals

3) Brake terminals

Terminal locations - Inverter Frame size F12 and F13

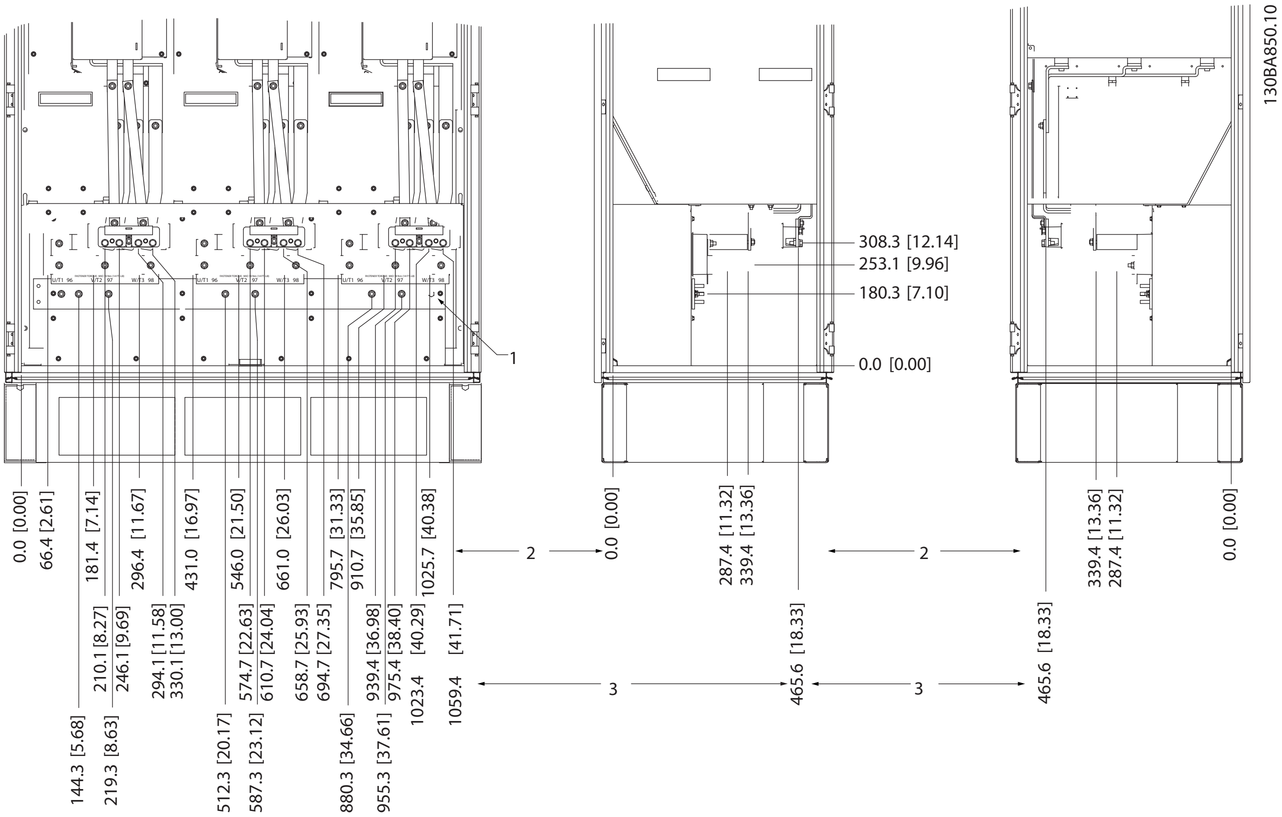


Illustration 6.54 Terminal Locations - Inverter Cabinet (Front, Left and Right Side View). The Gland Plate is 42 mm below .0 level.

1) Earth ground bar

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

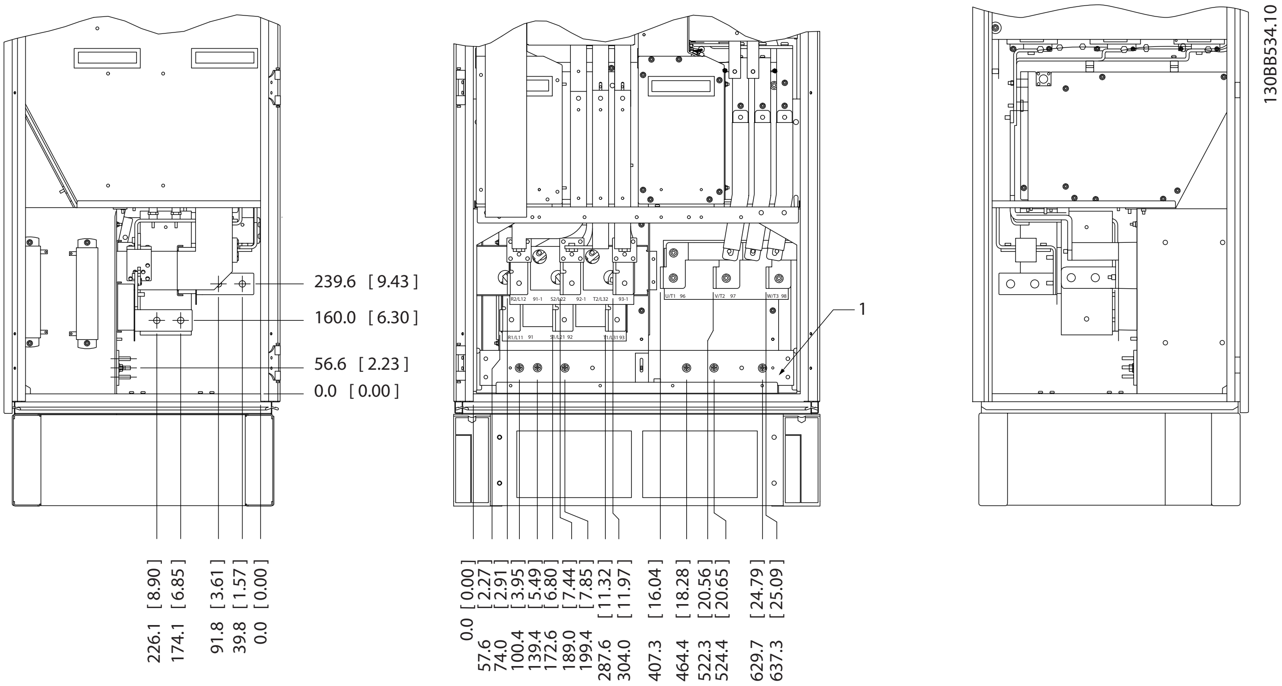


Illustration 6.55 Terminal Locations - Rectifier (Left, Front and Right Side View). The Gland Plate is 42 mm below .0 level.

1) Loadshare Terminal (-)

2) Earth ground bar

3) Loadshare Terminal (+)

Terminal locations - Options Cabinet Frame Size F9

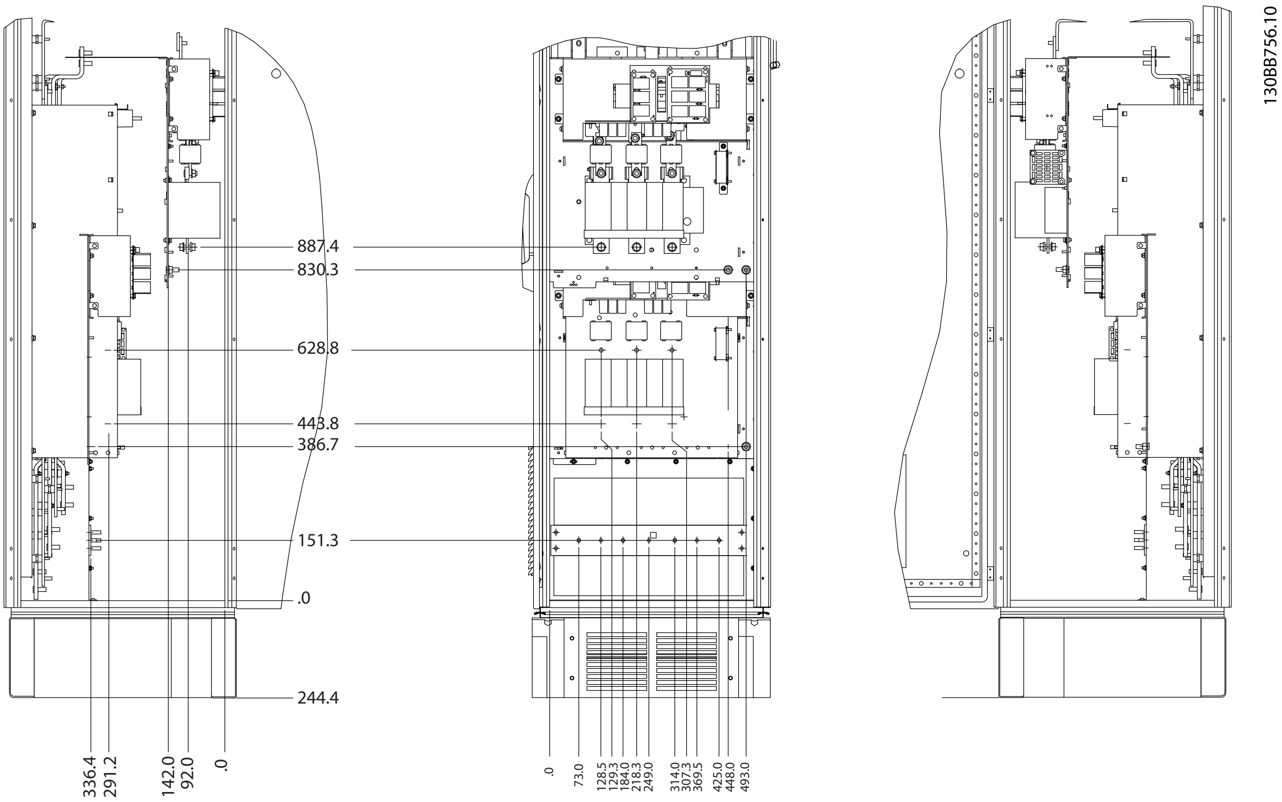


Illustration 6.56 Terminal Locations - Options Cabinet (Left, Front and Right Side View).

Terminal locations - Options Cabinet Frame Size F11/F13

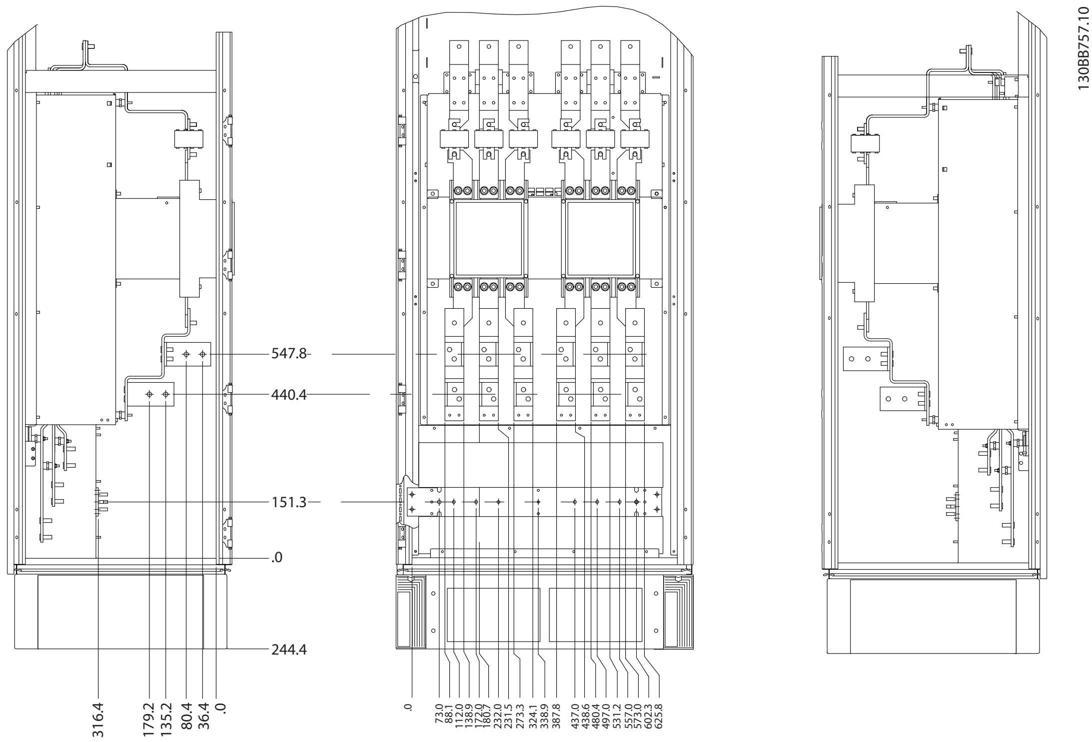


Illustration 6.57 Terminal Locations - Options Cabinet (Left, Front and Right Side View).

6.2.7 Cooling and Airflow

Cooling

Cooling can be achieved in different ways: By using the cooling ducts in the bottom and the top of the unit, by taking air in and out the back of the unit or by combining the cooling possibilities.

Duct cooling

A dedicated option has been developed to optimize 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 return the heat losses outside the facility, thus reducing air conditioning requirements.

NOTE

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 (i.e. Rittal Therm software). If the frequency converter is the only heat generating component in the enclosure, the minimum airflow required at an ambient temperature of 45 °C for the D3h is 102 m^3/hr (60 cfm) and for the D4h is 204 m^3/hr (120 cfm). The minimum airflow required at an ambient temperature of 45 °C for the E2 frequency converter is 782 m^3/h (460 cfm).

Airflow

The necessary airflow over the heat sink must be secured. The flow rate is shown in *Table 6.11*.

Frame size	Enclosure protection	Door fan(s)/Top fan airflow	Heatsink fan(s)
D1h	IP21/NEMA 1 IP54/NEMA 12	102 m^3/h (60 cfm)	420 m^3/h (250 cfm)
D2h		204 m^3/h (120 cfm)	840 m^3/h (500 cfm)
D3h		102 m^3/h (60 cfm)	420 m^3/h (250 cfm)
D4h		204 m^3/h (120 cfm)	840 m^3/h (500 cfm)
E1 P250T5, P355T7, P400T7		340 m^3/h (200 cfm)	1105 m^3/h (650 cfm)
E1P315-P400T5, P500-P560T7		340 m^3/h (200 cfm)	1445 m^3/h (850 cfm)
F1, F2, F3, F4 and F8/F9, F10/F11, F12/F13	IP21/NEMA 1	700 m^3/h (412 cfm)*	985 m^3/h (580 cfm)*
F1, F2, F3, F4 and F8/F9, F10/F11, F12/F13	IP54/NEMA 12	525 m^3/h (309 cfm)*	985 m^3/h (580 cfm)*
D3h and D4h	IP00/Chassis	255 m^3/h (150 cfm)	765 m^3/h (450 cfm)
E2 P250T5, P355T7, P400T7		255 m^3/h (150 cfm)	1105 m^3/h (650 cfm)
E2 P315-P400T5, P500-P560T7		255 m^3/h (150 cfm)	1445 m^3/h (850 cfm)

Table 6.11 Heatsink and Front Channel Air Flow

** 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 additional airflow to the unit. IP20 enclosures have a fan mounted to the top of the unit for additional 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.

NOTE

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

Once the fan is started, it runs for minimum 10 minutes.

External ducts

If additional 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.

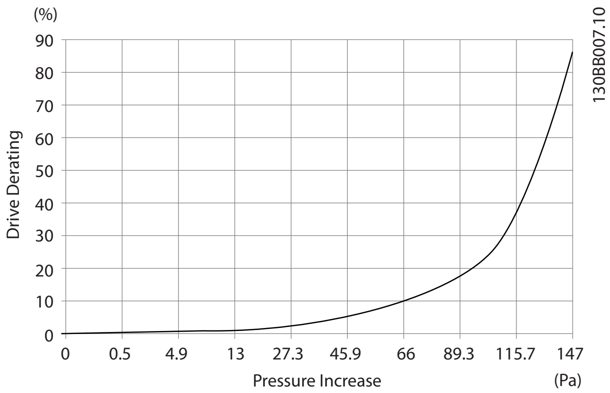


Illustration 6.58 D-Frame Derating vs. Pressure Change

Frequency Converter Air Flow: 450 cfm (765 m³/h)

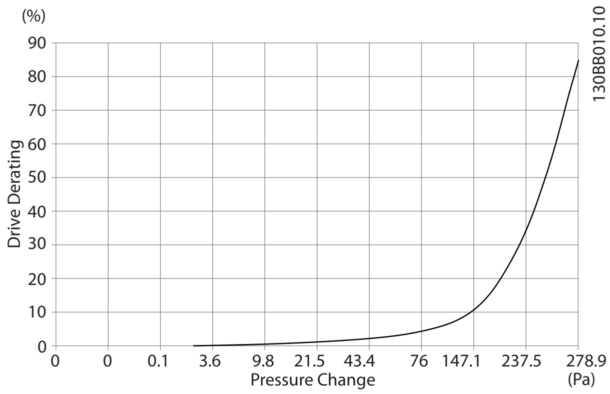


Illustration 6.59 E-Frame Derating vs. Pressure Change (Small Fan), P250T5 and P355T7-P400T7

Frequency Converter Air Flow: 650 cfm (1105 m³/h)

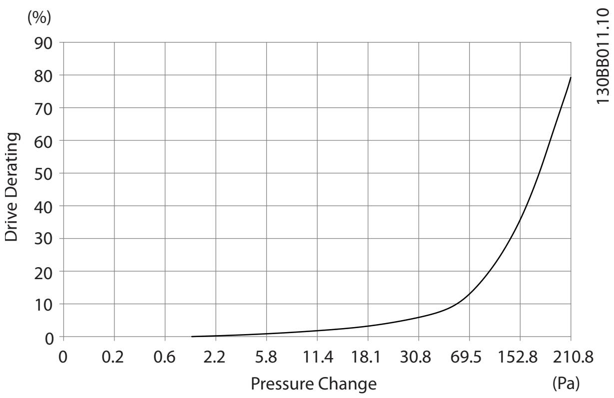


Illustration 6.60 E-Frame Derating vs. Pressure Change (Large Fan), P315T5-P400T5 and P500T7-P560T7

Frequency Converter Air Flow: 850 cfm (1445 m³/h)

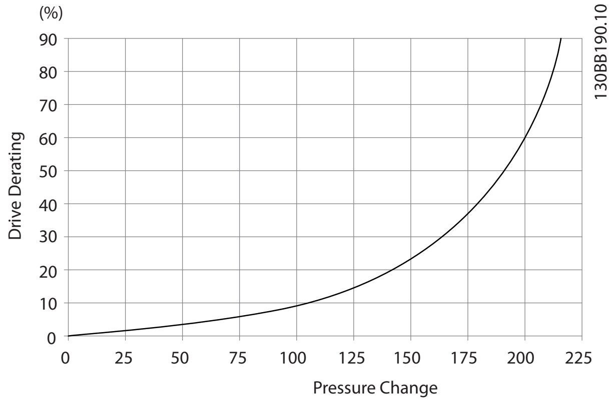


Illustration 6.61 F1, F2, F3, F4 Frame Derating vs. Pressure Change

Frequency Converter Air Flow: 580 cfm (985 m³/h)

6.2.8 Wall Mounting- IP21 (NEMA 1) and IP54 (NEMA 12) Units

This only applies to frame sizes D1h and D2h. It must be considered when choosing an installation site.

Take the relevant points into consideration before selecting the final installation site:

- Free space for cooling
- Access to open the door
- Cable entry from the bottom

Mark the mounting holes according to the installation drawings and drill holes where indicated. Ensure proper distance to the floor and the ceiling for cooling. A minimum of 225 mm (8.9 in) above and below the frequency converter is needed. Mount the bolts at the bottom and lift the frequency converter up on the bolts. Tilt the frequency converter against the wall and mount the upper bolts. Tighten all four bolts to secure the frequency converter against the wall.

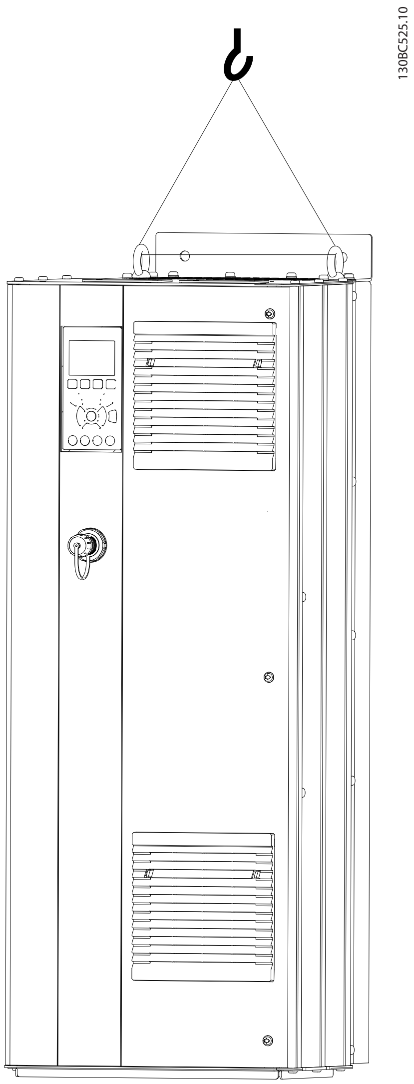


Illustration 6.62 Lifting Method for the D-Frame

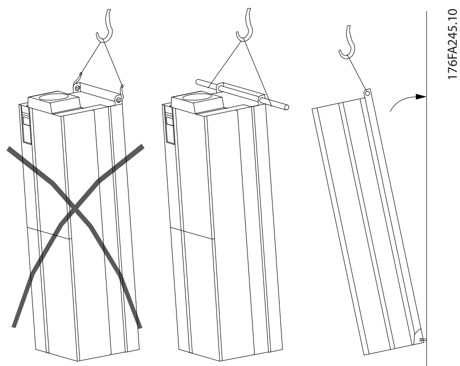


Illustration 6.63 Lifting Method for Mounting the E-Frame Unit on the Wall

6.2.9 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.

NOTE

The gland plate must be fitted to the frequency converter to ensure the specified protection degree, as well as ensuring proper cooling of the unit. If the gland plate is not mounted, the frequency converter may trip on Alarm 65, Control Board Over Temperature (D-Frame) or Alarm 69, Power Card Temperature (E and F-Frames).

Cable entries viewed from the bottom of the frequency converter - 1) Mains side 2) Motor side

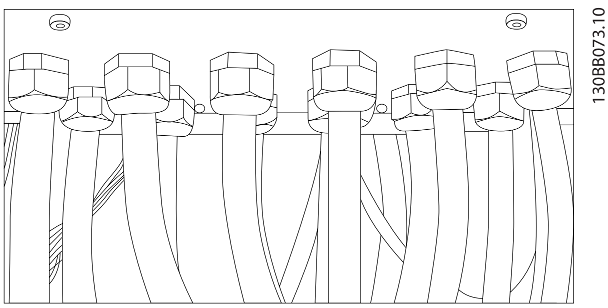


Illustration 6.64 Example of Proper Installation of Gland Plate

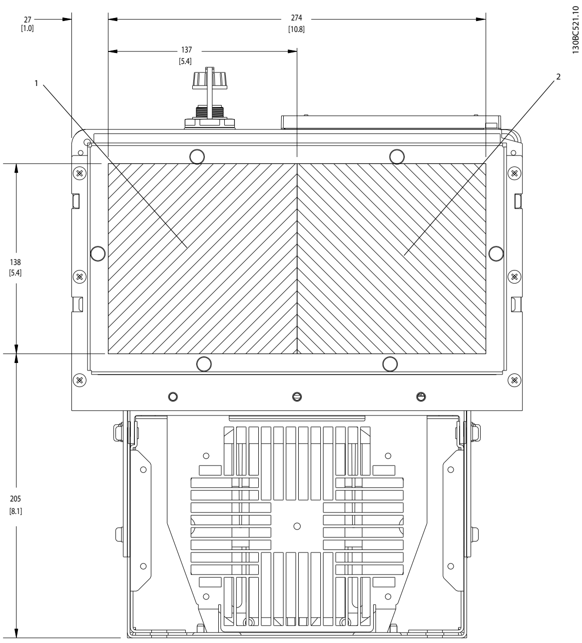


Illustration 6.65 D1h, Bottom View

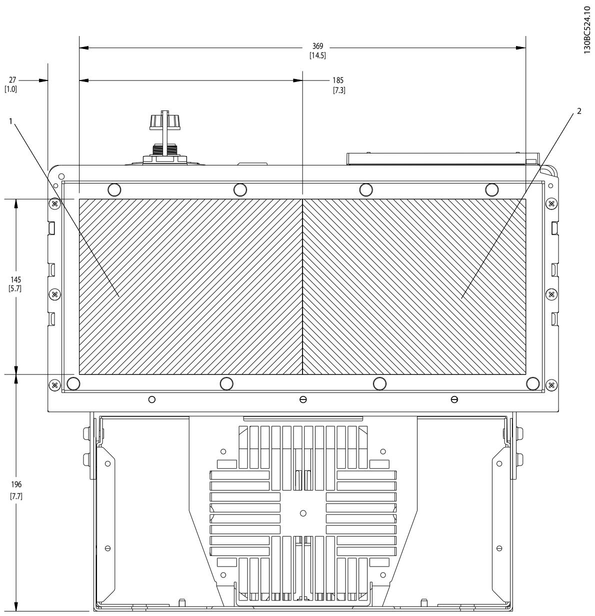


Illustration 6.66 D2h, Bottom View

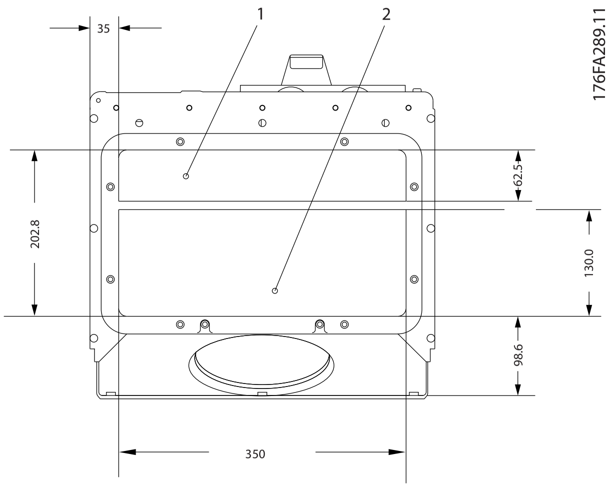


Illustration 6.67 E1, Bottom View

F1-F4: Cable entries viewed from the bottom of the frequency converter - 1) Place conduits in marked areas

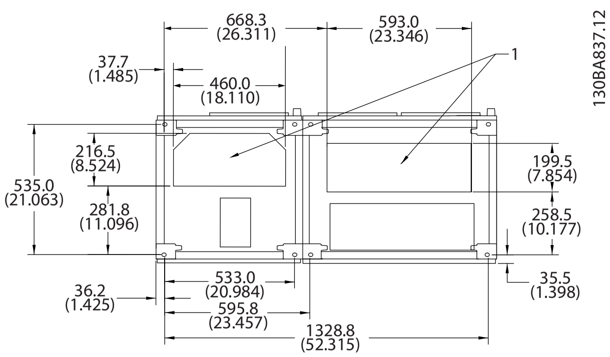


Illustration 6.68 F1, Bottom View

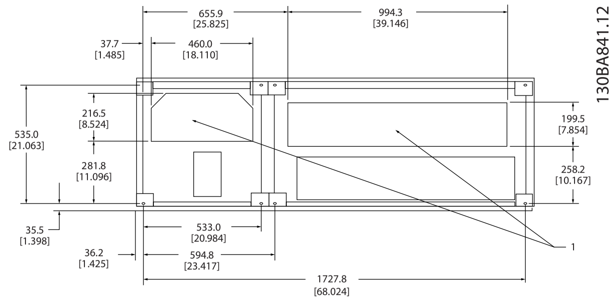


Illustration 6.69 F2, Bottom View

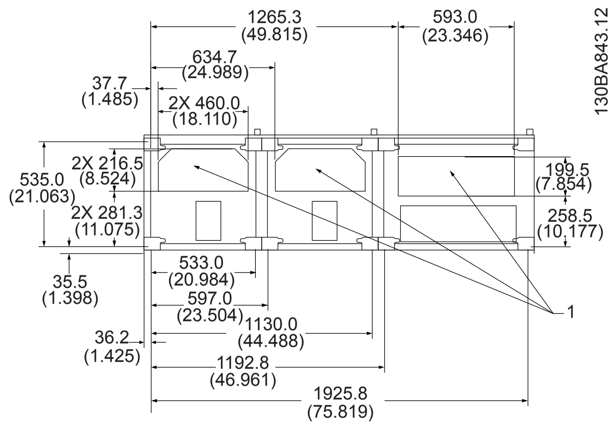


Illustration 6.70 F3, Bottom View

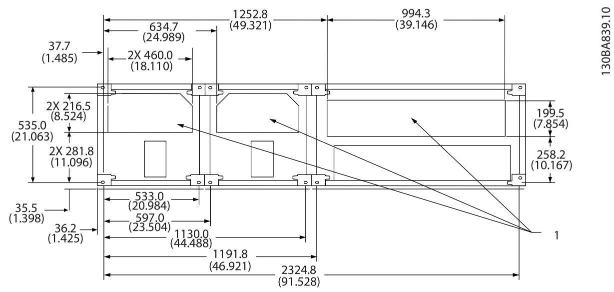


Illustration 6.71 F4, Bottom View

6

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

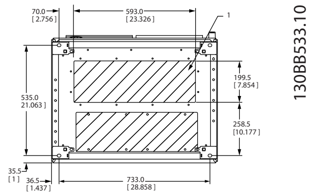
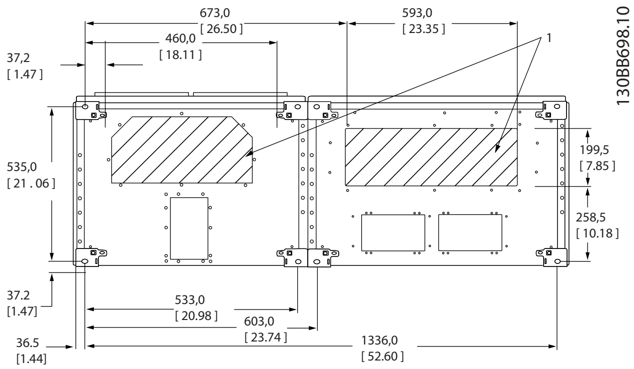
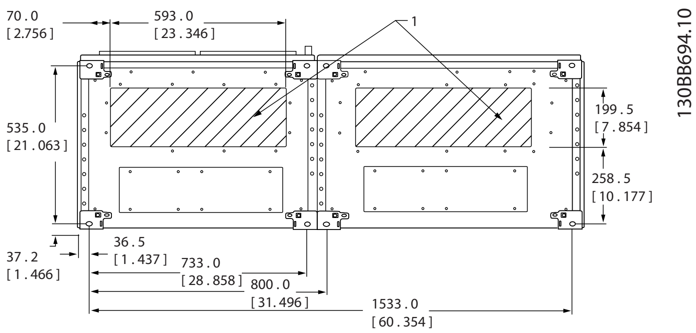
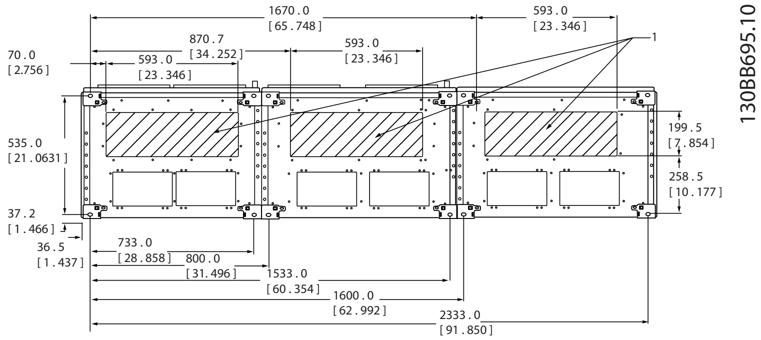
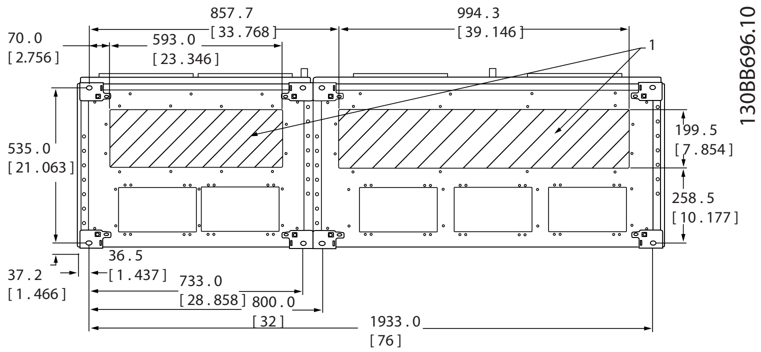
Frame size F8

Frame size F9

Frame size F10


Table 6.12

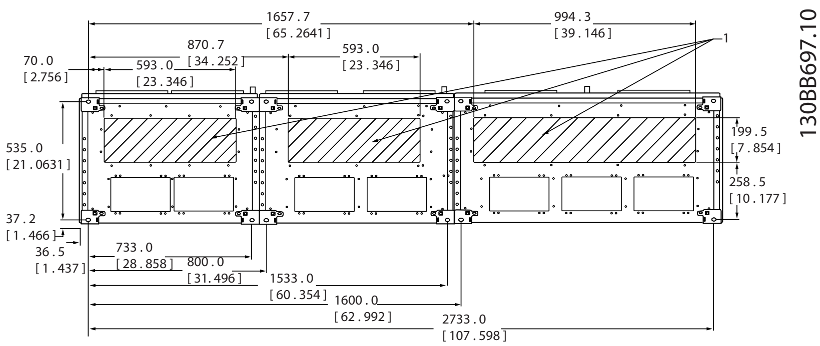
Frame size F11



Frame size F12

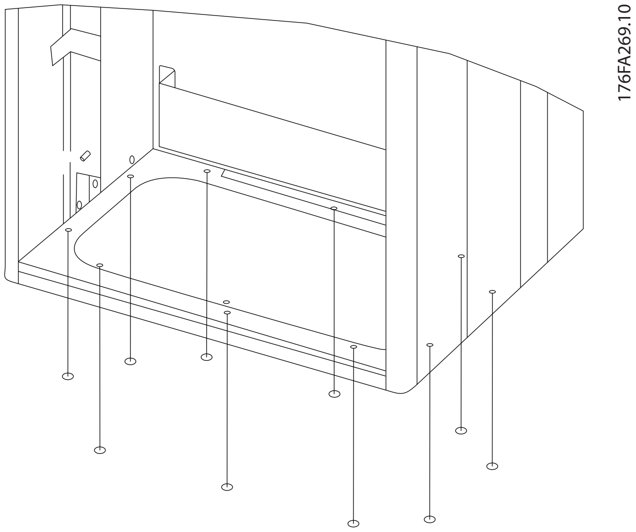


Frame size F13



F8-F13: Cable entries viewed from the bottom of the frequency converter - 1) Place conduits in marked areas

Table 6.13



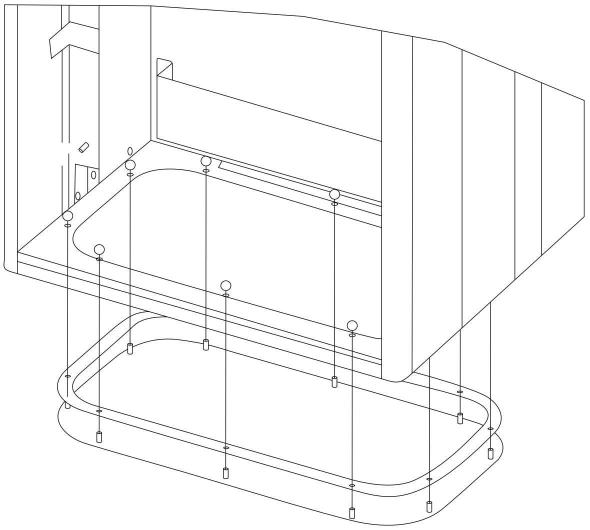


Illustration 6.72 Mounting of Bottom Plate, Frame Size E1.

6

The bottom plate of the E1 can be mounted from either inside or outside of the enclosure, allowing flexibility in the installation process. If mounted from the bottom, the glands and cables can be mounted before the frequency converter is placed on the pedestal.

6.2.11 IP21 Drip Shield Installation (Frame size D1h and D2h)

To comply with the IP21 rating, a separate drip shield is to be installed as explained below:

- Remove the two front screws
- Insert the drip shield and replace the screws
- Torque the screws to 5.6 Nm (50 in-lbs)

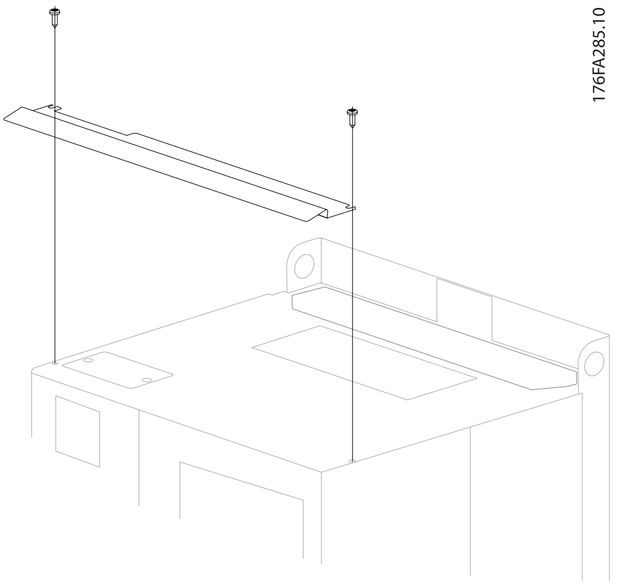


Illustration 6.73 Drip Shield Installation

6.2.12 Mechanical Mounting

1. Drill holes in accordance with the measurements given.
2. Provide screws suitable for the mounting surface. Retighten all four screws.

The frequency converter allows side-by-side installation. The back wall must always be solid.

Enclosure	Air space [mm]
D1h/D2h/D3h/D4h	225
E1/E2	225
F1/F2/F3/F4	225

Table 6.14 Required Free Air Space Above and Below Frequency Converter

6.2.13 Pedestal Installation on F-Frame Drives

Pedestals on F-Frame drives use 8 bolts instead of 4.

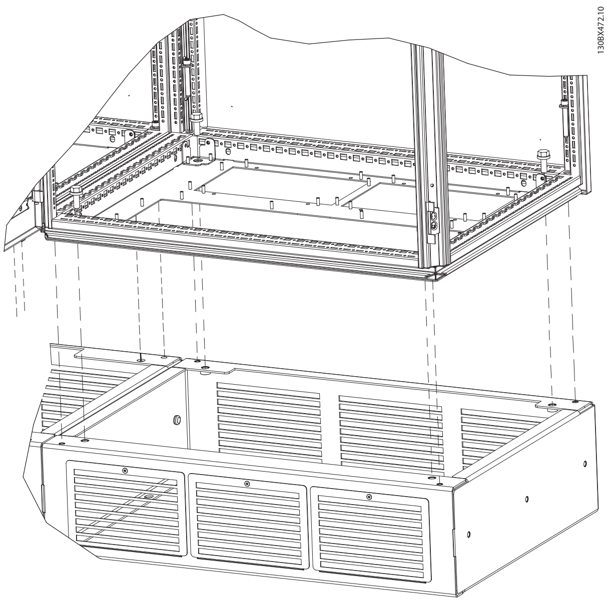


Illustration 6.74 Pedestal Bolt Installation

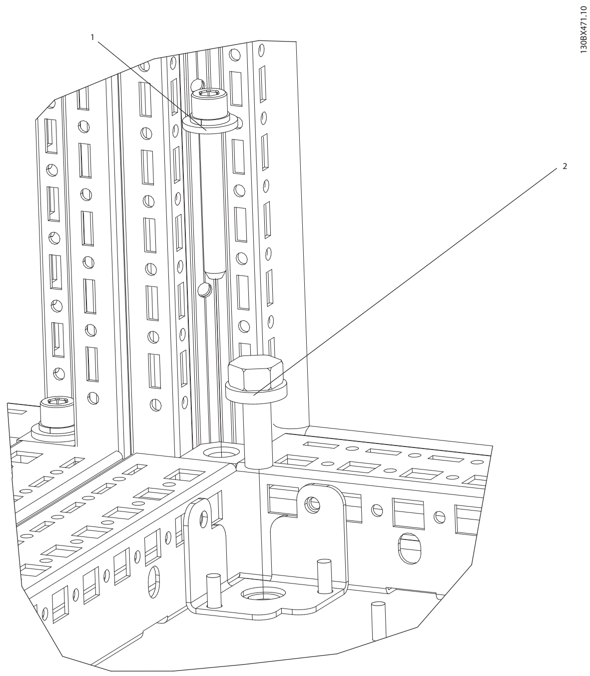


Illustration 6.75 Close-up Detail

1	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
2	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

Table 6.15 Legend to *Illustration 6.75*

7 Electrical Installation

7.1 Connections

7.1.1 Torque

When tightening electrical connections, it is important to tighten with the correct torque. Torque that is too low or too high results in a bad electrical connection. Use a torque wrench to ensure correct torque.

NOTE

Always use a torque wrench to tighten the bolts.

Frame size	Terminal	Size	Torque nominal [Nm (in-lbs)]	Torque range [Nm (in-lbs)]
D1h/D3h	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	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-F9 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

Cabling and Fusing

NOTE

Cables General

All cabling must comply with national and local regulations on cable cross-sections and ambient temperature. UL applications require 75 °C copper conductors. 75 and 90 °C copper conductors are thermally acceptable for the frequency converter to use in non-UL applications.

The power cable connections are situated as shown in *Illustration 7.1*. Dimensioning of cable cross section must be done in accordance with the current ratings and local legislation. See *4.3 General Specifications* for details.

For protection of the frequency converter, the recommended fuses must be used or the unit must be with built-in fuses. Recommended fuses are listed in *7.2 Fuses and Circuit Breakers*. Always ensure that proper fusing is made according to local regulation.

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

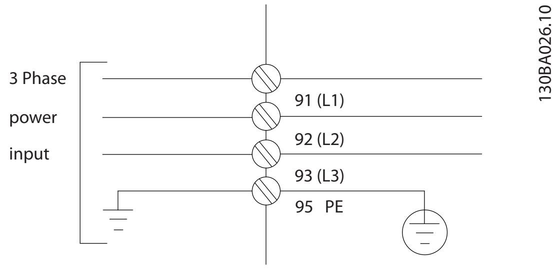


Illustration 7.1

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

[1)]*Protected Earth Connection*

NOTE

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*.

NOTE

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

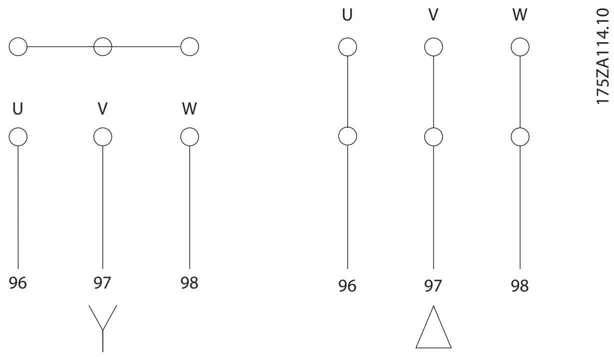


Illustration 7.2

See *4.3 General Specifications* for correct dimensioning of motor cable cross-section and length.

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 to the metal housing of the motor.

Make the screen connections with the largest possible surface area (cable clamp) by using the supplied 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*.

7

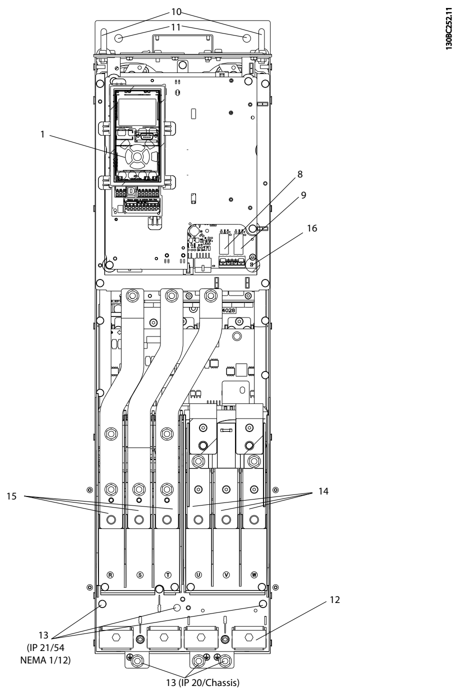


Illustration 7.3 D-Frame Interior Components

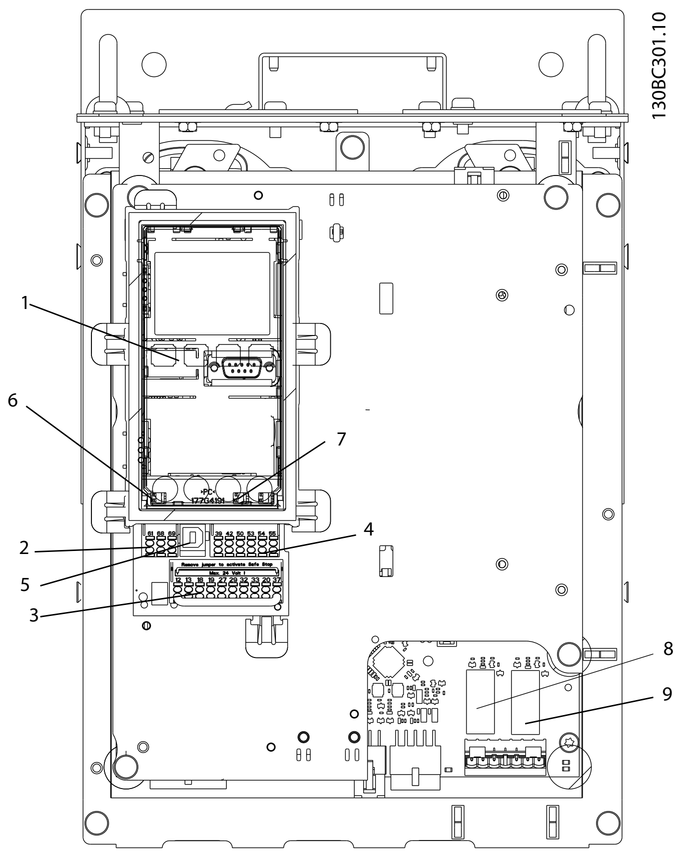


Illustration 7.4 Close-up View: LCP and Control Functions

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	analogue 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	analogue switches (A53), (A54)	15	Mains input terminals 91 (L1), 92 (L2), 93 (L3)
8	Relay 1 (01, 02, 03)		

Table 7.3

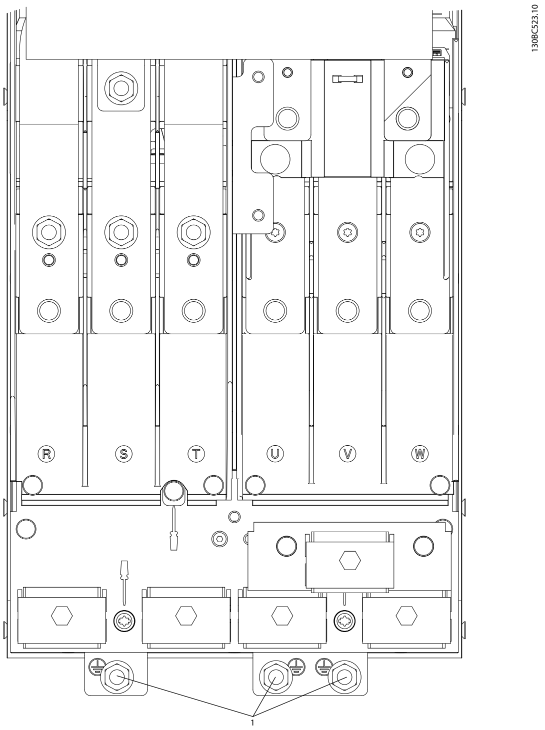


Illustration 7.5 1) Position of Earth Terminals IP00 (chassis), D-Frame Sizes

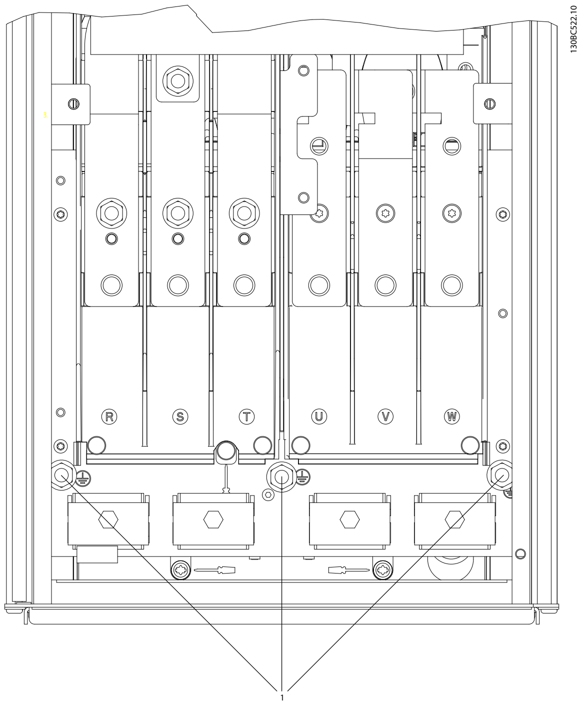


Illustration 7.6 1) Position of Earth Terminals IP21 (NEMA type 1) and IP54 (NEMA type 12), D-Frame Sizes

NOTE

D2h and D4h shown as examples. D1h and D3h are equivalent.

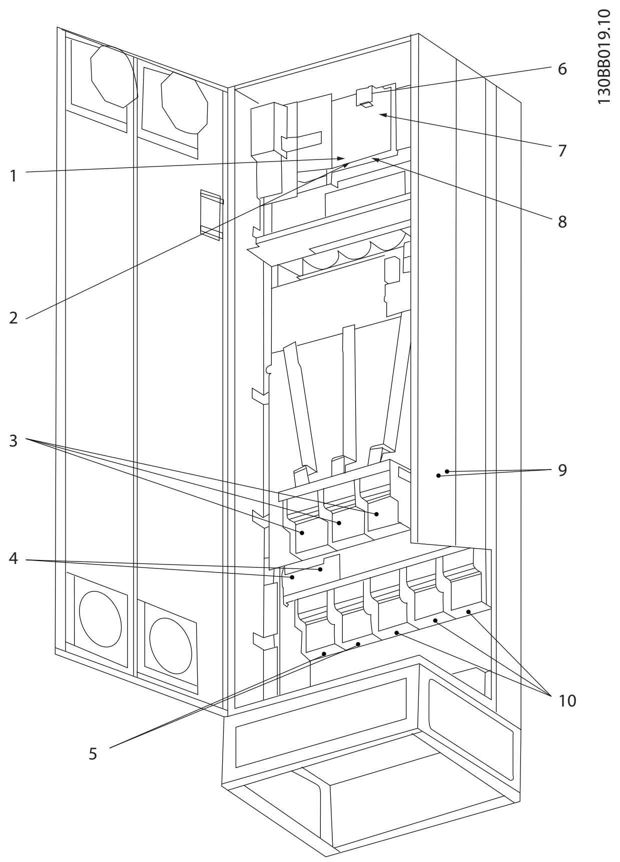


Illustration 7.7 Compact IP21 (NEMA 1) and IP54 (NEMA 12) Frame Size E1

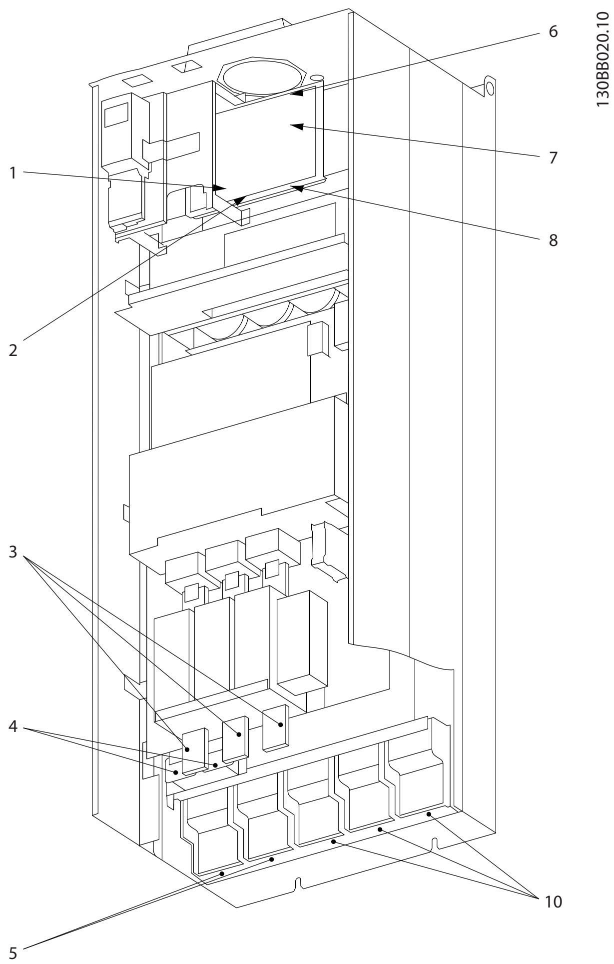


Illustration 7.8 Compact IP00 (Chassis) with Disconnect, Fuse and RFI Filter, Frame Size E2

1	AUX Relay	5	Load sharing
	01 02 03		-DC +DC
	04 05 06		88 89
2	Temp Switch	6	SMPS Fuse (see *7.2.4 Fuse Tables* for part number)
	106 104 105	7	Fan Fuse (see *7.2.4 Fuse Tables* for part number)
3	Line	8	AUX Fan
	R S T		100 101 102 103
	91 92 93		L1 L2 L1 L2
	L1 L2 L3	9	Mains ground
4	Brake	10	Motor
	-R +R		U V W
	81 82		96 97 98
			T1 T2 T3

Table 7.4

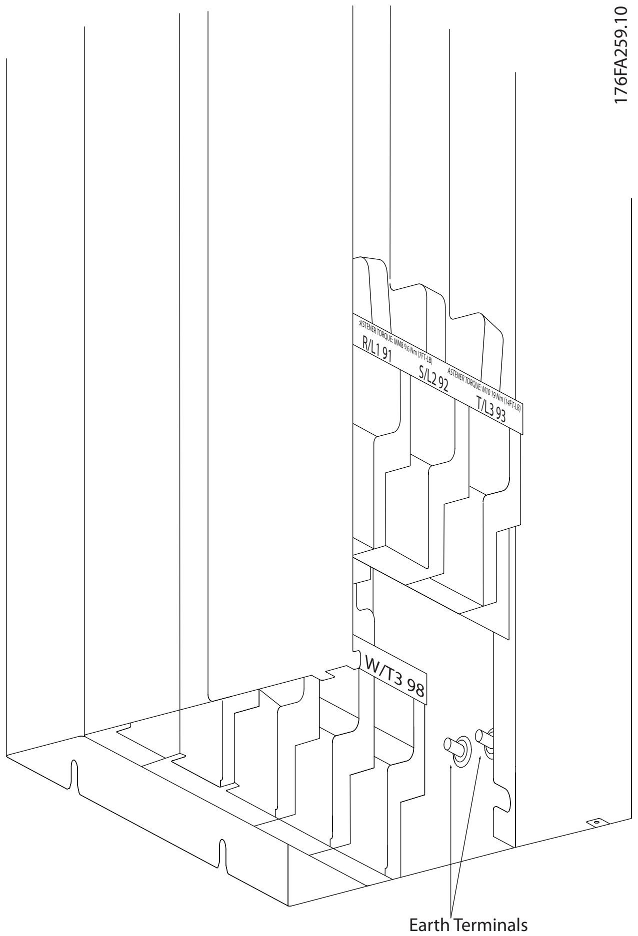


Illustration 7.9 Position of Earth Terminals IP00, Frame Size E

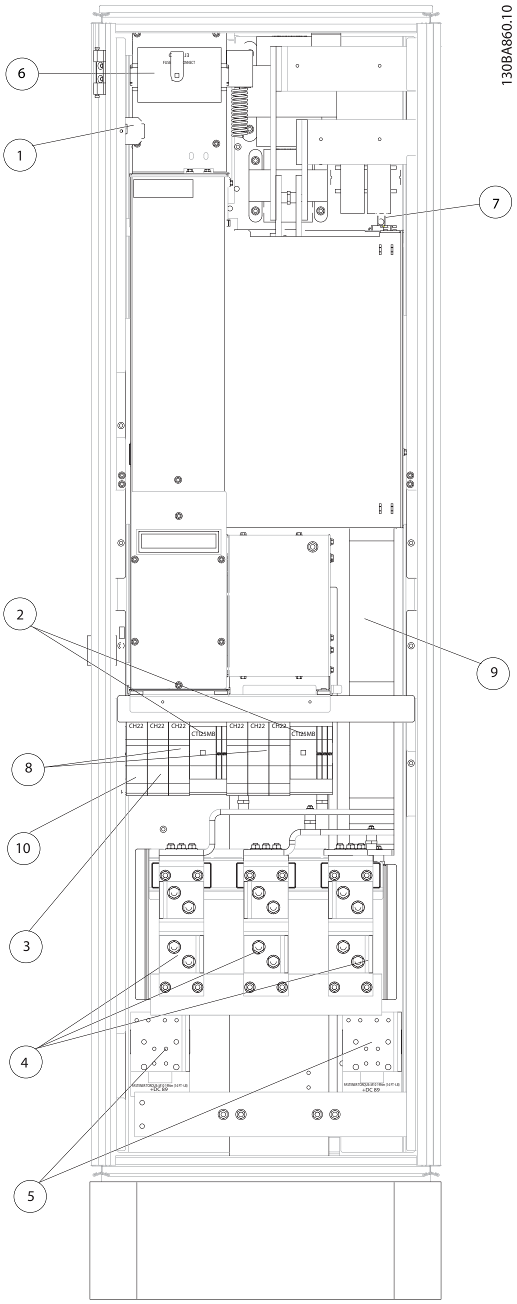


Illustration 7.10 Rectifier Cabinet, Frame Sizes F1, F2, F3 and F4

1	24 V DC, 5 A	5	Loadsharing
	T1 Output Taps		-DC +DC
	Temp Switch		88 89
	106 104 105	6	Control Transformer Fuses (2 or 4 pieces). See *7.2.4 Fuse Tables* for part numbers
2	Manual Motor Starters	7	SMPS Fuse. See *7.2.4 Fuse Tables* for part numbers
3	30 A Fuse Protected Power Terminals	8	Manual Motor Controller fuses (3 or 6 pieces). See *7.2.4 Fuse Tables* for part numbers
4	Line	9	Line Fuses, F1 and F2 frame (3 pieces). See *7.2.4 Fuse Tables* for part numbers
	R S T	10	30 Amp Fuse Protected Power fuses
	L1 L2 L3		

Table 7.5

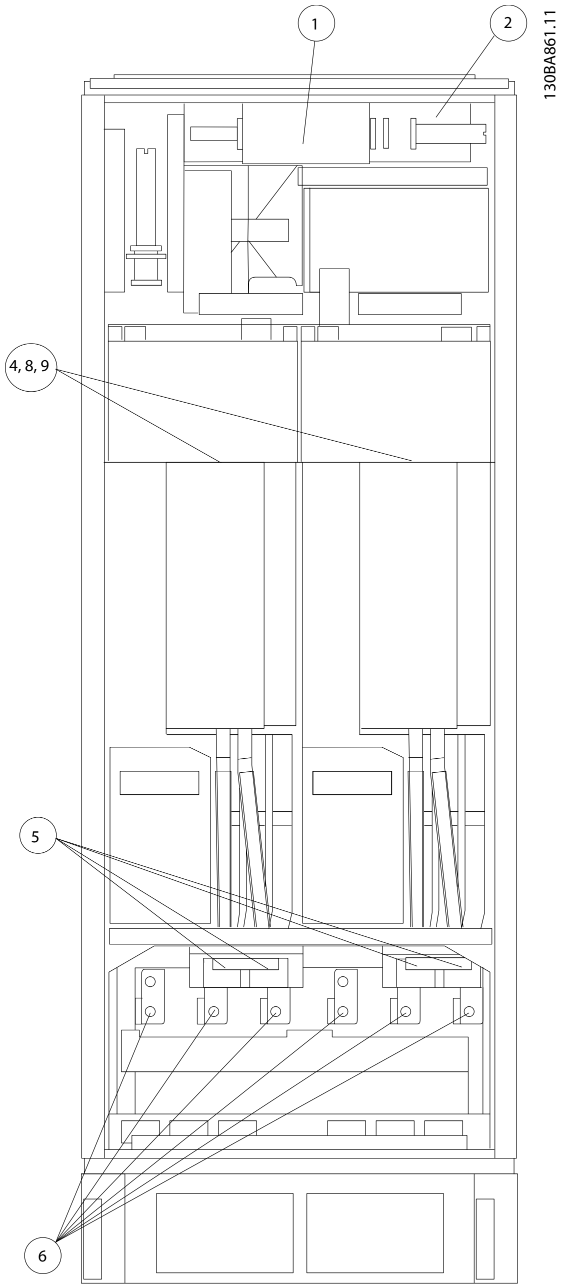


Illustration 7.11 Inverter Cabinet, Frame Sizes F1 and F3

1	External Temperature Monitoring	6	Motor
2	AUX Relay		U V W
	01 02 03		96 97 98
	04 05 06		T1 T2 T3
3	NAMUR	7	NAMUR Fuse. See *7.2.4 Fuse Tables* for part numbers
4	AUX Fan	8	Fan Fuses. See *7.2.4 Fuse Tables* for part numbers
	100 101 102 103	9	SMPS Fuses. See *7.2.4 Fuse Tables* for part numbers
	L1 L2 L1 L2		
5	Brake		
	-R +R		
	81 82		

Table 7.6

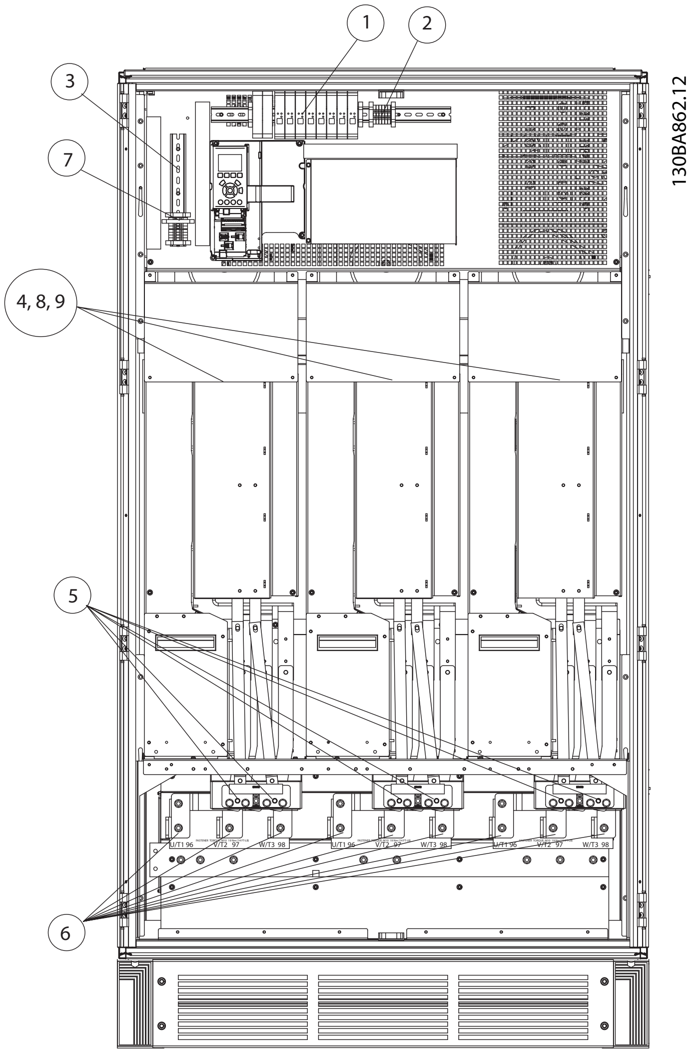


Illustration 7.12 Inverter Cabinet, Frame Sizes F2 and F4

1	External Temperature Monitoring	6	Motor
2	AUX Relay		U V W
	01 02 03		96 97 98
	04 05 06		T1 T2 T3
3	NAMUR	7	NAMUR Fuse. See *7.2.4 Fuse Tables* for part numbers
4	AUX Fan	8	Fan Fuses. See *7.2.4 Fuse Tables* for part numbers
	100 101 102 103	9	SMPS Fuses. See *7.2.4 Fuse Tables* for part numbers
	L1 L2 L1 L2		
5	Brake		
	-R +R		
	81 82		

Table 7.7

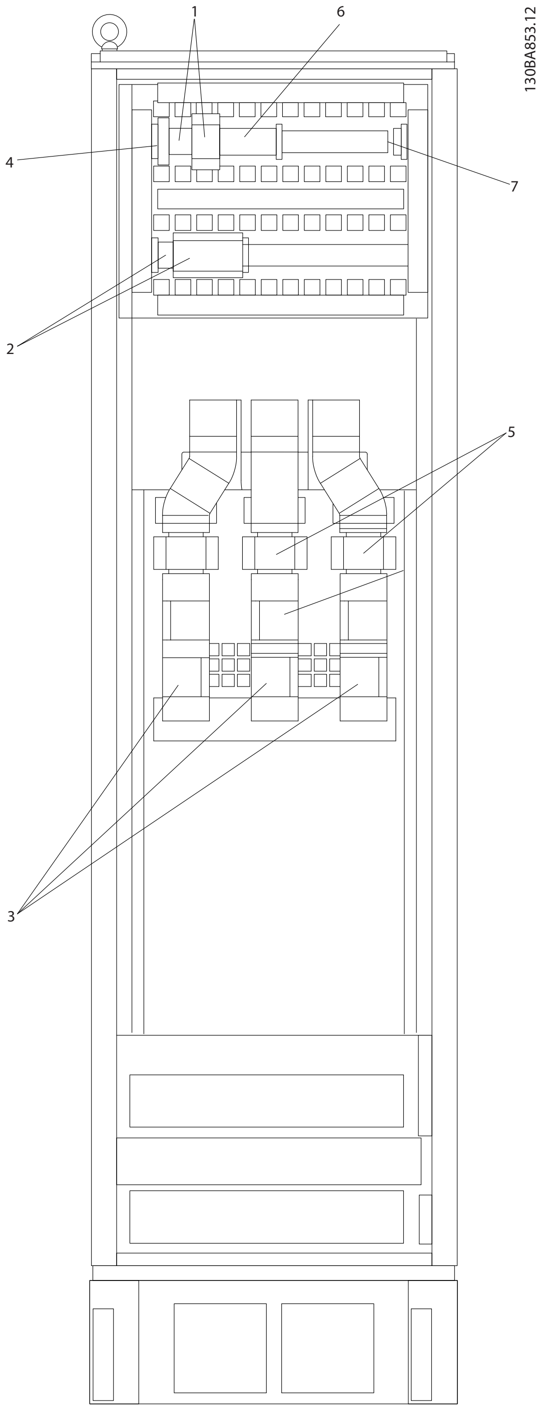


Illustration 7.13 Options Cabinet, Frame Sizes F3 and F4

1	Pilz Relay Terminal	4	Safety Relay Coil Fuse with PILZ Relay
2	RCD or IRM Terminal		See *7.2.4 Fuse Tables* for part numbers
3	Mains	5	Line Fuses, F3 and F4 (3 pieces)
	R S T		See *7.2.4 Fuse Tables* for part numbers
	91 92 93	6	Contactor Relay Coil (230 V AC). N/C and N/O Aux Contacts (customer supplied)
	L1 L2 L3	7	Circuit Breaker Shunt Trip Control Terminals (230 V AC or 230 V DC)

Table 7.8

7.1.3 Power Connections 12-Pulse Drives

Cabling and Fusing

NOTE

Cables General
All cabling must comply with national and local regulations on cable cross-sections and ambient temperature. UL applications require 75 °C copper conductors. 75 and 90 °C copper conductors are thermally acceptable for the frequency converter to use in non UL applications.

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

For protection of the frequency converter, the recommended fuses must be used or the unit must be fitted with built-in fuses. Recommended fuses can be seen in *7.2.4 Fuse Tables*. Always ensure that proper fusing is made according to local regulations.

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

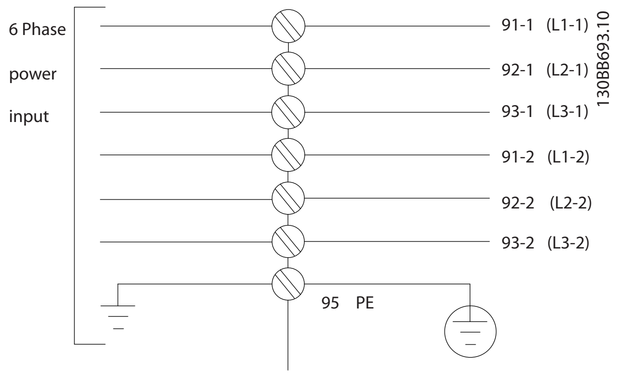


Illustration 7.14

NOTE

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*.

See *4.3 General Specifications* for correct dimensioning of motor cable cross-section and length.

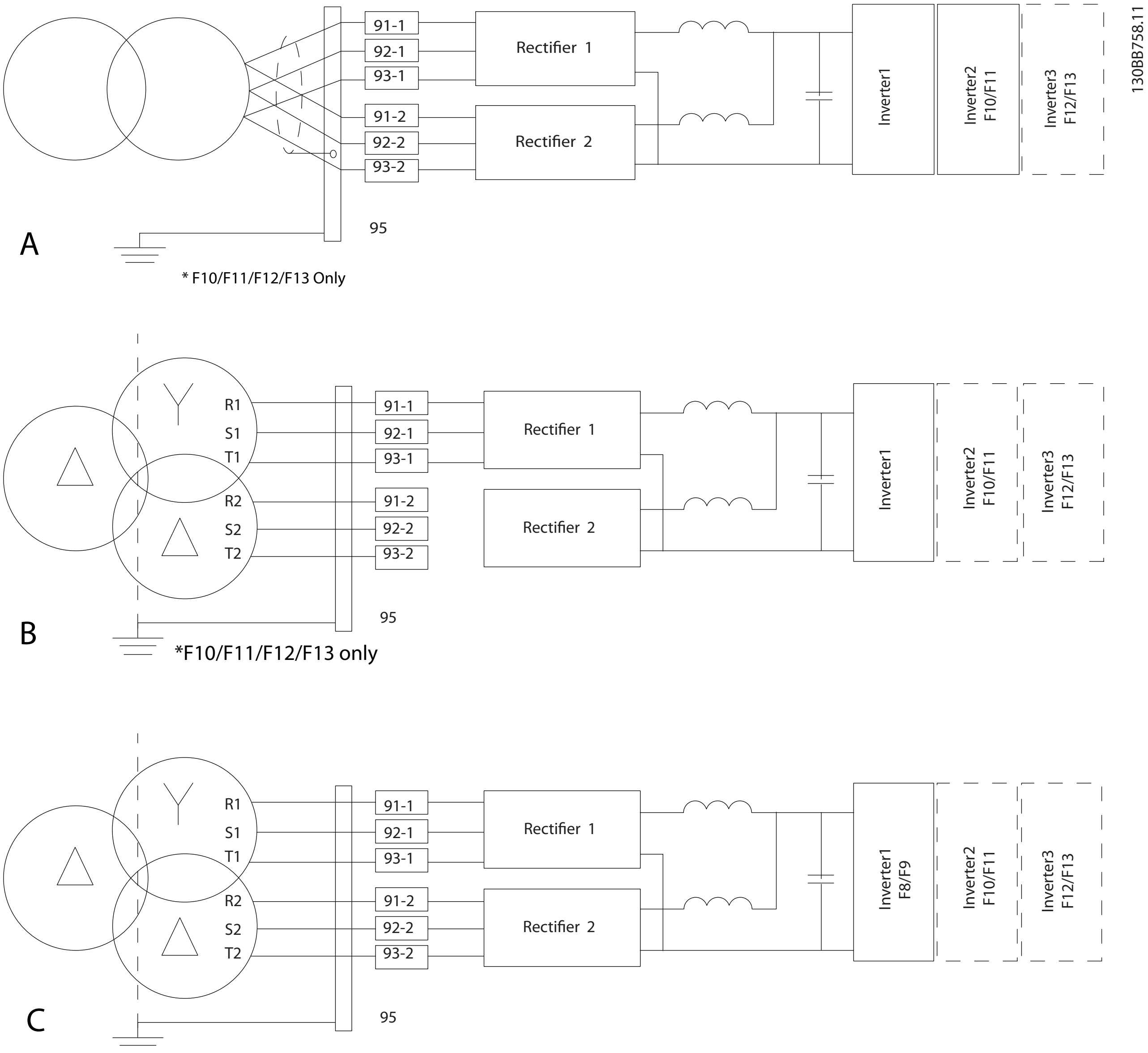


Illustration 7.15

A) 6-Pulse Connection[1), 2), 3)]

B) Modified 6-Pulse Connection[2), 3), 4)]

C) 12-Pulse Connection[3), 5)]

Notes:

[1)] Parallel connection shown. A single three phase cable may be used with sufficient carrying capability. Shorting bus bars must be installed.

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

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

[4)] In the unlikely event that 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 the factory for reconnection details.

[5)] No paralleling of mains cabling is shown here.

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 to the metal housing of the motor.

Make the screen connections with the largest possible surface area (cable clamp). This is done by using the supplied 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 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 7.9

[1)] *Protected Earth Connection*

NOTE

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

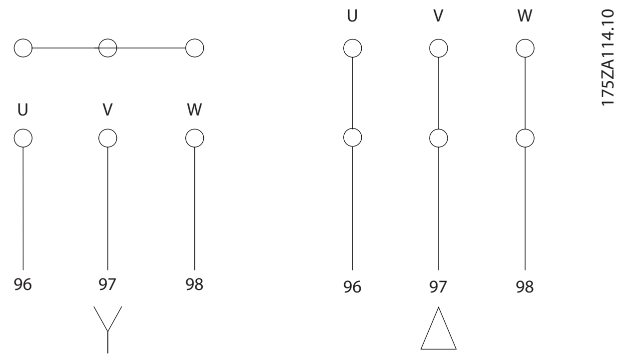


Illustration 7.16

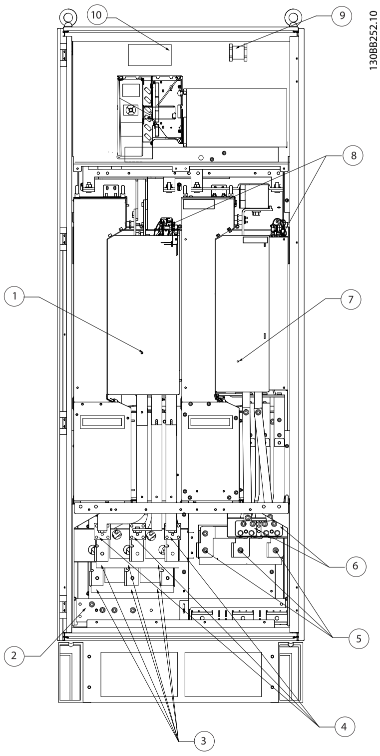


Illustration 7.17 Rectifier and Inverter Cabinet, Frame Sizes F8 and F9

1	12-pulse rectifier module	5	Motor connection
2	Ground/Earth PE Terminals		U V W
3	Line/Fuses		T1 T2 T3
	R1 S1 T1		96 97 98
	L1-1 L2-1 L3-1	6	Brake Terminals
	91-1 92-1 93-1		-R +R
4	Line/Fuses		81 82
	R2 S2 T2	7	Inverter Module
	L2-1 L2-2 L3-2	8	SCR Enable/Disable
	91-2 92-2 93-2	9	Relay 1 Relay 2
			01 02 03 04 05 06
		10	Auxillary Fan
			104 106

Table 7.10

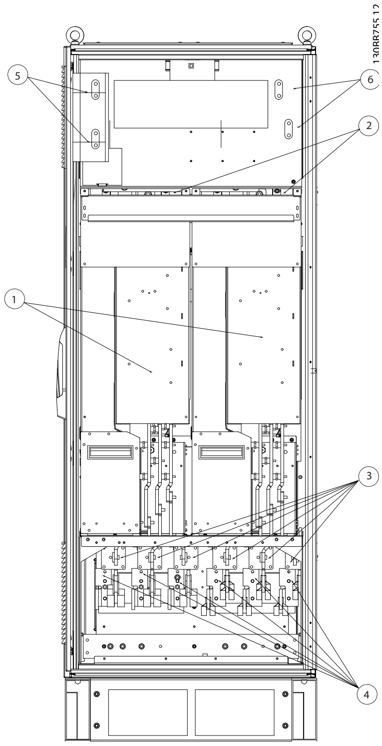


Illustration 7.18 Rectifier Cabinet, Frame Sizes F10 and F12

1	12-pulse rectifier module	4	Line
2	AUX Fan		R1 S1 T1 R2 S2 T2
	100 101 102 103		L1-1 L2-1 L3-1 L1-2 L2-2 L3-2
	L1 L2 L1 L2	5	DC Bus Connections for common DC Bus
3	Line Fuses F10/F12 (6 Pieces)		DC+ DC-
		6	DC Bus Connections for common DC Bus
			DC+ DC-

Table 7.11

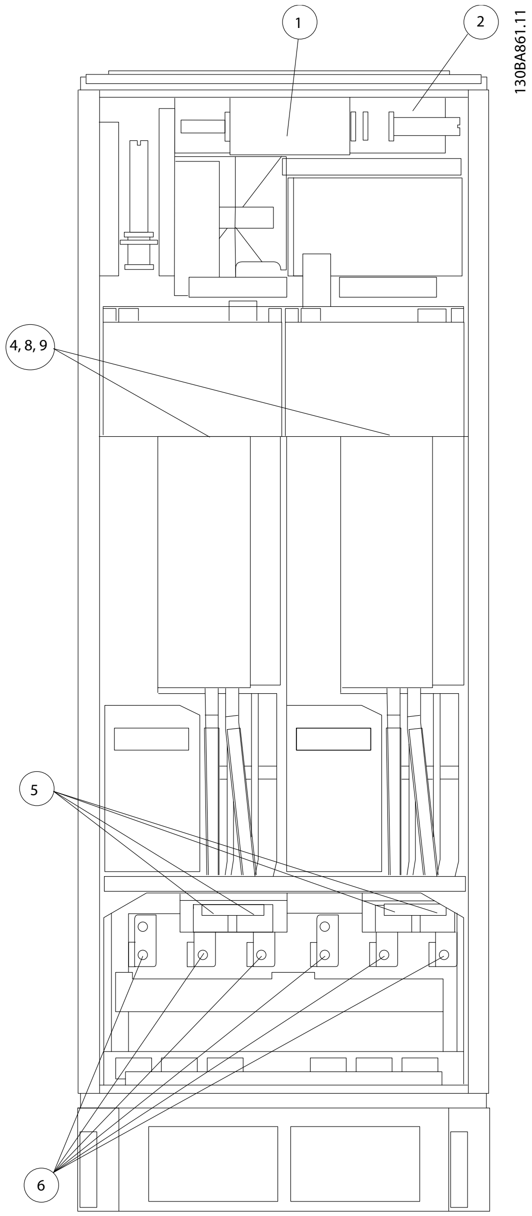


Illustration 7.19 Inverter Cabinet, Frame Sizes F10 and F11

1	External Temperature Monitoring	6	Motor
2	AUX Relay		U V W
	01 02 03		96 97 98
	04 05 06		T1 T2 T3
3	NAMUR	7	NAMUR Fuse. See *7.2.4 Fuse Tables* for part numbers
4	AUX Fan	8	Fan Fuses. See *7.2.4 Fuse Tables* for part numbers
	100 101 102 103	9	SMPS Fuses. See *7.2.4 Fuse Tables* for part numbers
	L1 L2 L1 L2		
5	Brake		
	-R +R		
	81 82		

Table 7.12

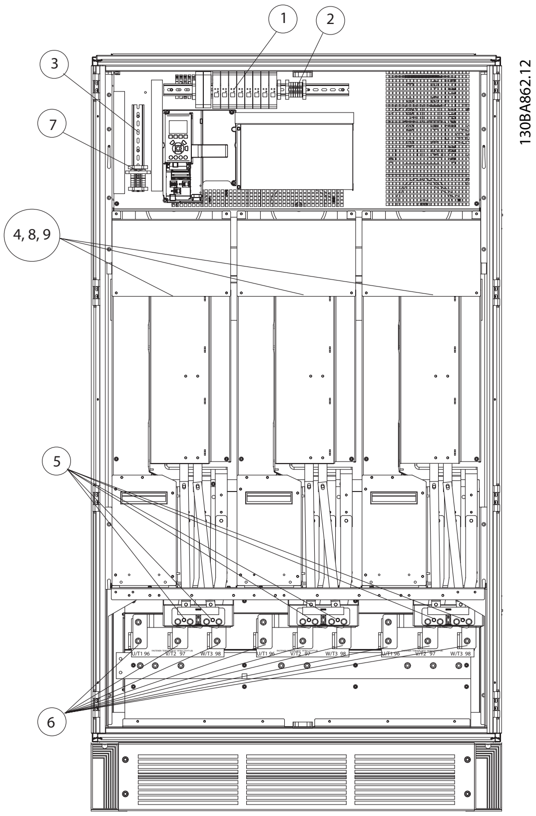


Illustration 7.20 Inverter Cabinet, Frame Sizes F12 and F13

1	External Temperature Monitoring	6	Motor
2	AUX Relay		U V W
	01 02 03		96 97 98
	04 05 06		T1 T2 T3
3	NAMUR	7	NAMUR Fuse. See *7.2.4 Fuse Tables* for part numbers
4	AUX Fan	8	Fan Fuses. See *7.2.4 Fuse Tables* for part numbers
	100 101 102 103	9	SMPS Fuses. See *7.2.4 Fuse Tables* for part numbers
	L1 L2 L1 L2		
5	Brake		
	-R +R		
	81 82		

Table 7.13

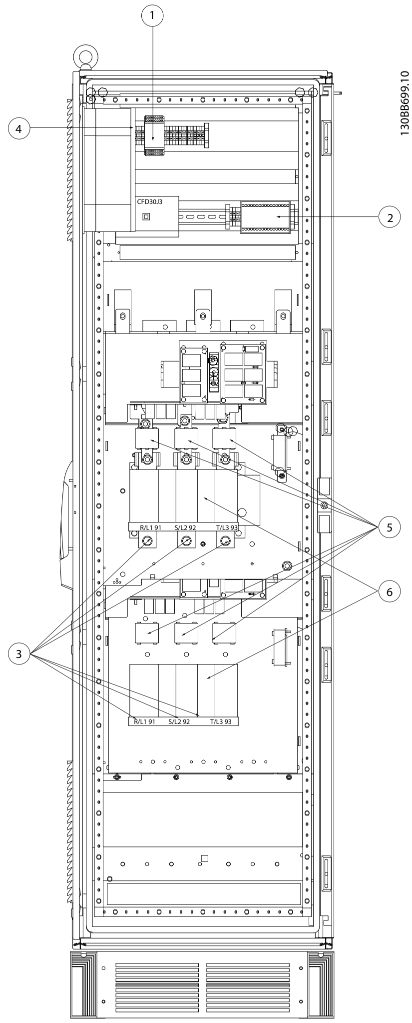


Illustration 7.21 Options Cabinet, Frame Size F9

1	Pilz Relay Terminal	4	Safety Relay Coil Fuse with Pilz Relay
2	RCD or IRM Terminal		See *7.2.4 Fuse Tables* for part numbers
3	Mains/6 phase	5	Line Fuses, (6 pieces)
	R1 S1 T1 R2 S2 T2		See *7.2.4 Fuse Tables* for part numbers
	91-1 92-1 93-1 91-2 92-2 93-2	6	2x3-phase manual disconnect
	L1-1 L2-1 L3-1 L1-2 L2-2 L3-2		

Table 7.14

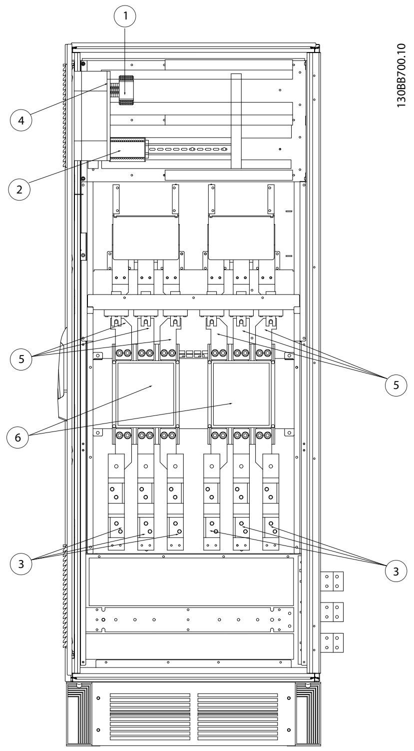


Illustration 7.22 Options Cabinet, Frame Sizes F11 and F13

1	Pilz Relay Terminal						4	Safety Relay Coil Fuse with Pilz Relay
2	RCD or IRM Terminal							See *7.2.4 Fuse Tables* for part numbers
3	Mains/6 phase						5	Line Fuses, (6 pieces)
	R1	S1	T1	R2	S2	T2		See *7.2.4 Fuse Tables* for part numbers
	91-1	92-1	93-1	91-2	92-2	93-2	6	2x3-phase manual disconnect
	L1-1	L2-1	L3-1	L1-2	L2-2	L3-2		

Table 7.15

7.1.4 12-pulse Transformer Selection Guidelines

Transformers used in conjunction with 12-Pulse frequency converters must conform to the following specifications.

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

1) Loading based on 12-pulse K-4 rated transformer with 0.5% voltage and impedance balance between secondary windings.

2) Leads from the transformer to the input terminals on the frequency converter are required to be equal length within 10%.

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.

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

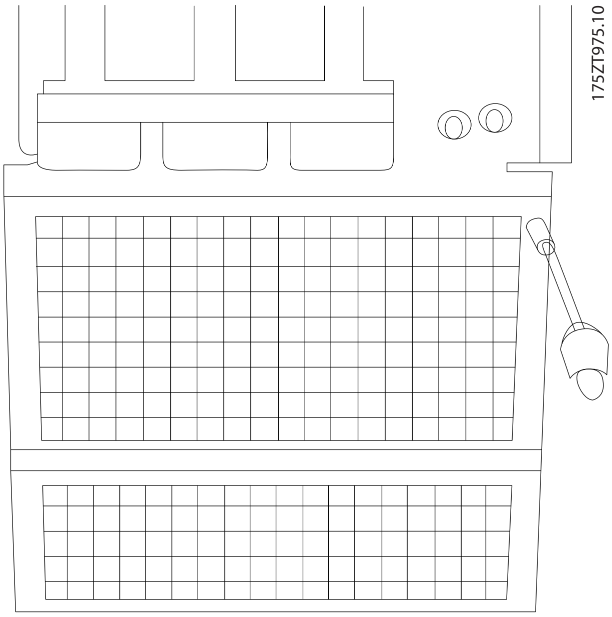


Illustration 7.23 Mounting of EMC shield

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 applied. The connection is made on the power card.

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

Table 7.16

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 be supplied from a common AC line (jumpers between 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 Amp fuse for protection. In UL applications, use a LittelFuse KLK-5 or equivalent.

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 component break-down inside the frequency converter (first fault).

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

⚠WARNING
Personnel and property must be protected against the consequence of component break-down internally in the frequency converter.

Branch Circuit Protection
In order to protect the installation against electrical and fire hazard, all branch circuits in an installation (switch gear, machines, etc.) must be protected against short-circuit and over-current according to national/international regulations.

NOTE
The recommendations given do not cover Branch circuit protection for UL.

Short-circuit protection
Danfoss recommends using the fuses/circuit breakers mentioned in *7.2.3 CE Compliance/UL Compliance* to protect service personnel and property in case of component break-down in the frequency converter.

7.2.2 Recommendations

⚠WARNING
In case of malfunction, failure to following these recommendation may result in personnel risk and damage to the frequency converter and other equipment.

The following tables list the recommended rated current. Recommended fuses are of the type gG for small to medium power sizes. For larger powers, aR fuses are recommended. For circuit breakers, Moeller types have been tested to have a recommendation. Other types of circuit breakers may be used provided they limit the energy into the frequency converter to a level equal to or lower than the Moeller types.

7

If fuses/circuit breakers are chosen according to recommendations, possible damages on the frequency converter will mainly be limited to damages inside the unit.

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

7.2.3 CE Compliance/UL Compliance

Fuses or Circuit Breakers are mandatory to comply with IEC 60364. Danfoss recommends using a selection of the following.

7.2.4 Fuse Tables

7.2.4 Fuse Tables are suitable for use on a circuit capable of delivering 100,000 Arms (symmetrical), 480 V, 500 V, or 600 V depending on the frequency converter's voltage rating. With the proper fusing the frequency converter short circuit current rating (SCCR) is 100,000 Arms.

7

Enclosure size	FC 300 model [kW]	Recommended fuse size	Recommended max. fuse	Recommended circuit breaker [Moeller]	Max trip level [A]
D	N90K N110 N132 N160 N200	aR-300 aR-350 aR-400 aR-500 aR-630	aR-300 aR-350 aR-400 aR-500 aR-630	-	-
D	N250	aR-700	aR-700		
E	P250 P315 P355 P400	aR-900	aR-900	-	-
F	P450 P500 P560 P630 P710 P800	aR-1600 aR-2000 aR-2500	aR-1600 aR-2000 aR-2500	-	-

Table 7.17 Recommended Fuses for CE Compliance, 380-500 V

Enclosure size	FC 300 model [kW]	Recommended fuse size	Recommended max. fuse	Recommended circuit breaker [Moeller]	Max trip level [A]
E	P355 P400 P500 P560	aR-700 aR-900	aR-700 aR-900	-	-
F	P630 P710 P800 P900 P1M0	aR-1600 aR-2000 aR-2500	aR-1600 aR-2000 aR-2500	-	-

Table 7.18 Recommended Fuses for CE Compliance, 525-690 V

7.2.5 High Power Fuse Tables

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	20 610 31.315	A50QS300-4	6,9URD31D08A0315	A070URD31KI0315
N110	170M2620	LA50QS350-4	L50S-350	FWH-350A	20 610 31.350	A50QS350-4	6,9URD31D08A0350	A070URD31KI0350
N132	170M2621	LA50QS400-4	L50S-400	FWH-400A	20 610 31.400	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 7.19 380-480/500 V, Frame Size D, Line Fuse Options for UL Compliance

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 7.20 380-480/500 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 7.21 380-480/500 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 7.22 380-480/500 V, Frame Size F, Inverter Module DC Link Fuses

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 7.23 525-690 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 7.24 525-690 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 7.25 525-690 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 500V UL listed fuse with associated current rating may be used to meet UL requirements.

7.2.6 Supplementary Fuses - High Power

Supplementary fuses

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

Table 7.26 SMPS Fuse

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 7.27 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 7.28 Manual Motor Controller Fuses

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

Table 7.29 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 7.30 Control Transformer Fuse

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

Table 7.31 NAMUR Fuse

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

Table 7.32 Safety Relay Coil Fuse with PILZ Relay

7.2.7 High Power Fuse Tables 12-Pulse

The fuses below are suitable for use on a circuit capable of delivering 100,000 Arms (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 Arms.

Power size	Frame	Rating		Bussmann	Spare Bussmann	Est. 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 7.33 Line Fuses, 380-500 V

Power size	Frame	Rating		Bussmann	Spare Bussmann	Est. 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 7.34 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 7.35 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 7.36 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 7.37 Manual Motor Controller Fuses

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

Table 7.38 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 7.39 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 7.40 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 7.41 Control Transformer Fuse

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

Table 7.42 NAMUR Fuse

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

Table 7.43 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 7.44 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		
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		
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 7.45 Mains Disconnects, E- and F-Frame 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 7.46 Mains Disconnects, 12-Pulse Frequency Converters

7.3.3 F-Frame Mains Contactors

Frame size	Power & Voltage	Type
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 7.47 F-Frame Contactors

NOTE

Customer supplied 230 V supply required for Mains Contactors.

7.4 Additional Motor Information

7.4.1 Motor Cable

The motor must be connected to terminals U/T1/96, V/T2/97, W/T3/98, earth to terminal 99. All types of three-phase asynchronous standard motors can be used with a frequency converter unit. The factory setting is for clockwise rotation with the frequency converter output connected as follows:

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

Table 7.48

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

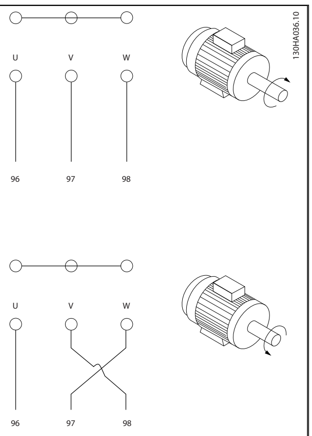


Table 7.49

The direction of rotation can be changed by switching two 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 the display.

F-Frame requirements
F1/F3 requirements
Motor phase cable quantities must be multiples of 2, resulting in 2, 4, 6, or 8 (1 cable is not allowed) to obtain equal numbers of wires attached to both inverter module terminals. The cables are required to be equal length within 10% between the inverter module terminals and the first common point of a phase. The recommended common point is the motor terminals.

F2/F4 requirements
Motor phase cable quantities must be multiples of 3, resulting in 3, 6, 9, or 12 (1 or 2 cables are not allowed) to obtain equal numbers of wires attached to each inverter module terminal. The wires are required to be equal length within 10% between the inverter module terminals and the first common point of a phase. The recommended common point is the motor terminals.

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

NOTE

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.

7.4.2 Motor Thermal Protection

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 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.

7.4.3 Parallel Connection of Motors

The frequency converter can control several parallel-connected motors. When using parallel motor connection, the following must be observed:

- Recommended to run applications with parallel motors in U/F mode *1-01 Motor Control Principle* [0]. Set the U/F graph in *1-55 U/f Characteristic - U* and *1-56 U/f Characteristic - F*
- VCC^{plus} mode may be used in some applications
- The total current consumption of the motors must not exceed the rated output current I_{INV} for the frequency converter
- If motor sizes are widely different in winding resistance, starting problems may arise due to too low motor voltage at low a speed
- The electronic thermal relay (ETR) of the frequency converter cannot be used as motor protection for the individual motor. Provide further motor protection by including thermistors in each motor winding or individual thermal relays. (Circuit breakers are not suitable as protection devices).

Installations with cables connected in a common joint as shown in the first example in the picture is only recommended for short cable lengths.

NOTE

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)*.

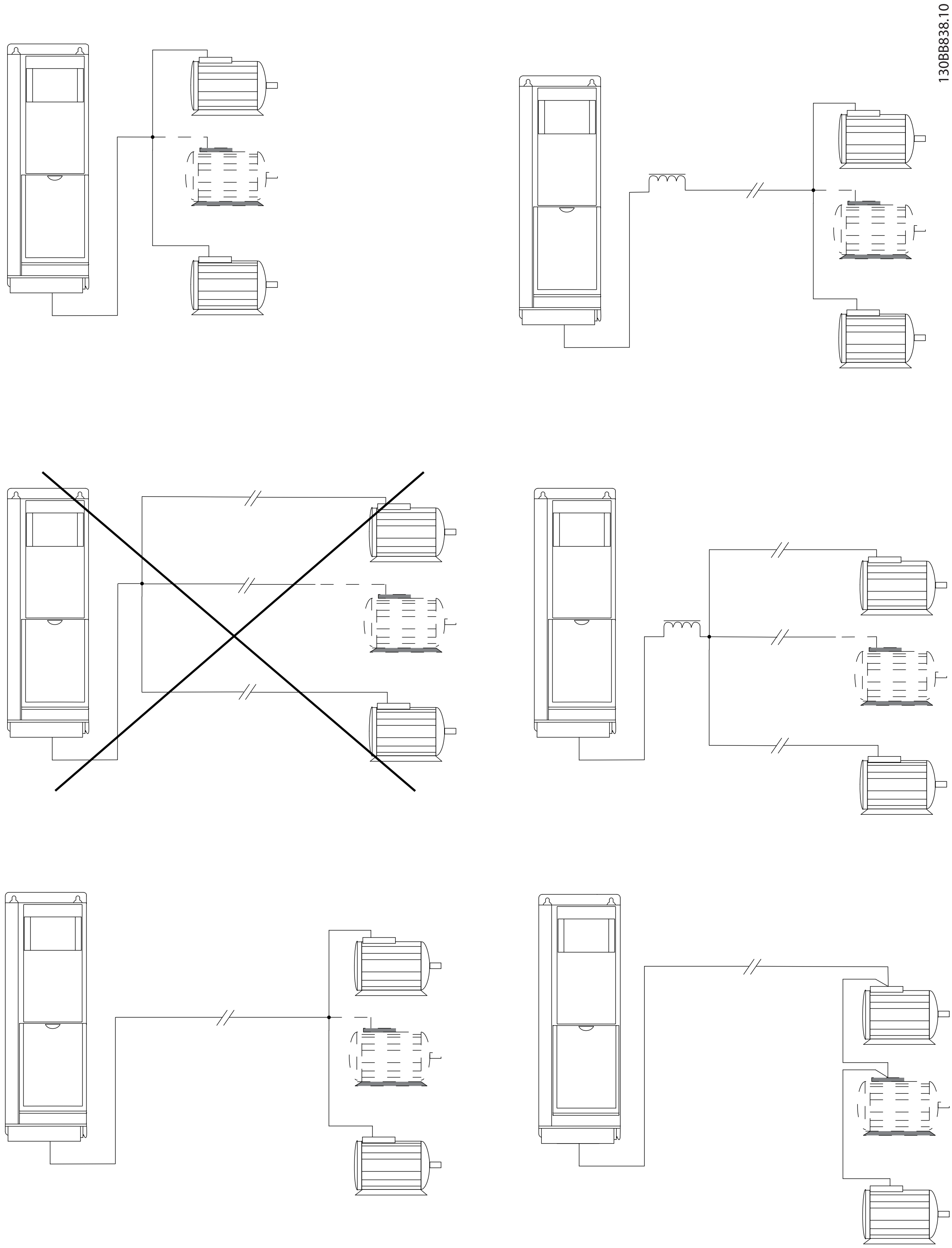


Illustration 7.24

b) Be aware of the maximum motor cable length specified in *4.3 General Specifications*.
c, f) 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).
d, e) Consider voltage drop across the motor cables.

Problems may arise at start and at low RPM values if motor sizes are widely different because small motors' relatively high ohmic resistance in the stator calls for a higher voltage at start and at low RPM values.

The electronic thermal relay (ETR) of the frequency converter cannot be used as motor protection for the individual motor of systems with parallel-connected motors. Provide further motor protection by e.g. thermistors in each motor or individual thermal relays. (Circuit breakers are not suitable as protection).

7.4.4 Motor Insulation

For motor cable lengths ≤ the maximum cable length listed in *4.3 General Specifications* the following motor insulation ratings are recommended because the peak voltage can be up to twice the DC link voltage, 2.8 times the mains voltage, due to transmission line effects in the motor cable. If a motor has lower insulation rating it is recommended to use a dU/dt or sine wave filter.

Nominal Mains Voltage	Motor Insulation
U_N≤420 V	Standard U_{LL}=1300 V
420 V<U_N≤ 500 V	Reinforced U_{LL}=1600 V
500 V<U_N≤ 600 V	Reinforced U_{LL}=1800 V
600 V<U_N≤ 690 V	Reinforced U_{LL}=2000 V

Table 7.50

7.4.5 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 proper grounding of the frequency converter, motor, driven machine, and motor to the driven machine is required.

Standard Mitigation Strategies:

1. Use an insulated bearing
2. Apply rigorous installation procedures
   - Ensure the motor and load motor are aligned
   - Strictly follow the EMC Installation guideline
   - Reinforce the PE so the high frequency impedance is lower in the PE than the input power leads
   - Provide a good high frequency connection between the motor and the frequency converter for instance by screened cable which has a 360° connection in the motor and the frequency converter
   - Make sure that 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
3. Lower the IGBT switching frequency
4. Modify the inverter waveform, 60° AVM vs. SFAVM
5. Install a shaft grounding system or use an isolating coupling
6. Apply conductive lubrication
7. Use minimum speed settings if possible
8. Try to ensure that the line voltage is balanced to ground. This can be difficult for IT, TT, TN-CS or Grounded leg systems
9. Use a dU/dt or sinus 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 screwdriver.

7.5.2 Control Cable Routing

Tie down all control wires to the designated control cable routing as shown in *Illustration 7.25* and *Illustration 7.26*. 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 details see the relevant fieldbus instruction. The cable must be placed in the provided path inside the frequency converter and tied down together

with other control wires (see *Illustration 7.25* to *Illustration 7.29*).

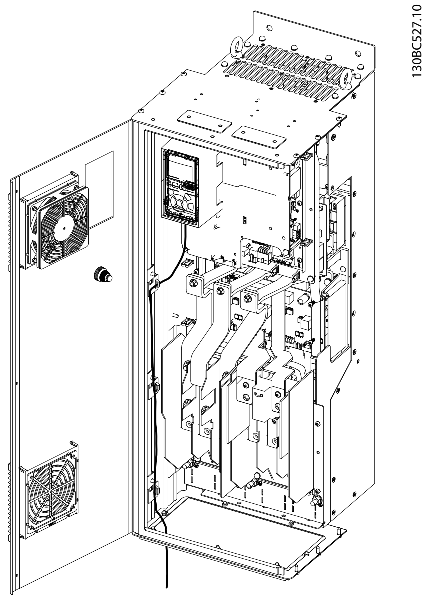


Illustration 7.25 Control Card Wiring Path for the D3h. Control Card Wiring for the D1h, D2h, D4h, E1 and E2 use the same Path

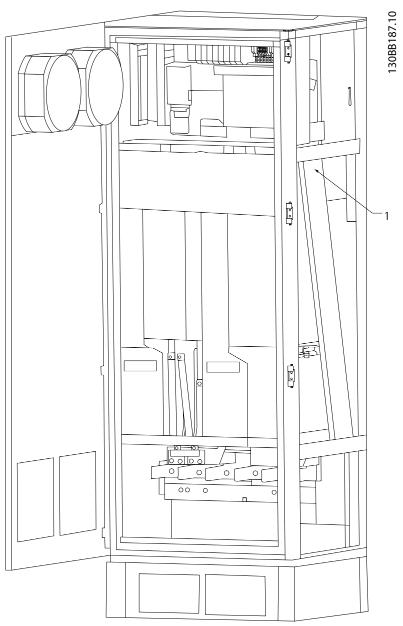


Illustration 7.26 Control Card Wiring Path for the F1/F3. Control Card Wiring for the F2/F4 use the same Path

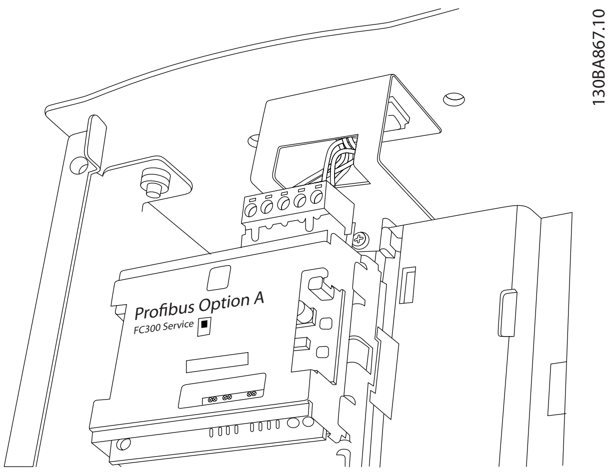


Illustration 7.27 Top Connection for Fieldbus

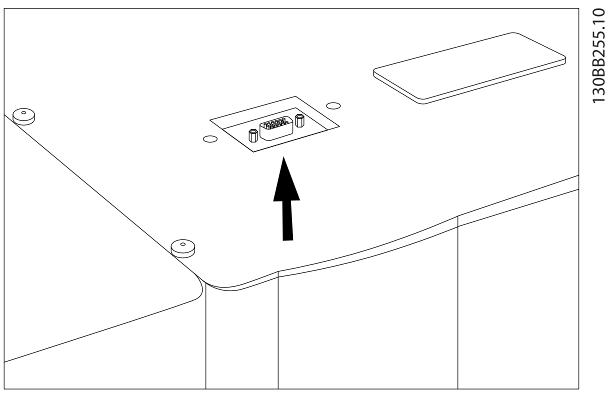


Illustration 7.28

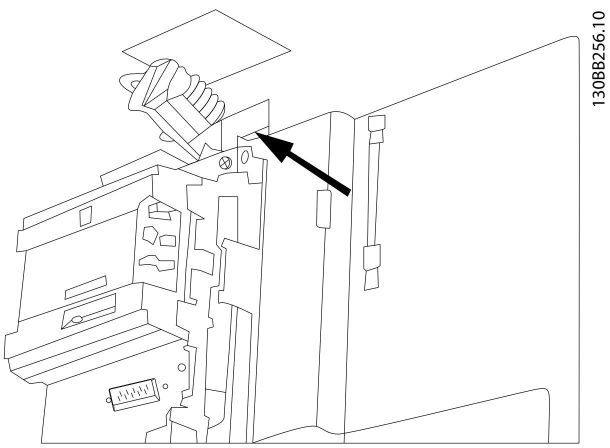


Illustration 7.29

In the Chassis (IP00) and NEMA 1 units it is also possible to connect the fieldbus from the top of the unit as shown in the following pictures. On the NEMA 1 unit a cover plate must be removed.
Kit number for fieldbus top connection: 176F1742

Installation of 24 V external DC Supply

Torque: 0.5-0.6 Nm (5 in-lbs)
Screw size: M3

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

Table 7.51

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

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 analogue I/O
4. USB Connection

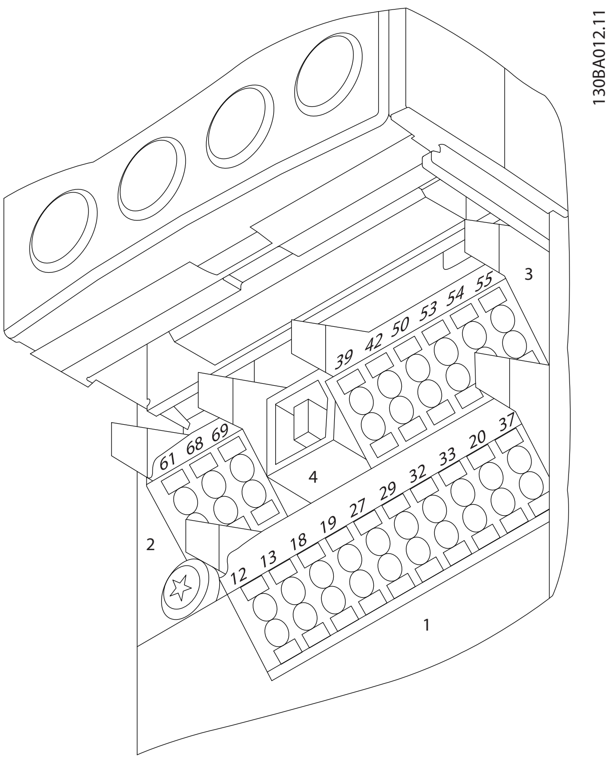


Illustration 7.30 Control Terminals (all Frame Sizes)

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 analogue 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 7.37*.

Default setting:

S201 (A53)=OFF (voltage input)

S202 (A54)=OFF (voltage input)

S801 (Bus termination)=OFF

NOTE

When changing the function of S201 (A53), S202 (A54) or S801 be careful not to use force for the switch over. It is recommended to remove the LCP fixture (cradle) when operating the switches. The switches must not be operated with power on the frequency converter.

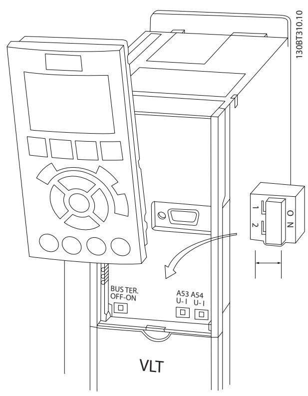


Illustration 7.31

7.5.5 Electrical Installation, Control Terminals

To mount the cable to the terminal:

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:

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

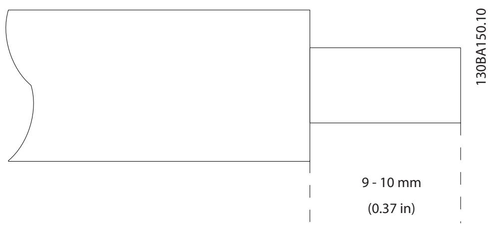


Illustration 7.32 1.

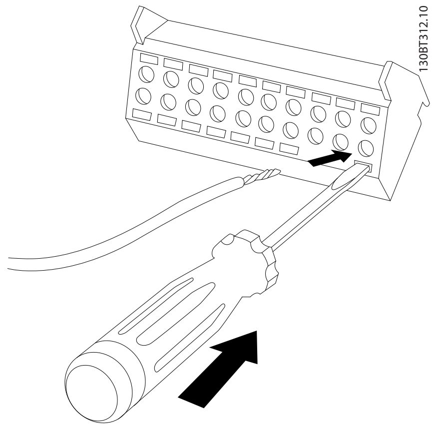


Illustration 7.33 2.

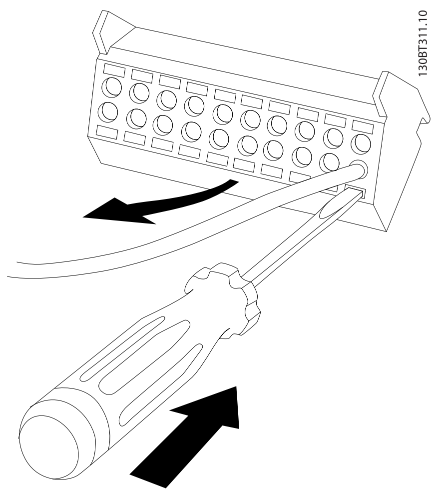


Illustration 7.34 3.

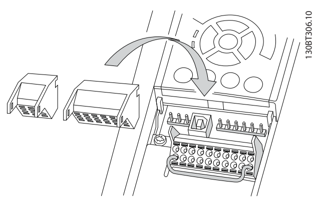
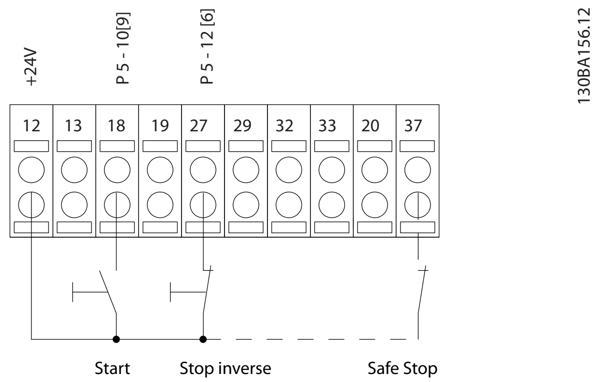


Illustration 7.35

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 stop inverse



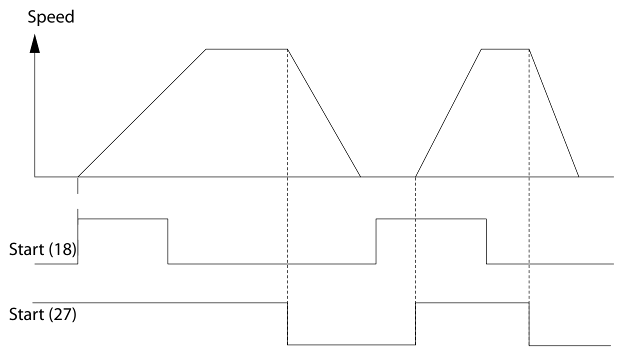


Illustration 7.36

7

7.5.7 Electrical Installation, Control Cables

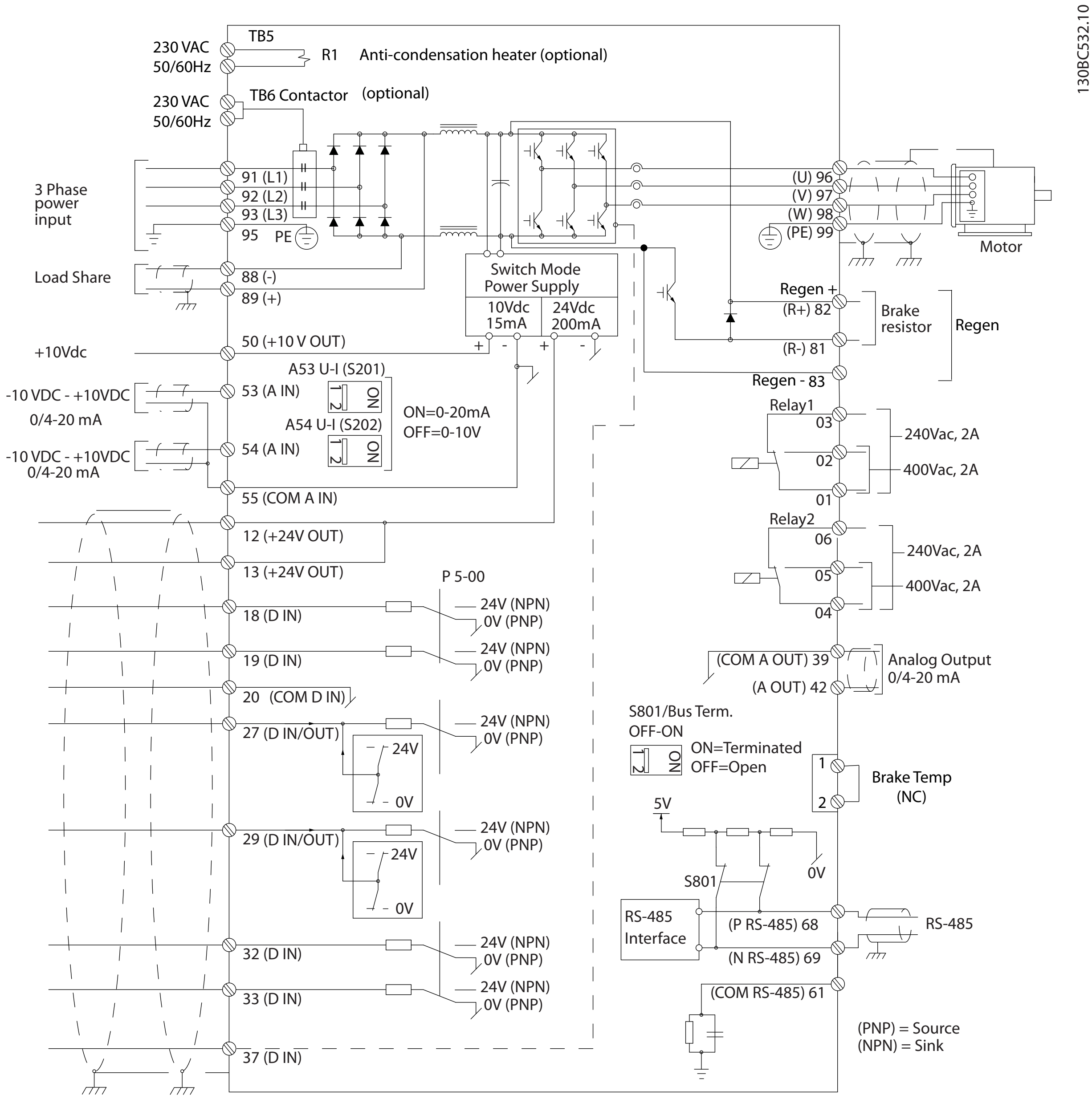


Illustration 7.37 Interconnect Diagram, D-Frame Frequency Converters

A=analogue, D=digital

Terminal 37 is used for Safe Stop. For instructions on Safe Stop installation, refer to *3.12 Safe Stop*.

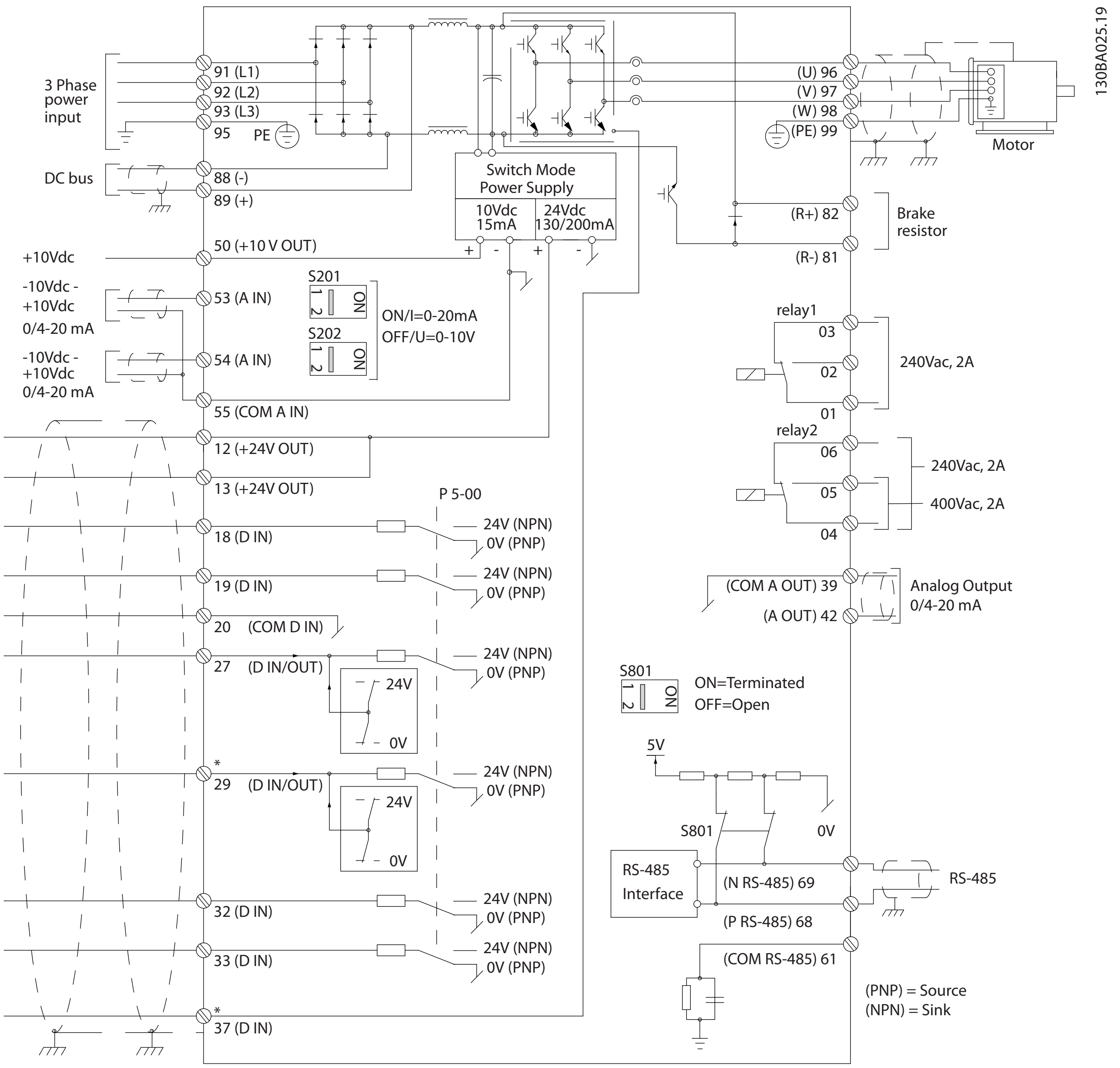


Illustration 7.38 Interconnect Diagram, E- and F-Frame Frequency Converters

Very long control cables and analogue signals may in rare cases and depending on installation 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. The digital and analogue inputs and outputs must be connected separately to the common inputs (terminal 20, 55, 39) of the frequency converter to avoid ground currents from both groups to affect other groups. For example, switching on the digital input may disturb the analogue input signal.

Input polarity of control terminals

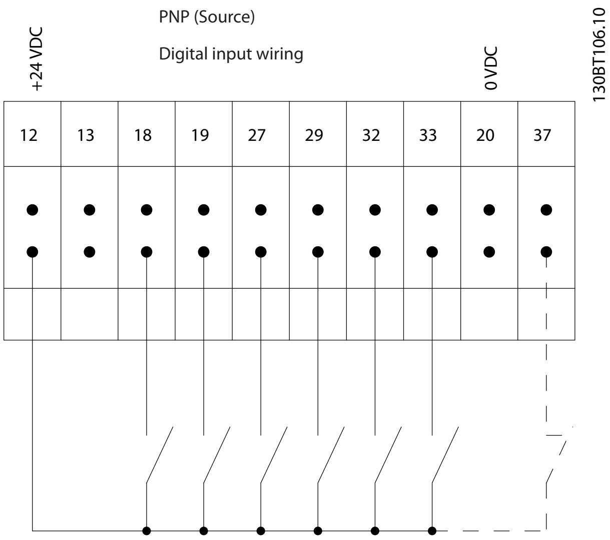


Illustration 7.39

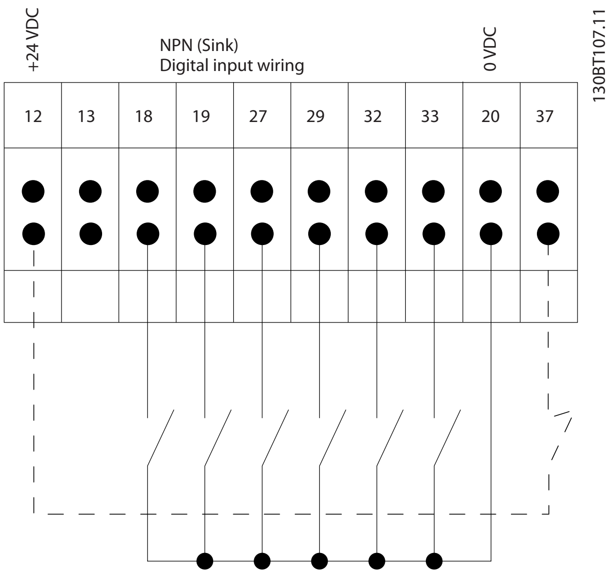


Illustration 7.40

NOTE

To comply with EMC emission specifications, screened/ armoured cables are recommended.. For more information, see *7.8 EMC-correct Installation*

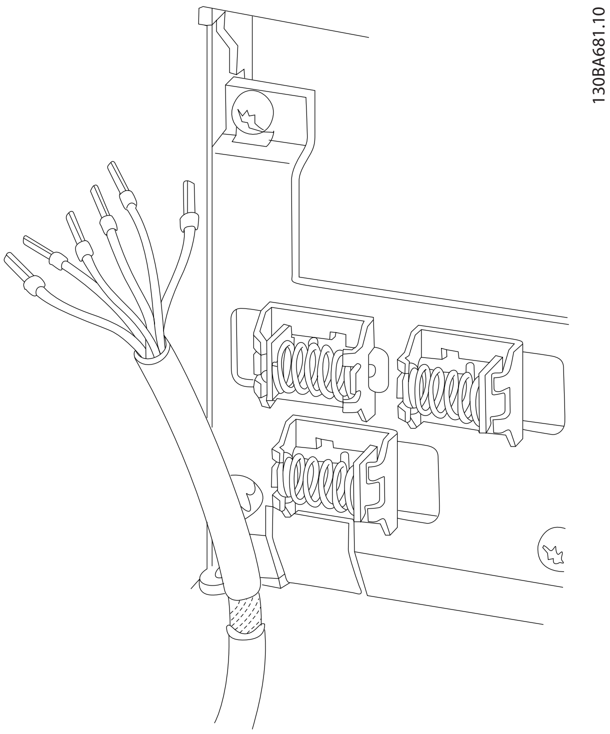


Illustration 7.41

7.5.8 12-Pulse Control Cables

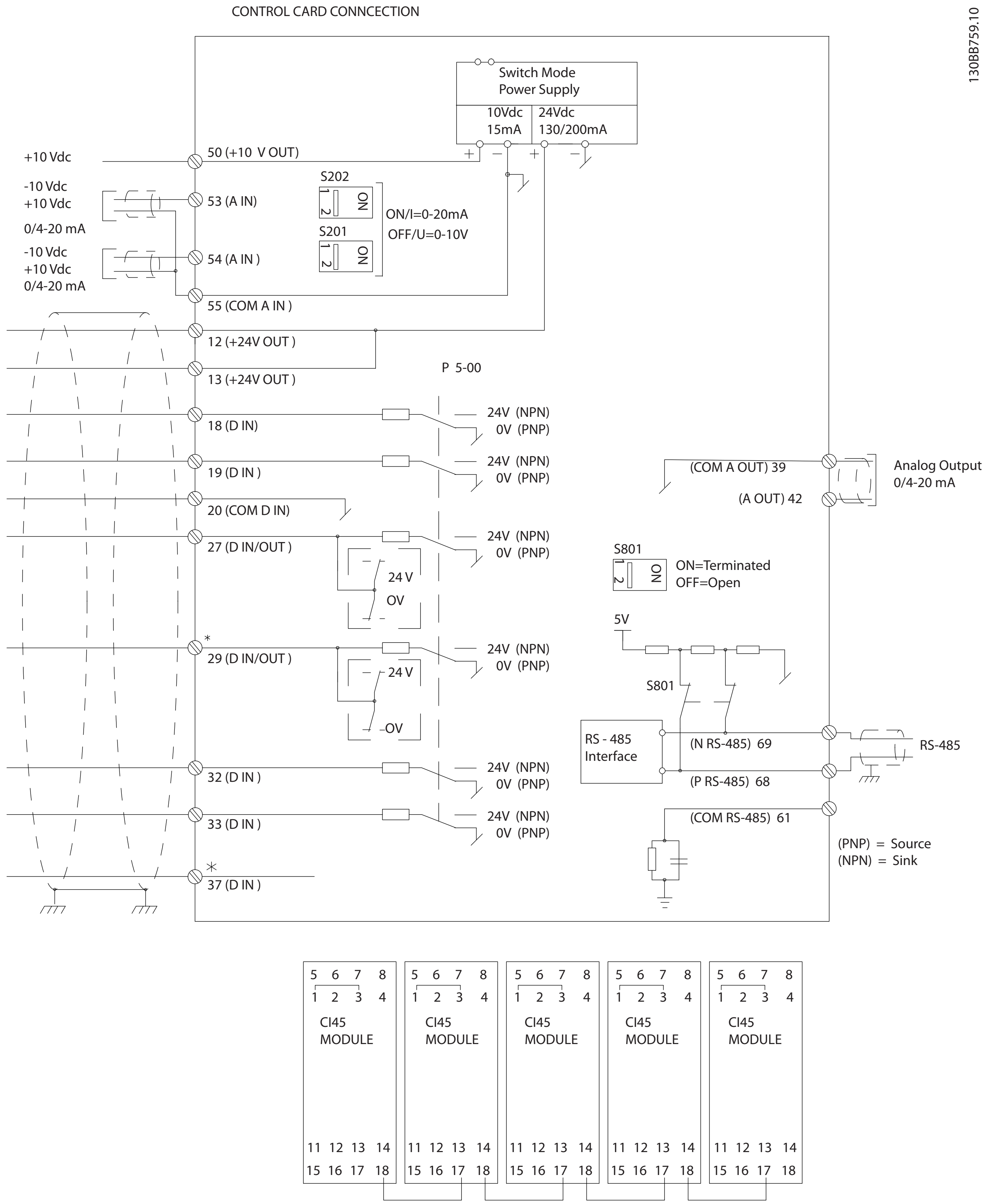


Illustration 7.42

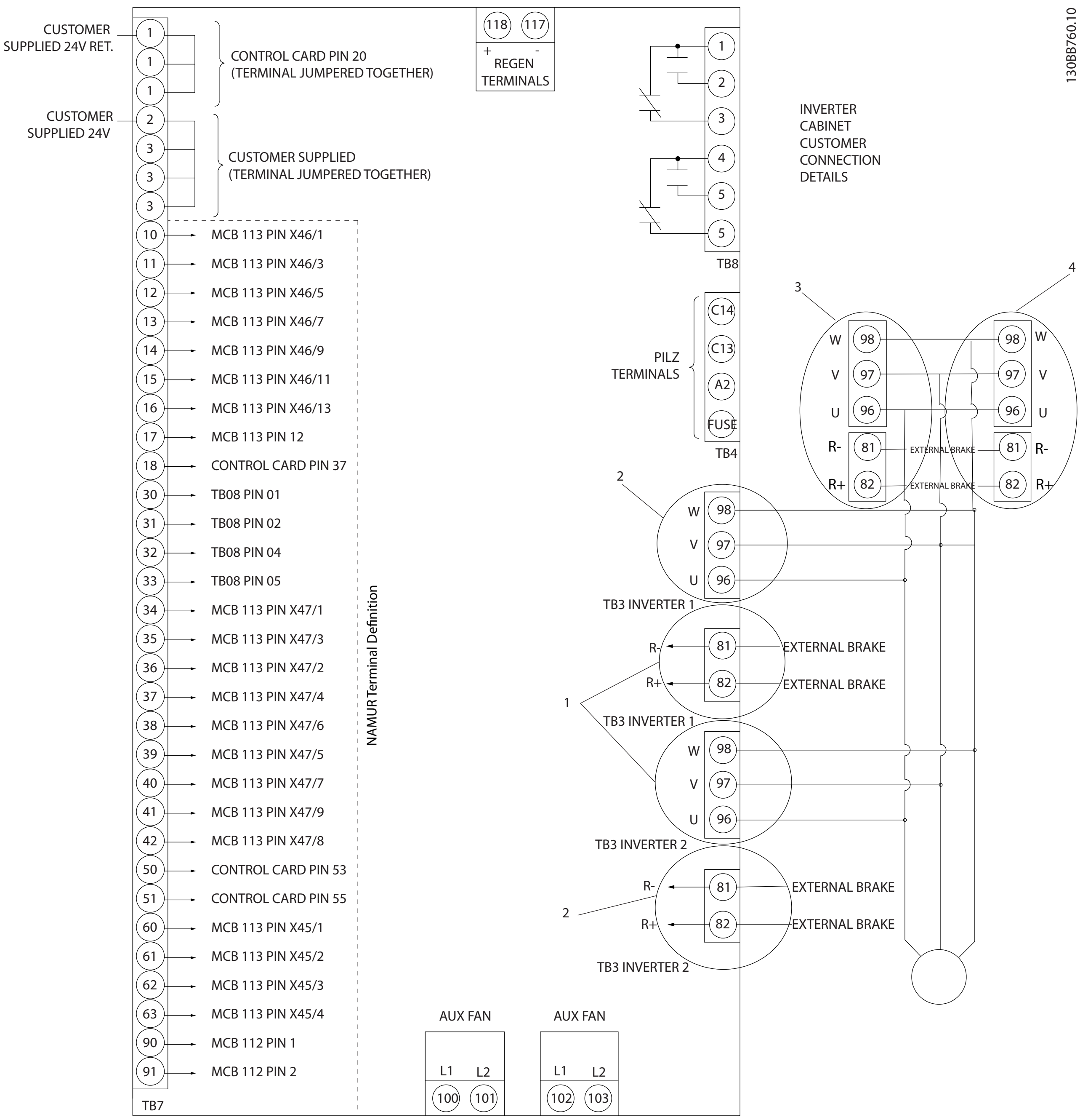


Illustration 7.43 Diagram Showing all Electrical Terminals without Options

Terminal 37 is the input to be used for Safe Stop. For instructions on Safe Stop installation, refer to *Safe Stop Installation* in *VLT® AutomationDrive Design Guide*. See also *3.12 Safe Stop*.

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

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

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

Very long control cables and analogue signals may in rare cases and depending on installation 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.

The digital and analogue inputs and outputs must be connected separately to the frequency converter common inputs (terminal 20, 55, 39) to avoid earth currents from both groups to affect other groups. For example, switching on the digital input may disturb the analogue input signal.

Input polarity of control terminals

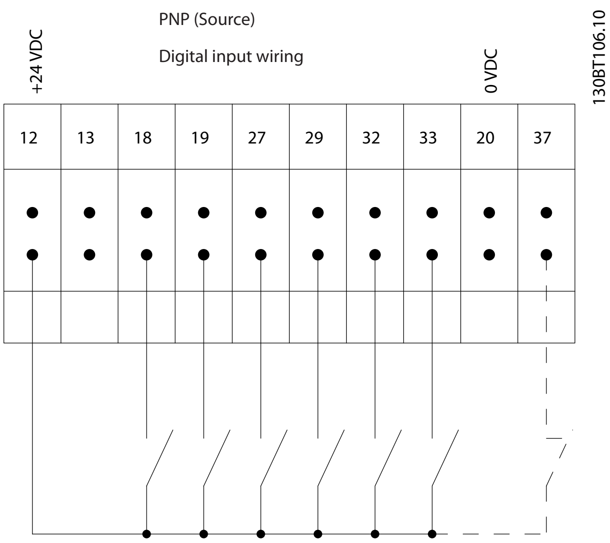


Illustration 7.44

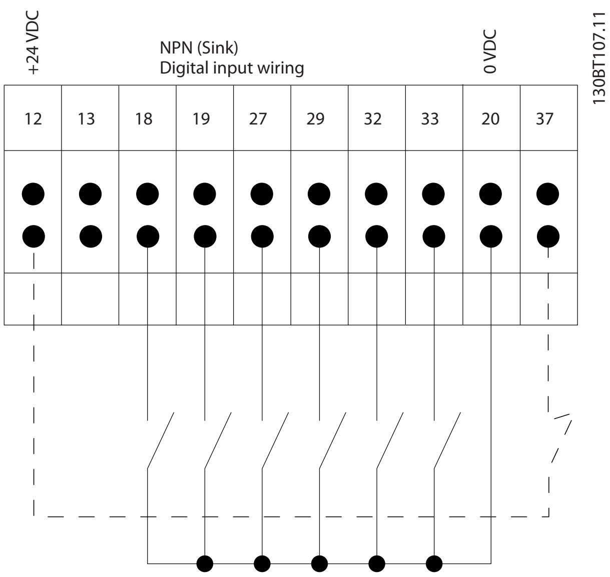


Illustration 7.45

NOTE

Control cables must be screened/armoured.

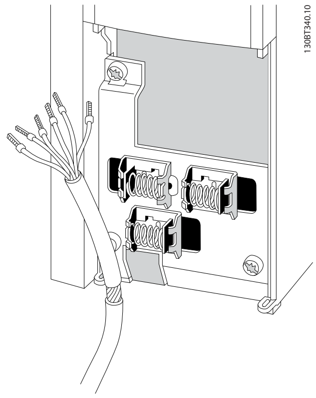


Illustration 7.46

7

Connect the wires as described in *VLT® AutomationDrive Operating Instructions*. Remember to connect the shields in a proper way to ensure optimum electrical immunity.

7.5.9 Relay Output E & F-Frame

Relay 1

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

Relay 2

- Terminal 04: common
- Terminal 05: normal open 400 V AC
- Terminal 06: normal 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*.

Additional relay outputs by using option module MCB 105.

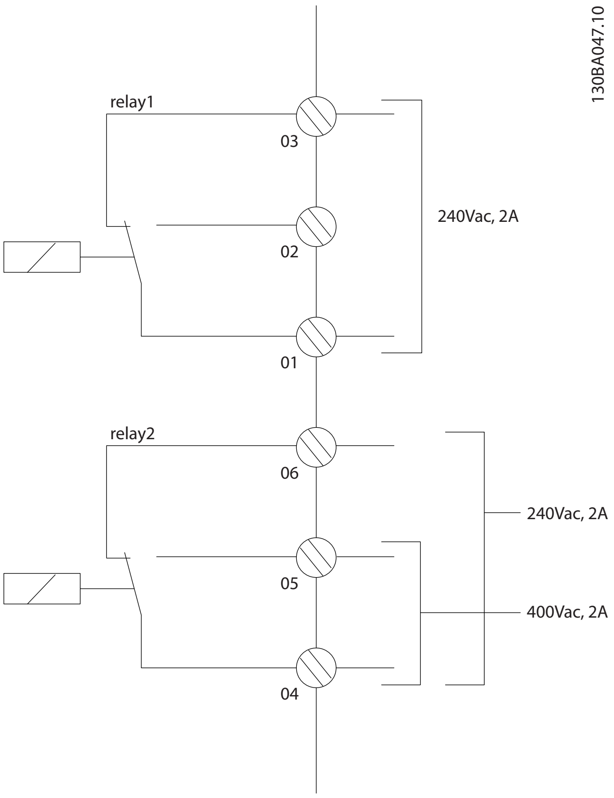


Illustration 7.47

7.5.10 Brake Resistor Temperature Switch

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

This input can be used to monitor the temperature of an externally connected brake resistor. If the input between 104 and 106 is established, the frequency converter will trip on warning/alarm 27, "Brake IGBT". If the connection is closed between 104 and 105, the frequency converter will trip on warning/alarm 27, "Brake IGBT."
A KLIXON switch must be installed that is `normally closed'. If this function is not used, 106 and 104 must be short-circuited together.
Normally closed: 104-106 (factory installed jumper)
Normally open: 104-105

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

Table 7.52

NOTE

If the temperature of the brake resistor gets too high and the thermal switch trips, the frequency converter will stop braking. The motor will start coasting.

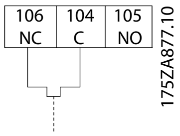


Illustration 7.48

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 numbers used	88, 89

Table 7.53

Contact Danfoss if further information is required.

7.6.2 Load Sharing

⚠WARNING

Note that voltages up to 1099 V DC may occur on the terminals.
Load Sharing calls for extra equipment and safety considerations. For further information, see load sharing Instructions.

⚠WARNING

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

Terminal No.	Function
88, 89	Loadsharing

Table 7.54

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 enables linking of the DC intermediate circuits of several frequency converters.

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. Connect the screen by means of cable clamps 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 7.55

See the *Brake instructions* for more information about safe installation.

NOTE

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, depending on the supply voltage, may occur on the terminals.

Frame size F Requirements

The brake resistor(s) must be connected 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 utilizing 4 shielded wires with ground pin 4 connected to the shield in the PC USB port. Connecting the PC to a frequency converter through the USB cable, there is a potential risk of damaging the PC USB host controller. All standard PCs are manufactured without galvanic isolation in the USB port.
Any earth ground potential difference caused by not following the recommendations described in *Connection to Mains and Earthing*, *VLT® AutomationDrive Operating Instructions*, can damage the USB host controller through the shield of the USB cable.
It is recommended to use a USB isolator with galvanic isolation to protect the PC USB host controller from earth ground potential differences, when connecting the PC to a frequency converter through a USB cable.
It is 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. It 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.

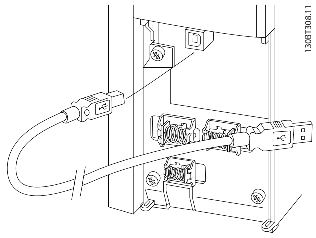


Illustration 7.49 USB Connection

7.6.5 PC Software

Data storage in PC via MCT 10 Set-Up Software:

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. Choose “Copy”
5. Select the “project” section
6. Choose “Paste”
7. Choose “Save as”

All parameters are now stored.

Data transfer from PC to frequency converter via MCT 10 Set-Up Software:

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

All parameters are now transferred to the drive.

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

7

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 380-500V frequency converters and 2.525 kV DC for 525-690 V frequency converters for one second between this short-circuit and the chassis.

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, so as to obtain electromagnetic compatibility (EMC).

- Safety earthing: Note that the frequency converter has a high leakage current and must be earthed appropriately for safety reasons. Apply 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. The lowest possible conductor impedance is obtained by keeping the conductor as short as possible and by using the greatest possible surface area. The metal cabinets of the different devices are mounted on the cabinet rear plate using the lowest possible HF impedance. This avoids having different HF voltages for the individual devices and avoids the risk of radio interference currents running in connection cables that may be used between the devices. The radio interference will have been reduced.
In order to obtain a low HF impedance, use the fastening bolts of the devices as HF connection to the rear plate. It is necessary to remove insulating paint or similar 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 cable cross-section must be at least 10 mm^2 or 2 rated earth wires terminated separately.

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 to comply with EN 61800-3 *First environment*. If the installation is in EN 61800-3 *Second environment,* i.e. industrial networks, or in an installation with its own transformer, deviation from these guidelines is allowed but not recommended. See also paragraphs *2.4.3 Frequency Converter and CE Labelling,3.5 General Aspects of EMC* and *3.5.2 EMC Test Results*.

Good engineering practice to ensure EMC-correct electrical installation:

- Use only braided screened/armoured motor cables and braided screened/armoured 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 drive to the motor is required. The EMC performance of flexible conduits varies a lot and information from the manufacturer must be obtained.
- Connect the screen/armour/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/armour 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/unarmoured motor or control cables inside cabinets housing the frequency converter(s), whenever possible.

Leave the screen as close to the connectors as possible.

Illustration 7.50 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*.

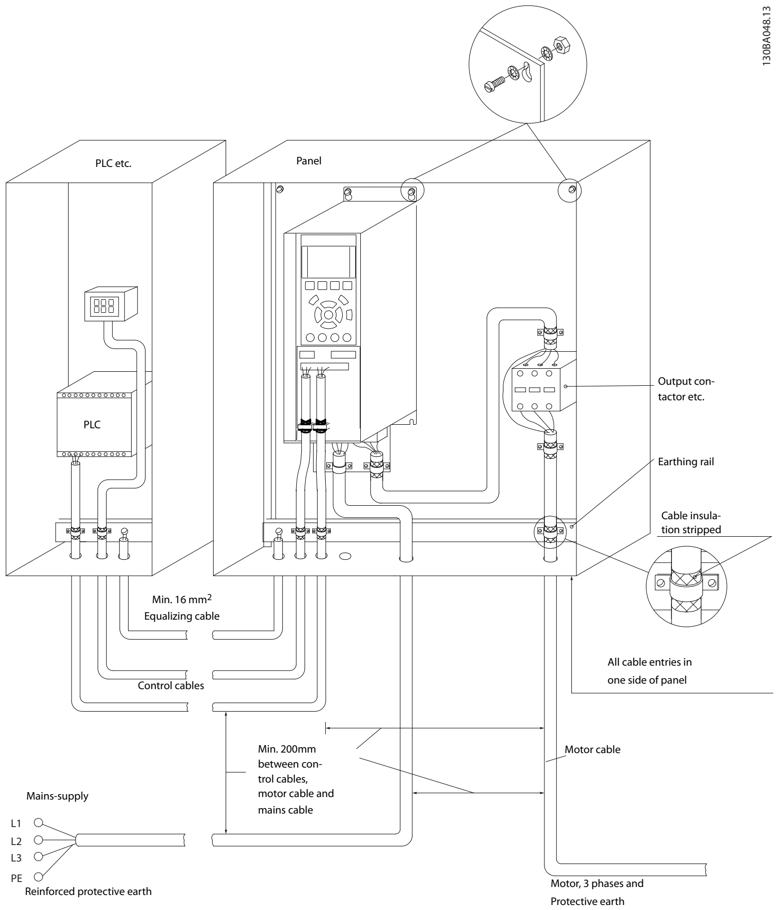


Illustration 7.50 EMC-correct Electrical Installation of a Frequency Converter in Cabinet

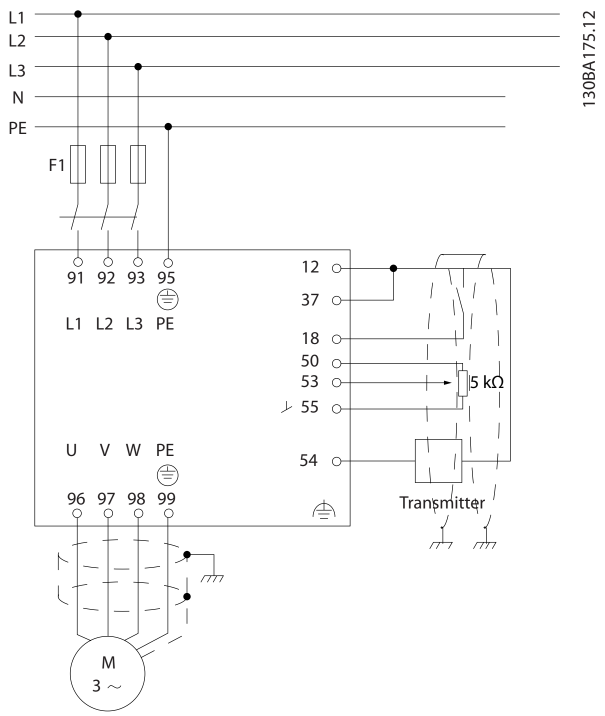


Illustration 7.51 Electrical Connection Diagram (6-pulse example shown)

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

Cable manufacturers rare state transfer impedance (Z_T) but it is often possible to estimate transfer impedance (Z_T) by assessing the physical design of the cable.

Transfer impedance (Z_T) can be assessed based on the following factors:

- The conductibility of the screen material
- The contact resistance between the individual screen conductors
- The screen coverage, i.e. the physical area of the cable covered by the screen - often stated as a percentage value
- Screen type, i.e. braided or twisted pattern

a. Aluminum-clad with copper wire.

b. Twisted copper wire or armoured steel wire cable.

c. Single-layer braided copper wire with varying percentage screen coverage.
This is the typical Danfoss reference cable.

d. Double-layer braided copper wire.

e. Twin layer of braided copper wire with a magnetic, screened/armoured intermediate layer.

f. Cable that runs in copper tube or steel tube.

g. Lead cable with 1.1 mm wall thickness.

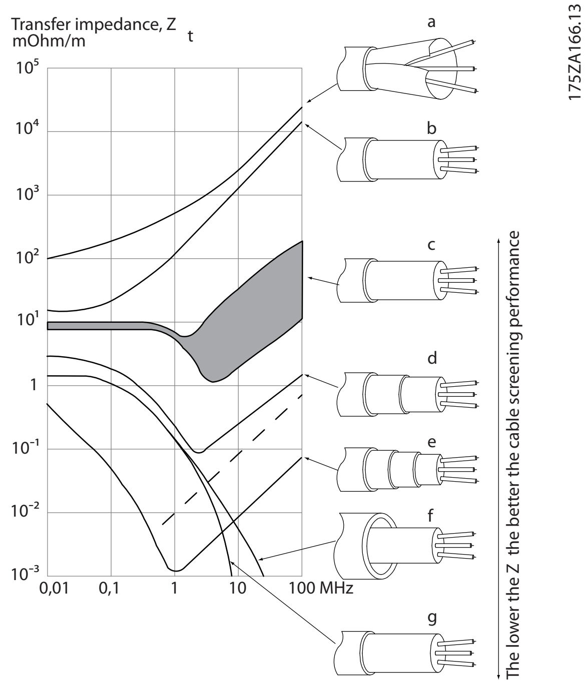


Illustration 7.52

7.8.3 Earthing of Screened Control Cables

Correct screening

The preferred method in most cases is to secure control and serial communication cables with screening clamps provided 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 that will disturb the entire system. Solve this problem by fitting an equalizing cable next to the control cable. Minimum cable cross section: 16 mm².

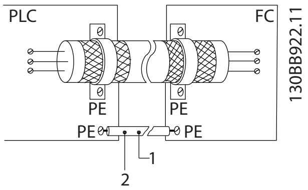


Illustration 7.53

1	Min. 16 mm^2
2	Equalizing cable

Table 7.56 Legend to *Illustration 7.53*

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

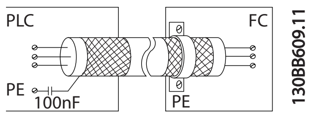


Illustration 7.54

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 7.56*:

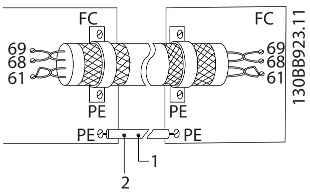


Illustration 7.55

1	Min. 16 mm^2
2	Equalizing cable

Table 7.57 Legend to *Illustration 7.55*

Alternatively, the connection to terminal 61 can be omitted:

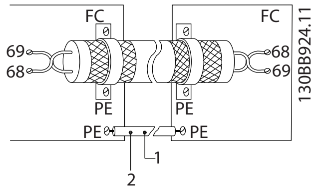


Illustration 7.56

1	Min. 16 mm^2
2	Equalizing cable

Table 7.58 Legend to *Illustration 7.56*

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 and 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 drive and *14-50 RFI Filter* on the filter. For further reference, see IEC 364-3. In case optimum EMC performance is needed, parallel motors are connected or the motor cable length is above 25 m, it is recommended to set *14-50 RFI Filter* to [ON].
1) Not available for 525-600/690 V frequency converters in frame sizes D, E and F.
In OFF, the internal RFI capacities (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).
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).

7.9.1 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 up into sine-wave currents with different frequencies, (*i.e.* different harmonic currents I_N with 50 Hz as the basic frequency):

Harmonic currents	I_1	I_5	I_7
Hz	50 Hz	250 Hz	350 Hz

Table 7.59

The harmonics do not affect the power consumption directly but increase the heat losses in the installation (transformer, cables). Consequently, in plants with a high percentage of rectifier load, maintain harmonic currents at a low level to avoid overload of the transformer and high temperature in the cables.

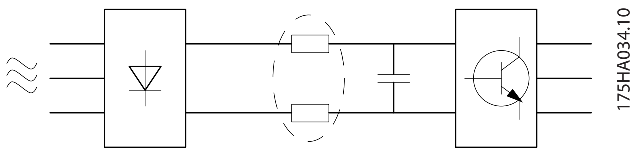


Illustration 7.57

NOTE

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 currents compared to the RMS input 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 7.60

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%.

7.9.2 The Effect of Harmonics in a Power Distribution System

In *Illustration 7.58*, 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.

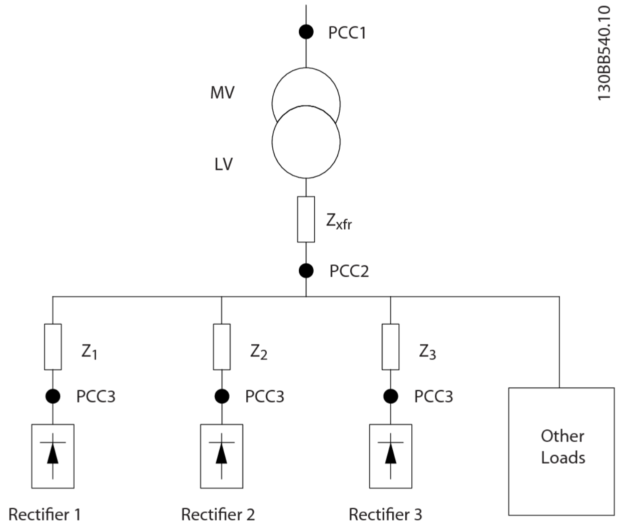


Illustration 7.58 Small Distribution System

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

Current distortion relates to apparatus performance and the individual load. Voltage distortion relates to system performance. It is not possible to determine the voltage distortion in the PCC knowing only the load's harmonic performance. In order 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}, 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 twofold

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

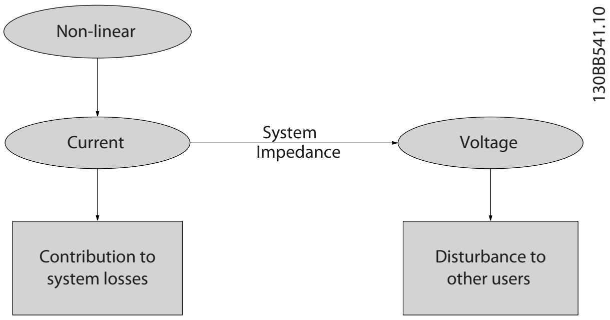


Illustration 7.59

7.9.3 Harmonic Limitation Standards and Requirements

The requirements for harmonic limitation can be:

- Application specific requirements
- 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: a 250 kVA transformer with two 110 kW motors connected is sufficient if one of the motors is connected directly on-line and the other is supplied through a frequency converter. 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. Different standards apply in different geographical areas and industries. The following standards are the most common:

- IEC61000-3-2
- IEC61000-3-12
- IEC61000-3-4
- IEEE 519
- G5/4

See the *Harmonic Filter AHF 005/010 Design Guide* for specific details on each standard.

7.9.4 Harmonic Mitigation

In cases where additional harmonic suppression is required, Danfoss offers a wide range of mitigation equipment:

- VLT 12-pulse drives
- VLT AHF filters
- VLT Low Harmonic Drives
- VLT Active Filters

The choice of 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, maintenance, etc.)

7.9.5 Harmonic Calculation

Determining the degree of voltage pollution on the grid and needed precaution is done with the Danfoss MCT 31 calculation software. The free tool *VLT® Harmonic Calculation MCT 31* is available at *www.danfoss.com*. The software is built with a focus on user-friendliness and limited to involve only system parameters that are normally accessible.

7.10 Residual Current Device

Use RCD relays, multiple protective earthing or earthing as extra protection, provided that local safety regulations are complied with.
If an earth fault appears, a DC content may develop in the faulty current.
If RCD relays are used, local regulations must be observed. Relays must be suitable for protection of 3-phase equipment with a bridge rectifier and for a brief discharge on power-up. See *3.7 Earth Leakage Current* for further information.

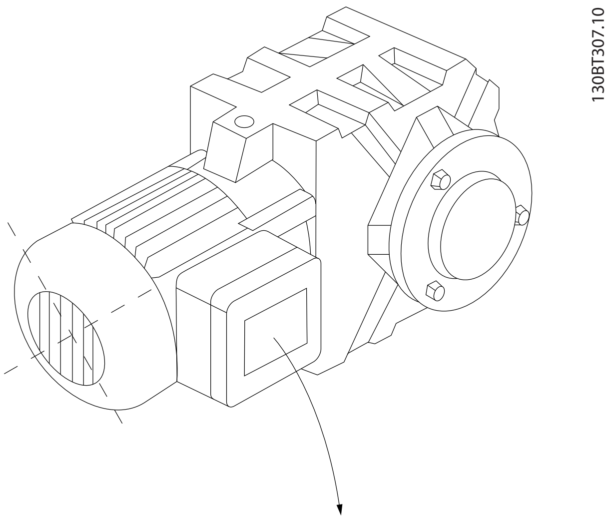
7.11 Final Setup and Test

To test the set-up and ensure that the frequency converter is running, follow these steps:

Step 1. Locate the motor name plate

NOTE

The motor is either star- (Y) or delta- connected (Δ). This information is located on the motor name plate data.



BAUER D-7 3734 ESLINGEN				
3~ MOTOR NR. 1827421 2003				
S/E005A9				
	1,5	KW		
n_2 31,5	/min.	400	Y	V
n_1 1400	/min.		50	Hz
COS θ 0,80			3,6	A
1,7L				
B	IP 65	H1/1A		

Illustration 7.60

Step 2. Enter the motor name plate data in this parameter list.
To access this list, first press the [Quick Menu] key 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)

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.

Stop the AMA during operation

- Press [Off] - the frequency converter enters into alarm mode and the display shows that the AMA was terminated by the user.

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, make sure to mention number and alarm description.

NOTE

Unsuccessful AMA is often caused by incorrectly registered motor name plate data or a too big a difference between the motor power size and the frequency converter power size.

Step 4. Set speed limit and ramp times

Set up the desired limits for speed and ramp time:

- 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

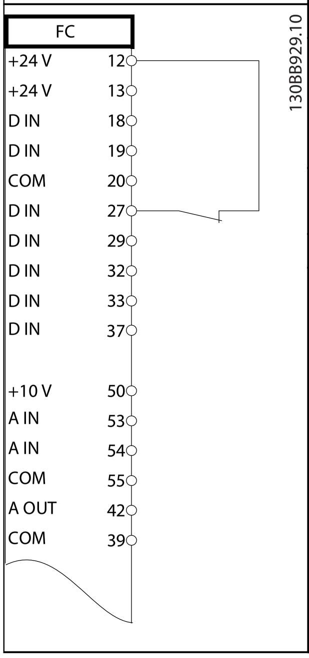
8 Application Examples

NOTE

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.

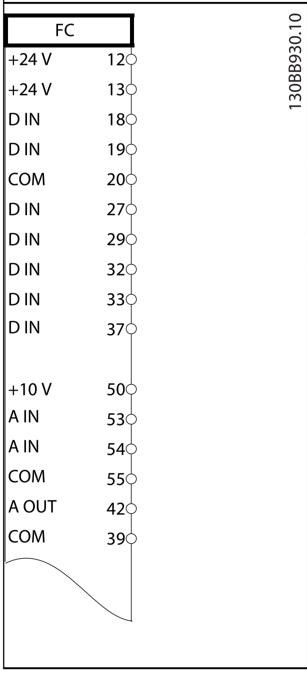
The examples in this section are intended as a quick reference for common applications.

- 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 analogue terminals A53 or A54 are required, these are also shown



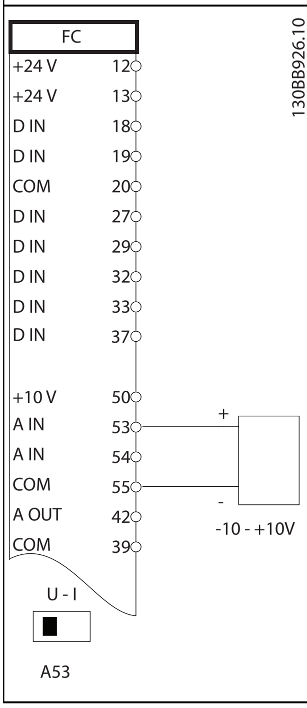
Parameters	
Function	**Setting**
1-29 Automatic Motor Adaptation (AMA)	[1] Enable complete AMA
5-12 Terminal 27 Digital Input	[2]* Coast inverse
*=Default Value	
Notes/comments: Parameter group *1-2* Motor Data* must be set according to motor	

Table 8.1 AMA with T27 Connected



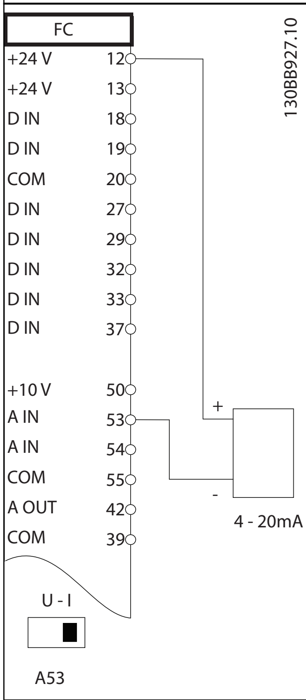
Parameters	
Function	**Setting**
1-29 Automatic Motor Adaptation (AMA)	[1] Enable complete AMA
5-12 Terminal 27 Digital Input	[0] No operation
*=Default Value	
Notes/comments: Parameter group *1-2* Motor Data* must be set according to motor	

Table 8.2 AMA without T27 Connected



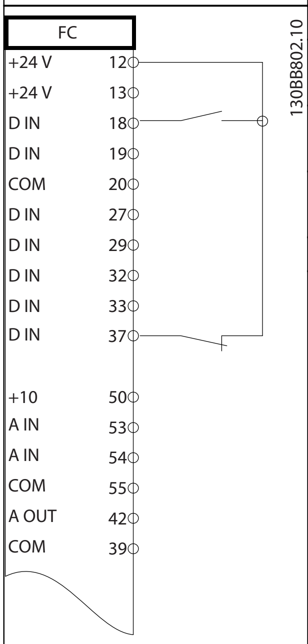
Parameters	
Function	**Setting**
6-10 Terminal 53 Low Voltage	0.07 V*
6-11 Terminal 53 High Voltage	10 V*
6-14 Terminal 53 Low Ref./Feedb. Value	0 RPM
6-15 Terminal 53 High Ref./Feedb. Value	1500 RPM
*=Default Value	
Notes/comments:	

Table 8.3 Analogue 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 Analogue Speed Reference (Current)



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

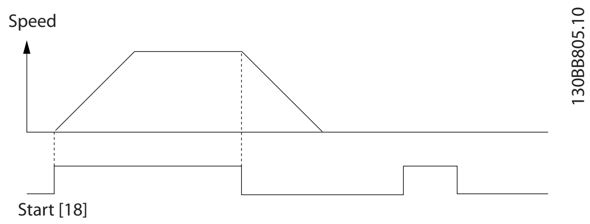
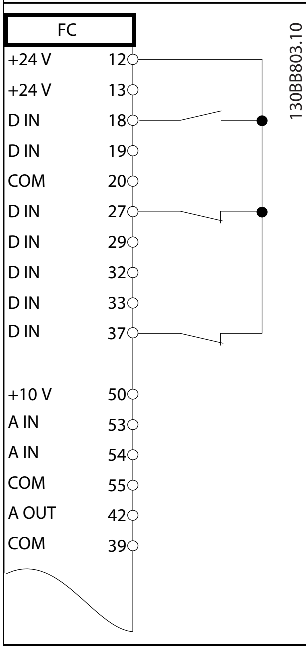


Illustration 8.1



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

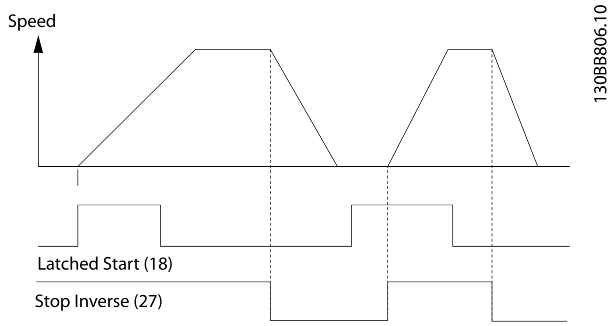
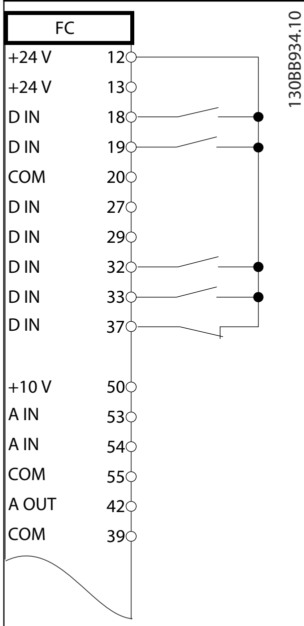


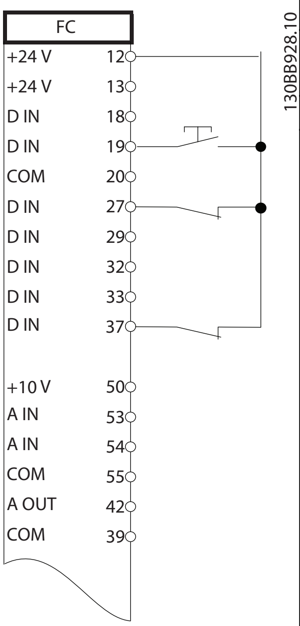
Illustration 8.2

8



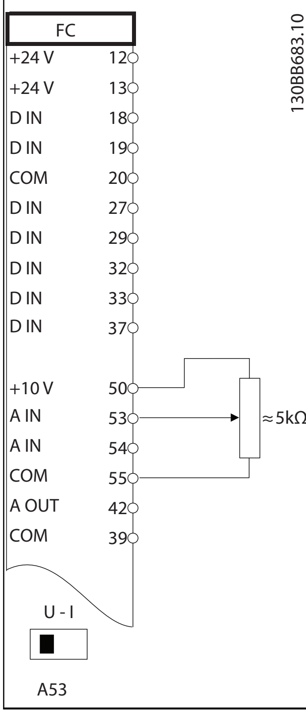
Function	Setting
5-10 Terminal 18 Digital Input	[8] Start
5-11 Terminal 19 Digital Input	[10] Reversing*
5-12 Terminal 27 Digital Input	[0] No operation
5-14 Terminal 32 Digital Input	[16] Preset ref bit 0
5-15 Terminal 33 Digital Input	[17] Preset ref bit 1
3-10 Preset Reference	
Preset ref. 0 Preset 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



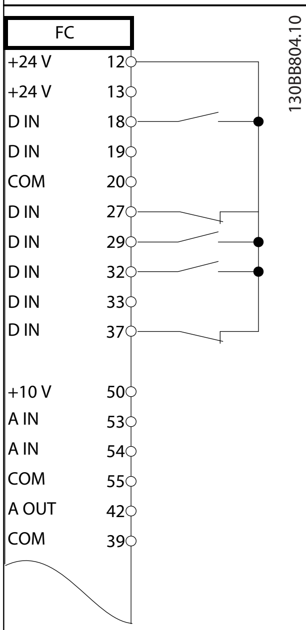
Function	Setting
5-11 Terminal 19 Digital Input	[1] Reset
*=Default Value	
Notes/comments:	

Table 8.8 External Alarm Reset



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)



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

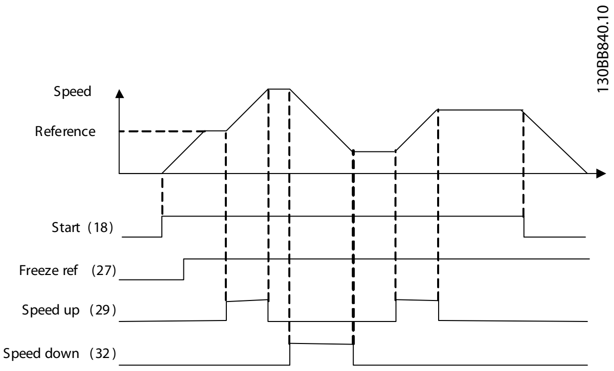


Illustration 8.3

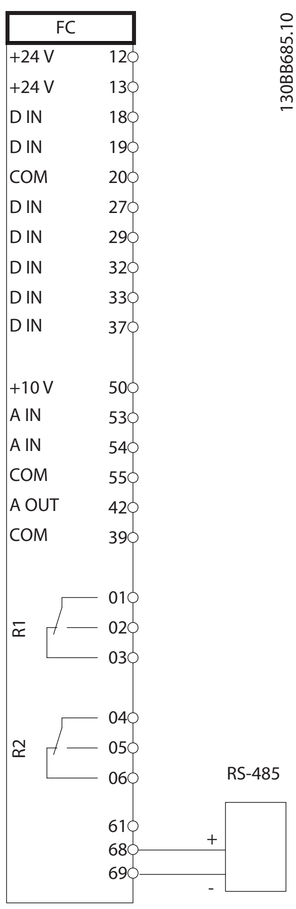
	Parameters	
	Function	**Setting**
	8-30 Protocol	FC*
	8-31 Address	1*
	8-32 Baud Rate	9600*
	*=Default Value	
	Notes/comments: Select protocol, address and baud rate in the above mentioned parameters.	

Table 8.11 RS-485 Network Connection

CAUTION

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

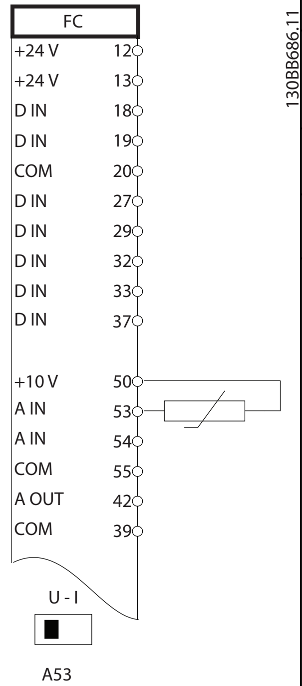
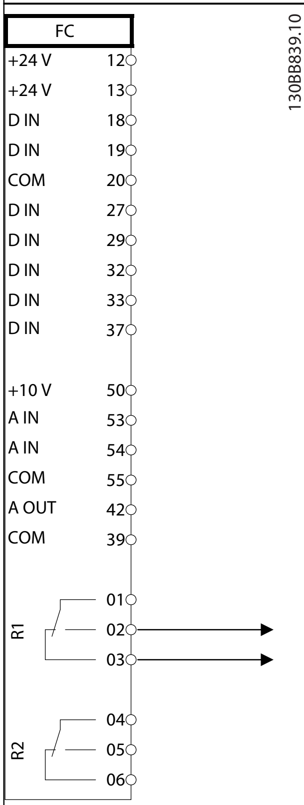
	Parameters	
	Function	**Setting**
	1-90 Motor Thermal Protection	[2] Thermistor trip
	1-93 Thermistor Source	[1] analogue input 53
	*=Default Value	
	Notes/comments: If only a warning is desired, *1-90 Motor Thermal Protection* should be set to *[1] Thermistor warning*.	

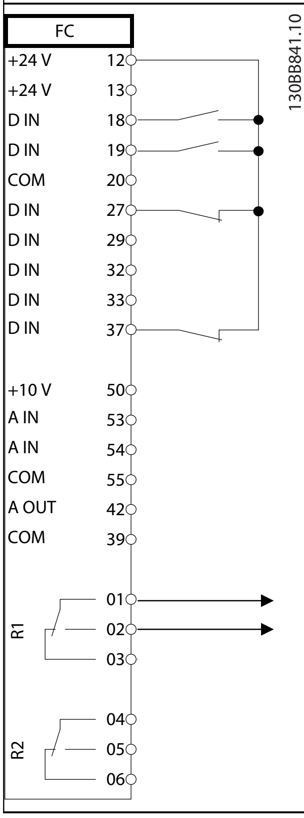
Table 8.12 Motor Thermistor

8



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 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 then the drive continues and the warning disappears. But Relay 1 will still be triggered until [Reset] on the LCP.	

Table 8.13 Using SLC to Set a Relay



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

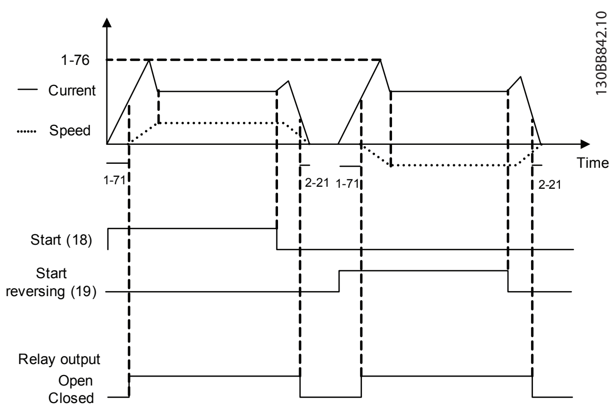


Illustration 8.4

8.1.1 Encoder Connection

The purpose of this guideline is to ease the set-up of encoder connection to the frequency converter. Before setting up the encoder, the basic settings for a closed loop speed control system will be shown.
See also *9.3 Encoder Option* .

Encoder Connection to the frequency converter

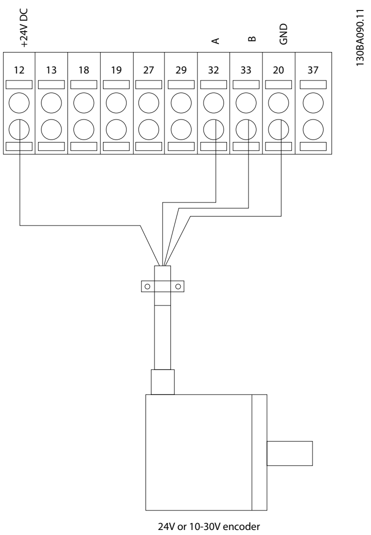


Illustration 8.5

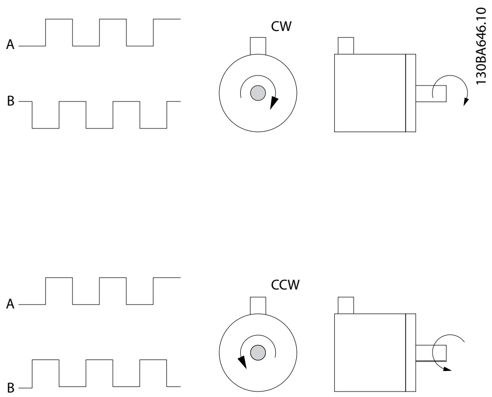


Illustration 8.6 24 V Incremental Encoder. Max. Cable Length 5 m

8.1.2 Encoder Direction

The direction of the encoder is determined by which order the pulses are entering the drive.
Clockwise direction means channel A is 90 electrical degrees before channel B.
Counter Clockwise direction means channel B is 90 electrical degrees before A.
The direction can be determined by looking into the shaft end.

8.1.3 Closed Loop Drive System

A drive system consist usually of additional elements such as:

- Motor
- Add
  (Gearbox)
  (Mechanical Brake)
- FC 302
- Encoder as feed-back system
- Brake resistor for dynamic braking
- Transmission
- Load

Applications demanding mechanical brake control will usually need a brake resistor.

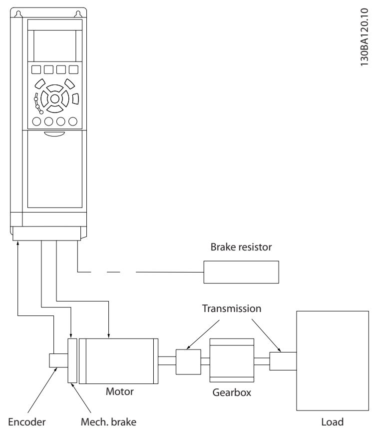


Illustration 8.7 Basic Set-up for FC 302 Closed Loop Speed Control

8.1.4 Programming of Torque Limit and Stop

In applications with an external electro-mechanical brake, such as hoisting applications, it is possible to stop the frequency converter via a 'standard' stop command and simultaneously activate the external electro-mechanical brake.
The example given below illustrates the programming of frequency converter connections.
The external brake can be connected to relay 1 or 2, see *3.9 Mechanical Brake Control*. Program terminal 27 to Coast, inverse [2] or Coast and Reset, inverse [3], and program terminal 29 to Terminal mode 29 Output [1] and Torque limit & stop [27].

Description
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 Torque limit and stop [27]) 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 (i.e. due to excessive overload).

- 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]

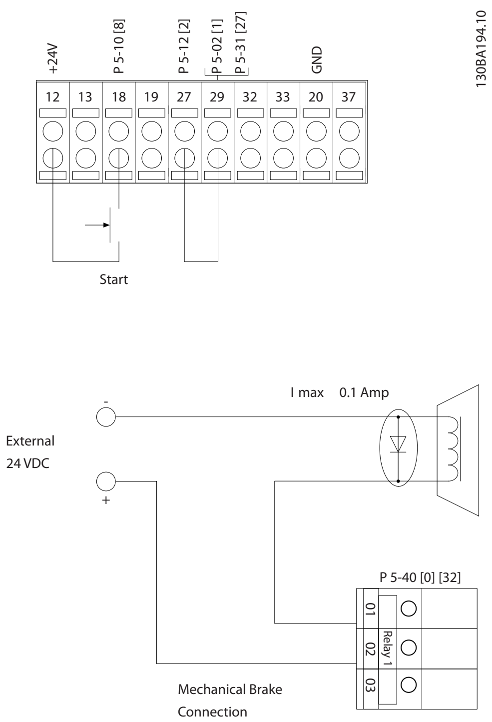


Illustration 8.8

9 Options and Accessories

Danfoss offers a wide range of options and accessories for VLT® AutomationDrive.

9.1.1 Mounting of Option Modules in Slot A

Slot A position is dedicated to Fieldbus options. For further information, see the instructions that accompany the optional equipment.

9.1.2 Mounting of Option Modules in Slot B

The power to the frequency converter must be disconnected.

For discharge time, see the instruction supplied with the option.

Ensure that the parameter data has been saved (i.e. by MCT 10 software) before option modules are inserted/ removed from the frequency converter.

- Remove the LCP, the terminal cover, and the LCP frame from the frequency converter
- Fit the MCB 10x option card into slot B
- Connect the control cables and relieve the cable using the enclosed cable strips
  * Remove the knock out in the extended LCP frame, so that the option will fit under the extended LCP frame
- Fit the extended LCP frame and terminal cover
- Fit the LCP or blind cover in the extended LCP frame
- Connect power to the frequency converter
- Set up the input/output functions in the corresponding parameters, as mentioned in *4.3 General Specifications*

9.1.3 Mounting of Options in Slot C

The power to the frequency converter must be disconnected.

It is strongly recommended to make sure the parameter data is saved (i.e. by MCT 10 software) before option modules are inserted into/removed from the frequency converter.
When installing a C option, a mounting kit is required. Refer to *5 How to Order* for a list of ordering numbers. 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.

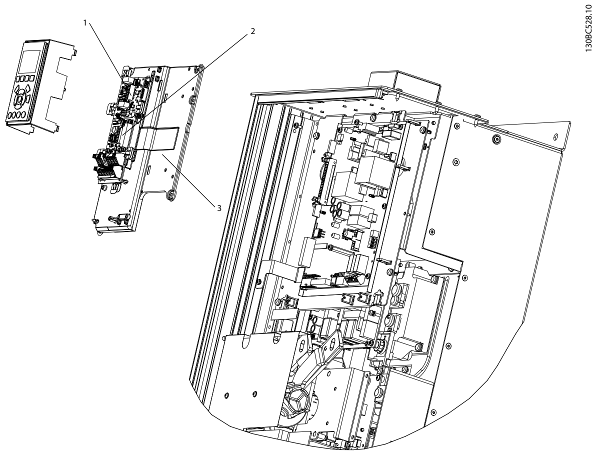


Illustration 9.1 Locations of Option Mounting Slots

1	Slot A
2	Slot B
3	Slot C

Table 9.1 Legend to *Illustration 9.1*

9

9.2 General Purpose Input Output Module MCB 101

MCB 101 is used for extension of digital and analogue inputs and outputs of FC 302.

Contents: MCB 101 must be fitted into slot B in the VLT® AutomationDrive.

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

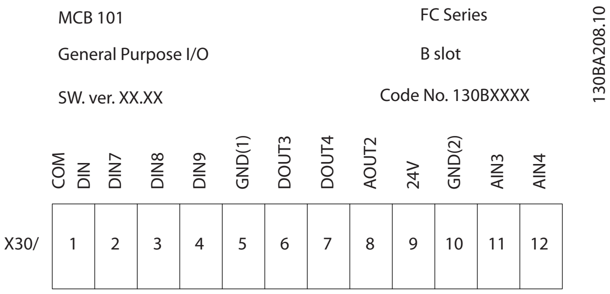


Illustration 9.2

9.2.1 Galvanic Isolation in the MCB 101

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

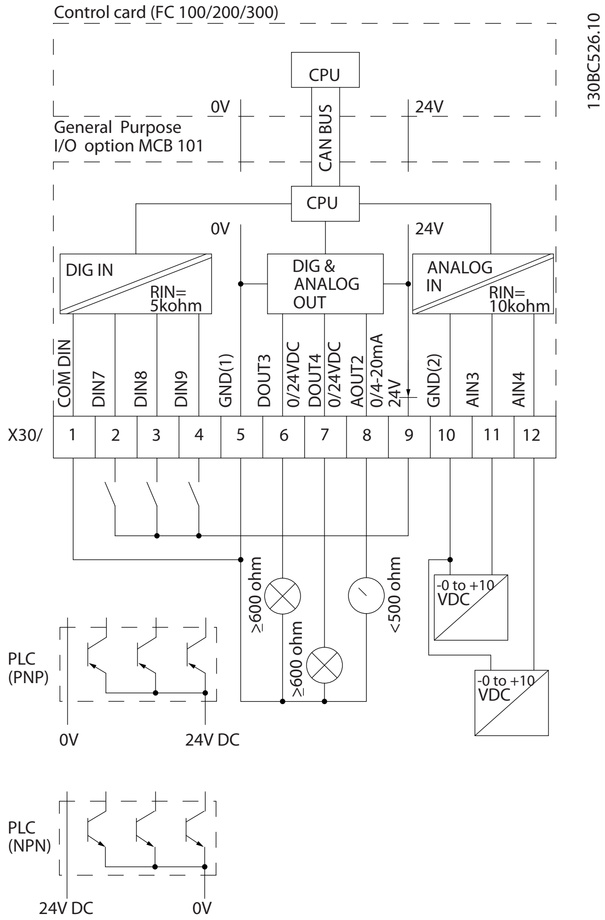


Illustration 9.3 Principle Diagram

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 Analogue Inputs - Terminal X30/11, 12

Analogue input	
Number of analogue 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 analogue inputs	10 bit (+ sign)
Accuracy of analogue 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 Analogue Output - Terminal X30/8

Analogue output	
Number of analogue outputs	1
Terminal number	42
Current range at analogue output	0-20 mA
Max. load GND - analogue output	500 Ω
Accuracy on analogue output	Max. error: 0.5 % of full scale
Resolution on analogue 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*.

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
Encoder monitor:
The 4 encoder channels (A, B, Z, and D) are monitored, open and short circuit can be detected. There is a green LED for each channel which lights up when the channel is OK.

NOTE

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*)

9

Connector designation X31	Incremental encoder (refer to graphic A)	SinCos encoder Hiperface® (refer to graphic B)	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

** Supply for encoder: see data on encoder*

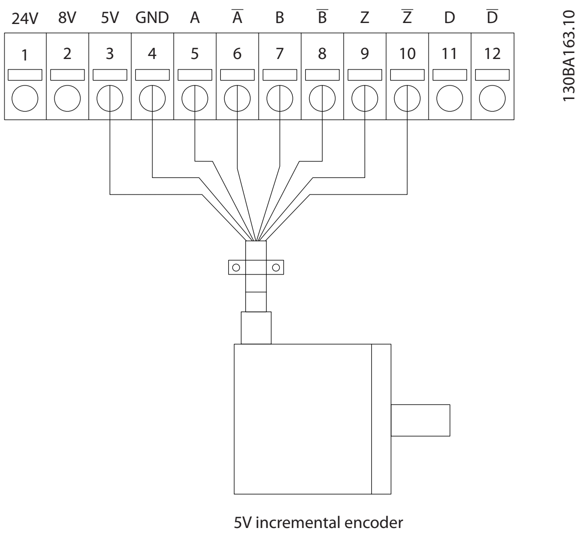


Illustration 9.4

Max. cable length 150 m.

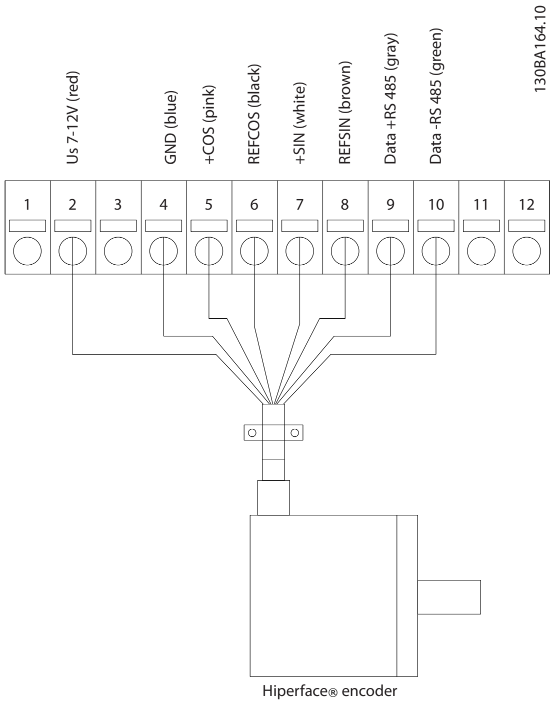


Illustration 9.5

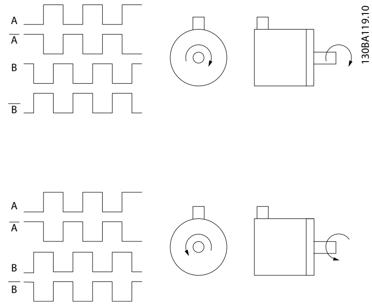


Illustration 9.6

9.4 Resolver Option MCB 103

MCB 103 Resolver option is used for interfacing resolver motor feedback to VLT® AutomationDrive. Resolvers are used basically 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 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

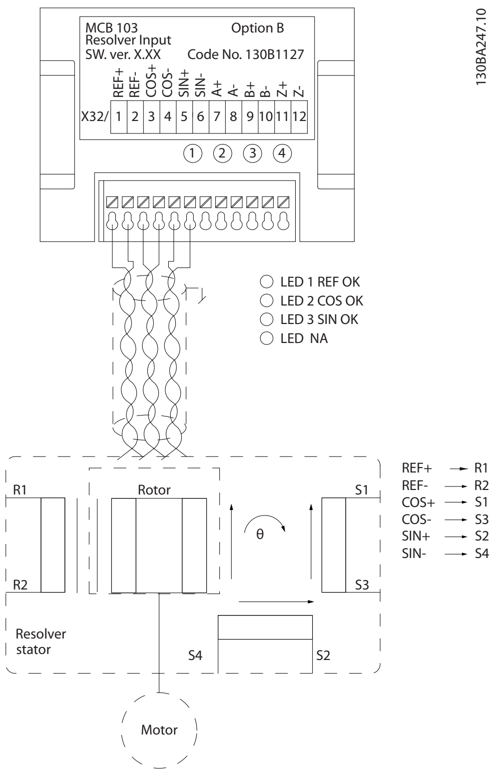


Illustration 9.7

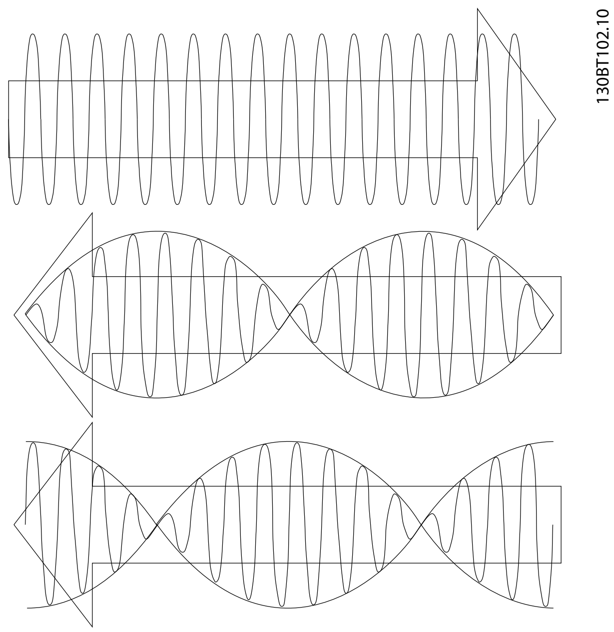


Illustration 9.8

9

NOTE

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

LED indicators

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

The LEDs are active when *17-61 Feedback Signal Monitoring* is set to *Warning* or *Trip*.

Set-up example

In this example 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.

NOTE

Resolver cables must be screened and separated from the motor cables.

NOTE

The screen of the resolver cable must be correctly connected to the de-coupling plate and connected to chassis (earth) on the motor side.

NOTE

Always use screened motor cables and brake chopper cables.

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*).

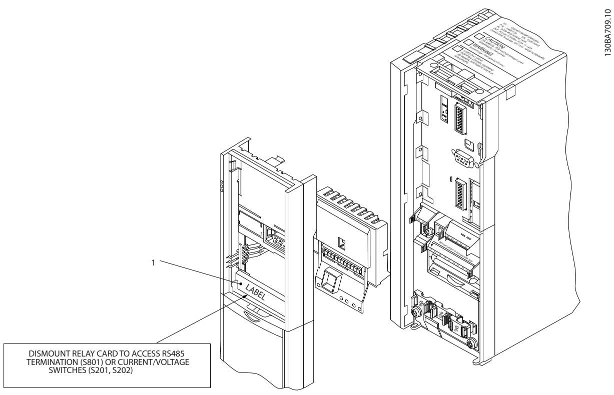


Illustration 9.9 A2-A3-B3

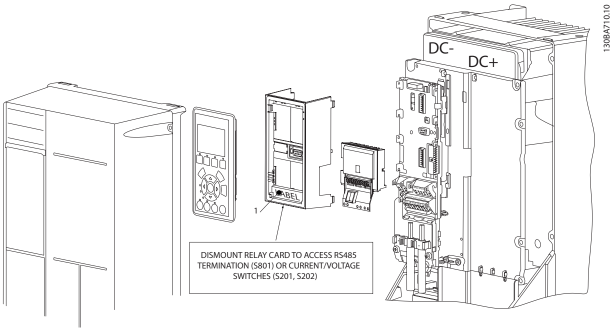


Illustration 9.10 A5-B1-B2-B4-C1-C2-C3-C4

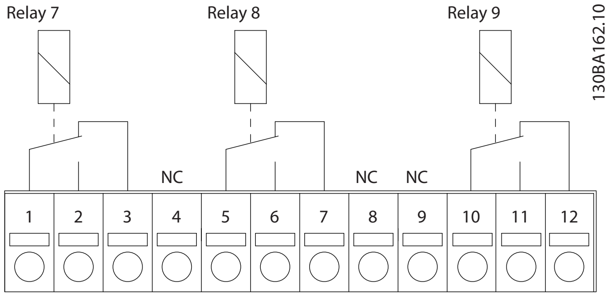


Illustration 9.11

1) **IMPORTANT !** The label MUST be placed on the LCP frame as shown (UL approved).

⚠WARNING

Warning Dual supply

How to add the MCB 105 option:

- The power to the frequency converter must be disconnected
- The power to the live part connections on relay terminals must be disconnected
- 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)
- Do not mix live parts (high voltage) with control signals (PELV)
- 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].

NOTE

Array [6] is relay 7, array [7] is relay 8, and array [8] is relay 9.

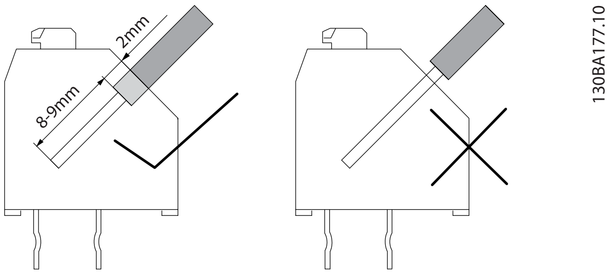


Illustration 9.12

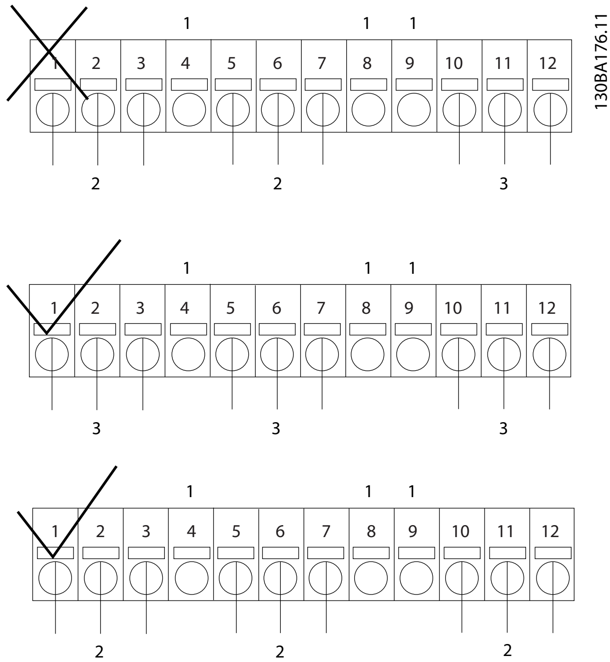


Illustration 9.13

⚠WARNING

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

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 option card installed. This enables full operation of the LCP (including the parameter setting) without connection to 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

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.

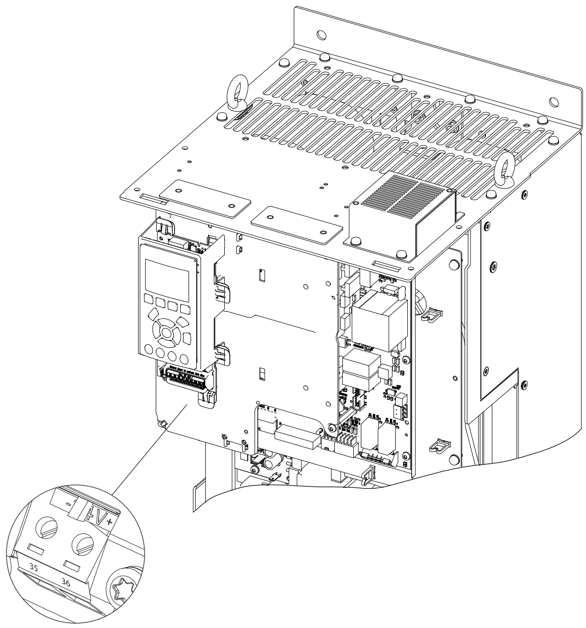


Illustration 9.14 24 V Backup Power Supply Connection

9.7 MCB 112 PTC Thermistor Card

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 Stop.

For information on mounting and installation of the option, see the instructions that accompany it. See also *8 Application Examples* for different application possibilities.

X44/1 and X44/2 are the thermistor inputs, X44/12 will enable safe stop of the FC 302 (T-37) if the thermistor values make it necessary and X44/10 will inform the FC 302 that a request for safe stop has come from the MCB 112 in order 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* Terminal 37 safe stop must be configured to the desired safe stop functionality (default is safe stop alarm).

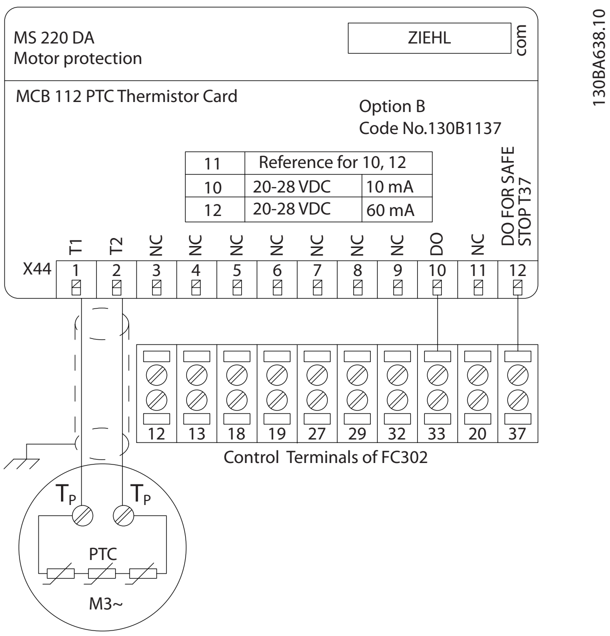


Illustration 9.15

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 Operating Instructions*, 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 analogue outputs and 4 SPDT relays to the standard I/O of the frequency converter for increased flexibility and to comply with the German NAMUR NE37 recommendations.

The MCB 113 is a standard C1-option for the Danfoss VLT® AutomationDrive and is automatically detected after mounting.

For information on mounting and installation of the option, see *9.1.3 Mounting of Options in Slot C*

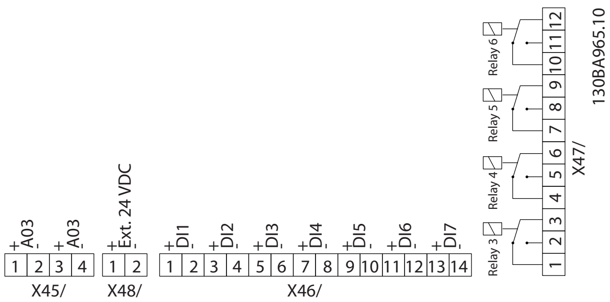


Illustration 9.17 Electrical Connections of MCB 113

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

9

is not needed, the option card can be supplied through internal 24 V from the frequency converter.

NOTE

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*.

NOTE

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

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

Analogue 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 send back into the frequency converter. If the energy can not be transported back to the motor, it will increase the voltage in the converter DC line. In applications with frequent braking and/or high inertia loads, this increase may lead to an over voltage trip in the converter and finally a shut down. Brake resistors are used to dissipate the excess energy resulting from the regenerative braking. The resistor is selected in respect to its ohmic value, its power dissipation rate and its physical size. Danfoss offers a wide variety of different resistors that are specially designed to our frequency converters. See *3.8.3 Selection of Brake Resistor* for the dimensioning of brake resistors. 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 enclosure is the IP66. The fastening screws must be tightened with a torque of max. 1Nm.

Enclosure	IP66 front
Max. cable length between and unit	3 m
Communication std	RS-485

Table 9.5 Technical Data

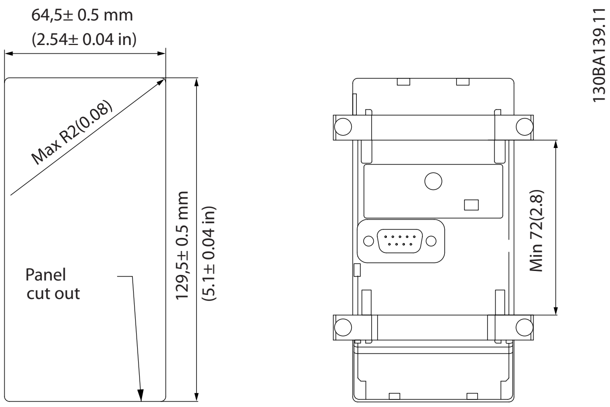


Illustration 9.18

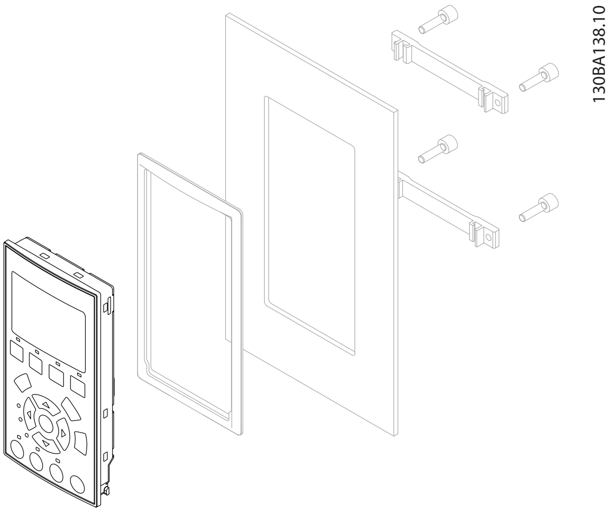


Illustration 9.19 Ordering no. 130B1113, LCP Kit with Graphical LCP, Fasteners, 3 m Cable and Gasket

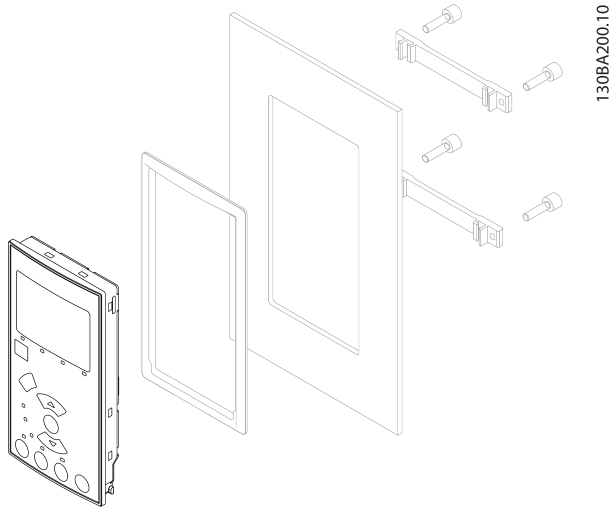


Illustration 9.20 Ordering no. 130B1114, LCP Kit with Numerical LCP, Fasteners and Gasket

LCP Kit without LCP is also available. Ordering number: 130B1117
For IP55 units the ordering number is 130B1129.

9.11 Sine-wave Filters

When a motor is controlled by a frequency converter, resonance noise will be heard from the motor. This noise, which is the result of the design of the motor, 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, which means that current and voltage become almost sinusoidal. Consequently, the acoustic motor noise is reduced to a minimum.

The ripple current in the Sine-wave Filter coils will also cause some noise. Solve the problem by integrating the filter in a cabinet or similar.

9.12 High Power Options

Ordering numbers for High Power options can be found in *5 How to Order*.

9.12.1 Frame Size F Options

Space Heaters and Thermostat
Mounted on the cabinet interior of frame size F frequency converters, space heaters controlled via automatic thermostat help control humidity inside the enclosure, extending the lifetime of components 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, available in two voltages:

- 230 V, 50 Hz, 2.5A, CE/ENEC
- 120 V, 60 Hz, 5A, UL/cUL

Transformer Tap Setup
If the cabinet light & outlet and/or the space heaters & thermostat are installed, Transformer T1 requires that taps be set to the proper input voltage. A 380-480/500 V frequency converter are 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	Tap to select
380 V-440 V	400 V
441 V-490 V	460 V
491 V-550 V	525 V
551 V-625 V	575 V
626 V-660 V	660 V
661 V-690 V	690 V

Table 9.6

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 organized and labelled to the specifications of the NAMUR standard for drive input and output terminals, which requires MCB 112 PTC thermistor card and MCB 113 extended relay card.

RCD (Residual Current Device)
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. Associated with each set-point is an SPDT alarm relay for external use. The RCD requires an external “window-type” current transformer (supplied and installed by the customer).

- Integrated into the safe-stop 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. Associated with each set-point is an SPDT alarm relay for external use.

NOTE

Only one insulation resistance monitor can be connected to each ungrounded (IT) system.

- Integrated into the safe-stop 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 4-wire emergency-stop push button mounted on the front of the enclosure and a Pilz relay that monitors it with the safe-stop circuit and the mains contactor located in the options cabinet.

Safe Stop + 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 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. Up to two starters are allowed (one if a 30 A, fuse-protected circuit is ordered) and are integrated into the safe-stop 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 two manual motor starters are selected
- Terminals are off when the incoming power to the drive 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
Designed for monitoring temperatures of external system components, such as the motor windings and/or bearings. Includes five universal input modules. The modules are integrated into the safe-stop circuit (requires purchase of safe-stop) and can be monitored via a fieldbus network (requires the purchase of a separate module/bus coupler).

Universal inputs (5)
Signal types:

- RTD inputs (including PT100), 3-wire or 4-wire
- Thermocouple
- analogue current or analogue voltage

Additional features:

- One universal output, configurable for analogue voltage or analogue 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

10 RS-485 Installation and Set-up

10.1 Overview

RS-485 is a two-wire bus interface compatible with multi-drop network topology, i.e. 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 that each repeater functions as a node within the segment in which it is installed. Each node connected within a given network must have a unique node address, across all segments. Terminate each segment at both ends, using either the termination switch (S801) of the 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, with e.g. a cable clamp or a conductive cable gland. It may be necessary to 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. 1200 m (including drop lines)
Max. 500 m station-to-station	

Table 10.1

10.2 Network Connection

One or more frequency converters can be connected to a control (or master) using the RS-485 standardized interface. Terminal 68 is connected to the P signal (TX+, RX+), while terminal 69 is connected to the N signal (TX-,RX-). See drawings in *7.7.2 Earthing*

If more than one frequency converter is connected to a master, use parallel connections.

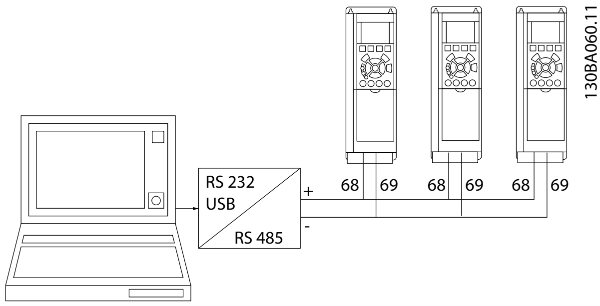


Illustration 10.1

In order to avoid potential equalizing currents in the screen, earth the cable screen via terminal 61, which is connected to the frame via an RC-link.

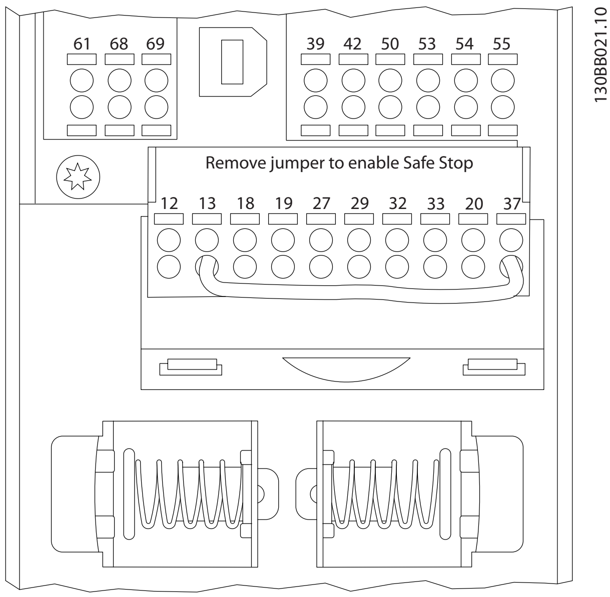


Illustration 10.2 Control Card Terminals

10.3 Bus Termination

The RS-485 bus must be terminated by 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, but keeping the greatest possible distance between the cables is recommended, especially where cables run in parallel over long distances. When crossing is unavoidable, the RS-485 cable must cross motor and brake resistor cables at an angle of 90°.

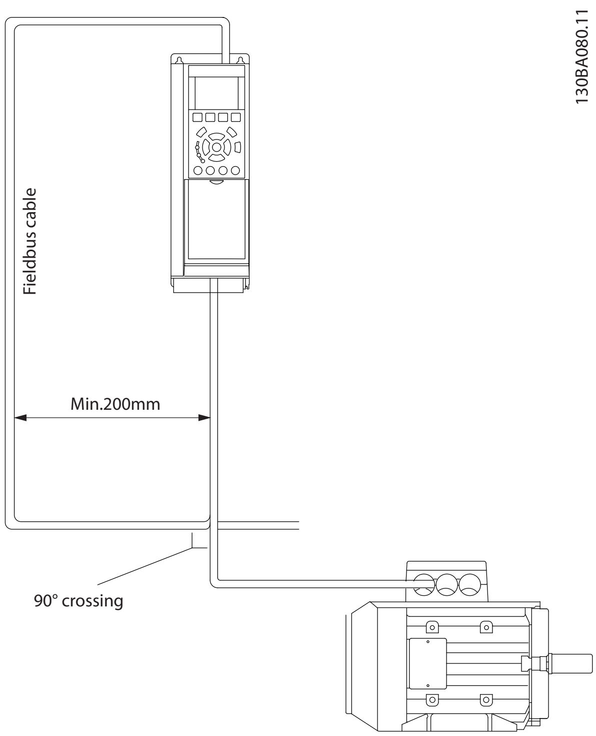


Illustration 10.3

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-slave principle for communications via a serial bus.
One master and a maximum of 126 slaves can be connected to the bus. The master selects the individual slaves via an address character in the telegram. A slave itself can never transmit without first being requested to do so, and direct message transfer between the individual slaves is not possible. Communications occur in the half-duplex mode.
The master function cannot be transferred to another node (single-master system).

The physical layer is RS-485, thus utilizing 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

10.7 FC Protocol Message Framing Structure

10.7.1 Content of a Character (byte)

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

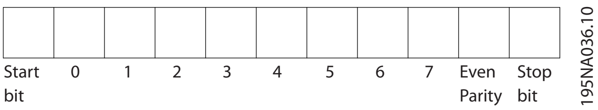


Illustration 10.4

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.

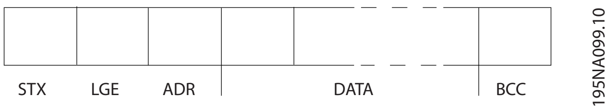


Illustration 10.5

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 slave 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 three types, and the type applies for both control telegrams (master⇒slave) and response telegrams (slave⇒master).

The three types of telegram are:

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

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

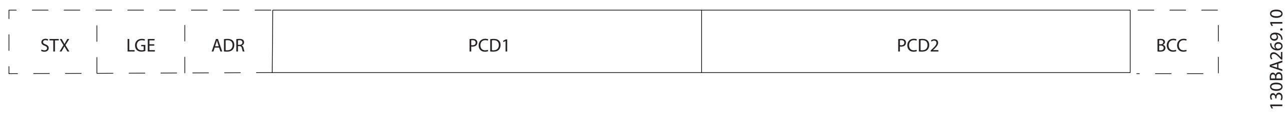


Illustration 10.6

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

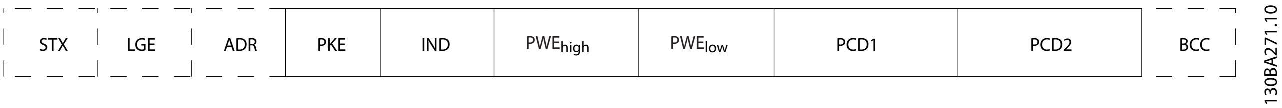


Illustration 10.7

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

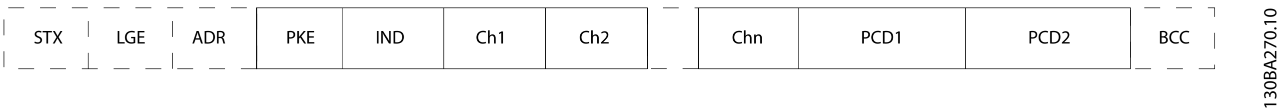


Illustration 10.8

10.7.7 The PKE Field

The PKE field contains two sub-fields: Parameter command and response AK, and Parameter number PNU:

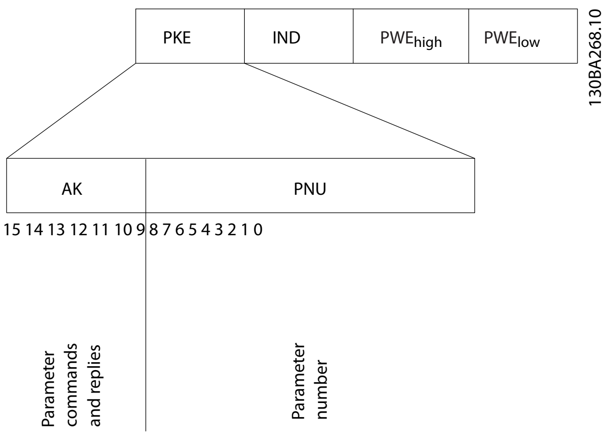


Illustration 10.9

Bits no. 12-15 transfer parameter commands from master to slave and return processed slave 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⇒Slave

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 Slave⇒Master

If the command cannot be performed, the slave sends this response:
0111 Command cannot be performed
- and issues the following fault report in the parameter value (PWE):

PWE low (Hex)	Fault report
0	The parameter number used does not exist
1	There is no write access to the defined parameter
2	Data value exceeds the parameter limits
3	The sub index used does not exist
4	The parameter is not the array type
5	The data type does not match the defined parameter
11	Data change in the defined parameter is not possible in the present mode of the 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

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, e.g. *15-30 Alarm Log: Error Code*. The index consists of 2 bytes, a low byte and a high byte.

Only the low byte is used as an index.

10.7.10 Parameter Value (PWE)

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

When a slave responds to a parameter request (read command), the present parameter value in the PWE block is transferred and returned to the master. If a parameter contains not a numerical value but several data options, e.g. *0-01 Language* where [0] corresponds to English, and [4] corresponds to Danish, select the data value by entering the value in the PWE block. See example - selecting a data value. 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."

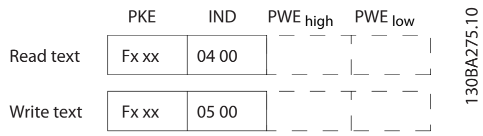


Illustration 10.10

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

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:
0s⇒conversion index 0
0.00s⇒conversion index -2
0ms⇒conversion index -3
0.00ms⇒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⇒slave Control word)	Reference-value
Control Telegram (slave⇒master) Status word	Present output frequency

Table 10.8

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 1000, corresponding to 100 Hz, see *10.7.12 Conversion*.

The telegram looks like this:

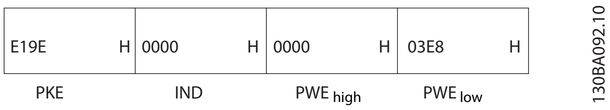


Illustration 10.11

NOTE

***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.**

The response from the slave to the master is:

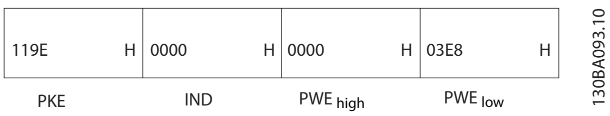


Illustration 10.12

10.8.2 Reading a Parameter Value

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

PKE=1155 Hex - Read parameter value in *3-41 Ramp 1 Ramp Up Time*
IND=0000 Hex
PWE_{high}=0000 Hex
PWE_{low}=0000 Hex

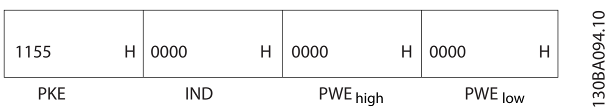


Illustration 10.13

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

1155 H	0000 H	0000 H	03E8 H
PKE	IND	PWE_{high}	PWE_{low}

130BA267.10

Illustration 10.14

3E8 Hex corresponds to 1000 decimal. The conversion index for *3-41 Ramp 1 Ramp Up Time* is -2, i.e. 0.01.
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 document, and strictly observes all requirements and limitations stipulated in the controller and frequency converter.

10.9.2 What the User Should Already Know

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 user 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
- Recognizes a message addressed to it
- Determines which actions to take
- Extracts any data or other information contained in the message

If a reply is required, the controller constructs the reply message and sends it.
Controllers communicate using a master-slave technique in which only one device (the master) can initiate transactions (called queries). The other devices (slaves) respond by supplying the requested data to the master, or by taking the action requested in 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's query by placing into it the device (or broadcast) address, a function code defining the requested action, any data to send, and an error-checking field. The slave's response message is also constructed using Modbus protocol. It contains fields confirming the action taken, any data to return, and an error-checking field. If an error occurs in receipt of the message, or if the slave is unable to perform the requested action, the slave constructs an error message, 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. This permits 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)

Table 10.9

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 10.10

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 10.11

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. This allows receiving devices 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 10.12 Typical Modbus RTU Message Structure

10.11.3 Start/Stop Field

Messages start with a silent period of at least 3.5 character intervals. This is 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 will consider it a continuation of the previous message. This causes a time-out (no response from the slave), 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 slave device addresses are in the range of 0 - 247 decimal. The individual slave devices are assigned addresses in the range of 1-247. (0 is reserved for broadcast mode, which all slaves recognize.) A master addresses a slave by placing the slave address in the address field of the message. When the slave sends its response, it places its own address in this address field to let the master know which slave is responding.

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 slave. When a message is sent from a master to a slave device, the function code field tells the slave what action to perform. When the slave responds to the master, it uses the function code field to indicate either a normal (error-free) response, or that an error has occurred (called an exception response). For a normal response, the slave simply echoes the original function code. For an exception response, the slave returns a code that is equivalent to the original function code with its most significant bit set to logic 1. In addition, the slave places a unique code into the data field of the response message. This code tells the master what error occurred, or the reason for the exception. See *10.11.10 Function Codes Supported by Modbus RTU* and *10.11.11 Modbus Exception Codes*.

10.11.6 Data Field

The data field is constructed using sets of two 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 slave device contains additional information, which the slave must use to perform the function 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 CRC value is calculated by the transmitting device, which 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 two values are unequal, a bus time-out results. The error-checking field contains a 16-bit binary value implemented as two 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 organized in coils and holding registers. Coils hold a single bit, whereas holding registers hold a 2-byte word (i.e. 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).

Coil number	Description		Signal direction
1-16	Frequency converter control word (see *Table 10.14*)		Master to slave
17-32	Frequency converter speed or set-point reference Range 0x0–0xFFFF (-200% ... ~200%)		Master to slave
33-48	Frequency converter status word (see *Table 10.14*)		Slave to master
49-64	Open loop mode: Frequency converter output frequency Closed loop mode: Frequency converter feedback signal		Slave to master
65	Parameter write control (master to slave)		Master to slave
	0=	Parameter changes are written to the RAM of the frequency converter	
	1=	Parameter changes are written to the RAM and EEPROM of the frequency converter.	
66-65536	Reserved		

Table 10.13

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 10.14 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 10.15 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 10.16 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 can be 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 following function codes in the function field of a message.

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

Table 10.17

10

Function	Function code	Sub-function code	Sub-function
Diagnostics	8	1	Restart communication
		2	Return diagnostic register
		10	Clear counters and diagnostic register
		11	Return bus message count
		12	Return bus communication error count
		13	Return bus exception error count
		14	Return slave message count

Table 10.18

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 slave). This may be because the function code is only applicable to newer devices, and was not implemented in the unit selected. It could also indicate that the server (or slave) is in the wrong state to process a request of this type, for example because it is not configured and is being asked to return register values.
2	Illegal data address	The data address received in the query is not an allowable address for the server (or slave). More specifically, the combination of reference number and transfer length is invalid. For a controller with 100 registers, a request with offset 96 and length 4 would succeed, a request with offset 96 and length 5 will generate exception 02.
3	Illegal data value	A value contained in the query data field is not an allowable value for server (or slave). 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 slave) was attempting to perform the requested action.

Table 10.19 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).

10.12.3 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 is for more characters than the parameter stores, the response is truncated. If the read request for a parameter is for fewer characters than the parameter stores, the response is space filled.

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 03HEX "Read Holding Registers." Parameters are written using the function 6HEX "Preset Single Register" for 1 register (16 bits), and the function 10HEX "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 03HEX "Read Holding Registers" and written using function 10HEX "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 (*8-10 Control Profile*=FC profile)

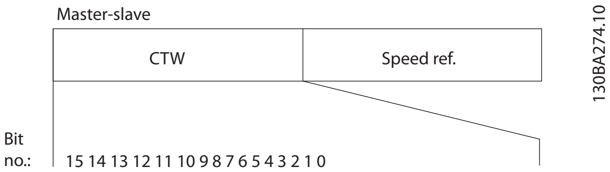


Illustration 10.15

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

Table 10.20

Explanation of the Control Bits

<u>Bits 00/01</u>
Bits 00 and 01 are used to choose between the four reference values, which are pre-programmed in *3-10 Preset Reference* according to *Table 10.21*.

Programmed ref. 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 10.21

NOTE

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

<u>Bit 02, DC brake</u>
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.

<u>Bit 03, Coasting</u>
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.

<u>Bit 04, Quick stop</u>
Bit 04=’0’: Makes the motor speed ramp down to stop (set in *3-81 Quick Stop Ramp Time*).

<u>Bit 05, Hold output frequency</u>
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*.

NOTE

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, i.e. when changing from logic ’0’ to logic ’1’.

Bit 08, Jog
Bit 08=’1’: The output frequency is determined by *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 choose from the four 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 10.22

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 (STW) (*8-10 Control Profile* = FC profile)

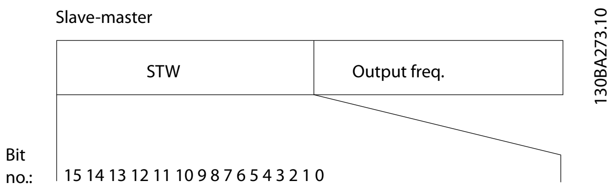


Illustration 10.16

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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

Table 10.23

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 e.g. 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 activate 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%.

All bits in the STW are set to '0' if the connection between the Interbus option and the frequency converter is lost, or an internal communication problem has occurred.

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.

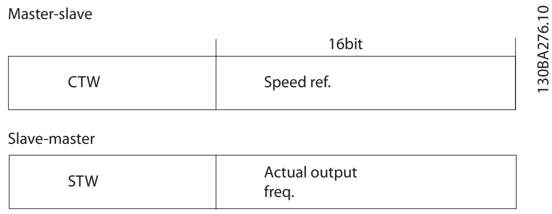

Illustration 10.17

The reference and MAV are scaled as showed in *Illustration 10.18*.

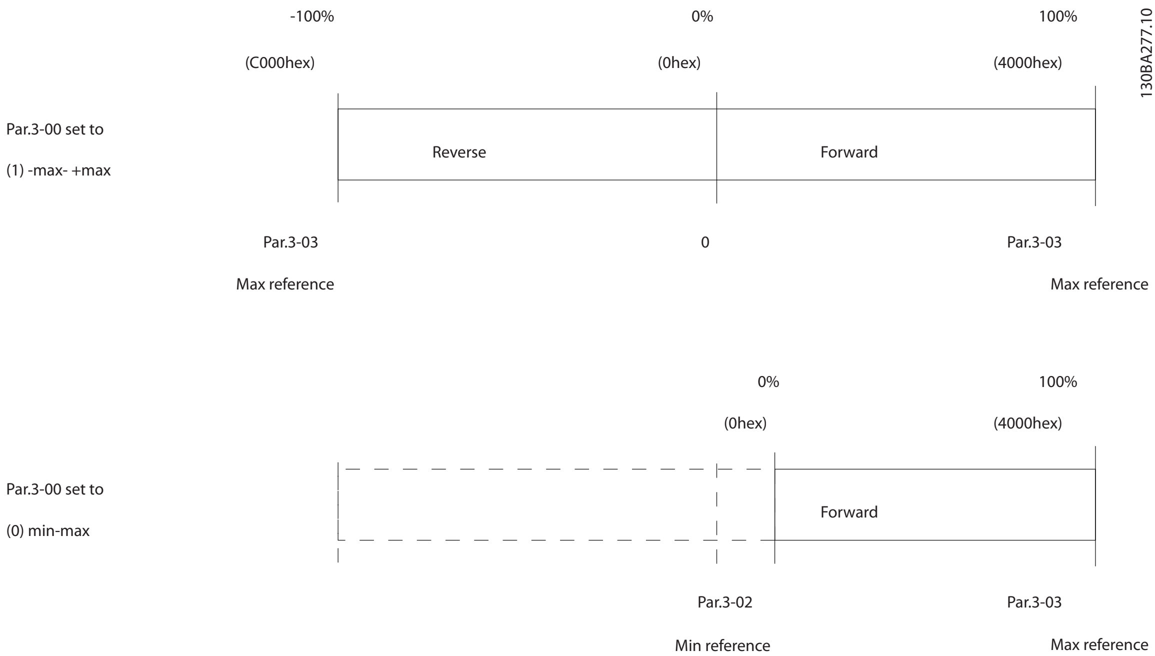

Illustration 10.18

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 slave.

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

Table 10.24

10

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 , 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.

NOTE

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.

NOTE

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.

NOTE

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
Activation of 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
Activation of 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
Is used to tell 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
Is used to reduce 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
Is used to increase 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
Bits 13 and 14 are used to choose between the four parameter set-ups according to *Table 10.25*:

The function is only possible if *Multi Set-up* has been chosen 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 10.25

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*.

NOTE

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 is used to notify a master (e.g. a PC) about the status of a slave.

Bit	Bit=0	Bit=1
00	Control not ready	Control ready
01	Drive not ready	Drive ready
02	Coasting	Enable
03	No error	Trip
04	OFF 2	ON 2
05	OFF 3	ON 3
06	Start possible	Start not possible
07	No warning	Warning
08	Speed≠reference	Speed=reference
09	Local operation	Bus control
10	Out of frequency limit	Frequency limit ok
11	No operation	In operation
12	Drive OK	Stopped, autostart
13	Voltage OK	Voltage exceeded
14	Torque OK	Torque exceeded
15	Timer OK	Timer exceeded

Table 10.26

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.

10

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 will be "1" after a switch-off acknowledgement, after activation of OFF2 or OFF3, and after switching on the mains voltage. Start not possible will be 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 by means of the stop button on the LCP, or that [Linked to hand] or [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
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%.

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